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Organic Farming
A Promising Way of Food Production

Edited by Petr Konvalina

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Meet the editor

Dr. Petr Konvalina is the Vice Dean for External Relations at the Faculty of Agriculture, University of South Bohemia in České Budějovice, Czech Republic. He is an Associate Professor in Plant Production. He is oriented towards organic plant production, wheat growing, organic plant breeding and organic food processing. In these topics he has published more than 100 reviewed scientific papers. The papers are mostly focused on the possibilities of practical use of genetic resources of wheat (emmer, einkorn, spelt) in organic farming. Dr. Konvalina has been involved in many national and international research and educational projects related to organic plant production.

Contents

Preface

Organic agriculture is a modern way of farming management, using limited amount of chemical treatments which have negative effects on the environment, human health or animal health. It produces organic food, and at the same time enhances the living conditions of animals. It contributes to environmental protection and helps biodiversity to increase. Organic farming does not mean going ‘back’ to traditional (old) methods of farming. Many of the farming methods used in the past are still useful today. Organic farming takes the best of these and combines them with modern scientific knowledge. Organic farmers do not leave their farms to be taken over by nature; they use all their knowledge, various techniques and materials available to them, in order to work with nature. In this way the farmer creates a healthy balance between nature and farming, where crops and animals can grow and thrive. To be a successful organic farmer, the farmer must not see every insect as a pest, every weed plant as out of place, nor find the solution to every problem in an artificial chemical spray. The aim is not to eradicate all pests and weeds, but to keep them down to an acceptable level and make the most of the benefits that they may provide.

The future development of organic food is never easy to predict. It makes it such a fascinating subject to study. At present, the sales of organic food are going through a trough and the organic industry is consolidating as it learns how to operate in a new environment. The big boom in the key markets for organic products; North America, the European Union and Japan, is faltering and the domestic purchasing power of many people is increasingly constrained (Reed, 2012). Simultaneously, organic agriculture, under the name of agro-ecology, is increasingly being presented as an answer to producing food sustainably, and improving the livelihoods of farmers in the global south. A recent report from the United Nations Special Rapporteur on the Right to Food, Olivier De Schutter, which recommends the global adoption of agro-ecology, is built on the sustained effort of academic researchers to demonstrate, through high quality research, the potential of organic agriculture (De Schutter, 2011).

The book contains 16 chapters written by acknowledged experts, providing comprehensive information on all aspects of organic farming and food production. The book is divided into three parts: Organic Farming and Plant Production, Organic Livestock, and Organic Foods. In the book there are chapters oriented towards organic farming and environmental aspects, problematic organic tuber crops production, quality and distribution of organic products, etc. Researchers, teachers and students in the agricultural field in particular will find this book to be of immense use.

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Section 1

Organic Farming and Plant Production

Chapter 1

The Role of Biological Diversity in Agroecosystems and Organic Farming

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Additional information is available at the end of the chapter

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Abstract

Ecosystems are the basis of life and all human activities. Conservation of biological diversity is very important for the proper functioning of the ecosystem and for delivering ecosystem services. Maintaining high biodiversity in agroecosystems makes agricultural production more sustainable and economically viable. Agricultural biodiversity ensures, for example, pollination of crops, biological crop protection, maintenance of proper structure and fertility of soils, protection of soils against erosion, nutrient cycling, and control of water flow and distribution. The effects of the loss of biodiversity may not be immediately apparent, but they may increase the sensitivity of the ecosystems to various abiotic and biotic stresses. The combination of biodiversity conservation with profitable food production is one of the tasks of modern sustainable agriculture that faces the necessity of reconciling the productive, environmental, and social goals. As further intensification of production and increase in the use of chemical pesticides, fertilizers, and water to increase yields are increasingly criticized, global agriculture is looking for other biological and agrotechnical methods in order to meet the requirements of global food production.

Keywords: Biological diversity, ecosystem, agroecosystem, ecosystem services, organic agriculture

1. Introduction

In compliance with the Convention on Biological Diversity (CBD), adopted in Rio de Janeiro in 1992, biological diversity is the variability among living organisms inhabiting all environments and ecological systems [1]. Biodiversity may therefore be considered at genetic, species, and ecosystem levels. According to Clergue [2], biodiversity is a very complex issue. In agroecosystems, it serves three basic functions: genetic, agricultural, and ecological functions. The first function of biodiversity involves maintaining species gene pool, in particular, the endangered ones. The second function, connected with agricultural activity, contains increasing the resistance of agroecosystems to abiotic and biotic stresses, as well as maintaining their productive role. Biodiversity has also ecological functions, for example, creating habitats with different flora and fauna species that have specific significance in agroecosystems.

The loss of biological diversity is one of the most important problems of the world and a threat to our civilization. The destruction of primary ecosystems, intensive farming, urbanization, and also infrastructure development cause depletion and weakening of the stability of ecosystems. Agroecosystems are the most at risk of losing biological diversity [3].

During the last decades, worldwide losses of biodiversity have occurred at an unprecedented scale and agricultural intensification has been a major driver of this global change [4]. The dramatic land use changes include the conversion of complex natural ecosystems to simplified ecosystems and the intensification of resource use, including application of more agrochemicals. The evaluation of ecosystems in the UK has shown a significant loss of biodiversity during the recent 50 years. Sixty-seven percent of 333 plant and animal species on agricultural lands have been endangered, mainly due to the intensification of farming [5].

The industrialization of agriculture has caused, directly and indirectly, a dramatic impoverishment of the fauna and flora compared to the situation a century ago [6–9]. This has contributed not only to the current biodiversity crisis in Europe as whole, but also to the decline in ecosystem services such as crop pollination and biological pest control [8]. As a result, the protection of farmland biodiversity has become a key issue in the EU and national agricultural and environmental policies, and large amounts of research and funding are devoted to biodiversity conservation, such as agri-environment schemes [3, 10–11].

Despite the commitment made by the Parties to the Convention on Biological Diversity to reduce the rate of biodiversity loss by 2010, global biodiversity indicators show continued decline at steady or accelerating rates, while the pressures behind the decline are steady or intensifying [12]. The main objective of the EU Biodiversity Strategy to 2020, which was adopted in 2011, is to maintain and strengthen ecosystems and their functions, and foster sustainable development of agriculture and forestry [13]. Biological diversity should also be preserved due to economic factors. Maintaining a high level of biological diversity makes agricultural production and the related activities more sustainable, which in turn, significantly affects human activities [14–15].

Biodiversity in agriculture can be perceived on two levels: the first is related to the diversity of species and cultivars, the breeds of farm animals, so the obtained "products"; and the second is related to the biodiversity connected with agricultural production, such as the diversity of plants and wild animals that accompany the crops, as well as the diversification of the agricultural landscape.

2. The role of traditional species, cultivars, and traditional animal breeds in maintaining biological diversity

The progress in agriculture has led to the situation that in the recent 100 years, approximately 75% of genetic resources have been lost due to the transition of farmers from growing traditional, local cultivars of lower productivity and replacing them with intensive cultivars. Although in the world there are at least 12 thousands of edible plant species, humans use only 150 to 200 of them, and 75% of food products around the world are produced from only 12 species of plants and animal species. The three main species of plants such as rice, maize, and wheat provide about 60% of the energy consumed by humanity. Such a low diversity is a major issue to food safety. From the point of view of the conservation of biodiversity and human health, we should promote traditional and local species and cultivars of plants, as well as old breeds of animals [16].

The most appropriate way of protecting genetic resources of plants is their conservation in situ in the regions strictly related to their origin. This type of protection allows us not only to preserve a given form in its place of origin, but also to continue its cultivation and selection in the traditional way. The protection of genetic resources of crops, in addition to the primary task of maintaining biodiversity, has also practical aims of delivering rich genetic material for further breeding [6].

Old and local cultivars of crops are distinguished by unusual qualitative characteristics (e.g., good taste, favorable chemical composition), low technological requirements, better adaptation ability to environmental conditions, resistance to pests and diseases, and reliable yields. The cultivation of old cultivars and forms is often connected with using environmentally friendly production systems, such as organic farming. Old varieties are usually cultivated on a limited area, at a local or regional level. In Poland, we cultivate the tradition of growing old and local cultivars of tomato, cucumber, onion, carrots, beans, pumpkin, vetch, and many other orchard fruits and vegetables. In recent years, the rapidly-developing low-input methods of farming promotes a wider use of old and local cultivars of plants, as well as old plant species, such as spelt wheat, emmer, einkor wheat, and their processing on the farm [6].

Traditional orchards, also called backyard orchards, are of great importance for plant genetic resources. They usually satisfy only the needs of their owners and their family, unlike the commercial orchards where the production of which is destined primarily for sale. Traditional orchards became a characteristic element of the landscape of the Polish countryside. Due to the longevity of the trees, they have survived to this day. They are supported by an agri-environment scheme in Poland [17].

Native animal breeds are very important due to the role they played in the history of the development of the regions from which they originate. Due to their ecological, landscape, ethnographic, and socio-cultural functions, they must be regarded as evidence of tradition and culture of local communities, and preserved for future generations. The conservation of genetic variability guarantees a secure future of livestock production and helps maintain a healthy livestock [6].

3. The role of wild flora and fauna diversity in agroecosystem

In intensive conventional farming, special attention is paid to the negative aspects of wild flora in agrocenoses (called weeds), as they cause yield losses. Since the 1990s, however, due to the promotion of the concept of sustainable agriculture, the importance of wild plants growing on fields has been underlined. They have started to be perceived not only as competitors to arable crops, but also as an element that increases the biodiversity in agroecosystems [18–20].

Currently, the tendency in weed control is to limit the number of weeds to such a level that do not cause significant yield decreases. Such an approach is consistent with the objectives of sustainable agriculture, and particularly promoted in the system of organic farming. The harmfulness of weeds is not the same in all agrocenoses and depends on: the species and its biology, their abundance, competitive ability, the type of agricultural culture and the purpose of cultivation, as well as the soil type, weather, and agrotechnical factors [21].

The results of the research indicate a positive influence of wild flora in preserving overall biodiversity of agroecosystems [20, 22]. Elimination of wild plants from plant canopy, and thus weakening their reproductive potential interferes with the processes occurring in soil and relations between flora, fauna, and microorganisms [23]. Studies have shown that the decrease in the number of weeds as a result of the intensification of agriculture in Finland, Germany, Denmark, and the UK caused a decline of the populations of birds, pollinators, and other insects on agricultural areas [20, 22, 24]. The results of the monitoring of common breeding birds, which have been conducted in the UK since the 1990s and in Poland since 2000 indicate that the decrease in the number of the species such as tawny pipit, goldfinch, hoopoe, and lapwing, following the intensification of agriculture and the reduction in the diversity of weed flora [25]. The seeds of weeds, especially from the *Polygonaceae, Chenopodiaceae*, and *Poaceae* families, such as *Chenopodium album, Polygonum aviculare, Echinochloa crus-galli, Rumex obtusifolius,* and *Stellaria media*, are important food components for many bird species [20, 26].

Weeds constitute the source of food, as well as the habitats for animals, including useful, pollinating insects [15]. The nectar and pollen producing plants include: *Anthemis arvensis, Cirsium arvense, Centaurea cyanus, Chenopodium album, Consolida regalis, Taraxacum officinale, Papaver rhoeas,* and *Sonchus arvensis* [20–21]. Many common weed species are significant for the maintenance of the population of valuable beneficial invertebrates (pest predators and parasites), thus supporting the natural pest control [20].

Providing pest control is one of most important functions of biodiversity. There is a significant importance of predatory arthropods in agroecosystems. Many species of invertebrates are specialized in eating aphids and other pests. Others are generalist predators such as spiders or ground beetles. One of the most important natural enemies of pests are spiders. Almost all known species of spiders are predators. Many species are common in crops. The most effective in pest control are species families *Licosidae, Linephidae, Salticidae, Tetragnatidae, Clubionidae,* and *Araneidae* [27]. An important feature of spider biology is its resistance to long periods of hunger when a prey is absent. On the other hand, when prey is in abundance, they can consume a huge amount of it, often killing more prey than they can actually eat [28]. Another very important taxa is *Coleoptera*. There are many species of *Coleoptera*, that are generalist predators feeding on aphids and other pests. In an agroecosystem, the beetle families *Carabidae, Staphylinidae, Coccinellidae*, and *Cantharidae* are the most important invertebrates. The best known natural enemies of aphids are ladybirds *Coccinellidae* and ground beetles *Carabidae* [29]. Predatory beetles are more common in organic crops and in diverse landscapes [30]. They are also not dependent on pest population density, while specialist natural enemies are. They are also present on the field before pest population has developed. There are more generalist predators that can control the population of pests. These are insects such as bugs *Hemiptera*, robber flies *Asilidae*, wasps, and ants *Hemiptera*. More specialized in aphid control are parasitic wasps *Apocrita-Parasitica*, hoverflies *Syrphidae*, lacewings *Chrysopidae*, and *Hemerobiidae*. Both types of natural enemies are effective in controlling aphids, but they affect them in different ways. Generalist predators limit pest population, but doesn’t eliminate all individuals so there is still a possibility to rebuild pest population. Specialists influence pest population slowly, preventing the increase in the population [31]. Diversity and activeness of natural enemies depends on the type of crop, diversity of landscape, and system of farming.

High plant species diversity increases the diversity of soil microflora and microfauna, including the organisms that are antagonistic against crop pathogens [32]. Certain wild flora species repel the crop pests or they act as trap plants for pests (e.g., *Chenopodium album* for black bean aphids). The allelopathic potential of many weed species has a stimulating or inhibiting effect on the development of crops and the presence of other weeds [21]. A large variety of flora and fauna is increasingly perceived as a valuable part of the agricultural landscape, especially in countries where intensification of agricultural production has led to a significant reduction of biodiversity of agroecosystems [19].

4. Biodiversity in the ecosystem services concept

Ecosystem services have become a top research issue in ecology, natural resource management, and policy [33]. Ecosystem services can be defined as the benefits that humans obtain from ecosystems [34].

In the report of Millennium Ecosystem Assessment [35], ecosystem services were divided into four basic types:

- provisioning (production of food, production of other raw materials such as wood, fuel, water supply, and others);
- regulating (regulation of air composition, climate, extreme phenomena, contamination, and biological processes);
- supporting (circulation of elements, primary production, soil formation, habitat function, hydrological cycle);
- cultural (recreational, aesthetic, cultural, and educational functions).

Biodiversity plays a major role in each group of these ecosystem services. It is crucial for the functionality, stability, and productivity of every ecosystem. In dynamic, agricultural landscapes, only a diversity of insurance species may guarantee resilience (the capacity to reorganize after disturbance) [8]. The species that occur in agrocenoses differ in terms of their potential value and input into the ecosystem services [15, 36]. Thus, increasing the diversity of species richness increases the probability of the total pool containing a species that will significantly affect the functioning of the ecosystem.

Biodiversity and ecosystem services are complex issues, which is reflected in many different interpretations of the significance of biodiversity to the ecosystem. The connections between biodiversity and ecosystem services are perceived differently by different authors [37]. Some authors even treat these concepts as one, which means that if the ecosystem services are managed properly, biodiversity will be preserved and vice versa ("ecosystem services perspective"). However, others claim that biodiversity is one of the ecosystem services and the conservation of the diversity of wild species, especially the endangered ones, is one of the goods that the ecosystem should deliver ("conservation perspective").

According to Fischer and Young [38], in biodiversity, everything is connected and contained in the same environment, but with no hierarchy. Mace et al. [37] suggest that the role of biodiversity in ecosystem services should be put into some order by assuming that different relationships exist at different levels of the hierarchy of ecosystem services. Following this concept, biodiversity may be the primary regulator of the ecosystem processes, as well as the final product and ecosystem service and good itself.

Biodiversity is considered one of the provision services that can supply: genetic resources for breeding new, more useful cultivars of plants or animal breeds; new active substances for medicine and pharmacology; or new ornamental plants [37]. Biodiversity in ecosystems determines most of the basic functions of the ecosystem, such as the distribution and circulation of elements in soil or the resistance of the ecosystem to pests and environmental conditions. It is generally considered that a more diverse ecosystem is a more stable ecosystem. The results of the studies indicate that an increased biodiversity at a given trophic level positively affects the productivity of this trophic level [39].

Ecosystems with high biological diversity provide many ecosystem services that concern, among others, provision of food, maintenance of pollinators, and biological control of pests [8, 15]. Pollination is one of the ecosystem services that are of special importance for humans. Recent studies estimate that 87 of major arable crops and 35% of the world crops are pollinated by animals [40]. The diversity of pollinators is essential for maintaining the provision of the services that Costanza et al. [34] evaluated at $14/ha/year. According to other authors, it amounts to $100 billion a year around the world [41]. The loss of biodiversity of agroecosystems, caused by the intensification of agricultural production and the loss of habitats, negatively affects the service of pollinators, which causes yield decrease [42].

The studies on the influence of biodiversity on ecosystem functions are difficult due to the complexity of the relationships within the ecosystem, the impact of agricultural production systems, and landscape. It is also difficult to generalize the results obtained in the given ecosystem over other ecosystems [43].

Meta-analysis carried out by Balvanera et al. [39] indicates that most of the published works show a positive influence of biodiversity on the functioning of ecosystem, the strongest at the level of communities. Costanza et al. [44] found a positive impact of biodiversity on the productivity of ecosystems in North America. According to these authors, 1% of the changes in biodiversity affects 0.5% of the changes in the value of ecosystem services. The research carried out in Europe provided evidence for the positive impact of biodiversity on the productivity of grasslands [45]. Lavelle et al. [46] pointed to the positive impact of diversity of soil organisms on plant productivity in agricultural ecosystems. Hillebrandt and Matthiessen [47] believe that the functioning of the ecosystem is dependent not only on biodiversity, measured by the number of species, but most of all, on species composition, and the abundance of individual species and functional groups. A recent review of the scientific literature concluded that most reported relationships between biodiversity attributes (such as species richness, diversity, and abundance) and ecosystem services were positive [48]. Despite rich evidence on the existence of the connection between biodiversity and ecosystem functioning, some authors still question this relationship [8, 49–50].

The protection of certain target species is the most socially recognized role of biodiversity, while its indirect role in processes occurring in ecosystems (such as the cycle of elements) is little known by a wider audience [37]. A higher perspective needs to deliver additional arguments for the protection of biodiversity, apart from the traditional arguments, connected with the protection of rare and charismatic species.

Authors of the report from ecosystem evaluation in the UK found that at present, we are not able to fully assess the relationship between biodiversity and ecosystem services that it provides [5]. Changes in the extent and condition of habitats may significantly affect biodiversity ecosystem services. Intensification of agriculture has caused agricultural production, along with provision services, to significantly increase, but at the same time, there was a reduction in the diversity of the landscape, the increase of soil erosion, the reduction of soil quality, and the decrease in the populations of birds and pollinators. Changes in ecosystems may have a positive or negative impact on human welfare. For example, the conversion of natural ecosystems into agricultural production areas increases farmers' income, but at the same time, decreases habitats for recreation and the threat of atmospheric phenomena. According to the authors of the report [5], these types of assessments, in addition to economic values, should also take into account human health and social values.

Until now, ecosystem services were regarded as public goods, not as a market product that has a monetary value. According to some authors, the lack of valuation is the main cause of the degradation of ecosystems and loss of biodiversity [3]. If we want to maintain our environmental safety, we have to "measure" ecosystems and biodiversity. The article of Costanza et al. [34], “The value of the world’s ecosystem services and natural capital", published in Nature in 1997, was a breakthrough study in the subject of ecosystem services valuation. The authors assessed the value of 17 basic services produced by ecosystems all over the world. They evaluated them at $33 billion per year, so almost twice the amount of the gross national product of the USA ($18 billion). The concepts of ecosystem services flow and natural capital stocks are increasingly useful ways to highlight, measure, and value the degree of interdependence between humans and the rest of nature [51]. Economic assessment of the value of the services provided by the environment is difficult, time-consuming, and flawed. The valuation of each group of ecosystem services should be performed using different methods [52–53].

5. The impact of different agricultural systems on biodiversity

One of the most important factors affecting the agroecosystem biodiversity is the method of the agricultural management and land use. Agricultural systems that are used in modern agriculture may differently affect the environment, including biodiversity. Intensive agriculture is considered as the main reason of the decrease of flora and fauna species diversity and abundance in agroecosystems [14, 54]. The use of fertilizers and pesticides, removal of mid-field woody vegetation and bounds leading to fragmentation and degradations of habitats are among the most important threats of agricultural ecosystems [37]. Moreover, areas with worse conditions for agricultural production are abandoned or afforested.

Decreasing populations of the birds associated with the agricultural landscape in many European countries can serve as an example of the loss of biodiversity due to the intensification of methods of agricultural production and changes in the landscape [25]. Benton et al. [55] found a relationship between the changes in the population of birds associated with agricultural areas and the number of invertebrates and agricultural practices in Scotland. Intensive agriculture was also found to have a negative effect on other groups of organisms: soil microorganisms, weed flora, earthworms, insects, spiders, and mammals [19–20, 55–59]. The analyses performed by Storkey et al. [9] for 29 European countries showed a positive correlation between the yields of wheat and the number of endangered species. The study of the list of endangered or extinct species of wild plants in Germany showed that agriculture is responsible for the decrease of populations of 513 out of 711 species [19]. The endangered taxa included 10.8% of weeds. Fifteen species were considered extinct, which constituted 25% of all the extinct species. In Poland, about 60 percent of the 165 species of archeophytes that accompany crops are endangered, mainly due to the intensification of agriculture [60].

Species' ability to tolerate human impacts: destruction, degradation and fragmentation of habitats, reductions of individual survival and fecundity through exploitation, pollution and introduction of alien species varies among taxonomic groups [61]. For instance, the proportion of species listed as threatened in the International Union for Conservation of Nature Red List is much bigger in amphibians than in birds [62].

Intensification of agricultural practices causes the loss of biodiversity, and thus influence important ecosystem services. It affects plant production, plant protection, pollination, decomposition processes, nutrient cycles, and the resistance to invasive organisms [15, 63–65]. In some cases, the intensification of agricultural production can lead to an increase in the population of some, or even rare, species. A higher productivity of agricultural areas in comparison with natural ecosystems means more feed (biomass of plants and fruit) for birds, mammals, and butterflies [8]. Söderström et al. [66] found a greater abundance of bird species on the areas used for agriculture and the reduction of the diversity in the period after the abandonment of farming, while Westphal et al. [67] found an increase in the population of bumblebees together with the increase in the area of rape cultivation. Habitat value is, therefore, often determined by food resources, which result from high productivity, which in turn may have other negative environmental consequences.

Negative impacts of conventional farming on the environment, the overproduction of food, and consumer dissatisfaction with the quality of the products obtained through such farming, caused the development of the concept of sustainable agriculture, which uses environmentally friendly methods of production [68–69]. Such assumptions are the basis of the development of alternative systems of agricultural production, such as integrated and organic farming.

An integrated production system uses technical and biological progress in the cultivation, fertilization, and plant protection in a harmonious way, which allows to obtain a stable efficiency and a proper level of agricultural income through the use of methods that do not pose a threat to the environment. It combines the most important elements of organic and conventional farming, and allows for simultaneous realization of economic, ecological, and social goals [69]. Integrated production ensures sustainable economic development of the farm, takes into account the needs of the environment, and it is also attractive for consumers due to the obtained quality of products. The results of the implementation of the integrated system in several European countries show that it managed to significantly reduce the use of chemical pesticides and synthetic nitrogen fertilizers, which led to, among others, an increase in the diversity of flora and fauna [68, 70]. The Directive on the sustainable use of pesticides (2009/128/EC) [71] has obliged all EU member states to prepare and implement integrated crop protection programs, which to some extent can protect the biodiversity of flora and fauna [72].

One of the proposed solutions for combining productive and environmental functions of agriculture is an approach called "ecological intensification" [33]. For ecological intensification, the primary interest is in managing the processes and conditions that mediate yield levels. Ecological intensification entails the environmentally friendly replacement of anthropogenic inputs and/or enhancement of crop productivity, by including regulating and supporting ecosystem services management in agricultural practices. Research efforts and investments are particularly needed to reduce existing yield gaps by integrating context-appropriate bundles of ecosystem services into crop production systems.

6. The significance of biodiversity in organic farming

The aim of organic farming is the production of high-quality food and, at the same time, the protection of the environment [73–74]. The ecological system is fundamentally different from other systems of agricultural production because it excludes the use of synthetic mineral fertilizers, growth regulators, chemical plant protection products, and synthetic feed additives. It is based on substances of natural origin, which are not technologically processed [74]. Organic farming system is based on the use of environmentally friendly production methods that include crop rotations with a large share of legumes, organic fertilizers, and non-chemical methods of plant protection. Due to the resignation from the application of synthetic mineral fertilizers and chemical plant protection products, organic farming has an even greater positive impact on the diversity of flora and fauna than the integrated system [19, 22, 56, 59, 75–77]. The results of many studies point to the positive effects of organic farming on diversity of flora and fauna on arable lands and grasslands [76–81].

Dynamic development of organic farming is observed in the EU, including Poland [82]. Some authors believe that the dissemination of ecological system on agricultural areas may help reverse the negative trend of the decline of biodiversity in the cultivated fields, which was caused by the intensification of agriculture [19, 82].

The most direct way to capture the effects of human activities on biodiversity is to analyze time-series data from ecological communities or populations, relating changes in biodiversity to changes in human activities. Such long-term research (1996–2011) on weed flora diversity in different crop production systems, organic, integrated, and conventional, were conducted in the Experimental Station of the Institute of Soil Science and Plant Cultivation – State Research Institute (IUNG-PIB) in Puławy, Poland [N: 51º28′, E: 22º04′] (Table 1).

Items	**Crop production systems**			
	Organic	**Integrated**	**Conventional**	**Monoculture**
Crop rotation	Potato Spring barley/spring wheat from 2005 + undersown crop Clovers and grasses (1st year) Clovers and grasses (2nd year) Winter wheat + catch crop	Potato Spring barley/spring wheat from 2005 + catch crop Faba bean or blue lupine Winter wheat + catch crop	Winter rape Winter wheat Spring barley/ spring wheat from 2005	Winter wheat
Seed dressing	-	+	+	
Organic fertilization	compost (30 $t\cdot ha^{-1}$) under potato + catch crop	compost (30 $t\cdot ha^{-1}$) under potato + 2 × catch crop	rape straw, winter wheat straw	wheat straw (every 2 years)
Mineral fertilization ($kg\cdot ha^{-1}$)	according to the results of soil analysis, allowed P and K fertilizers in the form of natural rock	NPK (85+55+65)	NPK (140+60+80)	
Fungicide	-	2 x	2–3 x	
Retardants	-	1–2 x	2 x	
Weed control	weeder harrow 2–3 x	weeder harrow 1x herbicides 1–2 x	herbicides 2–3 x	

Table 1. Major elements of the agricultural practices of winter wheat in different farming systems (1996-2011); source [59].

The study showed that long-term management in organic system increased the diversity of weed flora accompanying crops (Figure 1). Simplifying the crop rotation from the integrated system, through the conventional system to monoculture of winter wheat, associated with the increased use of herbicides, led to the depletion of the species in weed communities. In the 16-year period, the average number of weed species in integrated and conventional systems, as well as in wheat monoculture was similar (6.1–6.8), while in the organic system by about 3.5 times higher (22 species). During the 16 years of research, the changes in weed communities in winter wheat cultivated in this farming system were found, especially involving the decreasing abundance of nitrophilous species: *Chenopodium album* and *Galium aparine* and the increasing density of more sensitive to herbicides taxa, *Stellaria media, Capsella bursa-pastoris, Fallopia convolvulus*, and species of the *Vicia* genus [59].

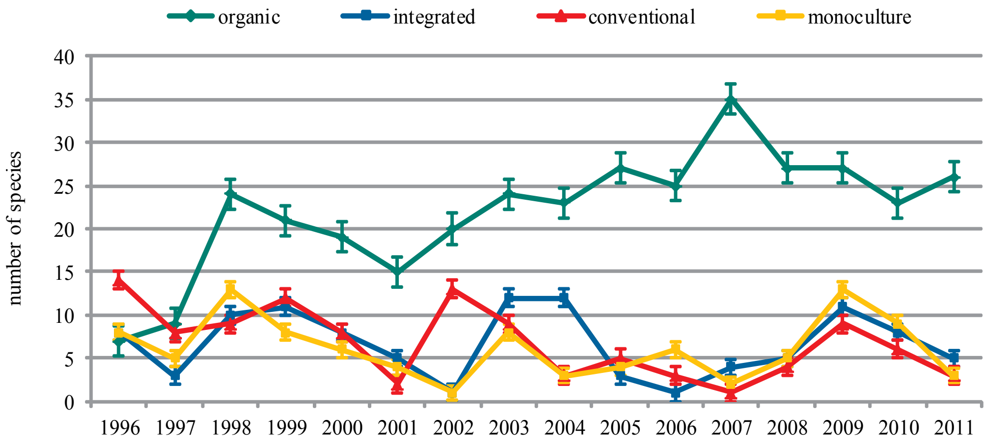

Figure 1. Weed plant diversity (± st. error) in winter wheat cultivated in different farming systems in years 1996–2011; source [59].

The agricultural practices applied in the compared farming systems (organic, integrated, conventional, and monoculture) of winter wheat differentiated the density of flora more than species composition. The largest number of weeds in the canopy of winter wheat at the dough stage was found in the organic system, 112 plants · m^{-2}, and the smallest for the integrated system, 18 plants · m^{-2}, on average (Figure 2). During the five years of the research (1997, 2001, 2002, 2007, 2008), the number of weeds in this treatment does not exceed 60 plants · m^{-2}, and only in two years (1996, 1999) was higher than 150 plants · m^{-2}, which means that it is possible to maintain weed infestation in organic cultivation of wheat at a relatively low level. Among the systems where herbicides were applied, the highest number of variability was observed in the monoculture of winter wheat.

Variability in species composition and abundance of weed flora throughout the years was influenced by the effectiveness of the applied methods of weed regulation and the weather conditions, which determined the germination of specific species of weeds and affected the density of wheat canopy and its competitiveness against weeds. In the systems where herbicides were applied, there were the highest fluctuations in the value of Shannon's and Simpson's indicators throughout the years (Figures 3 and 4). Shannon's diversity index value was the highest for weed flora in organic system and increased from 0.75 in 1996 to 2.64 in 2007 (Figure 3).

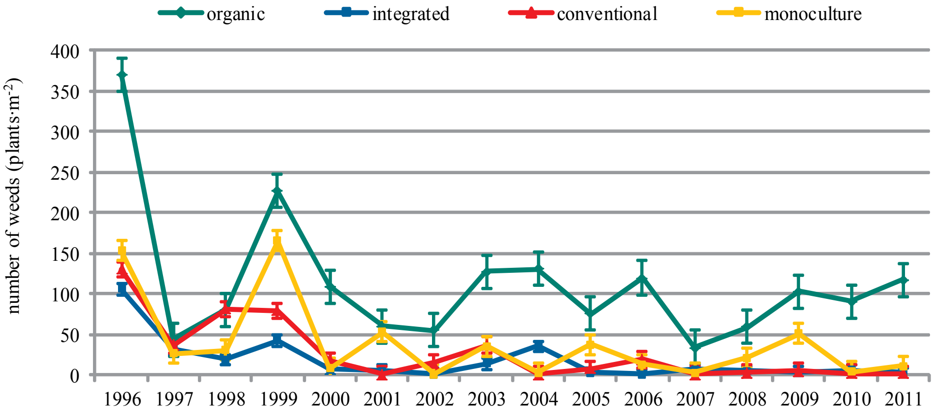

Figure 2. Weed abundance (± st. error) in winter wheat cultivated in different farming systems in years 1996–2011; source [59].

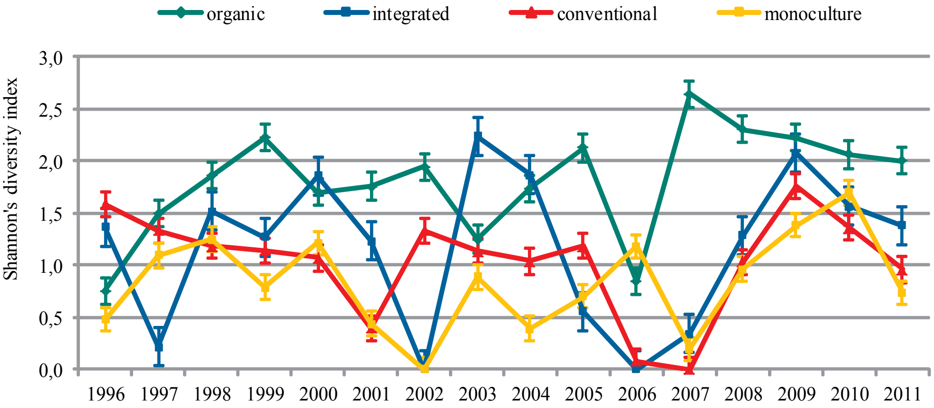

Figure 3. Shannon's diversity index values (± st. error) for weed communities in winter wheat cultivated in different farming systems in 1996–2011; source [59].

The dominance of some weed species in the community reflected in high Simpson's dominance index could affect the wheat yield more than diversified weed flora. A large diversity of weed species with low their quantity within species is less dangerous due to the yield because in multi-species weed community interspecies competition takes place. Interactions between weeds and the crop depend on the competitiveness and abundance of occurring weed species and the competitive abilities of the crop. In addition, those relationships are affected by environmental factors including soil conditions, weather, as well as agronomic practices.

It was found that weed communities in winter wheat cultivated in the organic system were characterized with a high qualitative and quantitative similarity in years, which was confirmed by the results of the ordination analysis (Figure 5).

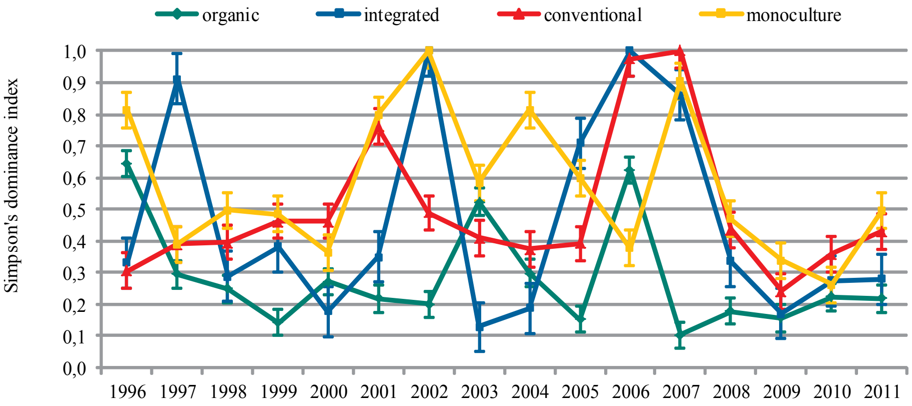

Figure 4. Simpson’s dominance index values (± st. error) for weed communities in winter wheat cultivated in different farming systems in years 1996–2011; source [59].

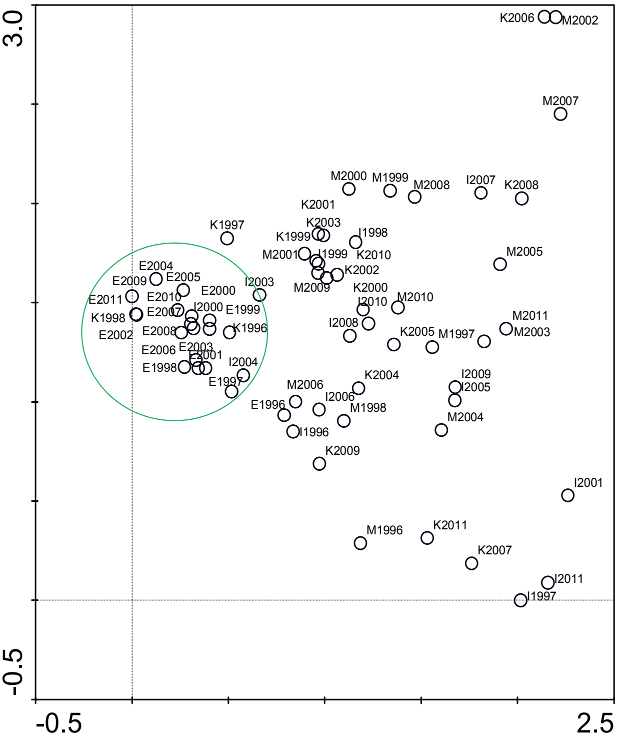

Figure 5. Ordination diagram of samples (represented weed flora communities in winter wheat cultivated in different crop production systems and years) in relation to first and second axes of Detrended Correspondence Analysis (DCA); source [59].

The comprehensive database that collates published, in-press, and other quality-assured spatial comparisons of community composition and site-level biodiversity from terrestrial sites around the world was created under the PREDICTS project (www.predicts.org.uk) [83]. Another example of a project that aimed to study the effect of different agricultural practices on diversity of flora, invertebrates, birds, and landscape in the east-south part of Poland and to prepare a geo-spatial database is the KIK/25 project (www. agropronatura.pl).

According to many research results, organic farming fulfills the promise to protect biodiversity better than conventional farming. Supporting farmers to convert their properties to organic land and to maintain organic farming within the scope of agri-environment schemes as a part of Common Agriculture Policy can have a significant impact in biodiversity as a result of management decisions farmers apply to their agricultural land [81].

7. Trends of changes in ecosystems and ecosystem services in the European Union

A large proportion of European biodiversity today depends on habitat provided by low-intensity farming practices, yet this resource is declining as European agriculture intensifies. Within the European Union, particularly the central and eastern new member states have retained relatively large areas of species-rich farmland; but despite increased investment in nature conservation here in recent years, farmland biodiversity trends appear to be worsening [11].

In the Report of the EU [84], analysis of the trends in the spatial extent of ecosystems and in the supply and use of ecosystem services at the European scale between 2000 and 2010 were presented. In the EU, urban land and forests increased while cropland, grassland, and heathland decreased (Figure 6). Many provisioning services showed increasing trends. Food and fodder crop production increased, even when agricultural areas decreased. More organic food was produced. More timber was removed from forests with increasing timber stocks. Total number of grazing livestock decreased.

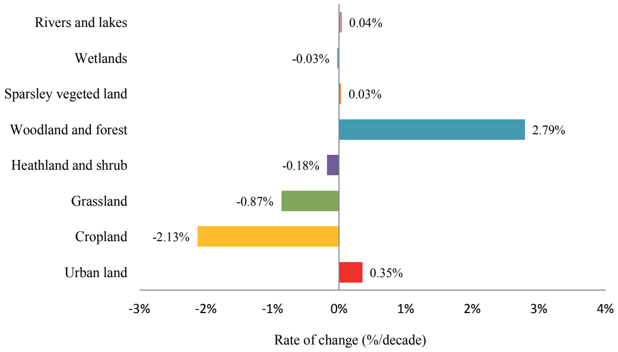

Figure 6. Change in the extent of surface area of ecosystems based on land cover data; source [84].

More area of natural environment was protected in 2010 than in 2000, but in contrast, the trends of two ecosystem services indicators that are directly related to biodiversity, pollination, and habitat quality were worsening (Figure 7). Crop production deficit was observed resulting from a loss of insect pollination. Habitat quality (regulation) slightly declined. There was a positive trend in the opportunity for citizens to have access to land with a high recreation potential.

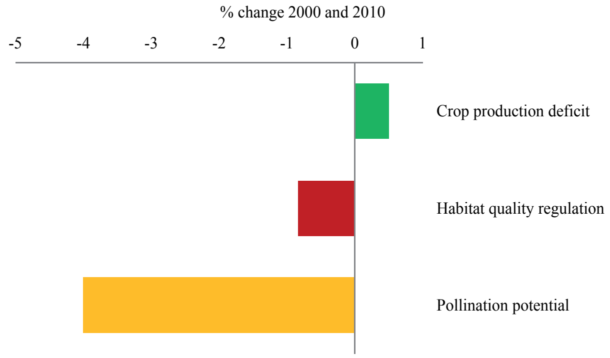

Figure 7. Main trends in ecosystem services in the EU between 2000 and 2010: Habitat maintenance and pollination; source [84].

Comparative studies show greater ecosystem quality for biodiversity as well as higher levels of rare species occurrence and species richness in lowland farmland in the central and eastern new member states than in Northern and Western Europe [11, 85]. In contrast to much of lowland EU, the main challenge and opportunity for farmland biodiversity conservation in the new member states is that a large number of species of conservation concern often still exist, e.g., in Polish field margins [11, 86]. These target species may have different requirements, creating conflicts when prescribing management measures. Simple but rigid measures applied over large areas can therefore be worse than existing management [11].

According to the EU Report, different trends in agriculture, ecosystems, and ecosystem services in EU countries were recorded (Figures 8 and 9) [84]. For example, in Poland relatively small changes were noted (increasing biomass built up and slightly negative trends in several services, including pollination potential) (Figure 8).

In France, where agriculture historically was more intensive than in Poland, slight decreases or status quo for many indicators were observed while the area under organic farming, timber stock, and forest area was rising (Figure 9).

Generally we see the following trends at the EU scale [84]:

For provisioning ecosystem services:

- More crops for food, feed, and energy are produced in the EU on less arable land. More organic food is grown. Textile crop production and the total number of grazing livestock have decreased.

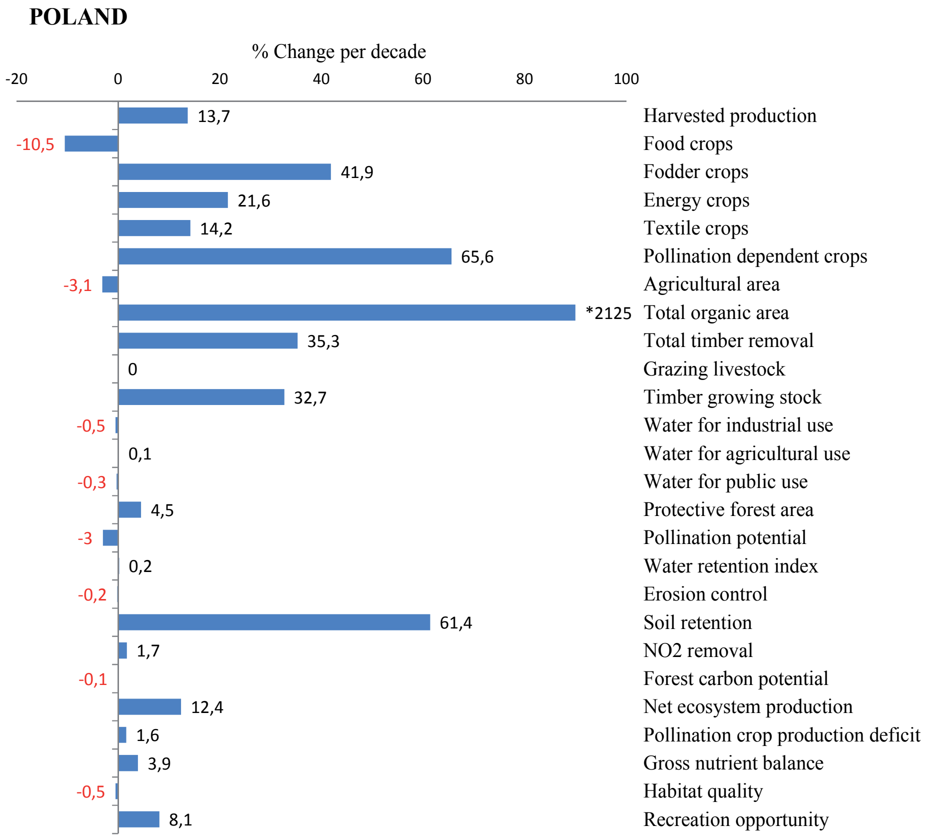

Figure 8. Trends in ecosystems and ecosystem services between 2000 and 2010 in Poland; source [84].

- The EU has used water in a slightly more resource-efficient way. Reported water abstractions decreased in both absolute and relative terms (relative to the naturally available water).

- Timber removals have increased and so, did the total timber stock.

For regulating ecosystem services:

- There is a substantial increase in net ecosystem productivity.

- Several regulating services, in particular those that are related to the presence of trees, woodland, or forests, increased slightly. This is the case for water retention, forest carbon potential, erosion control, and air quality regulation.

- Pollination potential and habitat quality show a negative trend.

For cultural ecosystem services:

- More land is protected and there is a positive trend in the opportunity for citizens to have access to land with a high recreation potential.

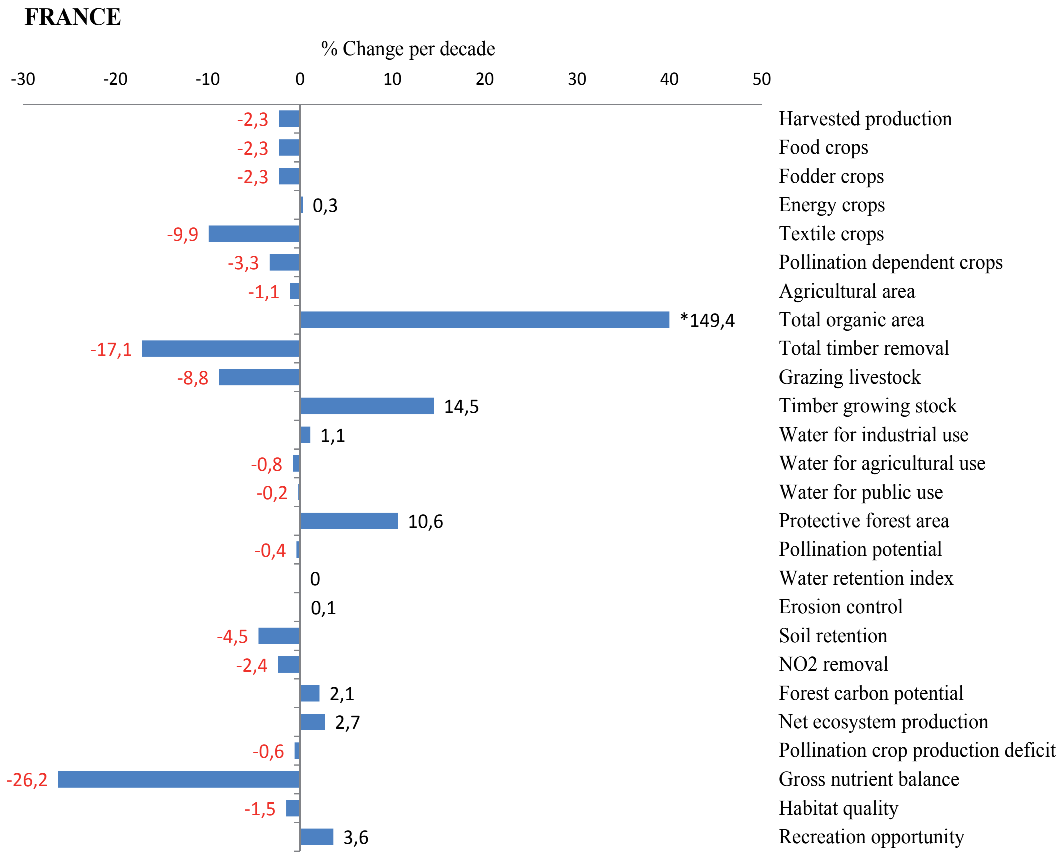

Figure 9. Trends in ecosystems and ecosystem services between 2000 and 2010 in France; source [84].

Costanza et al. [51] estimated the loss of global ecosystem services from 1997 to 2011 due to land use change at $4.3–20.2 billion/year, depending on which unit values were used. The biodiversity benefits for Europe and other countries of existing low-intensity farmland should be harnessed before they are lost. Instead of waiting for species-rich farmland to further decline, target research and monitoring to create locally appropriate conservation strategies for these habitats are needed now [11].

8. Summary

The protection of ecosystems and biodiversity is an important task and a key challenge to the world. The benefits of biodiversity conservation are difficult to notice in a short period of time or to economical evaluation. The benefits of the conservation of the species from extinction are important for future generations, because there may serve substances for medicine, genes useful in breeding, and others. At present, we do not know which plants may prove to be valuable in the future, which is why it is important to preserve as much gene pool as possible. Agriculture can contribute to the conservation of high-biodiversity systems, which may provide important ecosystem services such as pollination and biological control. Interdependencies between different groups of organisms, as well as the interaction between human activities and biodiversity require, however, further research. These studies should be conducted by experts from different disciplines in order to properly assess the value of biodiversity and ecosystem services, and create a strategy for the development of environmentally friendly agriculture and sustainable development of rural areas.

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Organic Farming as an Essential Tool of the Multifunctional Agriculture

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Abstract

This chapter aims at shedding light on the annals of organic farming and at defining its past and present meaning. Low-profile attempts were made in the first half of the last century when it comes to organic farming as it developed almost independently in the German and English speaking world. Organic farming has been established as a promising and innovative method of meeting agricultural needs and food production with respect to sustainability (climate change, food security and safety, biodiversity, rural development). Its value in terms of environmental benefits is also acknowledged. The differences between organic and conventional food stem directly from the farming methods that were used during the food items' production. Many people are unaware of some of the differences between the two practices. Agriculture has a direct effect on our environment, so understanding what goes into it is important. There are serious differences between organic and conventional farming; one of the biggest differences that is observed very frequently across all research between the two farming practices is the effect on the land. Conclusively, organic farming is a form of agriculture that relies on ecosystem management and attempts to reduce or eliminate external agricultural inputs, especially synthetic ones. It is a holistic production management system that promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity.

Keywords: Sustainability, environment, health, fertility

1. Introduction: History of organic farming

1.1. Growth and spread of the organic ideals

Many agricultural dogmas claim to strive towards sustainability [1]. Organic farming is the pinnacle of these models, and probably the one that is most acknowledged worldwide in the scientific and political arenas [2, 3], as well as by consumers as a whole. Today, organic farming is a legitimate system due to its history and evolution of practices, and rules and regulations [4, 5, 6, 7].

Organic farming is "a form of agriculture that uses fertilizers and pesticides (which include herbicides, insecticides and fungicides) if they are considered natural (such as bone meal from animals), but it excludes or strictly limits the use of various methods, including synthetic petrochemical fertilizers and pesticides; plant growth regulators such as hormones; antibiotic use in livestock; genetically modified organisms etc." [8]. As a result, it relies on techniques such as crop rotation, green manure, compost, and biological pest control.

Organic farming has dramatically grown in importance and influence worldwide throughout the years. A few statistics tell a fragment of the story: from almost negligible levels during the 1980s, the area of organic farms worldwide spanned to an estimated 43.1 million hectares in 2013 [9]; the worldwide organic market size was worth 54 billion euros in the same year [10]. However, these numbers depict only a part of what organic farming has become; scientists, educators, and agricultural policy makers have been making a change that formally began during the late 1970s. The growth of research on organic farming has been particularly striking, and the number and variety of organic curricula and degrees offered at universities in many countries are vast. At the first International Scientific Conference of the International Federation of Organic Agriculture Movements (IFOAM), held in Switzerland in 1977, a total of 25 presentations were offered. When the IFOAM conference returned to Switzerland in 2000, that number had multiplied more than 20 times, to well over 500 [11]. Before the 1970s, funds for organic research were extremely limited; today, significant public money is available in many countries: Denmark, France, Germany, Sweden, Switzerland, and the Netherlands are all reported to spend millions per year on organic research [12]. An important component of the advancement of organic farming has been its global spread. Five countries were represented when IFOAM was organized in 1972, and by the late 1990s, it had members from over 100 countries. IFOAM's scientific conferences, which until the mid-1980s had only been held in Western Europe and North America, have since been held in countries as diverse and dispersed as Burkina Faso, Australia, Hungary, and Brazil, among others. Further evidence that organic farming has gone global is that the UN Food and Agriculture Organization has been involved in it since 1999, with activities that include market analysis, environmental impact assessments, improving technical knowledge, and development of standards through the Codex Alimentarius Commission [13]. The United Nations Conference on Trade and Development has been involved in global trade of organic foods since 2001, particularly in assisting developing countries in increasing their production [14].

1.2. History

The concept we know today as 'organic farming' is a mixture of different views coming mainly from German and English-speaking societies. These ideas arose at the end of the 19th century, and between the two World Wars, as intensive and mechanized farming faced a crisis in the form of soil degradation, poor food quality and the decay of rural social life and traditions.

Inappropriate use of mineral fertilizers was disturbing plant metabolism, making them susceptible to pathogens and insect pests. At the same time, effective pesticides had not yet been developed. Physiologically acidic mineral fertilizers acidified the soil and brought about diminished root growth and degradation of the soil structure. Soil compaction caused by the use of machinery and reduced organic manuring caused droughts, and soils experienced a decline in fertility – referred to as "soil fatigue" (Bodenmüdigkeit) [15]. Despite the increased use of mineral fertilizers, agriculture suffered a dramatic drop in yields (up to 40% in countries like Germany) after World War I; only at the end of the 1930s – after more than 15 years – did yields reach pre-war levels [16].

Some consumers were worried about declining food quality: food that did not stay fresh, tasteless vegetables and fruits, and pesticide residue based on toxic heavy metals. Increased use of mineral fertilizers and pesticides was discussed by the public as a major cause of this decline. For example, an assumption that an elevated level of potassium in cancer cells was caused by the increased amount of potassium in fertilizers was not something unthought-of. Scientists such as Robert McCarrison in the UK or Werner Schuphan and Johannes Görbing in Germany confirmed some of these suspicions, such as lower vitamin levels in fruits and vegetables caused by increased nitrogen fertilization [17, 18]. Finally, the social and economic situation in the countryside changed dramatically with the mechanization of agriculture, industrialization of the food sector, and import of agricultural products. An imbalance arose between the urban centers; severe economic problems caused by low prices (due to imports) and indebtedness (due to purchase of machines, fertilizers, and pesticides) forced many small and medium-sized farms to give up. As a result, there was a general decline in rural tradition and lifestyle.

As a solution to this crisis, organic farming pioneers offered a convincing, science-based theory during the 1920s and 1930s that evolved into a successful farming system during the 1930s and 1940s. But it was not until the 1970s, with growing awareness of an environmental crisis, that organic farming attracted interest in the wider worlds of agriculture, society, and politics. The leading strategies that proposed to achieve sustainable land use included a biological concept of soil fertility, intensification of farming by biological and ecological innovations, renunciation of artificial fertilizers and synthetic pesticides to improve food quality and the environment and, finally, concepts of appropriate animal husbandry.

At the annual meeting of the American Association for the Advancement of Science (AAAS) in 1974, a panel of scientists targeted the "organic food myth", calling it "scientific nonsense" and the domain of "food faddists and eccentrics". They also blamed such "pseudoscientists" for causing panic among the public with regard to paying more for food [19] and also mentioned that the "organic myth" was counterproductive to human welfare, because it leads to a rejection of procedures that are needed for the production of nutritious food at "maximum efficiency" and was "eroding gains of decades of farming advancements". However, 7 years later, the journal of this same AAAS published a major research paper that found organic farms to be highly efficient and economically competitive when compared to conventional farming [7].

2. Comparison of organic and conventional farming system

In the recent years, agriculture has been oriented towards industrial and notably intensive farming practices aimed at ensuring enough food for humanity. However, these types of farming practices also caused several negative environmental impacts such as decreasing biodiversity. Many agroecosystems intensified their activities and became highly mechanized, while those unable to do so became increasingly marginalized and were sometimes forced to abandon their land, causing evenly destructive effects for biodiversity [20].

Currently, it is globally imperative that the increasing demand for food be met in a manner that is socially fair and ecologically sustainable over the long run. It is possible to design farming systems that are similarly productive and that enhance the provisioning of ecosystem services such as biodiversity, soil quality and nutrient, control of weeds, diseases and pests, energy efficiency, and the reduction of global warming potential, as well as resistance and resilience to climate change and crop productivity [21].

Organic farming is a system that favors soil fertility by maximizing the efficient use of local resources, while foregoing the use of agrochemicals and genetically modified organisms. The high quality of organic food and its added value based on a number of farming practices relies on ecological cycles, and it focuses on declining the environmental effect of the food industry, maintaining long-term sustainability of soil and reducing to a minimum the use of nonrenewable resources [22].

Organic farming practices have been launched to reduce the environmental impacts of agriculture. The results of studies that compare the environmental impacts of organic and conventional farming in Europe show that organic farming has a positive impact on the environment. Important differences between the two farming systems include soil organic matter (SOM) content, nitrogen leaching, nitrous oxide emissions, energy use, and land use. Most of the studies that compared biodiversity in organic and conventional farming showed lower environmental impacts from organic farming [23].

Furthermore, organic farming appears to perform better than conventional farming and also provides other important environmental advantages such as curbing the use of harmful chemicals and their spread in the environment and along the trophic chain, and reducing water use [22].

- *Health*

Organic practices contribute to better health through reduced pesticide exposure for all and increased nutritional quality in food products. In order to understand the importance of consumption of organic food from the viewpoint of toxic pesticide contamination, we should look at the whole picture: from the farmers who do the valuable work of growing food, to the waterways from which we drink, the air we breathe, and the food we eat. Organic food can nourish us and keep us healthy without causing the toxic effects of chemical agriculture [24, 25].

The population groups most affected by pesticide use are farmers. These people live in communities near the application of toxic pesticides, where pesticide drift and water contamination are common. Farmers, both pesticide applicators and fieldworkers who tend to and harvest the crops, come into frequent contact with such pesticides. Organic farming does not utilize these toxic chemicals, and thus eliminates this enormous health hazard to workers, their families, and their communities [25, 26].

Acute pesticide poisoning among farmers is only one aspect of the health consequences of pesticide exposure. Many farmers spend time in the fields, resulting in prolonged exposure, and some studies have reported increased risks of certain types of cancers among farmers as a consequence. The emerging science on endocrine disrupting pesticides reveals another chronic health effect of pesticide exposure [25, 27].

- *Environment*

Organic farming is often perceived to have generally beneficial effects on the environment compared to conventional farming [28, 29]. More specifically, organic food production eliminates soil and water contamination. Since organic food production strictly avoids the use of all-synthetic chemicals, it does not pose any risk of soil and underground water contamination like conventional farming, which uses tons of artificial fertilizers and pesticides. Also, organic food production helps preserve local wildlife; by avoiding toxic chemicals, using mixed planting as a natural pest control measure, and maintaining field margins and hedges, organic farming provides a retreat to local wildlife rather than taking away their natural habitat like conventional agriculture [30].

Agrobiodiversity is an important aspect of biodiversity that is directly influenced by different production methods, especially at the field level. It can also supply several ecosystem services to agriculture, thus reducing environmental externalities and the need for off-farm inputs. Moreover, organic farming helps conserve biodiversity. Avoidance of chemicals and use of alternative, all natural farming methods have been shown to help conserve biodiversity as it encourages a natural balance within the ecosystem and helps prevent the domination of a particular species over the others [31].

Various different approaches have been used in order to compare environmental impacts of farming systems, such as organic and conventional. Several studies have focused on biodiversity [31, 32], land use [33], soil properties [34, 35], or nutrient emissions [36, 37]. Life cycle assessment (LCA) studies have used a product approach to assess the environmental impacts of a product from input production up to the farm gate [38, 39]. According to the literature, Mondelaers et al. (2009) [40] used the meta-analysis method to compare the environmental impacts of organic and conventional farming, examining land-use efficiency, organic matter content in the soil, nitro-phosphate leaching into the water system, greenhouse gas (GHG) emissions, and the effect on biodiversity [23].

In a review of literature, Hole et al. (2005) [31] compared biodiversity in organic and conventional agroecosystems. They found that organic farming generally had positive impacts on biodiversity. However, they concluded that it is still unclear whether conventional farming with specific practices for biodiversity conservation (i.e., agri-environmental schemes) can provide higher benefits than organic farming. More studies published after 2003 supported the findings of Hole et al. (2005) [31] and Bengtsson et al. (2005) [41], but none found organic farming to have negative impacts on biodiversity. More specifically, herbaceous plant richness has been widely found to be higher in organic farms compared with conventional farms [42, 43], and several studies showed that landscape had more important impact on biodiversity than farming practices [44, 45]. It has also been found that organic farming, without additional practices, is not adequate for conserving some animal species [23, 44, 46, 48].

The main reason for the reduction of agricultural biodiversity during the last decades has been the change in agricultural landscapes [48, 49]. In Europe, formerly heterogeneous landscapes with a mix of small arable agroecosystems, semi-natural grasslands, wetlands, and hedgerows have been replaced in many areas by largely homogeneous areas of intensively cultivated farms [50]. This has resulted in declines in biodiversity and has caused an important loss of species [23, 51].

Regarding the soil ecosystem, Tuomisto et al. (2012) [23] had found that organic matter across all the cases was 7% higher in organic farms compared to conventional farms. The main explanation for higher organic matter contents in organic systems was that they had higher organic inputs such as manner or compost. Other explanations for higher SOM levels in organic systems were less intensive tillage and inclusion of leys in the rotation [52, 53]. Gosling and Shepherd (2005) [54] observed lower organic matter contents in organic farms by higher yields, and thus, higher crop residue leftovers in conventional systems, which can compensate the lower external organic matter inputs. Furthermore, they argued that leys do not necessarily contribute to the increase of organic matter because they have a low carbon–nitrogen ratio and, therefore, organic matter decomposes quickly.

According to some studies [55, 56], the main explanation for lower nitrogen leaching levels from organic farming per unit of area was the lower levels of nitrogen inputs applied. Raised nitrogen leaching levels were explained by bad synchrony between the nutrient availability and crops' nutrient intake [57]. Notably, after incorporation of leys, the nitrogen losses tend to be high [58].

In conclusion, organic farming is a method of crop and livestock production that considered an environmentally friendly agriculture practice and a holistic approach involving several requirements and prohibitions from a regulatory point of view, and receives primarily from European countries additional agri-environmental payments for ecosystem services such as biodiversity. In several countries, payments are available as single biodiversity measures such as insectary strips, hedgerows, crop rotation, or the retention of semi-natural areas in agri-environmental programs that also focus on conventional farming.

3. Organic farming, conservation agriculture, and sustainability

This chapter shows the connection between organic farming and sustainability-conservation models, how this interplay has evolved during the past years, and, more importantly, its future directions. Various agricultural models claim to achieve sustainability. Organic farming is one of those candidate models, and probably the most widely known and accepted on an international level. It is recognized in the scientific and political areas as well as by society as a whole. Organic farming has been established as a promising and innovative method of meeting agricultural needs and food production with respect to sustainability (climate change, food security and safety, biodiversity, rural development). Its value in terms of environmental benefits is also acknowledged.

Organic agriculture is developing rapidly, and statistical information is now available from 138 countries in the world. Its share of agricultural land and farms continues to grow in many countries. According to the latest survey on organic farming worldwide, almost 30.4 million hectares are managed organically by more than 700,000 farmers. Most of this land is in Latin America, followed by Asia, Africa, and Europe [9].

Organic farming works in harmony with nature rather than against it, and it involves using techniques to achieve good crop yields, without harming the natural environment, or the people who live and work in it. The methods and materials that organic farmers use are summarized as follows:

To keep and build good soil structure and fertility:

- Recycled and composted crop wastes and animal manures
- Right soil cultivation at the right time
- Crop rotation
- Green manures and legumes
- Mulching on the soil surface

To control pests, diseases, and weeds:

- Careful planning and crop choice
- The use of resistant crops
- Good cultivation practice
- Crop rotation
- Encouraging useful predators that eat pests
- Increasing genetic diversity
- Using natural pesticides

Organic farming also involves:

- Careful use of water resources
- Good animal husbandry

Future global food security relies not only on high production and access to food but also on the need to address the destructive effects of current agricultural production systems on ecosystem services [65] and to increase the resilience of the production systems to the effects of climate change. Conservation agriculture (CA) enables the sustainable intensification of agriculture by conserving and enhancing the quality of the soil, leading to higher yields and the protection of the local environment and ecosystem services [67].

CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels, while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes.

CA is characterized by three principles which are linked to each other, namely:

1. Continuous minimum mechanical soil disturbance (i.e., no tilling and direct planting of crop seeds).
2. Permanent organic soil cover.
3. Diversification of crop species grown in sequence and associations [62].

It has generally been demonstrated that CA allows yields to increase while improving soil and water conservation, and reducing production costs [60, 64]. In addition, CA has been shown to work successfully in a variety of agroecological zones and farm sizes. Indeed, another advantage associated with CA is that it can be applied to different farming systems, with different combinations of crops, sources of power and production inputs.

There is no real dispute that sustainable agriculture and organic farming are closely related terms. There is, however, some disagreement on the exact nature of this relationship; for some, the two are synonymous, while for others, equating them is misleading. Lampkin's definition of organic farming, quoted earlier, talks of sustainable production systems. Having provided his definition, he goes on to state: "...sustainability lies at the heart of organic farming and is one of the major factors determining the acceptability or otherwise of specific production practices." Similarly, Henning et al. precede their definition of organic farming, quoted above, by claiming that "it could serve equally well as a definition of 'sustainable agriculture'" [59]. Rodale even suggested that "sustainable was just a polite word for organic farming" [63]. Some of the research that has been carried out regarding the historical relationship between agricultural systems and the sustainability of the societies they support illustrates the point that a farming system need not be modern, mechanized, and using synthetic chemicals to be profoundly unsustainable [61].

Part of the difficulty in assessing the sustainability of agricultural systems, is the fact that both the units of measurement and the appropriate scales for measurement differ both within and across the commonly identified economic, biophysical and social dimensions of sustainability. For example, consideration of the effects of organic production on farm margins, soil fertility, and rural employment are difficult to combine in an overall measure. They are not so problematic if the effects are all in the same direction, but when one starts to consider trade-offs, as one indicator increases and another falls across different dimensions, then this factor becomes more significant. This is an issue which will not be solved simply by greater knowledge of the impacts of different production systems; even with complete information regarding impacts, one will still have to consider trade-offs with movement towards targets in some respects accompanied by reverses in others [61].

4. Organic practices

Throughout the years, organic farming has evolved in a diverse manner. Many sub-schools and sub-dogmas have appeared. Two of the most important, biointesive farming and permaculture, are discussed below:

4.1. Biointesive farming

Biointensive agriculture aims to result in maximum yields from the minimum area of land, while simultaneously improving and maintaining the fertility of the soil, as well as abiding by the rules of organic farming all the time. It is particularly designed for the small-scale grower. Biointensive cropping strategies (i.e., polycultures) are usually labor intensive [68].

4.1.1. Permaculture

Permaculture emphasizes eco-design [69]. Sepp [70] defines permaculture as a system in which every element fulfills multiple functions, and every function is performed by multiple elements. Energy is used practically and efficiently with a great focus on renewable forms, and diversity is favored instead of monoculture.

4.2. Crop rotation

Crop rotation is a very important piece of all organic cropping systems because it provides the basic function of keeping soils healthy, an efficient way to control pests, and other benefits. Crop rotation is defined as changing the type of crop grown on a particular piece of land from year to year [71]. There are both cyclical rotations, in which the same sequence of crops is repeated on the same field, and noncyclical rotations, in which the sequence of crops is diversified to meet the changing needs of the farmer.

Good crop rotation requires long-term strategic planning. However, planning that is too long term may prove futile as choices can be affected by changes in weather, in the market, labor expenses, and other factors. Conversely, lack of planning can lead to serious problems – for example, the buildup of soil-borne diseases of a critical crop, or imbalances in nutrients [71]. Problems like the ones mentioned above often take several years to become noticed and can catch even experienced farmers by surprise. In fact, rotation problems usually do not develop until well after the transition to organic cropping. Fallowing is also a noted part of crop rotation.

The design of a diverse crop rotation is the key to soil nutrients, weed, pest, and disease management. To achieve even some of these benefits of crop rotation, great focus on management is required, since diversity simply as a goal may lead to losses in production and productivity [72]. Therefore, there is a need for functional diversity [73]. In mixed intercropping, crop cycles tend to be similar to allow simultaneous management of the components (e.g., grass/clover leys or cereal with grain legumes), or completely different to allow separate management (e.g., cereals intercropped with forage legumes). Extremes of mixed intercropping systems can be seen in agroforestry [74] or perennial polyculture [75, 76].

Principles guiding the spatial arrangement of crops in polyculture are also well developed, dominantly originating from horticulture; they have been tested through research and developed by trial and error [77, 78, 79] of studies of traditional cropping systems [80, 81, 82].

4.3. No till and conservation till farming

In zero tillage, the soil is left undisturbed from harvest to planting, except for nutrient supply. Planting or drilling is accomplished in a narrow seedbed or slot created by coulters, row cleaners, disk openers, as well as in-row chisels [83]. Weed control is accomplished primarily with herbicides.

Conservation tillage is defined as tillage and planting system that maintains at least 30% of the soil surface covered by residue after planting (CTIC and Conservation Technology Information 1998). There are various benefits to this practice, with the most important being economic (conservation tillage operations reduce costs) and environmental (reduced cultivation implies reduced energy inputs [84], thereby ensuring less pollution and less disturbed soil, while organic matter accumulation is increased and CO_2 releases to the atmosphere are much reduced [85]).

4.4. Mulching

Mulching is the method of covering the surface of the soil with any decomposable material (grass, hay, leaves, waste etc.) Benefits include the soil is not dried by wind and sun exposure, moisture is reserved and soil erosion is prevented, rich humus is provided to the soil, and soil drainage is improved. It also leads to an increase in soil micro organisms and reduction in weed growth.

4.5. Composting

Composting is a process where microorganisms decompose organic matter to produce a humus-like substance called compost. The process is natural, provided the right organisms, water, oxygen, organic material, and nutrients are in place. By controlling these factors, the composting process can occur at a much faster rate [86]. The bacteria and fungi occurring in the soil convert dead organic matter present on its surface into a nutrient-rich medium. This is called composting, and the nutrient-rich medium is called compost. Following are the benefits of compost, compared to the usage of raw manure:

1. Making compost turns waste into a profitable resource.
2. Compost is environmentally friendly and promotes industry sustainability.

3. Compost adds organic material, thereby improving the soil structure and water retention.
4. Compost use reduces the need for inorganic fertilizers.
5. Causes slow release of nutrients – nutrients are released to the plants slowly, thus reducing the loss of nutrients to the environment.

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Chapter 3

Pollution Prevention, Best Management Practices, and Conservation

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Additional information is available at the end of the chapter

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Abstract

Farming imposes unenthusiastic externalities upon society. It effects by different sources such as loss of biodiversity, land erosion, nutrient overflow, more water usage and pesticides. Optimistic externalities include respect of nature, independence, free enterprise, and the quality of air. Natural methods decrease some of these costs. It has been proposed that organic farming can reduce the level of some negative externalities from (conventional) farming. Organic farming seems to be more appropriate as it considers important aspects such as sustainable natural resources and the environment. For sustainable agriculture, the most important key is the conservation of natural resources. As natural resources become increasingly short in supply, in the coming years the transition to a more resource-efficient economy must be a top priority. Agriculture is the most important sector for ensuring food security for next generations while decreasing the resource use and increasing resource recycling. Various studies have been conducted to compare organic and conventional farming systems and the result shows that organic techniques are less damaging than conventional ones because of the decreased level of biodiversity, less use of energy, and lesser amount of waste production. The researchers of various studies concluded that comparing conventional and organic farming demonstrated that organic agriculture poses lower environmental impacts. However, researchers believe that the perfect result would be the expansion of ways to produce the uppermost yields possible by the combination of these two farming systems and to develop the new system for environment, land, and sustainable forests. Biodiversity from organic farming provides assets to humans. Species found in organic farms increase sustainability by decreasing human inputs such as pesticides and fertilizers.

Keywords: Organic foods, externalizes, environment, impact assessment, conservation

1. Introduction

At present, across the world, industrialized and industrializing countries are consuming the earth’s resources at an alarming rate. The world population is continually on the climb. More people on earth and changing their consumption pattern increase their essential requirements for more basic human needs like food, water, shelter and energy. This leads to suggest that an essential rethink of the way we manage our natural resources.

Rising means of agriculture farming is the reason that human lives in the world today. For survival these are the necessary means without which there would be famines all over the world. From many thousands of years agricultural farming was a natural process that did not harm the land it was done on. Farmers used such methods for agriculture that after passing of many generations soil would still be fertile as ever, while modern agricultural practices have started the process of agricultural pollution and this causes the degradation of land, environment and ecosystem due to by-products of agriculture. No particular cause can be credited to the extensive agricultural pollution we face today. Agriculture is a multifaceted activity in which the growth of crops and livestock has to be balanced completely. Agricultural pollution progression stems from the many stages their growth goes through.

To be well thought-out a best management practice, an action is required which increase the crop production while reducing the impact on environment. This means that for healthy crop using the best management like reducing the pesticide treatment. Soil plays a very important role for healthy crops and its management is very necessary, it may be challenged by intensive production of horticultural crops. Farming technologies degrade the natural resource base because they require high toxic chemicals. Organic farming rely on the management of soil organic matter to increase the physical, biological and chemical properties of soil for optimization of crop production. Soil management controls the supply of nutrients to the crops. Soil processes furthermore play a key role in suppressing the pests, weeds and diseases. Agricultural research based on technology should be developed by specialist and then transferred to the farmers through demonstration. Environmentally friendly farming system relies on minimal chemical use like pesticide and herbicide because they play an important role in erosion control. Several authors have already described the potential effects of conventional farming versus organic farming on soil erosion control (Lotter etal, 2003; Erhart and Hartl, 2010, Goh, 2011).

The International Federation of Organic Agriculture Movements standards suggested that by using the minimal tillage, crop selection criteria, maintenance of soil plant cover and other methods which reduce the soil erosion, organic farmers should reduce the loss of top soil cover for better production of crops. Conservation tillage should be adopted by organic farmers especially if they are located in areas susceptible to erosion (IFOAM, 2000). The nutrient contribution is very important in organic farming. By organic manure and rotation nitrogen fixed in the legumes and supplied to the crop. Tillage is also very important because it contributes in incorporation and distribution of nitrogen in the topsoil (Koepke, 2003). This chapter explores how organic farmers can utilize a range of management practices to develop and maintain the soil fertility in order to achieve these wider goals.

1.1. Organic farming

In organic farming, food is grown and processed using no synthetic fertilizers, but pesticides derived from natural sources may be used in producing organically grown food (NOSB 1995). Organic farms reduce some of the negative impacts of conventional farming such as soil erosion and leaching of carbon and nitrogen [1-3]. Organic production has been practiced in the United States since the late 1940s. From that time, the industry has grown from experimental garden plots to large farms where products are formed and sold with specific organic labels. More than forty different state agencies currently certify organic food but their standards are different. According to the organic food production act of 1990, there would be a national list in which the synthetic and non-synthetic substances mentioned cannot be used in organic farming. Organic farming can contribute to protect the environment and nature conservation [4-5].

1.2. Principles of organic agricultural

- Organic farming or agriculture contributes to the health and well-being of plants, animals, soil, earth, and humans; it also provides the nourishment of ecological, physical, and social welfare as it provides chemical- and pollution-free food for humans.
- Equality is obvious in maintaining the integrity of the joint planet mutually amongst humans and further living beings. It is helpful in decreasing poverty and improves the quality of life.
- In the living ecological system, organic farming must be modeled because these methods fit the environmental cycles and equilibrium of the natural world.
- Natural farming should be accomplished in a vigilant and accountable way to promote the environment and generation at present and in the future.

1.3. Regulations for organic farming

The National Organic Program proposed some regulations that will ensure that organically labeled products meet consistent national standards.

- Any farm crop harvesting or handling operation that wants to sell an agricultural product as organically produced must adhere to the national organic standards.
- The national organic standards for production process address the methods, practices, and substances used in producing and handling crops, livestock, and processed agricultural products.
- Organically produced food cannot be produced using excluded methods, sewage sludge, or ionizing radiation.
- The organic crop production standards say that land will have no prohibited substance for 3 years before organic crop harvesting, no use of genetic engineering and ionizing radiation, soil fertility and crop nutrients will be managed, organic seeds and planting stock will be preferred, crop disease, pests, and weeds will be controlled.

- In the livestock standards, slaughtering of animals must be raised under organic management, organically raised animals may not be given hormones to promote growth, and all organically raised animals must have access to the outdoors, including access to pasture for ruminants.
- The handling standards say that all non-agricultural ingredients must be included on the National List of Allowed Synthetic and Prohibited Non-synthetic Substances.

1.4. Environmental benefits of organic farming

Organic farming considers the intermediate and enduring end product of farming interventions on the agro-ecosystem. Organic farming aims to manufacture food, whereas establishing an ecological equilibrium for prevention of soil fertility and other related problems. This method takes a positive move forward, as opposite to treating the problems when they come into view.

1.4.1. Soil

Soil structure practices such as crop rotations, symbiotic associations, and organic fertilizers are middle to organic practices. These promote soil fauna and flora by improving soil formation and structure. In turn, nutrient and energy cycling is increased and the retentive abilities of the soil for nutrients and water are enhanced, compensating for the non-use of mineral fertilizers. In soil erosion control such management techniques also play an important role. Crop export of nutrients is usually compensated by farm-derived renewable resources, but it is sometimes necessary to supplement organic soils with potassium, phosphate, calcium, magnesium, and trace elements from external sources [6-8].

1.4.2. Air

Organic farming reduces non-renewable energy use by decreasing agrochemical needs. It contributes to mitigating the greenhouse effect and global warming through its ability to appropriate carbon in the soil. Many running practices include recurring yield residues to the soil, use of crop rotations, returning of carbon to the soil for increasing the productivity, and increasing addition of nitrogen-fixing legumes. In many different studies, it was reported that the soils under organic farming have more carbon content as compared to other soils. The more organic carbon is retained in the soil, the more the mitigation potential of agriculture against climate change is higher [9-11].

1.4.3. Water

Pollution of ground water with synthetic fertilizers and pesticides is a major problem in many cultivation areas. Synthetic fertilizers are prohibited in organic farming, they are replaced by compost, animal manure, green manure (organic fertilizers), and through the use of greater biodiversity they contribute to enhance the structure of soil and water infiltration capacity. Risk of ground water pollution may be greatly reduced by properly managed organic systems.

Organic agriculture is greatly expectant as an uplifting measure in those areas where pollution is a genuine dilemma [12].

1.4.4. Genetically modified organisms

The use of these within organic systems is not permitted during any stage of organic food production because their potential impact on health and environment is not entirely understood. Organic farming encourages natural biodiversity. The organic label provides an assurance that these organisms have not been used intentionally in the production and processing of organic products. In conventional farming, increasing the use of genetically modified organism and due to the method of transmission of these organism in the environment (through pollen), organic farming will not be able to ensure that organic products are completely free from genetically modified organism in the future [13-15].

1.4.5. Biological services

The collision of natural farming on usual resources favors connections that are vital for both organic production and nature protection within the agro-ecology. Biological services results include stabilization forming and conditioning of soil, nutrient and waste recycling, predation and habitats. Development of pollution-free agriculture systems depends upon the consumer's purchasing power to buy organic products [6-7].

2. Pollution prevention in organic farming

Getting higher resources of farming and cultivation is why humans live in this world. Farming is an essential resource of continued existence; the lack of these resources leads to famines all over the world. Organic farming was a natural process for the last several years that did not harm the land; many generations of crops have been produced without affecting the fertility of soil. However, modern farming practices have started farming pollution that affects the ecosystem, land, and environment. Farming is a multifaceted activity in which the growth of crops and livestock has to be balanced perfectly [16].

2.1. Causes of farming pollution

2.1.1. Fertilizers

In earlier days, fertilizers have been considered the source of pollution, but in modern days, they treat local pests with new persistent species that have existed for many years and they are loaded with chemicals that are not natural. When pesticides have been sprayed, it mixes with the water and seeps into the ground. Plants absorb the leftover pesticide, and as a result, local streams become contaminated. When these crops are eaten by animals, they are also affected [17].

2.1.2. Livestock

In the past, livestock (cattle, sheep, pigs, chickens) were fed with natural diets, which was supplemented by the waste left over from the crops, and farmers would like to keep them on land. Thus, the animals helped to maintain the farm health as well. But these days, livestock is raised in overcrowded areas, fed with unnatural diets, and sent to slaughterhouses regularly. They cause farming pollution by means of emissions [18].

2.1.3. Weeds and pest

Reducing the natural species and growing unusual crops has become the standard in farming in different areas. The entry of new crops in the local market has resulted in new pest diseases and weeds that the population is not capable of fighting. As a result, local vegetation and wildlife are destroyed permanently. This simply adds to the process of farming pollution [19].

2.1.4. Contaminated water

One source of pollution is the use of contaminated water for irrigation. The water we use comes from ground water reservoirs that are clean and pure water. Other sources are polluted with organic compounds and heavy metals due to the disposal of industrial and agricultural wastes in local bodies of water. As a result, crops are exposed to that water and the process of agricultural pollution becomes harder to fight when such water poisons the livestock and causes crop failure.

2.1.5. Sedimentation

Soil has many layers but only the top layer supports farming. One common reason for the declining soil fertility is inefficient farming practices. Due to these practices, soil left open is eroded by water and wind. This soil is then deposited somewhere and causes sedimentation. This sedimentation causes soil rise in areas such as rivers, streams, ditches, and surrounding fields, and the process of agricultural pollution prevents the natural movement of water, aquatic animals, and nutrients to other fertile areas.

2.2. Effects of farming pollution

2.2.1. Effects on aquatic animals

Organic matter such as ammonia or fertilizers turned into nitrate decreases the level of oxygen in the water and causes the death of many aquatic animals. From animal wastes, bacteria and parasites can get into drinking water, which can cause serious health problems for a variety of aquatic life and animals. It is a hard issue to keep farming pollution in check as it seems. It is difficult to keep track of water levels, soil cleanliness, and industrial pollution. For the last few years, governments have become stricter about enforcing rules. Farmers are becoming aware about the damages and are looking for solutions; most of them are moving toward conventional farming. But for the process of farming pollution to be fully reigned in, there has to be a complete shift in the way cultivation is practiced.

2.2.2. Effects on health

The main source of pollution in water and lakes is farming pollution. Fertilizers and pesticide chemicals are absorbed by ground water and end up in drinking water and cause severe health problems. Oils, degreasing agents, metals, and toxins from farm equipment cause health problems when they get into drinking water.

2.3. Pollution prevention practices

Pollution prevention means reducing the originating of wastes. This will include practices that conserve natural resources by eliminating pollutants through increased efficiency in the use of raw materials, energy, water, and land. Pollution prevention minimizes pollution at the source, so pollution is not created in the first place and never enters into the environment. Environmental prevention has involved controlling and treating the pollution, which in many cases we continue to create. It is helpful in reducing the risks on health and the environment in many ways, such as eliminating the risks associated with the release of pollutants to the environment, avoiding the shift of pollutants from one medium to another medium, and protecting the natural resources for future generations. Pollution prevention can be promoted through several ways such as using voluntary pollution reduction programs, engaging in partnerships, providing technical assistance, funding demonstration projects, and incorporating cost-effective pollution prevention alternatives into regulations. It also involves using systematic management methods such as grass and tree planting technology, improvement of medium and low farmland, and overall use of rural energy resources in order to deal with and improve the ecological environment [20].

3. Management practices in organic farming

In production methods, soil texture plays a bigger role. It influences when a producer can till, the types of tillage methods used, and the frequency of green manure crops. The production methods developed are suited to the climate and soil texture of their farms.

3.1. Healthy soil

In an organic farming system, soil health is the key to success. Soil health can be assessed qualitatively. Many producers look for a dark, rich-colored soil with earthy smell and good organic matter. Earthy smell indicates that the soil is rich of microorganisms, which are vital to soil health. Some take a note of wildlife attraction to the field; birds can be a good indication of earthworms and other organisms. Some producers note the color of leaves and the development of root systems as crops grow; yellow leaves indicate low nitrogen levels, red color and dead spots indicate a plant is under stress, and dark green color with slow growth indicates low nutrient levels. Weeds growing in the field indicate which nutrients are available in the soil; they require the same nutrients but in different amounts. Fertile soil is called healthy soil; it contains sufficient chemical nutrients (macronutrients and micronutrients) for plant growth.

Those needed in larger amounts are called macronutrients such as nitrogen, phosphorus, calcium, sulfur, and potassium. Among them, nitrogen is commonly limited to plants and it is abundant in air; few free-living microbes and rhizobium associated with legumes can fix the nitrogen from air. While other minerals can move into the soil from the underlying rocks. When products are removed from the farm ecosystem, nutrients are removed from the soil. Among them, nitrogen is removed in the largest quantities, but fortunately it can be replaced from the air. Fertile soils can be easily tilled and have good structure, it allows good penetration and absorption of nutrients. Biological fertility such as microbes cycle chemical nutrients available via the breakdown of plant residue and animal wastes. They form a symbiotic relationship with the plants that increase the amount of soil that plants are able to search the nutrients.

3.1.1. Soil test

To check the level of soil fertility and nutrients, soil test may be needed. Soil test provide information about soil nutrients, pH, and organic matter. Some soil test results include macronutrients. These soil tests typically provide recommendations about fertilizers in farming. Soil testing can be beneficial for organic producers. Long-term changes in soil fertility help the producers to adjust soil management strategies such as crop selection, rotation, and green manure. Experienced producers do not feel the need to test the soil; they evaluate the health of the soil using production yield. For the soil test, it is very important that soil samples be collected and stored properly according to the instructions of the laboratory, especially in the case of soil biology, as soil organisms can die or multiply rapidly and this may invalidate the results. A few soil tests that are used by organic producers are as follows:

1. Soil food web Canada, Inc., measures the biodiversity (quantity of bacteria, fungi, and nematodes) in the soil, suggests optimal levels for different crops, and provides suggestions to increase the activity of soil.

2. Western Ag Innovations Inc. evaluates soil fertility by using a Plant Root Simulator probe. For this purpose, probes are placed in the soil for different time periods and measure the level of nutrient across the membrane. It will give a good estimate of nutrients available to the plants.

3. Kinsey's Agricultural Services analyze the soil sample by using the Albrecht system. Their recommendations are based on fertilizer preference, crop history, and type of operations.

4. ALS Laboratory group assesses the level of macronutrients and micronutrients in the soil. This test measures the level of nutrients that can be extracted, including organic matter, pH, and cation exchange capacity.

3.1.2. Soil biology

Soil biology can be encouraged by several methods. Many experienced producers suggest that green manure is one of the best methods to maintain the life of soil; other methods are animal manure and straw residue, selecting good rotation, and reducing tillage. Many farmers recommended that all straw be worked back into the soil to return the nutrients. They provide microorganism to increase the organic matter of the soil. Legume incorporation causes a change in microbial population toward greater metabolic activity and increases organic matter. Soil microorganisms are also affected by tillage; mostly producers try to keep less tillage operation and maintain some cover on all fields throughout the growing season. For this purpose, green manure is the best strategy as it covers the land and protects it from drying out. Organic producers must care and try to avoid methods that increase the soil erosion and kill soil microbes [21].

3.1.3. Soil organic matter

Organic matter is the key for maintaining water holding capability and soil health. Animal and plant residue, along with the soil organisms such as bacteria, fungi and nematodes, are the component of organic matter remains in the soil worked from year to year. As a result of climate and vegetation that existed before the land was broken, organic matter is formed. The four different divisions of soil organic matter are fresh organic matter, decomposing organic matter, stable organic matter, and living organism. When fresh organic plant material is added to the soil, microbes break it down and this moderately decomposed organic matter holds nutrients for growing plants. In the decomposition process, stabilized organic matter is the final product; it provides structure to the soil resulting in good aeration and water holding ability [22].

3.1.4. Soil applied

Some experienced producers use calcium, sulfur, gypsum, and rock phosphate after soil tests indicate low levels of nutrients. To improve the soil biology, microbial organisms are also used.

3.1.5. Foliar applied inputs

Some producers use foliar sprays as inputs on the plant when it is growing. These can be used to control the disease or to reduce the risk of disease. Most often, the intention is to feed the helpful organisms that reduce the risk of pathogens.

3.1.6. Manure and compost

Manure is an excellent organic fertilizer; its use is highly regulated by organic standards. To build the soil fertility many livestock producers use it. It can be used in different forms such as organic composted manure, deposition on crop land, and application of manure without being composted. For proper decomposition, it should be applied at a suitable time of the year and at a proper peak in the rotation. For more effectiveness, fresh manure should be incorporated soon to decrease the nitrogen loss and it should be applied in cool conditions; however, many producers will age manure for several years before putting it in the field, which is not so good [23].

Composting is one step forward to manure; it is a process that can be described as the aerobic decomposition of organic matter to produce a humus-like product called compost. In this process, microorganisms (fungi) are involved that convert the manure to humus, which is darker in color and has an earthy smell. Composting requires some machinery and effort to maximize the humus-producing potential of manure. To meet compost standards, producers must mange proper air, moisture, and temperature in the mass. Proper composting balance between carbon and nitrogen proportion is necessary. Careful planning is required when making an allowance for compositing animal wastes on farms. The location of the compost site matters a lot to avoid risks to ground water and nearby water sources. Enclosing livestock and collecting, transporting, and spreading compost and manure are costly and inefficient. The simple method adopted by some producers is that they allow livestock to graze crop land and put the fertilizers straight onto the field [24].

3.1.7. Nutrient amendments

A few producers use amendments such as seed inoculants and foliar spray on the green parts or soil. Organic amendments have very little reliable use. These products should be used carefully. Before using any amendment, it must be ensured that it is approved for organic production.

3.1.8. Seed inputs

Nitrogen fixation is very important for plant growth. For nitrogen fixation, rhizobial inoculants with legumes are used as they create an environment that favors the bacteria responsible for nitrogen fixation. They do not need seed inoculants, but some experienced producers suggest that if the inoculant is applied on or below the seed they give better results. Some additional products such as humates, mycorrrhizal fungi, and other microbes respond to crops differently, their response depending upon crop, crop cultivar, and management history.

3.1.9. Green manures

A green manure is a crop worked into the soil to provide nutrients to the organisms and ultimately to the crops. To sustain a healthy soil, the use of green manure in crop rotation plays an important role. Green manure is a legume that fixes nitrogen into the soil; availability of nitrogen depends on the growing condition, moisture, and inoculation. Producers recommended sweet clover, alfalfa, red clover, field pea, and faba bean for nitrogen fixation and oilseed and buckwheat to improve phosphorus availability.

3.1.10. Rotation of crops

Rotation is a planned sequence of crops, and organic producers consider it as the most important key in organic farming. A lot of scientific literature suggests that crop rotation is more beneficial than monocultures. The more variable the rotation, the more stable the yield. Resources can be used more effectively by rotating the crops with different characteristics. As we know, crops differ in their requirements of water, nutrients, and susceptibility to pests and diseases. The sequence of crops must be cautiously selected, which is well adapted to the fertility level, to avoid the disease potential that builds in crops. Rotation is planned according to the health of the soil such that crops that require tillage should be balanced with crops that build organic matter, and crops that utilize more nitrogen should be balanced with crops that supply nitrogen. Crop rotation is also very important in weed management. For different crops, different weed management practices are used. Each type of management practice is a disturbance that favors one weed species over the other. If annual crops are rotated with winter crops, then the disturbance pattern is varied and different species are disadvantaged at different times. This results in a more diverse weed community. This diversity can be beneficial as it increases the variety of food and shelter available to the beneficial organisms. Rotations are also crucial to insects and disease management. Insects and diseases are specific to a single crop; if they remain away for a long time from that crop, they are not able to increase to a dramatic level. Most producers consider rotation to be a work in progress that will change as the soil changes. A flexible rotation is recommended by most experienced producers to respond to changes in disease pressure, market, and contaminations by microbes. Organic producers take soil samples every couple of years and spend time in learning how they can improve the farming techniques.

3.2. Seeding

Seeding is the time when planning and reality come together. Most often, the weather determines when to seed, what to seed, and which equipment to use. The ideal time for seeding is when it grows in a weed-free environment. Weeds are much more competitive when the crop emerges, as compared to the established crop. Mostly producers are not able to buy new equipment for seeding; it is time to consider what can be done to give the best advantage to the crop. The time of seeding is very important; in wet years you can seed anytime, but in dry years, you must seed as early as possible. Try to avoid seeding in very hot temperatures; if you want to seed early, then notice the condition of soil; if you seed late, then control the weeds.

A number of factors are considered by producers for crop selection such as soil fertility, weed control, crop type, and previous crop in rotation, but experienced producers follow some criteria and then choose the variety of crop to plant. In this criteria, the varieties to select from are based on which ones grow well and have disease resistance, heritage varieties, high-quality crops such as wheat with high protein, varieties that are in demand in organic markets, and varieties that can give viable seeds for the next year. Producers identify the characteristics that are best suited to the organic production and then they seed. Organic producers think that heritage varieties are best because they are developed without chemical and fertilizer inputs. Under organic management, producers can perform and yield well.

Seed quality and seeding rate are very important in organic farming. Experienced producers do not consider it necessary to use certified seeds; some suggest it is important only when it was time to renew the seed. Some scientific studies confirm the advantage of high seeding rate. Higher seeding rate can increase the crops' ability to cover land. Increasing seeding rate may be more important under conditions of higher fertility, when weeds may be more competitive. Crop emergence can be affected by seeding equipment. Organic farmers favor different types of seeding equipment. The most preferred seeding equipment that are used by organic producers are air seeder, disk seeder, double disk press drill, and valmar spreader. These are used for different seeds according to the climatic conditions.

3.3. Weeds

For new organic farmers, weed management is very threatening. Organic fields share the same weeds as other farms. For determining the weed community, some factors are important such as soil texture, environmental variables, and crop rotation. The most common weeds, such as wild oats, bluebur, stinkweed and wild buckwheat, are found on organic farms. Many producers suggest that tillage can be a powerful weed management tool especially before and during seeding. Weeds that emerge before the crop gain more of the resources and thus have much more effect on the crop than weeds that emerge later. A second option for weed control exists after seeding but before the crop emerges. Some successful weed control practices used by organic producers are the use of solid crop rotation, delayed seeding, seeding with high rate, spiking in the fall to control quack grass, and growing alfalfa and sweet clover to suppress weeds. It is also very important in weed management practices to know the ecology of weed management.

3.3.1. Ecological weed management

For weed management, most of the organic farmers rely on multiple plans. Ecological weed management promotes weed suppression, instead of weed elimination, by increasing crop competition and phytotoxic effects on weeds. A specific method such as crop rotation is one of the best methods used by organic farmers to control weed management. Organic producers suggest that small grains or legumes must be planted for at least one year out of every five years to maintain soil health. If the legume is plowed under as a cover crop in the fifth year, four years of row crops may be grown prior to the green manure crop year. The same crop cannot be grown in sequential years; due to this, soybean cannot be grown in the same field year after year. The ideal crop preceding soybeans is winter rye. Soybean fields are rotated to a small grain (oats, barley, wheat, or rye) or corn.

3.3.2. Production practices

Organic farmers suggest some production practices for weed management such as variety selection where farmers select crop varieties (e.g., quick canopy-forming) that compete well with weeds within and between rows. As regards crop density, planting at the utmost modified population will provide the crop an enhanced competitive border over weeds. Closer row spacing generally has greater crop competition with weeds in row middles. For the rapid canopy, high germination rate seeds are more preferable. Date of sowing matters a lot; warm season crops are planted when the soil is warmed properly to facilitate the germination.

3.3.3. Physical tactics for weed management

These are the key factors to control weed management on all organic farms; it includes mulching, cultivation, and propane flame burning. Mulching is used in combination with manual labor in many horticulture operations for proper weed control. It is of two types, natural and synthetic mulches. These are used in organic operations along with polyethylene film and polypropylene landscape fabric. Mulch can be made from small grain and soybean straw. During decomposition, organic mulches add organic matter to increase soil porosity, water holding capacity, microbial populations, and cation exchange capacity. Straw mulch is used in organic horticultural operations, for example garlic, strawberry, and herb farms, to control weeds and protection from harsh environments.

Timely cultivation is critical in organic weed management. Depending on the crop, cultivation offers the least labor-intensive weed control method. Midwestern organic farmers used two to three row cultivations. First cultivation occurs at a slow speed, second cultivation usually is completed at mid-season at a faster speed, while third cultivation is again performed at a slow speed. Propane flame-burners have been added as an additional tool in their weed management toolbox by many organic farmers. When tillage with large machinery is not feasible, flaming is used during high field moisture, while in drier weather it is used in conjugation with cultivation.

3.4. Insects

The most experienced organic producers are serious about insect problems. During dry season the most common and problematic insect is the grasshopper. If the crop and soil were healthy, then there would be less insect problems. There are some specific recommendations for insects: for grasshoppers, use tillage to avoid egg laying, use foliar sprays, seed early and use alfalfa border; for lygus bugs, delay seeding; for wheat midge, select resistance varieties and delay seeding; and for aphids, keep an environment where predators flourish. Most producers do the best they can to control insects.

3.5. Tillage

In organic and conventional farming, soil erosion resulting from tillage is a major concern. Organic producers use more tillage; they use it for seed bed preparation, weed suppression, and for the incorporation of green manure. To prepare seed bed and to control weeds tillage, a harrow and cultivator is used; those who used disc seeders reported less cultivation because this method killed weeds. Some farmers used light tillage with harrow to control weeds before and after crop emergence. In a survey, organic producers were asked about the increase or decrease in their tillage operations, they replied that type of tillage had changed. At the beginning, organic producers used more tillage operations to control the weeds, but after that producers moved toward less tillage.

Tillage can be reduced, although it is the only method of terminating the green manure. Recently, producers have challenged the belief that tillage is needed for green manure termination through the method of rolling, mowing, and blading. One producer indicated that the wide-blade cultivator causes minimal disturbance to the soil and leaves much residue, so this was an effective way to terminate green manures while reducing the risk of soil erosion. Generally, tillage operations are used more in black soil where there is high weed pressure. Producers who used more tillage operations try to minimize erosion potential by understanding the condition of the soil.

3.6. Transition

A transition from conventional to organic farming is not an easy step; it takes time and requires a change in mind set. Some producers suggest that transition in the mind takes longer compared to the transition on the land. Producers learn more because new methods have come into practice such as green manure, rotation of crops, mechanical weed control, organic fertility management, and erosion reduction. Transition time is very important, because it provides time for the soil to become free from chemicals that remain in the soil due to conventional farming. Weed control and soil fertility is the top priority. It is an economically vulnerable time. Although the transition is difficult, organic farming made them feel empowered. New organic farmers recommend the following about tillage during the transition years: understand the soil; till in different directions in different years; for weed control, keep tillage to the minimum need; replace black fallow with weed fallow; try to avoid tilling light soils in dry years; and harrow the cereals when they are about four inches in height.

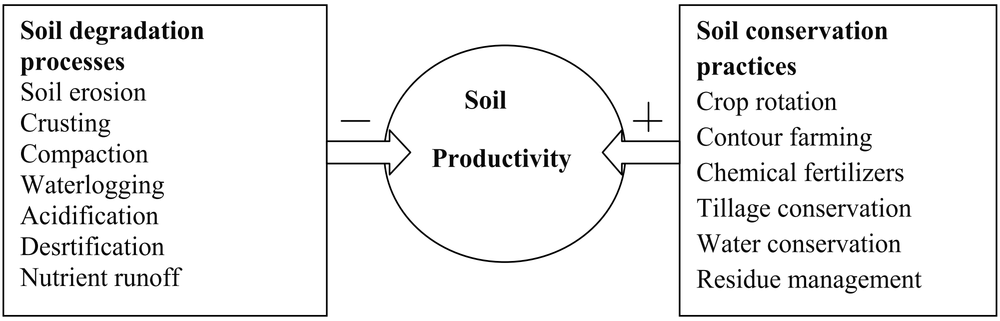
4. Conservation in organic farming

The most important key for sustainable cultivation is the conservation of natural resources, especially considering the decreasing conditional subsidies of the Common Agricultural Policy of the European Union for the coming years. If lower economic support compels farms to increase efficiency to reduce production costs, at the same time providings an interaction of agricultural activities with environment quality, suitable natural resources management will be a vital feature for farms.

4.1. Soil conservation

Soil is the production base of all agricultural systems and its conservation is the pillar of sustainability. Soil quality is affected by wind and water erosion and farming practices. Soil erosion is one of the factors of organic farming, so it is necessary to develop soil conservation practices. Conservation practices are usually those that decrease wind speed, reduce rate and amount of water movement, and raise soil organic matter levels. All these conservation managements are not employed to all situations; the management will depend upon the soil type, climate, topography, and type of farming in that area. Producers can use a number of conservation practices that are best for their farms. However, organic crop producers have to face great challenges because conservation practices that use herbicides are not an option. Some common organic crop production practices, such as post-emergent harrowing for weed control, are destructive to the soil. So producers may need to employ some additional conservation measures if practices such as post-emergent harrowing are used. To conserve the soil, some strategies are presented as follows.

Crop residues (roots, chaff, stems, and leaves) are the key source of organic matter replacement. These residues also contain nutrients such as phosphorus, sulfur, potassium, nitrogen, and micronutrients. They improve soil properties such as water infiltration, water storage, and particle aggregation. Among crops, the amount of residue produced and the rate of decay are



different. The combination of these two factors determines the quality of residue in relation to its value for soil conservation [25].

4.1.1. *Forage crops*

Forage crops contribute significant amounts of organic material to the soil and offer an alternative product in the form of hay, silage, or seed. Forage production for two to four years should also be considered as part of a normal crop rotation. Selection of forage species and management practices can be customized to specific problems such as drought, salinity, poor soil structure, low pH, and excessive soil moisture.

4.1.2. *Stubble cutting*

Moisture conservation is also important because the additional moisture will improve crop growth. It may also allow extending the rotation, which is another conservation practice. It can be enhanced by trapping more overwinter snow with "tall" or "sculptured" stubble. Tall stubble refers to stubble that is cut 12 inches high, while sculptured stubble refers to alternate swaths that are cut at normal height and taller.

4.1.3. *Direct seeding*

In organic farming, herbicides cannot be used. Organic crop production is not usually associated with direct seeding but some producers do put into practice direct seeding. However, organic producers possibly will think about this protection practice when low weed pressure and previous crop straw and chaff have sufficiently spread [26].

4.1.4. *Balancing of rotational crops*

An ideal rotation should be as diverse as possible; a diverse crop rotation can help soil nutrient availability because different crops remove different nutrients. Most commonly, sixteen essential nutrients are present in soil. In the rotation, growing legumes provides both nitrogen and non-nitrogen benefits to following crops. If legumes are inoculated properly, they fix 90% of their nitrogen necessity from the air and rest is obtained from the soil. However, during the growing season, nitrogen is exuded from legume roots and the legume residue decomposes and recycles the nutrients quicker than non-legume residues, thus more nitrogen is regularly accessible to the following crop than if a non-legume had been grown. When planning complementary rotational cropping, growth patterns of a variety of crops should also be taken into account. Crops with broad leaves such as polish canola, lentil, flax, and pea take out nutrients and moisture from more shallow rock bottom than cereals that belong to spring-seeded. Thus, winter wheat rooted deep uses moisture in the early growing season while the recurrent forages use nutrients and moisture from subsoil because they are deep rooted. Shallow-rooted crops are best adapted as compared to deep roots because they will not expand energy in search of moisture as compared to other crops. Medium root crops come into view as enhanced and modified to pursue shallow-rooted crops as they benefit from any moisture left at the depth, which is not used by the preceding shallow-rooted crop [27].

4.1.5. Total crop rotations

Summer fallowing is destructive to the soil because no new organic matter is returned to the soil during this year. Breakdown of soil organic matter increases due to tillage. Extending crop rotations is a conservation practice because it reduces the incidence of summer fallow. This practice can improve fertility, collective constancy, tilth, damp storage space, and conflict to soil erosion and deprivation, in addition to decreasing insects and disease problems. All these reported factors enhance yield productivity and have positive effects on soil sustainability. Decisions for cropping strategies would not be for a short duration but the long-term effects on the soil and environment should also be considered. A varied crop rotation should comprise pulses, seed oil, fall-seeded crops, and forages. Crop diversity level determines the implication of the rotational payback. During rotation, some selection and management of legume species is a vital aspect of achieving diversity and supplying nitrogen through symbiotic nitrogen fixation.

4.1.6. Tillage

During tillage crop residue, conservation is affected by the equipment type, speed, depth, and frequency of tillage, as well as soil and climatic factors. Limiting all these factors conserves crop residue and soil moisture. It has been difficult to convince researchers and extension services that rigorous tillage does not allow for soil and water conservation and decreases soil natural content. Tillage may be defined according to conservation farming as the integration of agronomic practices with the aim of conserving, improving, and efficiently using natural possessions [28]. On yield consistency, the farmers' point is correct but the reason of low yield in conservation tillage systems is only associated with the first few years of the changeover period between conservation practices and intensive tillage. Energy can be saved by adopting the method of reduced tillage and greater savings can be achieved by no-tillage [29]. Greater benefits can also be noticed in relation to environmental aspects; large amounts of crop residues on the soil surface reduce water runoff and nutrients loss [30].

In tillage operations during shallow tillage, crop residue accumulates near the soil surface and it will be most effective in reducing wind and water erosion by improving infiltration and reducing evaporation. Reducing tillage speed generally reduces crop residue burial. Residue conservation is significantly influenced by tillage equipment type; for instance, a wide-blade cultivator preserves considerably more remainder than a cultivator that is considered better than a discer. The addition of harrows to a field increases the amount of remnants buried, while adding a rod weeder to a cultivator does not considerably affect deposit lessening. The need of each tillage operation should be carefully considered according to the type of soil, but tillage should be avoid under wet soil conditions as this can degrade soil structure and significantly decrease surface residue levels [31].

4.1.7. Wind barriers

4.1.7.1. Annual crop barriers in crops

Taller annual crops have been used as barriers to a restricted degree in low residue-producing crops. A divider is placed in the seedbox so that two rows of wheat are seeded every seeder width. At harvest, the lentil is combined and the barrier strip left standing to trap snow and prevent wind erosion during the upcoming winter.

4.1.7.2. Strip cropping

In strip cropping, alternating strips of crop and summerfallow consists at an angle perpendicular to the prevailing winds. According to the soil, texture strip width varies. Wind erosion is more common in sandy soils as compared with clay and loam soils. Strip cropping works well for loam and clay soils where increase stripping will considerably decrease the potential for wind erosion. In sandy soil types, too many strips are essential to be convenient. When establishing strip widths, the size of field equipment should be kept in mind. This practice is more common in drier areas; however, it can be used in wetter areas where the pattern of strip formation is changed to avoid water erosion.

4.1.7.3. Cover crops

Rotations should also comprise the use of cover crops to protect the soil from water and wind erosion throughout susceptible periods, for instance, summer fallow when normally position stubble does not exist. Cereal yield should be seeded between August and September; fall frosts will be able to kill plant material and remain on the soil surface until spring planting, providing valuable soil protection. Winter wheat, fall seeded cereal may be used in a parallel fashion. In the following spring, these crops may be removed by tillage or used for short-term livestock grazing, or grown to maturity in the case of winter wheat or fall rye [32].

4.1.7.4. Shelterbelts

It can effectively decrease wind velocity for a distance of 20 or more times than their height. They effectively control wind erosion when planted at the right angles to current winds. The effectiveness of shelterbelts depends upon maintenance, in addition to height. They may also be helpful for increasing crop yields.

4.1.7.5. Perennial grass barriers

These are two rows of grass planted at right angles to current winds to decrease wind erosion, entrap snow, and reduce evaporative losses. Placement of barriers depends on soil type; these are closest on sands, moderately spaced on clays, and utmost apart on loams. Barriers may be placed further apart if other soil conservation practices are also being used. Tall wheatgrass is a weak participant with most field crops and will not spread beyond the seeded rows. It also grows high enough without accommodation to trap snow, helping in soil moisture renewal.

4.1.8. Green manure

The assimilation of any green vegetative material into the soil is called green manure. In crops, it adds organic matter to the soil and improves soil health. The extent of soil improvement depends on the type and quantity of plant material returned to the soil. Biennial or perennial legumes as green manure give great benefits to soil with poor level of organic matter but the time of implanting these legumes matters a lot. Grain legumes, such as pulses, can be used as green manure effectively because their annual growth habit will not contribute in nitrogen fixation as biennial or perennial legumes. However, they are more flexible to an accessible crop rotation. Non-legume crops can also be used as a green manure crop [33].

4.1.9. Animal manure

Animal manure, such as livestock and poultry, provides not only nutrients to plants but also affects soil tilth and particle aggregation. Organic matter contained in manure act as binding agents in stabilizing soil structure. The addition of manure changes the soil structure and this surely affects water infiltration, water holding capacity, and aeration, as well as resistance to wind and water erosion. Manure nutrient value depends upon some factors such as animal type and age, type of feed, amount of straw, and method and time of storage. In the manure, some micronutrients are helpful to prevent the plant deficiency symptoms from happening. The rate of manure application recommended by different soil testing laboratories that test the animal manure for nutrient content depends upon the availability of soil type, slope, location, and different construction practices. For the prevention of environmental contamination, rates of manure application should not exceed what a crop can use in one growing season. Following manure application to prevent nitrogen loss, it should be incorporated as quickly as possible into the soil for proper plant growth [34].

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Organic Weed Control and Cover Crop Residue Integration Impacts on Weed Control, Quality, Yield and Economics in Conservation Tillage Tomato-A Case Study

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Abstract

The increased adoption of conservation tillage and organic weed control practices in vegetable production requires more information on the role of various cover crops in integrated weed control, tomato quality, and yield. Two conservation-tillage systems utilizing crimson clover and cereal rye as winter cover crops were compared to a conventional black polythene mulch system, with or without organic weed management options, for weed control, tomato yield, and profitability. All cover crops were terminated with a mechanical roller/crimper prior to planting. Organic weed control treatments included: 1) flaming utilizing a one burner hand torch, 2) PRE application of corn gluten, 3) PRE application of corn gluten followed by flaming, or 4) intermittent hand weeding as needed. A non-treated control and a standard herbicide program were included for comparison. The herbicide program consisting of a PRE application of S-metolachlor (1.87 kg a.i./ha) followed by an early POST metribuzin (0.56 kg a.i. /ha) application followed by a late POST application of clethodim (0.28 kg a.i./ha). In general, high-residue clover and cereal rye cover crops provided substantial suppression of Palmer amaranth, large crabgrass, and yellow nutsedge. Across systems, minimum input in high-residue systems provided the highest net returns above variable costs compared to organic herbicide treatments that are costly and provide marginal benefit.

Keywords: Conservation agriculture, cover crop, fruit

1. Introduction

In recent years, growing concerns over the environmental impact of conventional agricultural practices, coupled with a surge in consumer demand for sustainably-produced products, have led to increased grower adoption of organic agriculture. In 2011, cropland in the United States (U.S.) dedicated to organic vegetable production totaled over 47 thousand ha [1]. Organically produced vegetable sales, were estimated at 1.07 billion USD in 2011 [1]. Given the steady rise in organic product interest and efforts to ensure agricultural sustainability, a substantial amount of research has been dedicated to organic fruit and vegetable production in order to guarantee successful adoption of these practices as an alternative to conventional agriculture.

Unlike conventional agricultural practices, an organic approach to agriculture eliminates the use of synthetic pesticides and fertilizers and, instead, relies on biological and cultural pesticide control and organic soil amendments such as manure and crop residue to maintain soil fertility [2]. The goal of organic agriculture includes producing food and fiber products in a manner that increases biodiversity, promoting soil health, and reducing environmental degradation due to agricultural practices. A number of ecological differences have been noted in previous research when comparing conventional and organic agriculture [3,4]. Comparisons of soil properties and pest population dynamics for organic and traditional farming practices note differences between these systems that affect the agroecosystem [3,4].

2. Case study

In the U.S. approximately 1.36 million tons of in the open, fresh market tomatoes, worth over 1.134 billion USD, were produced on nearly 41.2 thousand ha in 2014 [5]. Tomato production systems typically utilize conventional tillage, a bedded plastic mulch culture, and multiple herbicide applications to control weeds. These conventional tillage systems enhance soil erosion and nutrient loss by reducing rainfall infiltration [6]. Additionally, tillage increases aeration which increases the rate of organic matter mineralization in the surface soil, thus reducing soil organic matter content, soil cation exchange capacity and potential productivity [7, 8].

Plastic mulch can increase soil temperature which can expedite tomato harvest [9]. Tomato harvest was not early following a hairy vetch mulch system [10, 11]. The use of plastic mulches in sustainable or organic production systems is in question by some producers and consumers since the mulch itself is non-biodegradable and made of non-renewable resources. Another environmental disadvantage with using plastic mulch vs. organic mulches is increased chemical runoff from plastic mulch systems and subsequent offsite chemical loading [12]. Thus, the intensive use of pesticides in vegetable production has resulted in ecological concerns. Therefore, alternative production practices that reduce tomato production inputs while maintaining yield and quality are desired.

One alternative for alleviating the aforementioned concerns is the use of high residue cover crops combined with reduced tillage. Cover crops in conservation-tillage systems can be terminated during early reproductive growth by mechanically rolling and treating with burndown herbicides to leave a dense mat of residue (> 4,500 kg/ha) on the soil surface into which cash crops are planted [13, 14]. Adoption of high residue cover crops is increasing in southeastern U.S. corn (*Zea mays* L.) and cotton (*Gossypium hirsutum* L.) row crop systems [15, 16, 17, 18, 19, 20]. Because the southeastern U.S. typically receives adequate rainfall in the winter months, timely planted winter cover crops can attain relatively high maturity and biomass before termination. Cover crops can enhance the overall productivity and soil quality by increasing organic matter and nitrogen content [21], as well as aid in water conservation by increasing soil water infiltration rates [22]. Additionally, previous research has also focused on weed control provided by high residue cover crops in both field and vegetable crops [23, 24, 25].

Winter cover crop biomass can affect subsequent early season weed control [26, 27]. Cover crop residue facilitates weed control by providing an unfavorable environment for weed germination and establishment under the residue as well as allelopathy [28, 29]. Teasdale and Daughtry [30] reported 52–70% reduction in weed biomass with live hairy vetch cover crop compared to a fallow treatment owing to changes in light and soil temperature regimen under the vetch canopy. Teasdale and Mohler [27] reported that legume mulches such as crimson clover and hairy vetch (*Vicia villosa* Roth) suppressed redroot pigweed (*Amaranthus retroflexus* L.) at an exponential rate as a function of residue biomass.

However, adoption of cover crops in tomato production has been limited because (1) currently available transplanters have problems penetrating heavy residue and (2) heavy cover crop residue can intercept delivery of soil-active herbicides. Research in the last two decades has extensively debated the advantages and disadvantages of cover crops vs. conventional plastic mulch systems for tomato production. Better or comparable tomato yields with hairy vetch cover crop system have been reported compared to the conventional polyethylene mulch system [31, 32]. Akemo et al. [33] also reported higher tomato yield with spring sown cover crops than the conventionally cultivated check. However, weed control with cover crops varies with cover crop species, amount of residue produced, and environmental conditions. Teasdale [28] reported that biomass levels achieved by cover crops before termination was sufficient only for early season weed control. Supplemental weed control measures are usually required to achieve season long weed control and to avoid yield losses [34, 23].

Cereal rye and crimson clover are two common winter cover crops widely used in the southeastern U.S. Both cover crops contain allelopathic compounds and produce residues that inhibit weed growth [15, 29, 35]. Brassica cover crops are relatively new in the southeastern U.S. but are becoming increasingly popular due to their potential allelopathic effects. Therefore, the objectives of this research were to evaluate: 1) weed control in two different high residue cover crop conservation tillage systems utilizing the Brazilian [13] high residue cover crop management system including cover crop rolling and 2) tomato stand establishment, yield, and net returns of conservation-transplanted tomatoes compared to the polythene mulch system following three different organic herbicide management systems.

3. Materials and methods

Field Experiment. The experiment was established in autumn 2006 at the North Alabama Horticulture Experiment Station, Cullman, AL on a Hartsells fine sandy loam soil (Fine-loamy, siliceous, sub-active, thermic Typic Hapludults). The experimental design was a randomized complete block with four replicates. Plot size at both locations was 1.8 by 6 m containing a single row of tomatoes with a 0.5 m spacing between plants.

The two winter cover crops (cereal rye cv Elbon and crimson clover cv AU Robin) were compared to black polythene mulch for their weed suppressive potential and effect on yield and grade of fresh market tomatoes. Winter cover crops were planted with a no till drill in the fall. Rye was seeded at a rate of 100 kg/ha, whereas clover was seeded at 28 kg/ha. Since the overall objective was to evaluate weed control practices, general production practices included staking, traditional plant pest and plant pathogen methods, and fertilization was utilized to exclude any other pest and fertilization interactions and is a limitation of this case study. Nitrogen was applied at a rate of 67 kg/ha on rye plots in early spring of each year. Cover crops were terminated at flowering stage in late spring. To determine winter cover crop biomass production, plants were clipped at ground level from one randomly selected 0.25 m^2 area per replicate immediately before termination. Plant samples were dried at 65 C for 72 hours and weighed. Cover crops were terminated with a mechanical roller crimper prior to an application of glyphosate at 1.12 kg a.e. /ha^{-1}. The rolling process produced a uniform residue cover over the plots.

All three systems (two winter cover crops plus plastic mulch) were evaluated with and without herbicide for weed control. Organic weed control treatments included: 1) flaming utilizing a one burner hand torch, 2) PRE application of corn gluten, 3) PRE application of corn gluten followed by flaming, or 4) intermittent hand weeding as needed. A non-treated control and a standard herbicide program were included for comparison. The herbicide program consisting of a PRE application of S-metolachlor (1.87 kg a.i. ha^{-1}) followed by an early POST (EPOST) metribuzin (0.56 kg a.i. ha^{-1}) application followed by a late POST (LPOST) application of clethodim (0.28 kg a.i.ha^{-1}). The PRE corn gluten application occurred immediately after tomato transplanting while the PRE herbicide application occurred prior to placing the plastic on top of the beds, the EPOST application was applied two weeks after transplanting, and the LPOST application was delayed until tomatoes were near mid-bloom. Flaming and hand hoeing was accomplished one week after transplanting and subsequently every two weeks following until harvest. Tomato cv. ‘Florida 47’ seedlings were transplanted on April 12, 2007.

Tomato seedlings were planted with a modified RJ no-till transplanter (RJ Equipment, Blenhiem, Ontario, Canada), which included a subsoiler shank installed to penetrate the heavy residue and disrupt a naturally occurring compacted soil layer found at both experimental sites at a depth of 30-40 cm. Additionally, two driving wheels were utilized (one wheel on each side of the tomato row) instead of the original single wheel at the center of the row, to improve stability and eliminate drive wheel re-compaction of the soil opening created by the shank. The plastic-mulch plots were conventionally tilled utilizing a tractor mounted rototiller prior to bedding and plastic installation; tomatoes were hand transplanted in the plastic mulch each year. Water was applied to all the plots immediately after transplanting. Thereafter, plots were irrigated every other day using a surface drip tape. Fertilizer 13-13-13 was applied prior to planting achieving 448 kg of N/ha^{-1} and then 7.8 kg of calcium nitrate ha^{-1} was applied once every week with the irrigation system.

Weed control was evaluated by visual ratings (0% = no control, 100% = complete control) 28 days after treatment (DAT) of the EPOST herbicide application. All weed species present were evaluated for control (as a reduction in total above ground biomass resulting from both reduced emergence and growth). Stand establishment was determined by counting the number of living tomato plants in each plot two weeks after LPOST application. Ripe tomatoes were hand harvested from the entire plot area in weekly intervals and sorted according to size (small, medium, large, and extra large categories).

Statistical Analysis. Non-normality and heterogeneous variances were encountered with percent control data. Various approaches were tried to alleviate these statistical problems and the arcsine transformation was deemed the best compromise between achieving normality of residuals and among treatment homogeneity of variances. The transformed data were subjected to mixed models analysis of variance as implemented in JMP statistical software. Years, organic herbicide treatments and ground cover treatments were considered fixed effects while their interaction with treatment replication was considered random effects. Differences between treatments means were determined by Fisher's protected LSD ($\alpha = 0.05$).

Economic analysis. Net returns above variable treatment costs (NRAVTC) were estimated as the difference between revenues and variable treatment costs (US$ ha^{-1}). The average weekly dollar per box (assuming an 11.34 kg box^{-1}) price for the four harvest weeks was used to calculate revenue by grade (i.e., small, medium, large, and extra-large). The weekly prices were from domestic suppliers at the terminal market in Atlanta, Georgia [36]. Low- and high-end prices from 2007 were reported for each grade category from suppliers (domestic suppliers aggregated by State), excluding international suppliers. The low-end and high-end tomato prices by size were the average of prices in 2007 across suppliers, and are presented in Table 1. All prices were reported in 2007 US$.

Tomato Size	**Low-end Price**	**High-end Price**	**Mean**
		US$ box^{-1}	
Small	10.06	10.69	10.38
Medium	9.47	10.14	9.81
Large	9.34	9.99	9.67
Extra-large	9.41	10.28	9.85
Mean	9.57	10.58	

Table 1. Tomato prices by size by low-end and high-end price.

The average marketing year price, regardless of organic certification, received by producers in Alabama in 2007 for fresh market tomatoes across all sizes (7.21 US$ box^{-1}). For organically produced tomatoes, the average price received by Alabama producers for organic tomatoes in 2008 of 9.32 US$ box^{-1} across all sizes [37]. Data for organic tomatoes was not available in 2007. Therefore, the low-end prices by size were used in the analysis.

Productions costs for the three covers and five weed control treatments were adapted from 2008 tomato enterprise budgets [38] and experiment specific treatment costs. A partial budgeting approach was used to calculated variable treatments costs; therefore, the only costs considered were costs that differed by treatment and costs that varied by yield (Table 2). Costs that vary by yield include harvest costs, as well as grading and packing labor costs. Fixed costs, such as management costs, rent, and depreciation on machinery and buildings, differ by operation; therefore, they were not included in the analysis.

Weed Control	**Cover Type**		
	Plastic	**Rye**	**Clover**
		US\$ ha^{-1}	
No Treatment	2226	505	376
Handweed	3658	1937	1808
Flame Corn Gluten	12935	11214	11085
Flame	2859	1138	1009
Herbicide	2392	671	542

Table 2. Variable treatment costs (excluding costs that vary by yield).

4. Results and discussion

Cover Crop Biomass. The quantity of cover crop biomass produced at both locations differed among cover crops, with rye producing 9363 kg/ha, and crimson clover producing 5481 kg/ha of dry matter.

Weed Control. The major weeds in the cover crop and plastic mulch plots included Palmer amaranth (*Amaranthus Palmeri* L.), large crabgrass (*Digitaria sanguinalis* L.), and yellow nutsedge (*Cyperus esculentus* L.).

Palmer amaranth. Early *Palmer amaranth* control averaged over weed management systems, clover and rye cover treatments provided excellent *Palmer amaranth* control (90 and 96% respectively) compared to the conventional plastic system (5% control) (Table 3). The plastic system provides some inherent weed control regardless of additional inputs, however, it provided no weed control in the punched holes and the area adjacent the bed. *Palmer amaranth* control in clover utilizing corn gluten and flaming was equivalent to the clover plus herbicide standard. *Palmer amaranth* in rye utilizing all organic methods excluding hand weeding provided weed control equivalent to the rye plus herbicide standard. Late *Palmer amaranth* control ratings generally remained stable except increases for plastic due to the inherent control discussed above.

Large Crabgrass. Early crabgrass control averaged over weed management system reflected control similar to Palmer amaranth, clover and rye cover treatments provided excellent crabgrass control (92 and 98% respectively) compared to the conventional plastic system (5% control) (Table 4). All rye systems provided excellent control. Late season crabgrass control was generally higher than that of *Palmer amaranth*.

Yellow nutsedge. Early yellow nutsedge control averaged over weed management systems reflected control similar to Palmer amaranth and large crabgrass with clover systems providing an average 93% control and rye systems providing an average 95% control. Control in both clover and rye systems was excellent regardless of treatment revealing that winter cover crops suppress nutsedge in high-residue systems.

	% Weed Control					
	Early Control			Late Control		
Cover	**Pigweed**	**Crabgrass**	**Nutsedge**	**Pigweed**	**Crabgrass**	**Nutsedge**
Clover	90^{a}	92^{a}	93^{a}	92^{a}	98^{a}	98^{a}
Rye	96^{a}	98^{a}	95^{a}	88^{a}	97^{a}	98^{a}
Plastic	5^{b}	5^{b}	5^{b}	33^{b}	37^{b}	43^{b}
LSD (α = 0.10)	7	13	9	12	14	13
Weed Control[1]						
1	63^{ba}	64^{a}	63^{ba}	60^{b}	71^{a}	73^{ba}
2	57^{b}	61^{a}	64^{ba}	73^{ba}	81^{a}	82^{ba}
3	61^{ba}	61^{a}	55^{b}	77^{ba}	80^{a}	82^{ba}
4	65^{ba}	65^{a}	66^{ba}	61^{b}	65^{a}	66^{b}
5	72^{a}	72^{a}	74^{a}	86^{a}	87^{a}	96^{a}
LSD (α = 0.10)	10	10	12	15	18	17
Combination						
Clover 1	93^{a}	96^{a}	90^{a}	88^{a}	97^{a}	98^{a}
Clover 2	80^{a}	86^{a}	93^{a}	92^{a}	98^{a}	98^{a}
Clover 3	85^{a}	85^{a}	86^{a}	91^{a}	98^{a}	99^{a}
Clover 4	97^{a}	97^{a}	99^{a}	92^{a}	97^{a}	98^{a}
Clover 5	97^{a}	96^{a}	97^{a}	99^{a}	99^{a}	98^{a}
Plastic 1	0^{b}	0^{b}	0^{b}	6^{b}	20^{bc}	23^{b}

	% Weed Control					
	Early Control			Late Control		
Cover	**Pigweed**	**Crabgrass**	**Nutsedge**	**Pigweed**	**Crabgrass**	**Nutsedge**
Plastic 2	0^{b}	0^{b}	0^{b}	49^{ba}	50^{bac}	50^{ba}
Plastic 3	0^{b}	0^{b}	0^{b}	50^{ba}	50^{bac}	50^{ba}
Plastic 4	0^{b}	0^{b}	0^{b}	0^{b}	0^{c}	0^{b}
Plastic 5	23^{b}	23^{b}	25^{b}	61^{a}	65^{ba}	90^{a}
Rye 1	97^{a}	97^{a}	98^{a}	86^{a}	97^{a}	99^{a}
Rye 2	92^{a}	97^{a}	98^{a}	79^{a}	96^{a}	99^{a}
Rye 3	97^{a}	99^{a}	81^{a}	90^{a}	94^{a}	96^{a}
Rye 4	98^{a}	99^{a}	99^{a}	90^{a}	98^{a}	99^{a}
Rye 5	96^{a}	98^{a}	99^{a}	98^{a}	99^{a}	99^{a}
LSD ($\alpha = 0.10$)	17	17	21	27	31	29

[1] Weed control methods are as follows: (1) non-treated; (2) hand-weeded; (3) corn gluten + flame; (4) flame; and (5) herbicide.

Table 3. Weed Response to Cover Crops and Weed Control Methods – North Alabama Horticultural Research Center 2007.

Yield

Aside from the herbicide treatment, greater than 20% of the total tomato yield were cull tomatoes under plastic cover.

	Tomato Yield (kg/ha)						
Cover	**Cull**	**S**	**M**	**L**	**XL**	**Total**	**Market[2]**
Clover	5577^{a}	4838^{a}	9906^{a}	12298^{a}	263^{a}	32883^{a}	27305^{a}
Rye	5479^{a}	4778^{a}	9649^{a}	11031^{a}	272^{a}	31210^{a}	25731^{a}
Plastic	4226^{b}	2599^{b}	4566^{b}	7526^{b}	158^{a}	19074^{b}	14848^{b}
LSD ($\alpha = 0.10$)	612	576	1078	1931	197	3254	2931
Weed Control[1]							
1	4159^{c}	4006^{a}	6669^{b}	7149^{c}	283^{ba}	22266^{c}	18107^{c}
2	5112^{bac}	4634^{a}	8220^{b}	8466^{cb}	54^{b}	26486^{cb}	21374^{cb}
3	5554^{ba}	4003^{a}	8355^{b}	11248^{b}	241^{ba}	29402^{b}	23848^{b}
4	4547^{bc}	3871^{a}	6471^{b}	6565^{c}	58^{b}	21512^{c}	16966^{c}
5	6098^{a}	3845^{a}	10486^{a}	17996^{a}	518^{a}	38944^{a}	32846^{a}

	Tomato Yield (kg/ha)						
Cover	**Cull**	**S**	**M**	**L**	**XL**	**Total**	**Market**[2]
LSD (α = 0.10)	790	744	1392	2493	255	4201	3784
Combination							
Clover 1	5076^{bac}	4972^{bdac}	9197^{bdac}	10390^{bedc}	240^{a}	29874^{bc}	24799^{bc}
Clover 2	6204^{a}	6395^{a}	10218^{bdac}	10004^{bedc}	161^{a}	32982^{bac}	26779^{bac}
Clover 3	5673^{ba}	5315^{bac}	10814^{bac}	11284^{bc}	194^{a}	33280^{bac}	27608^{bac}
Clover 4	4233^{bac}	381^{ebdc}	7463^{bdc}	8029^{edc}	125^{a}	23660^{edc}	19427^{dc}
Clover 5	6702^{a}	3698^{ebdc}	11838^{ba}	21782^{a}	594^{a}	44615^{a}	37913^{a}
Plastic 1	2974^{c}	2107^{e}	2226^{e}	2629^{ed}	0^{a}	9937^{e}	6963^{d}
Plastic 2	4556^{bac}	2676^{ed}	5953^{de}	8388^{edc}	0^{a}	21574^{edc}	17018^{dc}
Plastic 3	5098^{bac}	2838^{edc}	5693^{de}	10491^{bdc}	238^{a}	24357^{dc}	19259^{dc}
Plastic 4	3494^{bc}	2143^{e}	2668^{e}	1892^{e}	0^{a}	10197^{ed}	6703^{d}
Plastic 5	5006^{bac}	3229^{ebdc}	6289^{dec}	14228^{bac}	552^{a}	29304^{bc}	24297^{bc}
Rye 1	4428^{bac}	4937^{bdac}	8584^{bdc}	8429^{edc}	610^{a}	26988^{c}	22560^{c}
Rye 2	4577^{bac}	4831^{bdac}	8490^{bdc}	7005^{edc}	0^{a}	24902^{c}	20325^{c}
Rye 3	5892^{ba}	3855^{ebdc}	8559^{bdc}	11970^{bc}	292^{a}	30567^{bac}	24676^{bc}
Rye 4	5913^{ba}	5659^{ba}	9283^{bdac}	9775^{bedc}	50^{a}	30679^{bac}	24767^{bc}
Rye 5	6587^{a}	4608^{ebdac}	13332^{a}	17978^{ba}	409^{a}	42913^{ba}	36327^{ba}
LSD (α = 0.10)	1368	1288	2410	4319	441	7277	6554

[1] Weed control methods are as follows: (1) non-treated; (2) hand-weeded; (3) corn gluten + flame; (4) flame; and (5) herbicide.

[2] Market is the marketable yield calculated by subtracting the culls from the total.

Table 4. Tomato Yield Response to Cover Crops and Weed Control Methods - North Alabama Horticultural Research Center 2007.

Economics

All treatments produced numerically higher NRVTC than the control, with the exception of plastic cover with flame treatment (Table 5). The clover cover and herbicide treatment produced the highest NRAVTC in 2007, followed by rye cover and herbicide treatment (Table 6). Both the non-treated control combined with clover and rye, as well as flame and hand-weeded treatments with clover cover, yielded higher NRAVTC than plastic with herbicide treatment. Across all cover treatments, corn gluten + flame had the lowest NRAVTC. The performance of corn gluten + flame was directly related to the cost of the corn gluten. As discussed above the corn gluten + flame weed control with clover cover had the third highest market tomato yields.

While total market yield is an important indicator of net returns, the distribution of tomatoes by size determines the level of revenue depending on the price by size. The price for each size is driven by the supply of each type of size and when the tomatoes are harvested during the season. This analysis did not consider harvest period in the revenue determination.

Cover Type	**Weed Control**[1]	**NRAVTC**[2] **Mean**	**NRAVTC**[2] **SD**	**Difference from Control**[3]
		(US$ ha^{-1})		
Clover	1	4680	1568	2254
	2	3718	1524	1293
	3	-5465	702	-7890
	4	2951	1526	525
	5	6910	1167	4485
Plastic	1	-769	421	-3194
	2	-245	2079	-2671
	3	-9088	1809	-11513
	4	-1439	480	-3865
	5	2426	549	0
Rye	1	4130	625	1704
	2	2262	651	-164
	3	-6261	1024	-8686
	4	3954	1663	1528
	5	6563	261	4137

[1] Weed control methods are as follows: (1) non-treated; (2) hand-weeded; (3) corn gluten + flame; (4) flame; and (5) herbicide.

[2] Net returns above variable treatment cost (NRAVTC); standard deviations are shown in parentheses.

[3] The control is plastic cover with no weed control.

Table 5. Net returns above variable treatment costs by treatment and the difference between treatments and the control.

This research demonstrates that high residue cover crops like cereal rye and clover can provide improved weed control compared to black polyethylene mulch. Previous research has also reported improved weed control with increased biomass production by cover crops [39]. Increased weed control has also been observed by Nagabhushna et al. [40] with an increase in the seeding rate of rye. Another important factor which could have facilitated increased weed control by rye and clover residue is rolling with mechanical roller crimper. The rolling process resulted in a uniform mat of residue on the soil surface that was a substantial physical barrier for weed seedlings to emerge through compared to tomato plant openings in the plastic mulch system that provides no barrier. Yenish et al. [41] also reported inconsistent control with cover crop residue and concluded herbicides were always required to achieve optimum weed control in corn. However, Yenish et al. cautioned weed control should not be the only criterion in selection of cover crops. Factors like cost and ease of establishment, impact on yield should be taken into consideration before selecting a cover crop. Results in this paper are short term effects of converting from a conventional plastic mulch system to two high-residue conservation tillage systems. These results indicate the economic possibility of growing fresh market tomatoes utilizing a conservation tillage system while maintaining yields and economic returns. However, the long term impact of these systems on yield and profitability require further investigation.

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Chapter 5

Preliminary Results Regarding the Use of Interspecific Hybridization of Sunflower with *Helianthus argophyllus* for Obtaining New Hybrids with Drought Tolerance, Adapted to Organic Farming

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Additional information is available at the end of the chapter

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Abstract

Taking into account the climatic changes expected in the future, significant shrinking of the current favourable ecological zones for sunflower is anticipated, and the transition period to that situation may be very short. The classical breeding process has a relatively long duration (7-9 years), so breeders are interested in taking advantage of some biotechnological methods (*embryo rescue*) for obtaining new sunflower lines with increasing tolerance to a certain stress factor.

Improving drought tolerance of sunflower cultivars is a priority for a breeding program of the National Agricultural Research and Development Fundulea (NARDI-Fundulea) because it provides stable productions under a changing climate condition already seen in the past twenty years.

In the period between 2008 and 2014 at NARDI-Fundulea, a research project was started to obtain new genotypes of sunflower with improved resistance to drought and heat through interspecific hybridization between *H. annuus* and H. *argophyllus* and that are suitable for application in organic culture. This research project received funding from the World Bank through a MAKIS project.

Keywords: Embryo rescue, interspecific hybridization, *H. argophyllus*, *H. annuus*, NARDI Fundulea, organic farming, drought

1. Introduction

In Romania, Vrânceanu (2000) [1] was able to obtain interspecific progenies *(H. annuus x H. argophyllus)* with drought resistance.

Interspecific hybridization is an additional technique to create new sources of genetic variability for the improvement of sunflower (Christov, 2013) [2]. With all the difficulties that may arise due to differences in the number of chromosomes (2x, 4x, 6x) and crossing incompatibility, interspecific hybridization is considered as an accessible way to incorporate wild germplasm into cultivated sunflower, especially to increase the resistance to abiotic stress factors (Iouraş and Voinescu, 1984) [3].

At the beginning of the project, 27 *H. annuus* parental lines were crossed with *H. argophyllus*, and two generations of interspecific hybrids/year were obtained in the greenhouse and house vegetation of NARDI-Fundulea in the first 2 years after the start of the project.

From each line hybrid obtained in 2008-2009 (Saucă et al., 2010) [4], six plants were selected, and their seeds underwent parallel backcross, self-pollination, and selection procedure.

As a result of this process, seven lines with significantly improved resistance to drought and heat (tested in field and laboratory) and that are suitable for organic farming system were selected in backcross 7. In 2015, these seven uniform lines with high production potential, oil content of over 43%, and resistance to broomrape and *Sclerotinia sclerotiorum* will be used to create commercial hybrids for ecological culture.

2. Background of organic farming

2.1. Definitions

The Ministry of Agriculture of Romania considered organic farming (similar to organic farming or biological agriculture), which differs fundamentally from conventional agriculture, as a "modern" process to cultivate plants, to fatten animals, and to produce food (www.mapam.ro) [5].

The Commission for Codex Alimentarius defines organic agriculture as "a production management system that promotes and maintains healthy development of agro-ecosystems, including biodiversity, biological cycles, and soil biological activity."

As science, organic farming deals with the systematic study of materials (living organisms and their environment) and functions (intra- and inter-relations material structures) of the agricultural systems, with design and management agro-ecosystems capable of providing for lengthy human needs for food, clothing, and housing, without reducing the potential environmental, economic, and social impact.

As occupation, organic farming is the activity that integrates theoretical knowledge about nature and agriculture in sustainable technological systems, based on the material, energy, and information resources of the agricultural systems (Toncea, 2000) [6].

To achieve this, organic farming relies on a number of objectives and principles, as well as on best practices designed to minimize human impact on the environment, while ensuring that the agricultural system operates as naturally as possible.

2.2. Principles underlying organic farming

Under the agreement in the integration of our country into the European Union, one of the measures imposed, inter alia, is the implementation of organic farming system. Apparently, this was something new, but some restrictions were easier to accept, for example, the interdiction for the use of chemical inputs that were not applied anyway on large surfaces in many agricultural areas due to economic considerations. However, a cause of concern is the lack of market demand for certified organic products and the low purchasing power of consumers. The price of an organic product is higher than its counterpart produced in the conventional system.

The normative acts operating in food production are particularly following the change in state of the art that occurred in agronomy. They do not refer solely on primary agricultural production sector, but also take into account the whole food chain, from primary production to final consumer. The agrifood complex is characterized by:

- Increasing the responsibility of those who practice this type of activity;
- Raising awareness and ability to reach market leadership.

Farms and organic agro companies are generally small- or medium-sized. Worldwide, most organic farms occupy small areas (0.5-30 ha), cultivate, and/or grow a small number of one, two, or three species of plants and animals and process one, two, or three different agricultural products.

Organic farming methods used in obtaining the unprocessed primary plant products, animals, and unprocessed animal products; animal and vegetable products processed for human consumption prepared from one or more ingredients of plant and/or animal origin; and compound feed and raw materials must meet the following conditions:

- Compliance with the principles of organic production;
- Non-use of fertilizers and soil improvers, substances used in animal nutrition, pesticides, food additives, growth promoters, cleaning and disinfecting products for livestock buildings, and products other than those permitted to be used in organic farming.

Developing of crop cultivation technologies targeted for alternative agriculture, especially for organic farming agriculture may improve the performance socio-economic indicators for these activities. This requires proper management of all the factors that contribute to high and stable yields per unit area, compliance with specific regulations and finally the recognition of finished products, in this case, an organic production certification.

2.3. Specific organic farming practices include

- Crop rotation as a prerequisite for the efficient use of farm resources;
- Very strict limits on chemical synthetic pesticides and chemical fertilizers, antibiotics for animals, food additives, and other substances used for additional processing of agricultural products;
- Not using of genetically modified organisms;
- Utilization of existing resources on site, such as using manure as fertilizer from animals and feed produced from the farm;
- Choice of species of plants and animals resistant to diseases and pests, adapted to local conditions;
- Livestock in freedom and open shelters and feeding them with organic feed;
- Using animal husbandry practices tailored to each race individually.

2.4. The objectives of organic farming

- Avoid all forms of pollution, both in products and in the environment;
- Maintain the natural fertility of soils, thereby ensuring food security in a sustainable planet;
- Allow farmers to have a decent life;
- To produce in sufficient quantities and at an appropriate quality level, thus ensuring the health of food consumers.

2.5. National and international legislations

The provisions on labeling of products from organic farming stipulated in Regulation (EC) no. 834/2007 on organic production and on labeling of organic products stated in Regulation (EC) no. 889/2008 that provide detailed rules for implementing Regulation (EC) no. 834/2007 are very precise and aim to offer consumers full confidence that products carrying the organic product label or the Community logo are obtained in accordance with the rules and principles contained in these regulations or, in the case of imports, are under the equivalent system with less demanding requirements.

To obtain and market labeled organic products and carrying specific organic production Community logo, producers must complete and strictly follow a rigorous process.

Thus, before you can obtain agricultural products that can be marketed as products of organic farming, the products must first undergo a conversion period of at least two years.

During the entire chain of production of an organic product, operators must constantly observe the rules established by Regulation (EEC) no. 834/2007.

In Romania, control and certification of organic products are currently provided by private inspection and certification bodies. They are approved by the Ministry of Agriculture and

Rural Development (MARD), based on the criteria of independence, impartiality, and competence as established in Order no. 688/2007 regarding the "Rules for organization of the inspection and certification system and approval of the certification and inspection bodies".

MARD's approval of control bodies requires a previous mandatory accreditation in accordance with European standard EN ISO 45011: 1998, which was issued by an agency authorized for this purpose. Following the inspections performed by regulatory bodies, certain products of operators complying with the rules of organic production may receive organic product certificate, and these products are permitted to be marked as "eco-labeled products".

Before the application of the label to an organic product, the following requirements must be fulfilled: the reference to organic production logo, name and code of the inspection and certification body that carried out the inspection and issued the organic product certification. The "ae" logo specific for national organic products, together with the Community logo, can be used for better views of consumer products from organic production.

The right to use the "ae" logo on product labels and packaging of organic products is given to producers, processors, and importers registered with MARD and holding a contract with a control body approved by MARD.

As part of the campaign to promote organic agriculture in the European Union (EU) at the initiative of the Directorate General for Agriculture and Rural Development of the European Commission, a website dedicated to this purpose was created: www.ec.europa.eu/agriculture/organic/home.ro.

The main objective of this site is to inform the general public about organic farming system as a starting point in the realization of promotional campaigns in different Member States.

Additionally, in order to promote the organic products, the European Commission provides support of up to 50% of information and promotion programs submitted by professional and inter-professional organisations, involving at least 20% of the actual cost of measures, and budget co-financing being provided by the State in accordance with Regulation (EC) no. 3/2008 on information and promotion actions for agricultural products on the internal market and in developing countries and Regulation (EC) no. 501/2008 that lays down detailed rules on implementing Regulation (EC) no. 3/2008 (information taken from the MARD website).

2.6. The national and international situations

If during the period 1950-1990 in Romania the objectives were to increase agricultural production to meet food requirements in view of the growing population, today the objectives are focused on finding new solutions that aim to respect the environment, create a system production that is economically viable, and maintenance and use of natural resources.

This new type of farming is called sustainable agriculture, and it involves a set of techniques and practices that should ensure a satisfactory production, ensuring food requirements are met and taking into account environmental protection.

After 1990, the gap recorded between quantitative indicators expressing the production potential and quality, caused by low endowment and equipment necessary to conduct the production process as well as related inputs, led to the development of technologies' extensive culture.

Another cause is the high fragmentation and dispersion of farms due to the implementation of the Land Law no. 18/1991. Currently, the farming land (14.8 million. Ha) is dispersed in about 40 million parcels. In 1972, the I.F.O.A.M. (International Federation of Organic Agriculture Movement) based in Germany was established. This federation groups more than 670 organizations and institutions from more than 100 countries worldwide.

The European Economic Community (EEC) recognized a majority vote of the European Parliament on 19 February 1986 on the existence of alternative agriculture based on resolutions adopted through Regulation 2092/91. A series of regulations were formulated, of which particularly important is Regulation EEC 1936/1995, which specified that from 1 January 2000, organic farming materials are the only ones to be used in sowing/planting.

According to I.F.O.A.M. statistics (February 2001), the world agricultural area intended for organic production was estimated to be 15.8 million hectares, with the largest area in Australia (7.6 million hectares), Argentina (3 million hectares), and Italy (1 million hectares).

In all EU countries, there is a real desire for developing OA, which will hold over 10% of the cultivated area. Agricultural area in the "bio" or "organic" agricultural systems in some countries is as follows: Italy - over 1.1 million ha, United Kingdom - 600,000 ha, France - 400,000 ha, Spain - 380,000 ha, and Austria - 250.000 ha. In the USA and Japan, about 20% of food is through organic production system.

In Romania, organically cultivated agricultural areas have seen a spectacular growth in the period 2010-2013, so at the end of 2013, about 301,148 ha were recorded by MARD.

Regarding the European organic food market, Germany has the biggest market, with sales of approximately 2.5 billion euro, and in terms of average consumption per capita of ecological products, Denmark and Switzerland are leading.

The markets for organic products are both the countries that depend on exports of organic products (Italy) and the countries that depend on imports of organic products (UK). Extremes of demand and supply in each country adjust by themselves. According to the study, the current situation appears to be changing because, in the UK, it is estimated that domestic production will meet the demand, while in Italy, the demand will increase. Today, increasingly more organic products are imported from Eastern Europe.

European Commission experts estimate that the market for organic products last year reached a value of 23 billion euro in the European Union. The organic market in the European Union is virtually all primary and processed agricultural produce (bread, wine, meat, milk, oil, fish, etc.). According to the study, organic products are generally 25-30% more expensive than conventional products, but depending on the supply and demand, the price could reach 400% of the price of the conventional ones.

Many local experts consider that countries in the Eastern Europe would need 10-15 years to be able to develop and structure the internal market at the level of the Western EU states. An argument invoked to support this assertion is the example of Spain, where it required about 17 years after integration to structure the internal market at the level of the other member states. Meanwhile, Spain exports almost all northern European market organic products. Eastern European countries will need to focus on organic production of the scanty products in the EU, including vegetable protein and red fruit, because Western countries have begun to significantly reduce production in sectors requiring a large labor force.

In Romania, the ecological production sectors benefit from European funding of about 200 million euro, which is available through a dedicated position in the new National Rural Development Programme (RDP) 2014-2020.

In addition, payments for OA, which are made by APIA, will continue. The registered farmers in organic agriculture will receive grants of 500 euro/hectare/year for growing vegetables, 620 euro/hectare/year for horticulture, 530 euro/hectare/year for vineyards, and 365 euro/hectare/year under organic cultivation of medicinal plants.

The experts appreciate that prices of organic products could be 10-20% higher than those of conventional ones if there are many farms and slaughterhouses certified. Romania currently has only 2-3 farms of laying hen organic certificates and some organic dairy farms, but instead the Romanian exports of organic wheat are significantly high, meanwhile part of this commodity is imported back as processed ecological products at prices 2-3 times higher than the conventional ones.

According to the MARD, the value of the domestic market of organic products in 2008 was about 20 million euro, while exports were at 100 million euro, which was twice the amount in 2006. Under an adjustment of Common Agricultural Policy (CAP) in 2009, Romania proposed that organic farming be financially supported by this package. Since this adjustment, CAP has created a financial reserve that allows the Member States to develop certain programs to fully support a particular context, technically called Article 68.

The financial envelope allocated to Romania for 2010 only amounted to EUR 5 million. The increase in the organic market in Romania continues; with only 86 registered organic food processors in 2008; in 2010, the number became 3,155; and in 2012, it was 15,194.

Exports of organic products in 2008 amounted to 100 million euros, which was equivalent to about 130,000 tons of products, of which only 1% were processed products and 0.94% were honey products. The primary export destinations were the Netherlands, Germany, Denmark, Italy, and the UK. Imports of organic products were worth 10.8 million euro, which was almost double the amount for 2007, with fruit and legume preserves, coffee, and sweets being the most significant products.

The turnover in organic agriculture worldwide was 46 billion dollars in 2007, up by 10% compared to 2006, while in Europe the figure reached a level of 15.4 billion euro, 15% more than in 2006.

The productive potential of agriculture ecological system of the country can reach up to 15-20% of the total agricultural areas largely concentrated in hilly mountain where technology maintenance and use of pastures were based on traditional methods - organic (manure application, utilization of grazing and/or mowing, use of fodder and clover ameliorating soil fertility, use of vegetable-livestock mixed system), but are not neglected arable land in the North-East.

At global level, two opposite trends are rising as an increasing concern:

a. **Overproduction** and negative side effects of industrial type of farming that include decreasing of soil fertility due to erosion, acidification, salinization, and exhaustion of the reserve of organic matter; reducing of biological and genetic diversity; increased risk of air pollution exhaust and ammonia, shallow and deep waters and soils with nitrates, and heavy metal contamination of food with toxic substances, etc.;

b. **Production for subsistence** and its negative consequences - hunger and social inequity.

These imperatives can be resolved only by organic farming, an agricultural practice in some countries that is called organic or biological farming, which sprang from the secular experience of agriculture.

Organic farming is not a miracle or a wonder, but a creation of nature-loving farmers, who aim for harmony and dynamic interactions among soil, plants, animals, and humans, or, in other words between supply natural ecosystems and human needs of food, clothing, and housing.

2.7. Practical aspects of OA

- The agro-ecological systems have long life due to components, structural and functional stability, and ability to cope with any disruptive or disturbing factor.

- Organic production is done on farms, individual households, family associations, agribusiness companies, and rarely in large agricultural associations and companies or holding. Organic products are obtained also in the aquatic environment, forest, and other natural systems.

- Generally, many agricultural and agro-ecological farms are in small- or medium-sized category. At world level, the average surfaces for organic farms are within 0.5 and 3.0 ha range, and most of them cultivate only 1-3 different agricultural species.

- All organic farms and agro-industrial societies undergo a longer or shorter conversion period, which is equal to the time between the start of ecological management and getting the certificate by the ecological farm or company.

- Certification is provided by a national or international organization that is recognized by the International Accreditation Service International Federation of Organic Agriculture Movements (IFOAM) and empowered to assess and guarantee in writing that its production or processing system is in compliance with the standards of organic agriculture.

- The transition from conventional to organic farming is done step by step, in order to protect the economy from the shocks of decreases in productivity, and to allow producers to gain confidence in the ecological systems. Certification of these business units is made as soon as a part of their work meets the environmental standards and provided that the two systems (conventional and organic) are clearly separated both in documentation and in production.

- With very few exceptions, organic farms are mixed, plant-animal type, on the one hand, to capitalize on higher crop and, on the other hand, to reuse as much of the nutrients extracted from the soil by plants grown. In this case, the structures of animal species and categories are determined by the potential of the farm and vegetable farming area, as well as the economic and financial resources (buildings and plant breeding, money) and the manpower (number of people, age, training) available in the farm.

Exceptions to this rule are organic vegetable farms and processing and marketing firms for semi-organic products. In such cases, the bulk of production is for direct human consumption (vegetables, fruits, canned vegetables and meats, cheeses, vegetables, and animal extracts); processing of the products is done with minimum consumption of energy, and this energy is, as far as possible renewable, sourced from animal manure (biogas), wind, and local fluid (residues and organic waste).

- The activities of farms and agro-industrial companies are carried out according to international and national rules. Any deviation from these standards results in losses, including the loss of farm and the ecological society.

- In organic farms and processing companies, all species and varieties of domesticated plants and animals are grown and processed, except those created by genetic engineering.

- Farms and processing companies of organic product are using mostly own financial economics and social resources. Land, goods, and services of the agro-ecological units are mainly privately owned, and the funds are secured, for the most part, from its own resources. In countries with developed organic farming, a significant share of financial resources is provided by the state through a diversified mechanism of subsidies (exemption from taxes, production inputs, and additional expenses to conventional agriculture). The workforce consists of organic agro-industrial unit farmers or owners and close relatives.

- Some farms and agro-industrial companies undertake labor from outside, also, but only for a determined period of time when the workload exceeds the skill and strength of the permanent employees.

Regarding the problems of agro-ecological systems, Köpke (2005) argued that compared with intensive farming system, ecological system is characterized by:

- Reduced availability of nutrients, especially nitrogen and phosphorus, with consequences on the level of yields (because of the limited growth) and especially on their quality;

- The danger of a high level of weed and pest infestations due to absence of chemical treatments. Claude Aubert, one of the pioneers of organic farming, supports with scientific arguments that for organic farming "the genotype is more important than the whole technology".

2.8. Reference of knowledge on the topic addressed

The Intergovernmental Panel on Climate Change (IPCC), which brings together experts from around the world, published on 6 April 2007 in Brussels a new report on the impact of global warming on people and the earth. This report is a readjustment of the report in 2001 and is recognized by 192 UN member states. The crucial passage of the new report indicates that "a drastic change in climate is expected if carbon concentrations in the atmosphere will reach 550 ppm (parts per million), which would cause a rise in temperature of about 3 degree Celsius. The main consequences of global warming are increasing ocean levels and extreme weather events (heat waves, droughts, floods, strong winds) that will bring major impacts like disappearance of animal and plant species, increasing human health risk, and inevitable demographic changes. Crop yields fluctuate from year to year, and this is being significantly influenced by climate variability and extreme weather events. Climate variability impacts all sectors of the economy, but agriculture remains the most vulnerable.

In Romania, from about 14.7 million ha of agricultural land, of which 9.4 million ha is arable land (64% of arable land), 7 million ha of agricultural surface (48%) soils are affected in different degrees by frequent droughts in most of the years and more than 6 million ha of agricultural land are affected by excess moisture in wet years. The extent and intensity of extreme weather events decrease annual agricultural production by at least 30-50%, and sustainable conservation of natural resources in agriculture is necessary to ensure scientific validity of all actions and measures to prevent and mitigate the consequences. Drought is a natural phenomenon caused by insufficient rainfall for meeting the crop requirements. The impact of drought is influenced by the severity of drought, physiological status of crop (including the development stage and cultivar adaptation) and soil properties.

The most severe effects are manifested especially on the rural population dependent on farming. Global climate changes as manifested by the increasing average temperature and change in rainfall regime have led, in recent decades, to an increase in drought-affected areas worldwide. In Romania, the areas most vulnerable to extreme drought are the south-eastern and Dobrogea, Baragan and southern areas of Oltenia, Muntenia, and Moldavia.

The term "desertification" refers to reduction or destruction of the biological potential of land that can lead to problems similar conditions in desert areas. Desertification includes the interaction of large-scale global climate dynamics, reflecting the general circulation of the atmosphere and ocean and climate physics of the earth's surface. It can be a result of the interaction of natural recurrence of droughty years with practice of irrational exploitation of the land, deforestation, and intensive grazing. Climatic data from the past century show a gradual warming of the atmosphere and a significant reduction in rainfall as limiting factors for crop growth and productivity and utilization of water resources. These changes can have significant impacts on growth and development of crops during the growing season, depending on the intensity of the disruptive factor, the manner and duration of action, and plant species vulnerability to extreme weather events during production.

Globally, according to studies, a significant warming in the coming decades is expected as a result of increased CO_2 concentration in the atmosphere and significant changes in precipitation. The IPCC report (2001) estimated an increase in global average temperature from 1.4°C to 5.8°C by 2100, depending on the emission scenario, which is 2-10 times more pronounced compared to the current condition. The amount of rainfall will record a rise/fall trend of between 5% and 20% globally, with significant differences occurring especially at the regional level. It will also intensify the occurrence of extreme weather conditions (winter and summer extreme temperatures, droughts, floods, tornadoes, hurricanes, etc.) with major consequences on the entire planetary ecosystem.

In Romania, projections of global scenarios for the period 1991-2099 as compared to the period 1961-1990 revealed an increase in the average air temperature of about 2°C during winter and 3.5°C to 4.3°C during summer (3.5°C and 4.3°C in the north and south, respectively). With regard to precipitation the expected changes are insignificant during summer and winter will be recorded water deficits. The northwest country regions are expected to become slightly wetter meanwhile the southwest and central regions will become drier.

In the twentieth century, global warming shows an annual average temperature rise of 0.3°C in almost the entire country, with the increase in temperature being more pronounced in the southern and eastern areas. Significant warming was experienced during winter and summer seasons (with Bucharest-Filaret being the most pronounced, 1.9°C), and significant cooling was found during fall in the western regions of the country.

Regarding the distribution of precipitation within year, there was a downward trend in the annual quantities especially in the central regions, and during the winter season, a decreased precipitation was observed in most regions, being more pronounced in the south and west.

Effects of global warming further include the following changes in the occurrence of meteorological phenomena in hot or cold season of the year: increased frequency of tropical days, decrease in the frequency of winter days, increasing average maximum temperature during winter and summer (up to 2.0°C in the south and southeast), significantly decreased thickness of snow in the Northeast and West, and increased annual production of winter atmospheric phenomena (frost, ice, frost).

Today, global climate change is associated with increased pollution, deforestation or changes in the landscape that caused an amplification on the process of aridization. As a result, some high-risk areas for drought tend to be affected by aridity and even by desertification (disappearance of vegetation cover and soil degradation). In our country, the high-risk territories for drought, with a tendency to be affected by aridity and desertification, include large areas of Dobrogea and southern Romanian Plain. These areas may be classified as areas most vulnerable to excessive and prolonged drought.

In the next decades, the implications of global warming in the industrial economy, water supplies, agriculture, and biodiversity will be very obvious. Globally, therefore, it has the effect of warming and increased frequency and intensity of extreme events, especially droughts and floods. The causes that lead to these phenomena are evident about both climate and human interventions or wasteful use of land and water resources, inappropriate agricultural practices, deforestation, overgrazing, and air and soil pollution.

During extreme droughts, the current agricultural practices recommended are: fixing assortment of varieties and hybrids at the beginning of each crop year and the use of appropriate technology depending on soil water reserves from sowing; cultivating a greater number of varieties/genotypes with different growing season for better use of the climate conditions, especially moisture regime. Significant yield losses can be prevented through observance of recommended sowing period, irrigation or application of a minimum tillage system, utilization of varieties adapted phenologically to the new climatic conditions (in order to avoid the occurrence of critical phases as pollination and grain filling during the maximal stress periods) and better adapted physiologically to stress.

In the long term, the necessary measures for the prevention and mitigation of climate change include reforestation programs, reducing pollution, restoring and upgrading anti-erosion work, and expansion of the development and improvement of sandy soils, etc. At the same time, educating people and raising awareness on environmental protection are major requirements in developing adaptation strategies to climate change.

Solutions and recommendations for the development of actions and procedures to prevent and minimize the effects of climate variability in agriculture must include the already well-known whole complex of measures (agro-technical, cultural, irrigation, etc.) and carrying out swift action and intervention to limit the consequences and spatial extension of the affected area.

However, addressing issues related to climate change impacts requires specialized scientific data and analysis, risk management in agriculture mainly involving actions concerning the management and conservation of environmental resources, and making the right decisions in the right perspective.

In 1996, the National Commission on Climate Change/CNSC (HG 1275-1296) was established, and in July 2005, Romania's National Strategy on Climate Change (GD 645/2005) was approved. Also, with Law no. 111/1998, Romania joined the United Nations Convention to Combat Desertification (CCD); the Convention adopted in Paris on 17 June 1994 the declaration that 17 June be recognized as the Desertification and Drought Day worldwide. (SMART financial - www. SMARTfinancial.ro.[7])

3. Improving sunflower to biotic and abiotic stress factors

NARDI-Fundulea has obtained an invaluable genetic basis with over 50 years of research experience. NARDI-Fundulea is the basic institution in Romania that provides the necessary seeds and parental lines of traditional culture system.

The requirements for sourcing germplasm to improve sunflower hybrids are becoming bigger and more important. The greater diversity is conserved, the more chances to meet the present and the future. Loss of genetic diversity or genetic erosion may occur as a result of many interrelated causes, such as socio-economic and agricultural, natural disasters such as epidemics, long periods of drought and floods, and even human contribution.

The collection, evaluation, and preservation of wild species of sunflower were done carefully and were the basic objectives of the scientific cooperation of the FAO Network Research Sunflower Sun. From its foundation in 1975 until today and in Vrânceanu's (2000) study [1], the main objective of improving the sunflower hybrid is said to be further improving productivity by increasing seed production and seed oil content. After seed production and oil content, the major objective of improvement is: genetic resistance to disease *(Sclerotinia sclerotiorum, Phomopsis helianthi)*, parasite *Orobanche sp*, drought, and heat; with less attractively for birds were obtained.

3.1. Material and methods

The genetic materials used were seven inbred lines of sunflower obtained at the NARDI-Fundulea and wild *H. argophyllus* known as resistant to drought.

Two locations were chosen for organic testing: Stupina (Constanta), known as pole drought in Romania, and Fundulea (Calarasi county).

The breeding methods used were: interspecific hybridization (first year of experimentation), embryoculture to save interspecific *embryo rescue* backcross, self-pollination, and selection. Two generations/year worked in the field and in the greenhouse, as illustrated below.

As we have a lot of data from all the years of experimentation, we will present only the results obtained in 2014, which was an extremely dry year in terms of ecological culture of the Stupina. Some of the results were published in international journals, while others are in print.

Regarding drought tolerance, we deduced the parameters of productivity (weight/head, TKW, and oil content), which will be presented for each new genotype obtained.

Each "slash" code (for example 1/1/1...n) inside graphs represents a descendent from an initial interspecific hybrid that further was subject of the general breeding scheme (individual selection, self-pollination, back cross and new selection scheme). The labels Stupina1-Stupina3 and Fundulea1-Fundulea3 represent the number of repetitions per location.

3.2. Results

From Figure 1, we can see great differences among some genotypes, even if they have the same lineage. In the same cross-breeding, it has been observed that every head is a distinct genetic entity. Therefore, the seed obtained from each phenotypically different head was seeded (three times/head) into one isolate plant/row.

Both lines (1/1/1 and 1/1/2) showed instability of seeds and head weights, both at Fundulea and at Stupina. For TKV, 1/1/1 in terms of Fundulea, showed some stability; the differences between the three plants are insignificant. For Stupina, although TKW values are reduced by approximately 50%, stable new lines show the three plants. In Figure 1, the same applies. Great unevenness and instability on seed production/head were observed. The fact that while seed production was low, except for plant Fundulea 1 (1/2/1), TKW recorded values were between 29 grams and 49 grams.

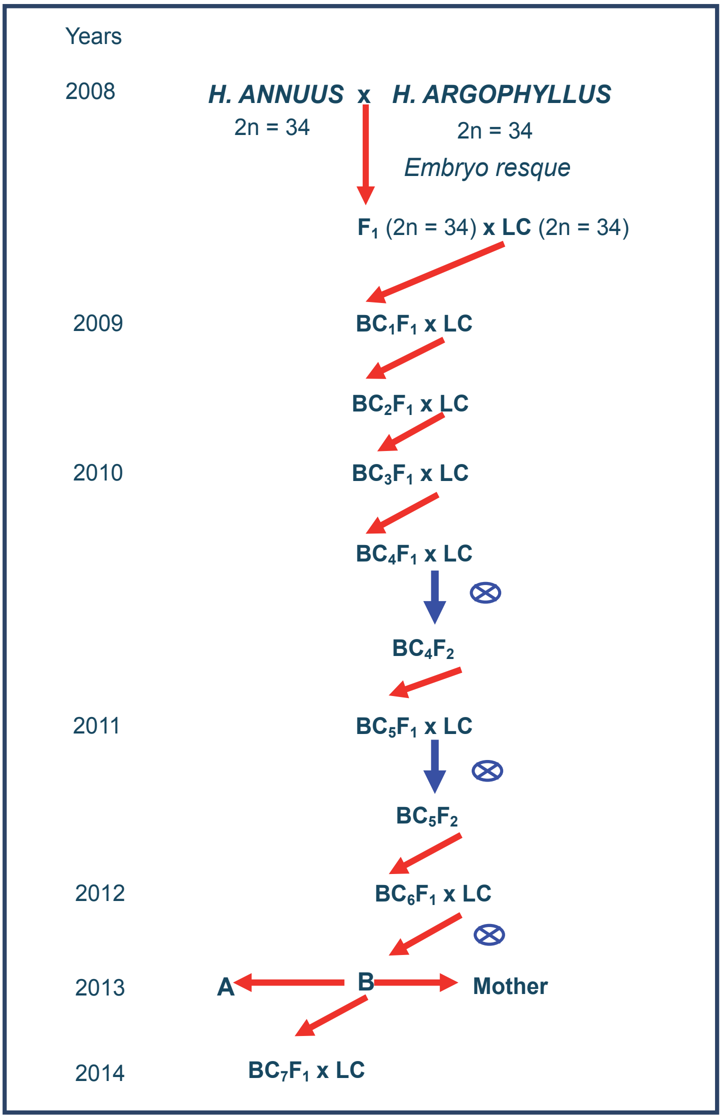

Figure 1. Sunflower breeding scheme

From Figure 4, one can see that the plant "Fundulea 3 (1/3/1)" progenies with a head weight of 70 grams at Fundulea and 38 grams at Stupina. The TKW for this genotype was the highest in both locations (49 grams).

Due to the very low values for both characters, in both locations, the genotypes 1/4/1 and 1/4/2 were not considered for the process of breeding for commercial hybrids (Figure 5).

In the extremely droughty conditions from Stupina, even the TKW and head weights were lower than in Fundulea they displayed a better uniformity.

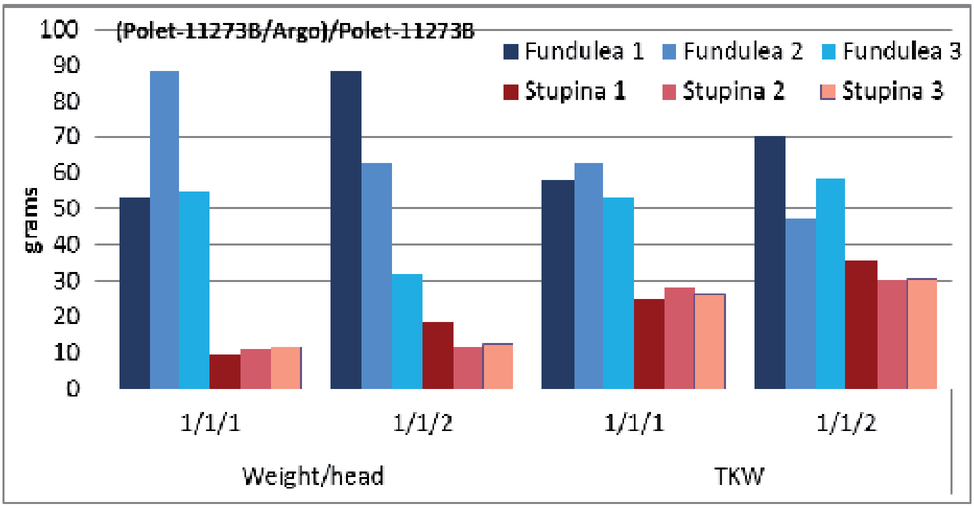

Figure 2. Average weight of head and TKW for the progenies of the progenies from backcross 7th generation of the 1/1/1 and 1/1/2 lines resulted from interspecific hybridisation Polet-11273B x *Helianthus argophyllus*

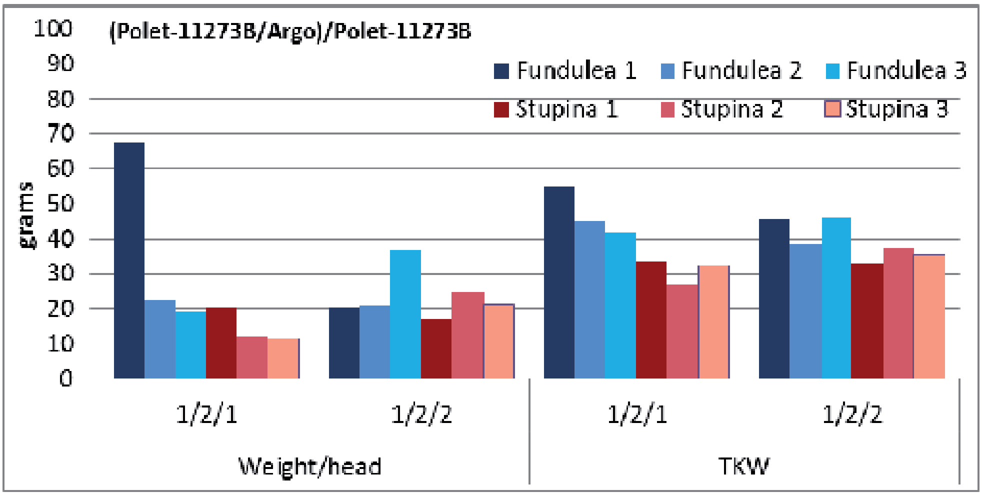

Figure 3. Average weight of head and TKW for the progenies of the progenies from backcross 7th generation of the 1/2/1 and 1/2/2 lines resulted from interspecific hybridisation Polet-11273B x *Helianthus argophyllus*

Due to the fact that the oil percentage is higher under heat and drought stress conditions, it is not surprising that all the genotypes obtained from hybridization of Polet-11273B x *Helianthus argophyllus* (Figure 6) have an oil content (estimated by NMR) greater than 40% at Stupina, significantly exceeding the oil content (determined with the same method) of the seeds obtained at Fundulea (29-33%)

From the hybridisation of line O-7493B with *Argophyllus*, 3 descendants with yield and oil content stability were selected: 3/1/1 (Figure 6); 3/2/1/ (Figure 7); and 3/4/2 (Figure 8). The seed

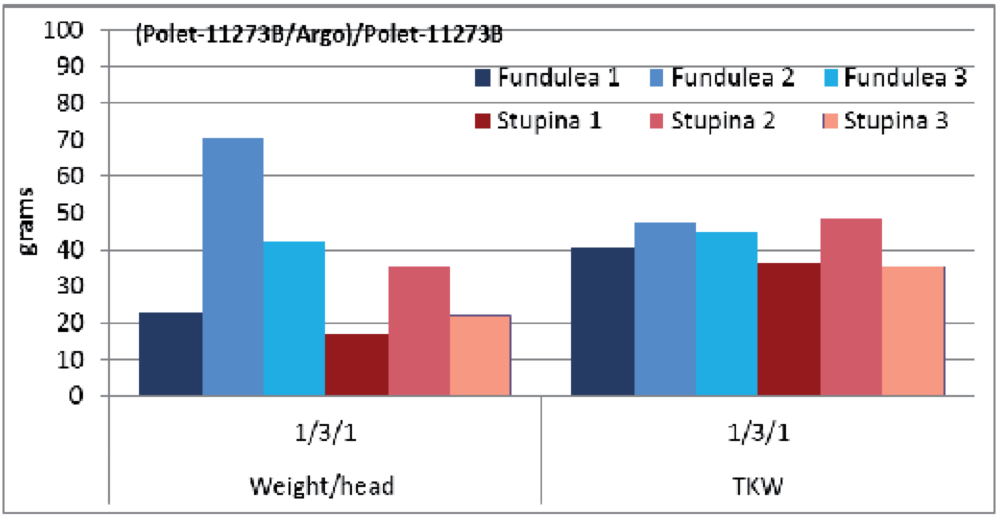

Figure 4. Average weight of head and TKW for the progenies of the progenies from backcross 7th generation of the 1/3/1 and 1/3/2 lines resulted from interspecific hybridisation Polet-11273B x *Helianthus argophyllus*

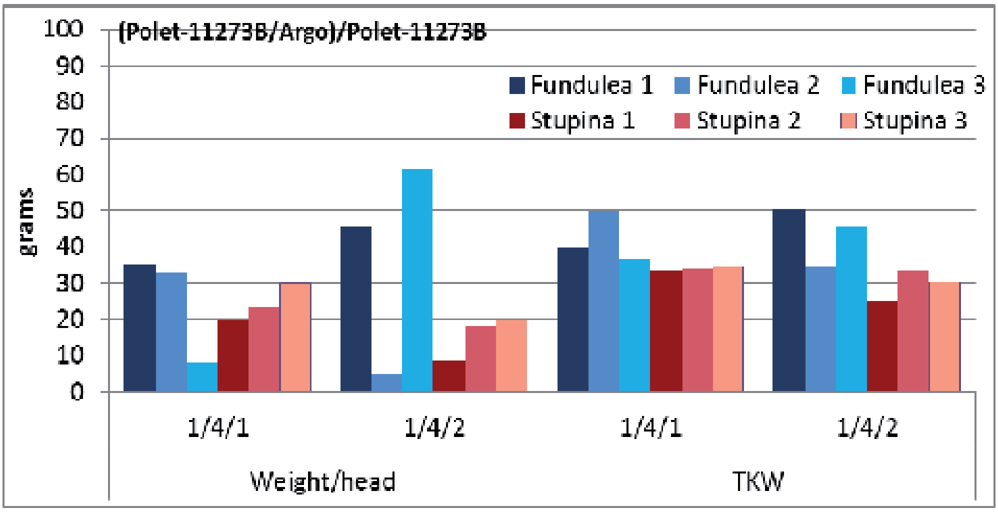

Figure 5. Average weight of head and TKW for the progenies of the progenies from backcross 7th generation of the 1/3/1 and 1/3/2 lines resulted from interspecific hybridisation Polet-11273B x *Helianthus argophyllus*

weight of heads of these descendants varied between 73 and 120 grams/head at Fundulea and between 25 grams and 60 grams at Stupina. The oil content varied between 32% and 40% at Fundulea and between 39% and 44% at Stupina (Figure 9).

After hybridizations, self-pollination, backcrossing, and selection of descendants of the hybrid Tard/85-19982B X *Helianthus argophyllus*, we obtained 11 new lines with a very large variability for the studied characters.

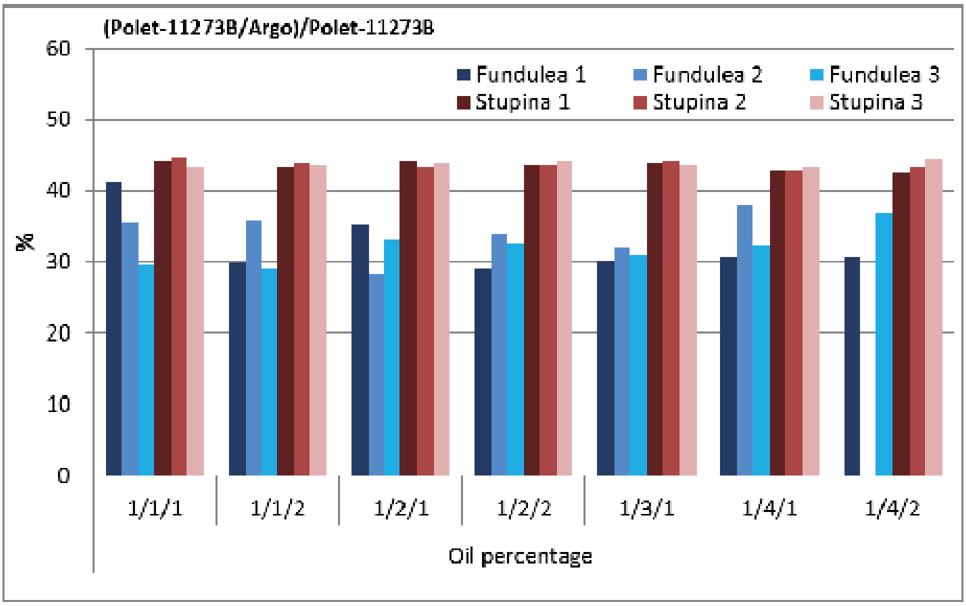

Figure 6. Oil content of the backcross 7th generation of sunflower lines obtained from interspecific hybridisation between Polet-11273B and *Helianthus argophyllus*

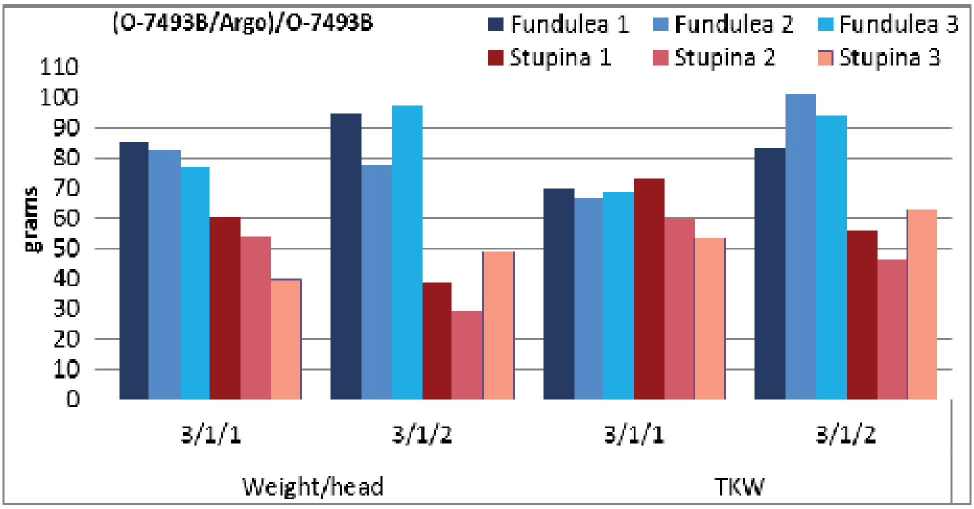

Figure 7. Average weight of head and TKW for the progenies of the progenies from backcross 7th generation of the 3/1/1 and 3/1/2 lines resulted from interspecific hybridisation between O-7493B and *Helianthus argophyllus*

Figure 11 shows that the weight of seeds/head in the case of line 11/1/1 was higher in the drought condition of Stupina. Therefore, the genotype "plant Stupina 2" achieved 72 g/head compared with "Fundulea 2" that produced only 40 g/head. Additionally, for the TKW character, this line proved to possess good adaptability to drought, reaching or exceeding the

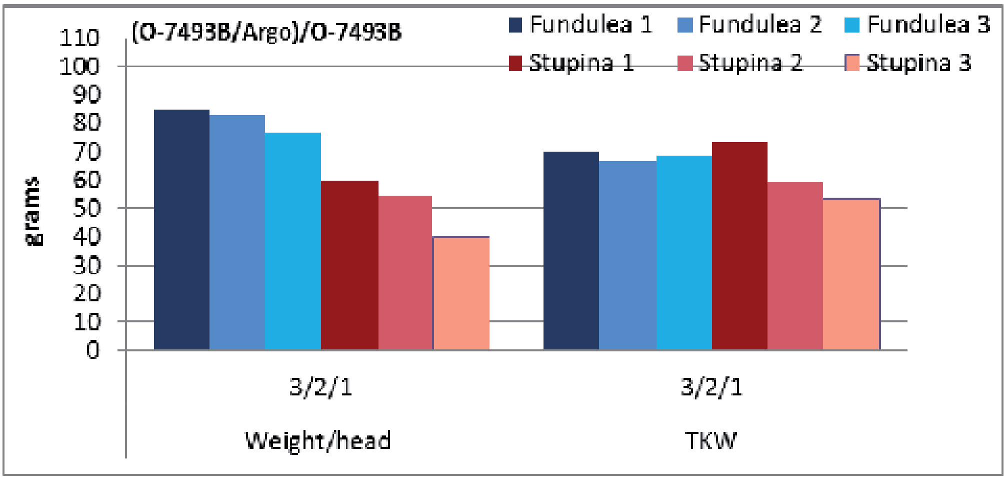

Figure 8. Average weight of head and TKW for the progenies of the progenies from backcrossth generation of the 3/2/1 line resulted from interspecific hybridisation between O-7493B and *Helianthus argophyllus*

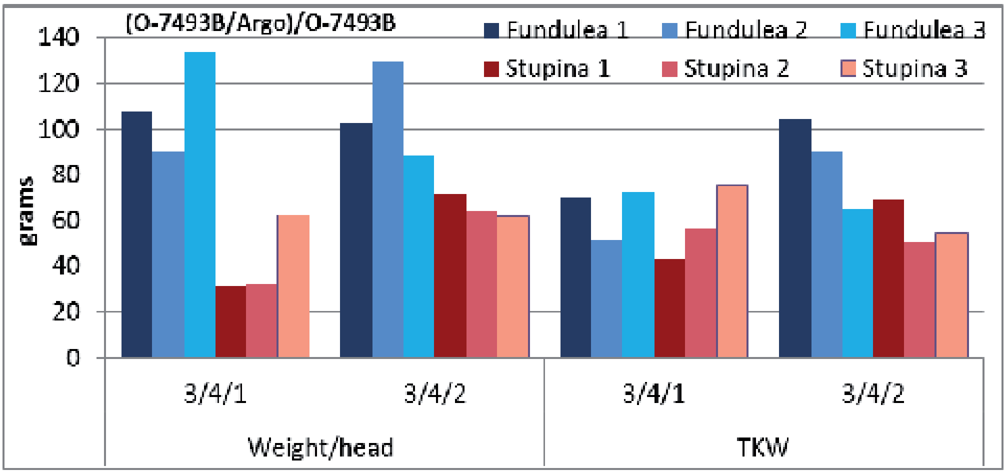

Figure 9. Average weight of head and TKW for the progenies of the progenies from backcross 7th generation of the 3/4/1 and 3/4/2 lines resulted from interspecific hybridisation between O-7493B and *Helianthus argophyllus*

values obtained at Fundulea, where the weather conditions were closer to normal. Another descendent of this interspecific hybridization is the line 11/2/1 (Figure 12) that achieved through the genotype "plant Stupina 2" a seed yield per head of 90 g and a TKW of 59 g being the only line out of all the combinations that have proven under drought conditions such a performance. It is necessary to mention that the line Tard/85-19982B is known to be like an intensive line with high yield under good irrigation and fertilization. In this case, it is obvious that the resistance and adaptability to drought were transmitted from the wild species, due to the fact that agro-ecological selection field from Stupina was not irrigated, and no fertilizer was applied.

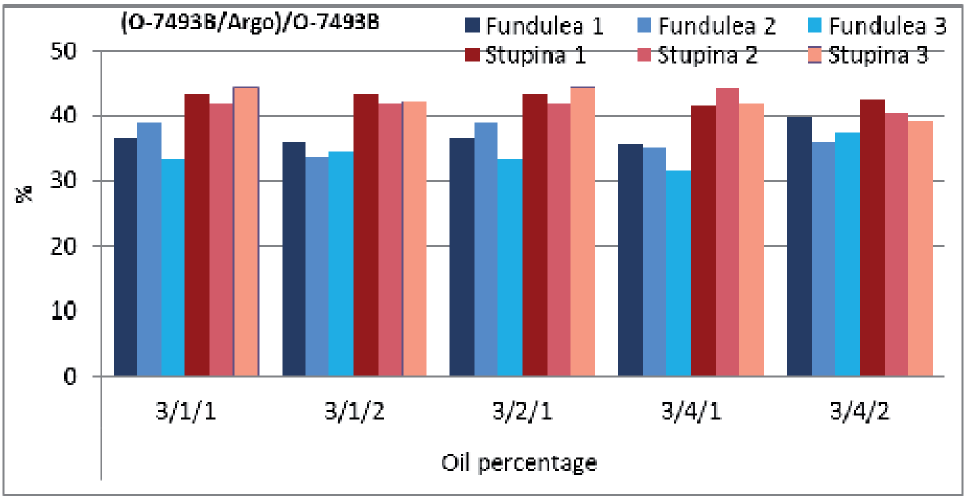

Figure 10. Oil content of the backcross 7th generation of sunflower lines obtained from interspecific hybridisation between O-7493B and *Helianthus argophyllus*

These two lines originating from this combination will be used to obtain commercial sunflower hybrids. For all other lines resulting from this combination, the breeding process will be continued through self-pollination and backcrossing, due to the fact that they represent a valuable biological material that can be further improved.

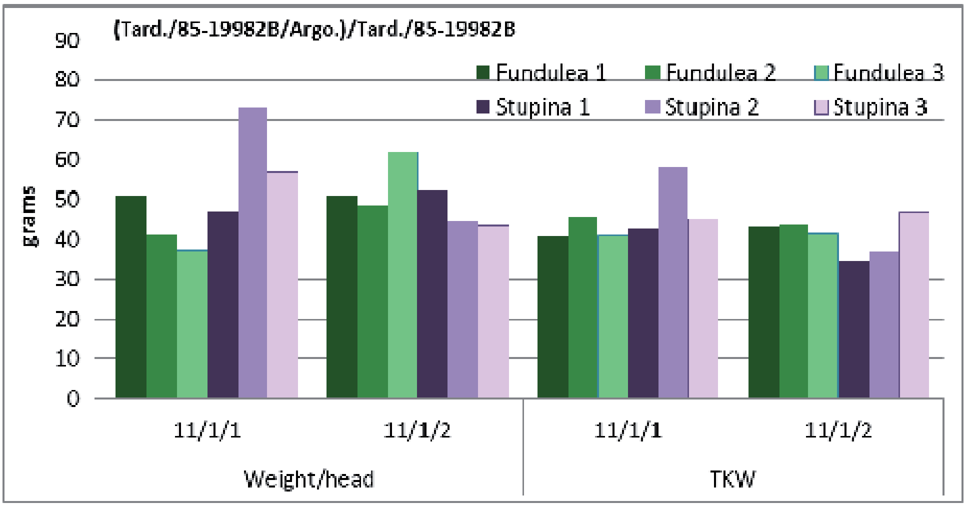

Figure 11. Average weight of head and TKW for the progenies of the progenies from backcross 7th generation of the 11/1/1 and 11/1/2 lines resulted from interspecific hybridisation between Tard./ 85-19982B and *Helianthus argophyllus*

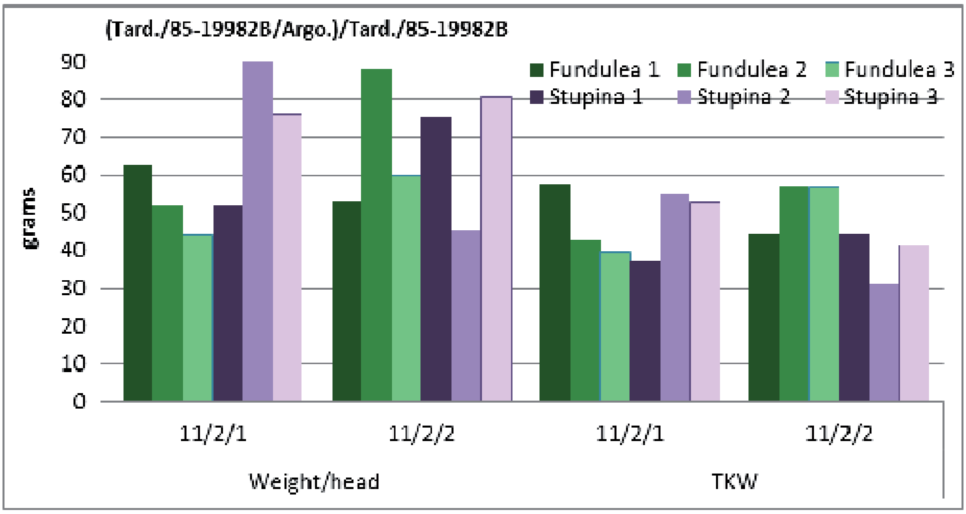

Figure 12. Average weight of head and TKW for the progenies of the progenies from backcross 7th generation of the 11/2/1 and 11/2/2 lines resulted from interspecific hybridisation between Tard./85-19982B and *Helianthus argophyllus*

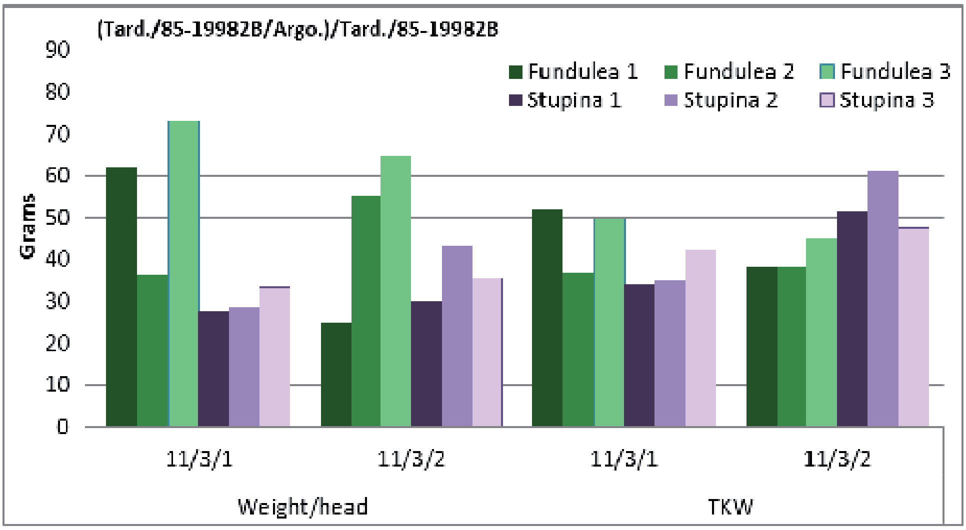

Figure 13. Average weight of head and TKW for the progenies of the progenies from backcross 7th generation of the 11/3/1 and 11/3/2 lines resulted from interspecific hybridisation between Tard./85-19982B and *Helianthus argophyllus*

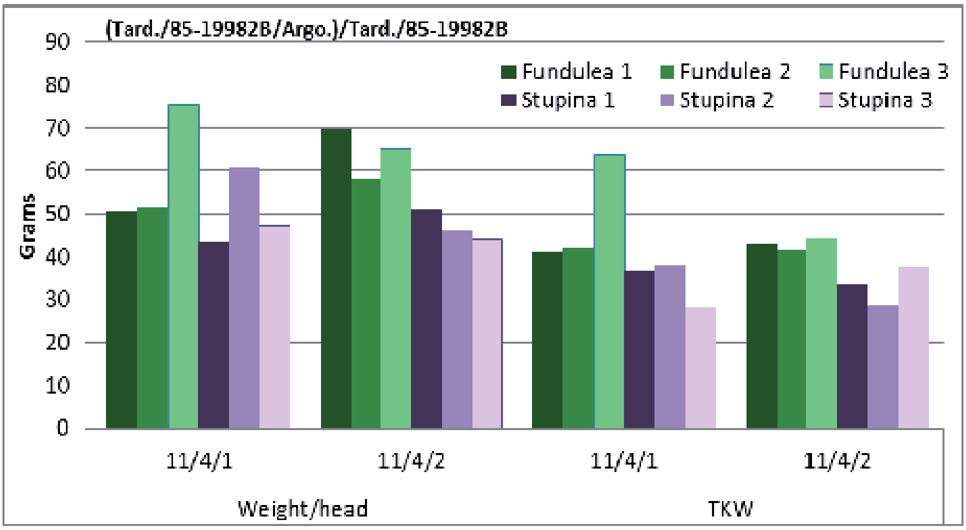

Figure 14. Average weight of head and TKW for the progenies of the progenies from backcross 7th generation of the 11/4/1 and 11/4/2 lines resulted from interspecific hybridisation between Tard./85-19982B and *Helianthus argophyllus*

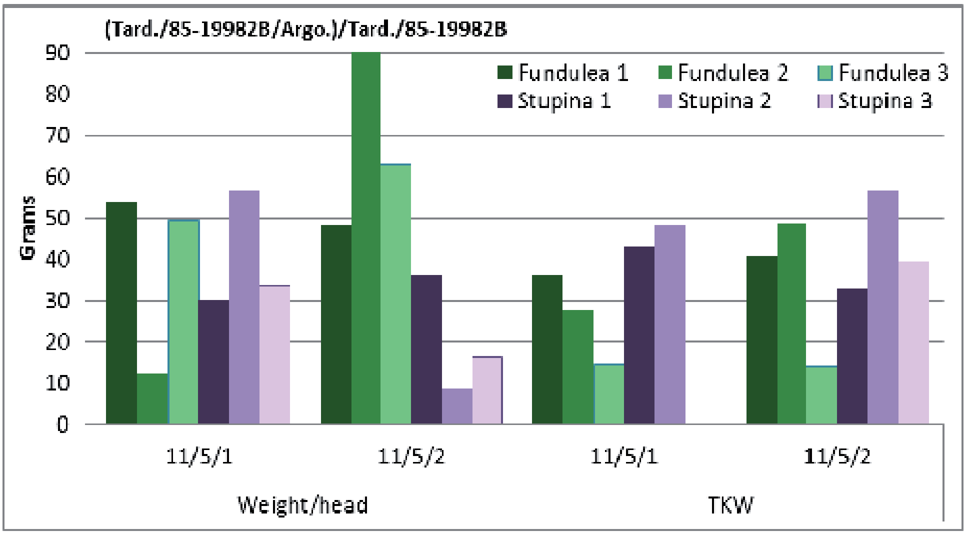

Figure 15. Average weight of head and TKW for the progenies of the progenies from backcross 7th generation of the 11/5/1 and 11/5/2 lines resulted from interspecific hybridisation between Tard./85-19982B and *Helianthus argophyllus*

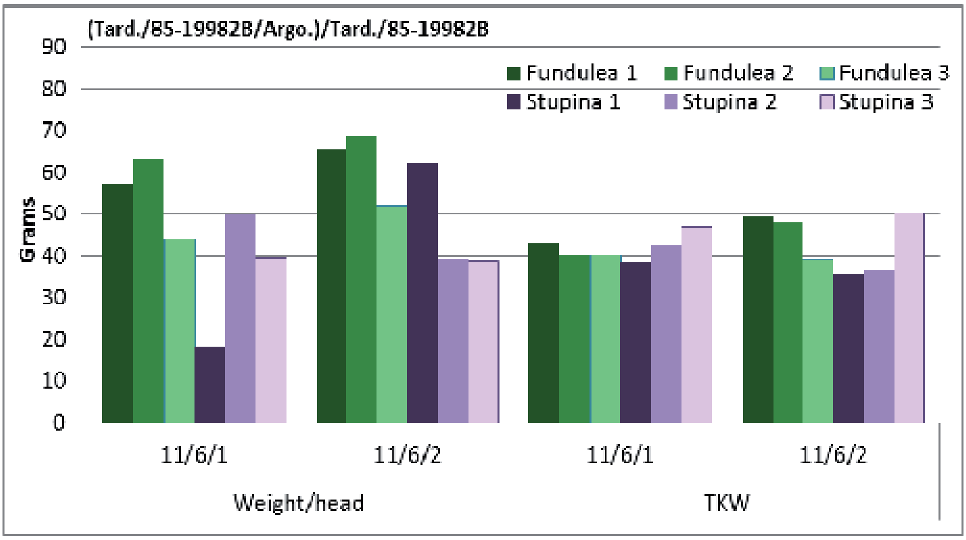

Figure 16. Average weight of head and TKW for the progenies of the progenies from backcross 7th generation of the 11/6/1 and 11/6/2 lines resulted from interspecific hybridisation between Tard./85-19982B and *Helianthus argophyllus*

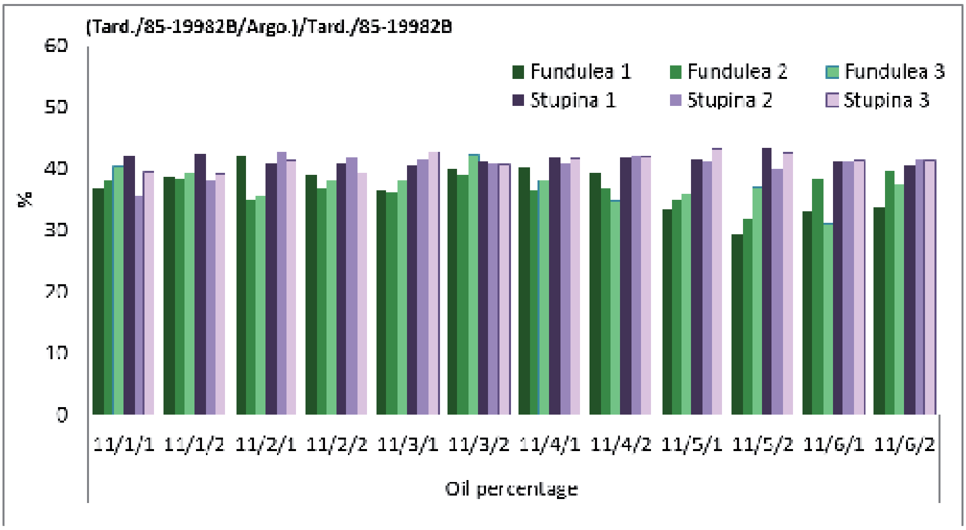

Figure 17. Oil content of the backcross 7th generation of sunflower lines obtained from interspecific hybridisation between Tard./85-19982B and *Helianthus argophyllus*

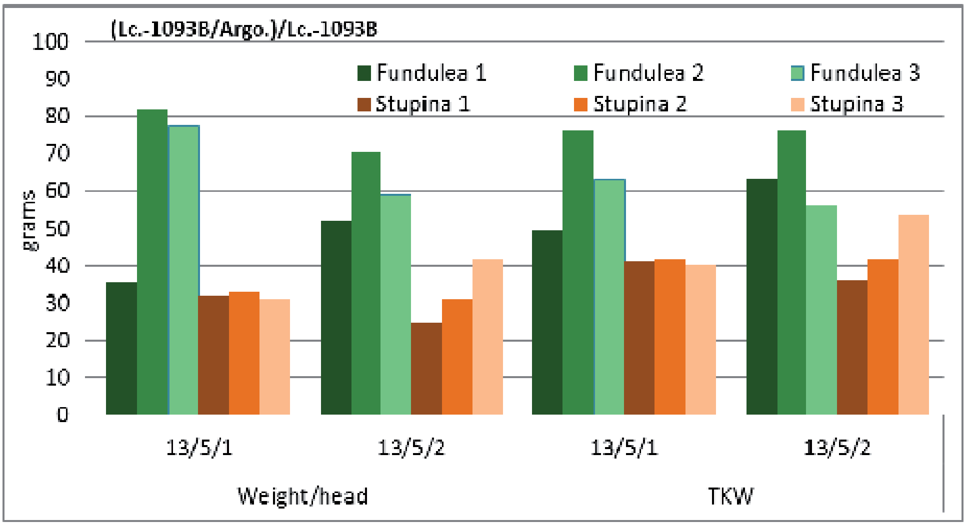

Figure 18. Average weight of head and TKW for the progenies of the progenies from backcross 7th generation of the 13/5/1 and 13/5/2 lines resulted from interspecific hybridisation between LC-1093 B and *Helianthus argophyllus*

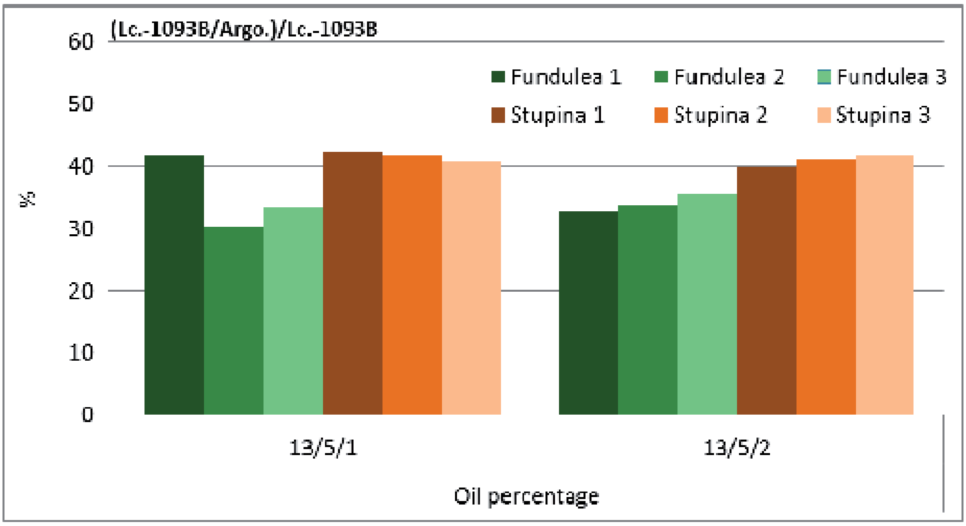

Figure 19. Oil content of the backcross 7th generation of sunflower lines obtained from interspecific hybridisation between LC-1093 B and *Helianthus argophyllus*

The inbred line 1093 B was considered by breeders as having a large ecological plasticity, and it is used in obtaining very valuable hybrids with resistance to plant diseases and *Orobanche*. In combination with *Argophyllus*, the results were spectacular. Even if the yield was very low under limited water conditions (Figure 17), the lines 13/5/1 and 13/5/2 proved a very good resistance to *Sclerotinia sclerotiorum* (at Fundulea) and bird atttack (at Stupina). It is necessary that at Stupina and under the agro-ecological management, there are enough tree windscreens were a lot of rooks and house sparrows are nesting and increasing very much their numbers. For the local farmers, these birds are source of damages not only for sunflowers but also for wheat and barley. This new line has the advantage that it is avoided by birds so even if the yield is low it is safe.

4. Conclusions

a. It is very important that together with the fulfillment of the main objective of the study (yield stability in water stress conditions in organic farming system), the results selection included achievements for biotic factors (resistance to *Sclerotinia* and *Orobanche*). Three genotypes with resistance to *Orobanche* in conditions of soil were identified, with a very high infestation with broomrape due to monoculture of sunflower for three years.

Under our experimental conditions, the genotypes with a longer vegetation period presented a better resistance to broomrape (Figures 20-21).

b. Some of the genotypes resulting from the interspecific hybridizations with *H. argophyllus* were not affect by the massive bird attacks from Stupina in 2014, when many farmers reported severe losses due to birds. This represents an important step in releasing sunflower hybrids with resistance or tolerance to this character (Figures 22-23).

c. In the conditions from Fundulea, in favorable year, a strong attack of *Sclerotinia sclerotiorum* was recorded, and this was a good opportunity to find among the tested combinations the reactions ranging from being tolerant to being sensible to this pathogen (Figures 24-25).

Figure 20. O-7493B X*Helianthus argophyllus* - genotype with sensitivity to *Orobanche cumana* and vegetation period of 115 days (Stupina location)

Figure 21. LC-1093 B X*Helianthuus argophyllus* - genotype resistant to *Orobanche Cumana* and vegetation period of 130 days (Stupina)

Figure 22. Tard/85 -19982B - genotype with seeds highly preferred by birds (Stupina)

Figure 23. Line 13/5/1 - genotype avoided by birds (Stupina)

Figure 24. Polet-11273B - obtained through hybridization backcross x androsterile line. Attack of *Sclerotinia sclerotiorum* on stem, Fundulea (2014).

Figure 25. LC 1093X - obtained through hybridization, with total resistance to *Sclerotinia sclerotiorum*, Fundulea (2014)

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Chapter 6

Biochar Technology for Sustainable Organic Farming

Suarau O. Oshunsanya and OrevaOghene Aliku

Additional information is available at the end of the chapter

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Abstract

The challenge of agricultural land depletion as a result of the pressure driven by the ever-growing population has brought about a renewed focus on the need for sustainable practices in agricultural production. Biochar is the solid carbonaceous product obtained when plant and/or animal biomass is subjected to pyrolysis. This chapter reviews the properties of biochar and its impacts when incorporated into the soil. Relative to its original organic form, this chapter iterates the benefits of biochar as a more sustainable organic approach towards improving agricultural soil qualities and hence crop yield due to its stability and duration in soils for hundreds of years. The impacts of biochar on soil physical, chemical and biological properties through the enhancement of soil nutrient and water-holding capacity, pH, bulk density and stimulation of soil microbial activities are by improving aggregation, porosity, surface area and habitat for soil microbes in biochar-amended soils. It is therefore recommended that biochar be used as soil amendment, especially to a degraded soil for a large and long-term carbon sink restoration.

Keywords: Biochar, Soil chemical properties, Soil water characteristics, Crop yield

1. Introduction

Throughout the world, intensive agriculture has often led to decline in soil physical, chemical and biological properties, leading to soil degradation. This decline in soil quality may be due to erosion and mining of nutrients and organic matter, hence preventing the soil from performing its functions such as regulating water flow, storing and cycling of nutrients, filtering, and transformation of organic and inorganic materials and sustaining biological productivity. However, considerably large amount of wastes such as crop residues, animal manure, etc. are being produced from many agricultural production systems. This organic waste may represent a considerable problem as well as new challenges and opportunities depending on how they are handled, which may determine whether there will be increase or decrease in biomass production, organic matter supply and decomposition rate.

In addressing the issue of decline in soil fertility, [1] reported that intentional and unintentional deposition of nutrient-rich materials on farmlands have in many cases led to an increase in soil fertility status. However, fresh residue materials have been reported to decompose until almost all carbon is lost [2]. This practice may not be sustainable when compared to the ever-growing human population per time. Thus, conversion of biomass to biochar could alter the transformation dynamics with respect to carbon sequestration. Soil carbon sequestration offers a large and long-term carbon sink to agricultural soils. Biochar is one of the sources of soil carbon sink, which could be obtained by subjecting biomass to pyrolysis. Pyrolysis is a process of combusting organic materials (biomass) under limited oxygen level [3].

Biochar as a soil amendment has become an important topic in soil science in the past few years, and the effects of biochar on agro-ecosystems are being studied by many researchers [4]. The conversion of biomass to bio-char as a carbon sink has been proposed before [5], but was not explicitly linked to an application to soil. As a soil amendment, biochar can greatly influence various soil properties and processes [6]. In fact, biochar may occur as a component of soil organic matter where slash-and-burn agriculture is widely practiced [7]. Many of the organic residues from agriculture, forestry and other production systems can be used to produce biochar and applied to agricultural soil both to sequester carbon and to improve the production potential of crops. This renewed focus in agriculture can be said to have started as a result of the discovery of the *Terra Preta de Indo* soils (Figure 1) located in the Amazon River Basin. From the assumptions surrounding the formation of the *Terra Preta* soils, agricultural scientists have come to believe that soil properties could be amended by applying biochar as an amendment [3]. Hence, biochar, the carbon-enriched, fine-grained product of biomass combusted under conditions of limited oxygen, is currently being widely studied for its effects as a soil amendment.

2. What is Biochar?

[8] defined biochar as a carbon-enriched, fine-grained and porous by-product of slow pyrolysis when organic material (feedstock) is thermally decomposed at low–moderate temperatures during long heating times under limited supply of oxygen. Feedstock may include wood materials, tree bark, crop residues, chicken litter, dairy manure or sewage sludge. Biochar is chemically and biologically more stable than the original fresh form from which it is produced due to its molecular configuration [9], making it more difficult to breakdown. This means that, in some cases, it can remain stable in soils for hundreds to thousands of years [10].

Source: [60]

Figure 1. Pictorial view of Latosol (left) and *Terra Preta* (right) soil horizon.

2.1. Properties of biochar

Biochars are characterized by certain morphological and chemical properties which are borne from the physico-chemical alteration of the original feedstock as a result of pyrolytic process. Characteristically, these properties of biochar differ since they are controlled by factors such as type of organic material from which they are made, pyrolysis conditions (i.e. final pyrolysis temperature or peak temperature, rate of heat application – slow or fast pyrolysis), rate and duration of charring [11,12,13]. The impact of biochar as an amendment depends on its properties. Key properties of biochar are the adsorptive properties that potentially alter soil's surface area, pore size distribution, bulk density, water-holding capacity and penetration resistance. Some physical properties of biochar determined by variations in feedstock type and pyrolysis condition are discussed below.

2.1.1. Large surface area and presence of micropores

Large surface area amendment property of biochar contributes to the adsorptive properties of soil and potentially improves pore size distribution, bulk density and consequently leading to an increase in the soil available water needed for crop growth and development. In addition, a strong direct relationship exists between a biochar's surface area and the pore volume as measured using N_2 adsorption and Braunauer-Emmett-Teller (BET) modelling [14,15]. [15] reported that the surface area could also be measured by using other compounds such as CO_2 on carbonaceous materials at the micrometer scale. [16] stated that understanding and determination of the relative abundance and stability of pores of different sizes are keys to soil ecosystem functioning. Important among these functions are aeration, hydrology and provision of habitat for microbes while the finer pores could be involved with molecular adsorption and transport [17].

Differences in production conditions, especially final combustion temperature, would result to variation in surface area of biochars even when they are produced from the same parent biomass. [16] stated that the relationship between the peak combustion temperature and surface morphological parameters (i.e. surface area, pore diameter and volume) of the resulting biochar is highly complex. [18] stated that there may be either no simple relationship between surface area and peak temperature, or surface area may increase with increase in peak temperature up to a certain threshold and then decrease. Due to variations in reports on surface area and peak temperature, [16] reported that the mechanisms responsible for increases in surface area with an increase in peak temperature or heating rate are not well understood. However, [11] reported that surface area increases with an increase in peak temperature of biochar production.

2.1.2. Adsorptive property

The adsorptive nature of biochar is related to its surface area. The adsorptive capability of biochar is determined by its surface chemical properties and porous nature. It is an important physical property due to its influence in the uptake and binding effect of materials from their surroundings [16]. [19] reported that biochar may adsorb poly aromatic compounds, poly aromatic and poly aliphatic hydrocarbons, other toxic chemicals, metals and elements or pollutants in soils, sediments, aerosols and water bodies.

2.1.3. Stability

This important physical property makes biochar a more sustainable soil amendment relative to its original fresh biomass for agricultural purpose. The evidence of high amounts of black carbon in the *Terra Preta* soils over a time suggests a high recalcitrant nature of biochar. However, degradation of at least some components (volatile matter or labile organic matter) of the biochar may occur [20]. On the other hand, [16] noted that the difference in sub-soil characteristics due to variations in microbial activity and oxygen content may affect biochar oxidation and aging. Biochar can move into sub-soil over time [21] to enrich the zone. Hence, other factors associated with its physical stability in soil include its mobility into deeper soil profile [16]. The aggregate stability of biochar-amended soil may also determine the susceptibility of biochars to microbial processes in subsoil. Mukherjee and Lal [16] explained that these factors not only enhance the stability of soil organic matter in the deeper profile but also improve availability of water and nutrients to crops and decrease erosion risks.

3. Restoring/improving soil properties

Biochar has the potential capacity to restore a degraded soil when added to the soil. Biochar mineralizes gradually over a long period of time when applied to the soil. Nutrients from biochar are released gradually to improve the physical, chemical and biological conditions of the soil. [12] reported that the impact of biochar as an amendment is a function of its properties such as large surface area and presence of micropores. These are key properties because they contribute to the adsorptive properties of soils and potentially alter soil physical and hydrological properties.

3.1. Biochar and soil properties

Figure 2 illustrates the interaction between biochar and soil. The application of biochar to the soil will alter the physical and chemical properties of the soil. [22] stated that the net effect of biochar on the soil physical properties will depend on its interaction the physico-chemical characteristics of the soil, the weather conditions prevalent at the particular site and the management of its application. Biochar application can reduce the bulk density of the different soils [23]. This could bring about improvement in soil structure or aggregation, and aeration enhancement, thus improving soil porosity. [17] reported that the higher the total porosity (micro- and macropores) the higher is soil physical quality. This is because micropores are involved in molecular adsorption and transport of water and nutrients while macropores affect aeration and drainage. Several studies have reported that as low as 0.5% (g g^{-1}) biochar application rate was sufficient to improve water-holding capacity and water retention [24,25]. Hence, this can be said to be good water-holding capacity amendment for sandy soils which are highly porous due to the preponderance of macropores.

3.2. Effect of biochar application on some soil physical properties

A key determinant of soil functions and processes is its physical properties, precisely and most importantly, its texture. Hence, the addition of biochar in soils with different textures should affect the soil hydraulic properties differently due to the fact that there is a correlation between soil texture and soil hydraulic properties. The impacts of biochar as a soil amendment on some soil physical and hydrological properties are briefly discussed below.

3.2.1. Soil surface area

Table 1 depicts a summary of results of biochar application on surface area. Soil surface area is an intrinsic property of soil determined by the sizes of its particles. The surface area of soils

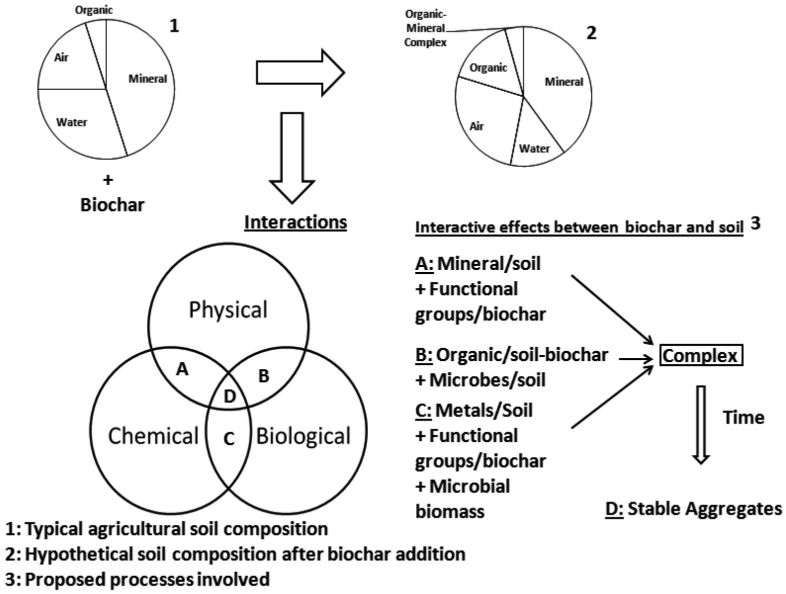

Figure 2. Schematic representation of interactions between biochar and soil [16].

is an important physical characteristic which plays a vital role in water- and nutrient-holding capacities, aeration and microbial activities [26]; hence, it can be said to be partly controlling the essential functions of soil fertility. However, the effectiveness of the surface area of a soil depends on its size – the larger the surface area, the greater the soil's water- and nutrient-holding capacities. This is particularly true for fine-textured soils. Thus, [16] reported that agronomic productivity improvement of biochar-amended soils may be linked to the higher surface area of the biochar–soil mixtures. [17,27,28] explained that the high surface area of biochar provides the space for formation of bonds and complexes with cations and anions with metals and elements of soil on its surface, which improves the nutrient retention capacity of soil. [28] reported that biochar incorporation can enhance specific surface area up to 4.8 times that of adjacent soils. [29] also reported increases in specific surface area of an amended clayey soil from 130 to 150 m^2 g^{-1} when biochar derived from mixed hardwoods was applied at rates of 0 to 20 g kg^{-1} in a long-term soil column incubation study.

3.2.2. Porosity

Table 1 shows a summary of results of biochar application on soil porosity. This is the ratio of the pore volume to the total volume of a representative sample of a porous medium. This factor is said to be associated with surface area. The total porosity or pore size distribution of biochar is a factor that can play an important role in the alteration of the properties of biochar-amended soils. Biochars are usually characterized by the preponderance of micropores, which may alter the pore size distribution of coarse texture soil when added. [24] reported that significant increases in mesoporosity occurred at the expense of macropores in waste-derived biochar-amended soil compared to the control. [24] further intensified that the higher the rate of biochar application the greater its effect on porosity. Hence, biochar could be a good replacement for tillage practices which causes short-term increase in porosity, but long-term decrease in aggregation and ultimately lowering soil porosity.

Soil type	Biochar type	Study type (scale)	Rate of biochar application `	SA	Porosity	Reference
			(g g^{-1})	(m^2 g^{-1})	(%)	
Residue sand	Municipal green waste, 450°C	Laboratory	0	-	0.46	[24]
			2.6	-	0.48	
			5.2	-	0.51	
Clarion fine loamy	Mixed hardwoods (Oak: *Quercus* spp., Hickory: *Carya* spp.), 500°C	Laboratory	0	130	-	[29]
			0.5	133	-	
			1.0	138	-	
			2.0	153	-	
Sandy soil	Jarrah woods (*Eucalyptus marginata*), 600°C	Greenhouse	0	1.3	56.1	[61]
			0.45	2.7	57.6	
			2.27	8.4	62.1	
Silt loam	Birch (*Betula pendula*), 400°C	Field	0	-	50.9	[62]
			1.2	-	52.8	

Table 1. Impact of biochar on Surface area (SA) and porosity of amended soils

3.2.3. Bulk density

Table 2 shows the results of biochar application on soil bulk density. Bulk density, which is defined as the mass of soil per its unit volume, has been known to have a negative correlation with surface area. [30] stated that well-structured soils (fine texture) are characterized by low bulk density values between 1.0 and 1.3 g cm^{-3} while poorly structured (coarse texture) soils are known to have high bulk density values between 1.6 and 1.8 g cm^{-3}. Hence, reports from both field and laboratory studies have shown bulk densities to have contrasting results to surface areas of biochar-amended soils. [29], [24] and [23] reported that application of biochar can decrease the bulk density of soils. [29] showed in a soil column incubation study that biochar-amended soil columns had significantly lower bulk density than no-biochar controls. [16] reported that biochar-amended column had a lower rate of compaction compared to the control or manure-amended soil columns when all the columns were subjected to compaction by gravity and periodical leaching events. They further stated that the decrease in bulk density of biochar-amended soil could be one of the indicators of the improvement of soil structure or aggregation and aeration, and could be soil-specific.

Soil types	Biochar type	Study type (scale)	Rate of biochar application	Bulk density	Reference
			% (g g^{-1})	g cm^{-3}	
Norfolk loamy sand: E	Pecan (*Carya illinoinensis*) shells, 700°C	Laboratory	0	1.52	[32]
			2.1	1.45^1, 1.52^2	
Norfolk loamy sand: E and Bt			0	1.34	
			2.1	1.36^1, 1.34^2	
Hydroagric stagnic anthrosol	Wheat (*Triticum* spp.) straw, 350–550°C	Field	0	0.99, 0.94^3	[63]
			1.1	0.96, 0.91^3	
			2.2	0.91, 0.86^3	
			4.4	0.89, 0.88^3	
Residue sand	Municipal green waste , 450°C	Laboratory	0	1.65	[24]
			2.6	1.55	
			5.2	1.44	
Clarion fine loamy	Mixed hardwoods, 500°C	Laboratory	0	1.21, 1.34^4	[29]
			0.5	1.10, 1.24^4	
			1.0	1.08, 1.24^4	
			2.0	1.08, 1.24^4	

Source: [16]. ^{1} measured after 44 days; ^{2} measured after 94 days; ^{3} measured after 1 year; ^{4} measured after 15 months.

Table 2. Soil bulk density as affected by biochar application

3.2.4. *Aggregate stability*

Results of studies showing biochar effect on soil aggregation are illustrated in Table 3. Studies have shown biochar to respond positively to aggregation. Though [16] reported that data on aggregate stability and penetration resistance of biochar-amended soils are scarce, a few studies generally showed that low-temperature (220°C) hydrochar made from spent brewer's grains (a residue from beer brewing) responded positively to aggregation of Albic Luvisol by significantly increasing water-stable aggregates as compared to the control treatment. [31] have reported that the formation of complexes of biochar with minerals, as the result of interactions between oxidized carboxylic acid groups at the surface of biochar particles, should be responsible for the improved soil aggregate stability (Figure 2). As a result, soil aggregates and pore size distribution can be improved by adding organic matter from biodegradation and thus improving soil hydraulic properties. However, other authors have reported contrasting results. For instance, [32] reported that with or without mixing Bt and E horizons with pecan shell (*Carya illinoinensis*), biochar-amended soil decreased aggregation compared to the control, while [33] reported mixing of biochar from pecan with switchgrass increased aggregation, but the effect was however significantly lower when the soil was treated only with biochar without mixing with switchgrass. From this trend of results, [16] concluded that a positive effect on soil aggregate stability would require the presence of a substrate (i.e switchgrass) along with biochar as an amendment.

3.2.5. Penetration resistance

Studies on the effect of biochar amendment on soil penetration resistance are illustrated in Table 3. Penetration resistance measures the capacity of a soil in its confined state to resist penetration by a rigid object [34]. It is affected by moisture content. Thus, it affects the potential for root growth and development. Ehlers et al. [35] found root growth to be inversely related to penetration resistance. Results from literatures have shown that the effect of biochar application on soil penetration resistance is dependent on time of application. Busscher et al. [32] reported that mixing Norfolk loamy sand E and E and Bt layers with pecan shell biochar produced at a temperature of 700°C increased penetration resistance measured after 44 days of application. Penetration resistance was, however, reduced when measured after 96 days of application. Thus, soil compaction may not be alleviated by biochar addition over short period of time, but may be altered in the long run due to changes in properties as a result of aging of biochar.

Soil types	**Biochar type**	**Study type (Scale)**	**Rate of biochar application**	**Aggregation**	**Penetration resistance**	**Reference**
			% (g g^{-1})	%	MPa	
Norfolk loamy sand: E	Pecan shells, 700°C	Laboratory	0	14.3	1.19[1], 0.80[2]	[32]
			2.1	12.9	1.27[1], 0.88[2]	
Norfolk loamy sand: E and Bt			0	27.3	0.71[1], 0.76[2]	
			2.1	20.9	0.88[1], 0.94[2]	
Norfolk loamy sand: Ap	Pecan shells, 700°C	Laboratory	0	9.95, 13.0*	1.04[1], 1.1[2]	[33]
			0.5	9.53, 12.7*	0.96[1], 1.15[2]	
			1.0	10.7, 12.3*	1.03[1], 1.02[2]	

Soil types	Biochar type	Study type (Scale)	Rate of biochar application	Aggregation	Penetration resistance	Reference
			2.0	9.23, 11.8^{*}	0.82^{1}, 0.87^{2}	
Albic Luvisol	Hydrochar, 220°C	Laboratory	0	49.8	-	[64]
			5	69.0	-	
			10	65.1	-	
		Greenhouse	0	10.3	-	
			5	20.8	-	
			10	33.8	-	

Table 3. Soil aggregation and penetration resistance as affected by biochar application

3.3. Hydrological properties

Several authors have reported positive response of soil hydrological properties to biochar amendment. This may be due to the fact that soil hydrological properties such as infiltration rate, moisture content, hydraulic conductivity, water-holding capacity and water retention are invariably related to soil surface area, bulk density, porosity and aggregate stability [16]. In other words, an alteration in these soil physical properties as caused by biochar application would lead to a change in soil hydrological properties.

3.3.1. Water-holding capacity, water retention and moisture content

Table 4 shows the results of biochar application effect on water-holding capacity. The amount of water in a soil is a function of its ability to hold and retain water for plant use against the influence of gravity. Fine-textured soils would have higher moisture content at the same tension as soils with coarse particles. This is because the ability of a soil to retain water is a function of the micropores in the soil, which is usually lower in coarse-textured soils. Hence, moisture required by plants to upset the evapotranspirational demand of the atmosphere may be limiting, especially in coarse-textured soils. Thus, application of biochar can increase water-storage ability of coarse-textured soils. Several studies have reported alterations in water-holding capacity and water retention in soils amended with biochar. [33] and [36] reported that 0.5% ($g\ g^{-1}$) biochar application rate was sufficient to improve water-holding capacity. Application of biochar produced from black locust (*Robinia pseudoacacia*) was reported to increase the available water capacity by 97%, saturation water content by 56%, but reduced hydraulic conductivity [25]. This can also influence soil aeration and temperature to a very large extent. [29] reported that results from a long-term column study indicated that biochar-amended Clarion soil retained up to 15% more water, with 13% and 10% more water retention at –100 KPa and –500 KPa soil matric potential, respectively, compared to control (unamended soils). [37] showed that coal-derived humic acid substances can increase water retention, available water capacity and aggregate stability of inherently degraded soils. [38] reported that biochar application increased the available water capacity in sandy soil, with no effect on a loamy soil, and decreased moisture content in a clayey soil. [16] suggested that such response may be due to the hydrophobic nature of the charcoal that caused alterations in soil pore size distribution. [38], therefore, advised that because the soil moisture retention may only be improved in coarse-textured soils, a careful choice of biochar/soil combination needs to be taken into consideration.

Soil types	Biochar type	Study type (Scale)	Rate of biochar application	Water holding capacity	Reference
			% (g g^{-1})	(g cm^{-3})	
Residue sand	Municipal green waste, 450°C	Laboratory	0	0.11	[24]
			2.6	0.16	
			5.2	0.20	
Norfolk loamy sand: Ap	Pecan shells, 700°C	Laboratory	0	0.64	[33]
			0.5	0.59	
			1.0	0.60	
			2.0	0.66	
Sandy loam	Ponderosa pine (*Pinus ponderosa*), 450°C	Laboratory	0	11.9	[36]
			0.5	12.4	
			1.0	13.0	
			5.0	18.8	
Silt loam	Birch, 400°C	Field	0	0.49	[62]
			1.2	0.54	

Table 4. Soil water holding capacity as affected by biochar application

3.4. Biochar and soil chemical properties

Most studies of biochar as a soil amendment have focused majorly on soil nutrient status, taking into consideration cation exchange capacity, nutrient content, pH, the carbon sequestration potential of the amended soil, and vegetative growth and yield of crops. Biochar has the potential to improve soil CEC due to the fact that it is often characterized by high CEC values, due to its negative surface charges and its high specific surface area as was reported for biochar produced from crop residues [39].

Furthermore, the immediate beneficial effect of biochar application on crop productivity in tropical soils may result from increase in availability of nitrogen, phosphorus, potassium, calcium, copper and zinc as reported for soils amended with secondary forest biochar [40]. Also, poultry litter biochar may result in strong increase in soil extractable phosphorus [41] when incorporated into the soil. In evaluating the effect of different biochars on soil chemical properties, [42] reported that biochar produced from poultry manure had higher electrical conductivity, nitrogen, phosphorus and pH values than that of garden waste. However, this may be due to their effects in reducing leaching and fixation of nutrients as moderate biochar additions are not a direct supplier of plant nutrients in the long-term.

3.5. Effects of biochar application on Soil Organic Carbon (SOC)

Biochar application can directly or indirectly affect SOC dynamics. Indirectly, biochar could affect net primary production and, thus, the amount of biomass that may remain in agro-ecosystems. This would result to alteration in soil carbon inputs. [8] stated that higher below-ground net primary production and increased root-derived carbon inputs after biochar application may particularly result in an increase in SOC.

Directly, biochar can inhibit degradation process, and as a result increase the mean residence time (MRT) of SOC (i.e. the mean time that a SOC-carbon atom spends in soil). As a direct consequence, biochar application would enhance SOC stabilization processes and contribute to SOC sequestration. The MRT of biochar-carbon is thought by some to be in the range of millennia [43]. However, information on biochar longevity in soil is meagre and varies between biochars and sites. For example, the MRTs of biochar in field experiments ranged from about 8 years for biochar produced by burning of forest trees during slash-and-burn agricultural practices [44] to 3,600 years for biochar produced from prunings of old mango (*Mangifera indica* L.) trees [45]. Also, biochar longevity in soil may be affected by differences in climatic conditions. For example, chemical and/or biological mineralization of natural chars produced from wood during bushfires was slower under Mediterranean climate when compared to temperate climates in Australia [46].

3.6. Liming effect

Biochar can be said to be acidic or alkaline in nature depending on the temperature of the materials used during pyrolysis. [47] explained that the acid functional group concentration in biochars produced from the biomass of rice, valley oak (*Quercus lobata Ne´ e*), etc decreased with increasing peak pyrolysis temperature as more fused aromatic ring structures were produced and more volatile matter was lost. The effectiveness of both types will depend on the pH of the soil to be amended. [48] stated that the alkaline biochars produced at higher pyrolysis temperature are more effective in supporting increases in biomass by improved growth conditions than acidic biochars presumably through increases in soil alkalinity. [49] stated that the moderation in aluminium toxicity may be the reason why biochar application has positive effects on productivity in tropical and irrigated systems on highly weathered and acid soils with low-activity clays. This is because the reduction of aluminium and iron concentrations in the soil solution will enhance the availability of previously bound phosphorus to plants, and plant roots would be able to explore even acid soils to absorb nutrients and water more effectively.

3.7. Effect of biochar on soil microorganisms

Studies have shown higher microbial biomass but yet lower microbial activity in biochar-amended soil than the neighbouring soils [50]. However, most studies have focused on biochar interaction with mycorrhizal fungi [50]. Specifically, biochar has been reported to have symbiotic relationship with the mycorrhizal system. According to [51], the four mechanisms by which biochar could improve mycorrhizal abundance (40%) and functioning are listed as follows:

i. Alteration of soil physico-chemical properties,

ii. Indirect effects on mycorrhizae through effects on other soil microbes,

iii. Plant-fungus signalling interference, and

iv. Detoxification of allelochemicals on biochar.

[52] noted 50% to 72% increase in soil biological nitrogen fixation through biochar application. [53] have hypothesized both bacteria and fungi to be better protected from grazers or competitors by exploring pore habitats in biochars. This is because biochar provides microbial habitat and refugia for microbes where they are also protected from unfavourable conditions.

3.8. Effect of biochar on crop yield

The summary of experiments assessing the impact of biochar addition on crop yield is showed in Table 5. From the agricultural perspective, the summary of the effect of biochar in regulating soil hydrological, physical and chemical properties results to improved soil productivity and consequently increased crop yield. However, the effect of biochar on soil health as well as crop productivity can be influenced by the forms (dust, fine particles, coarse grain) and the methods of application (surface application, top dressing, drilling) of biochar to soil. [54] clearly explained that even small quantities of biochar added to seed coatings may in some cases be sufficient for a beneficial effect.

[40] reported increasing crop yields with increasing biochar applications of up to 140 t carbon ha^{-1} on highly weathered soils in the humid tropics. Also, [55] found that the biomass growth of beans rose with biochar applications up to 60 t carbon ha^{-1}. Furthermore, scientists have reported that application of biochar on soil has significant effect on net primary crop production, grain yield and dry matter production [56,57,58,59].

Author	**Study outline**	**Results summary**
[65]	Cowpea on xanthic ferralsol	Char at 67 t/ha increased biomass by 150% Char at 135 t/ha increased biomass by 200%

Author	Study outline	Results summary
[40]	Soil fertility and nutrient retention. Cowpea was planted in pots and rice crops in lysimeters, Brazil	Biochar additions significantly increased biomass production by 38% to 45% (no yield reported)
[66]	Comparison of maize yields between disused charcoal production sites and adjacent fields, Ghana	Grain and biomass yield was 91% and 44% higher on charcoal site than control
[67]	Maize, cowpea and peanut trial in area of low soil fertility	*Acacia* bark charcoal plus fertilizer increased maize and peanut yields (but not cowpea)
[42]	Pot trial on radish yield in heavy soil using commercial green waste biochar (three rates) with and without nitrogen	Biochar at 100 t/ha increased yield ×3; linear increase 10 to 50 t/ha, but no effect without added nitrogen

Source: [16].

Table 5. Summary of experiments assessing the impact of biochar addition on crop yield

4. Conclusion

Biochar, as an amendment on soil physical, chemical and biological properties, depends on environmental conditions, dynamic properties of soils, biochar properties which are a function of the organic materials and conditions used for biochar production and the rate and method of application.

Notable soil physical properties found to be enhanced by biochar include soil surface area, bulk density, porosity, aggregate stability, penetration resistance and moisture content. Also, soil pH, organic carbon and cation exchange capacity were enhanced in biochar-amended soils. Biologically, mycorrhizal abundance, biological nitrogen fixation, microbial biomass and microbial habitats were improved in biochar-amended soils compared to unamended soils.

Modification of soil physical, chemical and biological properties by biochar application resulted to improved plant nutrient retention, acquisition and availability, leading to improved biomass growth, dry matter production and crop yields.

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Chapter 7

Role of Organic Sources of Nutrients in Rice (*Oryza sativa*) Based on High Value Cropping Sequence

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Additional information is available at the end of the chapter

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Abstract

The organic nitrogen (N) nutrition of organic manuring with biofertilizers had the highest rice equivalent grain yield, production efficiency, net energy return, as well as net monetary return and profitability in rice-based cropping sequence. The different rice-based cropping sequences did not differ with respect to yield and quality parameters. However, the organic N nutrition with organic manures along with biofertilizers proved significantly superior with respect to yield and quality parameters of rice, potato, and onion, respectively. The different rice-based cropping sequences differ with respect to nutrient uptake, e.g., rice-maize-onion had the highest removal of major (N, P, K), secondary (S), and micronutrients (Zn, Fe, Mn, Cu) than the rest of cropping sequence, which was significantly superior to the rest of the sequences. The organic N nutrition with organic manures along with biofertilizers proved superior due to its visible favorable effect on soil health with respect to nutrient status and microbial count and this indicates the utilization of this low-cost but long-term beneficial practice under high-intensity cropping for sustainable crop production.

Keywords: Biofertilizers, organic farming, high value crops, cropping sequence

1. Introduction

Organic farming is a production system that avoids or largely excludes the use of synthetic fertilizers, pesticides, growth regulators, and livestock feed additives. The objectives of environmental, social, and economic sustainability are the basics of organic farming.

The maintenance of good soil fertility is essential for sustainable crop production, which requires the regular use of organic sources of nutrient-like organic manure and biofertilizers to keep the farm income higher of the farming community. Organic agriculture is a holistic production management system, which promotes sustainable agriculture and enhances agro ecosystem health, including biodiversity, biological cycle, and soil biological activity. The organic farming practices on scientific principles are as productive as the conventional system. Organic systems showed greater soil health benefits reduced cost on production, are found better than inorganic practices, and enhanced profit margin with quality food. Interestingly, while exports of organic commodity are growing, domestic market demand is galloping for high-value crop produce, supports from government are increasing and innovation system support has started to grow. In such situation, it is necessary to develop suitable technology for meeting the challenges of the coming generation by providing good quality produce without deteriorating the socio-economic conditions of the farmer and with minimum environmental pollution. The farmers of ancient India adhered to the natural laws and this helped in maintaining the soil fertility over a relatively longer period of time [1]. These organic sources, besides supplying N, P, K, also make unavailable sources of elemental nitrogen, bound phosphates, micronutrients, and decomposed plant residues into available form in order to facilitate the plants to absorb the nutrients. Organic cultivation practices are very effective to improve the population of beneficial microorganisms in the soil having direct effect on enhancing the availability of macronutrients and micronutrients through correcting the deficiency induced by the conventional practices with the application of synthetic fertilizers, and consequently capable of sustaining high crop productivity and soil biological properties by modification of the soil environment [2].

The farmers can in turn, get good remuneration from the organically produced crops and vegetables if included in high-value crop sequences, e.g., aromatic rice–table pea and onion [3] due to their heavy demands in domestic, national, as well as international markets that may help the country in earning some foreign exchange. Therefore, a book chapter entitled “Role of organic sources of nutrient in rice (*Oryza sativa*) based on high value cropping sequence” was planned and executed with the following objectives:

1. To identify potential high-value cropping sequence suitable for irrigated ecosystem;
2. To study the effect of organic nitrogen sources on yield and quality of crop produce;
3. To study the effect of organic nitrogen sources on nutrient acquisition by the sequence.

2. Experimental details

2.1. Treatment details

2.1.1. Main plot: Cropping sequences (7)

- Sequence-1: Rice-Potato-Onion
- Sequence-2: Rice-Green Pea-Onion
- Sequence-3: Rice-Potato-Cowpea (Green Pod)
- Sequence-4: Rice- Green Pea -Cowpea (Green Pod)

- Sequence-5: Rice-Rajmash (Green Pod)-Onion
- Sequence-6: Rice-Rajmash (Green Pod)-Cowpea (Green Pod)
- Sequence-7: Rice-Maize (Green Cob)-Cowpea (Vegetable)

2.1.2. Sub plot: Manurial treatments (3)

- Control (without organic manures)
- 100% RDN through organic manures as 1/3 FYM + 1/3 Poultry Manure (PM) + 1/3 Vermicompost
- 100% RDN through organic manures as 1/3 FYM + 1/3 Poultry Manure (PM) + 1/3 Vermicompost + Azotobacter + PSB

Crop	Variety	Seed rate (kg ha^{-1})	Spacing (cm)
Rainy season			
Rice	HUBR 2-1	40 kg	20 x 15
Winter season			
Maize (Green Cob)	Pioneer Hybrid	20 kg	60 x 20
Green Pea	Early Apoorva	80 kg	30 x 10
Rajmash	HUR-137	80 kg	30 x 10
Potato	Kufri Badshah	2,000 kg	50 x 25
Summer season			
Onion	Agrifound Light Red	10 kg	20 x 15
Cowpea	Tokito Hybrid	10 kg	50 x 20

Table 1. Details of the variety of hybrid seed rate and spacing of different crops.

3. Rainy season (rice)

3.1. Field preparations

Proper field preparation and timely planting are essential for good crop yield. These factors influence the soil's physical property, particularly soil moisture, aeration, and plant nutrient availability. With a view to have good experimental unit for planting, initial ploughing was done by a soil turning plough followed by disking. The seed beds were properly prepared as per crop requirements before planting various crops.

3.2. Raising rice nursery

A well-drained fertile land having good irrigation facility was selected for raising rice seedlings. The nursery plot was ploughed twice and puddled in standing water to convert the upper layer of soil into fine soft mud. The field was leveled properly and 10 x 1.5 m^2 beds were prepared. A requisite amount of 36 kg organic manure was applied to each nursery of 15 m^2. Healthy, genuine, certified, and sprouted seeds at 40 kg per ha were properly spread, keeping a thin water film for a week. The seedbed was irrigated to maintain shallow, submerged rice.

3.3. Field preparation for transplanting

Proper field preparation is essential for a healthy rice crop. The experimental area was ploughed with a tractor during the summer and ploughed twice again before rice transplanting. Thereafter, the field was puddled with the cultivator. Finally, the field was laid out to meet the requirements of the experimental design. The field was puddled thoroughly, and four-week-old seedlings were transplanted at 3 seedlings per hill in rows 20 cm apart with hill to hill distance of 10 cm. As per treatment, full recommended doses of all the manures were applied just before transplanting. Irrigations were given to the crop at 16, 30, 18, and 32 DAT during the two years of experimentation. Two hand weedings were done at 26 and 65 DAT during both the years of experimentation. Except minor appearances of gundhi bugs, no major pests or diseases appeared. Hence, even bio-insecticides were not used due to the negligible impact of the gundhi bugs. Rice plants were harvested at physiological maturity of the crop after 108 DAT during the first and 109 DAT in the second year of experimentation. First of all, the border rows were harvested, bundled, and removed from the plots. Thereafter, the experimental rows from the net plot area were harvested. Plot wise harvested materials were carefully bundled, tagged, and taken to the threshing floor. Each bundle was weighed after complete sun drying and threshing. The grain yield was recorded separately after winnowing and cleaning. The straw yields was calculated by subtracting grain yield from the bundle weight and were converted to kg per ha based on net plot size harvest.

3.4. Biometric observations of rice

For recording biometric observations at different stages of crop growth, four hills in the net plot area were randomly selected and tagged. However, for the dry matter production, four hills were randomly selected from the sample rows (border rows) at different growth stages. The plants were then tagged and brought to the laboratory for the study. Four biometric observations were recorded at 30 DAT (tillering stage), 60 DAT (late jointing stage) and at harvest during both years. The plant samples collected randomly from the border row of the field were kept in an oven at 60°C till the constant weight arrived for determining the dry matter production per unit area. The panicle-bearing tillers were counted from the one square meter marked area after full anthesis. Ten panicles were randomly selected from tagged plants and the length was measured from the neck node to the tip of the upper most spikelet and average length was recorded. Ten randomly selected panicles were weighed and averaged to record per panicle weight. The filled grain of each of the ten panicles from each plot were counted and averaged. Grain samples were taken from the threshed and cleaned produce of each net plot and 1,000 grains were counted and weighed. Grain yield was recorded (kg $plot^{-1}$) after threshing, winnowing, cleaning, and drying. Thereafter, it was computed to kg per ha.

The difference of the bundle weight and grain yield gave the straw yield (kg plot^{-1}). Thereafter, it was computed to kg per ha.

4. Winter season

4.1. Field preparation

During the winter season, potato, green pea, rajmash, and maize are grown. The following packages of practices were adopted for these crops. Field preparation operations were common for all the *rabi* season crops. As a general rule, these crops require a well pulverized but compact seedbed for good and uniform germination. To avoid the mixing of soil under treatments, the individual plot was ploughed thrice by power tiller at proper tilth and finally the planking was done.

4.2. Weed management

During both years of experimentation, the weeding was done using a hand rotary weeder during the beginning of the first appearance of a thick flush of weed, e.g., 25 days after sowing followed by a second weeding at 45–50 days after sowing. The first weeding was done after recording observations for weed flora. However, to the wheat crop, only one weeding was given.

4.3. Irrigation

In both years of the experiment, irrigation was given according to the requirements of the different crops as per the schedule. In all, one irrigation was given to lentil, pea, and chickpea, two irrigations to mustard, three irrigations to potato and wheat, and as much as four irrigations was given to maize. Only minor appearances of pests or diseases occurred. Hence, even bio-insecticides were not used due to the negligible impact of the insect pests and diseases.

4.4. Harvesting

In general, all the crops were harvested by serrated edge sickle manually at the maturity of the respective crops. However, in case of potatoes, tubers were dug out at maturity. In green peas, two to three pickings of green pods were done; whereas, the green cobs of maize were harvested at the milky stage of the grains. Haulms of pea and maize stover were used as cattle fodder. In all the crops, the border rows and 0.5 m either side of plot rows were harvested and removed around the individual plots leaving only the net plot area. The harvesting of each net plot area was done separately and the harvested material from each plot was carefully bundled, tagged, and taken to the threshing floor and kept individually for sun drying.

4.5. Threshing

Each bundle was weighed after proper sun drying and then threshed individually. The grain/seed/pod/tuber yield of different crops were weighed and recorded separately after winnowing and cleaning. The straw stover yield were calculated/recorded separately and converted to q ha^{-1} based on the net plot size harvest.

5. Summer season

5.1. Field preparation

Onions and cowpeas were taken during summer season in different cropping sequences. Field preparatory operations were common for all summer season crops. After the harvesting of winter season crops in different sequences, pre-sown irrigation was given and individual plots were tilled thrice with a power tiller at proper tilth and finally planking was done.

5.2. Raising of onion seedling

Seeds of Agrifound light red variety were used. The seeds used for the nursery had more than 80% germination. The nursery beds (4 m x 2.6 m) were prepared carefully by incorporating sufficient quantity of well-rotten farm yard manure (20 kg bed^{-1}). Seeds were sown on the bed at 52 g per bed. After sowing, beds were given light and frequent water application through a water cane at the beginning to maintain moisture for seedling growth. Two light irrigations were also given at sowing and 10 DAS to maintain the growth of a thin layer of FYM was given to cover the seeds. The beds were covered with a thin layer of paddy straw on the same day to maintain congenial moisture and temperature condition. The paddy straw was removed after seed germination (10 DAS). Seedlings were transplanted at 60 DAS on 26.02.04 during the first year and 20.02.05 during the second year. However, cowpea seeds were treated with *Rhizobium* culture to improve the nitrogen fixation capacity before sowing the crop. Details of crop varieties used, seed rate, and spacing are given in Table 1.

5.3. Weed management

During both years of the experimentation, one weeding was done in the inter-row spaces by hand rotary weeder at 20 days after sowing and the weeds on the crop rows were removed manually.

6. Qualitative character of rice-based cropping sequence

6.1. Hulling of rice (%)

Two hundred grams of rice grains after threshing, winnowing, cleaning, and drying were taken for dehusking, and the brown rice thus obtained was weighed and then hulling (%) was calculated by the following formula:

$$\text{Hulling}\,(\%) = \frac{\text{Brown rice obtained after threshing (g)}}{\text{Total rice grain taken for dehusking (g)}} \times 100$$

6.2. Milling of rice (%)

One hundred grams of brown rice obtained after hulling was taken and kept for polishing by removing rice bran, embryo, and alurone layer and polished white kernels were thus obtained using the following formula:

$$\text{Milling}\,(\%) = \frac{\text{White polished kernels obtained (g)}}{\text{Brown rice taken for polished (g)}} \times 100$$

6.3. Head rice recovery (%)

Total white polished rice obtained after milling was taken and whole white kernels were separated, weighed and the percentage was calculated using the formula:

$$\text{Head Rice Recovery}\,(\%) = \frac{\text{Whole white kernels obtained (g)}}{\text{White polished kernels obtained after milling (g)}} \times 100$$

6.4. Shelling of maize (%)

Five randomly selected cobs were weighed and grains were separated and weighed. The shelling percentage was calculated by using the following formula:

$$\text{Shelling}\,(\%) = \frac{\text{Weight of kernels per cob (g)}}{\text{Weight of cob (g)}} \times 100$$

6.5. Protein content of each crop (%)

The protein content (%) in the grains was worked by multiplying the nitrogen content in grain by the factor 6.25 (A. O. A. C., 1960).

6.6. Protein yield

The protein yield (kg ha^{-1}) was obtained by the following formula:

$$\text{Protein Yield (kg/ha)} = \frac{\text{Protein content per cent } \times \text{Yield (kg/ha)}}{100}$$

6.7. Starch content of potato (%)

It was extracted and determined according to Carillo et al (2005).

Pungency estimation of allyl-propyl-disulphide onion: Allyl-propyl-disulphide content in the onion bulb was determined as Pyruvic acid (Hort and Fisher, 1970) using the following relationships:

$$\text{Pyruvate content}=\frac{\begin{array}{c}\text{Pyruvate content from}\\ \text{standard curve }(\mu\text{ mol})\end{array}}{\begin{array}{c}\text{Alliquat of test control solution}\\ \text{taken color development }(\text{ml})\end{array}}\times\frac{\begin{array}{c}\text{Total volume of soln.}\\ \text{of sample made }(\text{ml})\end{array}}{\begin{array}{c}\text{Wt of sample}\\ \text{taken for assay }(\text{g})\end{array}}$$

Carbohydrate content (%): It was determined by the method described by Loomis and Shull (1937).

Nutrient content: The seed and plant samples at harvest were used for chemical analysis of N, P, and K contents. The plants and seeds were dried in an oven and grained thoroughly in a wily mill to pass through a 30-mesh sieve. These were presented in labeled polythene bag for chemical analysis.

Total nitrogen: The total nitrogen was analyzed at harvest. The N content in seeds was also analyzed separately. Alkaline permanganate method [4] was employed for their estimation.

Total phosphorous: Total phosphorus was estimated during the harvest of the crop 0.05 M $NaHCO_3$ using Barten's reagent was employed for this purpose.

Total potassium: Total potassium was determined with the help of a flame photometer [5] during the harvest of both seed and straw.

Micronutrient: Micronutrient was determined with the help of an atomic absorption sector-photometer at the time of harvesting of both seed and straw.

Nutrient uptake: Nutrient uptake in grain (seed/bulb) and straw/haulm of the crops were calculated in kg/ha in relation to yield by using the following formula:

$$\text{Nutrient Uptake (kg/ha)}=\frac{\text{Nutrient content (\%)}\times\text{Yield (kg/ha)}}{100}$$

7. System study

Equivalent yield: Rice equivalent as well as system productivity were worked out by converting the yields of crops into rice equivalent, taking the help of price values used for the calculation of the economics. The productivity of cropping sequence was converted into rice equivalent yield using the formula:

$$\text{Rice Eq.Yield (kg/ha)} = \frac{\text{Productivity of component (kg/ha)} \times \text{Price of component(Rs/kg)}}{\text{Cost of Rice (Rs/kg)}}$$

Equivalent yields of potato and onion were also calculated as same manner as fallow in calculating rice equivalent yield.

Production efficiency of the system (PES): Production efficiency of the system was calculated by dividing the equivalent yield of rice in a sequence through 365.

$$\text{PES (kg/ha/day)} = \frac{\text{Rice equivalent yield of the system (kg/ha) in a year}}{365}$$

Nutrient uptake in the system: Nutrient uptake in the system was worked out by making a sum of nutrient uptake of a sequence.

Economic analysis

a. Cost of cultivation: The cost of cultivation of various sequences was worked out based on the most recent standard rate of materials.

b. Gross return: The yield of different component crops in the sequence were converted into gross return in rupees based on the current market price.

c. Net return: Net return for each crop sequence was calculated by deducting the cost of cultivation from the gross return.

Cost of cultivation, gross return, and net return under different treatments were worked out on the basis of prevailing cost of different inputs. Power and labor for different operations were calculated on a per hectare basis as per normal rates prevalent in the country. The costs of other inputs were considered as per market price. The total gross return was taken as the total income received from the produce of economic and stover yield. Net return was calculated with the help of following formula:

Net Return = Gross Return - Cost of Cultivation

Energy equivalent: The total energy return of the system was obtained by the conversion of economic yield of the sequence into energy equivalent; whereas, the net energy return was worked out by deducting total input involved in the sequence in energy term from the total energy return. The energy output: input ratio and energy productivity were obtained as follows:

$$\text{Energy Output: Input Ratio}=\frac{\text{Total energy return}}{\text{Total input involved in terms of energy}}$$

The various practices involved in crop production and economic yield of component crops in the sequences were converted into the equivalent value of chemical energy (MJ/ha). For these conversions, standard values as given by [6] were used (Table 2).

S. No.	Particulars	Units	Equivalent energy (MJ/ha)
Input			
1.	Human labor		
	Adult men	Man hours	1.96
	Women	Woman hours	1.57
2.	Diesel	Liter	56.31
3.	Electricity	KWH	11.93
4.	Chemical fertilizer		
	(a) Nitrogen	Kg	60.6
	(b) P_2O_5	Kg	11.1
	(c) K_2O	Kg	6.7
5.	Plant protection (Superior)		
	Granulated chemical	Kg	120
	Liquid chemical	ml	0.102
6.	Seeds		
	Potato	Kg	4.06
	Rice, maize	Kg	14.7
	Onion	Kg	15.8
	Cowpea, pea, rajmash	Kg	14.7
Output			
1.	Rice	Kg (dry mass)	14.7
	Cowpea, table pea, rajmash	Kg (pod)	3.89
2.	Onion	Kg (bulb)	2.60
3.	Potato	Kg (tuber)	4.06
4.	Maize	Kg (green cob)	4.41

Table 2. Energy coefficients.

8. Effects of organic sources in rice based on cropping sequence

8.1. Effect of weather in crops

Plants growing in natural environment are often prevented from expressing their full genetic potential for production as they are subjected to various biotic and abiotic stresses. Environmental factors are relatively more dynamic in determining the extent of growth and development of plants and play major roles in the completion of the plant life cycle. Every crop requires a definite set of environmental conditions for its proper growth and development. Matching the crop phenology to the climatic environment prevailing during the growing season is an important aspect to maximize genetic yield potential.

8.2. Economic yield of rice

In organic nitrogen sources, the application of 100% RDN through organic manure along with biofertilizers recorded the highest grain yield during both years of investigation. This might be due to better availability of nutrients through superimposition of organic manure along with biofertilizers. It was also observed that plants were well supplied with nitrogen, senescence of flag leaf was delayed, and respiratory losses were low. Potassium also had expressed, in addition of CO_2 assimilation rates, resulting in more supply of photosynthates along with micronutrients responsible for the effective translocation of photosynthates that probably accounted for the highest economic yield. In addition to these, *Azotobacter* produced growth promoting substances that improved seed germination and growth with extended root systems. It also produced polysaccharides that improved soil aggregation; whereas, PSB in the rhizosphere of rice rendered insoluble soil phosphate available to plants due to their production and secretion of organic acids, as well as due to the release of sufficient amounts of nitrogen by mineralization at a constant level, which in turn resulted in better crop growth and improvement in various yield components of rice.

8.3. Potato equivalent yield of winter season crops

The maximum potato equivalent yield was recorded under the sequence rice-potato-cowpea (green pod). It may be emphasized here that PEY of crops is the function of market price along with the yield of a particular crop. The potato itself produced higher economic yield and this is accompanied with better market value as a result of potato equivalent yield that were higher as compared to other sequences. Further nitrogen application through organic manures significantly augmented the potato equivalent yield due to the continuous raising of organic potato bio-dynamically on the same site, which improved tuber production by enriching soil fertility.

8.4. Onion equivalent yield of summer season crops

The maximum onion equivalent yield was recorded under the sequence rice-green pea-onion. The onion itself produced higher economic yield due to the inclusion of legume as a previous crop and this accompanied with better market value as a result of onion equivalent yield that were higher compared to other sequences. Further nitrogen application through organic manures significantly augmented the onion equivalent yield, which was due favorable growth and yield of onion crop.

9. Effect on quality parameters

9.1. Rice

The application of organic nitrogen also influenced protein content and protein yield due to the increase in the concentration of nitrogen in grains, which might have modified the proportion of grain constituents. The higher uptake of nutrients, particularly nitrogen, in the organic nitrogen treatments was probably responsible for the higher grain protein. Accumulation of protein in seeds may also be increased due to the continuous nitrogen supply and its translocation in seed buds and optimal nutrition. It is known that protein content imparts strength to the grain; higher protein content thus resulted in higher head rice recovery.

9.2. Potato

Amongst various nitrogen substitution treatments, maximum starch content was recorded under organic sources of nitrogen along with biofertilizers, especially due to higher concentration of potassium in poultry manure, which might have modified the proportion of tubers constituents with respect to starch.

9.3. Onion

Application of organic nitrogen significantly increased the allyl-propyl-disulphide and carbohydrate content (%) in onion bulbs might be due to increased volatile fatty oil content resulting in significantly higher production of allyl-propyl-disulphide in onion bulbs. Increased allyl-propyl-disulphide content with increasing organic nitrogen application was in close agreement with findings of [7, 8].

10. System analysis

10.1. Rice Grain Equivalent Yield (RGEY)

The maximum RGEY was recorded under the sequence rice-potato-onion. The higher production potential of potato and onion and better market prices were instrumental for attaining higher REY by this sequence [9, 10]. Rice equivalent yield is directly associated with the yield of respective crops in the sequence and so organic manure alone or along with biofertilizers enhanced the yield potential of crops, which ultimately increased the rice equivalent yield of the sequence.

10.2. Production efficiency

The sequence rice-potato-onion had recorded maximum production efficiency compared to the rest of the treatments and this was due to the better market price of potato and onion in the sequence [11]. Organic manures along with bio-fertilizers recorded the significantly highest production efficiency of the system and this was due to the highest rice grain equivalent yield of crops in the system.

10.3. Energetics

The maximum energy input was recorded in the rice-potato-onion sequence. The energy consumed by the potato through fertilizer, seeds, and human labor and that of the onion for irrigation (electricity) and inter-culture operations resulted in higher energy input. The energy involved in N fertilizer was particularly higher in sequences involving potato and onion, which relatively consumed a large proportion of energy in seeds. The pooled data indicated that the maximum gross energy output, net energy return, and employment generation was obtained in the rice-potato-onion sequence. This clearly exhibited that besides having more energy input, this sequence also produced the highest energy equivalent, resulting into maximum gross energy output, net energy return, and employment generation [12]. In general, the gross energy output, net energy return, and employment generation of the system remained comparatively higher during the second year than that of the first year. Application of nitrogen through organic manures along with bio-fertilizers recorded maximum average energy input, gross energy output, net energy return, and employment generation of the system because this sequence was more input intensive as well as had the highest productivity level.

10.4. Economics

Data related to economics as affected by various cropping sequences and organic nitrogen treatments of two years of experimentation are presented. The maximum cost of cultivation, gross return, net return, and profitability was recorded under the sequence rice-potato-onion, which was significantly higher than that of the other sequences. This was mainly due to the higher production potential of potato, accompanied with good monetary return from the onion. The highest values of cost of cultivation, gross return, net return, and profitability were associated with the application of nitrogen through organic manures along with biofertilizers. This was mainly due to higher productivity without a proportionate increase in the cost of cultivation.

10.5. Nutrient uptake

Nutrient uptake by different cropping sequences is the function of crop yield and nutrient content. The increase in these factors was responsible for the increased nutrient uptake during both years of experimentation of the system, which was at the maximum under the rice-cowpea-maize sequence. This was significantly superior to the rest of the sequences in this respect, which could be a higher productivity potential of maize ascribed to the increase in the available nitrogen, phosphorus, potassium, sulfur, zinc, iron, copper, and manganese contents in the soil resulting from the increased availability of nutrients through organic sources particularly through organic manure along with biofertilizers.

10.6. Soil fertility status

Data on the nutrient status of soil organic carbon, major (nitrogen, phosphorus potassium), secondary (sulfur), and micronutrients (zinc, iron, copper, and manganese), recorded maximum improvement, in this respect, was observed where pulse crops were incorporated in the sequence. Application of either organic manure alone or with biofertilizers significantly improved the soil status with respect to organic carbon and nutrients under study. It is quite obvious that this might have added greater organic sources and biofertilizer to the soil, ultimately improving the soil's organic carbon. Similarly, [13] also reported that 100% nitrogen (1/3 each from cow dung manure, neem cake, and composed crop residue) appreciably increased the organic carbon (6.3 g kg^{-1}) over the initial value (5.8 g kg^{-1}).

10.7. Soil health

The application of organic manure along with biofertilizer significantly improved soil pH, as well as electrical conductivity was associated with the decline in soil reaction might be due to organic compounds added to the soil in the form of organic manure and biofertilizer that produced more humus and organic acids in decomposition. The role of organics is attributed to the supply of essential nutrients by the continuous mineralization of organic manures, nutrient supplying capacity of the soil, and its favorable effect in the soil's biological (bacteria, actinomycetes and fungi) properties [14,15]

11. Conclusion

1. The inclusion, of the two high-value vegetable crops in sequence having 300%, rice-potato-onion had the highest rice equivalent grain yield, production efficiency, net energy return, as well as net monetary return and profitability. However, the best benefit ratio was highest in the sequence rice-potato-cowpea (green pod). Thus, rice-potato-onion was observed as the most intensive, stable, and profitable high-value cropping sequence for irrigated ecosystems.
2. The organic N nutrition of organic manuring with biofertilizers had the highest rice equivalent grain yield, production efficiency, net energy return, as well as net monetary return and profitability on rice-based cropping sequence.
3. The different cropping sequences of rice did not differ with respect to yield and quality parameters. However, the organic N nutrition with organic manures along with biofertilizers proved significantly superior with respect to the yield and quality parameters of rice, potato, and onion.
4. The different cropping sequences of rice differ with respect to nutrient uptake, i.e., rice-maize-onion had the highest removal of major (N, P, K), secondary (S), and micronutrients

(Zn, Fe, Mn, Cu) than the rest of the cropping sequences and was significantly superior to rest of the sequences.

5. The organic N nutrition with organic manures along with biofertilizers had the highest nutrient acquisition of major (N, P, K), secondary (S), and micronutrients (Zn, Fe, Mn, Cu).
6. The different cropping sequences of rice did not differ with respect to nutrient status as well as microbial count. However, inclusion of pulses in sequences showed positive improvement on soil health and the effect can be quite effective and visible on a long term basis.
7. The organic N nutrition with organic manures along with biofertilizers proved superior due to its visible favorable effect on soil health with respect to nutrient status and microbial count and this indicates the utilization of this low-cost but long-term beneficial practice under high intensity cropping for sustainable crop production.

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Chapter 8

Potatoes (*Solanum tuberosum* L.)

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Additional information is available at the end of the chapter

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Abstract

In the area of potato production, targeted research solving concrete and actual problems of potato producers runs on Czech University of Life Sciences in Prague. In the last few years, we were focused on the production of new potatoes designated for early harvest, and we were focused on capitalization of yielding and qualitative characteristics of colored potato variety. These findings were further utilized and transferred to the system of organic farming. Firstly, we watched the influence of organic farming on yield and quality of tubers. Ecological ways of cultivation had strong negative influences on yield (decrease of 36%). From qualitative characteristics, organic farming increased the content of polyphenols by 10.2%, decreased the content of nitrates by 11.0%, and decreased the content of reducing sugars by 22.0%. We also evaluated the possibilities and impacts of mulch on potato cultivation. The mulch on top of ridges affected the temperature of soil (it increased the temperature by 0.2–0.6 °C under black mulching nonwoven fabric, and it decreased by 0.5–0.8 °C under herbal mulch). The mulch also affected soil humidity (herbal mulch decreased the soil humidity) and adjust weed infestation (20 to 92% lower), soil erosion (95% lower), the occurrence of Colorado beetle (the number of larvae was 22.8% lower with herbal mulch and 88.7% higher with mulching textile), and late blight in potato vegetation.

Keywords: Potatoes, organic farming, mulching, plant extracts, quality tubers

1. Introduction

Potatoes in Czech Republic belong to the minority crops cultivated in the system of organic farming. Like the principal tuber crop, it forms ca. 0.5% of the whole certified area of Czech Republic. The area of consumption potatoes actuate over is an area of 200 ha (in 2012, 3,277 tonnes of organic potatoes were harvested on an area of 230 ha).

Cultivating potatoes organically is very demanding on producers. Producers must deal with the absence of chemicals used on crop protection, the absence of synthetic fertilizers, the obtainment of acceptable yield and good quality of tubers, and the necessity of applying all the procedures to create suitable conditions for growth and development of crops, like any other crop cultivated organically [1].

2. Environmental conditions

The potatoes originate from the mountain area that is why the foothill conditions suit them well. The optimum amount of precipitations for potatoes is 650 to 800 mm annually (60–70% of this amount during the vegetation). The precipitations during the first half of vegetation influence the growth of tops, the precipitations from May to half of July influence the number of tubers under the clump (with consideration of the time of planting and earliness of the variety). The precipitations in the second half of vegetation determine the weight of tubers. The deficiency of precipitations during the period of planting until emergence relatively positively affects the yield of tubers. Plants produce more roots and can manage water better [1].

In case of early potatoes, where the well-timed soil preparation and well-timed planting is important (it occurs until the end of April in the Czech Republic), we choose the fields with soil easily processed early in the spring. From the point of view of the regulation of fungi diseases, we prefer the open fields (air locations which provide quick drying of plants). The good choice of location can regulate the occurrence of late blight [2].

3. Choice of suitable variety

Like any other crops, the choice of variety in the system of organic farming is crucial. The quality and health conditions of chosen planting material are vital, too. Generally recommended are the varieties with shorter vegetation period (with quicker initial growth and quicker tuber formation), lower nitrogen requirements, and higher resistance against diseases [2]. In case of varieties with longer vegetation period (usually intended for autumn consumption and storage), it is important to choose varieties highly resistant against late blight [3].

The choice of variety is submitted to the purpose of production (direct consumption, washing or peeling, on food-processing products such as chips and potato puree). For the consumer varieties, the determining aspects are qualitative indexes expressed by table value. It is commonly expressed by so-called cooking type of tubers (based on evaluation of consistency of cooked tubers, moisture, structure, mealiness, darkening, and taste). For this purpose are potato varieties divided into four groups: (1) cooking type A – consistent, tallowy, of delicate to semi-delicate structure, cannot be overcook, very weakly to weakly farinaceous tubers (suitable for preparation of potato salads or for meals when it is necessary to keep the shape even after cooking, like in case of soups, and for common consumption); (2) cooking type B – semi-consistent, semi-farinaceous, pleasantly moist to dry (suitable generally as a side dish); (3) cooking type C – soft, farinaceous tubers, semi-moist to dry (suitable mainly for preparation of purees, potato dough, and potato pancakes); (4) cooking type D – rough, strongly farinaceous, and can be overcooked (undesirable for consumption purposes, usable for starch processing or for other products).

Until the present, no compact information is available in Czech Republic concerning the comparison of potato varieties in the system of organic farming.

The colored varieties are an interesting area for organic farming. They are more frequent in organic farms abroad. There is a speciality from the viewpoint of both appearance (colorfulness and shape of tubers) and nutritional value (mainly the high content of antioxidants and pigments). This area has been, in the long term, intensively examined by Prof. Ing. Karel Hamouz, CSc. and his colleagues from the Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences (CULS) in Prague. Their studies are deepening the known information about these varieties (antioxidant activity, content of anthocyanin in raw and cooked tubers). It is possible to find between them perspective varieties usable for the consumption or processing (production of natural dye agents or syrups). To this group belongs variety Valfi, which originates in Czech Republic (violet variety bred in Potato Research Institute Havlíčkův Brod).

4. Innovations in cultivation techniques

4.1. Nutrition and fertilization

The need of nutrients, specifically the plant uptake, is given by the level of yield of tubers. Potatoes need, in average, 80–130 kg of Nitrogen per hectare (it is possible to count the uptake of 40–50 kg of Nitrogen, 8.8 kg of Phosphorus, 22 kg of Potassium, and 8.4 kg of Magnesium per 10 tonnes of tubers). This need is covered by applied barnyard manure, green manure, compost, cattle slurry, or digestate. Then the level of available nutrients depends on the level of biologic activity of the soil, i.e., mineralization conditions (which are supportable by hoeing). It is also possible to enhance the biological procedures in soil by many preparations on the basis of nitrogen fixators such as Azoter or AlgaSoil-natural organic fertilizer made of seaweed. These preparations were tested in small-plot experiments on CULS's land.

4.1.1. Experimental verification

Azoter was applied by spraying a dose of 10 liters per hectare to the furrows during hand-planting. AlgaSoil was applied to the furrows near tubers in a dose of 70 kg per hectare during planting. During vegetation, the content of chlorophyll was measured by hand using the Chlorophyll Meter SPAD 502 (in five terms from the 56th to the 100th day after planting), and in case of preparation, AlgaSoil leaf samples were taken twice for analyses of nitrogen and other nutrients. After harvest, tubers were sorted by size into two groups (tubers under 4 cm and over 4 cm).

The application of Azoter supported nitrogen fixation in the soil, thanks to the three genus of nonsymbiotic bacteria contained in this preparation (*Azotobacter chroococcum*, *Azospirillum* *braziliense*, and *Bacterium megatherium*). This was also shown in plants with higher chlorophyll content in their leaves (Figure 1). The application of Azoter had positive effect on the yield of tubers that was higher by 1.1 t per hectare in comparison with untreated control (Figure 2).

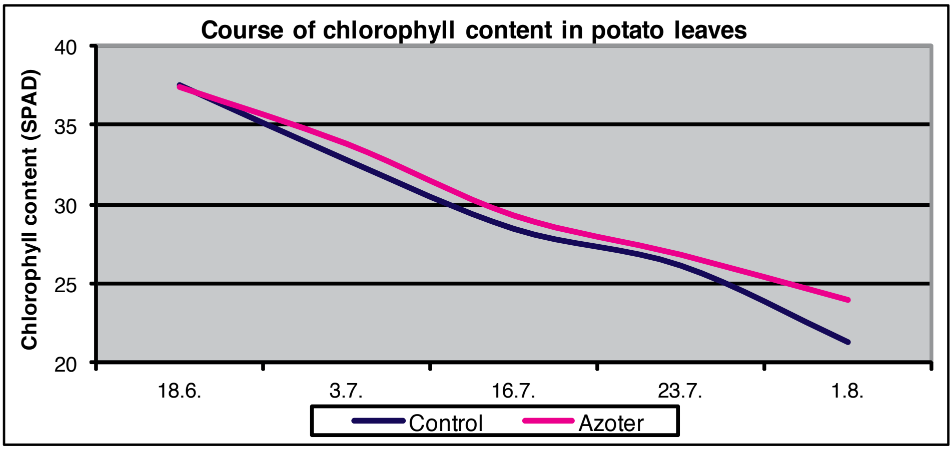

Figure 1. Chlorophyll content in potato leaves of Katka varieties in 2013 when measured by Chlorophyll Meter SPAD 502.

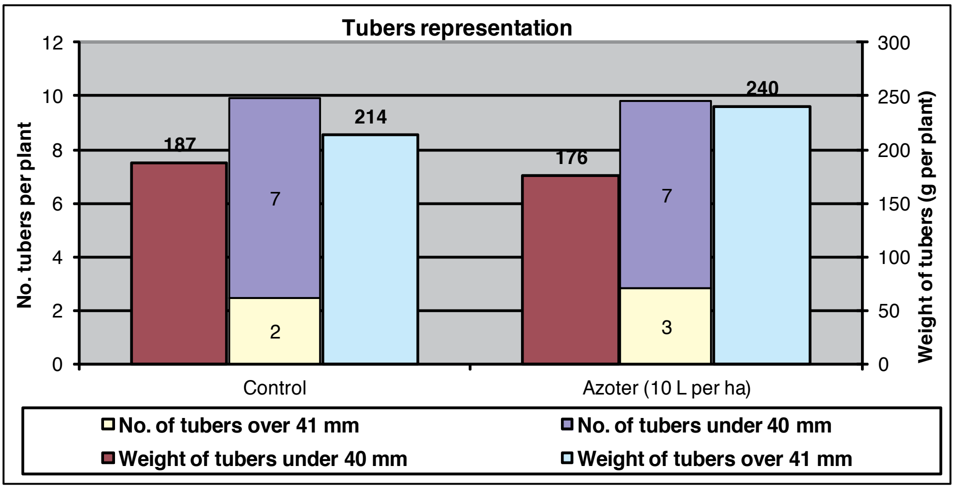

Figure 2. The final effect of Azoter on the numerical representation and weight of tubers under a clump of Katka variety in 2013.

AlgaSoil is a natural organic granulated fertilizer based on seaweed, which should work as a soil conditioner, ameliorate the soil structure, and increase the microbial activity and the utility of nutrients in soil. AlgaSoil also increased the chlorophyll content in leaves (Figure 3).

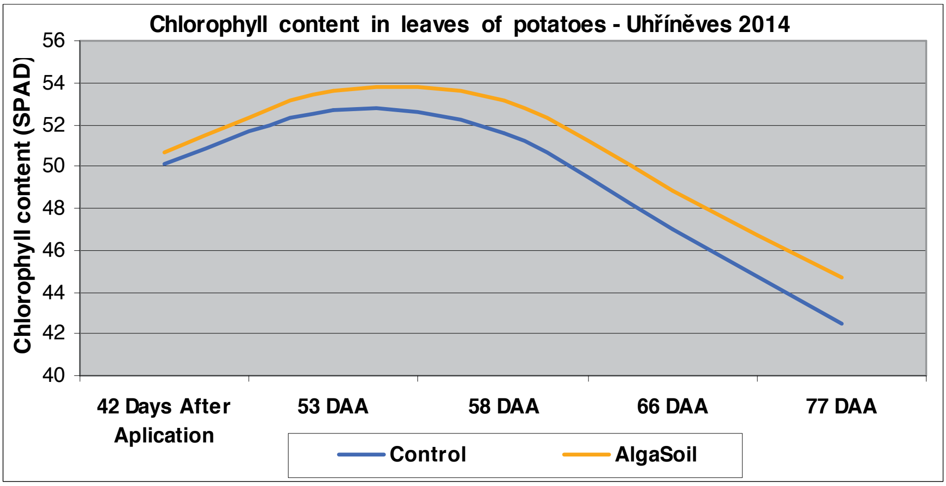

Figure 3. Course content of chlorophyll in the leaves after application of the fertilizer AlgaSoil.

There is known positive correlation between chlorophyll content and N content in plants [4]. The N content in variants treated by AlgaSoil (Figures 4 and 5) was 6% higher than in controls after first sampling (58th day after planting) and 24% higher after the second sampling (77th day after planting). Similarly, the chlorophyll content was higher on the 58th day by 3% as well as on the 77th day.

The AlgaSoil affected the size and final yield of tubers, which was higher by 3.6% (Figure 6).

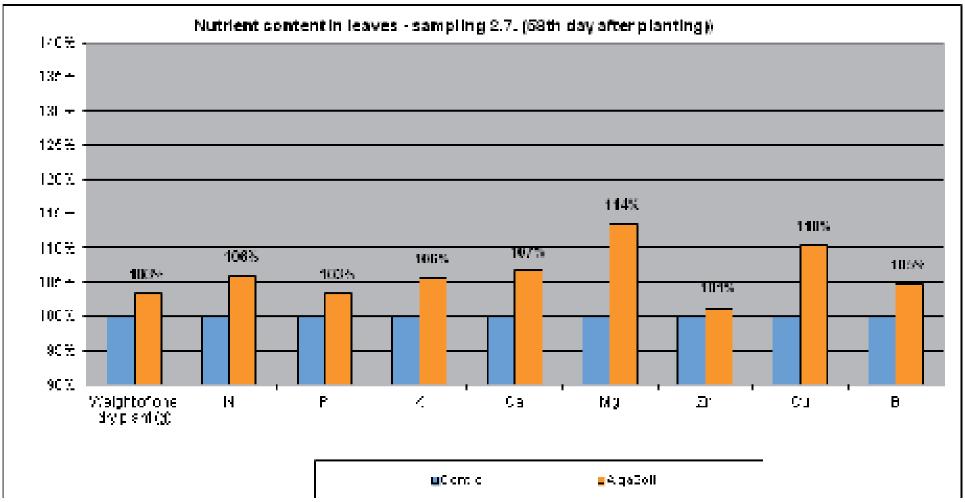

Figure 4. Results of laboratory analyses on the primary nutrients content in the leaves of potatoes on the 58th day after planting [14].

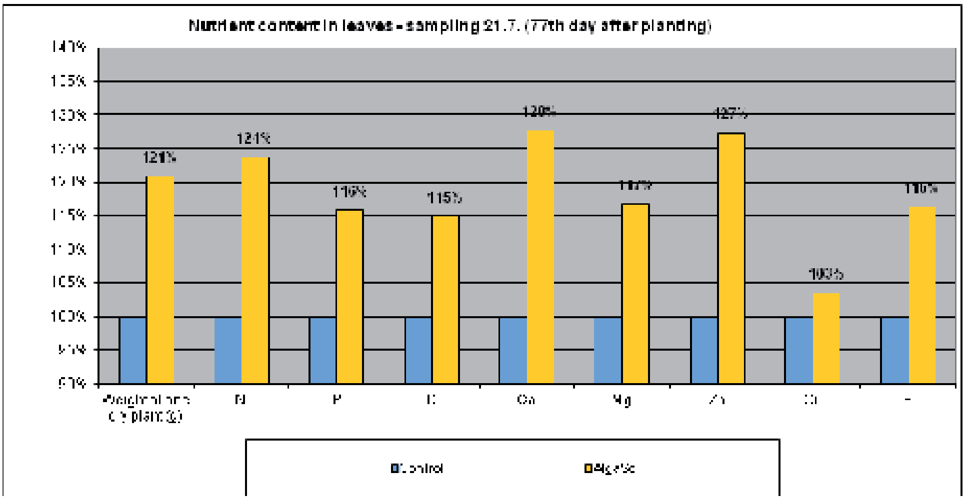

Figure 5. Results of laboratory analyses on the primary nutrients content in the leaves of potatoes on the 77th day after planting [14].

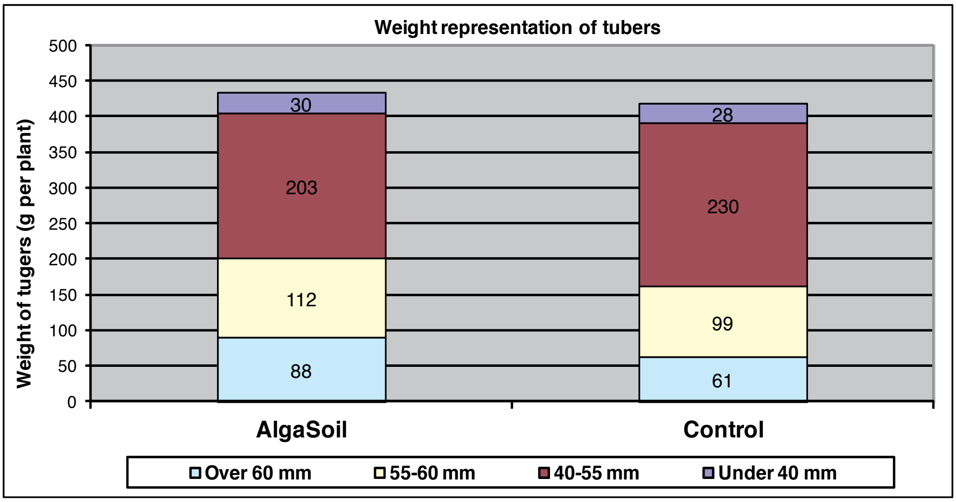

Figure 6. Size analysis under a clump of tubers after treatment with AlgaSoil.

5. Preparation of planting material and planting

The planting material intended for the conditions of organic farming is necessary to sprout or at least to bud. These procedures lead to lower sprout production, which means lower stalks production. This would express as lower tuber setting under the clump, but the tubers would reach the consumption size sooner. So, by these methods, we can increase the earliness and partially anticipate the decrease of production as a consequence of late blight attack. In case of early term of harvest combined with sprouting, it is possible to count the increase of yield of consumption tubers by 7–8% [8]. The disadvantage of the procedure is the increase of work requirements during biological preparations both ensuring the sprouting or budding and planting. The sprouted tubers are possible to plant only with suitable technology (potato planter or disc planting mechanism).

5.1. Size sorting of planting material

Size sorting of planting material on desired size can influence the shortening of vegetation of very early varieties and their yield of tubers.

5.1.1. Experimental verification

In a precise field experiment, three sizes of planting material were compared: variant A (tubers 25 to 35 mm), variant B (tubers 40 to 60 mm), and variant C (65 to 85 mm) with the aim of finding the influence of tuber size on potato yield characteristics. In the experiment, a very early variety called Impala was used. Every variant was set in three repetitions under non-woven fleece textile (Pegas-agro 17 UV) and an uncovered variant was used as control. The harvest and evaluation of yield happened on the 56th to 68th day from planting.

From Table 1, we can recommend big sorting of planting material (variant C) for very early harvest of early potatoes (for regular vegetation and for vegetation covered with nonwoven fabric CFT). It was verified by papers dealing with the size of planting material [5–7] that big sorting of planting material has a marked effect on tuber yield, even on earliness of vegetation (quicker start, thanks to bigger content of energy storage molecules, and quicker ability of regeneration in case of frozen sprouts).

Variant	Yield of ware potatoes (tons per hectare)	Average weight of 1 consumer tubers (g)	Total no. of tubers per plant
		Without cover – control (C)	
AC	12.7^{a}	48.9^{a}	9.7^{a}
BC	15.8^{ab}	40.4^{b}	13.3^{b}
CC	19.3^{b}	52.9^{a}	13.3^{b}
$HSD_{0.05}$	*4.02*	*7.73*	*2.65*
		White fleece textile (FT)	
AFT	17.8^{a}	57.4^{a}	9.5^{a}
BFT	21.2^{ab}	60.2^{a}	10.2^{ab}
CFT	24.5^{b}	63.3^{a}	12.6^{b}
$HSD_{0.05}$	*5.91*	*11.25*	*2.72*

Table 1. Effect of seed tuber size on yield and yield characteristics in the stands that cultivated without cover (C) and cultivated under nonwoven fleece textile (FT) in 2005–2006

5.2. Pre-sprouting

The aim of pre-sprouting is the formation of 15 to 25 mm long, colored, and firm sprouts with basis of roots. It is an intensive procedure, which can hasten emergence, vegetation growth, and even harvest [1]. From the view-point of organic farming, prepared planting materials can ensure quicker emergence of vegetation, which means better concurrence against weed. Quicker emergence also reduces the appearance of black scurf of tubers and stem canker. Pre-sprouting is a suitable procedure to speed up tuber production, and in case of late blight and Colorado potato beetle, tubers are in late state of consumption (pre-sprouting increases the yield assurance).

5.3. Treatment of planting material before planting

In conditions of organic farming, the grower has the possibility to treat potato planting material with allowed agents (this can mainly ameliorate and speed up the emergence of potatoes, than protect it against pests and diseases as in conventional cultivation). For interest, it is possible to specify some preparations, which we have tested (Albit, Amalgerol, Galleko, Special, Polyversum, Softguard). It is possible to apply these preparations on tubers before planting (ultra-low volume pesticide application of tubers in pre-shooting room) or directly during planting on the potato planter. It even partially treated the soil nearby simultaneously [1].

6. Treatment before emergence

The treatment before emergence consists of ploughing and harrowing with full mechanical cultivation. The first operation after planting is blind ploughing after 7 to 10 days. In case of early potatoes, it is suitable for quicker emergence to cover less with soil or to start with harrowing (chain harrow or tine harrow for regulation of emerging weeds in phase of cotydelons). Harrowing also disturbs the soil crust, decreases the height of the top soil above the tubers (meaning warmer through the ridges), so they emerge quicker [8]. With ploughing, we destroy weeds in furrows and on the sides of ridges (it is done most frequently 7 to 10 days after harrowing).

For acceleration of vegetation and early harvest, it is possible to cover the vegetation after planting with white nonwoven fleece textile or perforated foil. The nonwoven fleece textile also provides protection against low temperature, but it limits mechanical cultivation and in case of temperatures higher than 22 °C, plants can be damaged under fleece. In an average of nine years, nonwoven fleece textile probably increased yield of tubers by 23.2% in average of years and varieties in early terms of harvest (ca. 60 days after planting) [9].

It is possible to apply mulching materials on the soil surface (on ridges) to improve soil and nutritional conditions. The main benefits of mulching materials are evaporation regulation, reduction of temperature fluctuation of the soil, and repression of weeds. They can be sources of nutrients and can limit erosion and occurrence of some pests. The right choice of suitable mulching material is important for concrete stand.

The first group are organic (herbal) mulch, such as straw, chopped grass, biomass of intercrops, or other plant material, that can be applied on the ridge surface and usually come directly from the farm. For their application, we recommend manure spreaders, separators of bales of straw, or bedding semi-trailer. The straw is used as mulch mainly abroad. It is easy to store, so it is available during the whole vegetation time [10].

The second big group of mulching materials are plastic products or other waste materials (for example, paper). Considering the origin of plastic and the impact of its application on large-area agriculture, it is necessary to reduce this material and suitably replace it. The use of biodegradable foil or black nonwoven textile can bring certain easement in this area. Targeted processing and recycling of waste paper is possible to produce paper mulching matting with different firmness and durability. The firm VUC Services (www.ekocover.cz) is engaged in this processing and production in the Czech Republic.

In connection with mulch application, it is necessary to mention that mechanical cultivation during vegetation is not possible because of the mulching fabric or foil or it may be limited (in case of plant material). However, past studies imply that the absence of cultivation has no negative effect on tuber yield.

6.1. Application of mulching material

The experiments with herbal mulch, wheat straw, and black textile mulch (weight 50 g/m^2) conducted from 2008 to 2012 brought many answers in the area of temperature change, soil humidity, level of material degradation, biomass of weeds, chlorophyll content in leaves, occurrence of Colorado Potato Beetle (CPB), and Late Blight on tubers and size representation of tuber under clumps [11]. In 2014, we enlarged the experiment by other materials: biodegradable foil and two types of paper matting EkoCover (short-time matting with weight 270 g/m^2 and medium-term matting with weight 800 g/m^2).

6.1.1. Experimental verification

It was found that herbal mulch functions as an isolation and during tracked time decreased the soil temperature by 0.8 °C. Mulch also affected soil humidity conditions when the lowest soaking pressure of soil (that means the highest humidity of soil) was registered at mulching textile. Soil humidity with herbal mulch was in average of years comparable to the unmulched control.

The changed humidity and temperature conditions of soil influence even the nutrient availability in soil [12] and the whole nutritional state of vegetation within it. The source of nutrients for plants can even be its own herbal mulch. The chlorophyll content in leaves was higher by 3.7% in the case of chopped grass applied after planting or before emergence, and it was higher by 2.3% in the case of control (Figure 7). We found the lowest content of chlorophyll in leaves after using black mulching textile and straw (Figure 7 and 8). From known correlation of chlorophyll content and nitrogen content in plants [13, 14], it is possible to deduce that this vegetation had lower nitrogen content in leaves (nitrogen in soil was probably used in straw decomposition not by plants). Other mulching materials (such as paper mulching matting, biodegradable foil) applied after planting (Figure 8) induced lower chlorophyll content in leaves.

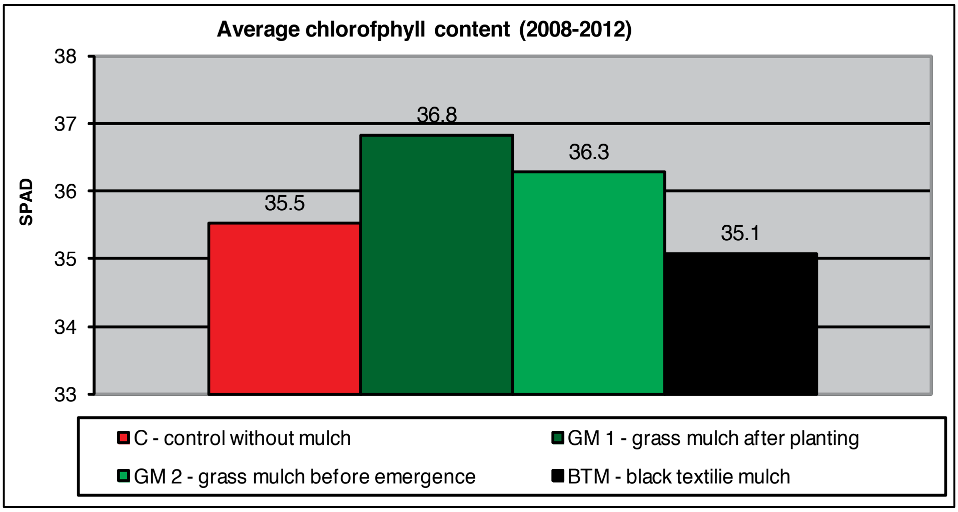

Figure 7. The chlorophyll content (SPAD in units) for each variant of mulch.

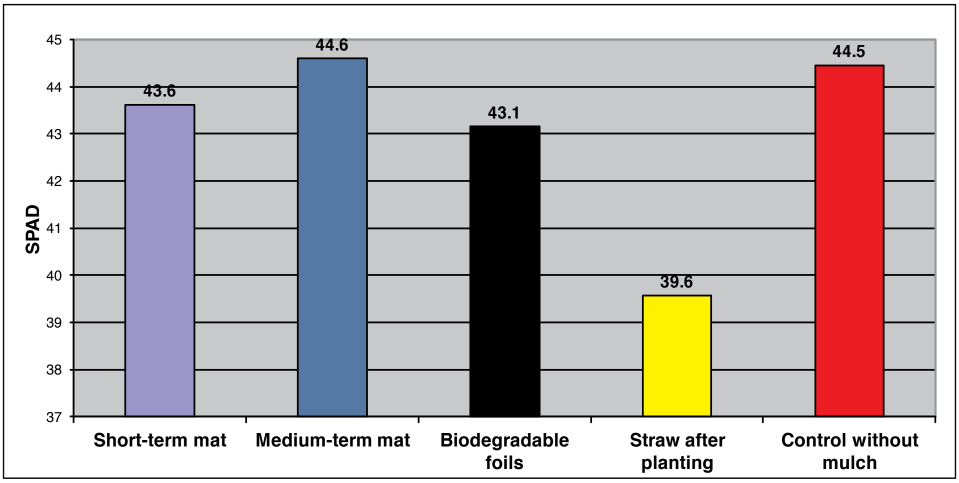

Figure 8. Chlorophyll content in experiments with biodegradable materials (Uhříněves, 2014).

Positive humidity and nutritional conditions affect even growth and biomass of weed and its regulation is ensured only by mulching fabric, biodegradable foil, and paper matting. The application of mulch (or the present weed biomass) is an effective way of soil protection against erosion because the soil is most vulnerable since the planting [15].

The mulch also affects the occurrence of CPB and the following damage of vegetation by the larvae of CPB. Chopped grass reduced the occurrence of CPB (Figure 9) and on the contrary, black mulch textile increased its attack (probably because of higher temperature of soil). The lowest occurrence was found on plots with applied straw. Similarly in 2014, the lowest occurrence of larvae was on straw and foil (Figure 10).

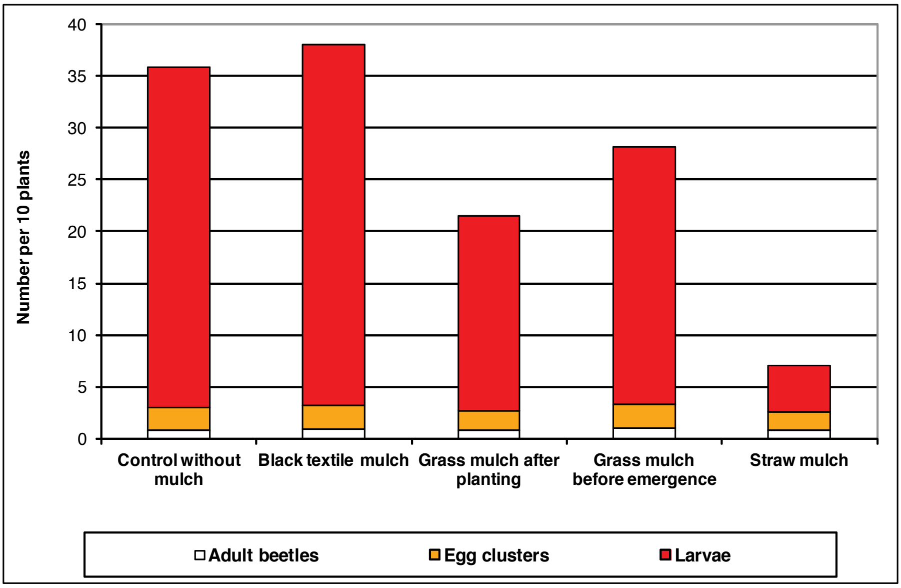

Figure 9. Dependence of the occurrence of beetles, nests with eggs and larvae of CPB on used mulching materials on station Uhříněves (2008–2012).

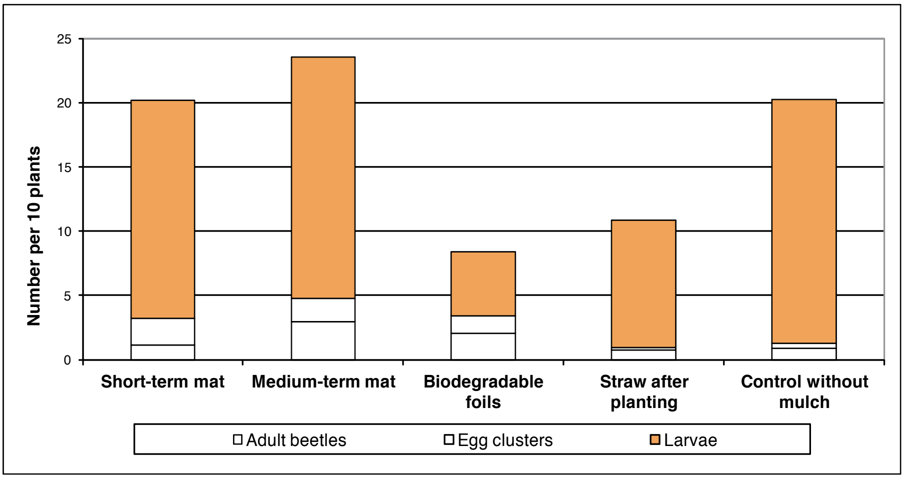

Figure 10. Dependence of occurrence of beetles, nests with eggs and larvae of CPB on used mulching materials (Uhříněves, 2014).

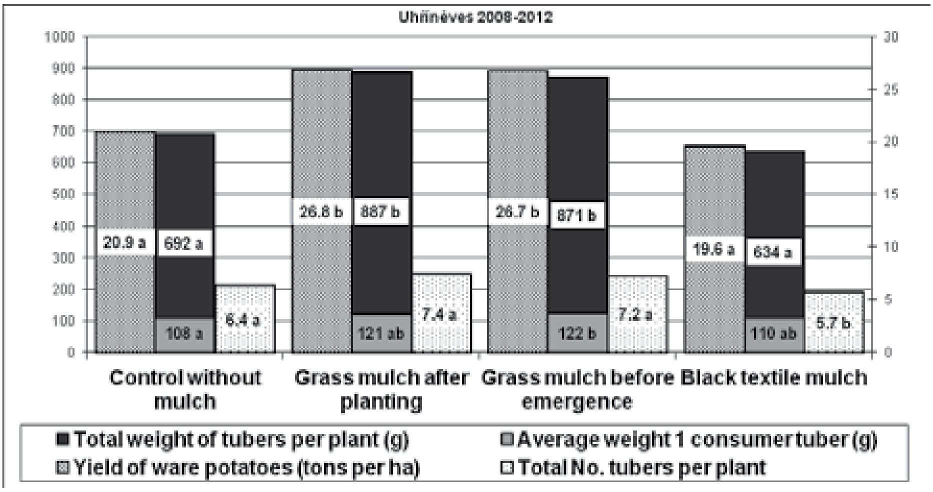

Figure 11. Total weight of tubers, number of tubers, and yield of ware potatoes at various ways to mulching in Uhříněves (different letters for average mean statistically significant differences at the 95% confidence level).

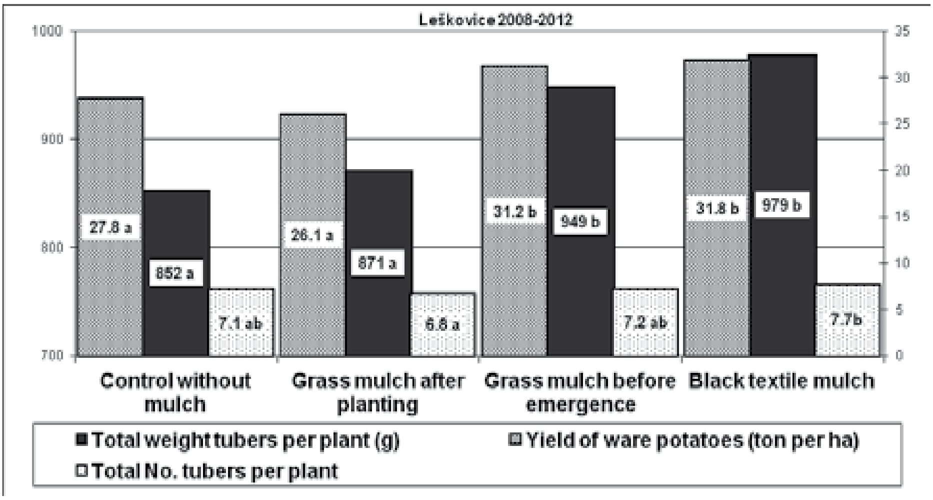

Figure 12. Total weight of tubers, number of tubers, and yield of ware potatoes at various ways to mulching in Leškovice (potato growing region).

The abovementioned factors affect consequent tuber production (Figures 11, 12 and 13). The higher yield of consumption tubers was after the application of chopped grass. Yield of tubers in Uhříněves was lower after the use of black textile mulch than at non-mulched control because of the great attack and damage of vegetation by larvae of CPB. On the contrary, the positive result was achieved with textile mulch on site in the potato processing area where the occurrence of CPB was not high. Black textile mulch positively increased the temperature of the soil and water content in the soil. It produced better conditions for growth and on this site was the highest yield of consumption tubers with textile mulch (higher by 4 t/ha against control).

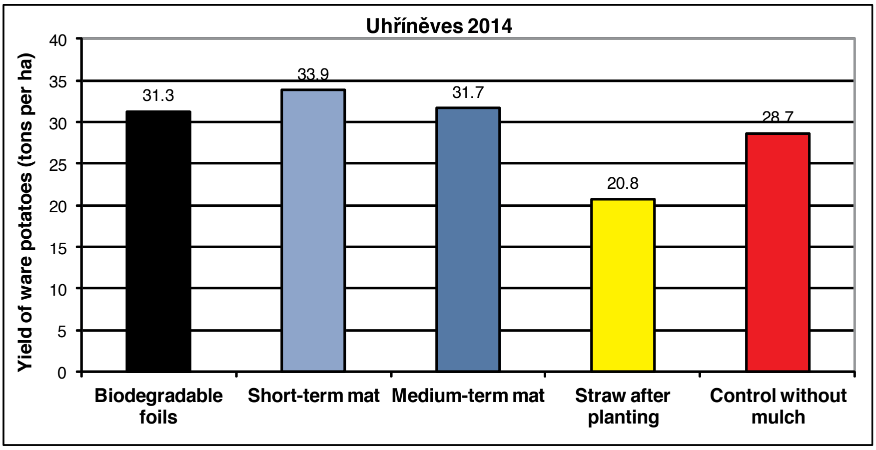

Figure 13. Yield of ware potatoes depending on the selected mulching material.

7. Treatment after emergence

After emergence of vegetation, we continue in mechanical cultivation, which consists of ploughing (eventually the use of weeder) and careful harrowing. Freshly emerged stalk is sensitive on damage, so we should practise harrowing only exceptionally. When the stalk is green and firm, harrowing is possible without great damage in the afternoon hours (when the stalks are withered). In that case, it is beneficial to use tine harrow. It damages stalks lesser than the chain harrow.

According to the need, ploughing (eventually harrowing) is repeated approximately 3 to 4 times until the full canopy closure [8]. The last cultivation intervention should be made until the formation of flower buds when they pile up the ridges as a precaution for transition of late blight from stalk to tubers.

In case the plant height reaches approximately 20 cm, it is suitable to apply (on the leaf or partially also on the soil) supportive preparations (Albit, Alga 600, Alginure, Amalgerol Premium, Ferbiflor, Lignohumate B, PRP-EBV and others).

8. Regulation of pests and diseases

Potatoes can have many diseases (i.e. viral, bacterial, or fungal). For the major part, it is possible to only apply preventive procedures. Direct intervention is possible only in case of fungal diseases.

Potato pests attack mainly stalks and tubers. Some of them are also transferring agents of diseases (for example, aphides transfer plant viruses).

8.1. Late blight (Phythophora infestans)

Late blight is a serious disease on the worldwide scale. If the conditions are favorable, it spreads quickly, and after three weeks, it is able to totally defoliate vegetation [16]. Its regulation in conditions of organic farming is very difficult. The grower must maximally use available preventive methods of pathogen regulation. The assumption is to use known pathogen biology including his weakness.

Varieties of potatoes show marked differences in susceptibility to the late blight. The choice of variety is deciding, because the possibilities of direct crop protection are limited in organic farming. Abroad are already known resistant varieties (Defender, Jacqueline Lee) or varieties with high resistance against it (Sapro Mira, Bionta).

Early term of planting and biological preparation of planting material reduce mainly the risk of yield loss because the later the epidemic shows up (in later stage of plant development), the bigger the tubers are and the lower the losses of yield.

For regulation of late blight, it is possible to use methods that decrease the time of moistening. In case of irrigation need, it is preferable to use the drop irrigation than the spray irrigation (it also saves water). Time-controlled irrigation can markedly decrease the time of moistening. The best time of irrigation is early in the morning, during dew [17]. Unambiguously, it is not suitable to irrigate in late afternoon hours when the stalks cannot dry up before sun-down and usually stay moistall night, which leads to wetting for a very long time and to higher risk of diseases.

The recommended methods of regulation of late blight are suitable organization of vegetation (spacing and row orientation). Orientation of rows is recommended for dominant air circulation. Wide rows (80 to 90 cm) can enhance air circulation and wider rows (90 to 120 cm) prevent canopy closure, which assure longer time of air circulation and makes vegetation dry faster after precipitation. But after, there is lower soil shading and higher concurrence of weeds. Weed occurrence in potato vegetation decreases air circulation and increases the infection risk. In addition, those weeds can be hosts to late blight (*Solanaceae*).

It is also possible to introduce some plants in the vegetation that can reduce the risk of late blight. These new plants form a barrier against the spreading of spores. Some studies mention positive effects of intercropping potatoes with wheat. Potatoes are planted diagonally to dominate air circulation and wheat is sowed in the furrows. Another alternative method verified in the project Blight-MOP with positive result was alternate (band) cultivation of varieties resistible and sensitive to the late blight on one site or cultivation of more varieties in one row. This mixture of varieties can improve control over pathogen, but induce practical problems with harvest and variety separation [18].

Balanced plant nutrition including microelements decreases the possibility of late blight infection of potatoes [1]. Overdose of nitrogen fertilizer forms less tubers and lots of stalks that dry up slower, which increases the infection risk. More resistant are mature "older" stalks [16] well-supplied with potassium [1].

In case of occurrence of late blight in the vegetation (when preventive methods did not work), it is possible to alternatively approach the destruction of the first infected plants on site. It can stop or slow down the spreading of the disease to the rest of the site. We have to eliminate not only the visibly ill plants, but also the plants around the focus point because they may be infected though without any symptoms. The appearance of symptoms takes around three days to one week (depending on environmental conditions). Results of these methods are the elimination of many apparently healthy plants, which are enclosed by the infected plants. For these purposes, it is possible to use, for example, a propane-butane burner, which can ensure the destruction of spores.

Opinions on the use of preparations on the basis that copper is markedly different (grower to grower, state to state) is mainly dependent on legislation. In some states, copper fungicide was limited. According to the EU, they determined a boundary of 6 kg of Cu/ha/year. In Scandinavia, copper fungicides cannot be used at all. Growers there are trying to use alternative products, but with smaller success. In present conditions, the ban of copper fungicide could destabilize the production of organic potatoes because there are no other effective alternatives for blight regulation.

In our experiments from 2009 to 2011, solutions of plant and animal origin were tested and supplemented with five hopeful commercial preparations (Figure 14). First, preventive spraying was always done before occurrence of blight, and consequent treatment was done according to prognostics and signalization. The site, where the experiment occurred, was typical for lower blight attack on stalks and tubers, so even the use of alternative spraying had satisfactory results compared with copper fungicide. We also observed mild phytotoxicity of preparation with the extract from walnut tree (*Juglans regia* L.), which probably had an effect on tuber yield.

Treatment	**Late Blight on the leaves (1–9)**	**Tuber blight**		**Tuber yield (tons per ha)**
		Number (%)	**Weight (%)**	
Kuprikol 50	7.6	0.4	0.3	26.1
5% solution of biomilk	7.5	0.6	0.5	23.3
10% extract from *Juglans R.*	7.6	1.0	0.9	22.6
MycoSin VIN*	7.6	1.1	0.3	28.0

*Note:** Only years 2010–2011, 9 points – without challenge

Table 2. Incidence of Late Blight on the leaves and tubers of potato (expressed in % of infected leaves and infected tubers)

Another comparison of commercial preparations is represented in Figure 14. Surprisingly, the best results on blight regulation were observed with preparations against Colorado potato beetle (Neem Azal T/S and safety net). It affirmed the recent finding that regulation of CPB in organic farming (regulation of leaf damage) has a positive effect on the decrease of blight in potato vegetation.

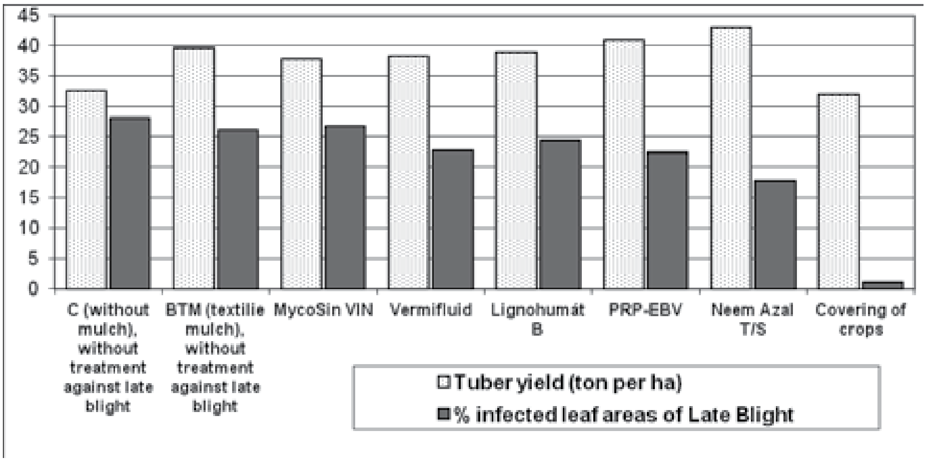

Figure 14. Results of applications support preparations in average varieties (Monika, Jelly, and Red Anna) on station Uhříněves (2009–2011).

8.2. Colorado potato beetle (Leptinotarsa decemlineata)

CPB is a pest of potatoes, which after overpopulation induce serious damage of vegetation and decrease of tuber yield [1]. The biggest damage is caused by its larvae. Their overpopulation can lead to clean-eating, leading to the destruction of vegetation. This pest should not be undermined.

From preventive precaution, it is possible to recommend pre-sprouting and early planting, not place the potatoes on near-by sites (easily admissible for beetles), aim for support of natural enemies (lady-bugs, heteroptera, earwig, and birds such as blackbird, pheasant, or partridge), and application of mulch. From variety experiments are some possible different attacks (attractiveness of varieties for Colorado beetle). The deciding factor can be the content of glycoalcaloids or trichomes on leaves.

Direct crop protection on large area consists of applications of biological insecticide. Currently registered in the Czech Republic are two effective substances: azadirachtin (in Neem Azal T/S) and spinosad (in Spintor). In some states, it is possible to use biological preparation Novodor FC on the basis of bacteria *Bacillus thuringiensis* var. *tenebrionis.*

On smaller areas, it is possible to use labor-intensive way of hand collecting (mainly of spring beetles), which aims to prevent the laying of eggs. Uniquely, it is possible to find special shakers or blowers (eventually vacuums), but they are usually homemade machines or prototypes.

9. Preparation of harvest and harvest methods

Removing stalks happens usually early in organic farming because of late blight (with the removal of stalks, we follow the regulation of inoculum and spread of infection on tubers). In case of very early potatoes, we remove stalks mainly for simplification of harvest and hardening of the peel (in this case 2 to 3 weeks before planed harvest). To remove the stalks, we use a mechanical stalk crusher in organic farming.

In case of production of planting material, stalk removal is necessary and unavoidable mainly from the point of view of viral regulation (eventually the pass of aphids). A more efficient procedure (mainly with planting material) is thermic removal of stalks (fire, vapor, or nitrogen).

On certain conditions it is possible to use even the tweezers of stalks (only with erect vegetation on consistent soil so it would not tear out the tubers). These machines are not available in the Czech Republic, so there are not even used [19].

10. Conclusion

Existing knowledge and experiences in the technology of cultivation of organic potatoes are continuously innovated and specific issues of growers are addressed. Especially valuable are the findings in the field of soil treatment and processing as they affect the soil state and the soil edaphon, which has an irreplaceable role in the system of ecological agriculture. Adequate soil treatment and application of organic materials, combined with biological preparations, have positive impact on the nutritional state of vegetation and are effective ways of how to balance nutrients in organic farming. In our experiments, the nutritional state of vegetation and the tuber yield improved by using soil preparations of Azoter (yield increased by 1.1 t/ha) and AlgaSoil (increase by 0.9 t/ha). The growers solved the nutrient deficit found during vegetation only marginally. Even here, the supply is growing and the organic grower already can apply liquid or organomineral fertilizers with quick nitrogen effect on the basis of actual nutritive state of plants. Another big group of preparation is the so-called supplemental plant preparations. We had the chance to verify some preparations of this group (Albit, Alga 600, Amalgerol, Lignohumate B, PRP-EBV, or Softguard) with positive results. Another benefit of these preparations is their possible effect on the health of plants.

The health, even the tuber yield, of potatoes is possible to influence with some other operation such as the choice of variety, size sorting of planting material, and treatment of plant material. The use of greater size sorting and of tubers of overplanting size increased the tuber yield in combination with early harvest. It is necessary in organic farming to perform biological preparation of planting material (pre-sprouting) because of late blight. Consequential growth of roots and vegetation vitality is possible to support with treatment of planting material before planting or application during planting (on potato planter).

The protection of soil and soil life is also important. The application of mulching material on top of ridges can help in this area (also as anti-erosion precaution). Another benefit of mulch is that it can be used in the regulation of CPB or aphids (mainly if we use herbal mulch or buffer strip), weed regulation (weed biomass was regulated by black mulching fabric and partially by grass mulch applied before emergence), the possibility of temperature and humidity regulation, and also the increase of tuber yield. The tuber yield was largely affected by concrete use of mulching material (the right choice of mulching material unrolls from concrete site and soil conditions).

Initial treatment of potato vegetation happens according to concrete environmental conditions of the year and the grower's experiences. We gain many valuable results about plant extracts of *Azadirachta indica* L., eventually Neem Azal and other plant extracts (*Juglans regia* L., *Pelargonium zonale* L.) as protection against late blight and CPB. However, they are not usable in practise because of their changing effectivity. The main regulation procedure includes: 1. choice and use of resistant varieties; 2. pre-sprouting of planting material and early planting; 3. suitable irrigation regime; 4. interchange of crops; 5. removal of stalks or use of copper fungicide.

Aimed liquidation of stalks stops not only the blight spread, but also its transition to the soil and on tubers. Another area using stalk removal is the regulation of maturation (tuber size) and regulation of viruses (in propagation vegetation). Experimental results indicate, that even after stronger pass of aphids, it is possible to use preventive methods (early varieties, pre-sprouting, early planting, buffer strip, or mulching) in organic farming and regulate the occurrence of viral diseases. Production of planting material is possible even in conditions of organic farming. It demands good knowledge and maximal usage of all regulation methods and procedures.

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Chapter 9

Organic Tuber Production is Promising — Implications of a Decade of Research in India

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Additional information is available at the end of the chapter

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Abstract

Alternative soil management practices like organic farming assume significance in the context of climate change for safe food production. Yams (white yam, greater yam and lesser yam) and edible aroids (elephant foot yam (EFY), taro and tannia) are tuberous vegetables with good taste and nutritive value. Six field experiments were conducted at the ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, India, over a decade (2004–2015) to compare the varietal response, yield, quality and soil properties under organic vs conventional system and develop a learning system. The elite and local varieties of EFY and taro and the three species of yams, including trailing and dwarf genotypes, responded equally well to both the systems. Organic management enhanced the yield by 10–20% and the net profit by 20–40% over chemical farming. The tuber quality was improved with higher dry matter, starch, crude protein, K, Ca and Mg contents. The anti-nutritional factor in EFY, oxalate content, was lowered by 21%. Physico-chemical and biological properties of soil were favoured and the organic system scored a significantly higher soil quality index. The cost-effective technologies were field validated. A learning system developed using artificial neural networks predicted the performance of EFY organic production system.

Keywords: Eco-friendly farming, root crops, yield, quality, soil health, learning system

1. Introduction

Worldwide concerns regarding food safety, environmental degradation and threats to human health have aroused interest in alternative sustainable agricultural systems [1]. “Land degradation” is considered to be one of the world’s greatest environmental challenges as per the UN millennium ecosystem assessment. Globally, 40% of the arable land is seriously degraded and

11% of this is situated in Asia [2, 3]. The land quality for food production ensures future peace. "Organic farming" is a viable option that enables sustainable production, maintenance of soil health, protection of human health and conservation of environment. It envisages non-use of synthetic chemicals, reduced use of purchased inputs and maximum use of on-farm-generated resources [3].

High input conventional agriculture that uses large quantities of chemical inputs and few C additions silently results in irrevocable ecological and environmental calamities [4, 5]. The necessity for environmental conservation along with the desire for safe foods has made organic farming one of the fastest growing agricultural enterprises [6]. It is well documented that there is a great demand for organic produce because of the belief that organic foods are more nutritious than conventionally grown ones [3, 7]. However, the nutritional or qualitative superiority of the organic food has yet to be proved conclusively. Reduced energy use and CO_2 emissions, employment generation, waste recycling and export promotion are the other merits of organic farming [3, 8, 9].

Tropical tuber crops constitute important staple or subsidiary food for about 500 million of the global population. Yams (*Dioscorea* spp.) and aroids are ethnic tuberous vegetables with good taste and medicinal values. They have high content of carbohydrate and are rich in energy. They also have higher protein content and better balance of amino acids than many other root and tuber crops. They are food security crops grown in tropical countries, mainly West Africa, the Caribbean, Pacific Islands and Southeast Asia. Tropical tuber crops in general and edible aroids like EFY, taro and tannia respond well to organic manures. Hence, there is great scope for organic production in these crops [3, 10–14]. There is a great demand for organically produced tuberous vegetables among affluent Asians and Africans living in Europe, USA and Middle East. Research and development on organic farming of tropical tuber crops is less focussed and documented. There is not much documented scientific evidence or information about the effects of organic management on yield, nutritional quality and soil health [3].

2. Why organic agriculture?

The major challenge faced by world agriculture is the production of food for a population of nine billion by 2050, with the anticipated climate change [15, 16]. There is an urgent call for transformations to increase the productive capacity and stability of smallholder agricultural production systems [15]. There is considerable discussion about the inadequacy of the present system of agricultural intensification and growth, which relies on increased use of capital inputs, such as fertilizers and pesticides [15, 17]. The generation of unacceptable levels of environmental damage and problems of economic feasibility are cited as key problems [17, 18]. Increasing concerns about the negative impacts of industrial agriculture have led to a serious debate over the feasibility of transition to alternative forms of agriculture, which are capable of providing a broad suite of ecosystem services while producing stable yields for human use [15}. Greater attention is thus being given to alternative models of intensification, and in particular, the potential of sustainable land management technologies. Such practices can provide private benefits for farmers, by improving soil fertility and structure, conserving soil and water, enhancing the activity and diversity of soil fauna, and strengthening the mechanisms of nutrient cycling [15]. These benefits can lead to increased productivity and stability of agricultural production systems [19–23] and offer a potentially important means of enhancing agricultural returns and food security as well as reducing the vulnerability of farming systems to climatic risk. Organic agriculture is one such promising alternative.

3. Organic farming feasible in selected areas and crops in India

In India, approximately 62% of cropped area is rain-fed, where there is little or no use of fertilizers and other agro-chemicals due to poor resources with smallholder farmers. Thus, promotion of organic farming in India is advocated initially in these rain-fed areas particularly in the hilly regions of northern and northeastern parts and dry land areas of the country. The Fertilizer Association of India has identified totally about 50 districts in the states of Orissa, Jharkhand, Uttranchal, Himachal Pradesh, Jammu and Kashmir, Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh as low-fertilizer-consuming districts with the consumption ranging from 1.79 kg ha^{-1} to 19.80 kg ha^{-1} as against the national average of 90.2 kg ha^{-1} [24, 25]. This means that there is immense scope for organic farming in these selected areas and for selected crops in India, like pulses, oilseeds, tuber crops, etc., for which conventionally little or no fertilizers and agro-chemicals are used. On the other hand, some areas growing tea, coffee, cashew, nuts and spices may be easily brought under organic farming with a thrust on export of organic produce. In other words, rather than promoting organic farming *en masse*, it would be appropriate to carefully delineate areas or crops, where fertilizer use is nil or nominal, or demarcate export-oriented crops that can give a reasonable yield of high-quality produce without using chemicals. It is noteworthy that tuber crops hold great promise in this regard [24].

4. Tuber crops: Underground crops with hidden treasures

Tropical tuber crops, including cassava, yams (greater yam, white yam and lesser yam), sweet potato and aroids (EFY, taro and tannia), form the most important staple or subsidiary food for about 500 million global population [24]. Tuber crops are the third most important food crops for humans after cereals and grain legumes. These crops possess high photosynthetic ability, have the capacity to yield under poor and marginal soil conditions and can tolerate adverse weather conditions. They are also recognized as the most efficient in converting solar energy, cassava producing 250×10^3 kcal ha^{-1} and sweet potato 240×10^3 kcal ha^{-1}, when compared with 176×10^3 kcal ha^{-1} for rice, 110×10^3 kcal ha^{-1} for wheat and 200×10^3 kcal ha^{-1} for maize; hence, the tropical root crops are known to be a cheap source of energy supply. They can serve as a substitute for cereals due to higher contents of carbohydrates and calories. The higher biological efficiency and the highest rate of dry matter production per unit area per unit time make tuber crops inevitable components of our food security systems. Besides, they have the potential to serve as sources of alcohol, starch, sago, liquid glucose, vitamin C and raw materials for many other industrial products and animal feed. At times of famine, tuber crops have come in handy to overcome catastrophes and provide relief from hunger [24].

Tuber crops are cultivated in India mainly as rain-fed crops in the southern, eastern and northeastern states. These crops are the source of livelihood to small and marginal farmers and tribal population in these areas. Cassava production is mainly reported in the states of Kerala, Tamil Nadu, Andhra Pradesh and NEH regions. Sweet potato is cultivated mainly in the states of Orissa, Bihar, Jharkhand, eastern Uttar Pradesh, West Bengal, Madhya Pradesh, Maharashtra and Karnataka. Other tuber crops like yams (greater yam, white yam and lesser yam) and aroids (EFY, taro and tannia), popular as vegetables, are not yet commercially cultivated, being confined only to the home gardens in almost all the states (except EFY, which is cultivated on a commercial scale in Andhra Pradesh) [24].

5. Prospects of organic farming in tropical tuber crops

Organic farming is a viable strategy targeting on sustainable production and soil, environmental and human health hand in hand. Conventional agriculture using chemical inputs results in higher yield, but it is ecologically unfriendly as it has negative impacts on food, soil, water and environmental quality. Indiscriminate use of chemical fertilizers for decades has lowered the organic carbon status of our soils to <1%. Moreover, pesticide residues cause concern over the safety of food. In traditional agriculture, though the use of chemicals (fertilizers and pesticides) is not in practice, adequate care is not often taken for the maintenance of soil health and fertility [24].

Most of the tuber crops are grown by small and marginal farmers in rain-fed areas and tribal pockets and hence the use of chemical fertilizers and insecticides is limited except in the case of cassava in the industrial production areas of Tamil Nadu (Salem, Dharmapuri, Namakkal, and South Arcot districts) and Andhra Pradesh (Rajahmundry district). Tuber crops in general and aroids in particular, like EFY, do respond well to organic manures and there is considerable scope for organic production in these crops. Further, the tropical tuber crops are well adapted to low-input agriculture. They are less prone to pest and disease infestations. Research work done in India and elsewhere had shown that the use of chemical fertilizers are beneficial in maximizing production of these groups of crops. A perusal of data in Table 1 indicates the organic production potential of tropical tubers and experimental evidences clearly indicate that productivity can be achieved satisfactorily even in the absence of chemical fertilizers through proper supplementation of nutrients using organic sources. Moreover, at present, there is a great demand for organically produced vegetables, particularly aroids and yams, among affluent Asians and Africans living in developed nations (Europe, USA and Middle East). The export of these tuberous vegetables will gain impetus through special government programmes like the Agri Export Zone (AEZ) Programme in Kerala [24].

Tuber crop	Tuber yield obtained due to application of organic manure (OM) alone		Tuber yield under OM + NPK			Reference
	OM used	Tuber yield (t ha^{-1})	OM + NPK	Tuber yield (t ha^{-1})	% increase or decrease over OM alone	
Cassava	FYM	10.45	FYM + NPK	28.17	+169.57	[26]
	Ash	12.25	FYM + NPK	28.17	+129.95	[26]
	Ash + FYM	13.29	FYM + NPK	28.17	+111.96	[26]
Sweet potato	FYM	15.57	FYM + NPK	18.88	+21.25	[27]
White yam (intercrop in coconut)	FYM	7.55	FYM + NPK	14.96	+98.15	[28]
	Coir pith compost	9.03	Coir pith compost + NPK	24.61	+172.53	[28]
	Green manuring with sunhemp	7.16	Green manure + NPK	16.06	+124.30	[28]

Source: Reference [29]

Table 1. Organic production potential of tropical tuber crops

6. Issues in organic tuber production

Practical applications and operational methodologies in organic farming, especially in tuber crops, are not available due to lack of comprehensive research in this field. Absence of package of practices recommendations for organic farming of tuber crops hinders the implementation and promotion of this sustainable alternative production system. Many methods and techniques of organic agriculture have originated from various traditional farming systems all over the world, where there is the non-use of chemical inputs. To the maximum extent possible, organic production systems rely on crop rotations, crop residues, animal manures, legumes, green manures, farm wastes, mineral-bearing rocks and aspects of biological pest control to maintain soil productivity, supply plant nutrients and control pests, diseases and weeds. Being highly responsive to organic manures and having fewer pests and disease problems when compared with cereals and vegetables, the main issue in organic production of tuber crops is the proper scientific use of a wide variety of cheaper and easily available organic sources of plant nutrients [24].

7. Strategies for organic tuber production

Building up of soil fertility of the land: Before the establishment of an organic management system, the fertility status of the land must be improved by growing green manure crops like cowpea twice or thrice in a year and incorporation of the green leaf matter at the appropriate pre-flowering stage. This will help re-establish the balance of the eco-system and offset the yield decline, if any, during the initial period of organic conversion, as tuber crops are highly nutrient-depleting crops. Virgin land or barren land, if available, will also be highly suitable for organic farming of tubers [24].

Use of planting materials produced by organic management: Varieties cultivated should be adapted to the soil and climatic conditions and as far as possible resistant to pests and diseases. Local market preference should also be taken into account. The planting materials should be produced by adopting organic management practices [24].

Meeting nutrient needs in organic tuber production: The potential organic sources of plant nutrients for tropical tuber crops are farmyard manure (FYM), poultry manure, composts like vermicompost, coir pith compost, mushroom spent compost, saw dust compost, press mud compost, green manures, crop residues, ash, oil cakes like neem cake, etc. Table 2 indicates the average nutrient contents in these organic sources [24].

Vermicompost, produced by chemical disintegration of organic matter by earthworms, is an ideal blend of plant nutrients with the worm enzyme and probiotics to boost the crop performance. It contains higher amount of nutrients, hormones and enzymes and has stimulatory effect on plant growth. If farmers can produce vermicompost utilizing on-farm wastes, organic farming of tuber crops becomes profitable [24].

Coir pith, an organic waste obtained as a by-product during the process of separation of fibre from coconut husk in the coir industry, is normally resistant to bio-degradation due to its high content of lignin, accumulating as an environmental pollutant. Extraction of 1 kg of coconut fibre generates 2 kg of coir pith, and in India, an estimated 5,00,000 MT of coir pith is produced per annum. The Coir Board in collaboration with TNAU has developed the technology for converting coir pith into organic manure using PITHPLUS, a spawn of edible mushroom, *Pleurotus sajor caju*. Coir pith compost developed from coir waste is a good form of organic manure and a soil conditioner and can be applied to tuber crops [24].

Organic manures	**N (%)**	**P_2O_5 (%)**	**K_2O (%)**
Farmyard manure	0.50	0.20	0.40
Poultry manure	1.20–1.50	1.40–1.80	0.80–0.90
Vermicompost	1.50	0.40	1.80
Coir pith compost	1.36	0.06	1.10
Press mud compost	1.30	2.20	0.50
Mushroom spent compost	1.84	0.69	1.19
Sawdust compost	1.00	0.50	0.50
Biogas slurry	1.41	0.92	0.84
Neem cake	5.00	1.00	1.50
Bone meal	3.50	21.00	–
Municipal compost	1.20	0.04	0.90

Source: Reference [24]

Table 2. Average nutrient contents of some organic manures

The practice of green manuring for improving soil fertility and supplying a part of N requirement of crops is age old. Approximately 15–20 t ha^{-1} of green matter can be obtained from green manure crops like cowpea when grown in systems involving tuber crops. Nitrogen contribution by green manure crops varies from 60 to 280 kg ha^{-1} [24].

Biofertilizers offer a cheap and easily available source of nutrients, especially N and P, besides enhancing the efficiency of native and applied nutrients in the soil. The commonly used N biofertilizer for tuber crops is the N-fixing bacterium, *Azospirillum lipoferum*, which can partially meet the N demand of the crop. Powdered neem cakes also serve as an organic N source. These organic N supplements unlike the fertilizer N do not suffer much loss in the fields and enhances the N recovery. Phosphorus-solubilizing and phosphorus-mobilizing organisms such as phosphobacterium and mycorrhizae are helpful in augmenting P availability of the soil [24].

Besides, natural reserves of rock phosphate are permitted for use as P fertilizer. Potassium for these crops can be supplied using K-rich organic amendments such as wood ash, rice straw and composted coir pith. K mobilizers can also be used for enhancing the K availability and meeting the K requirements. Harnessing the above-mentioned easily available organic sources of plant nutrients conjointly and judiciously to meet the nutrient needs of highly nutrient-exhausting crops like tropical tubers will definitely help maintain/promote productivity in organic farming in the absence of chemical inputs [24].

Pest, disease and weed management: When compared with cereals and vegetables, tuber crops have fewer pest and disease problems. Barring a few major ones, like cassava mosaic disease (CMD), cassava tuber rot, sweet potato weevil (SPW), *Phytophthora* leaf blight in taro, and collar rot in EFY, the others are of minor significance. In general, for the management of pests and diseases, non-chemical measures or preventive cultural techniques can be resorted to. This includes use of tolerant/resistant varieties, use of healthy and disease-free planting materials, strict field sanitation (against almost all), deep ploughing (e.g. tuber rot), roguing the field (e.g. CMD), use of pheromone traps (e.g. SPW), use of trap crops (e.g. SPW, root knot nematodes), adapted crop rotations, use of neem cake (collar rot, tuber rot), use of bio-control agents like *Trichoderma, Pseudomonas* (collar rot, leaf blight), etc. [24].

Normally, two hand weedings are advocated in tuber crops for efficient weed management. As most of the tuber crops (except sweet potato) take approximately 75–90 days for sufficient canopy coverage, raising a short-duration intercrop (like green manure/vegetable/grain cowpea, vegetables, groundnut, etc., in cassava, cowpea in yams and aroids) can also help to a great extent to reduce weed problem. Mulching the crop using any locally available plant materials (green leaves, dried leaves, etc.) immediately after planting (in yams and aroids) will help conserve moisture and regulate temperature, apart from weed control [24].

8. A decade of research on organic farming of tropical tuber crops

The following research programmes were taken up at ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala, India, during 2004–2015:

- Organic farming of EFY
- Varietal response to organic farming in EFY
- Validation and popularization of organic farming technology in EFY
- Organic farming of yams
- Organic farming of taro
- On-farm validation of organic farming of yams and taro

The major objectives were:

- To develop appropriate technologies for organic production of EFY, yams and taro, which would be safe and of good quality
- To assess the impact of organic farming in these crops on productivity, tuber quality, soil health and economics

8.1. Methodology

8.1.1. Study site, experimental design, treatments and test variety

Six separate field experiments were conducted at ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, India, over a decade (2004–2015) to compare organic management over conventional system in EFY, yams and taro in an acid Ultisol (pH: 4.3–5.0). The site experiences a typical humid tropical climate. The mean annual rainfall was 1,985 mm, maximum and minimum temperatures were 31.35°C and 24.50°C, respectively, and relative humidity was 76.65%. In general, for all the sites, prior to experimentation, the fertility status of the soil was found to be medium to high for organic C (0.75–1.03%), low for available N (159–255 kg ha^{-1}) and high for available P (142–217 kg ha^{-1}) and available K (337–528 kg ha^{-1}).

The impact of conventional, traditional, organic and biofertilizer production systems was evaluated in randomized block design (RBD) in EFY (var. Peerumade local) with five replications. Comparative response of five varieties of EFY (Gajendra, Sree Padma, Sree Athira and two locals) under organic and conventional farming was also evaluated in split plot design. The gross plot size was 4.5 m × 4.5 m (25 plants) accommodating nine net plants. All the three trailing genotypes of edible *Dioscorea* (white yam: *D. rotundata* (var. Sree Priya), greater yam: *D. alata* (var. Sree Keerthi) and lesser yam: *D. esculenta* (var. Sree Latha)) were evaluated under conventional, traditional and organic farming systems in split plot design. The gross plot size was 7.2 m × 3.6 m (32 plants of white yam and greater yam and 36 plants of lesser yam) accommodating 12 net plants of white yam and greater yam and 14 plants of lesser yam. The dwarf genotype of white yam (var. Sree Dhanya) was also evaluated under conventional, traditional, organic and integrated systems in RBD with five replications. Similarly, the response of three varieties of taro (Sree Kiran, Sree Rashmi and local) to conventional, traditional and organic farming systems was studied in split plot design. In split plot design, varieties/species were assigned to main plots and production systems to sub-plots and replicated thrice. Details of production systems are given in Table 3.

The on-station organic production technology developed for EFY was validated through on-farm trials (OFT) conducted at 10 sites covering 5 ha in Kerala under the project financed by the National Horticulture Mission. In yams and taro, the technologies were confirmed through OFT conducted at seven sites.

Chemical inputs were not used for a year prior to the start of the investigations. In "conventional plots", FYM + nitrogen, phosphorus, potassium (NPK) fertilizers were applied. Farmers' practice of using FYM and ash was followed in "traditional plots". In "organic farming plots", FYM, green manure, ash, neem cake and/or biofertilizers were applied to substitute chemical fertilizers. In "biofertilizer farming", FYM, mycorrhiza, *Azospirillum* and phosphobacterium were applied. In "integrated farming", FYM, chemical fertilizers and biofertilizers were used. Organically produced planting materials were used for the study.

Crop	**Description of production systems**			
	Conventional	**Traditional**	**Organic**	**Biofertilizers/integrated**
EFY	FYM @ 25 t ha^{-1} + NPK @ 100:50: 150 kg ha^{-1}	FYM @ 36 t ha^{-1} + ash @ 3 t ha^{-1}	Seed treatment in FYM + neem cake + *Trichoderma harzianum* slurry. Application of FYM @ 36 t ha^{-1} (FYM: neem cake mixture (10:1 ratio) incubated with *Trichoderma harzianum*) + *in situ* green manuring with cowpea (green matter @ 20–25 t ha^{-1}) + neem cake @ 1 t ha^{-1} + ash @ 3 t ha^{-1}	Biofertilizers FYM @ 25 t ha^{-1} mycorrhiza @ 5 kg ha^{-1} *Azospirillum* @ 3 kg ha^{-1} and phosphobacteria @ 2.5 kg ha^{-1}
Yams	FYM @ 10 t ha^{-1} + NPK @ 80:60:80 kg ha^{-1}	FYM @ 15 t ha^{-1} + ash @ 1.5 t ha^{-1}	FYM @ 15 t ha^{-1} + *in situ* green manuring with cowpea (green matter @ 15–20 t ha^{-1}) + neem cake @ 1 t ha^{-1} + ash @ 1.5 t ha^{-1} + biofertilizers (*Azospirillum* @ 3 kg ha^{-1} mycorrhiza @ 5 kg ha^{-1} and phosphobacteria @ 3 kg ha^{-1})	
Dwarf white yam	FYM @ 10 t ha^{-1} + NPK @ 80:60:80 kg ha^{-1}	FYM @ 15 t ha^{-1} + ash @ 1.5 t ha^{-1}	FYM @ 15 t ha^{-1} + *in situ* green manuring with cowpea (green matter @ 15–20 t ha^{-1}) + neem cake @ 1 t ha^{-1} + ash @ 1.5 t ha^{-1} + biofertilizers (*Azospirillum* @ 3 kg ha^{-1} and mycorrhiza @ 5 kg ha^{-1})	Integrated FYM @ 10 t ha^{-1} + NPK @ 40:30:80 kg ha^{-1} + biofertilizers (*Azospirillum* @ 3 kg ha^{-1} and mycorrhiza @ 5 kg ha^{-1})
Taro	FYM @ 12 t ha^{-1} + NPK @ 80:25:100 kg ha^{-1}	FYM @ 15 t ha^{-1} + ash @ 2.0 t ha^{-1}	FYM @ 15 t ha^{-1} + *in situ* green manuring with cowpea (green matter @ 15–20 t ha^{-1}) + neem cake @ 1 t ha^{-1} + ash @ 2.0 t ha^{-1} + biofertilizers (*Azospirillum* @ 3 kg ha^{-1}, mycorrhiza @ 5 kg ha^{-1}and phosphobacteria @ 3 kg ha^{-1})	

Table 3. Description of production systems in various organic farming experiments

8.1.2. Plant and soil measurements

Pooled analysis of yield data was performed. Yield stability index was calculated using the following formula: stability index = (Avg Y−SD)/Ymax, where Avg Y = average yield over five years, SD = standard deviation, Ymax = maximum yield over the five years. A stability index value towards unity indicates greater stability. Proximate analyses of tubers for dry matter, starch, total sugars, reducing sugars, crude protein, oxalates and total phenols [30–33], mineral composition of corms, namely P, K, Ca, Mg, Cu, Zn, Mn and Fe contents [34], chemical parameters of soil, namely organic C (soil organic matter (SOM)), pH, available N, P, K, Ca, Mg, Cu, Zn, Mn and Fe status [35], physical characters of the soil such as bulk density, particle density, water-holding capacity (WHC) and porosity [36], plate count of soil microbes, namely bacteria, fungi, actinomycetes, N fixers and P solubilizers [37] and the activity of dehydrogenase enzyme [38], were determined by standard procedures. Economic analysis was performed; net income and benefit:cost ratio were computed. The soil quality index (SQI) was computed in EFY based on the method developed by Karlen and Stott [39]. The analysis of variance of data was performed using reference [40] by applying analysis of variance technique (ANOVA) for RBD and split plot design.

8.1.3. Development of a learning system

A learning system was developed using artificial neural networks (ANN) to predict the performance of EFY production system [41, 42]. A three-layered system with one input layer, one output layer and one hidden layer was developed. The input layer neurons included temperature, rainfall, planting material, FYM, potassium, phosphorus, ash, neem cake, *Azospirillum*, phosphobacteria, mycorrhiza and green manure. The output layer neurons were total biomass, corm yield, canopy spread and plant height.

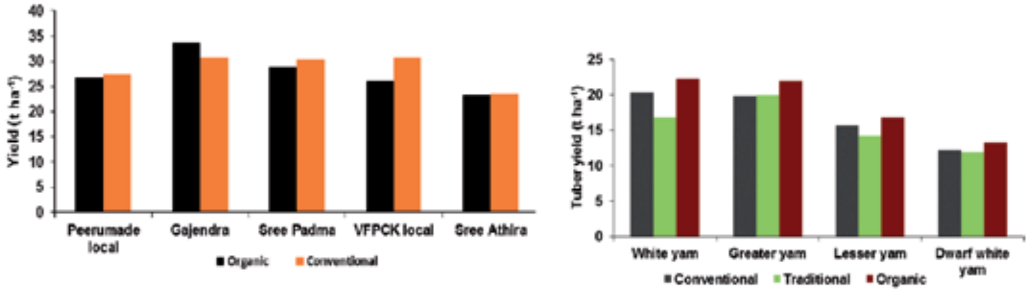
8.2. Implications

8.2.1. Varietal response to organic management

Pooled analysis indicated that the elite and local varieties of EFY and taro and all the three species of *Dioscorea* were on a par under both the systems (Figure 1). However, the Gajendra variety of EFY and all the species of *Dioscorea* yielded more under organic farming than conventional practice (Figure 1). In taro, all the varieties produced slightly higher yield under chemical farming.

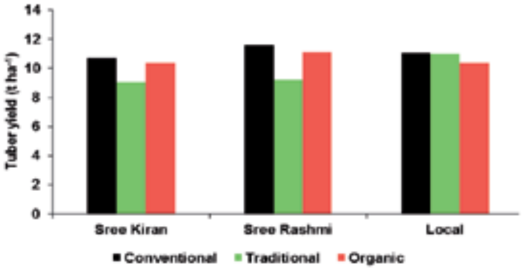
8.2.2. Yield and economics

Organic farming resulted in 10–20% higher yield in EFY, white yam, greater yam, lesser yam and dwarf white yam, i.e., 20, 9, 11, 7 and 9%, respectively (Table 4). This is contrary to some of the reports that crop yields under organic management are 20–40% lower than those under comparable conventional systems [43, 44]. Taro preferred chemical-based farming as a slight reduction in the crop yield was noticed under organic farming (5%).



EFY

Yams



Taro

Figure 1. Varietal response to organic farming in tuber crops

It has been reported that yields were directly related to the intensity of farming in the prevailing conventional system [45, 46]. This means that in areas of intensive farming system, shifting to organic agriculture decreases the yield depending on the intensity of external input use before conversion [48, 49]. As EFY and yams are traditionally grown with low external inputs using organic wastes and manures available in the homesteads, organic management in the present study has shown a potential to increase yields over conventional practice. The higher yield may be due to the overall improvement in the physico-chemical and biological properties of soil under the influence of organic manures [9, 50, 51].

Tuber crop	Conventional	Organic	% increase/decrease
EFY	47.61	57.10	19.93
White yam	20.31	22.21	9.35
Greater yam	19.87	21.96	10.51
Lesser yam	15.75	16.83	6.85
Dwarf white yam	13.23	12.18	8.62
Taro	11.12	10.61	−4.58

Source: Reference [47]

Table 4. Yield (t ha^{-1}) under organic vs conventional management in tuber crops (pooled mean)

Tropical tuber crops, like EFY and yams, are nutrient-exhausting crops. In general, the nutrient removal by these crops yielding 17–33 tonnes of tuber was 112–180 kg N, 15–24 kg P and 93–239 kg K per ha [52]. The potential yield of these crops can be obtained by proper renewal of soil with adequate amounts of nutrients. These results highlight that in the absence of chemical fertilizers, in organic agriculture, a higher yield can be obtained through proper addition of nutrients based on soil testing by way of cheaper and easily available, on-farm-generated organic sources [3].

The long-term performance of organic vs conventional management in aroids and yams was analysed through the stability index calculated over a five-year period, and it was found that organic farming was equally stable as that of conventional practice (Figure 2).

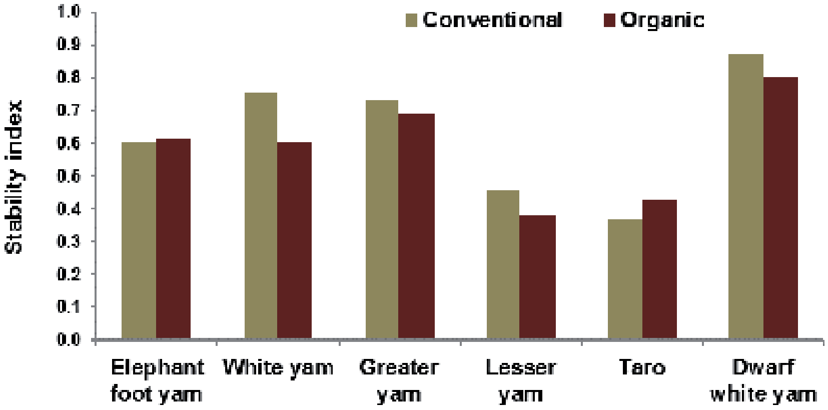


Figure 2. Yield stability index in organic vs conventional management in aroids and yams

The view of field experimentation in EFY is given in Figure 3. Yield trend over five years and pooled analysis indicated the significantly superior performance of organic farming in EFY (Figure 4; Table 5). Cost–benefit analysis in EFY indicated that the net profit was 28% higher and an additional income of Rs. 47,716 ha^{-1} was obtained due to organic farming, which was obviously due to 20% higher yield [12] (Table 5).

In yams, up to third year, organic farming proved to be superior; thereafter, it was on a par and slightly lower than conventional practice. Pooled analysis in yams indicated that organic farming was significantly superior to conventional practice and produced 9.12% higher yield (Figure 5; Table 6). Species × production systems interaction was absent. However, in all the species, organic farming produced slightly higher yield than conventional practice. Dwarf white yam also responded similarly to both the systems with slightly higher yield under organic practice (Figures 6 and 7).

In taro, yield trend over five years (except during the first year, when organic farming was superior to conventional practice) and pooled mean indicated that organic farming was on a par with conventional practice, but chemical farming produced a slightly higher yield (Table 4; Figures 8 and 9). This was because taro leaf blight could not be controlled by organic measures.

Field view of organic farming of EFY Organic corms

Conventional corms Bumper yield of organic corms

Figure 3. View of field experimentation in EFY

Production systems	Mean corm weight (kg plant^{-1})	Corm yield (t ha^{-1})	Gross income (Rs. ha^{-1})	Gross costs (Rs. ha^{-1})	Net income (Rs. ha^{-1})	B:C ratio
	(Pooled mean of 5 years)					
Conventional	3.91	47.61	3,80,872	2,12,812	1,68,060	1.79
Traditional	3.69	44.96	3,59,680	2,18,800	1,40,880	1.64
Organic	4.69	57.10	4,56,776	2,41,000	2,15,776	1.90
Biofertilizers	3.45	42.07	3,36,528	2,16,240	1,20,288	1.56
CD (0.05)	0.292	3.550				

Source: Reference [12]

Table 5. Yield and economic advantage of organic farming over other production systems in EFY

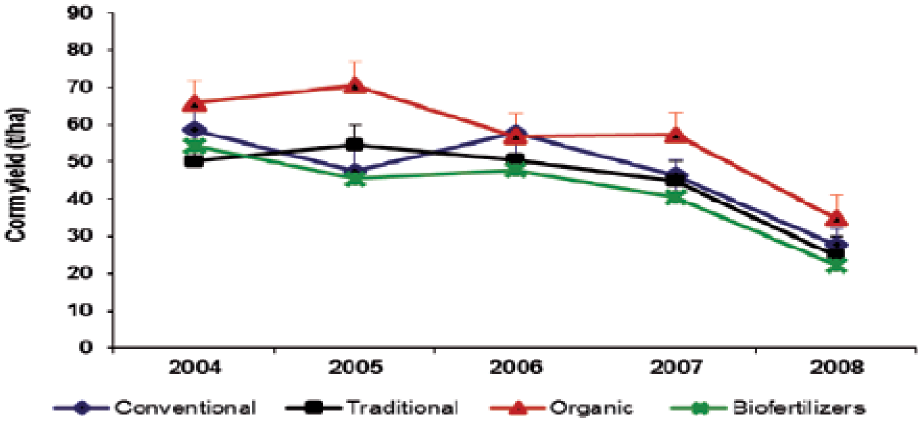


Figure 4. Yield trend over years as influenced by production systems in EFY

Field view of organic farming of yams: Green manuring, cost effective component

Organic white yam tubers

Organic greater yam tubers

Organic lesser yam tubers

Figure 5. Field experimentation on organic farming of trailing genotypes of yams

Species/production systems	Conventional system	Traditional system	Organic system	Mean of *Dioscorea* species
Dioscorea rotundata	20.31	16.76	22.21	19.76
Dioscorea alata	19.87	19.97	21.96	20.61
Dioscorea esculenta	15.75	14.18	16.83	15.58
Mean of production systems	18.64	16.97	20.34	
CD (0.05)	*Dioscorea* species: 1.23; production systems: 1.23; species × systems: NS			

Source: Reference [3]

Table 6. Yield response of *Dioscorea* species to production systems (t ha^{-1}) (pooled mean)

Field view of organic farming of dwarf white yam: Green manuring, cost effective component

Figure 6. Field experimentation on organic dwarf white yam production

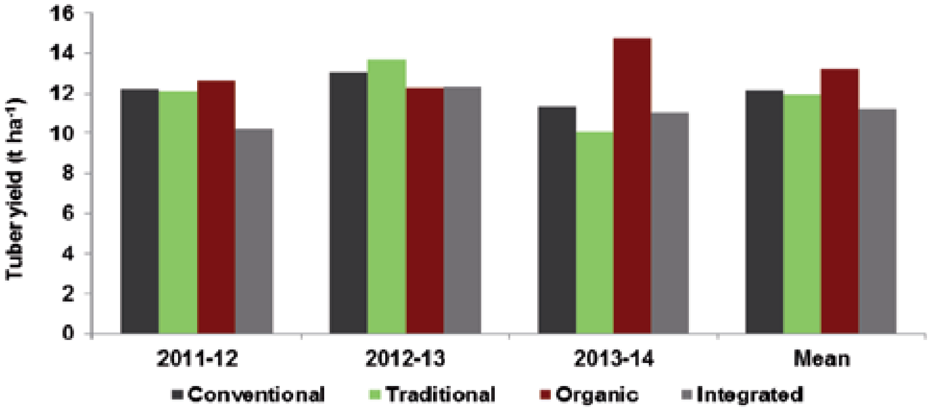


Figure 7. Yield trend over years as affected by production systems in dwarf white yam

Figure 8. Field view of organic taro production with green manuring as the component

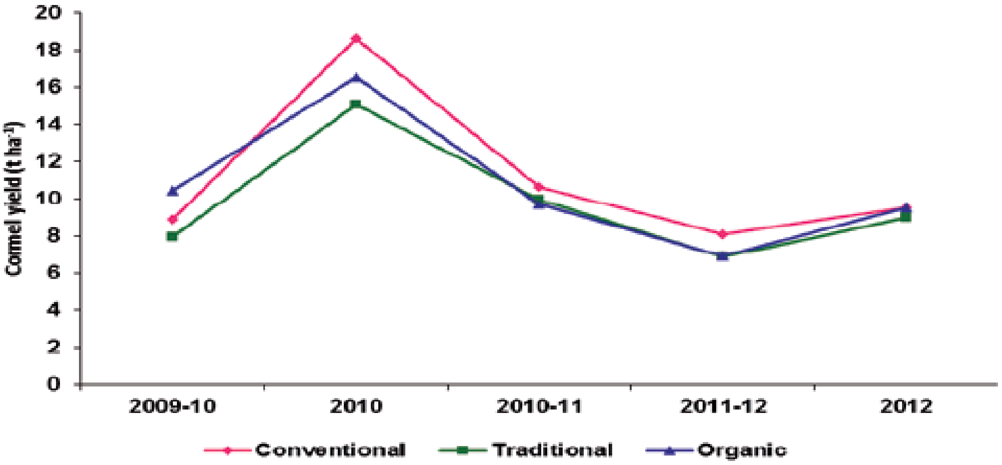


Figure 9. Yield trend as affected by production systems in taro

8.2.3. Nutritional quality of tubers

It is well known that plants absorb nutrients in the form of inorganic ions irrespective of whether the nutrient source is organic or inorganic. The absorbed nutrients are re-synthesized into compounds that determine the quality of the produce, which is largely decided by the genetic make-up of the plants [5, 12]. However, in the present research, dry matter and starch contents of organically produced EFY corms were significantly higher (by 7 and 13%), and crude protein (by 12%), K, Ca and Mg (by 3–7%) were slightly higher than those of conventional corms (Tables 7 and 8 and Figures 10 and 11). The anti-nutritional factor, oxalate, content in EFY was significantly lower (by 21%) due to organic management. Total sugar and total phenol contents of conventional corms were significantly higher. In yams, the tuber quality was improved with significantly higher Ca, slightly higher dry matter, crude protein (by 6–7%), K and Mg contents. Synthetic fertilizers enhanced the total sugars, reducing sugars and total phenol contents slightly. The cooking quality of organically produced tubers did not differ from that of conventional tubers (Tables 7 and 8 and Figures 10 and 11).

Earlier reports indicate that organic crops contain more dry matter, minerals, especially Fe, Mg and P, by 21, 29 and 14% over conventionally produced ones [7]. As stated in references [3, 53], higher levels of K were found in organic tomatoes. There is a higher population of micro-organisms in organically managed soil. These micro-organisms produce many compounds that combine with soil minerals and make them more available to plant roots [54], which might have ultimately enhanced the mineral content of tubers.

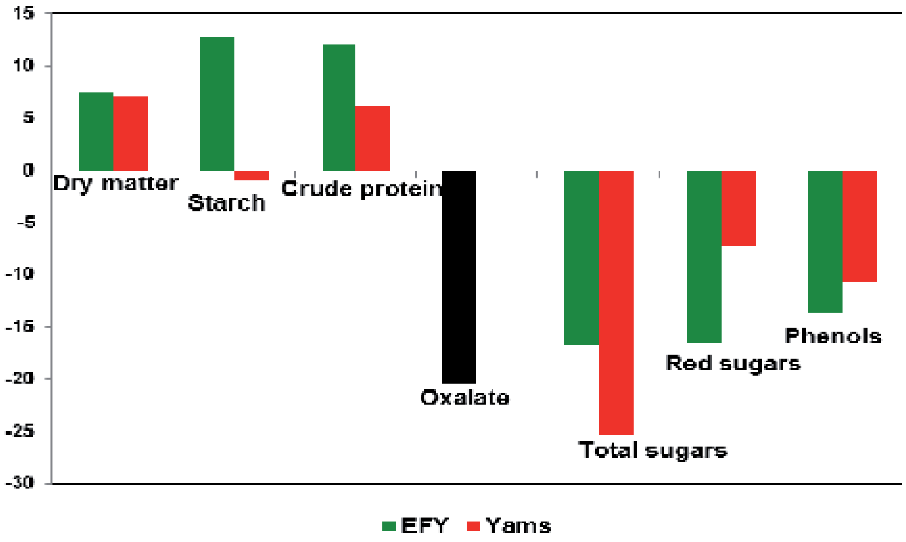


Figure 10. Per cent increase/decrease in biochemical parameters of organic tubers

Biochemical parameters	EFY			Yams		
	Organic	Conventional	CD (0.05)	Organic	Conventional	CD (0.05)
Dry matter (%)	21.41	19.93	1.061	33.56	31.36	NS
Starch (% FW basis)	16.54	14.68	0.937	26.40	26.70	NS
Crude protein (% FW basis)	2.04	1.82	NS	2.04	1.92	NS
Oxalate (% DW basis)	0.186	0.234	0.0259			
Total sugars (% FW basis)	1.98	2.38	0.257	1.88	2.52	NS
Reducing sugar (% FW basis)	0.65	0.78	NS	0.12	0.13	NS
Total phenols (mg 100 g^{-1})	69.70	80.80	8.28	37.20	61.60	NS

Source: Reference [14]

Table 7. Comparison of biochemical constituents of organic vs conventional tubers

Mineral content (mg 100 g^{-1}) (DW basis)	EFY			Yams		
	Organic	Conventional	CD (0.05)	Organic	Conventional	CD (0.05)
P	427.50	455.20	NS	411.80	472.40	39.79
K	1813.00	1714,00	207.40	1,051.30	1,026.70	NS
Ca	152.20	142.00	17.58	72.70	57.70	11.35
Mg	276.50	268.10	NS	180.60	161.70	NS
Cu	1.04	1.08	NS	0.24	0.29	NS
Zn	11.02	11.62	NS	4.49	4.45	NS
Mn	2.32	3.21	0.419	0.35	0.32	NS
Fe	71.90	86.60	NS	5.03	5.13	NS

Table 8. Comparison of mineral content of organic vs conventional tubers

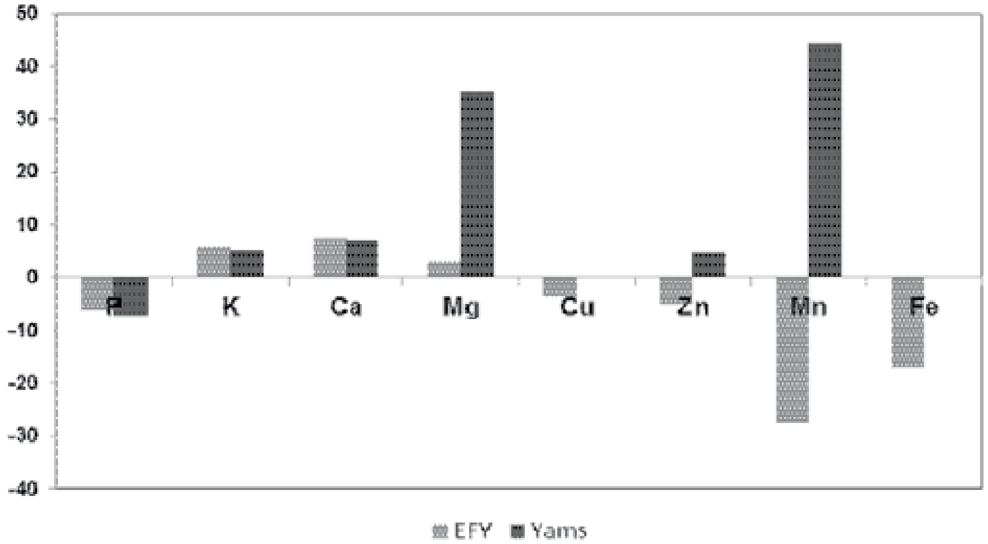


Figure 11. Per cent increase/decrease in mineral composition of organically produced tubers

Biochemical parameters of tubers were not significantly affected in taro and dwarf white yam. However, in taro, organic cormels had higher dry matter, starch and total sugars; conventional cormels had higher phenol, fibre and ash contents. Mineral content of cormels of taro also remained unaffected due to the production systems, though there was a slight increase in P, K, Ca and Mg contents in organic cormels (Figure 12).

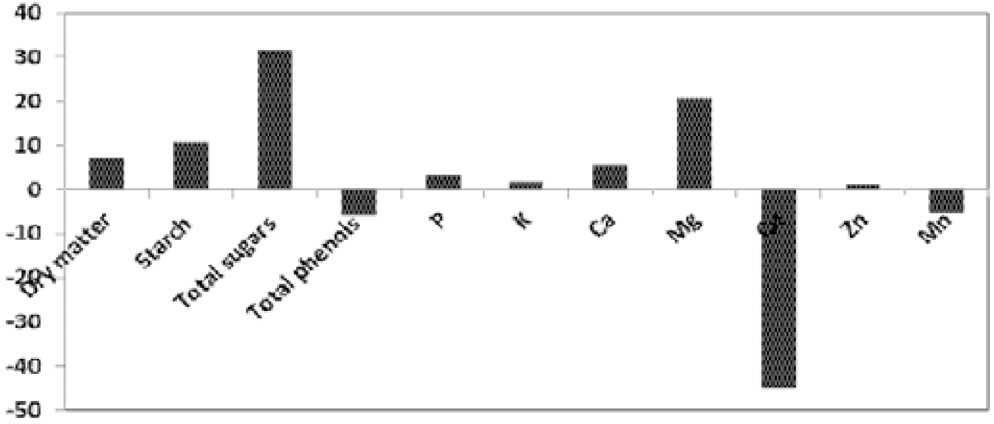


Figure 12. Per cent increase/decrease in biochemical and mineral composition in organic cormels of taro

8.2.4. Soil quality

8.2.4.1. Physico-chemical–biological indicators

The water-holding capacity was significantly higher under organic management (14 g cm^{-3}) in EFY and yams over conventional practice (11–12 g cm^{-3}). It was 28, 15 and 19% higher than that of conventional practice in EFY, yams and taro, respectively (Tables 9 and 10). Increased aeration, porosity and water-holding capacity of soils have been observed under organic management [51, 55, 56]. Moreover, changes in organic matter contribute to changes in soil biological and physical properties [9]. The higher organic C and organic matter contents under organic management in these crops might have resulted in the formation of stable soil aggregates leading to a slight decrease in bulk density and increase in water-holding capacity [3].

There was significant improvement in pH in organic farming (0.77, 0.46, 1.11 and 1.20 unit increase over conventional system) in EFY, trailing yams, dwarf white yam and taro (Tables 11 and 12). Several earlier workers have reported that significant improvement in pH under organic management may be due to elimination of NH_4 fertilizers, addition of cations especially via green manure applications, decrease in the activity of exchangeable Al^{3+} ions in soil solution due to chelation by organic molecules and self-liming effect of the Ca content in FYM (0.14%) and ash (20–40%) [3, 57–59].

The organic C content increased by 14–40% in organic plots over conventional plots in these crops (Tables 11 and 12). Higher organic C status of organic plots might be attributed to considerable addition of organic manures particularly green manure cowpea. In EFY, exchangeable Mg, available Cu, Mn and Fe contents were significantly higher in organic plots (Figure 13). Organic plots showed significantly higher available K (by 34%) in yams and available P in taro (Tables 11 and 12). Higher available P in organic plots may be due to solubilization of native P by organic acids during decomposition of organic manures and increased mineralization of P from the added organic manures [3, 12]. The higher content of available K in organic plots may be due to the higher content of K in the organic manures, especially green manure and ash (Table 2), greater mining of K from the sub-surface layers by the extensive root system of green manure crop of cowpea, and dissolution of K from the inaccessible K minerals in the soil by organic acids during green manure decomposition [3, 12].

The soil pH is the most important determinant of soil nutrient availability. As reported in reference [59], the rise in soil pH to neutral range under organic management in these crops might have enhanced the availability of major, secondary and micro-nutrients to some extent. Moreover, organic manures used in the study, FYM, green manure cowpea and neem cake that contain major, secondary and micro-nutrients might also have contributed to this [3, 12].

hysical parameters	**EFY**				**Yams**			
	Organic	Conventional	CD (0.05)	% increase or decrease	Organic	Conventional	CD (0.05)	% increase or decrease
Bulk density (g cm^{-3})	1.54	1.58	NS	−2.29	1.61	1.63	NS	−1.23
Particle density (g cm^{-3})	2.29	2.30	NS	−0.61	2.27	2.40	NS	−5.42
Water-holding capacity (%)	14.11	10.99	2.442	+28.38	14.21	12.38	1.604	+14.78
Porosity (%)	36.51	31.35	NS	+16.45	31.30	32.07	NS	−2.40

Source: Reference [14]

Table 9. Comparison of physical parameters of soil under organic vs conventional management in EFY and yams

At present, deficiency of secondary and micro-nutrients (Zn, S, B, Mo, Fe, Mn and Cu) is a rampant soil problem affecting crop productivity and profitability of farming in India [5, 12]. This is mainly due to the continuous use of high analysis fertilizers, which do not provide secondary and micro-nutrients. Based on research conducted for a decade in these crops, it has been proved beyond doubt that organic farming helps to reinstate soil productivity. Organic agriculture that envisages elimination of synthetic chemical fertilizers through strict use of organic manures helps to refurbish the soil health, by improving organic matter, neutralizing soil acidity, supplying almost all essential nutrients in the available form and ultimately conserving soil fertility [3, 5, 12].

Physical parameters	**Taro**			
	Organic	**Conventional**	**CD (0.05)**	**% increase or decrease**
Bulk density (g cm^{-3})	1.72	1.74	NS	−1.38
Particle density (g cm^{-3})	2.63	2.63	NS	+0.26
Water-holding capacity (%)	11.73	9.84	NS	+19.20
Porosity (%)	34.64	33.64	NS	+2.97

Table 10. Comparison of physical parameters of soil under organic vs conventional management in taro

Chemical parameters	**EFY**				**Yams**			
	Organic	Conventional	CD (0.05)	% increase or decrease	Organic	Conventional	CD (0.05)	% increase or decrease
pH	5.32	4.55	0.285	+0.77 unit	5.47	5.01	0.212	+0.46 unit
Organic C (%)	1.40	1.18	NS	+19.02	0.86	0.75	NS	+14.00
Available N (kg ha^{-1})	125.60	103.30	NS	+21.59	193.00	162.00	NS	+19.14
Available P (kg ha^{-1})	65.20	57.30	NS	+13.13	270.00	289.00	NS	−6.57
Available K (kg ha^{-1})	362.00	340.90	NS	+6.19	343.50	256.40	40.21	+33.97

Table 11. Comparison of chemical parameters of soil under organic vs conventional management in EFY and yams

The population of bacteria was considerably higher in organic plots than in conventional plots; 41 and 23% higher in EFY and yams, respectively. Organic farming also favoured the fungal population by 17–20%. While the N fixers showed an upper hand in organically managed soils by 10% over conventional management under EFY, P solubilizers remained more conspicuous under organic management of yams (22% higher than conventional management) (Table 13). The dehydrogenase enzyme activity was higher by 23 and 14% in organic plots in EFY and yams (Table 13).

In these studies, the organic resources used to replace chemical fertilizers were FYM, green manure, neem cake and ash. Green manuring with cowpea (incorporation of 15–20 t ha^{-1} of green matter) was the most cost-effective component among these. The decomposition of these organic manures to release available plant nutrients involves intense microbial activity over chemical fertilizer-applied conventional plots. This might have resulted in higher microbial population and dehydrogenase enzyme activity in the organic plots. Several earlier workers also noticed increased microbial population in cultivated organically managed soil [3, 9, 60].

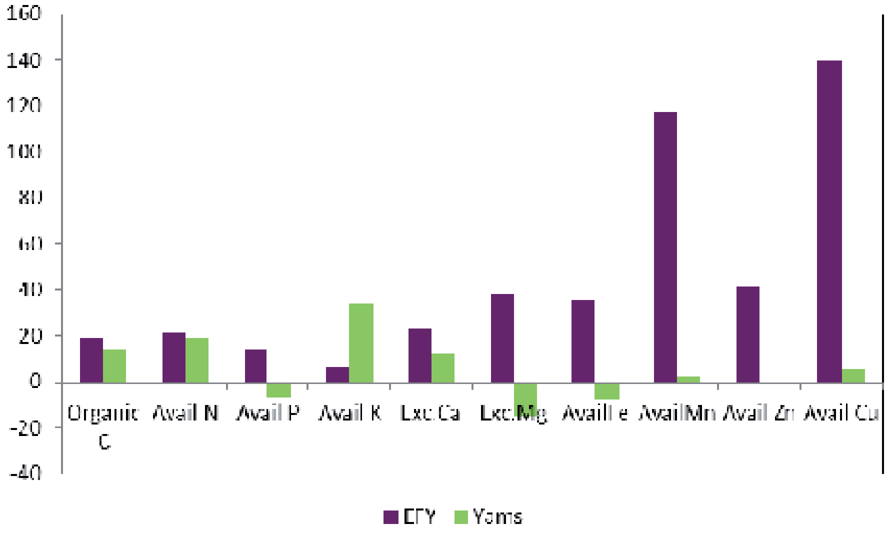


Figure 13. Per cent increase or decrease in chemical properties of soil under organic management in EFY and yams

Chemical parameters	Dwarf white yam				Taro			
	Organic	Conventional	CD (0.05)	% increase or decrease	Organic	Conventional	CD (0.05)	% increase or decrease
pH	5.68	4.56	0.467	+1.11 unit	6.68	5.48	0.473	+1.20 unit
Organic C (%)	2.29	1.97	NS	+16.46	0.84	0.60	NS	+39.03
Available N (kg ha^{-1})	119.80	109.80	NS	+9.11	105.00	103.50	NS	+1.45
Available P (kg ha^{-1})	107.30	98.00	NS	+9.49	75.10	47.10	20.34	+59.44
Available K (kg ha^{-1})	453.00	312.00	NS	+45.19	148.00	202.00	NS	−26.73

Table 12. Comparison of chemical parameters of soil under organic vs conventional management in dwarf white yam and taro

8.2.4.2. Development of SQI

In EFY, the organic system scored a significantly higher SQI (1.930), closely followed by the traditional system (1.913) (Figure 14). The SQI of conventional (1.456) and biofertilizer systems (1.580) were significantly lower. The SQI was driven by water-holding capacity, pH and available Zn followed by SOM.

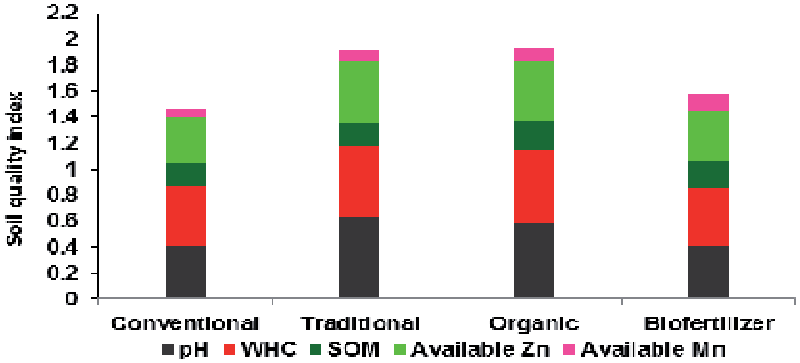


Figure 14. Effect of production systems on SQI in EFY (Source: Reference [13])

Biological Parameters	EFY				Yams			
	Organic	Conventional	CD (0.05)	Per cent increase (+) or decrease (-) in organic farming	Organic	Conventional	CD (0.05)	Per cent increase (+) or decrease (-) in organic farming
Bacteria (cfu g^{-1} soil)	31×10^7	22×10^7	NS	+40.90	118×10^3	96×10^3	NS	+22.91
Fungi (cfu g^{-1} soil)	6×10^6	5×10^6	NS	+20.00	7×10^2	6×10^2	NS	+16.66
Actinomycetes (cfu g^{-1} soil)	22×10^5	24×10^5	NS	−8.33	11×10^3	12×10^3	4.682	−8.33
N fixers (cfu g^{-1} soil)	182×10^5	165×10^5	NS	+10.30	7×10^3	11×10^3	NS	−36.36
P solubilizers (cfu g^{-1} soil)	5×10^6	5×10^6	NS	0	11×10^3	9×10^3	NS	+22.22
Dehydrogenase enzyme (μg TPF formed g^{-1} soil h^{-1})	1.625	1.323	NS	+22.82	1.174	0.786	NS	+49.36

Source: Reference [14]

Table 13. Comparison of biological parameters of soil under organic vs conventional management in EFY and yams

Soil quality is the capacity of a soil to function within natural or managed ecosystem boundaries to sustain plant and animal productivity in order to maintain or enhance water and air quality and support human health and habitation [61]. In this study, organic farming, which is a supplemental C management practice (SCMP) significantly changed a number of soil properties including soil pH, SOM, exchangeable Mg, available Cu, Mn and Fe contents and WHC. Thus, the indicator properties could be changed mainly through SOM building practices brought about by the strict use of organic manures especially green manuring continuously for five years under organic management. This framework emphasizes that soil quality assessment is a tool that can be used to evaluate the effects of land management on soil function.

9. On-farm validation of organic production technologies

Demonstration trials were conducted during 2008–2009 in 10 farmers' sites to cover an area of 5 ha in Kollam and Pathanamthitta districts of Kerala to compare the yield, quality, economics and soil fertility under the organic management practices with the existing farmers' practice and conventional practice (present package of practices recommendations) in EFY (Figure 15). Organic farming resulted in higher corm yield (34.60 t ha^{-1}) and additional income (Rs. 43,651 ha^{-1}) over conventional farming. Organically produced corms had significantly higher dry matter and Mg contents and significantly lower oxalate content. The chemical properties of the soil, especially K, was seen to be favoured under organic farming (Table 14).

Production systems	Yield (t ha^{-1})	Corm dry matter (%)	Oxalate (DW basis %) content of corms	Mg content of corms (mg 100 g)	Available K of soil (kg ha $^{-1}$)	Net income (Rs ha^{-1})	B:C ratio
Conventional	24.50	19.29	0.221	91.90	98.80	70,069	1.40
Traditional	22.20	20.00	0.218	91.80	88.70	41,925	1.23
Organic	34.60	21.00	0.191	95.30	142.70	1,13,720	1.49
CD (0.05)	7.750	1.162	0.0076	2.045	40.02		

Source: Reference [11]

Table 14. Agronomic, nutritional and economic implications of organic management in EFY under validation trials

OFT were laid out in seven sites with three practices, conventional, traditional and organic, in Thiruvananthapuram and Kollam districts of Kerala to validate the on-station-developed organic farming technologies in yams (greater yam, lesser yam and dwarf white yam) and taro (Figure 15). In all sites, tuber yield under organic management was on a par with conventional practice in these crops (Figure 16). However, the yields under organic management were 8, 17, 21 and 29% higher over chemical-based farming in greater yam, lesser yam, dwarf white yam and taro, respectively. In general, there was significant improvement in pH, organic C and available K status under organic management in the sites. Soil microbial population was also improved under organic practice in these sites.

Farmers convinced about green manuring

Organic corms of EFY

View of OFT on yams and taro

Farmers with organic tubers of greater yam

Figure 15. On-farm validation trials conducted in Kerala

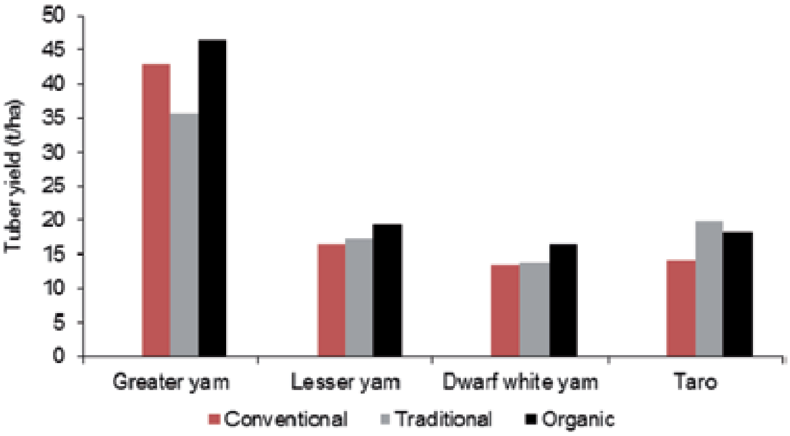


Figure 16. Yield under various practices in OFT in yams and taro

10. The package

Use of organically produced seed materials, seed treatment in cow-dung, neem cake, bio-inoculant slurry, FYM incubated with bio-inoculants, green manuring, use of neem cake, bio-fertilizers and ash formed the strategies for organic production (Figure 17). The organic farming package for EFY is included in the Package of Practices Recommendations for crops by Kerala Agricultural University [62].

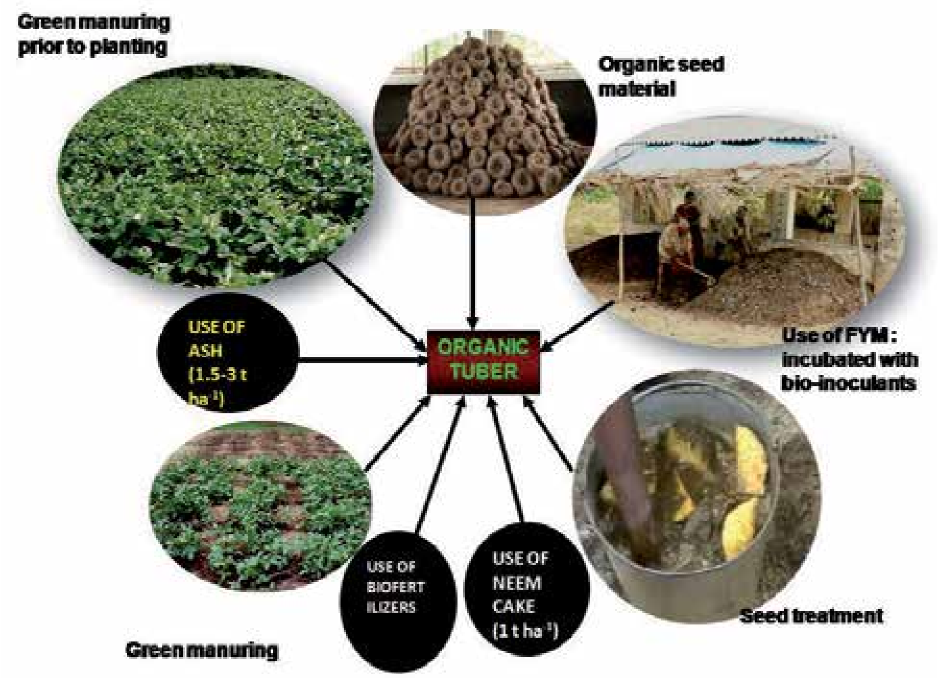


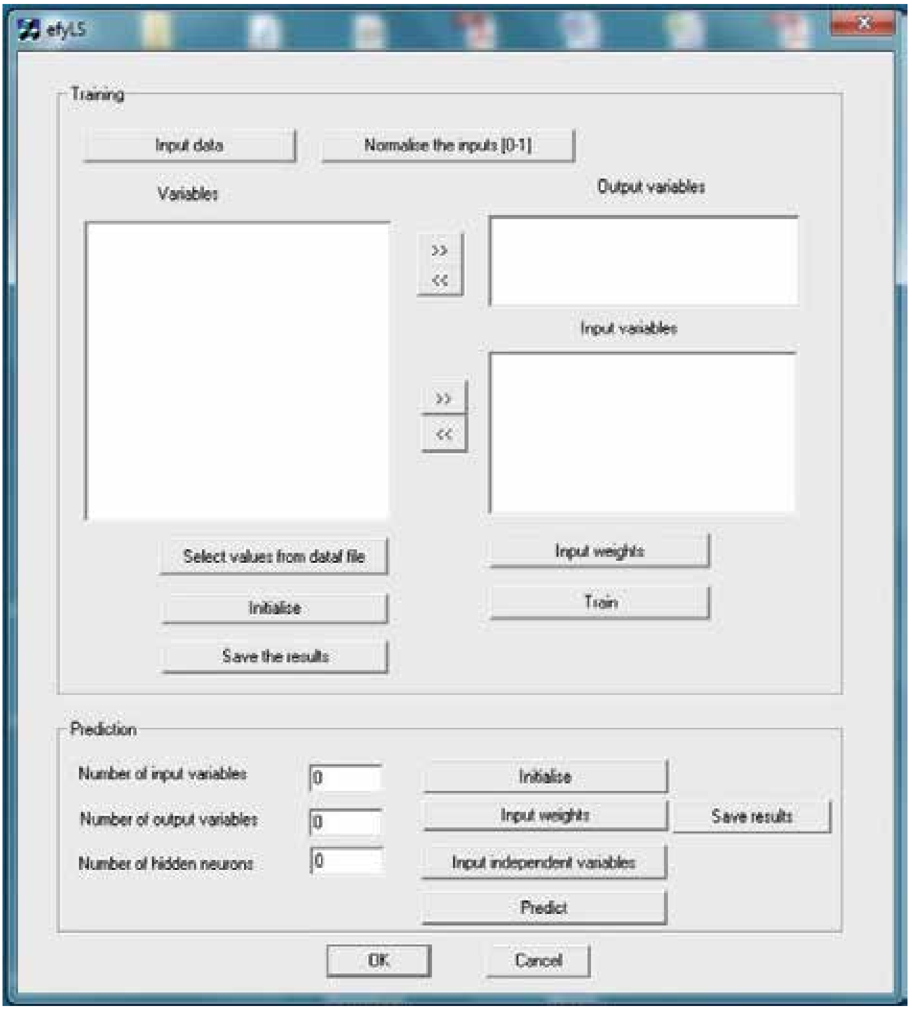
Figure 17. Essential components of organic tuber production

11. Development of a learning system

A learning system was developed using ANN to predict the performance of EFY production system. A three-layered system with one input layer, one output layer and one hidden layer was developed. The input layer neurons included temperature, rainfall, planting material, FYM, potassium, phosphorus, ash, neem cake, *Azospirillum*, phosphobacteria, mycorrhiza and green manure. The output layer neurons were total biomass, corm yield, canopy spread and plant height.

11.1. Structure of the system

A three-layered feed-forward back-propagation network (FFBPN) (Figure 18) was designed for this learning system [41]. Its block diagram (Figure 19) explains the flow of the inputs and the modifications made on it while it passes through the different layers before the output is generated.



Number of input variables 0
Number of output variables 0
Number of hidden neurons 0

Figure 18. Learning system to predict the performance of EFY production system

Input layer of the network is composed of 12 neurons represented by I1, I2,..., I12. The activities of neurons in the input layer represent the raw information that is fed into the network. Inputs added to the neurons of the input layer are given in Table 15.

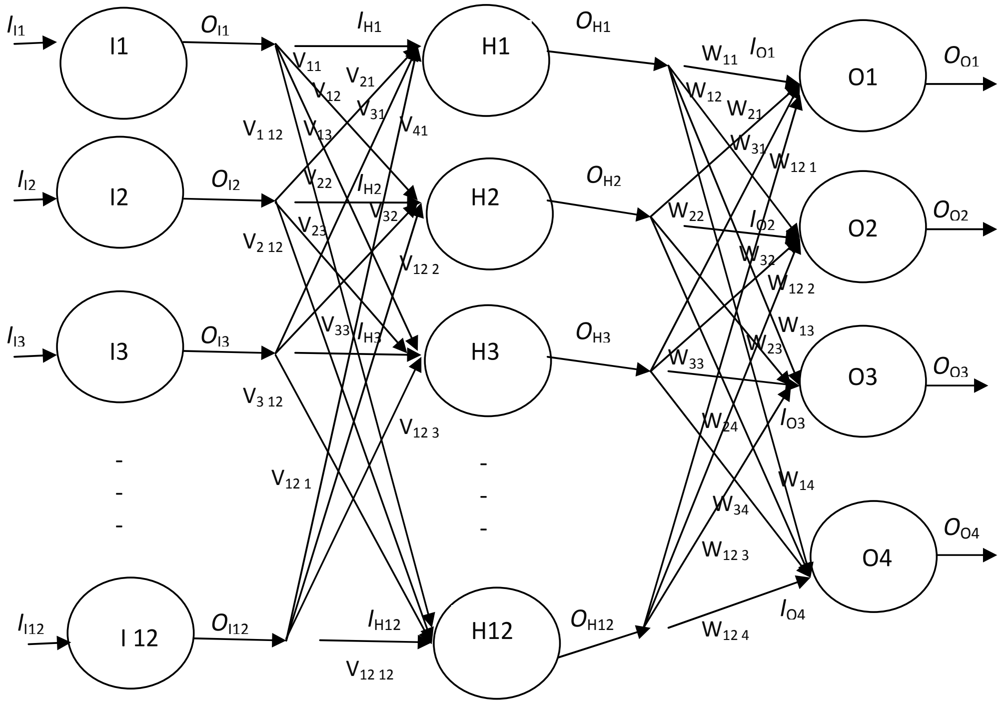


Figure 19. Structure of the three-layered FFBPN of the learning system

Sl. No.	Inputs added	Neuron of the input layer
1.	Temperature (°C)	I1
2.	Rainfall (mm)	I2
3.	Planting material (kg)	I3
4.	Farmyard manure (kg)	I4
5.	Potassium (kg)	I5
6.	Phosphorus (kg)	I6
7.	Ash (kg)	I7
8.	Neem cake (kg)	I8
9.	*Azospirillum* (kg)	I9
10.	Phosphobacteria (kg)	I10
11.	Mycorrhiza (kg)	I11
12.	Green manure (kg)	I12

Table 15. List of inputs added to various neurons in the input layer of the FFBPN

As linear activation function is operating in the input layer of the network, the input (I) and output (O) of the input layer are the same:

$$\{O\}_t = \{I\}_t \tag{1}$$

The hidden neurons H1...H12 are connected by synapse to the input neurons. Let $V_{m,p}$ be the weight of the arc between *m*th input neuron and the *p*th hidden neuron. The input to the hidden neuron is the weighted sum of the outputs of the input neurons to get I_{Hp}, i.e. the input to the *p*th hidden neuron as

$$I_{Hp} = \sum_{m=1,p=1}^{12,12} V_{m,p} O_{I,m} \tag{2}$$

where

$O_{I,m}$ is the output of *m*th input neuron.

In the hidden neurons, sigmoidal function is operating and thus the output of the *p*th hidden neuron is given by

$$O_{Hp} = \frac{1}{(1 + e^{-\lambda(I_{Hp} - \theta_{Hp})})} \tag{3}$$

where

O_{Hp} is the output of the *p*th hidden neuron

I_{Hp} is the input of the *p*th hidden neuron and

θ_{Hp} is the threshold of the *p*th hidden neuron, which is initialized to zero in this system

Input to the output neurons is the weighted sum of the outputs of the hidden neurons. Input to the *q*th output neuron I_{Oq} is calculated as follows:

$$I_{Oq} = \sum_{n=1,q=1}^{12,4} W_{n,q} O_{H,n} \tag{4}$$

where

O_{Hn} is the output of the *n*th hidden neuron and

$W_{n,q}$ is the weight of the arc between *n*th hidden neuron and *q*th output neuron.

Sigmoidal function is operating in the output neurons also, and the output of the *q*th neuron is given by

$$O_{Oq} = \frac{1}{(1 + e^{-\lambda(I_{Oq} - \theta_{Oq})})} \tag{5}$$

where

O_{Oq} is the output of the qth output neuron

I_{Oq} is the input of the qth output neuron and

θ_{Oq} is the threshold of the qth output neuron which is initialized to zero in this system

11.2. Training of the system

A three-layered FFBPN was designed for this learning system. Three years data (Table 16) on various aspects of cultivation of EFY were used for training the system.

Inputs	**Input neuron**	**Years**		
		2004	**2005**	**2006**
Temperature (°C)	I1	27.91	28.68	27.91
Rainfall (mm/season)	I2	2,179.90	1,862.95	2,082.45
Planting material (kg)	I3	750	750	750
FYM (t ha^{-1})	I4	25	25	25
Nitrogen (kg ha^{-1})	I5	100	100	100
Phosphorus (kg ha^{-1})	I6	50	50	50
Potassium (kg ha^{-1})	I7	150	150	150
Ash (kg ha^{-1})	I8	0	0	0
Neem cake (kg ha^{-1})	I9	0	0	0
Azospirillum (kg ha^{-1})	I10	0	0	0
Phosphobacteria (kg ha^{-1})	I11	0	0	0
Mycorrhiza (kg ha^{-1})	I12	0	0	0
Outputs	**Output neuron**	**2004**	**2005**	**2006**
Total biomass (kg plant^{-1})	O1	3.48	3.19	3.14
Corm yield (kg plant^{-1})	O2	2.95	2.83	2.93
Canopy spread (cm plant^{-1})	O3	110.37	111.61	101.18
Plant height (cm plant^{-1})	O4	55.87	62.54	48.72

Table 16. Values used for training the learning system

Weight matrix obtained between input and hidden layers and between hidden and output layers is stored in the database and is used for making predictions with other input data-sets. This system learns about the EFY production system when the independent variables like weather parameters, soil and nutritional parameters of the system as well as the corresponding dependent variables of the system like com yield, canopy size, etc., are fed as input into it. Once it learns about a particular system pattern, it can predict the outputs corresponding to another set of independent variables of a similar pattern. The system can be trained for various independent–dependent variable patterns so that dependent variables for another set of same independent variables can be predicted accurately. When more and more inputs are used for training as well as prediction, the system learns more and its precision increases.

12. Constraints in promotion of organic farming

In India, the availability of organic manures is a major constraint. It is estimated that to feed 1.4 billion population by the year 2025, a minimum of 301 million tonnes of food grains are needed. To meet this demand, it will be necessary to harness 30–35 million tonnes of NPK from fertilizer carriers and an additional 10 million tonnes from organic and biofertilizer sources [63]. Thus, only approximately 25–30% nutrient needs of Indian Agriculture can be met by utilizing organic sources solely [24, 64]. Organic manures are bulky (high cost of handling and transportation), of low analysis, slowly available and variable in composition. The availability of cattle dung for organic farming will be further limited as this is a major source of fuel in rural households. Apart from these, green manuring and recycling of farm wastes as manures have not become popular as these are more time and space consuming and their impacts on productivity are not rapidly discernible. At present, certification procedures are cumbersome and expensive [24, 64].

13. Future thrust

Some of the future lines of action for promotion of organic farming have been identified [24, 64, 65]. Proper delineation and identification of prospective areas and crops (like tuber crops) may be helpful for effective promotion of organic farming. There is a need to undertake systematic research on the comparative values/advantages of organic farming over conventional farming on a long-term basis for promotion of organic farming. The package of practices recommendations for organic farming has to be popularized. The extent of availability of potential organic sources needs to be ascertained along with measures that may be helpful in improving the convenience of their use. Environmental impact, especially water and air quality effects, of organic farming needs to be assessed.

Weed management options particularly under climate change by nonchemical and biological methods are limited and need evaluation. The benefits accruing through organic farming on crop yield, quality, market preference and price advantage may be properly understood and promoted among the farmers and consumers [24].

14. Conclusions

In order to attain sustainable food-cum-livelihood-cum-environmental security in India, we may require an array of alternatives to chemical intensive agriculture. Instead of seriously debating on organic vs conventional agriculture it is better to examine critically the costs and benefits of the different alternative management options. It has been conclusively proved in tuber crops that organic management is an alternative viable option for sustainable and safe food production with less soil degradation and environmental pollution. Tuber crops, especially EFY and yams are prospective candidates for organic farming. EFY is the most responsive, followed by greater yam, white yam, lesser yam and taro. Generation of sufficient biomass, addition of crop residues, green manuring, farm waste recycling, fortification of manures through proper composting, adoption of crop rotations involving legumes, establishment of biogas plants and development of agro-forestry for alternate source of fuels are some of the strategies that will help promote organic farming of tuber crops. These practices would help a great deal in supplementing/rationalizing the use of inorganic fertilizers, which cannot be totally eliminated in Indian Agriculture.

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Section 2

Organic Livestock

Abundance and Risk Factors for Dermatobiosis in Dairy Cattle of an Organic Farm in the Tropical Region

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Additional information is available at the end of the chapter

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Abstract

Studies about *Dermatobia hominis* larvae have been described, but no data were found regarding dairy cattle from organic production system in tropical region. The herd consisted of 40 dairy crossbred zebu x taurine. Fortnightly inspection (915 inspections) with mapping for the presence of larvae in the body surface was carried out over the period of a year in the area of the Integrated Agroecological Production System –IAPS/RJ – a technical cooperation project. The results indicated predominance of parasitism in females (average 21.98). In males, the highest number of nodules were on the right side (4.46); in females, highest number of nodules were on the left side. The infestation in adults (average 31.55) was highest; animals in lactation were less infested (average 8.01); in young animals, the most infested side was the left; the most infested coat was the black on white (average 36.69); the less infested coats were red with typical shades (average 14.13) and light brown and dark (12.33). Each increment of 1 mm^3 of water caused a mean increase of 1.03 in the relative risk of occurrence of dermatobiosis and with every one degree increased there was an average increase of 1.14 in the relative risk for infestation.

Keywords: Nodular subcutaneous myiasis, organic management, bovine

1. Introduction

Dermatobia hominis (Linneus Jr., 1781) (Diptera: Cuterebridae), commonly known in Brazil as "mosca do berne" (warble fly), has high incidence in cattle bred in many regions of the country. It infests a considerably large number of hosts, cattle being the most affected. This fly's larva once on the skin of those animals causes furuncular myiasis, also known as dermatobiosis, which is characterized by the formation of nodules in the host.

The study of seasonal variations of this fly allows us to know the periods of higher parasitic intensity, and also to correlate the facts operating in the growth of its population. Several authors are engaged in studying the seasonal variation of fly's larva and its relation to climate elements: temperature, precipitation, and humidity, showing that the presence of the warble is associated with regions that have moderately high temperatures during the day and relatively cold overnights, median and abundant rainfall, dense vegetation, and a considerable number of animals. Also, the rainy season is the period of highest occurrence. Even with all these characteristics, the index of parasitism by *D. hominis* can vary according to environmental conditions, regional differences. It also depends on the location of the parasite in the host.

In conventional livestock, the larva population on the cattle is controlled with the use of chemical larvicide. On the other hand, organic rural properties must meet the standards contained in the 60th Article of Normative Instruction No. 46, 2011, Ministry of Agriculture and Supply, which regulates organic production in Brazil, restricting the use of allopathic medicines [1].

Several studies about seasonality and *D. hominis* larvae's control have already been described, but no data were found related to this infestation in dairy cattle raised under organic systems. The goal of this study was to provide subsides about this parasitic skin disease in organic breeding; to verify the location and distribution of the larvae on the body surface of the cattle; to determine the intensity of infestation related to gender, age, and coat color; and the influence of the climatic factors in infestation rates. This study also provides basis to the creation of a dermatobiosis control program in organic dairy production systems.

2. Literature review

The parasitism rate of *D. hominis* may have some variations due to climate conditions. In addition, there may be differences in the location of the parasite in the host.

2.1. *Dermatobia hominis*: Geographical distribution and biology

According to [2], flies of the species *D. hominis* are diurnal and are found in tropical forests. According to [3], flies of *D. hominis* were never found in stables and houses, being more abundant on the edges of woods, forests, and eucalyptus plantations. As [4] says, this fly is well adapted in Brazil, mainly concentrated in regions of hot and humid climate, with abundant vegetation and in altitudes lower than 1000 meters. According to [5], the life cycle of *D. hominis* has two well-defined stages. The nonparasitic stage corresponds to the soil pupation and adult flies in forest, and the parasitic stage corresponds to the entire development of larvae in the subcutaneous tissue of the host. The flies copulate in the first 24 hours after their emergence. Few hours after fertilization, the females begin to frequent the vicinity of cattle corrals, meeting several species of fly vectors. The deposition of their eggs is made during the flight in the lateral–ventral region of the vector after its capture and immobilization. The incubation period of eggs in the vector is of approximately eight days, and when this vector meets the host, the larvae break the eggs and penetrate through the hair follicles into the skin causing nodular myiasis. The larval period can go from 25 to 60 days. It is at night or early in the morning that mature larvae leave the host and go to the ground to pupate, avoiding the sun.

In Colombia, [6] observed higher prevalence of *D. hominis* in rainy season. [7] reported the occurrence of dermatobiosis throughout the year in Argentina, with infection peaks in rainy season, with warmer temperatures and higher humidity. [8] observed a higher incidence of infestation by larvae of *D. hominis* in the months of November and March, in São Paulo, Brazil, with decreased incidence until June. Larger infestations by warble were verified in March and April, in the state of Paraná (Brazil), with lower incidence in August and September, according to [9]. The authors linked the higher incidence of this parasitosis with rainy season. As [10] says, the highest prevalence of *D. hominis* during the rainy season is due to the better development conditions for the parasite, where a greater number of larvae can reach the pupal stage.

[11] described that the warble is distributed in approximately 20 states in Brazil, with higher abundance in Rio Grande do Sul, Santa Catarina, Paraná, Rio de Janeiro, Espirito Santo, Distrito Federal, and Goiás. The author mentions that the parasite does not occur in the states of Amapá, Rondônia, Ceara, Rio Grande do Norte, and Sergipe. According to the author, the soil conditions in these places do not offer conditions for the parasite to complete its life cycle. According to [4], *D. hominis* life cycle is complete in 80–150 days.

Observations related to seasonal variations in *D. hominis* in the city of Governador Valadares, Minas Gerais, made by [12] revealed that there is a positive correlation between parasitism by larvae *D. hominis*, relative air humidity and rainfall. However, no relationship was observed between ambient temperature and parasitism rates. Seasonality studies of the warble in cattle from the city of Guaíba, RS, mentioned by [13] have shown that in the warmer seasons of the year, that is, during the spring and summer, infestations happen with higher intensity. [14] in surveys conducted in Campo Grande – MS observed higher rates of warble infestation in periods of higher rainfall and higher relative humidity, with no positive correlation between ambience temperature and infestations in animals and also reported the presence of larvae throughout the study period with maximum amounts in March and May.

By studying the seasonal fluctuation of *D. hominis* in bovine skins coming from slaughterhouses, [15] observed that the highest percentages of infestation occurred when the months before had recorded increases in average temperature and rainfall. These factors may favor the penetration of larvae in the soil decreasing the pupation time of *D. homins* larvae. In addition, such climatic conditions also benefit its vectors' pupation.

In southeastern Brazil, the months of spring and summer, which correspond to the rainy season, are the most favorable period of year for the occurrence of dermatobiosis in cattle. Smaller infestations happen during the dry season in the months of autumn and winter according to [16] and [17].

According to [18], in Brazil, losses caused by of *D. hominis* larvae reach 250 million dollars per year.

2.2. Body distribution of *Dermatobia hominis* larvae

A study on variations related to infestations of cattle by *D. hominis* larvae was held in Viamão – RS by [19], when the author observed higher incidence of warble in the anterior left part of cattle. [13] observed that, in cattle, 73% of subcutaneous nodules caused by *D. hominis* larvae were distributed in the anterior parts. The most infected parts were the ribs (31.9% of the observed nodules), scapula (21.5% of the observed nodules), forelegs (17.8% of the observed nodules), and neck (8.8%).

[20] verified the parasite dynamics of warble, noting its incidence in relation to decubitus in cattle of the Canchin race, in São Carlos – SP. The incidence of parasitism was higher on the left side (14.2 nodules on average) compared to the right side (10.5 nodules). According to the author, the higher incidence of parasitism on the left side can be explained due to the fact that this region was more exposed to the vectors of *D. hominis'* eggs. In his observations it was possible to say that most of the animals during their rest leaned on their right side, that is, 2.360 animals observed, 1.183 had the habit of lying on their left side, while 1.447 were lying on their right side. In another study, [21] found that the regions of the forelimbs and the left blades were more parasitized. According to the author, low parasitism in posterior regions was due to the tail, which acts as a broom protecting such areas up to approximately the seventh rib. The data showed that, although protected posterior regions are equivalent to 41.06 % of the body surface of the animal, only 16.20 % were infested by warble. In another study by [22], in the city of Seropédica in the state of Rio de Janeiro, it was observed that the body region with the highest number of nodules was the blade, followed by the ribs and the forelimbs. It was also observed that, in cattle antimeres, the left side had 50.46 % of the nodules, and the right side 49.54 %. But this difference was not statistically significant. [23] conducted a study regarding the seasonal fluctuation of larvae *D. hominis* on cattle skins from slaughterhouses, observed a higher incidence of nodules caused by the larvae of *D. hominis* in the anterior region, with a 97.8 % rate.

[24] observed a significantly higher frequency of *D. hominis* nodules in females (16.7%) than in males (14.7 %). The presence of larvae in adult animals (15.4 %) is also more significant than in younger animals (12.1 %) and when it comes to the coat, the highest frequency of larvae was observed in the dark ones (black). Considering the body part, the one that was the most parasitized was the left anterior quadrant.

2.3. Organic dairy production system

In conventional livestock, the larva population on the cattle is controlled with the use of chemical larvicide; on the other hand, organic rural must meet the standards contained in the 60th Article of Normative Instruction No. 46, 2011, Ministry of Agriculture and Supply, which regulates organic production in Brazil, restricting the use of allopathic medicines [1]. The term "organic" refers to animal and vegetable food that are produced without the use of fertilizers;

pesticides; insecticides; antimicrobials; antiparasitic, transgenic, or any other drug that may contain harmful residues to human health, including agricultural products to conventional dairy farms [25].

Milk production in organic systems does not reach 0.1% of national production, which is about 25 million liters per year, due to several factors, such as: rural extension work enabling the process to small producers; the lack of scientific research adapting livestock production in organic system to the tropical reality; as well as food pasture fertilizers, racial patterns, and health care with the herd, such as endo- and ectoparasites control and mastitis [26].

3. Materials and methods

3.1. Location

The study was conducted from September 2009 to August 2010 in an area that belongs to the Sistema Integrado de Produção Agroecológica (Integrated Agroecological Production System) – SIPA (Fazendinha Agroecológica Km 47), technical cooperation project between Embrapa Agrobiologia, Empresa de Pesquisa Agropecuária do Estado do Rio de Janeiro (Agriculture Research Corporation of Rio de Janeiro State) (PESAGRO – Rio /Seropédica), and Universidade Federal Rural do Rio de Janeiro (Rural Federal University of Rio de Janeiro) [27]. SIPA is located in the city of Seropédica, metropolitan region of Rio de Janeiro state, currently occupying 70 hectares and incorporating, in addition to vegetable production area and fruits, a fragment of forest, a forest garden, and areas of agroforestry and ornamental species. Pastures subdivided into paddocks total 30 hectares.

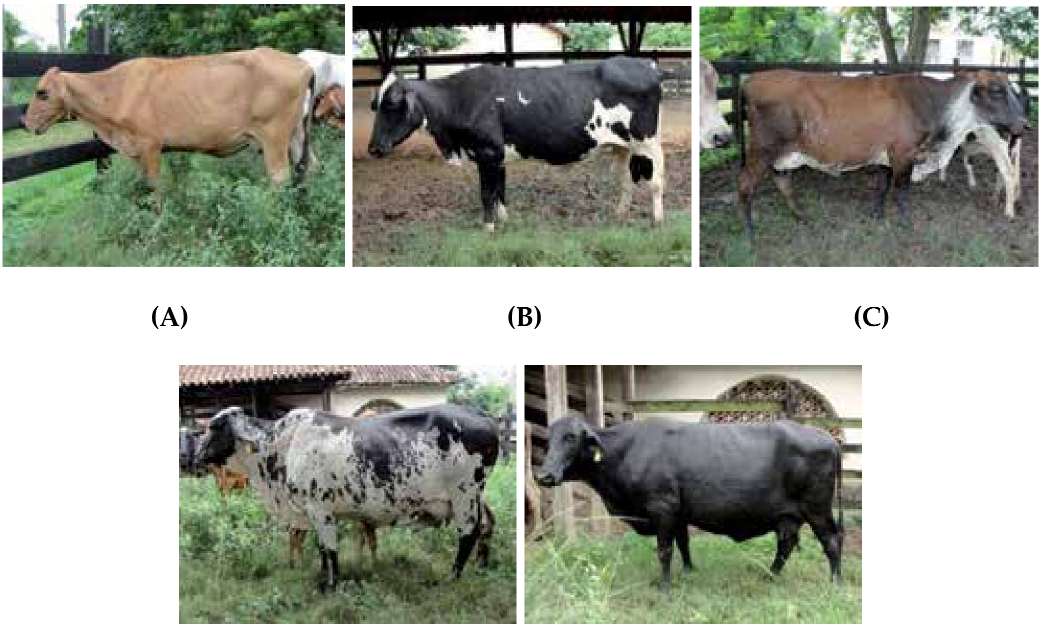
3.2. Weather

The meteorological data used were temperature (T) of the air, relative humidity (RH), and precipitation (PP) obtained from the Agrometeorological station situated in SIPA's area.

The climate is hot and humid with little pronounced winter. The average temperature of the coldest month is higher than 20 ° C (68°F) and the maximum temperature in the summer can exceed 40 ° C (104° F). The rainfall is characterized by the existence of a rainy season in summer and dry in winter. The annual rainfall is around 1.300 mm, although it is mostly rainy in spring and summer, the occurrence of prolonged drought is common in the months of January and February [27].

3.3. Animals

The herd consisted of 40 crossbred dairy animals Zebu x European (Gir x Holstein), divided into lots of young and adult animals. The young ones were divided into two further lots: suckler calves (birth to 6 months) and weaned calves (from 7 months to 18 months or 330 kg), and a lot of adult animals consisting of dry cows, in lactation, and a bull. The determination of the coat of animals followed the Girolando characterization [28]. (Figures 1 A, B, C, and D).



(A) **(B)** **(C)**

(D) **(E)**

Figure 1. Colors of the coat: **(A)** brown; **(B)** black on white; **(C)** red typical shades; **(D)** white on black **(E)** black.

3.4. Management of animals

The management system was semi-intensive: the animals remained in the corral during the day, where accumulation of manure could take place, and returned to the grass in the late afternoon. A physical model for organic milk production is implemented. Throughout the management, animal welfare, including avoidance of psychological stress in the herd, is prioritized. All the pickets have access to clean drinking fountains with good-quality water and shaded areas with afforestation. Containment fences are electrified and made with flat wire, in order not to represent a risk of injury to the animals.

The pastures are used in a rotation system. To supply the smaller forage production that happens in the dry period (period of lower growth of pastures), a cultivated area is managed to offer a forage supply in the trough. It is estimated that the period of lowest forage production in the region begins in mid-June and goes on until late October; that is, 135 days (or nine Fortnights) of drought and lower temperatures at night. A dairy Gir bull is used to ensure the reproduction of cows as well as the welfare of animals.

3.5. Health Management

The health management system established was developed for the SIPA project “Fazendinha Agroecológica Km 47.” It is based on the folowing: animal welfare, strategic control of parasites, and homeopathic therapy, always stressing prevention as the most important aspect with regard to treatment. The specific objective was the reestablishment and maintenance of herd health in that organic system, and the general goal was to facilitate the structuring of an experimental organic dairy cattle system.

Homeopathic medicines have been prepared by the Pharmacy School from Instituto Hahnemanniano do Brasil. Drugs are in accordance with the rules of the Brazilian Pharmacy in the form of liquid presentation, and packaged in appropriate amber glass containers. The ways of administration are oral, nasal, or vaginal.

As already mentioned, throughout the management, the priority is the animal's welfare, including avoiding of psychological stress in the herd. "Good management practices in dairy cattle with emphasis on preventive health" established for this breeding system follow the definitions of the 60th Article of Normative Instruction No. 46, 2011, Ministry of Agriculture and Supply.

The basic requirements under Article 60 of MAPA IN No. 46 [1] are as follows: (1) follow the principles of animal welfare at all stages of the production process; (2) keep hygiene and health throughout the breeding process, consistent with current health legislation and the use of products that are authorized in organic production; (3) provide preventive health techniques; (4) offer nutritious healthy food, with quality and in correct amounts according to the nutritional requirements of each species; (5) offer good-quality water and in appropriated quantities, free of chemical and biological agents that may compromise their health and vigor, quality product and natural resources, according to the parameters specified by law; (6) the use sanitary facilities that are functional and comfortable; and (7) dispose in an environmentally appropriate way, the production wastes.

Vaccinations against FMD, brucellosis, clostridial diseases, salmonellosis, and rabies follow the current schedule in health-surveillance Ministry of Agriculture Livestock and Supply. Homeopathy is the adopted therapy for treatment and prevention of major diseases of dairy cattle, with a Homeopathic protocol developed for this creation system.

A supplement freely provided to the entire herd was formulated according to this system, composed of salt, sulfur (for animal feeding), and dicalcium phosphate.

3.6. Monitoring dermatobiosis (berne)

Inspection was performed biweekly (mapping the presence of larvae), totaling 915 inspections. The animals were inspected by anatomical demarcation, and their body divided into antimeres: anterior upper right (RADS), anterior lower right (RADI), posterior upper right region (RPDS), lower right posterior region (RPDI), anterior upper left (RAES), left anterior inferior (RAEI), posterior upper left region (RPES), and posterior lower left region (RPEI). The presence of the larvae (Figure 2) was observed in the different regions, and the data recorded in documents, according to the methodology of [29], with modifications (Figure 3).

Figure 2. Presence of *D. hominis* larvae in subcutaneous tissue of cattle.

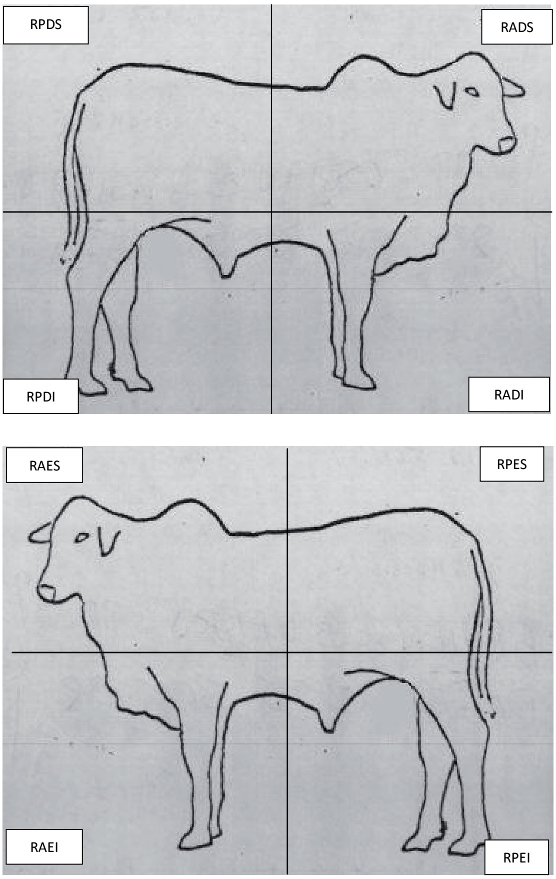


Figure 3. Field spreadsheet to map the dermatobiosis in cattle, according to the methodology of [29] with modifications.

3.7. Statistical Analysis

The berne description of the amounts into categories of each attribute were studied, and performed some exploratory data analysis through bar charts, box plots and calculating the average number of warble per studied animal. To compare the berne counts among the quadrants defined by anatomical demarcation, we used nonparametric Wilcoxon and Kruskal-Wallis test [30], due to the presence of nonnormal data [31]. To verify the association between the inherent variables to the animals and climate we used the generalized linear bivariate model of *Poisson* [32]. The dependent variable was the larva counted in each animal, the independent variables or explanatory variables were related to the animal profile (gender, age, and coat) and climatic factors (average temperature, rainfall, and relative humidity). As the dates of collection were different between adults and young animals (suckling calves and weaned calves), a stratified analysis was made taking into consideration the age of the animals involved in the study. The relative risk indicator is a measure of association, where two or more variables are correlated, being one of the ways used to the assessment in epidemiological statistics to answer the correlations between two outcome and exposure variables, where RR = 1 lack of association occurred; 0 <RR <1 protection factor, and RR> 1 risk factor.

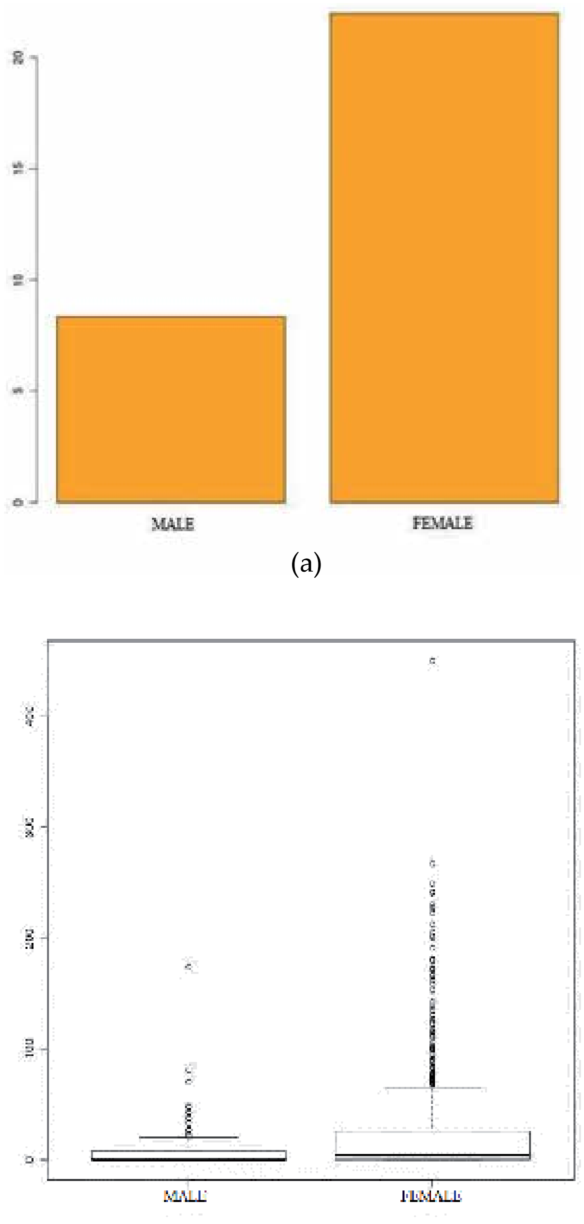
In the period of study, 915 berne counts in cattle were made (inspections), in which 391 were in adult cattle, 356 in weaned calves, and 168 in suckling calves. Of the total, 784 females and 131 males were counted. Of the 915 counts, 354 were made in cattle coat with red color in typical shades, 180 in fur animals with white on black, 87 in cattle with black color coat, 198 counts in animal with light brown and dark coat, and 96 counts in animal with black on white coat.

To adjust the climate data to the study database, the average was calculated for each of them (Average temperature, rainfall, and relative humidity) taking into consideration a fifteen-day delay period preceding the collecting day.

All statistical analyses were performed using statistical package R [33].

4. Results and discussion

The results of monitoring of the herd dermatobiosis indicated that there was a significant predominance of parasitism in the females (total average 21.98 bernes per female against total average rating of 8.37 bernes per male), as shown in Figure 4 (A), where the average number of nodules per sex in each animal is observed. Also, greater variability in females than in males was observed, as shown in Figure 4 (B). Also in relation to gender, males showed a higher number of nodes on the right side (total of 4.46 against 3.90 on the left), where the RPDs (Posterior Right Upper Region) was the most infested (2.16). In females, the highest number of nodules were concentrated on the left side (total of 11.17 against 10.70 on the right) and RADS (Anterior Right Upper Region) was the most affected (6.98). Table 1 shows the average number of nodules per animal according to sex. It was found that there was significant difference (p-value <0.001) regarding the amount of bernes between males (8.37) and females (21.98).



(a)

(b)

Note: Total of 915 counts of warble in cattle (inspections), with 784 females and 131 males in cattle. The average total number of bernes per female on the herd was 21.98 and the average total number of bernes per male was 8.37.

Figure 4. Distribution of parasitism in cattle according to gender **(A)**. Degree of infestation variability between sexes in the herd **(B)**.

Average number of warbles per animal		**Gender**		**Wilcoxon P-value**
		Male	**Female**	
	Animal Total	8.3 7	21.98	*<0.001**
Left quadrant	Lower Anterior	0.59	1.55	*0.004**
	Upper Posterior	1.44	2.58	*0.017**
	Upper Anterior	1.75	6.46	*<0.001**
	Lower Posterior	0.12	0.60	*<0.001**
	Total	3.90	11.17	*<0.001 **
Right quadrant	Lower Anterior	0.29	1.51	*<0.001 **
	Upper Posterior	2.16	1.88	*0.362*
	Upper Anterior	1.89	6.98	*<0.001 **
	Lower Posterior	0.12	0.55	*0.0111 **
	Total	4,46	10,75	*<0,001 **

* Significant values assuming a significance level of 5%

Table 1. Average number of bernes per animal according to sex and distribution in their respective quadrants

A significant prevalence of parasitism in females agrees with the results found by [24]. Regarding the most infected body region, there was divergence of results in other studies since all author studies cited here [19, 13, 21, 22, and 23] indicate a predominance of infestation in the anterior region, unlike the results found in males in this study, where the most affected body region was the posterior upper right region (RPDS) with an average of 2.16 bernes per animal. Also, in relation to the group of males in the herd, the prevalence of nodules on the right (total of 4.46 against 3.90 on the left) contradicts the results found by [19] in the study of Viamão – RS; as well as [20], who observed that the incidence on the left side is related to prevalence of the right lateral-sternal decubitus at rest time. [21] also found prevalence of parasitism on the left and [22] in a study conducted in Seropédica – RJ found no statistically significant difference between the number of nodules on the right and left sides of cattle.

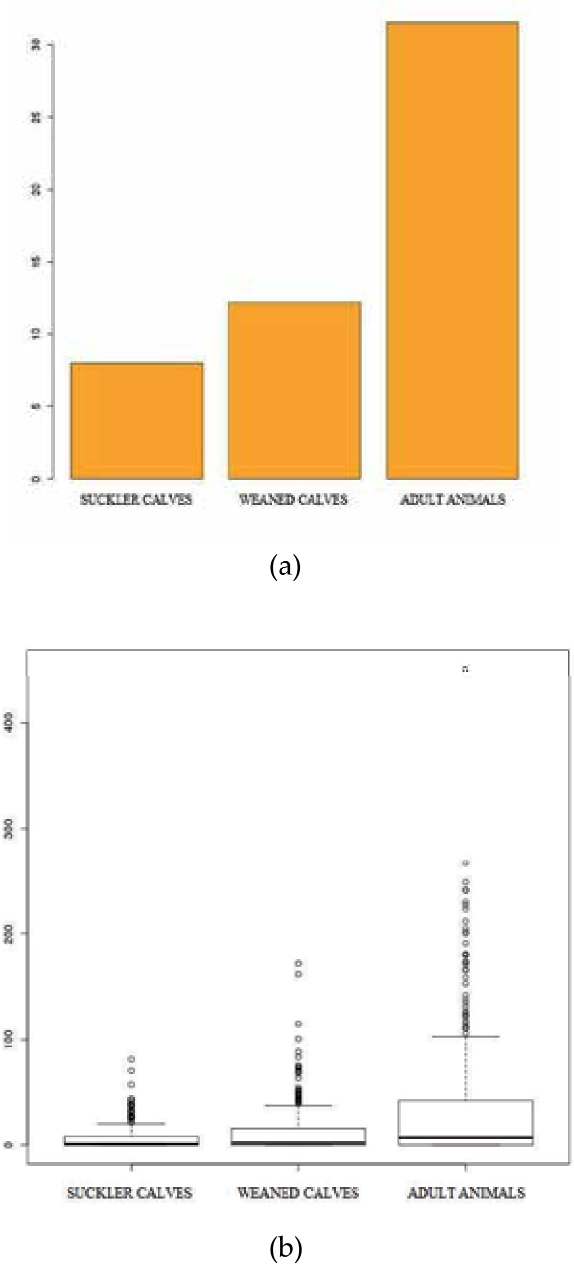
Considering the age of the animals, it was found that the number of adult animals that were affected by berne (total of 31.55) was significantly higher (p <0,001) than younger animals of the herd (total of 8.0 in suckling calves and 12.21 in weaned calves); the variability in this group was also higher than the variability in the younger group. In the group of young animals, the most affected ones by the parasitosis were weaned calves and (total of 12.21 per animal), therefore, the group of suckler calves was the least infested by the larvae of *D. hominis* (total of 8.01 per animal) as shown in Figure 4 (A), where the average number of bernes per animal according to the age is observed. Figure 4 (B) shows the variability of the total number of bernes, considering the age of cattle. Based on age, in both groups of young animals, the most infested side was the left one (total of 4.04 and 6.47 per animal), and the most affected body part in the group of suckling calves was the RADS (Anterior Right Upper Region), averaging 1.69 berne per animal, while in the group of weaned calves it was the RAES (Left Anterior Upper Region), averaging 3.53 bernes per animal. In the group of adults, the more infested side was the left (total of 15.71 nodules per animal) and the most affected region was the RADS (Anterior Right Upper Region) (average of 10.68 bernes per animal), as shown in Table 2. It was found that there is significant difference (p <0.001) compared to the amount of bernes related to age.

Average number of grubs per animal		**Age**			***Kruskal-Wallis p-value***
		Suckling	**Weaned**	**Adults**	
	The animal Total	8.01	12.21	31.55	*<0.001 **
Left quadrant	Lower Anterior	0.47	0.73	2.38	*<0.001 **
	Upper Posterior	1.65	1.83	3.28	*0.7614*
	Upper Anterior	1.63	3.53	9.37	*<0.001 **
	Lower Posterior	0.29	0.38	0.76	*0.0033 **
	Total	4.04	6.47	15.71	*<0.001 **
Right quadrant	Lower Anterior	0.40	0.78	2.19	*<0.001 **
	Upper Posterior	1.69	1.38	2.48	*0.6788*
	Upper Anterior	1.69	3.23	10.68	*<0.001 **
	Lower Posterior	12.26	12.43	0.62	*0.1312*
	Total	4.02	5.79	15.68	*<0.001 **

* Significant values assuming a significance level of 5%

Table 2. Average number of berne per animal in the herd according to age and distribution in their respective quadrants

This study regarding the age of the animals, including the evaluation of results referring to the sides in which the highest level of infestations occurred, has shown in the youth group and adult group an agreement with results of previous researches. But, in the adults' group and in the suckling calves' group, although presenting a predominance of infestation on the left side (total of 15.71 and 4.02, respectively), it was observed that the most infested body region was the RADS (Anterior Superior Right Region), averaging 10.68 bernes per animal and RPDS (Posterior Superior Right Region), averaging 1.69 bernes per animal, respectively, different from that indicated in previous studies by [19] held in Viamão – RS, as well as [20], which linked the prevalence of parasitism on the left side to the right lateral-sternal decubitus at rest time. [21] also found prevalence of parasitism on the left and [22] in Seropédica – RJ did not find statistically significant difference between the number of nodules on the right and left sides of cattle.



Note: Total of 915 bernes counts in cattle (inspections) in which 391 were in adult cattle, 356 in weaned calves, and 168 in suckling calves. The average total number of bernes per adult animal was 31.55, the average total number of bernes per weaned calf was 12.21, and the average total number of nodules per suckling calf was 8.01.

Figure 5. Average number of nodules per animal according to the age of the animal (A). Variability of the total number of bernes considering the age of animals **(B).**

Considering the presence of the larvae of *D. hominis* and the animal's coat, it is observed that the coat with a higher level of infestation is the black on white (total 36.69), while showing lesser infestation rates were typical red shades (14.13) and the light and dark brown (12.33).

In Table 3 we observe the average number of bernes per animal according to type of animal coat. There is a significant difference (p-value <0.001) comparing the amount of bernes between the coats. In Figure 5 (A) the average number of bernes per coat type in each animal is shown. Figure 5 (B) shows the variability of the total number of bernes in relation to the type of coat of the animal.

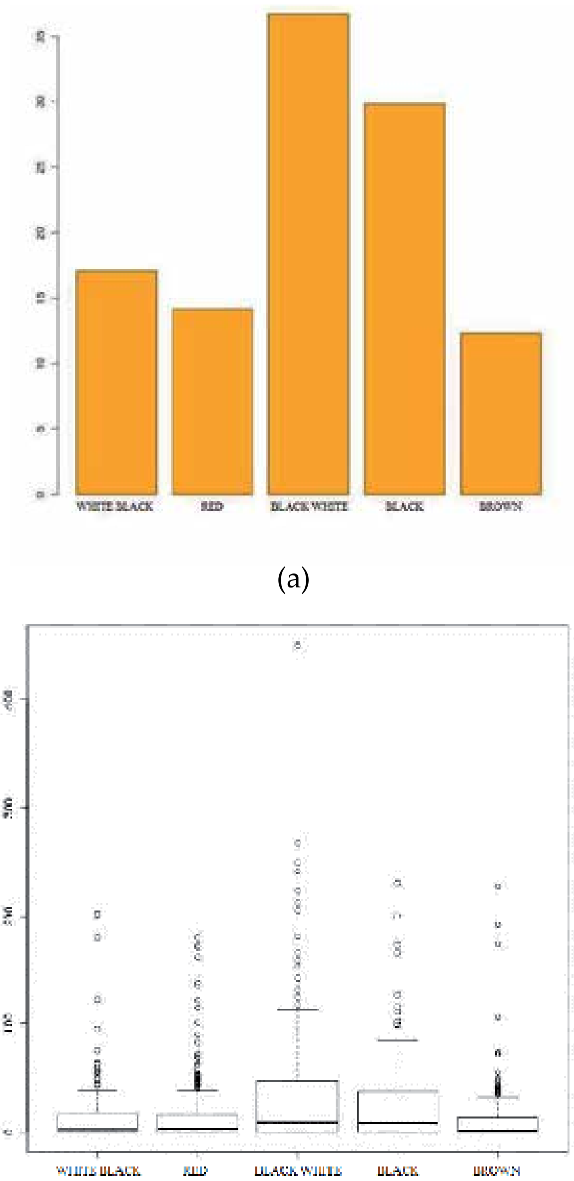
According to a study conducted by [24], the parasite frequency of occurrence was higher in dark-coat animals (black) unlike what was found in this study.

Average number of warbles per animal		**Coat color**					***Kruskal-Wallis*** *p-value*
		White-Black	**Red**	**Black-White**	**Black**	**Brown**	
	Total per animal	17.08	14.13	36.69	29.82	12.33	*<0.001 **
Left quadrant	Lower Anterior	1.80	0.86	3.37	1.59	0.31	*<0.001 **
	Upper Posterior	1.05	1.70	5.04	2.33	1.98	*<0.006 **
	Upper Anterior	4.30	4.72	10.69	8.74	2.57	*<0.001 **
	Lower Posterior	0.44	0.38	0.91	0.80	0.40	*0.0016 **
	Total	7.59	7.66	19.94	13.46	5.25	*<0.001 **
Right quadrant	Lower Anterior	1.26	0.85	2.79	2.30	0.47	*<0.001 **
	Upper Posterior	1.08	1.07	3.01	2.83	2.44	*<0.007 **
	Upper Anterior	6.82	4.25	10.22	11.02	3.83	*<0.001 **
	Lower Posterior	0.53	0.35	0.83	0.48	0.39	*0.0892*
	Total	9.59	6.52	16.52	16.08	7.07	*<0.001 **

* Significant values assuming a significance level of 5%

Table 3. Average number of bernes per herd animal taking into consideration the coat type and distribution in their respective quadrants

As shown in Table 4, the months of highest occurrence of dermatobiosis were November and December, 2009, while the lowest levels of infestation by larvae of *D. hominis* were recorded in June and July, 2010. The period of highest infestation was the rainy season (spring and summer), and the record of the lower parasitism rates occurred during the dry season (fall and winter). The occurrence of parasites was observed throughout the study period. These findings coincide with observations of [6, 7, 10, 13, 16, and 17]. They also coincide with a study made by [14] on the observations of larvae presence throughout the study period, but differing in the months of maximum count. The results of this study also confirmed the observations of [8] in his study in the State of São Paulo, where he found higher occurrence of parasitosis in



(a)

(b)

Note: Total 915 warble counts in cattle (inspections), of which 354 were in cattle with red coat color in typical shades, 180 in animals with white on black coat, 87 in black coat color cattle, 198 in animals with light brown and dark coat, and 96 in white on black coat color. The average total number of bernes per animal was 14.13 in cattle with red coat color in typical shades; 36.69 in animals with black on white coat; 29.82 in animals with a black coat color; 12.33 in cattle with light or dark brown coats; and 17.08 in animals with white on black coat.

Figure 6. Average number of bernes by coat type in each herd animal **(A).** Variability of the total number of bernes in relation to the type of coat of animals **(B).**

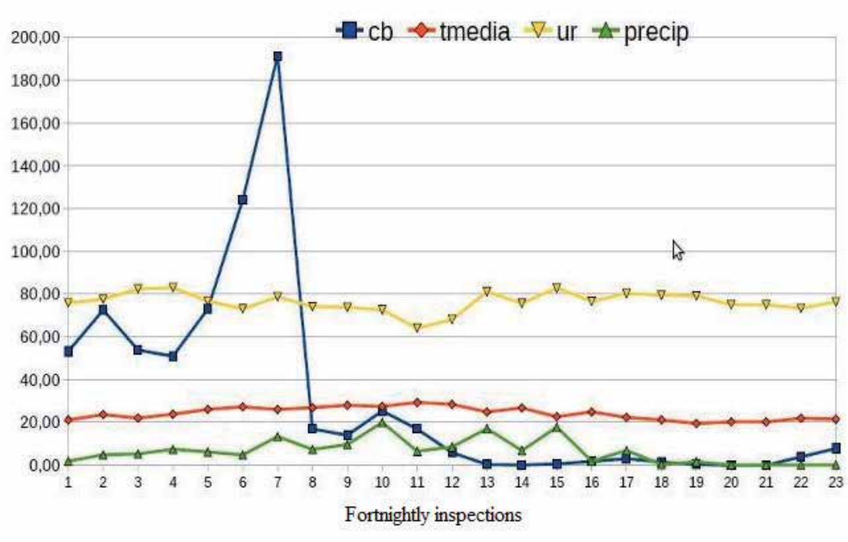
November, with a decrease until July, as well as the results found by [9] in his study in the state of Paraná, where major infestations in the rainy season period was also noted, differing only in the months of highest and lowest occurrence of dermatobiosis.

Months/Years			**Quantity of Bernes**			
			Young animals		**Adult animals**	
			Average	**Total**	**Average**	**Total**
Rainy season	Spring	September/2009	26	1.381	63	2.263
		October/2009	21	821	52	1.886
		November/2009	35	1.422	99	3.546
	Summer	December/2009	33	1.393	104	3.748
		January/2010	5.3	223	20	709
		February/2010	3.1	125	11	409
Dry season	Autumn	March/2010	0.2	10	0.2	8
		April/2010	0.5	24	1,2	43
		May/2010	0.6	32	2.3	82
	Winter	June/2010	0	2	0.2	6
		July/2010	0.1	3	0.4	6
		August/2010	4	209	5.8	198

Table 4. Monthly averages of the average number of larvae *Dermatobia hominis* from September 2009 to August 2010

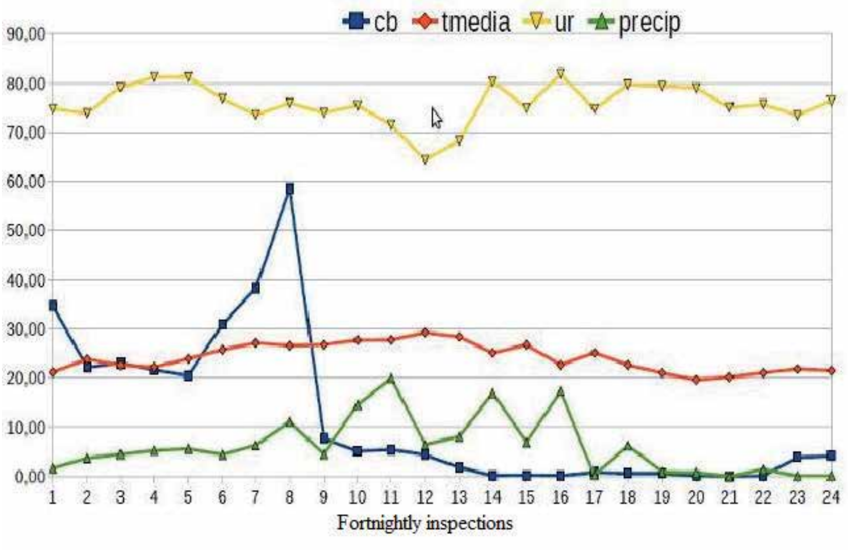
The fluctuation of the larvae of *D. hominis* during the studied period along with the climatic data are found in Figures 6 and 7, which show the highest levels of infestation occurring at the beginning of the study period as well as the highest rates of rainfalls, relative humidity air, and average temperature. The lowest averages in the occurrence of dermatobiosis occurred in the second half of the study period, coinciding with the lowest levels of rainfalls, relative humidity, and average temperature.

Risks relating to possible risk factors (intrinsic characteristics of the animal itself – gender, age coat, and climatic factors – rainfall, average temperature, and relative humidity) related to the occurrence of dermatobiosis are shown in Table 5. The results found, with reference to climatic variables, showed that with regard to rainfall and relative humidity, each increase of 1 mm^3 of water generates an average increase of 1.03 in the relative risk of occurrence of dermatobiosis in the herd, and each increase of 1°C in average temperature generates an average increase of 1.14 of relative risk to infestation by larvae of *D. hominis* in cattle. The results were significant for all studied weather variables. According to the study made by [15], increased percentages of infestation by larvae of *D. hominis* are related to the increase in average temperature and rainfall, which favors the penetration of larvae in the soil, reducing its time of pupation. Such



Note: The climatic variables are lagged by 15 days, so the average was calculated for each climate variable in the 15 days before each visit.

Figure 7. (cb) Average number of bernes in adult animals, (tmedia) average temperature, (ur) relative humidity, and (precip) rainfall during the experimental period.



Note : The climatic variables are lagged by 15 days, so the average was calculated for each climate variable in the 15 days before each visit.

Figure 8. (cb) Average number of bernes in young animals, (tmedia) average temperature, (ur) relative humidity, and (precip) rainfall during the experimental period.

observations are confirmed by the results of this study, unlike the findings of [12, 5] in Governador Valadares, Minas, Gerais, and [14] in surveys conducted in Campo Grande – MS, which found no positive relationship between parasitism and average temperature.

Also, with regard to the results shown in Table 5, it was observed that adult females of the herd presented a relative risk 2.63 times higher than males to infestation by larvae of *D. hominis*.

Adult bovine animals had a relative risk for dermatobiosis 3.94 times higher than suckler calves, while weaned calves showed a relative risk of 1.52 times more than the suckling calves.

The black on white coats were the most susceptible to infestation by larvae of *D. hominis*.

The white on black coats showed a relative risk 2.98 times higher for developing dermatobiosis than light and dark-brown coated animals.

Variables	**RR**	**IC 95%**
Gender		
Male (ref.)	1.00	[1.00; 1.00]
Female	2.63*	[2.47; 2.79]
Age		
Suckler calves (ref.)	1.00	[1.00; 1.00]
Weaned calves	1.52*	[1.43; 1.62]
Adult animals	3.94	[3.72; 4.17]
Coat Color		
Brown (ref.)	1.00	[1.00; 1.00]
Black white	2.98*	[2.84; 3.12]
Black	2.42*	[2.29; 2.56]
White black	1.39*	[1.30; 1.48]
Red	1.15*	[1.09; 1.20]
Rainfall	1.03*	[1.02; 1.04]
Average temperature	1.14*	[1.13; 1.15]
Relative humidity	1.03*	[1.02; 1.04]

* Significant at 0.05 level

Table 5. Estimate of the relative risks (RR) and their respective confidence intervals of 95% (CI 95%) from the bivariate analysis of generalized linear models

The area occupied by Fazendinha Agroecológica Km47 incorporates a fragment of forest, a forest garden, and areas of agroforestry, and the climate is hot and humid with rainfall characterized by a rainy season in summer, and according to [4], the habitat of *Dermatobia hominis* is in hot and humid regions, with abundant vegetation and [5, 3, 2, and 14] state that there are plenty of those parasites on the margins of tropical forests and areas. It is noteworthy that the area or location of this study presents excellent conditions for the development of dermatobiosis, thus favoring the occurrence of high infestation levels as it was observed in the early months of the study. Also, because it is an organic system, the use of antiparasitic is strictly prohibited and contrary to the national law [1 and 25]; yet, this work observed improvement in the general appearance of the herd and improvement in conditions while handling of animals, as they have become extremely docile and receptive. Beyond these observations, the development of clinical diseases in cattle caused by parasitic load has not been registered.

5. Conclusions

- The ideal coats in this situation are the light and dark red and brown coated in typical shades;
- The degree of infestation was significantly higher in females than in males;
- It was not possible to say that there is influence of the right external–lateral decubitus in a parasitized body side;
- The temperature is the climatic factor that most influenced the parasitosis;
- The largest infestation rates occurred during the rainy season between spring and summer.

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Chapter 11

Organic Livestock Farming — Challenges, Perspectives, and Strategies to Increase Its Contribution to the Agrifood System's Sustainability — A Review

Alfredo J. Escribano

Additional information is available at the end of the chapter

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Abstract

The livestock sector is of great importance for the sustainability of rural economies and many ecosystems; however, it also has a high environmental impact. Due to the growing demand for animal products, there is a need to design new livestock production systems that allow the combination of food security and sustainability. Within this context, organic livestock may be a useful strategy to achieve such a pivotal goal. However, there is a lack of studies that integrate the existing knowledge, specifically in organic livestock, and integrating the main aspects implied in its practice (its externalities and challenges). The present work aims to fill this knowledge gap, providing strategies and insights that will help stakeholders and policy makers to improve the sustainability of both the organic sector itself and that of the whole food system.

Keywords: Organic, cattle, livestock, sustainability, food system

1. Introduction

There has been considerable growth in the number of organic livestock farms [1] in response to the necessity to fulfill the growing demand for animal products predicted for 2050 [2]. Furthermore, it is required to combine it with the farms' profitability, environmental protection, food safety, and ethical concerns. Due to this, organic livestock farms are nowadays not a despicable part of the census. However, there is no consensus about the consequences of organic livestock farming systems to the sustainability of the overall food system. This lack of convergence has its roots in the effect played by the different characteristics and contexts of the farms. Moreover, some barriers are challenging the development of the sector and shaping its future perspectives. Within this context, and in view of the lack of studies addressing the

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sustainability of the organic livestock sector as a whole by integrating different points of view, it is very timely to conduct a thorough study of this type. Due to this, the present review was carried out, aimed at improving the knowledge about the organic livestock sector such that it will be possible to adopt a holistic view that increases our understanding of its challenges and future perspectives, with a special emphasis on the sustainability of both farms and the whole food system. This integrative knowledge and approach will help stakeholders and policy makers to make decisions, either at the farm level (implement organic farms) or making policies. Thus, they both will be able to design strategies that increase the sustainability, competitiveness, and success of organic livestock farms, looking at the sustainability of the food systems as a final and priority goal.

1.1. Socio-economic and environmental role of livestock production

Animal production systems are of great importance for the sustainability of rural economies and many ecosystems. The economic importance of livestock activity is reflected by the weight of the agricultural sector in the regional gross domestic product. For example, in rural areas located in southern Europe, cattle, swine, and small ruminants sectors billed 396.46 M € in 2010, representing 36.10% of the agricultural sector production in some regions [3].

From the social point of view, it is noteworthy that in semi-arid regions, such those in the Mediterranean basin, the extensive livestock production systems are often the main activity, and even the only source of livelihood. This dependence of the sector highlights the need to protect and enhance it, as it contributes to the creation of jobs, to the rural economy, and to the fixation of the rural population, which are vital for sustainable development in rural areas worldwide [4-5].

From a cultural perspective, the particularities of the different livestock systems are crucial for the conservation of the heritage, including breeds, landscapes, and habitats of high aesthetic and environmental value [6-7], which redounds in the economic development of the rural areas.

Regarding the environment, livestock activity involves lots of environmental benefits [8], especially when it is carried out under environmentally-friendly production systems, such as the extensive, pasture-based, low-input, and/or organic systems.

However, the livestock sector also has an important environmental impact. This sector employs 30% of the overall area not covered by ice and uses around 80% of global agricultural land. It also generates most of the greenhouse gas (GHGs) emissions in the agricultural sector, accounting for 14.5% of human-induced GHGs, exceeding that from transportation [9].

Moreover, it is a major consumer and polluting water resources, contributing around 30% of N and P content of watercourses [10-13]. These data are even more striking in the case of the bovine meat sector as beef is often the food of animal origin with greater ecological impact [14-18]. Moreover, various socio-economic factors have led to either the abandonment or the intensification of the farms, which threatens the conservation of valuable agro-ecosystems.

Such environmental impact, along with the increasing demand toward animal products, makes it difficult to combine profitability, competitiveness, and environmental sustainability. Consequently, it is necessary to design and implement sustainable livestock systems globally (environmentally, socially, and economically), in which organic ones have an important role to play.

2. Objectives

The objectives of the present work is (i) to fill the existing knowledge gap with regard to the sustainability, challenges, and perspectives of the organic livestock sector, as well as regarding its contribution to the agrifood system's sustainability. Moreover, this study is also aimed at (ii) providing strategies and insights that will help stakeholders and policy makers to improve the sustainability of both the organic livestock sector and that of the whole food system.

3. Externalities of organic livestock farming systems

To reduce the abovementioned environmental impacts, different production systems have been developed. Among them, organic livestock farms have been studied by several authors in order to assess their potential and impact on environmental [19-22] and socio-economic aspects (sustainable rural development) [23-24].

However, some results are contradictory and some papers are not conclusive, which make it difficult to generalize the advantages of the organic livestock sector at either farm level or globally. This lack of convergence in the results is due to the fact that the externalities of organic livestock farms are highly dependent on their structure, the breeds reared, as well as their management, context, and marketing strategies [23-25, 129]. In other words, it seems that there is no one-size-fits-all solution. Moreover, papers normally address specific aspects of the farms (i.e., economic, health, welfare, etc.), which does not allow an integrative picture of the situation.

In order to deal with this scenario, many points must be addressed, as [26] argued, "the concept of organic animal farming can only fulfill the criteria for sustainability if all requirements on animal health, welfare, and ecological soundness are strongly considered and controlled". Due to this, an analysis of the aspects mentioned by these authors, along with those related to the economic and social aspects, have been included in the present work.

3.1. Social dimension: Sustainable rural economy and development

An important part of the world forms part of the so-called "rural areas". In the case of the European Union, rural areas cover 90% of its territory, where over 23% of the European population lives in them, and another 35% lives in intermediate zones. In these areas, farming is one of the main drivers of sustainable rural development [27].

However, these areas are going through processes of depopulation that reduces the sustainability of such areas, from the social, economic, and environmental points of view. Due to this, there is a necessity to develop strategies that allow overcoming this issue. Within these strategies, organic farming has become popular, even in the legislative environment. In fact, [28] defines organic production as "a system of farm management and food production that plays a dual societal role: on the one hand it provides food products to meet specific consumer demands; on the other hand it delivers public goods that contribute to the protection of the environment and animal welfare, as well as to the development of rural areas".

As a consequence, several researchers have evaluated the contribution of organic livestock to sustainable rural development [29-30], of which most of them have been reviewed and discussed by [24]. Some of them have considered that organic production is an important pillar of sustainable rural development, since this production model generates more positive externalities than the conventional one in terms of conservation of agro-ecosystems, creation of jobs, farms′ profitability, workers΄ income, and local economy.

In this regard, it is fair to mention that most of the benefits provided by the organic production model in relation to rural development seem to be due to both their participation in short marketing channels [31-32] and obtaining a higher price (“price premium”) for their organic products [33-34]. According to the authors cited, this premium price is necessary for organic farms profitability, especially during the years of conversion, because the farms′ incomes are often reduced and costs increased [31-32]. However, there is controversy on the relationship between the condition of being organic and short marketing channels, but in general terms, such relationship is weak [24, 35].

However, few studies addressed the potential role of organic livestock production systems (studies usually mix agriculture and livestock) towards sustainable development, despite having been proposed to be models of it [30]. Furthermore, such studies show contradictory results and did not adopt a holistic approach (social, economic, and environmentally public policies), which is really needed. Due to this, [24] summarized the studies published with regard to organic livestock sector and discussed them with the results of the case study they carried out addressing organic beef cattle farms located in southwestern Europe.

Studies dealing with this topic paid special attention to the number of jobs created, salaries paid, and the profitability of the farms. Thus, authors such as [36] found no increased presence of labor in organic livestock farms when compared with conventional holdings. On the contrary, [24] found that organic beef cattle farms (mainly those that also fattened their calves) used more labor. However, these last authors stated that this was mainly due to both the higher degree of business diversification of these farms and the fact that for many of the farmers, the farm under study was not the only source of income. Both aspects increased the necessity to hire external workforce. Moreover, [24] found that the salaries paid by the organic farms were lower than those of the conventional ones, which is contrary to the findings of the review carried out by [23]. However, these two last studies did not focus only livestock farms, such that results cannot be compared precisely.

[37] concluded that organic dairy farms may contribute more to the local economy and economic development of rural communities located in the northeast and upper midwest of the U.S. than average and similar-size conventional dairy farms. As they stated, in Vermont, organic dairy farm sales revenue would result in greater state-wide impacts of 3% in output, 39% in labor income, 33% in gross state product, and 46% in employment relative to the impacts from an equivalent level of sales revenue to conventional dairy farms. In Minnesota, these economic impacts are 4, 9, 11, and 12% greater.

Later, [24] found that organic beef cattle farms that fattened their calves performed better from the economic point of view. These authors compared these full-cycle organic farms with (i) conventional farms that scarcely fattened their calves and (ii) organic farms with no fattening period. This comparison allowed them to conclude that the differences were mainly due to the consequences that some differential factors had on overall economic performance, more than the condition of being organic. These factors were the following: most of the farms that fattened their calves were full-cycle (they were part of an association that had the organic crops, the mill, the livestock farms, the trucks, and even established contracts with supermarkets). Moreover, they all received the subsidies for organic farming (in the other organic group of farms they did not), and they sold their fattened calves at a price 25% higher than that of the conventional ones. However, as the production cycle (and the age at which calves were slaughtered) was longer, these farms showed lower economic performances when it was calculated per year.

In summary, the authors have come to the conclusion that many of the benefits provided by organic production in relation to rural development are not due to the mere fact produced under the ecological model, but to sell their products through short marketing channels [31-32] and to obtain a higher price (“price premium”) for organic products [33-34]. This is especially important during the years of conversion because farm incomes are often reduced, and its costs increased.

Moreover, the pathway followed by the products (marketing channels) has a great impact on the sustainability of the food system. Thus, transportation accounted for 17.43% of the total energy consumed by the Spanish food sector in 2000 [38]. In this sense, it is important to comment that short marketing channels (and “local” products) are commonly thought to have lower environmental impacts. However, the concentration of supply can lead to lower emissions of GHGs of short marketing channels, in which small amounts of products are transported by vehicle or fuel. In fact, [38] found that most of that 17.43% of energy consumed by transport comes from road transport due to their lower energy efficiency per load transported.

3.2. Environmental dimension

Pasture-based and low-input livestock systems (e.g., the organic systems) are key to the ecosystems in which they are integrated as they provide with numerous benefits, such as increased carbon sequestration, improved quality of the pastures, and reduction of scrub invasion and risk of fire [5, 8, 39].

According to [28], livestock production is fundamental to the organization of agricultural production on organic holdings in so far as it provides the necessary organic matter and nutrients for cultivated land and accordingly contributes towards soil improvement and the development of sustainable agriculture. [40] completed this view arguing that organic livestock provides organic nutrients that are recycled at the farm level, allowing the production of on-farm inputs, which increases their sustainability. Similarly, [41] claimed that when cattle are introduced in environmental systems, increased efficiency and sustainability occurs. However, organic livestock farms do not always present a significant cultivated area, so that their differences with conventional farms with regard to this parameter may be few [24]. Moreover, mixed crop-livestock farms could miss out on potential economies of scale. To overcome these interactions, organic mixed crop-livestock farms could be a solution, since [42] observed that these farms exploited the diversity of herd feed resources more efficiently than the rest of the groups, which varied in both their degrees of mixing these two components and their organic/conventional status.

In relation to water resources, some authors have found that its use is more efficient in organic farms, and that water retention is increased, leading to higher resistance to drought [43]. Moreover, in these farms, land degradation is prevented and soil fertility increased [44]. These aspects are of particular interest in semi-arid areas, where water shortages often occur, and both soils and pastures are poor. Additionally, it has been shown that agrobiodiversity is greater in organic agro-ecosystems [20, 21, 45], which greatly increases the number of interactions between system components and their complexity. Therefore, their resilience is increased, which is key for their adaptation and resistance against pests, diseases, and climate change. In parallel, their higher degree of business diversification make them less vulnerable in the face of market changes [25, 44, 129].

When looking at comparisons between organic livestock farming systems and conventional ones, several authors have shown that organic systems have a greater potential to preserve the environment, mainly with regard to biodiversity [19-21]. These positive externalities are the consequence of many factors, such as the reduced use of inputs, better nutrient recycling, less use and exploitation of non-renewable/external resources, and finally, ecotoxicity.

These aspects are of great importance, since the increasing degradation of the agricultural soils and the reduction in the supplies of fresh water are two of the most serious problems that humankind is facing. These problems pose an impediment to achieving food security, especially if one takes into account the growing population and demand for animal products. It is even more relevant in developing countries and in semi-arid areas characterized by pasture-based (low-input/pasture-based/extensive) production systems. According to several authors [46-47], organic livestock systems have the potential to contribute to the sustainability of these areas.

Due to the advantages provided by organic livestock production, it would be logical to think that this production model allows facing the two main challenges of the food system: sustainability and food security. In this sense, [48] stated that a shift to organic production will be increasingly necessary for the renewal of resources (mainly water and soil) and to secure sustainable food security. However, there is much debate in this sense [49], due to the lower production that organic production often shows, the increased need for agricultural land for organic production, and the scarcity of organic fertilizers of good quality.

Regarding the environmental impact in terms of GHGs and energy use, extensive and low-input farms (including the organic ones) tend to be more sustainable [50-52]. Among other reasons, this is due to lower consumption of fossil fuels and energy. However, some studies conclude that emissions in organic systems may be higher than those of the conventional ones [16], because they have lower production per unit of input. In this sense, [22] showed that the product carbon footprint in dairy cow organic farms was significantly higher than that of the conventional farms [1.61±0.29 vs. 1.45±0.28kg of CO_2 equivalents (CO_2 eq) per kg of milk].

This divergent results are showing that the differences among studies are mainly due to the productive system under study, its context, the experimental design work, and the units and limits of the study (farm level, hectare, unit of product, food system, etc.), more than their conditions of being organic.

One of the aspects that plays a great effect on greenhouse emissions of the farms is the quality of the feed. In this sense, [53] measured the GHGs from enteric fermentation and manure on organic and conventional dairy farms in Germany in order to assess the effect of different feeding practices. In general terms, lower emissions from enteric fermentation were found when feed quality and feed intake was increased (which normally means feedstuff, instead of pastures). In general terms, results depended strongly on the calculation methodology, especially those related to enteric fermentation. Moreover, differences between the methods were particularly prominent when high amounts of fiber-rich feedstuff were used. As feed quality management on farms influences milk yield and enteric CH_4 emissions, these aspects should be part of advisory concepts that aim at reducing GHG emissions in milk production.

In line with these results, [22] stated that feed demand per kilogram of milk, high grassland yield, and low forage area requirements per cow are the main factors that decrease PCF (product carbon footprints). They observed that the interaction between GHG mitigation and the farm's profitability is key for improving efficiency and sustainability. Thus, for organic farms, a reduction of feed demand of 100 g/kg of milk resulted in a PCF reduction of 105 g of CO_2 eq/kg of milk and an increase in incomes of approximately 2.1 euro cents (c)/kg of milk. For conventional farms, a decrease of feed demand of 100 g/kg of milk corresponded to a reduction in PCF of 117 g of CO_2 eq/kg of milk and an increase in management incomes MI of approximately 3.1 c/kg of milk. Accordingly, farmers could achieve higher profits while reducing GHG emissions.

Regarding the environmental externalities of the different livestock species and sectors, dairy cows are those that have received more attention. [54] studied the productive, environmental and economic performances of organic and conventional suckler cattle farming systems. They found that the reduction in the use of inputs resulted in a 23% to 45% drop in NRE (non-renewable energy) consumption/ha, 5-20% of which is a drop in non-renewable energy per ton of live weight produced. The authors stated that, however, the shift to organic farming does not significantly affect gross GHG emissions per ton of live weight produced, but suggested that net GHG emissions could be lower for organic farming systems due to the carbon sequestration in grasslands. Contrary to the results that are normally found when GHGs are measured per kg of product, the lower productivity per hectare (fewer animals reared per hectares) allowed a reduction from 26% to 34% in net GHG emissions per hectare of farm area in the study of [54].

[55] reviewed studies that compared different beef production systems using life cycle analysis (LCA). They classified such systems by three main characteristics: origin of calves (bred by a dairy cow or a suckler cow), type of production (organic or non-organic), and type of diet fed to fattening calves (roughage-based -<50% concentrates, or concentrate-based -≥50% concentrates). They observed that organic farms had lowers GWP (global warming potential) and use of energy (on average 7% and 30%, respectively) than that of the non-organic systems. However, they showed higher eutrophization potential, acidification potential, and land use per unit of beef produced. Lower GWP (on average 28% lower), energy use (13% lower), and land use (41% lower) were found per unit of beef for concentrate-based systems when compared with roughage-based systems. Although these results are not giving the whole picture (because aspects such as biodiversity, carbon sequestration, and others were not included in all the studies), the authors came to interesting conclusions that we cite literally:

- Environmental impacts were lower for dairy-based than for suckler-based beef
- GWP was similar for organic and non-organic beef
- GWP, energy use, and land use were lower for concentrate- than roughage-based beef
- Dairy-based beef showed the largest potential to mitigate environmental impacts of beef
- Marginal grasslands unsuitable for dairy farming may be used for production of suckler-based beef to contribute to the availability and access to animal-source food

The study of [56] studied the potential environmental impacts of four different types of organic dairy farms, paying special attention on the farm´s structure (the percentage of grassland on total farm area, and feeding intensity). The results showed that farms with high feeding intensity tend to show ecological advantages with regard to their climate impact and their demand for land. On the contrary, low-input farms showed to be better with regard to animal welfare, milk quality, and ammonia losses. But more interestingly, when they assessed the overall environmental index of the farms, low-input and mixed ones showed the best results. Finally, the authors pointed out the necessity of using a wider range of environmental parameters, since results may differ greatly between studies, farms, and systems.

[57] measured the carbon footprint of the organic dairy sector, based on farm data from six European countries. The results showed that the main contributor to the farm´s carbon footprint was enteric fermentation, which has much to do with the feed management, as exposed earlier.

To sum up, high-quality feedstuffs reduce enteric methane emissions, and this is important because these emissions account for a high proportion of total GHGs (45% of them in the study of [57]). However, one must keep in mind that the environmental impact of the farms belongs to just one pillar of global sustainability. Hence, with regard to feed, other factors must be taken into account, such as the competence with human food.

Regarding the methodological aspects of the assessment of farm sustainability, it must be remembered that the different parameters, frameworks, and approaches available, as well as the limit of the study and the context of the farms, make it difficult to integrate results and make conclusions. In this sense, [57] stated that the method for calculating the carbon footprint could be improved, since this calculation does not take account of carbon sequestration. This aspect is very important for extensive livestock systems (either organic or not), especially for ruminant ones, since cattle grazing captures 20% of the CO_2 released into the atmosphere by deforestation and agriculture worldwide [58]. If carbon sequestration were included in the evaluations (as done by [25, 129]), extensive farms and sensitive ecosystems would show better results in the evaluations of their environmental impact, which could lead to higher public support, competitiveness, and sustainability.

In relation to the organic beef cattle sector, [25, 129] carried out a comparative assessment of the sustainability of organic and conventional beef cattle farms located in agroforestry systems and rangelands of southwestern Spain. It is worthy to mention that conventional farms where extensive, pasture-based, and low-input; and that all farms had cows, either with presence of a fattening period of the calves or just selling them at the weaning age. These two last productive orientations where selected as they are representative of the sector and the area under study. The results showed that organic farms had a higher overall sustainability, especially with regard to the environmental dimension. In this sense, the authors reported that the agro-ecosystem management (agricultural practices) and farm structures were slightly more environmentally friendly. For example, organic farms tend to implement more measures to reduce erosion and to improve soil fertility, also developing better dung management that avoided nitrogen fluxes and allowed farmers to elaborate compost. Only clear differences where found regarding the use of pesticides, herbicides, and/or mineral fertilizers. This is consistent with the findings of [59] in smaller organic beef cattle farms located in a more humid area (northwestern Spain).

Hence, the presence of an approach and configuration of the farms oriented to organic principles (namely, the environmental systems) found in the study of [25, 129] was really scarce, since the improvement and/or maintenance of the ecosystem did not constitute an important driver nor a motivation of the farmers to run their organic adventure. A higher degree of farmer's engagement and awareness toward the sustainability of the agrifood sector is needed. Specifically, the implementation of such sustainable management practices of the agro-ecosystem, such as diversification (the integration of crops, livestock, and trees), are advisable for sustainable land use management [60, 61] and reduce their carbon footprint [57]. Also, these measures deserve to be taken into account by policy makers due to their positive agro-environmental and socio-economic externalities [24].

With regard to swine, Dourmad et al. (2014) evaluated the environmental impacts (per kg of pig live weight and per ha of land used) of 15 European pig farming systems, comparing them with their conventional counterparts, among other types of farming systems, from which "traditional" was an interesting classification worthy of being mentioned since they account for an important part of the livestock sector and rural economy of many areas. This system was defined as "using very fat, slow-growing traditional breeds and generally outdoor raising of fattening pigs". When looking at the results, one can observe that the main differences were found between the traditional systems and the rest of farms. Environmental impacts were, in general terms, lower for conventional farms, when they were measured by kg of pig produced. Conversely, when expressed per ha of land use, mean impacts were 10% to 60% lower for traditional and organic systems, depending on the impact category. These results are in line with those abovementioned, and as previously explained, they are mainly due to the higher land occupation per kg of product and the longer productive times.

Another important point that [62] mentioned was the effect of the autochthonous breed on the environmental impact of the farms. They stated that the use of traditional local breeds, with reduced productivity and feed efficiency, results in higher impacts per kg of live weight. [63] added that the effects of the use of autochthonous breeds have not been adequately demonstrated with regard to some topics (different than the preservation of the genetic heritage and traditional landscape—aesthetical values). Due to this, [24] and [63] highlighted the necessity to deeply study the interactions and effects of the different livestock systems, especially those with beef cattle, since the scientific literature in addressing this sector is scarce. In line with this argument, [64] mentioned that agricultural practices affect biodiversity in a higher degree than the breeds itself.

Due to these results, context, and the scientific literature available that addressed the topic, [25, 129] came to the conclusion that the externalities of organic farms (when compared with the conventional ones), are highly dependent on their production system, their context (socioeconomic, environmental, political, and institutional), and their marketing strategies. These conclusions can also be found in other studies, such as the review of [23] about the organic sector as a whole and its relationship with rural development.

Therefore, the future strategy of research and innovation in organic farming must prioritize productivity gains that address the farms as a whole, while paying major attention to secure the positive ecological performance organic agriculture can provide, since the environmental benefits it provides are absolute goods and cannot be relativized by the fact that yields are currently lower than in conventional agriculture. Moreover, there is a high potential for reducing the yield gap between organic and conventional farms through agricultural research [47].

4. Factors influencing organic livestock farms' success

4.1. Regulation and certification bodies

With regard to the legislative side, it is very important to note that regulations on organic production embrace a wide variety of organic farms; they allow using different animal breeds, structures, agro-ecosystem managements, feeding strategies, and marketing strategies. As a consequence, organic the livestock farm's success and perspectives are really different from one place to another. For example, [65] found that the situation in North Germany was in contrast to the region in the south, where the variability of amount and proportion of the different feed types is predominantly independent of the milk yield. Many factors shape these differences, such as the ecosystems on which farms are based and consumers' demands and willingness to pay.

Additionally, the different criteria of the certification bodies (public and private) act in the same way, since they usually decide whether some exceptions to the regulations can be applied at the farm level. Due to this, it is important to unify criteria. Also, the cost of certification is not affordable for many farmers (especially small farmers, which play a great role in sustainability and food security). Fortunately, nowadays, many efforts are being made to both facilitate the market of organic products worldwide (i.e., agreements between the European and American (USDA) standards) and to reduce cost of certification (i.e., by means of Participatory Guarantee Systems).

Moreover, organic regulations and private standards do not cover marketing aspects (key in the social, economic, and environmental sustainability), so that it is difficult to evaluate to contribution of the organic livestock sector to the sustainability of the food system.

4.2. Implementation of organic farms: Its consequences on the farms' economic and productive performance

Some studies have assessed the consequences of converting livestock farms to the organic system. Their feasibility and success depend upon the structure and context of the previous (conventional) farm. To cite an example, ruminants pasture-based farms such as those located in southwestern Europe and in the Mediterranean basin (especially those oriented to meat production) may be easily converted into organic ones since conventional and organic farms are quite similar [66-67]. On the contrary, species that are mainly reared under intensive production systems will have to go through a difficult process of conversion, e.g., poultry, swine, and dairy cows. And in parallel depending on the farmers´ motivations for converting, the situation of the farms, and their perspectives vary.

As monogastric production systems are not so linked to land as ruminants ones are, and due to the higher prices of organic feedstuffs, it is far more difficult for farmers to convert to produce under the organic system. In this sense, swine rearing under free range production systems (such as those of the dehesa ecosystem in southwestern Spain) appears to be the system that could be converted to the organic model successfully. However, the weaning period seems to be the bottleneck of this sector, because many veterinary interventions are usually needed.

Moving from species to farms structure, it is interesting to note that mixed livestock production systems are those with a higher resilience (also economically), which would allow an easier transition to the organic system [25, 129]. Accordingly, [68] claimed that co-grazing sows with heifers can diminish the parasite burden of the heifers, and that the pig inclination for rooting can be managed in a way that makes ploughing and other heavy land cultivation more or less superfluous. With regard to poultry, there is an indication that quite big flocks can be managed efficiently in a way where the flock act as weeders in other crops or fight pests in orchards. This integration of feed resources of the farms with the different livestock species is possible due to their different grazing habits [69, 70], and is pivotal for the sustainability of the agroecosystems and rural areas [25, 129].

However, the consequences of the conversion process and externalities of organic farms may be very changing, since they depend on many factors [66, 23, 25, 35, 129], such as the socioeconomic and environmental context of exploitation, the climate and topography of the land, the production system under study, the species reared, the regulations on course, the influence of private standards of certification, the availability of organic inputs and prices thereof, the development of the organic industry and marketing channels, and the consumer's behavior (demand and willingness to pay). In order to deal with these uncertainties, researchers have conducted studies that have evaluated the ease of conversion of different conventional farming systems to the former one: for dairy goats [71] and dairy cattle [72]. Therefore, before making conclusions about the adequacy of organic livestock farming, one must establish the limits of the study (local or global scale), its objectives, and motivations. Later, a multidisciplinary assessment of farm sustainability, a SWOT analysis, and an assessment of the feasibility of success along with a study of farms competitiveness must be carried out, as proposed by [67, 73].

In relation to organic beef cattle farms, although there is controversy, studies mainly show that organic farms have worse economic results than their conventional counterpart when they are studied by farm and year since they used to have longer production cycles when the farms are under the Common Agricultural Policy's (CAP) conditions [25, 59, 129] or not [74]. They are also more dependent on both subsidies and premium prices. Finally, higher production costs (mainly derived from feeding and during the conversion period) have also been observed [25, 59, 74-75, 129].

[54] analyzed the productive, environmental and economic impacts of the conversion process of conventional suckler cattle farms. They reported that the ban on chemical fertilizers led to a drop in farm area productivity and meat production (by 18% to 37% for the latter) and farm income (more than 20%). These drops were not compensated by the increase in the meat selling price (+5% to +10%). However, the use of inputs was reduced (by -9% to -52%), which is really important for the sustainability of pasture-based/low-input ruminant farms.

With regard to milk production, [76] found that organic systems had greater milk production. However, it seems that milk production per animal [77] and agricultural area [40, 78-79] is lower in organic farms.

Although at first glance, this lower milk production seems negative, this could have very positive implications and advantages. Firstly, cows could have a longer productive life (longevity), which in turn could make animals produce more liters in their entire life, thus reducing the environmental and economic impact of rearing heifers. Secondly, the increase of the productive capacity of the cows has been followed by health problems such as increased somatic cell counts and mastitis, as well as reduced fertility rates and tolerance to heat stress, which could be reduced if cows reduce their production level. Moreover, such reduction would help to reduce the amount and/or proportion of non-structural carbohydrates given to the animals, which would reduce the risk of acidosis, lameness, and other secondary disorders. In this sense, [76] observed that cattle on conventional farms were fed approximately twice as much grain as cattle on organic farms. All these advantages match part of the goals set in the Strategic Research and Innovation Agenda for Organic Food and Farming set by the European Technology Platform (TP Organics) [80]: improved health, robustness, and longevity.

Moreover, as the price of organic milk seems to be more stable [81], the consumption of mothers' milk by calves may be a profitable strategy in farms where milk is not the main marketable product. Thus, [82] found that the consumption of mothers' milk by calves resulted in high weaning weights at 3 months of age, and Keifer et al. (2014) found that organic dairy cows farms performed economically better than the pasture-based conventional farms analyzed.

Not all is about ruminants. Other sectors, such as rabbits, have also been studied. Thus, [83] showed that the effects on zootechnical parameters are due to the production system and genetics. They found that hybrid rabbits reared under conventional housing had the highest average daily gain, and local grey and organic, the lowest.

4.3. Public subsidies: The Common Agricultural Policy (CAP) in the European Union

Despite the abovementioned low productivity in organic farms, their higher environmental externalities should drive a higher support by the rural development measures of the EU's CAP [24, 84-85], since they play a greater role in the conservation of traditional landscapes and ecosystems by means of a "greener" agro-environmental management, which is finally of great importance for the sustainable development of the surrounding rural areas, where the agricultural sector remains an essential driver of the rural development of this area [27]. In this sense, [84] have claimed the necessity to recognize in a higher degree the role of the extensive livestock systems on environmental and cultural heritage preservation.

4.4. Animal nutrition: Legislation and market

Animal nutrition constitutes an important pillar of organic livestock production. Thus, [86] found that feeding strategies among Wisconsin organic dairy farms were major determinants of herd milk production and income over feed costs. These findings may serve current organic and transition farmers when considering feeding management changes needed to meet organic pasture rule requirements or dealing with dietary supplementation challenges.

In relation to organic feedstuffs, the most important obstacles are the difficulty to find them and their prices. This situation is aggravated by the farms' high external dependence of feedstuff due to decoupling between crops and livestock. These facts reduce the organic livestock farms′ adaptability, and their access to feed additives and materials of high quality. As a result, the organic livestock sector face a big challenge that, along with other factors, has lead to a situation characterized by organic livestock farms without organic products, which reduces their profitability and future perspectives of success. This has been observed either in beef cattle [25, 129], dairy cows farms [87], or other species [88].

One possible solution for overcoming this barrier would be the use of local agricultural by-products for animal nutrition since their price is usually low, and according to [89], they allow to add to their economic value, while providing an environmentally sound method for disposal of the by-product materials. Also, it would lead to either an increase in the incomes for the organic business that sell such by-products or a reduction in the expenditure related to their disposal.

European regulations limited the use of many feed additives, such as mineral preparations, with the aim that organic livestock farms rely on soil minerals. However, their levels can be low in some areas, which can lead to some mineral deficiencies, as observed by [90] in organic calves. This limitation is especially important in the case of dairy cattle, since nutritional requirements of cows are really high. Due to this, researchers are looking for new feedstuffs that are both allowed and useful for the organic livestock sector, such as minerals sources (seaweed in [91]), different pastures (birdsfoot trefoil by [92]), and fat supplements [93].

As the ration for organic herds has been required to be 100% organic by the European regulations, [94] investigated the possible effects of 100% organic feed on the energy balance in Swedish organic dairy herds as indicated by blood parameters, and concluded that the legislative restrictions "did not appear to have had any detrimental effects on the metabolic profiles of organic cows in early lactation and there was no evidence that organic cows were metabolically more challenged or had a severe negative energy balance".

However, the feed resources of the own farm are usually scarce and/or of poor quality in many areas. Thus, [46] pointed out that the availability of the forages in semi-arid areas, such as the Mediterranean basin, is seasonal, and that its quality is not always optimal. Due to this, the supplementation of the animals is frequently needed. Nevertheless, their availability is low, because for the feed industry it is really costly to turn organic or to create an organic line of products, as they must separate the conventional and the organic lines of productions, and the profitability of this investment is very questionable. Moreover, the bureaucracy would increase the workload of the companies, thus reducing their agility and profitability. In this sense, more concrete instructions for the inclusion of feed additives should be introduced in the regulations.

A correct nutritional management is the basis for an optimal health status and, as a consequence, adequate levels of productivity. Furthermore, this productivity has been identified as key to reduce the GHG emissions from livestock. Due to this, policy makers should seriously address this topic since many conventional companies of the feed sector have a really good portfolio of feed additives that are not susceptible for having not-allowed products (such as GMO or residues of antibiotics), and could improve rumen fermentation (thus reducing the enteric methane emissions), reduce the use of antibiotics (reducing the environmental pollution and public health issues related to them), which would increase the efficiency of the livestock sector, and finally, the competitiveness and sustainability of it. Good examples of additives would be limiting amino acids (such as methionine in dairy cows), chelated (also called "organic") minerals, salts of organic acids, yeasts, essential oils, and fat supplements, among a large list of them. Specifically, organic minerals allow a correct nutritional management, reduce the exploitation of resources, and reduce environmental pollution.

4.5. Animal health, welfare, and technical management

As a consequence of the growth in the number of organic farms worldwide, many veterinarians are encountering this method of production. However, they normally suffer from lack of knowledge with regard to the management of animal health suitable to this type of production, such that it "sustains and enhance the health of soil, plant, animal, human and planet as one and indivisible" (according to IFOAM). The focus is to achieve and maintain high herd health and welfare status with low usage of veterinary medicines [95]. The EC regulations for organic farming [28] state that organic livestock should be treated preferably with phytotherapeutic products. However, almost no phytotherapeutic product is registered for livestock, and information regarding veterinary phytotherapy is really scarce [96].

As health and welfare of organic livestock are highly interrelated, veterinarians not only must avoid livestock illness, but also maintain the animals´ physical, mental, social, and ecological well-being [97]. However, the combination of "natural behavior/living" with optimal health and welfare status is not easy, as [98] and [99] interestingly stated, extensive production systems (e.g., free range production) expose livestock to increased disease challenge, and "a healthy system does not automatically mean good welfare for the individual". However, outdoor housing also has benefits [100]; outdoor housing with functional wallows and access to grass and roots or outdoor runs and roughage can enhance pig welfare and reduce pen-mate-directed oral activity and aggression, which is a really important issue in piglet production.

[99] came to the conclusion that animal health is as good or better than in conventional farming, with the exception of parasitic diseases, and that organic farming systems have a "welfare potential", but organic farmers must deal with the dilemmas and take animal welfare issues seriously. [101] explores how the special organic conceptions of animal welfare are related to the overall principles of organic agriculture. They identified potential routes for future development of organic livestock systems in different contexts (northwestern Europe and tropical low-income countries). Moreover, as outdoor-reared animals make more use of the farm's feed resources, negative consequences can also be found with regard to food safety. Thus, it has been demonstrated that a significant number of organic eggs had dioxin contents that exceeded the EU standard [102].

When one analyzes the health and welfare status of different livestock species, one rapidly realizes that the control of intestinal parasites and to achieve adequate nutritional management are the main bottlenecks and challenges.

Regarding ruminants, [103] also identified these two issues as challenging after studying organic goats. Later, [77] observed lower calf mortality, less incidence of mastitis, fewer rates of spontaneous abortions, and reduced ectoparasite loads in organic farms. However, internal parasite control was again detected as a weak point (greater prevalence was observed in organic farms). Fortunately, animals in the organic system exhibited lower parasitic resistance to anthelmintics, which gives hope to improve herd health status by means of future strategies. [104] reviewed the prevalence of zoonotic or potentially zoonotic bacteria, antimicrobial resistance, and somatic cell counts in organic dairy production; and they found contradictory results in relation with in bacterial outcomes and Somatic Cell Count (SCC) between conventional and organic farms.

Later, [105] discussed the effects of weaning calves at an older age on welfare and milk production. They claimed that foster cow systems with additional milking might be a promising alternative since calves can satisfy their sucking motivation and have social contact to mothers/adult cows; and additionally, weaning stress might be reduced and milking the cows when suckling calves could lead to an increased total milk production. However, this system has economical consequences that must be assessed carefully. Due to this, the authors concluded that further research is needed to reconcile consumers' demands and the possibilities of farmers using such systems.

With regard to animal welfare, [106] assessed the welfare state of dairy cows in European farm systems (extensive and/or low-input farms compared with organic ones) using the Welfare Quality® assessment protocol. Farms had mainly an acceptable and enhanced overall welfare state, although specific problems were found (injuries and discomfort of the lying areas, mutilations, poor human-animal relationship, or insufficient water provision). [107] indicated that most of the organic and conventional farms would have been unlikely to achieve many criteria of audit and assessment programs currently used in the U.S. dairy industry. The parameters recorded were the following: neonatal care, dehorning, pain relief, calf nutrition, weaning, age at weaning, pain relief after and during dehorning, size of the calving area, body condition score, animal hygiene scores, hock lesions, and use of veterinarians. [108] explored how calf welfare is approached in six different organic dairy farms and how far the concept of naturalness is implemented. They observed differing understandings of "naturalness" and welfare, which lead to such diversity of organic farms in aspects that should be shared. In this sense, [82] found that some farmers had difficulties accepting negative implications of suckling systems such as stress after weaning.

The reliance of veterinary drugs is a hot topic that globally is trying to be reduced. In organic farms, where limitations in the use of veterinary drugs are higher, health-related problems can occur, thus undermining the farm’s profitability. To reduce these situations, [94], through the CORE Organic ANIPLAN, carried out a study with organic dairy farms of seven European countries, aiming at minimizing medicine use through animal health and welfare planning. Overall, after the implementation of the plan, there was a reduction in the total treatment incidence, and an improvement of the udder health situation across all farms. Hence, these authors concluded that the plan applied "can be regarded as a feasible approach to minimizing medicine use without the impairment of production and herd health under several organic dairy farming conditions in Europe".

Regarding beef cattle, [24, 59] found less use of veterinary medicines. These results are in line with those of [76], who found that the use of outside support and vaccinations were found to be less prevalent on organic dairy farms than on conventional farms. These last authors found little difference in the average reported somatic cell count and standard plate count.

In relation with monogastrics, parasites also constitute a concern. Due to this, the topic was also addressed under the framework of the COREPIG project, a pan-European project on organic pig production focused on the "Prevention of selected diseases and parasites in organic pig herds". One of the results of this project has been the publication of review papers that have provided really valuable information and reflections on the current status and challenges of the swine sector. [109, 110] reported that sows are kept in a variety of different production systems, "with some countries having totally outdoor management at pasture, some keeping animals indoors with concrete outside runs, and others having combinations of these systems". Although reports suggest that relatively few health and welfare problems are seen, the problem of parasites is also a concern within this sector (they are more prevalent in the organic sector). According to the arguments above exposed by [98] and [99], the authors discussed that organic sows had more behavioral freedom, but may be exposed to greater climatic challenges, parasite infestation, and risk of body condition loss. So that, again, the combination of welfare, health, and productivity poses an issue. Even, public health could be compromised, [110] highlighted the high exposure to *T. gondii* in organic pig farms in Italy, indicating a potential risk for meat consumption.

[111] also studied the health and welfare of suckling and weaned piglets in six EU countries. For this purpose, these authors used animal-based parameters from the Welfare Quality® protocol, and showed the main issues prevailing in these farms. [112] studied issues related to weaning in piglets, and they concluded that diseases around weaning are multifactorial so that "in order to solve problems around weaning, the complexity and the individuality of farm systems need to be taken into account".

Furthermore, it has also been reported that some disorders in pigs are less frequent under the organic system, namely, respiratory problems, skin lesions (including abscesses and hernias) and tail wounds. However, joint lesions, white spot livers, and parasitic infections were more common among organic pigs [100]. Due to this, although organic herds consumed three times less antibiotics than conventional ones, the reduction of anthelmintics seems to be more complicated. However, these researchers did not find any difference in mortality rate nor if more pigs in need of treatment in the organic herds.

Fortunately, it seems that some strategies to control the parasites in organic production are coming to scene. Thus, [100] recommended to rotate outdoor areas with as long interval as possible, i.e., by including the pigs in the crop rotation. Furthermore, they stated that an increase in the number of specialized organic farms will help carry out other management strategies needed to maintain the good health of the pigs: implementation of age-segregated production and buying piglets from only one or few units.

Finally, the aquaculture growing sector has also been assessed from the organic side. [113], after studying the open aquaculture systems, reported that both organic and conventional systems present unresolved and significant challenges with regard to the welfare and to environmental integrity, due to many issues such as water quality, escapes, parasites, predator control, and feed-source sustainability. Finally, they concluded that under the current situation, open net-pen aquaculture production cannot be compatible with the principles inherent to organic farming.

4.6. Marketing of organic products and consumer’s behavior

Organic livestock farms (when pasture-based and low-input) are perceived as socially more acceptable than intensive ones because they provide many environmental services, such as reducing the risk of fire, improving soil fertility and pastures quality, as well as biodiversity and carbon sequestration. Moreover, they have lower environmental impact linked to land use change (deforestation) and to the use of energy (extraction, manufacturing feedstuff, transportation, etc.) [19-22]. Furthermore, they do not compete with humans for food, which could be another argument to buy organic as the concern about food security has become mainstream. Note that around 70% of the grains used by developed countries are fed to animals and that livestock consume an estimated one-third or more of the world's cereal grain, with 40% of such feed going to ruminants, mainly cattle [114].

However, out of the farm gate, the lack of development of the marketing channels and industry, low consumers awareness of organic products, and their low willingness to pay a premium price for them hinder the demand for organic animal products. As a consequence, most of the farmers are not able to sell their products to the organic market and at a price that allow them to cover their production costs; one can easily find many organic farms without organic products [25, 88, 129]. In the case of livestock, this situation is due to: (i) the difficulty to find organic feedstuff and its cost and (ii) low consumer demand linked to low level of knowledge, awareness, and willingness to pay premium prices. Specifically, in the beef sector, the demand for organic weaned calves (not fattened) was almost non-existent, which make it very difficult to carry out the market of organic beef [25, 129].

In the few cases in which producers can manage to sell their products as organic, such scarcity of developed channels causes the price differential between organic and conventional products to be still high, feeding a loop characterized by reduced per capita consumption and low presence of organic products in the supermarkets [115-116]. As a consequence, demand and willingness to pay consumers for organic products is reduced [117], especially in relation to beef and in countries such as Spain [118-119], despite being one of the first producers in Europe. In order to reduce the cited price differential and increase consumption, a wider distribution of these products is key.

In the case of beef, this little demand is partly due to the fact that consumers do not perceive clearly the differences between organic and conventional meat [115]. Therefore, [120] showed that there is a clear need to excel in organic meat products, quality, and environmental contribution. However, it is can be complex to define and evaluate the quality characteristics of a meat product, especially when the benefits of organic meat over conventional are not clear from the sensory, nutritional, and health aspects[115], particularly when they are compared with conventional extensive systems, such as those present in the pasture.

In summary, it is necessary to note that the demand for organic meat could stagnate due to the following reasons: price differential with conventional meat, inelasticity of demand for this product, and limited knowledge and awareness about the product by consumers. Fortunately, there are strategies that could solve this weak domestic demand, such as exporting. However, meat export is not a strategy easy to carry out due to the cost of transportation and storage, the bureaucracy, and the needed know-how.

Moreover, the approach should not be to just find the markets for organic products, but other additional strategies must be studied. Firstly, it must be taken into account that there is a change in consumer preferences towards local [121-123] and more sustainable [122, 124] products. Moreover, the level of knowledge and awareness about organic products is really low in some countries and regions in Europe [119], leading to the fact that consumers find it hard to differentiate between organic, local, traditional, and sustainable [122, 125-127]. Additionally, one cannot assume that all consumers believe that all organic products are totally complying with the organic principles (many consumers may have not even heard about such principles) and that the organic principles match with the internal triggers and values of the consumers.

To overcome this diversity in the market, organic products should try to be linked to other quality standards. The products with more added value (they would be more than organic) and the growing consumer preferences towards them have both been called 'organic-plus', and have been described by some authors [124]. Within this trend, environmental sustainability, freshness, and local economy are attributes of relevance. In other words, the consequences of the agrifood system (marketing channels, distribution) are becoming important for a growing number of consumers. However, these topics are not covered by the organic regulations, and most of the organic products have been produced and marketed through the mainstream agrifood system; conventional marketing channels characterized by the concentration of production, exporting most of the production, low domestic consumption, and concentration in supply centers and large retail chains. This orientation of organic production into conventional marketing channels and production systems (monocultures and agrochemicals) has been well-documented and is known as "conventionalization" of the organic production and "input substitution" [128].

As a consequence, this type of production (despite being organic) does not always provide consumers with products as fresh, local, and sustainable as they desire, nor positively impact environmental protection and/or rural development in such degree, as was explained above.

In summary, it seems that organic products are not the solution for many consumers that really want to access sustainable products. If organic companies and/or policy makers do not take into account these aspects, the growth of the organic sector, as well as their positive externalities, will be limited.

5. Conclusions

Organic livestock farming (especially its organic principles than regulations) may be a useful strategy to overcome the challenges of the agricultural sector (sustainability, food security, and food safety) while matching with consumers′ tendencies (animal welfare, health, environmental protection, etc.). Furthermore, organic livestock farming could be also an interesting strategy for the eternal rural development issue and the farms' decreasing profitability.

However, the combination of complying with organic regulations and objectives and principles of organic farming while increasing overall sustainability is not an easy task. Due to this, it is inappropriate to generalize the benefits of organic livestock farming itself, since the feasibility of implementing organic livestock production systems and their consequences varies greatly, and are site and time-specific. Therefore, it must be remembered that any production system that does not evolve from its initial state (i.e., defined by law) and do not take into account both the time and spatial scales cannot be sustainable worldwide and for a long time. Due to this, a SWOT study along with an assessment of the future effects and difficulties of organic farms under specific contexts is really needed. By doing so, it will be possible to design site-specific and successful options that comply with organic regulations and principles, while being sustainable.

Moreover, some topics must be addressed in order to increase the organic livestock farm's success. Firstly, it has been observed that most of the farmers do not focus on sustainability nor environmental improvement, and that many farms are easily complying with the organic regulations without carrying out environmentally-friendly management practices in their agro-ecosystems. Due to this, improved education and training of farmers and consultants regarding conservation agriculture and GHG mitigation are really needed.

Secondly, there is a need to design feeding strategies that provide adequate nutrition, especially in areas with environmental constraints, such as arid and semi-arid areas. Moreover, regulations should both unify criteria and facilitate the production of feed additives by companies, because the consequences of it could be really important and positive for the organic livestock sector and for the sustainability of the food system.

Thirdly, the knowledge of the veterinarians with regard to animal health management must be improved as fast as the sector is growing. Related to this, more light must be shed on the relationship between animal welfare, "natural living-behavior", and animal health. Furthermore, health care protocols must be developed for each species, including research on alternative and complementary methods of disease prevention.

Fourthly, CAP schemes should be improved in order to reward systems that produce positive externalities in a greater extent despite being low in productivity, since the agricultural sector remains an essential driver of rural areas. These systems contribute to environmental, cultural, and heritage conservation, which finally lead to revitalized rural areas and overall sustainability (from the economic, social, and environmental standpoints).

Finally, and more urgently, special attention must be paid on the marketing strategies of organic products (organic plus products and marketing channels) since this is the main constraint of the sector, and it is the point where there are more possibilities for improvement for both farm profitability and overall sustainability of the food system.

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Organic Dairy Sheep Production Management

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Additional information is available at the end of the chapter

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Abstract

Organic production systems are based on natural processes, the use of local feed resources, and the maintenance of biodiversity in all senses. Several studies have noted the positive effects of organic sheep milk production systems on animal welfare, animal health, product quality, and environmental impact. On the other hand, it has been reported that dairy sheep organic farms show lower milk yields and increase the susceptibility to environmental impacts compared with conventional farms. The standards that regulate feeding management in organic systems are one of the most critical factors that influence milk production performance. Lower milk production is also associated with poor ability to adapt specialized dairy breeds to organic management, low genetic potential for milk production in native and local breeds, and elevated dependence on environmental conditions. However, the aim of organic dairy production is not to reach maximum dairy productivity but rather to integrate animal and crop production and to develop a symbiotic relationship between recyclable and renewable resources; furthermore, organic production positively affects the employment rate and quality of life in rural communities. Organic dairy sheep production is one means of improving the balance between society's demand for food and the ecological impact of the agro-alimentary industry.

Keywords: Sheep, milk production, organic system, sustainability

1. Introduction: A brief overview of organic farming

Society's demand for foodstuffs is growing at a higher rate than current levels of production due to population growth and the rise in average income. According to the FAO, "food security exists when all the people, at all times, have physical, social and economic access to sufficient, safe and nutritious food." Over the last few years, some consumers have expressed increasing concern regarding the origins of their food, its social and ecological impacts, and the fairness of its production. These customers prefer organic products, based on their perception that organic farming generates benefits associated with animal welfare, food quality, food safety, environmental concerns, and community development [1].

Due to its agro-ecological and holistic approaches and the competitive prices for organic products in the market, organic farming has developed into a small but important sector in agricultural production [2]. In 2012 alone, the "organic market" was worth approximately 50 billion euros. The International Federation of Organic Agriculture Movements (INFOAM) [3] reported that in 2012 some 37.5 million hectares of land were dedicated to organic agriculture, which represented 0.87% of total agricultural land. Australia is the country with the largest area used in organic agriculture, with 12 million hectares, followed by Argentina (3.19 million ha) and the USA (2.2 million ha) (Figure 1).

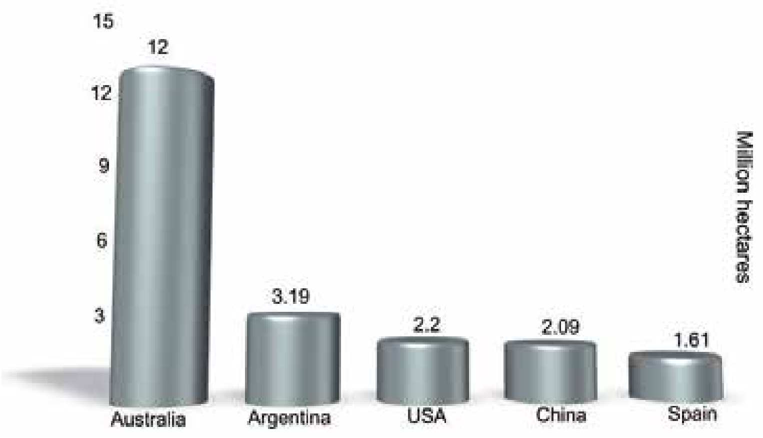


Figure 1. Countries with the largest areas of land dedicated to organic agriculture [4].

The quantity of land dedicated to organic agriculture appears to be small; however, at the local level in several countries, the impact of organic systems is very important. Although smallholder farms grow 70% of the world's food, 50% of those without food security are small-scale farmers from underdeveloped and developing countries [5]. Smallholder organic farmers from developing countries account for 73% of land certified for organic production [3]. These producers use organic techniques in soil and water and holistic management, practices that allow them to be productive, achieve food security, and increase their incomes. Ayuya et al. [6] note that organic certified smallholders are less likely to suffer multidimensional poverty compared with conventional producers.

There are an estimated two million certified organic farmers worldwide; of this total, producers in developing countries account for 80%: 34% in Africa, 29% in Asia, and 17% in Latin America [7]. The countries with the highest numbers of organic producers are India (650,000 producers), Uganda (189,610 producers), and Mexico (169,703 producers) [5] (Figure 2). Some countries, such as India, Ethiopia, Mexico, and Uganda, have promoted the participation of smallholder

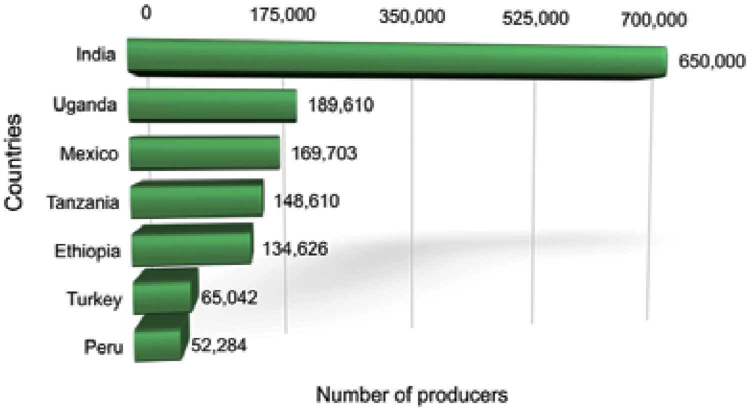


Figure 2. Countries with the largest number of certificated organic producers (adapted from [4]).

farmers in the organic market, through certification schemes such as "group certifications" and the so-called participatory guarantee systems, which link organic producers to international and domestic markets. Organic agriculture, therefore, represents an option to improve agro-ecological, social, and economic conditions in developing countries and emerging markets.

The cycle of production–consumption of certified organic products can be observed mainly in regions with high purchasing power, where consumers are able to pay the price premium of such products. In this sense, the main consuming countries of organic products are industrialized countries; the leader in organic food retail sales is the USA, with 22,590 million euros annually, followed by Germany (€7,040 million/year), France (€4,004 million/year), Canada (€2,136 million/year), and the UK (€1,950 million/year). Developed countries also have the highest consumption per capita of organic products, led by Switzerland (€189.1/year), Denmark (€165.8/year), and Luxembourg (€143.0/year) [4].

1.1. Organic livestock production

Organic livestock production is a holistic system aimed at the integration of animal and crop production and the development of a symbiotic relationship of recyclable and renewable resources [8–10]. The grassland and grazing areas used by organic livestock activity represent two-thirds (27 million hectares) of agricultural organic land; this reflects the importance of animal production within the organic production industry [4].

Organic livestock farming involves radical changes in production processes related with major attention to health and animal welfare, environmental conservation, quality, and food safety [10]. The diversity of organic livestock farms relies not only on natural local resources, animals used, climatic conditions, products manufactured, and commercialization but also on the production and farming strategies of each organic farmer.

Verhoog et al. [11] distinguish three types of organic farmers. In the "non-chemical approach," the producers are pragmatic organic farmers who formally follow organic farming standards but continue to have a conventional problem-solving approach with economic motives to conversion. The second type of producers follow the so-called "agro-ecological approach," with a more systematic approach and closed cycles; they focus on efficient production without causing damage to ecosystems. Finally, the "integrity approach" farmers develop farms where soil, plants, animals, and the farm as a whole are regarded as an organism with an intrinsic value. Each organic farming approach will determine different feed, breeding, reproduction, and health requirements.

Some of the positive effects of organic livestock practices are promoting sustainable land use, improving animal welfare and increasing product quality. The methods used exert a positive effect on biodiversity and ecological balance. Furthermore, organic management may contribute to the safeguarding of agricultural functions, with positive effects on the employment rate and the quality of life in rural communities [12, 13]. For these reasons, organic livestock farming can improve the balance between the demand for human food and the ecological impact of the agro-alimentary industry.

2. Organic dairy sheep production

Milk and dairy products constitute a high share of all organic products sales, positioned in second place behind only fruits and vegetables, and in first place for animal products, with 15% of total organic sales [14]. Sheep milk production has an important economic role in industrial countries due to high prices for dairy products, mainly cheese. Additionally, sheep milk represents a source of high quality protein and calcium in arid areas, especially for hungry or malnourished people [15].

Organic dairy sheep farms represent a system focused on producing high-quality nutritious milk, by implementing production methods that reject the use of agrochemical products, artificial compounds, pesticides, growth promoters, and forage additives and that utilize crop rotation and the reuse of organic residues. In some countries, such as Spain or Greece, organic dairy sheep systems are an essential factor for rural development for three reasons: their low environmental impact, their use of autochthonous breeds, and the diversity of transformation of milk and manufacturing processes [16].

According to Perez et al. [17], milk production is one of the most complex systems in organic production, which complicates the conversion from conventional to organic production. This is due to the large quantity of technological innovations that have been developed within the industry. However, several other authors claim that conversion from conventional to organic production systems in small ruminants appears to be less complicated in terms of management when compared with other farm species. This situation may be mainly because the management of sheep feeding does not differ dramatically between organic and conventional production systems [18–20].

Sheep have several characteristics that promote the transition process, such as easy management, effective adaptation to diverse environmental, geographic and climatic conditions, and high efficiency in the use of available sources of grazing [19, 20]. These characteristics conform with the management practices suggested by organic standards, which dictate that feeding must be based on extensive grazing and that supplementary feed should come from organic farms (certified feed industry) [21].

Organic dairy sheep farms are generally located in harsh environments, where dairy cattle production is not feasible. Organic dairy sheep nutrition is based on grazing in natural pastures and using winter fodder crops; therefore, the seasonal effects on milk sheep production are strong. The grazing system of organic dairy sheep farms promotes the continuity of traditional pastoral systems, which is the key to the sustainability of rural areas, the conservation of traditional systems of production, and the preservation of cultural heritage [22].

Location		Name of regulation	Date of publication	References
Global or regional				
FAO-WHO		*The Guidelines for the Production, Processing, Labeling and Marketing of Organically Produced Foods (Codex Guidelines)*	1999	[23]
INFOAM		*Standard for Organic Production and Processing*	August 12, 2012	[3]
EAC[1]		*East African Organic Products Standard, EAS 456:2007*	April, 2007	[24]
EU[2]		*Council Regulation (EC) No 834/2007 on organic production and labeling of organic products with regard to organic production, labeling and control*	June 28, 2007	[25]
Continent	*Country*			
America	Argentina	*National Law 25.127. Ecological, Biological and Organic Production*	September 8, 1999	[26]
	Brazil	*Law No. 10.831 and decree No. 6.323 (2007)*	December 23, 2003	[27]
	Chile	*Law 20.089 from National System of Organic Products Certification*	December 12, 2005	[28]
	Costa Rica	*Law of Development, Promotion and Foment of the Organic Agricultural activity. No. 8591*	August 14, 2007	[29]
	Mexico	*Law of Organic Products*	February 7, 2006	[30]
	United States	*National Organic Program*	December 21, 2000	[31]
Africa	Tunisia	*Law on Organic Agriculture No. 99-30*	April 5, 1999	[32]
	Uganda	*Uganda Organic Standard (UOS)* *East African Organic Products Standards*	2004 April, 2007	[24, 33]
Asia	Japan	*Japanese Agricultural Standards for Organic Livestock Products*	October 27, 2005	[34]
	India	*National Programme for Organic Production (NPOP)*	May, 2001	[35]
Oceania	Australia	*National Standard for Organic and Bio-Dynamic Produce. Edition 3.4*	July 1, 2009	[36]
	New Zealand	*Technical Rules for Organic Production. MAF Standard OP3,*	June, 2011	[37]

[1]EAC, East African Community, [2]EU, Europe Union

Table 1. Organic production standards.

The technical challenges faced by organic dairy sheep producers are regulated by international and regional standards, such as EU regulation No. 834/2007 [25], IFOAM standard for organic production and processing [3], Basic Standards and Codex Guidelines [23], and local regulations in each country (Table 1). Sheep milk production under organic management within defined standards entails challenges in feed, reproductive management, breeding, health, and welfare practices.

2.1. Feed management in organic dairy sheep farming

Organic dairy sheep systems involve extensive management, with high levels of nutrient self-sufficiency and efficient nutrient utilization. This livestock system requires management strategies with highly complex crop rotation to produce both forage and concentrate feed. Regardless of production system type (conventional or organic), the lactation process in dairy sheep requires feed rations with high levels of nutrients during mammogenesis, lactogenesis, and lactation [38]. Bencini and Pulina [39] have estimated that to produce a liter of sheep's milk with 7% fat content requires 7.1 mega joules of metabolizable energy (MJ of ME).

Country	**Breed**	**DMY (kg/day)**	**Fat %**	**Protein %**	**SNF%**	**TS%**	**References**
Organic management							
Italy	Sardinian	1.23(l)	6.74	5.7	-	-	[42]
Italy	Sardinian	1.44	6.46	5.61	10.65	17.11	[43]
Czech Republic	[1]Crossbred	0.82(l)	7.94	6.49	12.25	20.19	[44]
Greece	Karagouniko	1.1	6.8	5.7	11.6	18.5	[45]
USA	[2]Crossbred	-	8.69	6.33	12.19	20.88	[46]
Czech Republic	East Friesian	1.03	6.65	5.30	11.1	17.75	[47]
Mexico	East Friesian (EF)	0.56	6.63	5.14	10.2	16.85	[48]
	EFxPelibuey	0.39	8.03	5.33	10.6	18.71	
	EFxSuffolk	0.55	6.98	5.29	10.4	17.42	
Conventional management							
Spain	Churra	1.0(l)	6.54	5.7	12.03	18.57	[49]
Israel	Awassi Assaf	2.77	4.68	5.13	-	-	[50]
Italy	Valle del Belice	1.58	7.32	5.69	-	-	[41]
Czech Republic	East Friesian	0.87	8.0	5.71	11.59	17.86	[51]
Spain	Lacaune	1.04	6.14	4.89	9.85	15.99	[52]

TMY, total milk yield; DMY, daily milk yield. SNF, Solids non-fatty; TS, Total solids, [1]First lambing crossbred ewes, Lacaune (50%), East Friesian (37.5%) and Improved Wallachian (12.5%). [2]Crossbred ewes Lacaune X East Friesian.

Table 2. Milk production and composition of dairy sheep in organic and conventional production systems.

The energy and protein content in dairy sheep rations must be adequate and sufficient to support maintenance requirements as well as milk production [40]. Pulina et al. [41] note that energy intake is the most important factor that influences milk production and composition, followed by protein and fiber content of the diet. An adequate amount of energy in dairy sheep diets increases glucose content in the blood, which promotes the synthesis of lactose, the activation of mammary and systemic regulators (insulin, IGF, thyroid and neurohormones, etc.), and the increased uptake of milk precursors (glucose, acetate, butyrate, amino acids, NEFA, vitamins, and minerals) [41].

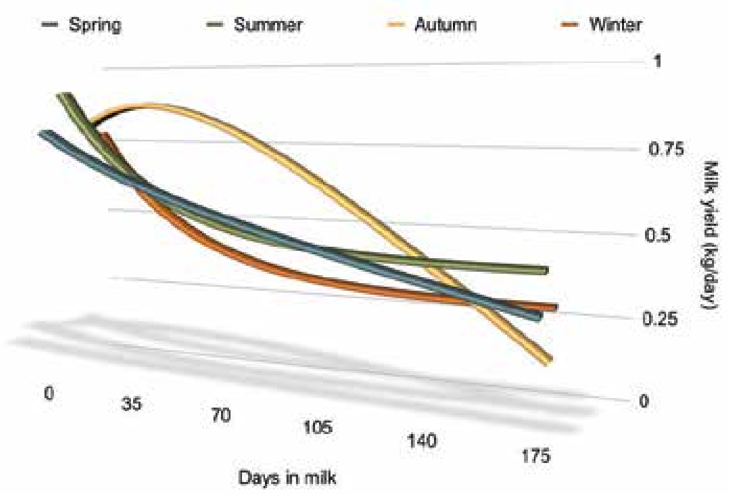
The standards that regulate feeding management in organic systems are one of the most critical factors that influence milk production performance and quality of milk (Table 2). Organic regulations limit the use of concentrate and reduce the range of ingredients that can be included in organic rations. This situation may cause deficiencies of energy, protein, and minerals (zinc, molybdenum, selenium, copper, and iodine), which increases the risk of nutrient imbalances [53, 54]; it has been reported that underfeeding ewes in early lactation, when nutritional requirements are highest, results in lower milk yields [55].

European organic standards require feed rations based on forage (minimum 60% of daily dry matter inclusion) and primarily homegrown ingredients [25]. One of the major challenges in organic management is to formulate high forage diets with an adequate energy concentration due to the low energy value of most forages (<11 MJ of ME per kg DM) when compared to concentrate feeds (>13 MJ of ME per kg DM) [56]. The stage of lactation determines the percentage of forage in the total ration, which can comprise up to 100% of the total ration. Organic dairy sheep can graze in natural or cultivated pastures, and different strategies of feeding can be used to follow organic standards.

The feed management on most organic dairy sheep farms is based on grazing. Grazing is the interaction between animals using the pasture and the pasture itself [57]. Systems based on natural pasture grazing utilize less fertilizer and are considered more ecological. However, the high level of pasture in diet, the availability and quality of forage, and the change from grazing fresh herbage to consuming conserved forage are associated with lower milk yields for sheep under organic management compared with milk yields on conventional farms [58, 59].

The availability and quality of pastures and conserved forage change significantly throughout the year, producing a seasonality effect on milk production. Angeles-Hernandez et al. [60] analyze the effect of lambing season on milk production in sheep under organic management; they conclude that sheep with autumn lambing showed significantly ($P = 0.002$) higher milk yields (Figure 3). This may be due to the sheep having been pregnant during the summer, when the availability of forage reaches its maximum, producing a positive effect on the differentiation of mammary secretory cells as well as on the buildup of the animal's physical condition.

Zervas et al. [58] analyze the milk production and live-weight changes in ewes in both conventional and organic systems. Ewes under organic management were fed with grass hay plus barley grain, and ewes under conventional management were fed with grass hay plus balanced concentrate feed. Milk yields of ewes fed organically were significantly lower ($P <$



Lactation curve adjusted using the Wilmink model [61] ($Y = a + be^{kt} + ct$.)

Figure 3. Lactation curves per lambing season of dairy sheep under organic management (adapted from [60]).

0.001) when compared with conventional-fed ewes (134 vs. 180 kg/year, respectively). Also, ewes in conventional management showed higher values of live-weight gain ($P < 0.01$) in the period between lambing and weaning (organic 67 vs. conventional 79 g/day).

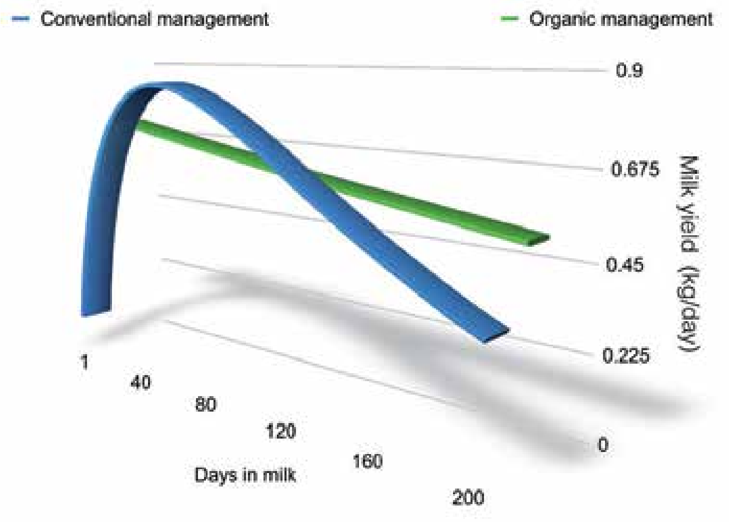


Figure 4. Lactation curves of conventional and organic dairy sheep farms (adapted from [62]).

Some studies note that milk yields of dairy sheep under organic management can be similar or higher than conventional dairy farms, which can be explained in part by lower stocking rates and high availability of forage per animal [43, 63]. Angeles-Hernandez and Gonzalez-Ronquillo [62] compared the milk production and lactation curves of conventional and organic dairy sheep farms; these authors used the Wood model [64] to analyze a total of 7,501 weekly test-day milk yield records from crossbred dairy ewes. There were no differences in milk yields between organic and conventional dairy sheep farms (97 vs. 103 kg, respectively), but there were significant differences ($P < 0.05$) in the shape of the lactation curve (Figure 4), traits that defined the shape of lactation curve (peak yield and time of peak yield), and parameters of the Wood model (Table 3). Sheep in organic systems showed a higher percentage of lactation curves with atypical shape (without peak of lactation) (Table 3), which could be beneficial in this system, as the risk of negative energy balance and metabolic disturbances in early lactation is lower (Figure 4).

	Traits of lactation curve			**Parameters of Wood model**			**Proportion of atypical shapes**
Type of farming	TMY(kg)[1]	PY(kg)	PT(kg)	*a*	*b*	*c*	(%)
Organic	97.3	0.79^b	20.9^b	0.51^a	0.43^b	0.011^a	52.6
Conventional	103.0	0.85^a	86.9^a	0.25^b	1.89^a	0.002^b	10.5
P-value	0.06	0.05	0.001	0.01	0.001	0.001	

[1] TMY, total milk yield adjusted to 200 days in milk; PY, peak yield; PT, time to peak yield; *a* is the production of milk at beginning of the lactation (kg), *b* and *c* are parameters of inclining and declining slopes of lactation curve before and after the PY, respectively.

Table 3. Characteristics of lactation curve and parameters of Wood model from lactation of organic and conventional dairy sheep farming (Adapted from [62]).

Pasture farming systems result in milk characterized by a chemical composition that has beneficial properties for human health. Organic sheep milk has a high fat content (Table 2) due to rations rich in fiber [15]. Several studies report that milk and dairy products from certified organic production systems contain higher concentrations of protein, cis-9, trans-11 CLA, α-linolenic (α-LNA), transvaccenic acid, docosapentanoic acid, eicosapentanoic acid, total n-3 fatty acids, α-tocopherol, and β-carotene than those from conventional production systems [65–67]. Tsiplakou et al. [45] conclude that sheep milk produced under organic farming conditions has higher nutritive values, with elevated contents of MUFA, PUFA, α-LNA, cis-9, trans-11 CLA, and ω-3 FA compared with that from conventional systems.

2.2. Effect of genetic factors in organic dairy sheep farming

The breed or genotype of dairy sheep is one of the main factors that affects milk yields and chemical composition. The choice of breed in organic systems must be considered, with an emphasis on animal characteristics that ensure their welfare and health, such as adaptation to local environmental conditions, vitality and resistance to disease, and absence of specific health problems associated with certain breeds [23, 25].

According to Nauta et al. [2], the different production and marketing strategies of organic farmers demand different breeds. Current dairy breeds have been modified through selective breeding programs to produce high levels of milk, which may make them unsuitable for a traditional and more natural production system. However, the "non-chemical approach" organic farmers use specialized dairy sheep breeds to reach economically viable milk yields, and organic farmers with other production approaches use specialized dairy sheep breeds during the conversion process, usually with moderate milk production performance (Table 2).

The main strategies of animal breeding in organic dairy systems are selection (within and among breeds) and crossbreeding. Selection in organic farming should be used to reinforce, in a sustainable manner, the relationship between the animal and the environment in which it is produced [21]. There are differences in the characteristics and magnitude of genotype due to external factors (i.e., environmental interaction between conventional and organic systems) [68]; the specific approximation to environmental conditions of organic management determines different selection traits for both production systems (Table 4).

The program of selection on organic dairy sheep farms can be applied to specialized, local, or native breeds to improve dairy production traits, but it mainly promotes the selection of vital traits that improve animal well-being, sustainability, health, and flock efficiency [69] (Table 4). Nauta et al. [2] noted that 43% of organic farmers were seeking functional traits as a breeding goal, 32% productive traits, and 25% conformation traits.

Trait	Heritability
General disease resistance	0.05-0.80
Resistance to parasite infection	0.25-0.40
Somatic cell count	0.12-0.13
Longevity	0.05-0.13
Female fertility	0.07-0.20
Mature size	0.47
Feeding characteristics	0.10
Udder shape	0.20-0.24
Teat size	0.18-0.39
Milking ease	0.01
Milk production and composition	
Milk production	0.28-0.32
Fat content	0.41-0.62
Protein content	0.51-0.53
Fat yield	0.17-0.29
Protein yield	0.18-0.27

Data from: [21, 70-77].

Table 4. Important traits in organic dairy sheep breeding.

Organic dairy production can benefit from using native or local breeds genetically adapted to their environment; these breeds are more resilient to climatic stress and are resistant to local parasites and diseases, enabling them to utilize a lower quality of feed [78]. Organic farming may contribute to the maintenance and improvement of the variability of dairy sheep breeds. The use of native breeds can also help support food, agricultural, and cultural diversity, in that the milk and cheese produced from sheep are an expression of a regional cultural tradition. Native breeds also promote local food security and represent a valuable genetic source for improving health and performance traits in the future [12, 78]. However, under organic management, the use of local sheep breeds that are not specialized in milk production may hinder the achievement of sufficient milk yields to reach economic viability. In these situations, crossbreeding can be an option as an improved genetic strategy [79].

Crossbreeding of native breeds with specialized dairy breeds is a viable option to improve dairy production parameters and promote adaptation to feed sources, climate, and the management and market conditions of organic milk production systems, through heterosis and the combined attributes of different breeds [48]. When animals are genetically adapted to specific/extreme environmental conditions, they will be more productive and production costs will be lower. Furthermore, genetic groups adapted to organic dairy management help to safeguard animal health and welfare [78].

Angeles-Hernandez et al. [48] carried out an evaluation of the effect of genetic group on milk production and composition on an organic dairy sheep farm; they compared three genetic groups: East Friesian (EF), EFxPelibuey (local hair breed) (EFxPL), and EFxSuffolk (EFxSF). They found significant differences among genetic groups in milk yield and milk composition (Figure 5). EFxPL sheep showed a lower milk yield (59.8 kg), protein yield (20.8 g/day), and fat yield (31.3 g/day) compared to the other groups. EF and EFxSF showed similar values of milk yield (76.1 ≅ 75.8 kg), protein yield (28.8 ≅ 29.1 g/day), and fat yield (37.2 ≅ 38.4 g/day, respectively).

The EFxSF group showed appropriate milk yield and chemical composition; these contribute not only to an increased cheese yield but also to a differentiation of cheese flavor. However, crossbreeding presents challenges in terms of maintaining a correct proportion of purebred–crossbred populations; furthermore, in systems with inadequate management, biodiversity may be jeopardized by the elimination of certain purebreds (specialized and native breeds) [21].

The goals of organic dairy production farms are more than maximum milk productivity; their objectives are directed to favoring animal health and welfare and to improving the quality of their products with minimum environmental impact. In this sense, genetic improvement strategies must be individually selected and designed for each farm according to resource availability, local market conditions, and management approach.

2.3. Economic implications of organic dairy sheep farming

Organic dairy sheep farming provides income to thousands of families and contributes to regional development, especially in isolated and less favored areas. It also generates employ-

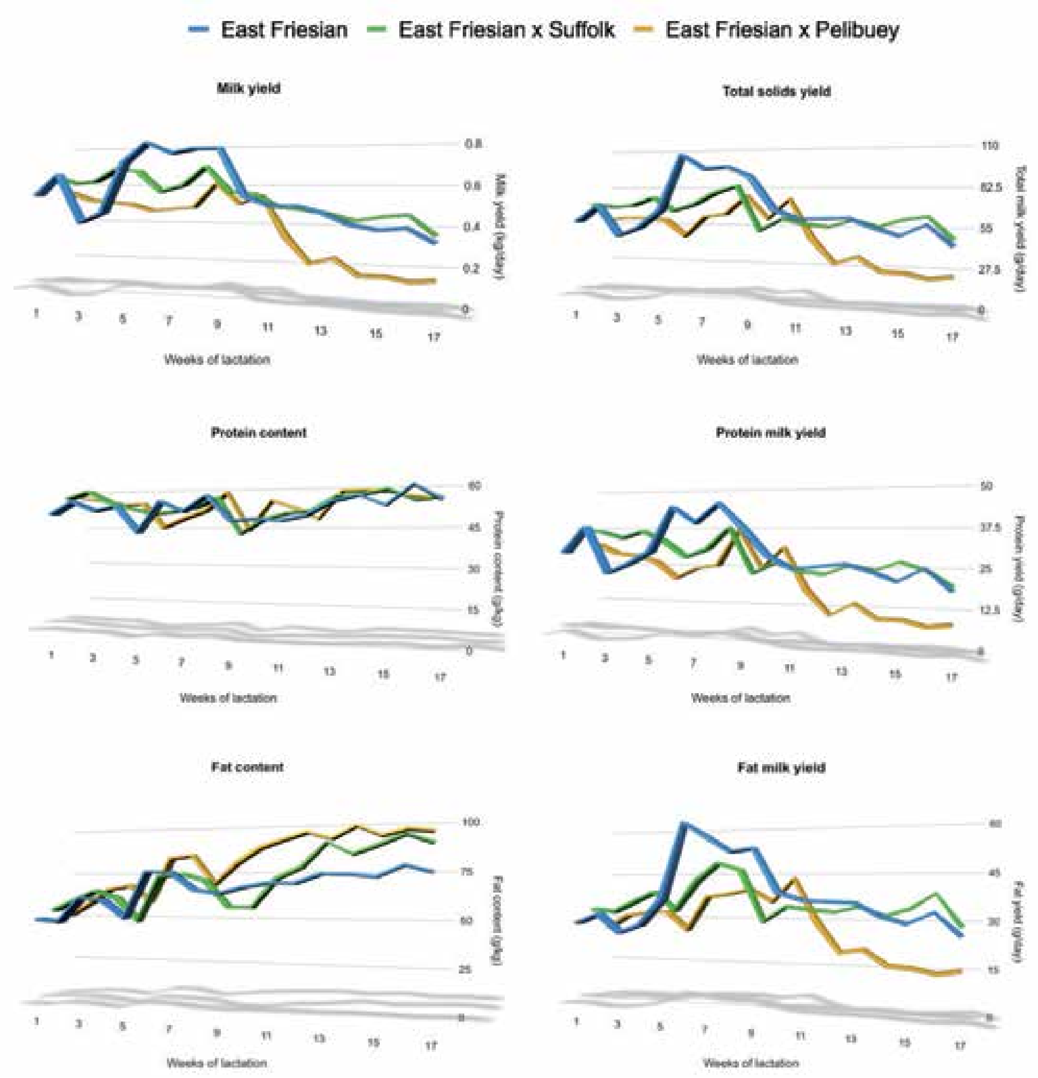


Figure 5. Effect of genetic group on milk production and composition in sheep under organic management (adapted from [48]).

ment, promotes closer links with local markets, restores connections between farmers and customers, and increases incomes in the local economy through exports [13].

The specific productive approach of organic dairy sheep farms determines its economic stability and profitability. The main factors that affect the expected returns of dairy sheep farming are milk yield and price of dairy products [80]. The competitive prices of organic products has played an important role in the expansion of interest in organic systems. Frequently, organic products obtain a premium price when compared to products from conventional farms. The magnitude of the premium depends on product availability and market demand.

The premium in price for organic sheep milk over conventional milk ranges from 8% to 36% within European market [81], 51% in New Zealand [82], from 47% to 79% in the USA [83], and a price difference of approximately 20% to 30% in Mexico [79]. In the case of the gross production value of meat and lambs, the variation arises mainly from fluctuations in price. Gross production value for ewe meat (non-productive ewes) contributes less to the total gross production value of the farm.

Gerrard et al. [84] have noted that organic dairy sheep farms show lower investments in items such as acquisition of animals, equipment depreciation, and agronomic management (less use of fertilizers and chemical compounds). However, it should be taken into account that in the case of organic farming, the value of animal capital is lower due to the fact that the flock consists mainly of crossbred dairy ewes [79]. It has also been reported that organic dairy sheep farms employ more people in comparison with conventional farms. Padel and Lampink [85] noted the higher number of working hours on organic farms (10–50% greater), and they considered salaries to be an expense with a higher impact on the total cost of organic milk sheep production.

The initial investment for establishing an organic farm, as for a conventional farm, includes investments in buildings (stables and barns), equipment (milking machine, feeders), animal capital, pasture area, and grain supplements for feeding throughout the year. An added investment that needs to be considered for organic farms is the certification process, as well as the fact that during the conversion process the commercialization of dairy products with a premium price is not yet possible.

The questions that we have to ask when comparing conventional systems vs. organic systems in general terms are as follow: How will sustainable intensification work in practice? How can farmers and other producers improve their production systems to produce food in more sustainable ways? Being less susceptible to volatile food prices, how can niche-level innovations and consumer interpretations and social practices be better integrated into the mainstream food security discourse? For example, organic systems offer the security of avoiding chemical fertilizers, antibiotics, hormones, and synthetic growth promoters, all of which involve human risk through the increase in allergies and antimicrobial resistance. How will the transformations of the food system play out in terms of geographical area, food security and animal welfare?

From the economic perspective, the dominant message is the importance of the profit motive, which drives the production system. However, the cost to the environment must also be taken into account. For this reason, we have to analyze the "economic sustainability" based not only on economic profitability but also on the relationship of farmers to their land environment and the sustainability of their activity [86]. There may also be hidden costs of production not only from agricultural intensification [87] but also from organic production [88].

3. Conclusion

Organic production is not a method of production that can solve all the problems of the dairy sheep industry; it is mainly an approach to production focused on satisfying the current demand for dairy products, but without the adverse effects of intensified livestock production. Moreover, organic farming is a production method with a specific market focus on products of premium quality and high standards of production. Organic sheep milk production can provide a balance between society's demand for food and the ecological impact of the agro-alimentary industry, through the comprehensive implementation of conservation practices and the ecological utilization of natural resources.

The production of organic sheep's milk requires research along specific lines, aimed at developing better methods of production, distribution, and marketing of their products. These must be focused mainly on genetic improvement, preventive medicine, welfare, nutrition management, and promotion of nutritional characteristics, in accordance with defined production approaches and regulations.

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Section 3

Organic Foods

Chapter 13

The Use of Organic Foods, Regional, Seasonal and Fresh Food in Public Caterings

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Additional information is available at the end of the chapter

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Abstract

The chapter focuses on possibilities to improve the quality of meals in public, especially school catering facilities. It presents the options for diet modifications towards a sustainable use of organic foods, local and seasonal food by optimizing portions of meat and meals prepared of fresh ingredients. From an economic, environmental and nutritional point of view, evaluation and comparison of the original and optimized meals can contribute to a more efficient use of foods and motivate staff in public catering facilities to comprehensive food assessment.

An overall evaluation shows that more favourable nutritional parameters may be achieved by the optimization of meals. A greater use of local, seasonal and organic foods, a reduction in meat portions and lower level of processing make energy and greenhouse gas emission savings and it is possible to sustain the costs within standard. The purchase during a season and shortened distribution channels may compensate the higher price of organic foods. The trend of increased use of ready-to-cook foods does not usually lead to a higher nutritional and health quality, lesser burden on the environment and an economic effect. However, it may be assumed that the expansion of knowledge of catering managers of nutritional quality and environmental impacts, with better experience in optimizing meals and with the proper motivation, parameters of meals in public catering facilities may be combined and thus contribute to the sustainable management in food services.

Keywords: School meals, nutritional quality, environmental aspects, economics, optimization

1. Introduction

The task of school meals is to provide proper nutrition to students during their stay at school and, at the same time, form positive nutritional, hygiene and social habits of students [1]. Generally, school meals should be an example of good nutrition and should make children acquainted with new meals that children do not know from home and, at the same time, teach them the food and dining culture [2]. It also aims at a change of wrong habits that children bring from their families. This includes, for instance, the insufficient consumption of fruit and vegetables, legumes, fish, wrong amount of food, less soup, higher consumption of sweet dishes, dumplings and fatty dishes. Consolidating and acquiring hygiene, cultural and social habits, which include personal hygiene (especially hand washing), the cultural and hygienic rules of dining, a proper use of cutlery, table manners etc., is also a part of this education [3]. Easy accessibility, mostly at the place of school attendance, and subsidized meals, which become available for all social groups, may be included among the positives of school catering. Certainly, mass catering has some disadvantages. These include a limited selection of dishes, poor quality of service (in essence, it is a self-service), often poorer quality of food, smaller portions, eating in haste, also the environment is not usually very calm and the optimal time and duration of a meal are not respected [4]. Catering managers, chefs and service staff, as well as methodological workers and educators, who train personnel for school catering facilities, are in a position to meet the considerable demands made of them due to efforts to eliminate the drawbacks.

The menu is the result of efforts to comply with the set of school food standards and regulations and also an operating plan of the facility for a certain period (usually a month). Menus are drawn up by school catering managers in collaboration with the executive chef in order to suit not only the principles of a healthy diet but also technical possibilities and staff deployment of the facility as well. They should be varied, creative, modern and meet the nutritional recommendations for children [5].

The principle of full use of seasonal market opportunities is very important. An executive chef must be familiar with the offer of foods, especially fruit and vegetables, and their prices. It is also important to take into account the operating conditions of the facility, technical and mechanical equipment of the kitchen, serving system, the number of staff and their qualification, the supply situation when drawing up a menu. The alternation of different cooking techniques is essential as well. Besides meat meals, the meals that contain vegetable protein (soufflés, vegetable, legume and cereal meals), meals accompanied by cheese, cottage cheese, dairy products should be put on the menu. Each lunch should be complemented by a vegetable side dish or a salad (excluding sweet meals), fruit or raw vegetables. In case of a necessary change of the menu, the alternative meal should be similar in the energy and biological content to the originally planned meal [6].

Menus in school catering facilities should be nutritionally balanced, offering tasty and attractive meals to diners not too financially demanding and, last but not least, manageable. The main tasks for the kitchen staff are:

- adhere the energy and biological values of the diet (reducing fat intake or sugar used),
- respect the age categories of children boarding in the facility (nursery, primary, secondary schools)
- take into account the season and the use of seasonal foods,
- provide the diversity of meals in relation to consistency, colour, taste and technological treatment,
- guarantee the greatest possible variety of foods from different groups in order to provide adequate intake of nutrients, vitamins and minerals through: including all kinds of meat – beef, low-fat pork, poultry and especially fish, changing side dishes and different kinds of vegetables regularly and avoiding using the same foods, that undertaken different technological treatment, in one day [7].

2. Literature review

2.1. The nutritional quality of meals

The nutritional quality reflects a content of substances, which has positive effects on human nutrition, their internal composition and proportions. The nutritional role of school lunches involves delivery of about 35% of the recommended daily energy intake [2]. In modern history, there have been changes in eating habits and physical activity. More meat, meat products and sweets are eaten, a lot of sweet, chemically flavoured drinks are drunk, a sedentary lifestyle prevails. Naturally, this lifestyle leads to overweight and obesity. Many school cafeterias and vending machines placed in the corridors of schools, whose range of goods resemble classic fast food restaurants, which children prefer to healthier alternatives offered in school catering facilities, contribute to the unhealthy trend. The main deficiency is the internal structure of meals, often dominated by animal products and an associated excess of animal fat, cholesterol. Another problem is the inadequate intake of certain vitamins and minerals.

The nutritional intervention aimed at the change of technological methods of food preparation, that would still respect traditional Czech cuisine at the same time, appears to be a quick way to make school meals healthier. The intervention program has been running since 1993 and its principles read:

- Meat – use rather less often, but of a high quality and fat-free. Do not use trimmed parts for further processing in school meals, use plant foods (legumes, oat flakes) to get quantity and energy value.
- Milk and dairy products – include as often as possible, choose low-fat products, e.g. in the form of drinks, sprinkles and baking with cheese, salads with yogurt. Provide dairy snacks.
- Vegetables and fruits – with each meal. Prefer raw vegetables (salads, side dishes), favour frozen vegetables to pickles during off-season

- Legumes – generally increase their share in the diet. Offer more frequently and in smaller portions (e.g. adding to soups, minced meat, soufflés and salads).
- Desserts – prefer healthier alternatives based on the processing of dairy products (cottage cheese, custard), use oat flakes, whole meal flour, reduce sugar and fat.
- Fat – keep animal fat to a minimum, use vegetable oils (sunflower), preferably without heat treatment (salads), reduce the use of roux [8].
- The nutritional quality of school meals is based on the recommended nutrient intakes provided in 1989. These focus on the issue of energy demands, the major nutrients and other essential factors for the human body. They are based on the physiological needs of a human body and are calculated for different categories according to age, physical activity and physiological condition [9].

Recommended nutrient intakes are guidelines for creating so-called consumer's basket. It describes the average food consumption calculated from the basic range of foods in the form of "as purchased" (i.e. it takes into account losses, e.g. when trimming vegetables, fruits, etc.). Food consumption is expressed as a percentage and should correspond to the monthly average with allowance of ± 25% [10]. The consumption of meat, fish, milk, dairy products, fruit, vegetables, potatoes, legumes, sugar and fat may be monitored by means of the consumer basket [11]. There is a rule that the average intake of vegetables, fruit, fish and legumes represents the lower limit, which may be exceeded, and the intake of free fat and sugar represents the upper limit, that is desirable to be decreased [10]. Czech School Inspectorate and Regional Hygiene Station monitor if the consumer basket is respected [3]. Recommended nutrient intakes are updated at regular time intervals. Currently, the Czech Republic has adopted a new list of recommended nutrient intakes from the German-speaking Central European countries – the so-called Reference values for nutrient intake (DACH - Deutschland, Austria, Chuisse). These should be taken into account when developing new nutrition standards for school meals. However, setting up new consumer's baskets may not be as fast as it might occur. The reasons are economical, and perhaps political and social as well, also the current eating habits of our population may influence that. The recommended intake of protein is rapidly reduced (from current 2.4 g/kg of body weight to 0.9 g/kg of body weight) according to the DACH; therefore, it may cause some dissatisfaction of the part of diners within our eating habits [9].

The tool to combine different food commodities in order to meet the consumer's baskets is called “the recommended dietary variety“. It is not officially set; however, it specifies the number of times in a month a certain type of food should be included on a menu: milk, legumes, fish, etc. [12]. Therefore, not only the fact that the consumer's basket is filled is observed but also the way it is filled in: e.g. preference of lean meat to fatty meat or smoked-meat products, raw or cooked vegetables to pickled, cutting down on sugary and fried meals (max. two per month), the inclusion of sufficient quantity of fish, legumes, substituting conventional side dishes with, for example, millet, buckwheat, couscous, oat flakes, etc., providing fruit and vegetables on a daily basis. The requirement for using different cooking techniques comes from the recommended dietary variety [6]. The different types of dishes should be included usually only once a month. Exceptions are seasonal foods that may be used more frequently. In addition to classic recipes, school catering facilities may use their own or regional recipes but they must comply with all the principles mentioned above [13].

When drawing up the menu, we are limited by the consumer basket and financial limit, and the recommended dietary variety is used as a guideline. Menu is usually drawn up by the catering manager in cooperation with the executive chef for a few weeks in advance, usually for a month, and later it is specified. It must conform not only to the principles of healthy nutrition but also financial, technical and personnel capabilities of the catering facility [5]. If, for any reason, a change is needed, an alternative dish should resemble the originally planned dish in terms of energetical, as well as biological aspects [6].

2.2. Ready-to-cook foods

There have been growing requirements in the area of food preparation, hygiene and final treatment and dining, that modern and classic gastronomy has to meet. There are four basic guidelines to prepare and distribute meals in a public catering facility:

1. Joint catering facility – dishes are prepared in a local kitchen of fresh ingredients, as well as ready-to-cook foods. Capital and operating costs are higher (staff, energy) and facility management must be professionally qualified. The more school uses fresh ingredients, the more hygiene must be respected. Demands on input check of goods, storage and preparation and needs for workspace increase. Preparing meals in their own kitchens is mainly a matter of boarding schools.
2. Cook & Chill - dishes are refrigerated and supplied by a professional food provider or from a central catering facility. Dishes are cooled to 3°C immediately after cooking, may be portioned and then stored in cool conditions (0–3°C) by an external supplier. The staff of the school catering facility provides only heating (which must not exceed 30 min) and distribution. There are strict hygiene requirements for the preparation and storage if the dishes are produced by a central catering facility. It must be cooled within 90 min and should not be stored for more than 3–5 days until being re-heated. Cooled products are used mainly at secondary schools.
3. Frozen system – a professional provider provides frozen dishes as individual portions or the whole menu. They are frozen to –18°C after cooking and the temperature is maintained during the transport. The cooling chain from the producer to the final treatment before being served must not be interrupted. Workers of a school catering facility provide heating; meals may be portioned for serving where necessary. After that meals must be continuously served. The advantage of this system is that the necessary investments to draw up a menu are low, as well as low demands on the qualification of staff. The system is mainly used at secondary schools.
4. Hot meals – dishes are provided already completely ready and warm by an external supplier – a catering company that provides distribution in the facility as well. Each serving of dish is put into a thermo box or a food container (larger amount) immediately after cooking. Thermo boxes retain the internal temperature of 70°C from the filling to the

distribution of meals. The temperature when served is then 65°C. For cold foods, the temperature should be in the range of 8–10°C. The system of hot meals (60%) dominates, followed by the joint catering facility (about 20%) at the full-time German schools.

In the Czech Republic, the system of the joint catering facilities still clearly dominates. In Europe and around the world, there are significant differences in terms of the range of school meals, support and forms of preparation and distribution of meals. The differences result from the traditions, economic strength and social policies of individual countries. Globalization trends have brought an increase in the use of ready-to-cook foods, convenience foods and ready-to-eat meals, which always have a higher degree of processing than the base material, in a number of countries and in the Czech Republic as well. These dishes or foods, convenient for immediate consumption, are in most cases frozen, canned or dehydrated and therefore they must be somehow processed before consumption. The importance of using ready-to-cook foods has its benefits, especially in terms of time savings needed to prepare, workforce and costs, they extend the range of dishes, which would be difficult to prepare in ordinary kitchens, support the creativity of a chef. Some facilities are unreasonably mistrustful of these foods and products. Partially, they may be put off a higher price of the ready-to-cook foods, even though the difference is relative in many cases. It is worth being aware, however, when the use of ready-to-cook foods is appropriate and in what cases we may do without them. Chlumská [14] points out a finding that the use of ready-to-cook foods or ready-to-eat meals is one of the most common complaints against the school board from conscious parents. According to her, school catering facilities tend to use these products partly because the market offers an increasingly greater choice, as well as due to reduction of staff, when school catering facilities must provide the preparation of meals with fewer employees than before.

2.3. Economic aspects of school meals

Depending on how the school board is managed and how the state and municipalities participate, European countries may be divided approximately into three groups: the first one includes the states where school meals are provided to children for free (Finland and Sweden), the second one includes the states where school meals are organized centrally or regionally in some way and the costs are partly covered by the state or municipalities (France, Belgium), and finally in the third group there are states where school meals are not uniformly organized or not implemented in the way that we know in the Czech Republic [15].

School meals are not based on profit in most countries, thus differ from conventional manufacturing company in a market economy. Therefore, costs are one of the most important criteria and affect pricing greatly. The cost of providing food service may be, in terms of the types of costs, divided into the costs of foods, personnel costs – salaries, training and social statutory costs and operating costs – energy, other materials, services, depreciation, etc. [16].

In countries that support school meals, diners only cover a portion of the actual price of the meals. School facilities in the Czech Republic must follow nutritional standards, the average consumption of foods and financial specifications for the purchase of foods for each age group. The part of the price of a meal paid by parents (i.e. the price of foods) may be set differently based on an agreement with parents at private schools. At schools that are run by municipalities, county or state, the price of foods is limited by so-called financial specifications, which are specified in the school food regulation [14]. The set financial specification must amount to the sum that enables a school catering facility to meet the requirements for the consumer's basket. It also specifies the financial spread – an amount of money that school facilities may use to make a lunch – i.e. soup, main course, salad, dessert and beverage [15]. At present, the cost for foods to make a lunch for one diner ranges from 14 to 37 CZK, which corresponds to 0.5 – 1.2 Euro, in the Czech Republic.

Personnel costs include wages and salaries of the employees of the facility, their further education and working instruments and are funded from the state budget.

Energy consumption, costs of services, costs of other materials and depreciation of tangible assets make up a significant portion of operating costs. These costs are covered by the institutor. Although the amount of personnel and other operating costs are based on a calculation, it is not a normative expense but a cost that may be influenced by an effective and efficient use of available resources [16].

From an economic point of view, the quality of school meals may be influenced in a few ways only, virtually through bargains, donations or grants as extra sources of money [1]. The more diners of a facility, the easier it may be to achieve beneficial agreements or quantity discounts for ordered foods. Purchase of seasonal foods, especially fruits and vegetables, is another way to influence the price of foods and respect the nutritional standards at the same time. Their price change regularly according to a season and thus to their availability. The money saved on purchase may be used to enrich and improve (pot. make cheaper) the diet [17].

2.4. Environmental aspects of school meals

Our eating habits are created especially in the context of public catering. High-quality and healthy foods in catering facilities show not only the value chain of diners but also an environmental responsibility. A sustainable economic system must support especially environmental-friendly regional production and consumption of fresh natural foods.

Food production uses an increasing amount of energy with a corresponding negative impact on the environment. An important factor is the origin of foods, resp. transport distance from a producer to a consumer. A reduction in the proportion of meat on the menus and consumption of regional vegetable products allows caterers to reduce the impact on the environment. The negative impacts of the use of ready-to-cook foods or ready-to-eat meals, processed products and products stored for a long time outweigh their benefits due to the heating and cooling of foods, special packaging and transport costs [18].

Research shows that the use of local, seasonal and organic foods and the preparation of fresh meals of them may significantly reduce the proportion of greenhouse gas emissions (GHG) in catering facilities.

An indirect energy consumption, i.e. energy that comes from foods, their production, processing and trade, constitutes up to 63% of total GHG emissions in catering facilities. The largest amount of GHG comes from meat in catering facilities. The use of meat and meat products in Austrian catering facilities makes up 14% of the total amount of the foods, therefore 63% share of GHG emissions in the indirect energy consumption is very high.

The implementation of sustainable diets and thus optimized meat portions and increases of the share of vegetarian dishes have also saving potentials within GHG emissions. Vegetarian dishes produce up to 99% less GHG emissions in comparison with meat dishes. Also the use of regional and seasonal foods and organic foods makes emissions savings. Local foods have the potential to save up to 50%. Using foods from an organic production can reach up to 40% savings. A level of food processing plays an important role in addition to the criteria of regionality, seasonality and organic farming with regard to the GHG emission topics. Each step represents a further production of GHG. One kilogram of fresh conventional potatoes produces 0.31 kg CO^2eq, but one kilogram of potato chips produces 4.36 kg of CO^2. The trend of an increased use of ready-to-cook foods in catering facilities has primarily economic reasons (e.g. less staff needed). However, this is often compensated by a greater need for goods. Constant heating and cooling, special packaging and food miles (mileage when transporting food to the kitchen) and often questionable additives as well have negative effects on the environment [18].

2.5. Local foods

School catering facilities are one of the major purchasers of local products [19]. The reason for the preference of local foods is that these foods are much fresher due to short distribution routes than the foods that take long-distance routes. Therefore, fresher local foods generally tend to taste better and more valuable nutritional parameters. The fact that the closer the food is to the consumer, the lesser burden on the environment during their transport is also important. Reduction in the proportion of meat on the menus and consumption of local vegetable products allow caterers to significantly reduce environmental impacts, as well as take into account the financial aspect (Eagri-Regionální potravina, 2009–2013). An extension of the path that an agricultural product takes from the producer to the consumer may lead to a loss of authenticity. Consumers and also control bodies may supervise the foods produced in local conditions better and thus there is an indirect pressure on producers to maintain the quality of their products at a high level. Another reason for the preference of local foods is that these foods are much fresher due to short distribution routes than the foods that take long-distance routes. Therefore, fresher local foods generally tend to taste better and more valuable nutritional parameters. The fact that the closer the food is to the consumer, the lesser burden on the environment during their transport is also important [20]. A significant aspect to prioritize local foods is that it promotes employment in the region. Then prosperous farmers, processors and vendors represent a guarantee of maintaining or even expanding the number of jobs.

2.6. Organic foods

Reasons for the introduction of organic foods in schools are mainly attempts to encourage children to eat healthier and better diet. Equally important is the positive impact on dietary habits and a healthy lifestyle. Organic foods are not used in school catering facilities in the Czech Republic very frequently. Currently, it is estimated that approximately 150–300 kindergartens and schools use organic foods in significant quantities, which represents about 1.5–3% of the total 10,500 schools (nursery, primary and secondary schools). The schools that have participated in one of the pilot projects for the introduction of organic foods in schools or alternative schools (especially Waldorf kindergartens and schools), where the use of organic food is a part of their philosophy, have been ahead [14]. The reason for the low interest in organic foods is their high price. Currently, no financial subsidies for their purchase are provided [21]. However, the price of school meals in the school catering facilities, which have introduced organic foods, has increased only very moderately by about 10%. Organic cereal products, legumes and dairy products are used most often. Conversely, baked goods, meat and meat products and other products are used in the smallest amounts in schools. Many countries have supported the use of organic foods in schools and other public catering facilities in various ways including legislative measures, subsidies and other incentives. For example, the Italian government has adopted a law requiring the use of organic products in school catering facilities. Therefore, the Italian legal system" creates direct and explicit relationship between local organic products and catering services." This national law has created an environment that encourages many municipal authorities to start purchasing organic products. The support of catering facilities, while optimizing diets that account of local, seasonal, fresh and organic foods, will enhance regional economic structures, potential energy savings in catering facilities and offer healthier boarding

3. Objective of the study

The main objective of the UMBESA project is to support catering facilities when introducing sustainable diets. This can be achieved by increased use of organic, local, seasonal and fresh foods and reducing meat portions. These steps should support not only the environmental protection but also physiological and optimal nutrition. The project consisted of five main parts. The first part focused on the current consumption of foods and diet composition in school catering facilities, these documents should establish a basis for change. The second part dealt with the evaluation of similar projects, which aimed to introduce the above mentioned criteria towards sustainable diets and the objective was to identify the strengths and weaknesses of these projects. The third part aimed to identify the current networks of suppliers of school catering facilities and stakeholders who are involved in the field of public catering, at the same time, new stakeholders were identified and a new network, meeting the sustainability criteria (e.g. regional and organic suppliers), was proposed. The fourth part of the project had as its object assessment of opinions on the current state of catering services and the state after introducing some changes (see the fifth part of the project), a survey had been carried out. The fifth part of the project dealt with the actual implementation of changes and it is discussed in this chapter as the main output of the project.

As described before, the aim of the experiments within the project is an active support of the introduction of sustainable diet in catering facilities. In selected school catering facilities, certain recipes were chosen (hereinafter original dishes) and modified (hereinafter optimized dishes) according to the criteria of sustainability (an introduction of ecological, local and fresh foods and a reduction in meat portions). These two dishes were evaluated and compared within the selected criteria. The aim of this part was to assess whether a change of diet contributes to sustainability and also answer the following questions:

- What measures can be realized in catering facilities to optimize towards sustainability?
- What economic, ecological and nutritional–physiological positives and negatives arise in catering facilities using sustainable foods?

4. Methodology

Methodical procedure briefly describes the methodology of the individual parts of the project, with the greatest focus on the methodology of experimental cooking and their evaluation.

4.1. Analysis of foods and menus

Lists had been drawn for each school, which grouped foods into appropriate groups using the annual statement of the shopping list of foods for the reference year of 2011, which included the price of foods, as well as their suppliers. At the same time, the lists had been drawn up and assessed according to their origin – regionality of foods, their seasonality, processing – frozen, fresh and ready-to-cook foods and also from the perspective of organic production. Furthermore, the lists of dishes according to the proportion of main ingredients – meat, vegetarian and sweet, as well as proportions of organic ingredients, ready-to-cook foods and local ingredients, had been drawn up according to the menu.

4.2. Search of similar projects

Two Austrian, two Czech and two international projects were selected to map out the initial conditions, implementation and factors for success and failure. The authorized representatives of these projects were interviewed; the interviews were subsequently evaluated and reduced in accordance with the summarizing criteria. The analysis according to Kotter's 8-Step Change Model “Leading Change“ [22] was performed. The supporting factors, as well as inhibiting factors of success, were found.

4.3. Networking

In the first instance, the current network of suppliers in various catering facilities was identified as a part of search of the ingredient consumption, see Section 4.1. As a second step, a potential supplier network was found and an extensive list of suppliers in various regions and districts was drawn up. At the same time, the selected suppliers were questioned regarding their attitudes to the issue of regionality and seasonality of offered products while creating the potential network. The last activity within networking was to create groupings of regional participants and set up the Steering Committee of the project that discussed the progress of the project and inclusion of dissemination of the results of individual project activities at regular meetings.

4.4. Survey among diners

The survey was carried out in the form of two questionnaires, one at the beginning and another one at the end of the project. The questionnaire included topics such as satisfaction with the catering facility, with its offer, attitude of staff, questions about eating habits of the respondents and, in conclusion, inquiries concerning the project itself. Descriptive statistics, factor and group analysis had been used to evaluate the results and a profile of borders that may be used to propose specific changes to catering facilities was set.

4.5. Experimental cooking

In the fifth part of the project, practical experiments in the context of experimental cooking were carried out, where an original and optimized dish was cooked and mutually compared. The recipes for the original and optimized dishes were presented and recorded by the chosen catering facilities. Relevant data including the preparation of foods, recipes, cooking process (time, equipment used, number of employees, water consumption) were collected during each cooking. The dishes were evaluated from several different vantage points.

4.5.1. Environmental assessments

Ecological assessment was performed by analyzing CO^2 emissions. CO^2 emissions of foods that had been identified within the SUKI project [23] were used as baseline data. The emission burden data of foods that had not been investigated within the SUKI project were complemented by the literature and the GEMIS database search. CO^2 emissions were determined within the ingredients that are most important in terms of quantity. It was necessary to determine CO^2 emissions by at least 50% of the ingredients for one dish.

4.5.2. Economic assessments

Economic assessment was performed by analyzing costs. The following costs were included into the analysis:

- Cost of foods: the current prices of foods including VAT were taken into account.
- Personnel costs: the period of active work was multiplied by the average hourly wage and the number of persons.
- Operating costs: i.e. costs of water and energy.

4.5.3. Nutritional–physiological assessment

The calculation of nutrients was made with the help of a nutrition consultant. The production method (biological, conventional) was not taken into account within the nutritional–physiological assessment. Original and optimized dishes were compared with respect to the amount of calories, protein, fat, carbohydrates and fibre.

4.5.4. Organic – Regional – Seasonal

The proportions of biological, local and seasonal ingredients were determined within the original and optimized dishes.

4.5.5. Qualitative assessment

A sensory evaluation test was used. The test includes food tasting carried out either by the staff themselves or by diners. The results were discussed with the managers of the catering facilities.

5. Results

This part briefly describes the main results of each stage of the project with the greatest focus on the assessment of the experimental part of the project, i.e. experimental cooking.

5.1. Analysis of foods and diets

- The analysis of food consumption in Czech catering facilities showed that the most used group of foods is vegetables (including potatoes) at 34%. The other most commonly used group consists of the cereal products at 16%. They are followed by meat and meat products, as well as dairy products at 14%. The proportion of fruit is 11%. The last group at 12% includes other products.
- The proportion of fresh ingredients is on average 78%, 6% of frozen ingredients and 16% of ready-to-cook products.
- Currently, organic foods are not used in Czech catering facilities or they are used in quantities of less than 1%. That is due to a limited budget for foods and prohibitive costs of organic foods. This corresponds to the total organic food market situation in the Czech Republic, which has not been sufficiently developed yet, the share of organic production on arable land is still too small to successfully compete with conventional products in catering.
- The proportional share of seasonal fruit and vegetables varies from 30 to 90%. It reaches 47% on an average. Undoubtedly, the potato consumption is the biggest item accounting for about 60%. Another important item consists of onions, cabbage, carrots, tomatoes and cucumbers. From fruits, the most important are apples and plums of our domestic production. It is worth noting that the second most frequently used fruits are bananas, which do not meet the criteria of sustainability, both seasonal and local, and it would be good to substitute them with domestic fruit.
- The proportional share of local products varies from 17 to 86%. The average is 39%. The analysis shows that the catering facilities in bigger cities use less local products than the

catering facilities in smaller towns, logically, the reason for that is a larger food market and offer in bigger cities. From the local production, meat, dairy products, cereal products, fruit and vegetables prevail. Most ready-to-cook and frozen products have their origins outside the region.

- The analysis of main meals shows that 62% of the main meals are meat meals. Vegetarian meals make up 21%, fish meals 7% and sweet meals 9%.

5.2. Search of similar projects

Based on a detailed analysis of six successful projects (Kuratorium of Vienna Retirement homes, the project in the catering facility of the Lower Austrian provincial office, German restaurant ESPRIT, Italian project iPOPY and the Prober Union, two Czech projects "Organic food for schools" and "School full of health"), there are these fundamental factors of success:

- Use of external influences for change (e.g. childhood obesity).
- Explanation of the meaning of the project to stakeholders.
- Extensive information campaign.
- Setting realistic and achievable targets in the short term.
- Perseverance despite the initial failure.
- Setting goals for the future.
- Building long-term relationships between the entities.
- Adapting the project to existing habits and structure.
- Constant communication with stakeholders.
- Gradual implementation of measures, smooth implementation of the objectives.
- Gaining supporters during the project.
- Value conviction of a person in chargé.

5.3. Networking

An important outcome of networking was a catalogue of ingredient suppliers in each region that was provided to catering facilities in order to enable them to obtain ingredients from local suppliers. The project had been also promoted and consulted within the Steering Committee composed of representatives of the government, experts and business leaders. The survey among suppliers resulted in the following main conclusions:

- It is very important to document the origin of products according to the surveyed suppliers. About 74% of interviewed producers expect that the regionality becomes a sales argument in the future. The amount depends primarily on the size and trade tendency of the producer. Smaller producers try to show the quality of their products using the regionality. The current problem is too many regional brands, which people may find confusing, as well as selling products under a foreign brand and a lack of awareness about the quality of local foods. More than a half of respondents think that the regional origin does not affect the price.

- The seasonality issue concerns mainly fruit and vegetable producers. A large group of the interviewed producers rely on stable buyers who are familiar with seasons when different kinds of fruits and vegetables ripen; therefore, they do not need to be further informed. They do not intend to include the seasonality as the sales argument.
- Regarding the expansion of product diversity, 70% of interviewed producers draw up their offer not concerning reactions of consumers. If we evaluate the cooperation of the producers, we find out that most of them have both stable and vague relationships, as well as regionally focused relationships, because these groups complement each other and eventually intersect, for example, when a customer becomes a stable client.
- It is gratifying to note that most local producers have an increasing interest in their products and that the society slowly begins to realize the true quality and value of local products.

5.4. Survey among diners

About 703 diners of participating Czech catering facilities participated in the first wave of the survey and 713 diners in the second wave. Overall, it may be summarized that their satisfaction with the catering facility, its atmosphere and quality of food had increased.

5.5. Experimental cooking

At least three experimental cooking of original and optimized meals, which were compared using several criteria, took place in each partner catering facility. As an example, the experimental cooking of tomato sauce with beef is being described here.

The original meal consisted of classic tomato sauce with beef and bread dumplings. The optimized meal included a reduced portion of meat and turkey meat substituted for beef, couscous for bread dumplings and some of the ingredients in an optimized meal came from organic production.

5.5.1. Economic assessment

The analysis shows that the costs of optimized meal are by 17% higher. The price per serving is 0.2 EUR higher. More expensive are especially the costs of ingredients and personnel costs, it is due to a greater need for active involvement of staff. Conversely, operating costs are lower because simpler technological demands for preparation dominate.

5.5.2. Environmental assessment

Ecological assessment shows about 69% smaller environmental burden when cooked optimized meals. The ingredients for the original and optimized meal in the total proportion of 99% were included into the assessment.

5.5.3. Nutritional–physiological assessment

One portion of the original dish contains 601 calories, 33 grams of protein, 11 grams of fat, 96 grams of carbohydrates and 4 grams of fibre. A portion of the optimized dish contains 513 calories, 35 grams of protein, 14 grams of fat, 63 grams of carbohydrates and 5 grams of fibre. The nutritional values were taken from nutritional tables. The percentage difference of indicators is shown in Figure 1.

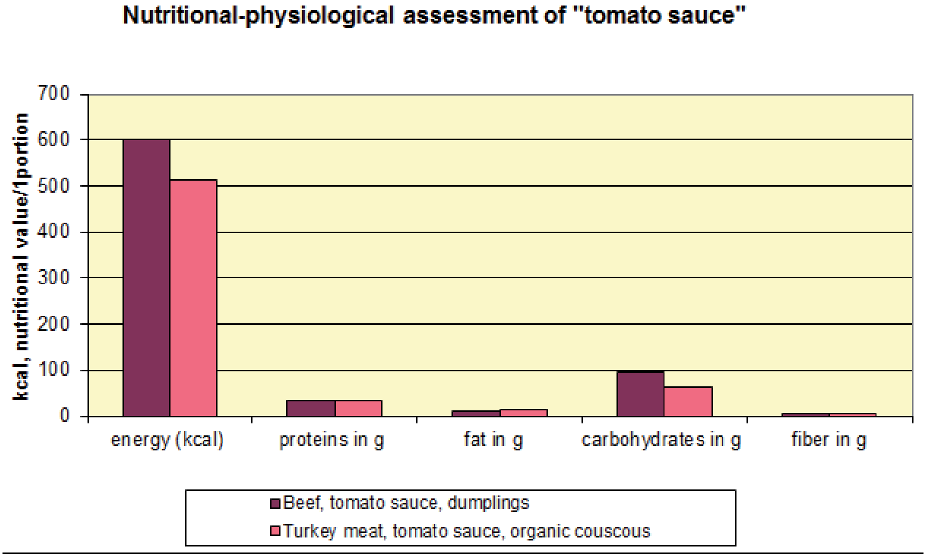

Figure 1. Nutritional-physiological assessment of tomato sauce

5.5.4. Assessment according to the production method (organic, conventional)

100% of ingredients for the original dish were produced in conventional agriculture, whereas the proportional share of organic ingredients in the optimized meal is 23%.

5.5.5. Assessment according to the processing method (fresh, frozen or ready-to-cook)

Both the original and optimized dishes do not contain frozen ingredients and consist of fresh and ready-to-cook ingredients only. The proportional share of fresh ingredients is 44% in the original dish and 86% in the optimized dish.

5.5.6. Assessment of seasonality

Seasonality is assessed for vegetables and fruit, the original dish contains onion and the optimized dish contains onion and tomatoes. The original dish may be described as seasonal in the months of May, June, July, August and September. The optimized dish may be described as seasonal in the months of June, July, August, September and October.

5.5.7. Assessment of regionality

To assess the regionality, the origin of main ingredients of a meal was determined as a percentage, i.e. that the percentage of these ingredients constituted at least 80% of the meal. Regionality of ingredients may vary during the year, depending mainly on a purchase of seasonal ingredients. The original dish contains almost no seasonal products and the suppliers remain the same throughout the year and the proportional share of local ingredients is 35%. The optimized dish contains 37% of local ingredients in the months from June to September, whereas in other months it is 0%.

5.5.8. Qualitative assessment

Ten employees of catering facility answered in the carried survey that the original dish leads in the overall ranking, but also scores in the individual categories of taste, smell and appearance better than the ready-to-eat meal. The results are shown in Figure 2.

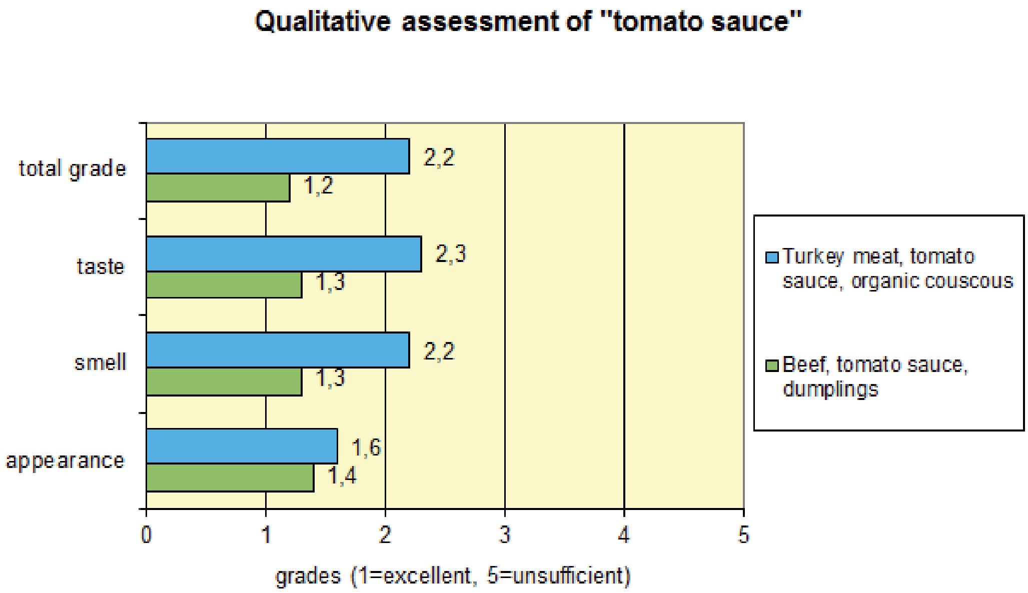

Figure 2. Qualitative assessment of tomato sauce

5.5.9. Results of other selected dishes

Table 1 shows the results of other selected experimental cooking. The results in each column are always related to the optimized meal. The costs column shows the difference between costs of the optimized meals per serving, the CO^2eq column evaluates the environmental burden, i.e. the difference in the amount of produced greenhouse gases and the share-of-organic-ingredients column and the share-of-fresh-ingredients column display the difference in proportion of organic and fresh ingredients. For the sake of clarity, the aspects identifying areas of improvement are marked in green, aspects that show deterioration are marked in red and aspects with no indication of a change are yellow.

Original meal	Optimized meal	Costs	CO_2eq	BIO-share	Share of fresh foods
Risotto with vegetables and pork	**Couscous risotto with vegetables and chicken**	+ 24%	+ 2%	+ 31%	–2%
Pork goulash with dumplings	**Bean goulash with bread rolls**	–3%	–41%	-	–66%
Fillet with potatoes	**Carp with potatoes**	+ 45%	–21%	+ 13%	+ 15%
Meat rolls with mashed potatoes	**Meat rolls with spinach and tricolour rice**	–7%	–35%	-	–13%
Meatball with mashed potatoes	**Burger with broccoli and cheese and mashed potatoes**	+ 24%	+ 47%	-	+ 2%
Stuffed cabbage leaf, potatoes	**Cabbage leaves stuffed with buckwheat, potatoes**	–7%	–18%	-	+ 180%
Fried meatballs	**Buckwheat burgers**	+ 16%	–65%	-	–26%
Bread pudding with cream cheese	**Bulgur with fruit and raisins**	+ 12%	–74%	-	–51 %

Table 1. Results of experimental cooking

5.5.10. Discussion on meal optimization

There were a total of 32 experimental meal preparations, whose aim was to compare the original and optimized meals in several respects, had been performed. These general conclusions result from the assessment of each meals:

- Economic perspective: It always depends to what extent the original meal was modified, e.g. costs may be reduced when meat portion sizes reduced significantly, on the contrary, the increase of costs may be connected with the use of organic foods and some fresh and local foods (e.g. using fresh carp instead of frozen cod), the highest price increase was in our case by about 45%, the highest price reduction was by about 78%, the optimized meals are on average by 2% more expensive. Some conducted studies (e.g. results of the project "Organic food for schools") show that consumers have an interest to pay more for quality.

- Environmental perspective: Most of modified meals result in decreased production of greenhouse gases and thus a positive environmental effect. The most significant reduction was by 88%, the greatest increase was by about 345%; however, this figure is completely beyond the average increase in emissions, which makes up approximately 20%. Putting this excessive result aside, emissions of the optimized meals decreased by 74% on an average.

- The proportion of organic ingredients: Regarding the share of organic foods in recipes, only a small proportion of experimental cooking included such foods. In particular, dry foods, alternative foods such as bulgur, then vegetables and in one case meat were used. However, the inclusion of organic foods, particularly meat, meant an increase in the price of meal. This fact is due to the current state of the organic food market, where their prices are still significantly higher than the prices of their conventional analogies.
- The proportion of fresh ingredients: The proportion of fresh foods had increased significantly at the expense of the ready-to-cook foods. The average increase reached 90%.

6. Conclusion

The diet structure of monitored school catering facilities shows that the normative indicator of the nutritional quality of food (consumer basket) is respected. Traditional meat dishes (62%) prevail, the trend of vegetarian diet is slow, but positive. Seemingly satisfactory representation of vegetables in a diet is given by traditionally high consumption of potatoes. Organic foods are almost absent in Czech school catering facilities. The reason is high price and low availability. Great variability in the consumption of local foods (17–86%) and seasonal foods (30–90%) indicates significant reserves for suppliers and catering facilities. Larger facilities tend to use ready-to-cook foods and ready-to-eat meals more. Their origin is mainly supraregional. Greater use of local, organic, seasonal and fresh foods is possible, thanks to the relationship between producers and food distributors in the region. Optimizing rarely improve all the required parameters, particularly difficult is to coordinate economic aspects with an ecological criterion, as well as use of fresh, local and organic foods. However, in many cases, improvements in the above mentioned parameters did not mean a noticeable increase in prices. Motivation of staff and consumers towards sustainable diet is a long process that requires continuous awareness of both parties. School meal plays an irreplaceable role in education in a healthy lifestyle.

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Chapter 14

Alternative Foods — New Consumer Trends

Mehdi Zahaf and Madiha Ferjani

Additional information is available at the end of the chapter

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Abstract

Increased globalization of food systems, large-scale production and distribution, and retail sales have changed the way food is produced and consumed. The dis-embedded globalized system is characterized by "industrial food" and not well-informed food choices. This has also created many concerns with respect to food safety, food security, health, and sustainability. Food alternatives are developing leading to embedded localized systems. These "alternative food" options include labels such as local, natural, pesticide-free, ecologically friendly, slow food movement, and localvores. The traditional marketing approach and specifically consumer marketing theory are not sufficiently prepared to handle the advent of new types of consumers. These consumers are looking for more than a product, i.e., value products. The objective of the current study is to understand the motives and concerns, product preferences, and consumption patterns of alternative food consumers in both developed and developing countries. To this end, a survey was administered in two countries. The population targeted for this study is alternative food shoppers. Results show mitigated differences between developed country consumers and developing country consumers in terms of food culture and food importance, perception of organic versus local foods, and foods channels of distribution.

Keywords: Organic food, local food, consumer behaviour, distribution

1. Introduction

1.1. New food market realities

The last two decades were driven by two major trends in the agriculture industry: an increase in the use of genetically modified food (GMF) and an increase in food-related diseases, such as mad cow, bird flu, and more recently the horsegate [33]. Emerging efforts to provide food safety and quality has led to a grown number of quality assurance schemes both at national and international levels. To this end, several "new" alternatives eliminate a number of concerns towards industrial food production and distribution. These "alternative foods" options include labels such as local, natural, organic, and more recently, paleo. Advocates of these movements are against any industrialization of the food chain, its production, and distribution. This system is based on two major elements, namely: (i) food mileage and carbon footprint and (ii) non-industrialization of the food chain. It is obvious that support for the local economy and country of origin are by-products of such system.

The organic market moved from a niche market to a mainstream market in the last two decades. This trend originated in the nineties, following a number of food scares in the conventional sector. The global market for organic products was approximated at US $18 billion in 2000, then US $23 billion in 2002, then increased by 43% reaching US $33 billion in 2005, and US $50 billion in 2008 [40, 36]. In the last decade, double-digit growth rates were observed each year [41]. Further, there are 633,891 farms managing 31 million hectares of "organic" land [40]. Although organic agriculture is now going mainstream, its credibility might be jeopardized as the production methods and processes are being industrialized [4]. Padel and Foster [26] claim that "*Although demand for organic food is still buoyant, there are signs that markets are maturing and growth rates over the last years have slowed to below 10%*". The main critics are not related to the key elements in the current definition of organics. On the contrary, these concerns are directly related to some economic, environmental, and social ideals such as production systems, size of the operations, distribution systems and channels, and capital intensity. The by-product of this situation is what Bean and Sharp [4] call alternative food systems (AFS). These systems are sustainable and economically, socially, and environmentally more viable. Concepts such as local, fair trade, and paleo come into play here.

2. Alternative foods

2.1. Variety and food labels

Aside from hardcore consumers that are very knowledgeable, others are still not well educated about the meaning of alternative food labels. Although there is a lack of a widely accepted single definition of these new alternative food concepts, there are serious attempts to provide clear bounds to this label. In fact, radial distance, such as 100 miles, replaced ambiguous characteristics such as political lines of distinction [39] or distinct characteristics of people and places [3]. In addition, Geographical Indication Labels (GIs) provide a clear signal to identify a local product. The European Union, for instance, recognizes two basic categories of GIs: the Protected Designation of Origin (PDO) and the Protected Geographical Indications (PGI). These labels help consumers not only recognize where the product comes from but also the production methods used [15].

The use of the term "organic" is restricted to farms, products, processors, and other intermediaries in the value chain between production and consumption, which have been certified by Certifying Bodies. The USDA[1] provides organic labeling to "*products raised without the use of most conventional pesticides, petroleum or sewage-based fertilizers, or genetically engineered materials*", in addition to the use of renewable resources and conservation. "Transitional organic" is also a restricted label and describes farms which have made the commitment to move toward organic certification. According to an FiBL[2] survey on organic rules and regulations, there are 82 countries with organic regulation and 16 countries in the process of drafting legislation [10]. In the same report, the organic sector is considered as the linchpin to face the challenges of food security, climate change, poverty alleviation, hunger, health, and biodiversity stewardship. Since the principles of organic agriculture include issues of social justice, Browne et al. [7] noted that sustainability and organics are closely linked and that ethical and organic trading are beginning to overlap.

Besides ensuring no use of genetic engineering, pesticides, additives, or fertilizers, local food labels should provide the consumer the value related to operation size, as well as distribution. In other words, buying local food should contribute to protecting the local farming economy, as well as the environment by reducing “food miles”. In addition, culture is another important dimension which might be considered in defining local foods. Besides associating terroir and local food products with PGI, PDO, TSG (Traditional Specialty Guaranteed), food baskets, distributor’s own label, or slow food, Bérard and Marchenay [5] underline the concept of localized food, which is based on the cultural dimension [20]. Consumers, particularly locavores, are becoming considerate not only about where their food comes from and production processes but also the way the food is made and creative versions of regional food classics of each season [12]. That said, it is important to consider what consumers qualify as “locally grown” since it determines differentiation patterns and, consequently, profits [9].

Labels like “local”, “natural”, “paleo”, “pesticide-free”, and “ecologically friendly” are not regulated and tend to be used by small farms catering to local or regional clientele. With the exception of marketing board-regulated products like dairy or chicken, production and handling of foods sold under these labels are for the most part not monitored or regulated, except by governmental agencies and district health units, and then only in terms of health/safety inspections and only as required by law. As a result, information on farms operating outside of the organic certification system is scattered and incomplete. Lastly, “organic” foods have to be differentiated from “functional” foods [35]. Organic foods tend to be regulated and are based on supply side value while functional foods are not very regulated and are based on demand side value. While both types of product are marketed to achieve the same objective (i.e., healthy products), the market positioning is very different.

2.2. Motivations and reasons to buy

Studying what determines consumer preferences for local food, as well as organic food, has been the concern of numerous studies in different countries [26, 6].

Aprile et al. [2] piloted a segmentation analysis of olive oil consumers in order to analyze consumers’ attitude towards local produce in Naples, Italy. They identified four clusters of local food consumers: local traditionalist, local ecologist, local fans, and local health conscious. Results show that seven factors explain consumer attitudes towards local food consumption:

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[1] United Stated Department of Agriculture.

[2] The Research Institute of Organic Agriculture (FiBL)

health concerns, altruism, environmental concerns, local habitual, local origin, certification, and specialties. Willingness-to-pay for PDO and PGI labels and other quality signals vary across the different identified segments. Similarly, Aguirre [1] conducted a comparative synthesis of the organic consumer profile in four different locations, US, Canada, Europe, and Costa Rica, based on three criteria: socio-demographics, purchase motivations, and main concern. The results indicate important similarities among the US, Canada, and Europe organic consumer with the Costa Rican consumer. Particularly in the four locations, the purchase motivations relate to health, environment, no-use of chemical, some concern about ethical issues, and helping farmers. Despite some differences in the barriers to purchase, consumers in all four locations state factors such as price and availability or unstable supply.

The importance of consuming local food is increasingly converging across different countries and cultures. Green et al. [16] conducted a study in four European countries (Finland, Germany, Italy, and UK) and the results of the study reveal the relative importance of risk associated with consuming conventional industrialized food, as well as the issue of provenance of food as a key element of the cultural framework in all countries. This highlights the fact that consumers seek alternative food as a way to reduce this risk and the importance of trust to facilitate choices in complex choice situations. Consequently, in making complex decision choices, consumers tend to use "pragmatic decision aids" rooted in cultural frameworks, as well as "craft skills", in order to assess food quality [16].

When it comes to understanding the main reasons for organic food consumption, Tarkiainen and Sundqvist [34] suggest that it is a way of life connected to a particular value system that affects attitudes, and consumption behavior. Padel and Foster [26] tried to ascertain those underlying values taking into account differences among consumers in terms of frequency of purchase and demographics (gender, marital status, number of children, etc.). Those values include enjoyment, unity with nature, respect for nature, taking care of family, benevolence, etc. More specifically, organic food-sales volume increase is due to consumers' self-interest motives that are predominant (e.g., personal health, high food quality, and taste). These are widely cited in the literature as the key factors to explain consumers' purchasing decision of organic food [24, 42]. However, it has been argued that organic food consumers might also have altruistic motives (e.g., environmentally friendly, animal welfare, fair trade). In Canada, organic food consumers mainly identify health and the environment, as well as support of local farmers, as main motives for their food consumption [19]. In the same vein, the Norm Activation Theory [29] explains altruistic behavior by feelings of moral obligation to act on one's personal internalized norms. This theory is particularly relevant in explaining consumers' attitudes towards organic food as an ethical food choice, which is based on political, ecological, and religious motives [21]. These political motives confirm Weber's [37] statement that human behavior is a way to affirm oneself and differentiate social status and belonging to groups.

Overall, growing consumer demand for alternative foods has been attributed to consumers' concerns regarding nutrition, health, the environment, and the quality of their food [14, 23, 31]. Further, various studies conducted in Europe and the US have explored consumer behavior and have tackled the issue of determining consumers' motivations and preferences for organic products [42, 38]. Although some consumers are environmentally conscious, most studies confirm the predominance of egocentric values like health, attitude towards taste, and freshness that influence alternative food choices [13, 42]. That said, Padel and Foster [26] show that motives and barriers may change with the purchasing frequency and across product categories. They distinguish between regular consumers who are generally families with at least one child suffering from asthma or food allergies and non-buyers who are more skeptical about organic food benefits and more sensitive to price premiums. They also highlight that consumers consider fruits and vegetables as the "key entry points" to the "organic experience", followed by other categories such as eggs and dairy, grocery products, meats, and soft drinks. In addition, their study reveals that trust appears as an important factor in deciding where to buy. In fact, consumers trust more specialist organic or local shops rather than supermarkets and large corporations.

On the other hand, the main reasons that prevent consumers from buying alternative foods are expensiveness, limited availability, unsatisfactory quality, lack of trust, lack of perceived value, poor presentation (packaging, display) and misunderstanding of the production processes, and lack of information [13, 14, 23]. In fact, the lack of information is related to the ability of consumers to locate organic products, to learn about the organic certification process, in addition to their ability to identify an organic product. The easiest way is to look for the word "organic" on the label. However, some consumers are familiar with various organic labels and might choose based on other features such as "natural". Conversely, previous research on the recent growth of consumer interest in local food shows that it is attributed to increased concerns with safety and accountability about food, in addition to a desire to support regional farmers, the local economic and natural environment. Consumers want to know where their food comes from and how it is grown or raised.

2.3. Global versus local production and distribution

With the rapid growth of the organic supply, producers moved from traditional production methods to more industrialized production methods. Industrial farming addresses efficiently and effectively the challenges related to the cost and logistics of moving produced foods to national and global markets. Conventional food value chain applies an important downward pressure on price leading to the issues of profitability and productivity. This has resulted for some small farmers - concerned with the philosophical aspects of organic production – indiminished credibility of the organic standard and in a refusal to industrialize. These key contradictions lead to a "bifurcation" between market- and movement-oriented organic distribution systems since dedicated consumers continue to support alternative organic networks [28]. It has also hardened the value chain against entry by these small farmers. Hence, the challenge that the alternative food system is facing is a gap that spans between the consumerism/producerism system in place, the current food chain, and the alternative value delivery network/value chain.

Furthermore, this gap is broader between developed and developing countries. It is interesting to shed the light on similarities and differences between developed and developing countries in terms of the variables that might shape the buying behavior of organic foods consumers versus local foods consumers. As a matter of fact, there were almost 1.9 million organic producers in 2009, an increase of 31% since 2008, mainly due to a large increase in the production in India. Further, 40% of the world's organic producers are in Asia, followed by Africa (28%), and Latin America (16%). In North America, Canada allocates 0.7 million hectares to organic production while the United States has 2 million hectares. This represents 7% of the world's organic agricultural land.

One could infer that developing countries are increasingly concerned about providing food safety and all the ecological, social, and economic motivations behind adopting this option. However, some studies proved that "*the main aim of several developing countries' policies and/or legislative approaches for organic agriculture is income generation through the promotion of certified organic food*" [30]. In Tunisia, for instance, the Tunisian government developed policies, established a National Commission for Organic Agriculture and a certification authority, assigned a budget to cover 30% of investments of organic farmers and 70% of certification costs over five years to encourage farmers' conversion to organic production to comply with EU Regulation since 1999. Those incentives made Tunisia ranked 35th worldwide, and the 1st among African countries, in terms of certified area (87,000 hectares). An interesting aspect to grasp is the role of these institutions in promoting and educating Tunisian consumers about organic food.

3. Conceptual framework

The approach of the current study is based on an integrative production-distribution-consumption model (cf. Figure 1). There are three layers of decision in this model: (i) supply chain related to certification and production methods; (ii) value delivery network related to the channels of distribution broken down into three main categories, long or standard channel, short channels, and direct channels; and finally, (iii) the consumer behavior related to the psychographics influencing the consumption of alternative food.

The tri-Party model shows the alternative food value that will be assessed in this study. Basically, consumers are assumed to have a certain *food culture* that is directly related to the degree of economic development. This in turn sets the current standard of food production that leads ultimately to food concerns. These concerns will—again—influence the way consumers perceive and eat food (food culture). Consequently, these perceptions give rise to food preferences and, more importantly, reasons to buy and requests regarding food quality, freshness, environmental and economic impacts, and healthiness. This is assumed to depict a certain size of operations (large versus small). This in turn will impact the type of channel members involved in these operations. It is assumed here that the distribution channels are very short, counting a maximum of two members: one producer/farmer and one distributor (if there are any). These channels create values that are logically different depending on the point of sale. Lastly, depending on the market coverage and the channel size, farmers, producers, or distributors will have a marketing approach adapted to the value offered to the target market.

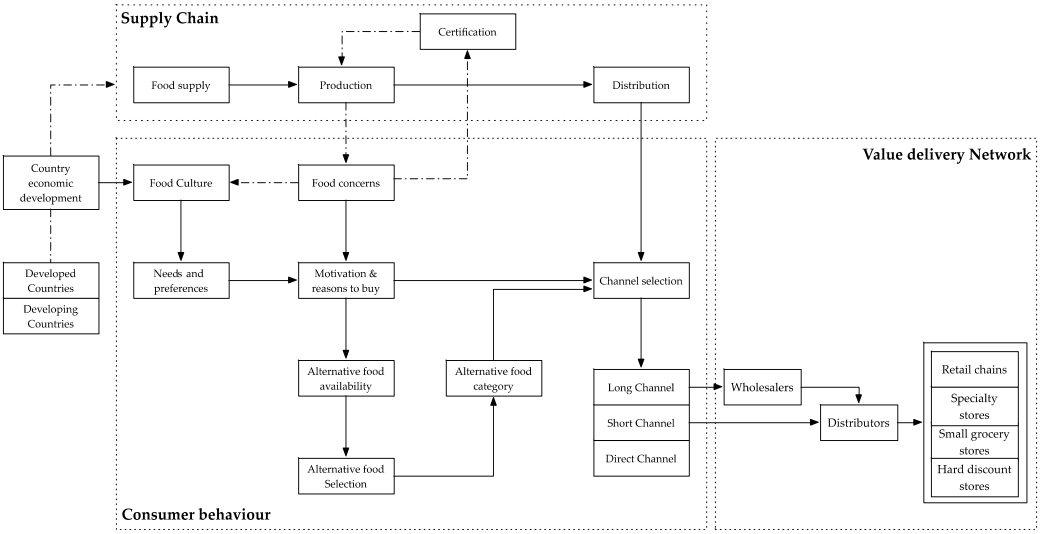

Figure 1. Integrative Production-Distribution-Consumption Model

4. Research design

4.1. Objectives

The current study aims to uncover the demand and supply side factors that affect the alternative foods supply chain and how value is created through the distribution channel and perceived by the final consumers. This value needs to be determined and estimated at the demand side level. Further, the logistics of the value delivery network need to be investigated. This will lead to an in-depth understanding of the value added in the alternative food distribution system, the current market structure, as well as its determinants. Further, building trust in the organic food (OF) supply requires more than just ensuring product quality and product knowledge, or labeling and setting proper pricing and communication strategies, as actually trust is missing at various levels of the marketing value delivery system and the food supply chain. The dimensions of trust necessary to achieve market growth have to be integrated to the OF product positioning and the distribution strategies. Moreover, this will provide a detailed assessment of the actual purchasing situation in the current distribution system, e.g., superstores, specialty stores, and farmers' market. This analysis is done taking the perspective of both a developed country (Canada) and a developing country (Tunisia). This will help to understand the importance of the value delivery network in creating value added to the target market. Hence, the second objective is to explore the market responsiveness to the different distribution strategies used in developed and developing countries. In order to target more efficiently consumers, we need to provide a more precise and useful profile of these consumers, who they are, what they eat, how they buy, where they buy, and why they eat alternative foods. This will lead to an in-depth understanding of the major forces shaping the current market structure, as well as an understanding of the challenges faced by the main players of the alternative food industry.

Hence, our objectives can be summarized as follows:

1. Determine alternative food consumers' purchasing behavior in terms of how consumers buy, where they buy, reasons to buy, attitudes, expertise, and trusted channels of distribution;
2. Compare consumers' purchasing patterns of developed and developing countries; and
3. Cluster alternative food consumers with regard to their psychographics in both country types.

4.2. Operational framework

This operational model shows the alternative foods value that will be assessed in this study. Basically, as it is shown in Figure 2, consumers are assumed to have requests and preferences regarding food quality, freshness, environmental and economic impacts, and healthiness. This is assumed to depict a certain size of operations (country economic development). This in turn will impact the expertise and familiarity of these consumers with regard to alternative foods. These elements are the foundation of the motivation to buy alternative foods.

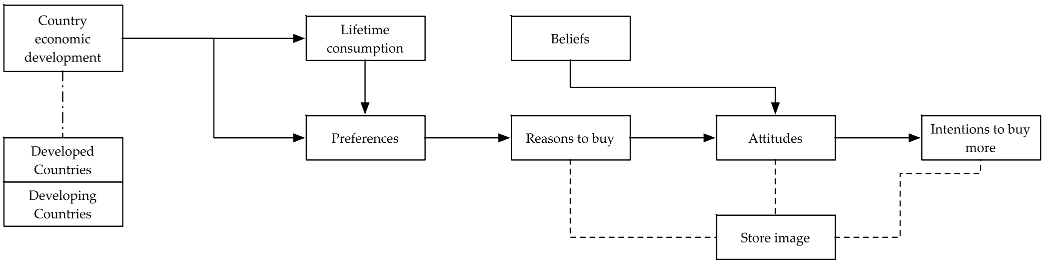

Figure 2. Operational Framework

Preferences will drive the motivation to buy alternative foods. It is assumed that beliefs, motivation, and attitudes are prerequisites to intentions to buy. Lastly, store image as defined above plays a moderating role here.

4.3. Measurement and scaling

To address the study objectives, a quantitative design is required. The design will help profile consumers by country and their purchasing patterns. The conceptual framework depicted in Figure 1 has been developed to assess the alternative food consumption schemes. This in turn is expected to lead to the development of a second model that also takes into account the key factors shaping this new market. The former model has been tested using a structured questionnaire. Prior to developing the survey, secondary data was collected in Canada and Tunisia using major sources of information, as well as informal interviews with industry key players (experts, certifiers, and government representatives). These gatekeepers can provide the most recent and accurate information about the alternative food market and industry.

Information obtained from these key players, while fairly comprehensive within its scope, is not necessarily accurate. This is illustrated by the example that in order to reach various target export markets, some farms, products, and businesses are certified by multiple bodies simultaneously.

The output of these interviews helped design the questionnaire. This latter is structured into three sections. The first section deals with consumers' general opinion about organic food, consumption and shopping habits, and reasons for buying organic products (measured on a 5-point Likert scale). The second section of the survey measures consumers' psychographics in terms of trust, beliefs, and attitudes (all measured on a 5-point Likert scale). Finally, the third section is structured to design a socio-demographic profile of our respondents. The survey was developed by selecting other case study questionnaires on the topic of alternative food marketing [27, 11, 32, 13, 17]. Prior to administering the survey, a pre-test was done and minor modifications were made. Quantitative data for this study has been analyzed using the Statistical Package for the Social Sciences (SPSS). A total of 500 questionnaires were collected, and 480 questionnaires were usable. Data was cleaned and missing values were replaced using the mean. All variables were tested to check their internal consistency. Further, all reliability tests were coupled to a series of factor analyses to determine the structure of the data. Factor analyses also helped to test if the items were measuring the right constructs. Results from factor analysis and reliability analysis show good levels for an exploratory study [18].

4.4. Sampling design

To address the abovementioned objectives, alternative food consumers have been surveyed to assess their consumption behavior/patterns. Hence, a survey was administered to consumers in a developed country (Canada) and a developing country (Tunisia). The population targeted for this study is alternative food shoppers (organic food, certified organic food, local food, and fair trade food). For the purpose of gaining a good representation, respondents needed to fit within a specific profile. The idea was to randomly select alternative food consumers that make their purchase mainly at small producers' farm gates, community farmers, farmers' market, community groceries, specialty stores, and community chain stores. Further, they had to consume at least one of the following product categories: fruits, vegetables, dairy, bread, meat, and prepared food. They also had to be in charge of household grocery/food purchases. This being said, countries have been selected based on the stage of alternative food product's life cycle. Further to this, it is well known that food is culture in developing countries while in developed countries, this is not the case [5].

The point of contact of data collection—point of respondent interception—was selected according to the value delivery network. It is obvious that developing countries present different marketing distribution patterns than developed countries. More precisely, the delivery chain differs as per (i) channel size and type, (ii) alternative food products variety, and (iii) channel position—number of layers in the distribution system. Developed countries align all types of channels of distribution while developing countries have limited distribution channels embodied mainly in the direct channels (producers) and, to a limited extent, in short channels (specialty stores). Lastly, there is a two-prong challenge related to surveying some of these distribution players: (i) limited availability of some alternative food, and (ii) the limited size of the population requires a large sample size sufficient enough to ensure consistency of the results without reaching any saturation.

5. Results

5.1. Overall consumers profile

Consumers have been profiled using the data collected from the respondents who indicated that they currently purchase alternative foods (mainly organic and local). Overall, the typical alterative food consumers are aged 25 to 35 years old (30.1%); single (63.3%); household composed of 4 to 5 persons (38.6%); have at least an undergraduate degree (51.5%); buy at least two organic food products (90.8%); eat mainly national country-based organic (32.1%); buy organic food mainly from supermarkets; and finally, consider price as the major determinant when buying alternative foods.

5.2. Lifetime consumption: Familiarity and expertise

Consumers have been regrouped using their lifetime consumption. As per Cunningham's [8] work, if respondents have been buying alternative foods on a regular basis, then they are classified as regular alternative food consumers (RAFC); while if they haven't been consuming alternative foods for a very short period of time, then they are tagged as non-regular alternative food consumers (non-RAFC). It is important to note here that alternative foods have been defined in broad terms of consuming either organic foods (certified, fair trade, local) or local (foods). Accordingly, respondents are distributed as follows: 63.1% of RAFC and 36.1% of non-RAFC. This means that a third of the consumers has been consuming alternative foods for more than a year while the rest of the sample have shorter experience with the product. Lastly, RAFC and non-RAFC are almost equally distributed on the Canadian sample, while in the Tunisian sample there are more non-RAFC (76.9%) than RAFC (23.1%).

Lifetime consumption could serve as a proxy to several indicators such as experience with the product, knowledge about the points of sales and price differentials, and level of trust. To corroborate this, several ANOVAs were run to check if there are significant differences between RAFC and non-RAFC in terms of their familiarity and expertise with regard to alternative foods. Results show that RAFC are more familiar than expert when compared to non-RAFC. These findings are summarized in Table 1.

	RAFC	Non-RAFC	Significance level
Familiarity with alternative foods	4.68	3.21	0.000*
Expertise	3.76	2.40	0.000*

Table 1. Familiarity and Expertise of RAFC and non-RAFC

5.3. Purchasing pattern

5.3.1. Purchase criteria and preferences

Given that the survey did not clearly define what alternative food is, it is assumed that respondents understand this concept. Further, there was no differentiation between local, local organic, fair trade organic, and certified organic. This is also evidenced by how respondents addressed the question related to alternative food preferences. In terms of local food consumption, 21.9% of respondents indicated they do purchase local organic food, 32.1% purchase national organic (Nationally produced – Canada or Tunisia), 7.3% buy certified organic, 4.3% buy fair trade organic foods, and 33.8% have no specific preference.

Attributes	Canada	Tunisia
National organic	11.9%	20.9%
Certified organic	2.3%	5%
Local organic	15.4%	6.5%
Fair trade organic	0.8%	3.8%
No preference	21.3%	12.3%

Table 2. Cross Tabulation: Country versus Product Preferences

Table 2 shows that RAFC and non-RAFC are mainly looking for the national and/or local food dimension. This downgrades certification and fair trade to lesser importance. These consumers are more hardcore alternative food consumers looking for good value products.

Further, when classifying these results by country, it is clear that consumers in developing countries do not clearly differentiate between the different types of alternative foods. This is mainly due to cultural food factors; the agricultural sector is not industrialized yet in developing countries. Consumers tend to associate agricultural production to local/national production. Imports are not as important as for developed countries. This is evidenced by the Chi-square test. It shows that there is an association between the country and alternative food preferences ($\chi^2 = 53.88, \quad p = 0.000$).

Furthermore, a simple mean analysis[3] shows that the three most important criteria when buying alternative foods are: healthiness (4.79), quality (4.79), and support to the local economy (4.81). Taste and environmental friendliness do not seem to be important purchasing criteria (mean lower than 1). Moreover, RAFC show higher means on the five dimensions than the non-RAFC. However, the only significant differences are related to taste and environmental friendliness. This shows again that regardless of their familiarity and expertise, the most important factors for consumers are intrinsic attributes (healthiness and quality) and extrinsic attributes (support to the local economy).

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[3] On a five-point Likert scale.

5.3.2. Point of purchase

Question 10 of the survey measures consumers' perception of the store offering and value. This is a very important indicator of the store impact on consumers' choices. Table 3 shows that all dimensions are relatively important to all consumers; quality, convenience and services being the most important factors. Price is moderately important and presents the lowest score (3.51). The mode for all dimensions is 4 on a scale of 5. Hence, all criteria are considered by consumers but to different extents when buying alternative foods.

	Mean	**Mode**
It is convenient to do my shopping in this store	3.68	4
It offers a wide variety of products	3.60	4
It offers good quality products	3.82	4
It offers the services I am looking for	3.67	4
It offers good prices	3.51	4

Table 3. Store Choice Mean Analysis

To complement these analyses, bivariate correlations were run to show that store choice is related to intentions to buy, attitudes, and reasons to buy. This proves the homogeneity and structure of the purchase behavior.

Lastly, an ANOVA was run to check if there are differences between developed and developing countries in terms of store choice. Results are not conclusive. However, even though there is no significant difference between both countries, it is interesting to note that consumers in developed countries have higher scores on all dimensions than developing countries. This clearly shows that the former countries have a stronger store image than the latter countries. This is mainly related to the degree of economic development and the structure and maturity of the value delivery network.

5.3.3. Buying process

In the current study, the buying process is measured with a multi-step sequence starting with motivations, beliefs, reasons to buy, and ending with intentions to buy more alternative foods. This latter variable is dependent on attitudes that is, in turn, dependent on beliefs and reasons to buy. Attitudes are considered as a proxy for the final purchasing behavior. Two simple linear regressions were run to test the buying process. Before running the first regression, a factor analysis was run to determine the number of dimensions of the variable beliefs towards alternative foods. Results show two dimensions: one related to the intrinsic attributes such as taste and healthiness, and another one related to the extrinsic attributes such as price and the meaning of alternative foods.

Regression 1 tests the influence of the reasons to buy and beliefs (intrinsic and extrinsic) on attitudes (cf. Table 4).

Independent	Sig.	Beta
Reasons to buy	0.000*	+0.394
Intrinsic beliefs	0.000*	+0.305
Extrinsic beliefs	0.069	-0.049

Table 4. Regression 1: Reasons and Beliefs on Attitudes

Reasons to buy and intrinsic beliefs are determinants of attitudes. Both explain 33.5% of the variance of this latter variable and both have a positive influence on attitude. It is important to note that consumers do not consider extrinsic beliefs when building their attitudes. This shows clearly that such consumers look more for a value rather than a product. Regression 2 tests the last link in the process, namely the influence of attitudes on the intentions to buy more alternative food products (cf. Table 5).

Independent	Sig.	Beta
Attitude	0.000*	0.699

Table 5. Regression 2: Reasons and Believes on Attitudes

As expected, attitudes have a positive effect on intentions to buy more alternative foods (R^2=32.1%). To recapitulate, Regressions 1 and 2 show that there is a linear relationship between reasons to buy, beliefs, attitudes, and intentions to buy more alternative foods.

It is important to test whether these results hold true for both countries. Several ANOVAs have been run to test differences and similarities between Canada (developed country) and Tunisia (developing country). All results are depicted in Table 6. It is obvious that there is no significant difference between both countries in terms of reasons to buy, attitudes, and intentions to buy. However, there is a difference in terms of intrinsic and extrinsic beliefs. It is also important to note that Canadians score higher than Tunisians on all variables except for extrinsic beliefs. This is in line with the previous regression results.

Variable	Mean Tunisia	Mean Canada	Sig.
Belief – Intrinsic	3.70	3.89	**0.000***
Belief – Extrinsic	3.61	3.36	**0.007***
Reasons to buy	3.87	3.90	0.661
Attitudes	3.97	4.00	0.285
Intentions to buy more	3.72	3.77	0.543

Table 6. ANOVA Inter-country Tests

Further, all consumers score relatively higher on attitudes and reasons to buy. As expected, the lowest scores are for extrinsic beliefs. As stated in the literature review, extrinsic beliefs do make more sense for developed countries than developing countries.

5.4. Clustering consumers

Since the main focus is to classify consumers with regard to their motivation, attitudes, beliefs, expertise, and their intentions to buy more alternative foods, various analyses were run. Therefore, cluster analysis and discriminant analysis are natural techniques to segment the alternative food market and discriminate between consumers. This approach is best suited to identify consumption and behavior patterns and create a consumer typology. Specifically, we are more interested in exploring differences in behavior between the segments than predetermining the number of segments.

Different combinations of socio-demographic indicators and psychographic variables have been implemented to determine with minimal bias an optimal segmentation strategy. The idea is to maximize intra-group homogeneity and intra-group heterogeneity. This allows for more robust profiling, as consumers behave in the same way when they belong to the same segment and behave differently if they belong to different segments. Note that homogeneity and heterogeneity are defined with regard to the segmenting variables. A good segmentation is defined as a segmentation strategy that maximizes both the inter-group homogeneity and intra-group heterogeneity. Conversely, a broad segmentation is defined as a segmentation strategy that minimizes both the inter-group homogeneity and intra-group heterogeneity.

Different combinations of socio-demographic indicators and psychographic variables have been used to segment the market. Several of these combinations show problems with either the intra-group homogeneity or the inter-group heterogeneity. Alternatively, for the purpose of having a good measure of intra-group heterogeneity, several ANOVAs were run to make sure that consumers in different segments have different profiles. All tests were conclusive.

5.5. Intentions to buy more alternative foods

Our aim here is to classify respondents based on their intentions to buy more alternative foods. Question 8 prompts respondents to rate their willingness to buy more alternative foods in the future. This has been done using a five-point itemized scale, with a median point of 3. A two-step cluster analysis was run. Results show that we have a good segmentation strategy with three distinct segments (cf. Table 7).

Segments	Percentage	Mean
High intentions to rebuy	27.8%	4.86
Moderate intentions to rebuy	58.7%	3.63
Low intentions to rebuy	13.6%	2.01

Table 7. Cluster Analysis for Intentions to Buy More

Half of the consumers have moderate intention to rebuy alternative food in the future while a third of the respondents are more than willing to rebuy alternative foods in the future. Further, cross tabulations between the cluster membership and the type of alternative food consumers (RAFC–non-RAFC) show that there is an association between the type of consumers and their intentions to rebuy alternative foods. As expected, most of the high intentions to rebuy consumers are RAFC while most of the low intentions to rebuy consumers are non-RAFC.

5.6. Reasons to buy alternative foods

The two-step cluster analysis shows one cluster with high scores on the five dimensions of reasons to buy, namely healthiness, taste, environmental friendliness, quality, and support for the local economy. Factor analysis confirms one dimension for reasons to buy. A simple mean analysis[4] was run and results corroborate this finding (cf. Table 8).

	Mean	**Mode**
Healthiness	4.01	4
Taste	3.59	3
Environmental Friendliness	4.02	4
Quality	3.79	4
Support for the Local Economy	3.91	5

Table 8. Mean Analysis of Reasons to Buy

To investigate this finding more, several statistical checks were performed. One last cluster analysis was run to explore the effect of the country on the reasons to buy. It is interesting to see that there are two clusters intimately related to the country classification (cf. Table 9). These clusters are composed of consumers that have moderate to high reasons to buy.

	Cluster 1	**Cluster 2**
Cluster size	52%	48%
Clustering variable: Country	100% Canada	100% Tunisia
Clustering variable: Reasons to buy	3.90	3.87

Table 9. Cluster Analysis for Country and Reasons to Buy

5.7. Beliefs toward alterative foods

It is clear from Table 10 that true believers have positive extrinsic and intrinsic beliefs; while skeptics have the opposite beliefs. The third segment is a hybrid segment that has high intrinsic beliefs and low extrinsic beliefs.

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[4] Measured on a five-point Likert scale.

	Intrinsic Attributes	Extrinsic Attributes	Size of the Cluster
Segment 1: Skeptics	Low	Medium	29.6%
Segment 2: True believers	High	High	45.7%
Segment 3: Hybrids	High	Medium	24.7%

Table 10. Cluster Analysis for Beliefs Toward Alternative Foods

To investigate these findings more and to get plausible explanations, cross-tabulations with the type of consumers have been run (cf. Table 11). A third of the respondents are true believers and new RAFC (non-RAFC) 14.4% are RAFC. Further, there are almost three times more non-RAFC skeptics than RAFC skeptics. Lastly, there is an even distribution of non-RAFC hybrids and RAFC hybrids. These findings are in line with the results presented above. There is a strong association between the segments and the type of consumers ($x^2 = 14.97,\ p = 0.000^*$).

	Non-RAFC	RAFC
Skeptics	17.6%	6.9%
True believers	31.2%	14.4%
Hybrids	15.3%	14.6%

Table 11. Cross-tabulations of Type of Consumers and Belief Clusters

5.8. Combined clusters: Country-based clustering

Combining country and familiarity to beliefs leads to the following segments (cf. Table 12):

Segments	Acronym	Familiarity	Intrinsic beliefs	Extrinsic beliefs
Cluster 1	Tunisia	Medium	Medium	Medium
Cluster 2	Canada 1	Low	Medium	Medium
Cluster 3	Canada 2	High	High	Medium

Table 12. Cluster Analysis for a Combination of Variables

This clustering strategy shows that extrinsic beliefs are not important regardless of the country. Further, results show that there is only one cluster in Tunisia that scores medium on all variables. This could be explained by the fact that the food culture is not based on food concerns. As mentioned above, there is not industrialization of the agricultural sector. Conversely, Canada presents two opposite profiles: (i) consumers familiar with alternative food products and have expertise to assess these products,-these consumers have moderate to high beliefs; and (ii) consumers that have limited expertise regarding alternative foods, and have negative beliefs.

6. Discussion

This exploratory study has academic and practical implications to both producers/distributors and consumers. Even though alternative food has not been clearly defined in the study, results show that consumers buying local foods and fair trade or local/national organic have a purchasing behavior slightly different from what is known in the current literature. Using familiarity and expertise (lifetime consumption) as a segmentation variable provides several insights on the current behavior of RAFC. Results show that RAFC are hard-core consumers. As a matter of fact, lifetime consumption has been used as a proxy of several other psychographic indicator such as trust, reasons to buy, beliefs, and intentions to buy more. Further, this adds to the classical segmentation strategy that has been used so far in the literature. For instance, compared with [22], our clustering strategy provides more insight into the why, who, and what alternative consumers buy.

Each segment exhibits a separate and distinct behavior from the other segments. RAFC are habitual purchasing consumers and non-RAFC are variety-seeking consumers. First, when buying alternative food products, RAFC are making straight habitual purchases and have their own purchasing scheme. They are characterized as consumers who are motivated by intrinsic and extrinsic attributes but only by intrinsic beliefs. This explains why these consumers have strong principle-oriented lifestyles as they also look for locally produced products and/or purchases that might help the local economy. They also care about the product quality and the healthiness. As expected, these consumers are 18 to 35, single, and educated. Gender is not determinant here; males and females exhibit the same behavior. Further to that, they buy all types of OF products ranging from fruits, vegetables, and dairy to meat. Second, non-RAFC buy alternative foods occasionally; for less than a year. For these consumers, the main reason to buy alternative foods is healthiness. However, there is a significant difference between RAFC and non-RAFC in terms of taste and environmental healthiness of alternative foods. These consumers do not perceive significant differences between alternative food and conventional food. Non-RAFC seem to have a basic trust structure. This is in accordance with [32, 19]. For instance, non-RAFC base their trust on the information available at the point of purchase because they do not collect information to build their knowledge based on OF. These consumers are not fully principle oriented.

One of the main forces that affect the current state of the market is food culture. As per Figure 1, food culture is dependent on the economic development of the country. In the context of the current study, food culture is a by-product of the industrialization or non-industrialization of the agricultural sector. In developing countries, the agricultural sector is using basic production techniques leading to the production of small quantities. These findings need to be related to the product life cycle. For instance, the organic market is driven by conventional marketing strategies and is consistently looking to standardization of the supply. This defeats the intrinsic sustainability objective of such products. This study shows the importance of the production operations and the distribution logistics. There is a clear differentiation between developed countries (using all possible distribution channels) and developing countries (using less complex distribution schemes and shorter channels). The channels reflect a certain market reality. Consumers buy from long channels because of convenience and price. They offer a local value targeted toward a certain consumer profile; these are customers that buy alternative foods for health reasons. Conversely, short channels are production method driven. These channels serve consumers that have a principle-oriented lifestyle; thus, the support of the local economy is the main drive of this market demand. Price is not an issue here.

One of the limitations of the study has been that consumers might not *fully* understand what alternative food means. Further, the analyses performed in the current study did not focus—on purpose—on the type of alternative foods. Rather, it focused mainly on (i) difference between the expertise of the consumers and (ii) differences between developed and developing countries. It would have also been interesting to study the importance of the frequency of purchase as well as price premiums. Further, the typical alternative food consumer in Canada and Tunisia is not consistent with previous research that indicates a female with a higher-level education. Having profiled this consumer, however, it is noted that consumers in both countries are very similar in terms of demographics. It is important to recognize that consumers may not fully understand the meaning of alternative foods, and thus demographics alone are not sufficient to explain the purchase behavior. Future research should be undertaken to assess the effects of different marketing ideas and also to examine if consumers understand the meaning of locally produced food.

To recapitulate, the starting point of the marketing model depicted in Figure 3 starts with the market needs. Depending on the degree of consistency of the need and the knowledge level of the target market, there are two schemes: habitual consumers (RAFC) and variety seeking consumers (non-RAFC). The more the consumers know about their needs, the more they will look for an enhanced value capturing mainly intrinsic beliefs. These consumers will look for basic channels offering quality, convenience, and services. Conversely, if consumers have limited knowledge but are driven by social consciousness (sustainability and helping the local economy), then they will buy from longer channels (specialized, community grocery stores) under the impression that food is local.

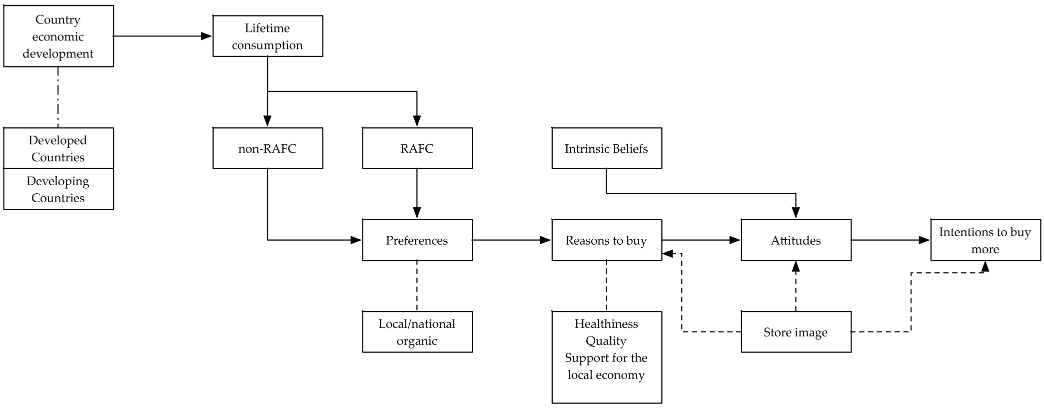

Figure 3. Final Model

7. Conclusion

Alternative food research is an area of study with a vast number of possible areas of future research. Local farmers will find value in knowing that market potential does exist for their product, and consumers are expressing an interest in purchasing locally produced food in short channels of distribution. Their motivation to buy local food products is not driven by fear and concerns over food products but rather by quality, healthiness, and support for the local economy. In terms of channels of distribution, it is obvious that convenience and service are key for the channels choice. These two factors are a proxy for trust. This result is consistent with the findings from the study conducted in Ontario [25], which also found a willingness to buy local food products if available in more conventional stores.

Although consistent with other research that has profiled a typical local food consumer, farmers should not solely target the typical demographic profile (well-educated woman with above average income and family) but should consider the importance of product attributes to all consumers when creating their marketing approach. For example, knowing that a product is locally produced, and promoting it based on quality indicators (e.g., nutrition, health benefits, taste, and reduced food mileage) might be a better strategy than just focusing on the typical local foods consumer. Contrary to the existing literature on sustainability, and the concept of embeddedness, this study did not indicate that the consumer's concerns and/or fears changed the consumer’s decision to buy local. While the study does reveal that concerns have altered the purchasing patterns and behaviors of consumers, these concerns about foods might relate more to the Bovine Spongiform Encephalopathy (BSE) crisis for example than the fear of the globalized food system. Further exploration of the reasoning behind the decision to buy local could be explored in order to determine if social theory and the desire to purchase sustainable products plays a role in consumers' decision-making.

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Conventional and Organic Farming — Does Organic Farming Benefit Plant Composition, Phenolic Diversity and Antioxidant Properties?

Alfredo Aires

Additional information is available at the end of the chapter

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Abstract

The growing demanding from consumers for healthier foods, produced using environmentally friendly farming practices has resulted in the rapid expansion of organic farming. There are numerous studies about the importance of organic farming but the majority of the results are sometimes contradictory, inconsistent and show no clear link between organic farming practices and enhancement of the nutritional quality of plant-derived foods. As such, ongoing research into the effects of organic farming and cultivation practices in comparison with intensive farming, is very important. The objective of this chapter is to discuss the most recent data and variation in the responses of plants to farming regimes in order to better understand the relationship between agricultural practices and high levels of valuable compounds (glucosinolates, phenolics, minerals, vitamins, antioxidants), as well as low levels of undesirable components such as nitrates, nitrites and microorganisms.

Keywords: Organic farming, conventional faming, nutrient diversity, phytochemicals, quality, safety

1. Introduction

Research studies continue to show that the desire of consumers to be able to purchase healthier fruits and vegetables, produced by a more sustainable and environmental friendly agricultural system, is increasing day-by-day. The majority of these studies attempt to show how safe and nutritious organic foods are for humans [1] and animals [2]. According to European regulations

[3] organic farming is defined as an overall system of farm management and food production that combines the best environmental practices, high levels of biodiversity, the preservation of natural resources, the application of high animal welfare standards and utilises production methods in line with the preference of consumers for products produced using natural substances and processes. The aim of an organic farming system is to provide to the consumer with fresh, tasty and natural food, while respecting natural systems and the environment. To achieve this, several principles and rules are followed in order to minimize human impact on the environment, while at the same time ensuring the agricultural system operates as naturally as possible [4]. Several different approaches are employed, but all of them are guided by strict rules [3] aimed at protecting the integrity of the environment, plants, animals and biodiversity.

A fundamental aim of organic farming is the provision of healthy, high quality plant and animal-derived foods. The concept of food quality can be defined in many different ways. Often, the quality of food is based on visual characters such as shape, size and colour, but can also be described as containing fewer pesticides, or more nutrients, or even containing specific functional properties due to elevated levels of phytochemicals [1, 5]. Thus, there is no one sole concept of quality. Nonetheless, countless studies of quality always refer to at least one or more of the following criteria: (i) food safety (absence of undesirable components like nitrites and pathogenic microorganisms); (ii) primary nutrients (minerals and vitamins, for example); (iii) secondary metabolites and phytochemicals that are closely associated with the beneficial health properties of plant and animal-derived foods; and (iv) observed health effects. However, research studies using these criteria vary widely, with investigative topics ranging from the taste of the food to how the food in question benefits health. Despite this diversity, the link between organic products and their nutritional, functional, and biological values is far from being fully understood. Therefore, in this chapter, we discuss recent advances in organic farming, particularly its differences from conventional farming, highlighting the differences in vitamins, minerals, phytochemicals, antioxidant activity and sensorial properties.

2. Factors and constraints affecting crop and plant-derived food composition

Growing crops in any part of the world is affected by many variables, including environmental, agronomical, social and economic factors, among others. These factors can affect not which particular type of agricultural system is employed, or which type of crop produced, but also and more importantly, the quality of the crop. Both conventional and organic farming systems are always heavily influenced by such factors. These factors can be grouped into 4 main types (Figure 1): a) socio-economic; b) pre-harvest; c) harvest; and d) post-harvest.

A recent study [6] showed that the choice between an organic or conventional farming system is primarily dependent on socio-economic factors, secondarily dependent on social aspects and then all of the remaining factors follow on. In fact, when farmers implement any production system or crop, their first question is: How profitable is it to produce? The answer will depend on the choices the farmer makes about what crops to grow, where to grow them, and

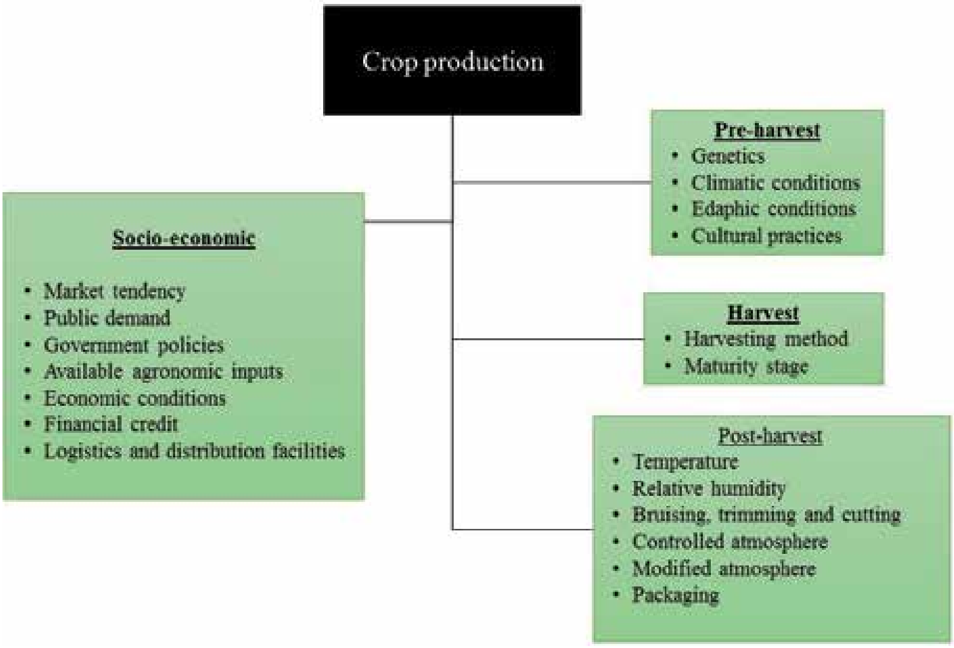

Figure 1. Constraint factors of any crop yield and production.

what technologies he uses. In addition, farmers tend to follow the system producing a higher financial income, lower financial risks, lower labour requirements, and if possible, the greatest pleasure [7]. The ability to obtain credit will also influence the choice of crops, farming systems and technologies [8]. The level of technical and scientific knowledge of production will also affect a farmer's propensity to choose a particular crop or production system [9, 10]. Moreover, the capital requirement for any crop development is always present, but can vary seasonally and is often far higher during harvesting than at other times during the production period. Any financial or labour constraint can negatively affect negatively the farmer´s productivity and, therefore, income [11].

Another social aspect of decision to farm organically or conventionally is public demand [12]. If a farmer wants to succeed, then there must be a demand for their products, to generate an income, otherwise the farmer will switch to another, more profitable crop, whether it is organic or not.

Production is also affected by pre-harvest factors. In general, these factors include all physical factors, such as genetics, geology, soil and climatic conditions and cultural practices [13, 14, 15]. In other words, after a specific crop has been chosen, its success will depend on the outcome of the complex interaction between numerous elements such as the biology of the plant, interaction between plant and soil, crop management techniques, mineral and organic nutrition, chemical or biochemical treatments, and the watering regime employed, among other factors. Climatic parameters such temperature, humidity, altitude, rainfall and wind, are all fundamental factors affecting the variation of plant and crop success [16, 17] and thus their nutritional quality as food. Temperatures can limit the growth of crops; water is a key factor in plant growth with different crops requiring water at different times; altitude primarily affects the average temperatures and consequently the type of farming; wind can have a destructive effect on crops physically, as well as increasing the dryness of soils, reducing moisture and increasing the potential for soil erosion. The soil type will influence crop cultivation because different crops prefer different soils, e.g., clay soils with their high levels of water retention are widely used to produce rice, as rice requires a lot of of water to grow successfully [18, 19], whilst sandy soils are more suited to roots, tubers and vegetables, due to their need for better drainage, which is a requirement for good development of their roots [20]. Thus, selecting the right crop for the given specific conditions is fundamental to increasing yield and quality.

Another set of factors are relate to the harvest period. It is widely accepted that stage of maturity at harvest can have a critical influence on the nutritional content of the crop. Zaro et al. [21], observed marked changes in the level of bioactive compounds present (anthocyanins, carotenoids, ascorbic acid, phenolics) and in antioxidant activity of purple eggplants at the fruiting stage. They found a decrease of such compounds and beneficial properties when plants were harvested at earlier stages (I and II). The same tendency was recently observed [22] in carrots, where a relatively high amount of falcarindiol, an important antioxidant compound, was present during very early harvest (i.e. 103 to 104 days after sowing) compared with a later harvest (i.e. 117 to 118 days after sowing). The same trend was also recently noted [23] for anthocyanin content in blueberries when harvested earlier, but not when harvested at full maturity. Thus, correct choice of harvesting time is crucial in preserving the quality of fresh produce during storage. This way, it is possible to provide the consumer with high quality fresh food products.

After harvesting, several factors (identified here as post-harvest factors) can interfere with the quality of fruit and vegetables. Among them are temperature regime of storage, relative humidity of storage, type of atmosphere used if any, and packaging [24, 25]. Temperature management during shelf-life is one of the most important means of preserving the quality of fresh roots, fruits and vegetables. After harvest, any delay in cooling, or choosing the wrong temperature regime, can result in losses in nutritional quality, flavour, taste and saleability. Tano et al. [26], found that the quality of mushrooms, tomatoes and cabbages stored under a fluctuating temperature regime was severely affected by extensive browning, loss of firmness, increased weight loss, increased level of ethanol in plant tissues, and fungal infections due to physiological damage and excessive condensation, when compared with products stored at a constant temperature. Similar observations were recently made [27] for mandarins, when low storage temperatures (2, 5 and 8 ºC) resulted in a loss of orange peel colour, volatile compounds, and flavour. Thus, storage temperature is a fundamental factor affecting nutrients, colour and flavour [27]. In addition, particular attention should be paid post-harvest procedures such as cleaning, bruising, trimming and cutting, which may also affects the quality of products if they are conducted in inappropriate conditions or improperly performed [28]. Thus, the quality and stability of plant-derived food products will be strongly dependent on the interaction of several different factors and, therefore, an understanding of the physiological and biochemical process in plants and foods during the period of shelf-life, is crucial to maximising their nutritional quality and bioactive composition, and thereby their properties beneficial to health.

3. Conventional versus organic

Organic farming has increased in popularity in recent decades due to the public's perception that health problems may arise from the consumption of plant-derived foods produced under intensive farming practices. This growing concern lead to a considerable number of studies into the effect of organic production on nutrients (mineral, vitamins) and phytochemicals such as polyphenols, antioxidant vitamins (A, C, E), glucosinolates, carotenoids and isoflavones, among others. Although a large number of studies about the differences between plants produced under conventional and organic farming systems is now available, most of the studies present contradictory facts, inconsistent results and the differences are often reported as negligible. Consequently, it is important to study the variation in nutritional quality and safety of plant-derived food produced under both organic and conventional farming methods. In the following paragraphs we discuss recent findings about the effect of the two different agricultural systems on the variation in nutrients and phytochemicals in plant-derived food, focusing on the major differences already discovered.

3.1. Variations in vitamin, mineral, amino-acid and nitrate content

The nutritional value of food is essentially a function of its vitamin and mineral content, particularly those related to important beneficial functions in animals and humans [29]. Essential minerals required in the human diet include, among others, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), sulphur (S), boron (B), chromium (Cr), cobalt (Co), copper (Cu), iodine (I), manganese (Mn), molybdenum (Mo), selenium (Se), tin (Sn), and zinc (Zn) [30, 31] and the essential vitamins include mainly A, B (all vitamins of the B complex), C, E and K [30]. Compared with conventional farming, organic production relies on sustainable management practices, which include crop rotations, cover cropping, nutrient recycling, integrated pest management, and use of organic fertilisation [32], among other practices. All these practices, according to the majority of consumers have indeed had a positive impact on food quality, enhancing the levels of beneficial minerals and vitamins [33]. However, from a scientific point of view, the question of whether organic plant-derived foods are more nutritious than conventional ones remains.

Conventional farming usually relies on massive doses of readily soluble forms of mineral fertilisers (mainly in N, P, K form), whilst organic farming relies on the incorporation of organic material into the soil, normally through the use of animal manure as fertiliser [34]. Composted manure is the most commonly used fertiliser in organic farming [35] and thus the general consumer perception is that organic foods are better because they are produced using natural and safe agronomical inputs [33], and thus they are more nutritious.

Throughout the past 15 years, several comparative studies have demonstrated significant differences in the content of vitamins, minerals and free amino-acids (Table 1). However, several authors claim that no major or significant differences are found in mineral and vitamin content in fruits and vegetables produced under organic or conventional farming systems, and several others report that for some specific nutrients, conventionally grown plant-derived foods usually contain higher average levels (Table 1).

Products tested	Nutrients analysed	Key-results	Reference
Lettuce, spinach, carrots, potato and cabbage	Iron, Mg, and P	**Higher** in **organics**	[36]
Chinese mustard, Chinese kale, lettuce, spinach	Vitamin C, β-carotene and riboflavin	**Higher** in **organics**	[37]
Wheat	Minerals (N, K, Mg, Ca, S, Fe,)	**Similar** in **both**	[38]
Red potatoes	Minerals (K, Mg, P, S and Cu)	**Higher** in **organics**	[39]
Wheat	Essential Amino acids	**Lower** in **organics**	[40]
Wheat	Minerals (P, K, Ca, Zn, Mo, Co)	**Similar** in **both**	[40]
Kiwi fruits	Minerals (N, P, K, S, B, Ca, Mg)	**Higher** in **organics**	[41]
Tomato	Vitamin C	**Lower** in **organics**	[42]
Broccoli	Vitamin C	**Similar** in **both**	[43]
Spinach	Nitrate	**Lower** in **organics**	[44]
Strawberry	Vitamin C	**Similar** content	[45]
Broadbean, bean, lettuce, pepper, watermelon.	Nitrates	**Lower** in **organics**	[46]
Acerola	Vitamin C and carotenoids	**Higher** in **organics**	[47]
Strawberries	Vitamin C and carotenoids	**Similar** in **both**	[47]
Cauliflower	Vitamin C	**Higher** in **organics**, but only when higher organic fertiliser levels were applied	[48]
Potatoes	Essential amino acids	**Higher** in **organics**	[49]
Strawberries	Ascorbic acid	**Higher** in **organics**	[50]
Cauliflower	Soluble solids, nitrates, P and K	**Similar** in **both**	[51]
Green pepper	Weight, firmness, thickness, N and P	**Lower** in **organics**	[52]
Tomatoes	Vitamin C	**Higher** in **organics**	[53]
Apple	Aromatic volatiles, organic acids and sugars	**Higher** in **organics**	[54]

Table 1. Differences in the content of nutrients in organic and conventional fruit and vegetables

Some research studies have claimed that organic amendments can have a positive effect on the content of antioxidant vitamins such as vitamin C [47], but others claims that the effect is negative [42], whilst others still, claim no significant difference [43, 45, 55]. Thus, there is a discrepancy in the results, and external factors such as crop variety, crop location, climate and growing conditions [56] can all exert an effect. Moreover, it is unlikely that mineral fertilisers or manure alone can affect the nutritional content of fruits and vegetables. Nonetheless, the majority of authors seems to agree that an organic production system is friendlier than an intensive or conventional farming system and the choice of organic system as an alternative to conventional practice can be justified by its lower environmental impact [57].

Another important issue related to the nutritional quality and safety of organic food is nitrate content, particularly in fresh vegetables. Nitrates are a natural consequence of the mechanism by which plants absorb the element nitrogen, in the form of NO3-, from fertilisers or organic material [58]. Although nitrate is an important component of plants, it has the potential to accumulate in tissues, particularly in green leafy vegetables [59] and thus, nitrate from fertilizers could accumulate in vegetables on a large scale. The danger of this, lies in the fact that nitrates can be reduced to nitrites, which can react with amines and amides to produce "N-nitroso" compounds, responsible for gastric cancer [60]. In order to maximize the health benefits from eating vegetables, measures should be taken to reduce levels of nitrates and nitrites [59]. This is particularly true in organic farming due to the large quantities of manure used as natural fertiliser, which is sometimes reported as having the potential to elevate levels of nitrates and nitrites up to, or above, maximum residue levels (MRLs), which is dangerous. However, some studies report that manure fertilisers have no significant effect on nitrate levels because organic products should always contain fewer nitrates than their counterparts produced by conventional methods, due to their lower concentration of nitrogen-based fertilisers [61, 62]. Furthermore, several other authors have reported that nitrate content is more closely related to genotype, soil conditions, growth conditions (i.e., nitrate uptake, nitrate reductase activity, and growth rate), storage and transport conditions, than to mineral or organic amendments [63]. More recently [64] it was shown that that nitrate accumulation in vegetables is more closely related to the quality of water and water accumulation in vegetable tissues. Thus, the results available until now from various different studies are sometimes contradictory and doubts still remain. Nonetheless, based on the fact that organic farming enhances specific nutrients and is less aggressive to the environment, it is more beneficial than conventional farming, which is seen as more aggressive to the environment, fauna and flora, and ultimately, to animals and humans.

3.2. Influence on bioactive compounds and functional properties of foods

3.2.1. Glucosinolates, phenolics, carotenoids and pigments

Recent scientific advances in plant-derived foods studies have mainly focused on the potential health effects of phytochemicals in plant foods. Phytochemicals, also known as bioactive compounds, are naturally occurring substances in plants, functioning mainly as secondary metabolites [65]. Their distribution in plants is considered to be the result of the natural adaptation of plants to environmental stress, pathogen infection, insects and other pests [66]. According Harbone [66], phytochemicals can be divided into different classes: phenolics (e.g. phenolic acids, flavonoids, anthocyanin), terpenoids (e.g., carotenoids, xanthophylls and other pigments), alkaloids (e.g., indole compounds), and sulphur-containing compounds (e.g., glucosinolates). Table 2 gives a brief summary of phytochemicals commonly found in fruits and vegetables, and the potential health benefits associated with them. To date, studies have shown that phytochemicals can have a protective effect on human health (Table 2 and Table 3), including mopping-up free radicals, reduction of oxidative stress, inhibition of cell proliferation, induction of cell differentiation, inhibition of oncogene expression, suppression of gene expression in carcinogenic processes, modulation of detoxification enzymes, stimulation of the immune system, regulation of hormone metabolism, and antibacterial and antiviral effects [67]. Strong associations have been also found between disease risk reduction and consumption of foods with a high content of glucosinolates (anti-cancer), tocopherols (cardiovascular), phenolics and carotenoids (eye-health) [68].

Phytochemicals		**Example of food sources**	**Proposed health benefits found in literature**
Class	**Example**		
Phenolic acids	Gallic acid, caffeic acid,	Tea, kiwi fruit, strawberries, pineapple, coffee	Antioxidant and anti-inflammatory
Flavonols	Quercetin	Red and yellow onions, tea, wine, apples, cranberries, beans	Antioxidant, anti-inflammatory, enzyme inhibitor and immune modulation
Flavanols	Catechins	Chocolate, tea, grapes, wine, apples, cocoa, black-eyed peas	Antioxidant, anti-hypertensive, anti-inflammatory, anti-proliferative, anti-thrombogenic, and lipid lowering effects
Flavones	Apigenin	Chamomile, celery, parsley	Lowers high blood pressure, antioxidant and anti-inflammatory
Anthocyanins	Cyanindin	Blackberry, blueberries, red wine, strawberries	Improvement of vision, and neuroprotective effects
Isoflavones	Genistein	Soy, alfalfa sprouts, red clover, chickpeas other legumes	Reduction in blood pressure, antioxidant activity
Lignans	Secoisolariciresinol	Linseed, sunflower seeds, sesame seeds, pumpkin seeds	Improves glucose control, prevents pre-cancerous cellular changes, decreases the incidence of several chronic diseases
Stilbenes	Resveratrol	Grape skins and seeds, wine, nuts and peanuts	Antioxidant, anti-inflammatory, protects the body against nitric oxide, keeps the blood vessels optimally dilated

Phytochemicals		**Example of food sources**	**Proposed health benefits found in literature**
Class	**Example**		
Carotenoids	Lycopene, beta-carotene and other types of carotenes	Carrots, spinach, tomato and several other types of fruits and vegetables	Neutralisation of free radicals that cause cell damage
Monterpenes	Limonene	Citrus oils, cherries, spearmint, garlic, maize, rosemary, basil	Antioxidant, anti-inflammatory, anti-cancer, helps with weight management ("fat cleanser") and helps clear cholesterol
Diterpenes	Gingkolides	Gingko biloba	Protects neurons against Abeta1-42-induced synapse damage and cognitive loss
Triterpenes	Ginsenosides	Ginseng	Boosts the immune system and may lower blood sugar levels
Phytosterols	Sitosterol	Sunflower oil, avocados, rice bran, peanuts, soybeans	Inhibits 5-alpha reductase in prostate tissue
Alkaloids	Capsaicin	Chili pepper	Reduces the expression of proteins that control growth genes that cause malignant cells to grow
Glucosinolates, isothiocyanates	Sulforaphane, allyl-isothiocyanate, phenethyl-isothiocyanate,	Broccoli, mustard, cress, cabbages and all Cruciferae family plants	Neutralisation of free radicals that causes cell damage. Protection against some cancers
Indoles	Alliin, allicin	Onions, garlic, leeks	Antimicrobial agents and decreases LDL cholesterol

Table 2. Examples of some important phytochemicals commonly found in foods

- antioxidant activity
- neutralises free radicals and reduces oxidative stress
- inhibition of cell proliferation
- induction of cell differentiation
- inhibition of oncogene expression
- inhibition of tumour gene expression
- induction of cell cycle arrest
- induction of apoptosis
- inhibition of signal transduction pathways
- phase II enzyme
- glutathione peroxidase (GPX)
- catalase
- superoxide dismutase (SOD)
- enzyme inhibition
- phase I enzyme (block activation of carcinogens)
- cyclooxygenase-2 (COX-2)
- inducible nitric oxide synthase (iNOS)
- xanthine oxide
- enhancement of immune functions and surveillance
- anti-angiogenesis
- inhibition of cell adhesion and invasion
- inhibition of nitrosation and nitration
- prevention of DNA binding
- antibacterial and antiviral effects

• enzyme induction and enhancing detoxification

[1] Adapted from Liu and Finley [67].

Table 3. Proposed health protective mechanisms of dietary phytochemicals[1]

Glucosinolates are sulphur-containing compounds mainly present in the Cruciferae family. When consumed, they are hydrolysed via myrosinase (EC 3.2.1.147, thioglucoside glucohydrolase) into isothiocyanates (ITCs) and other derivative products [69], that up-regulate genes associated with carcinogen detoxification cellular mechanisms [70]. Clinical studies have shown that the products of glucosinolate hydrolysis can reduce the incidence of certain forms of cancer [71].

Other compounds such as carotenoids lutein, β-carotene and tocopherols in addition to their role as vitamins, are also powerful antioxidants [72]. Tocopherols and carotenoids have been associated with the decrease of certain forms of cancer [73] and with a reduction in risk of cardiovascular diseases [74], whilst lutein protects against the development of cataracts and age-related macular degeneration [75], even if according Trumbo and Ellwood [76] there is no credible scientific evidence to support a health claim that lutein or zeaxanthin intake can reduce the risk of age-related macular degeneration or cataracts.

Phenolic compounds are a large group of secondary metabolites, categorised according to their chemical structure, into different classes, with phenolic acids, flavonoids, stilbenes and lignans being the most relevant ones [77]. They all have in common the presence of labile hydrogen able to neutralise or mop-up free radicals, and as such they are recognised as powerful antioxidants. Fruits and vegetables are the richest potential sources of these substances [78].

As mentioned above, the diversity of the chemical composition of plants, and thus by extension of phytochemicals is determined by a number of factors, including genotype, ontogeny, growth conditions, management practices and the environment. Thus, it might be expected that differences caused by organic vs. conventional growing practices may cause associated differences in phytochemical levels and diversity. Increasing organic food consumption is partially as a result of consumer perception that organic foods are healthier, but do organic foods actually contain more phytochemicals than conventional foods? Are the levels of phytochemicals in organic production relevant? Is the diversity of phytochemicals in foods affected by agronomical practices?

Table 4 summarises some of the results from different studies conducted over the last 15 years into the difference in phytochemical content in fruits and vegetables produced under organic and conventional farming practices. This is not an exhaustive list, but unsurprisingly several different conclusions are drawn. Recent studies [79, 80, 53] have indicated that organic produce contains higher concentrations of certain phytochemicals associated with health, than those produced under conventional farming systems. In addition, some studies [81, 82] reinforce this idea, stating that the abiotic and biotic stress induced by organic farming practices seems to overcome the variability among samples and consequently, the use of organic practices may be a means of increasing the levels of phytochemicals. However, according a recent observation [83] there is little evidence for any differences in the health benefits of organic and conventional produce. The differences often found may in fact be due to cultivar genotype influence and climatic variation rather than agricultural practices. The same observations was made by Oh et al. [84] and Lv et al. [85].

Crops & products	Bioactive substances	Key-results	Reference
Apple	Polyphenols	**Higher** in **organic** production	[86]
Chinese cabbage	Flavonoids	**Higher** in **organic** production	[87]
Spinach	Flavonoids	**Higher** in **organic** production	[87]
Green pepper	Flavonoids	**Higher** in **organic** production	[87]
Pear	Polyphenols	**Higher** in **organic** production	[88]
Yellow plum	Quercetin	**Lower** in **organic** production	[89]
Apple	Anthocyanins	**Higher in organic** production	[90]
Tomato	Lycopene	**Similar** content in both systems	[91]
Broccoli	Total glucosinolates	**Lower** in **organic** production	[92]
Strawberry	Polyphenols	**Similar** content in both systems	[93]
Tomato	Carotenes	**Higher in organic** production	[94]
Tomato	Polyphenols	**Lower in organic** production	[95]
Blueberry	Polyphenols	**Higher** in **organic** production	[96]
Tomato	β-carotene	**Higher** in **organic** production	[42]
Tomato	Lycopene	**Lower** in **organic** production	[42]
Carrot	Carotenoids	**Similar** content in both systems	[97]
Egg-plant pulp	Phenolics	**Similar** content in both systems	[98]
Cauliflower	Glucosinolates	**Similar** content in both systems	[48]
Strawberry	Anthocyanins	**Higher** in **organic** production	[79]
Soybeans	Isoflavones	**Lower** in **organic** production	[99]
Broccoli and collard greens	Glucosinolates	**Higher** in **organic** production	[100]
Watercress	Glucosinolates	**Lower** in **organic** production	[100]
Broccoli	Glucosinolates	**Lower** in **organic** production	[80]
Tomato	Polyphenols and lycopene	**Higher in organic** production	[53]
Pepper	Higher	**Lower** in **organic** production	[101]
Broccoli	Polyphenols	**Similar** content in both systems	[102]
Broccoli	Glucosinolates	**Higher** in **organic** production	[102]

Table 4. Summary of studies comparing phytochemical contents in fruits and vegetables from organic and conventional production

These authors stated that the most important factor affecting the phytochemical composition of plants is the interaction between genotype, environment and agronomical practices. Therefore, it is crucial to select the optimal environment conditions, genotype and best agronomical practices, in order to maximise the levels of a components beneficial to health.

In order to accurately evaluate the differences between organic and conventional farming systems, all the factors affecting quality of produce must be controlled, which is a major limitation of some studies through their poor experimental design. So, an accurate evaluation of all these aspects should be made over a substantial period of time (more than one year at least) in order to assess the eventual changes related to the year, seasonal effect, genotype or agronomical practices employed. A multi-year sampling study to evaluate farming systems with the necessary consistency to draw valid conclusions, is a minimum requirement [103].

3.2.2. *Antioxidant activity*

Closely linked to phytochemical content is the variation in antioxidants. Antioxidants, by definition, are any substance that reduce or inhibit oxidation or other reactions caused by oxygen and peroxides and free radicals, and which protect the body from the deleterious effects of free radicals [104]. Well-known antioxidants includes enzymes, vitamins (C and E), carotenes, polyphenols and others capable of counteracting the damaging effects of oxidation. They are important, because to date, epidemiological studies have shown their preventive effect against several infectious processes such as cancer, and neurodegenerative and cardiovascular diseases [105, 106, 62, 81]. As with primary nutrients and phytochemicals, the effect of organic farming practices on the antioxidant properties of plant-derived foods is controversial. It is common to find an association between organic farming practices and an increase in antioxidant content, and the converse is also true (Table 5).

Wang [81] found that organic practices result in an increase antioxidant activity in blueberries (measured by the ORAC) due to the increase of phenolic acids and anthocyanin content when compared with a conventional system, whilst Garuso and Nardini [107], didn′t find any substantial difference in antioxidant activity in wines produced under organic and conventional farming practices. Similar observations were made by Unal et al. [108] for Brassicacea vegetables. They didn′t detect any significant difference in antioxidant activity in brassicas produced under organic and conventional practices. However, Stracke et al. [97], when comparing the organic and conventional cultivation of apples over three years, observed that organic apples presented on average 15% higher antioxidant content, as determined by FRAP, TEAC and ORAC than conventionally produced fruits, but these authors also observed that inter-annual climatic variations were more critical to the antioxidant capacity than the type of farming. Despite these inconsistencies, the majority of authors seem to agree that the type of farming system may affect the phytochemical composition and thus by extension the amount of antioxidant activity. Since organic farming does not provide as much nitrogen as conventional fertilizers [56], as well as causing more stress to the plants (Straus et al., 2012)[109] than conventional farming, it has the potential to influence the synthesis of antioxidants, increasing their levels and thus increasing antioxidant activity, as recently reported [110]. Therefore, at least theoretically, it can be concluded that organic farming has a tendency to produce foods with more nutritional value, based on their enhanced antioxidant content and activity.

Crops & products	Antioxidant activity in organic compared to conventional counterpart	Reference
Blueberries	**Higher** in **organics**	[81]
Apples	**Similar** in **both**	[111]
Fruits and vegetables	**Similar** in **both** and no consistent trends were found	[112]
Tomato	**Higher** in **organic**	[113]
Grapes and wines	**Higher** in **organics**	[114]
Lettuce	**Similar** in **both**	[115]
Tomato	**Higher** in **organics**	[110]
Tomato	**Higher** in **organics**	[116]
Brassicas	**Lower** in **organics**	[108]
Oranges	**Similar** in **both**	[117]

Table 5. Some examples of studies comparing antioxidant activity of fruits and vegetables produced under organic and conventional farming practices

3.3. Consumers' sensory expectations and preferences related to variability of antioxidant activity and phytochemical content of organic foods

There is common belief that organic food is healthier and safer than conventional food. According to the vast amount of literature already published, some of which is reported in this chapter, organic food is free of chemical residues, contain fewer nitrates and more antioxidants. In respect of product quality, surveys in the last 10 years [118, 119, 120, 121, 122, 123] indicate that consumers consider organic foods to be more beneficial for human health than their conventional counterparts, even if those studies often assume a lack of knowledge on behalf of the consumers of the aims and production practices of organic farming. Moreover, consumers often buy organic foods based on an emotional view, such as a desire to preserve traditional products and processes [124]. According to a survey conducted in Turkey in 2012 [120] consumers indicated 4 main reasons to buy organic foods: they are healthier, they have higher quality, the price is normally acceptable, and the food is microbiologically safe. As Monk et al. reported in 2012 [125], for the majority of consumers, the idea of enhanced nutrition, being free from chemicals, and a better taste, are the major advantages of organic foods. Consumers often think that organic food is better because it tastes better, but apart from physical and sensorial qualities, the understanding of nutritional quality by consumers seems to be a question of the ability to find credible information [118], which they often can't. A recent survey [126] showed that 78% of consumers when questioned about the quality of labelling information, responded that they didn't believe that all food labelled 'organic' was, in fact, organic, and neither did they totally believe in their healthier effects. Often, consumers purchased organic food due to personal morals or beliefs such as: 'I feel obliged to buy organic food to protect my health' and 'I feel obliged to buy organic food to protect the health of my family' [126]. The same authors observed that consumers repeatedly reported that they experience difficulty in getting more knowledge about a product's properties, certification bodies, and labels etc... Nonetheless, nowadays consumers tend to be more conscious and more aware about the positive effects of organic foods on health and the environment [127], and as a result are buying more organic foods.

4. Conclusions

Since the 1980s, organic farming has been increasing due to growing demand from consumers for high quality foods, with lower pesticide residues, less synthetic fertilisers and produced using environmentally friendly practices. Presumably, animal and plant derived foods have fewer chemical residues and veterinary drugs in them when compared with conventional ones. The growing perception from consumers that organic foods are healthier and safer, has to the rapid growth of this type of production seen over the last 20 years. Although the beneficial properties of these foods for human health have not been unequivocally proven, the accumulation of nutritional metabolites in organic cultivation has been well documented. Recent studies have shown that organic foods are, from a nutritional point of view, at least similar to conventional ones, if not slightly better. Also, recent epidemiological studies advocate that under organic farming practices, plants can accumulate nutrients and phytochemicals, enhancing their biological value and thus increasing the nutritional quality of foods. Moreover, the growing evidence of lower pesticide exposure to consumers of organic foods, is one of the main reasons for converting to organic farming. Although more and more well-documented studies are still required to improve our understanding of which factors contribute to differences between organic and conventional farming practices, the most recent findings provide evidence-based knowledge that organic farming is a sustainable way of producing healthier and safer plant-derived foods.

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Chapter 16

Quality and Nutrient Contents of Fruits Produced Under Organic Conditions

Taleb Rateb Abu-Zahra

Additional information is available at the end of the chapter

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Abstract

Organic farming is an agricultural practice that raises plants especially vegetables and fruits without the use of synthetic pesticides, herbicides, fertilizers, or plant growth regulators. All over the world, the interest for organic farming has increased recently. Different greenhouse experiments were carried out in the northern Jordan Valley, to compare the effect of four fermented organic matter doses (1.5, 3.0, 4.5, and 6.0 kg m^{-2}), or different organic matter sources (cattle, poultry, and sheep manure in addition to 1:1:1 mixture of the three organic matter sources) with that of the conventional fertilizer and control treatments on different fruit quality parameters.

Results obtained showed that fruit titratable acidity (TA) percentage, size, moisture content, and ammonium and nitrate contents were higher in the conventionally produced fruits in comparison to the organically produced fruits. The organic treatments tended to produce fruits with higher anthocyanin, total soluble solids (TSS) percentage, dry matter content, ascorbic acid, total phenols, and crude fibre content in comparison to the control and conventionally produced fruits. In most cases, sheep manure source and 4.5 kg O.M m^{-2} treatment amount produced the best results.

Keywords: Nutrients, pigments, quality

1. Introduction

1.1. Environmental Issues

Environmental issues are capturing more and more of the world's attention; therefore, researchers and scientists are aiming at improving environmental quality through the adoption of techniques and measures that have a reduced impact on the environment [1]. Conventional agriculture practices utilize high-yield crop cultivars, chemical fertilizers and pesticides, irrigation techniques, and mechanization that have a huge impact on our environment [2]. Plants are subjected to attack by a large and diverse number of pathogens and pests; as a result, crop producers often use large amounts of agrochemicals in an attempt to improve and protect the fruit quality and plant vigor [3]. Ever since people have become aware that health is linked to health environment, the control and reduction of pollution have become the focus of worldwide concern [4]. Pollution is becoming a serious problem in agricultural regions; for example, various mineral fertilizers and agrochemicals lead to pollution and serious health problems in humans, hence alternative production techniques which employ biological or organic compounds for disease and pest control are needed [5]. In addition to the human health concern of elevated heavy metal concentrations in soil, they can cause harm to native ecosystem and accumulation in plant tissue can result in damage to wildlife [6]. Plant toxicity is the primary concern for elevated zinc concentration in soil, whereas the potential for risk to the herbivores is the primary concern with elevated cadmium concentration in soil, while human health concerns focus on lead concentration for which the most pertinent pathway is direct ingestion of soil [7].

1.2. Organic culture

Organic farming, which essentially excludes the use of many inputs associated with modern farming, most notably synthetic pesticides and fertilizers, is becoming more and more popular worldwide [2, 8]. Consumer's awareness of the relationship between foods and health, together with environment concerns, has led to an increased demand for organically produced foods. In general, the public perceives organic foods as being healthier and safer than those produced through conventional agricultural practices [9]. Consumers demand organic products because they believe they are more favorable and respectful to the environment and human health [10]. Organic foods have a nutritional and sensory advantage in comparison to their conventionally produced counterparts. Advocates for organic produce claim that it contains fewer harmful chemicals, is better for the environment, and may be more nutritious [11].

2. Fruit nutrient contents

2.1. Mineral contents

Mineral contents of fruits were found to be higher in fruits produced under conventional systems in comparison to the fruits produced under organic systems [12]. For example, bell pepper fruits, which were produced under conventional systems, were characterized by a high content of minerals (Table 1). The highest contents of zinc and iron in bell pepper were obtained in the conventional treatment with significant differences between other treatments, while there were no significant differences among the organic matter treatments, which could be attributed to the high application of chemical fertilizers [13].

Treatments	Zinc content (ppm)	Iron content (ppm)
Conventional	1.410 a	57.75 a
Cattle manure	1.170 b	45.50 b
Poultry manure	1.163 b	39.75 c
Sheep manure	1.165 b	39.25 c
Mixture manure	1.227 b	42.75 bc

*Means within each column having different letters are significantly different according to Least Significant Difference at 5% level.

Table 1. Effect of culture systems on contents of zinc and iron in bell pepper fruit

The contents of calcium, magnesium, sodium, potassium, and phosphorous in bell pepper fruit were significantly higher in those produced with conventional system than all those produced with organic matter systems (Table 2); even though the highest calcium content was obtained by the conventional treatment, there was no significant difference with the poultry manure, which could be due to the high use of limestone in the chicken food mixture [13].

Treatments	Calcium (mg 100 g^{-1})	Magnesium (mg 100 g^{-1})	Phosphorus (mg 100 g^{-1})	Sodium (mg 100 g^{-1})	Potassium (mg 100 g^{-1})
Conventional	260 a	89.25 a	394 a	26.1 a	2323 a
Cattle manure	243 b	79.50 b	315 b	19.1 b	1889 bc
Poultry manure	257 a	81.75 ab	362 ab	19.9 b	1820 c
Sheep manure	239 b	84.50 ab	349 ab	18.1 b	1986 b
Mixture manure	246 b	77.75 b	348 ab	19.6 b	1915 bc

*Means within each column having different letters are significantly different according to Least Significant Difference at 5% level.

Table 2. Effect of culture systems on contents of calcium, magnesium, phosphorus, sodium, and potassium in bell pepper fruit

2.2. Ammonium and nitrate

Vegetables represent the most important source of nitrogen for human nutrition, which is essential for growth. Therefore, its accumulation in plants is a natural phenomenon resulting from uptake of the nitrate ion that is found in excess amounts, and the intensive use of nitrogen fertilizer and manure causes nitrate contamination of the environment; therefore, vegetables can accumulate high levels of nitrogen and, when consumed, pose serious health concerns [13]. Ammonium and nitrate contents in conventionally grown strawberry fruits were 49.4 and 23.6 ppm, respectively, due to high use of inorganic nitrogen fertilizers, whereas it was found that ammonium content was 32.3 ppm and nitrate content was extremely low in organically produced fruits [10]. The nitrate content in bell pepper fruit was very low (<200 mgkg^{-1}), for all different cultural systems (organic or inorganic), even though the minimum value of nitrate content for organically produced bell peppers and the maximum value for fertilized bell peppers were found below the safe limit [13].

3. Fruit quality

3.1. Total soluble solids and titratable acidity

All organically produced fruits had significantly higher total soluble solids (TSS) and lower titratable acidity (TA) in comparison to the conventionally produced fruits [5, 14]; for example, sensory attributes are important aspects of fruit quality, and the balance between sweetness and sourness are the most important determinants of overall quality of fruits [15]; for example, acceptance of the flavor quality of strawberry fruits is minimum 7% for TSS content, while the maximum is 0.8% for TA [16]. Organically grown strawberries had significantly higher TSS (7.1%) and lower TA content (0.93%) in comparison to the conventionally grown strawberries that had 6.6% TSS and 0.99% TA. On the other hand, addition of animal manure improved bell pepper fruit taste by increasing the percentage of TSS and the addition of animal manure decreased the percentage of TA in bell pepper fruit [10].

3.2. Total phenols

Phenolic metabolites may suit human health and contribute to the prevention of chronic diseases such as cancer and cardiovascular diseases [17]. In addition, phenolic compounds play a vital role in plant defense mechanisms against insect, fungi, and animal herbivores [18]. Levels of phenolic compounds were higher in organically grown fruits than the levels in conventionally produced fruits, because the restricted use of herbicides, pesticides, insecticides, and chemical fertilizers was reported to accelerate synthesis of phenolic compounds in organically produced fruits [19].

3.3. Ascorbic acid (Vitamin C)

Ascorbic acid content in fruits is cultivar dependent according to Leskinen et al. [20]; levels of ascorbic acid in organically produced fruits were consistently higher than the levels in the conventionally grown ones [8]. The highest fruit ascorbic acid content (50.5 mg 100 g^{-1} fruit fresh weight) was obtained by the organically treated berry fruits, whereas the conventional treatment gave the lowest ascorbic acid content (41.25 mg 100 g^{-1} g fruit fresh weight), according to Abu-Zahra et al. [10]. On the other hand, Cayuela et al. [14] did not find significant difference in the ascorbic acid content between organic and conventional grown strawberry fruits. Also manure type has an effect; the highest amount of vitamin C was obtained from the sheep manure–treated pepper fruits, while the lowest amount was obtained by the conventionally produced pepper fruits [10].

3.4. Crude fiber

Fruit crude fiber content highly differs according to fruit dry weight [21], but it is found to be higher in organically produced fruits in comparison to conventionally produced fruits [10]; the high crude fiber content in the organically produced fruits could ensure better nutritional and health benefits related to fiber consumption [22]. The highest strawberry crude fibre fruit value (8.13%) was obtained by the 4.5 kg organic matter/m^2, which was significantly different from the conventional, and control treatments [13]. Although, crude fiber of bell pepper fruit was improved by the use of the cattle manure which produced the highest (2.96%) crude fiber content in comparison to the conventional system which produced the lowest content (2.8%) [23].

3.5. Fruit size

Fruit size is highly affected by the farming systems; the conventional agriculture resulted in the biggest fruits, in comparison to organically produced fruits. The large fruit size in the conventional farming system may be due to the good availability of soil nutrients that produced vigorous plants with higher yield and larger fruits. But it was observed that the use of high amount of organic matter (6 kg O.M/m^2) produced a large fruit size, which may be due to the good improvement of physical and chemical properties of the soil [10, 24].

3.6. Fruit fresh weight

Fruit weight depends on cultivar and temperature rather than on the culture system (organic or conventional) [10]. Moreover, most researchers found only small and non-significant differences between organic and conventional systems in respect to fruit weight [20]. But in an experiment conducted on strawberry plants, they observed that the use of chemical fertilizers were found to produce the highest significant average fruit weight compared to fruits produced by using organic materials or without using any type of fertilizers [10, 25].

3.7. Fruit moisture content and dry weight

Fruit moisture content showed an opposite trend to fruit dry matter content; organically produced fruits had more dry matter and lower water content in comparison to the conventionally produced ones. The decrease in fruit water content of the organically produced fruits was reflected on increasing fruit dry matter content in comparison to the conventionally produced fruits that produced the lowest fruit dry matter and highest water content [10]. For example, the highest strawberry moisture content (93.37%) was obtained by the conventional system which produced the lowest fruit dry matter content (6.63%), while strawberry fruits that are produced under organic systems, contains 92.61% moisture content and 7.39% of dry matter content [10].

3.8. Fruit pH

The fruit taste is highly affected by the fruit pH; addition of organic materials was found to lower the strawberry fruit pH, especially by using sheep manure as a source of organic matter

[24]. However, in an experiment conducted on pepper plant, results do not show any significant differences between all of the used organic and inorganic treatments on fruit pH [23].

4. Fruit pigments

4.1. Chlorophyll

Chlorophyll content of the leaves was increased by the use of organic matter applications; the highest increase was obtained by using the sheep manure as a source of organic matter, while the lowest amounts of leaf chlorophyll content were obtained by the use of chemical fertilizers [26].

A promotional effect of organic matter treatments on chlorophyll contents might be attributed to the fact that nitrogen is a constituent of chlorophyll molecule [3]; moreover, nitrogen is the main constituent of all amino acids in protein and lipids that act as a structural compound of the chloroplast. Contradictory data about the relationship between growth and chlorophyll content of leaves have been reported in which bio-fertilizers increased the content of photosynthetic pigments [27].

4.2. Anthocyanin

Organically grown fruits developed a significantly stronger color than conventionally grown ones [14]. The highest anthocyanin content of strawberry fruits (42.88 mg 100 g^{-1}fruit fresh weight) was obtained by the 6 kg O.M/m^2 treatment, while the least anthocyanin content was obtained by the control treatment (neither synthetic fertilizers nor organic materials). In spite of that, the anthocyanin content of the control treatment of strawberry plants remained within the ranges between 17.8 and 41.8 mg 100 g^{-1}, and values lower or higher than that range should not be acceptable [10].

In another study conducted on red pepper fruits, the highest anthocyanin (38.5 mg 100 g^{-1}) amount was obtained by the mixture of different organic matter treatment. And the least anthocyanic content was obtained by the conventional culture system, which proves that organic farming provides peppers with the highest intensities of red and yellow colors, while the conventional fruits were those with the lowest values of color intensity [23].

4.3. Lycopene

It is recorded that fruit lycopene content was the highest in conventional agriculture, but without significant differences from the different organic matter sources. Also fruit lycopene was affected by the organic matter source, and the lowest lycopene content was obtained by the poultry manure source–treated pepper fruits, which means lycopene fruit content does not improve by the use of organic matter treatments in comparison to conventional agriculture that hastened fruit lycopene content [23].

5. Conclusions

Fruit characteristics from plants cultivated in soil supplemented with animal manure were generally better than those from plants grown in soils only or supplemented with chemical fertilizers. In most cases of animal manure sources, sheep manure gave the best results. On the other hand, the use of chemical fertilizers was found to increase the fruit lycopene content and improve fruit size and yield by increasing the fruit weight. Organic foods contain fewer harmful chemicals, are better for the environment, and may be more nutritious.

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Organic farming is a progressive method of farming and food production it does not mean going back to traditional (old) methods of farming. Many of the traditional farming methods used in the past are still useful today. Organic farming takes the best of these and combines them with modern scientific knowledge. Authors' task was to write a book where many different existing studies could be presented in a single volume, making it easy for the reader to compare methods, results and conclusions. As a result, studies from different countries have been compiled into one book. I believe that the opportunity to compare results and conclusions from different authors will create a new perspective in organic farming and food production. I hope that our book will help researchers and students from all over the world to attain new and interesting results in the field of organic farming and food production.

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