Organic Agriculture and Innovative Crops under Mediterranean Conditions

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Abstract

Climate change is the greatest environmental threat facing humanity worldwide. Areas of South-East Europe and Mediterranean basin are expected to be among the most vulnerable countries to climate change. As a result of climate change, new species and crops have been introduced and may be introduced in the coming years. In addition, FAO considers that Organic Agriculture is an effective mitigation strategy to climate change and can build robust soils that adapt better to weather extremes associated with climate change. This review provides an overview of the growth performance of new innovative crops, including chia, camelina, quinoa, teff and nigella and retrovative crops such as flax and emmer wheat, based on experimental investigations conducted under Mediterranean conditions and organic cropping system. Several studies, performed under organic system, have proved that innovative crops can also be grown for alternative uses. Quinoa and chia could be successfully used in animal feed. Moreover, quinoa could be exploited as a medicinal plant due to saponins extracted from seed coats. Nigella and camelina seeds contain oils which can have several uses in pharmaceutical and food industries. Flax seed oil is rich in omega-3 fatty acids and can be accepted in the diets designed for specific health benefits. According to the literature, it is observed that innovative crops cultivated under organic system present better quality and similar yields as with those cultivated under conventional system, and in some cases, even higher. Taking all these into account, organic agriculture could also be characterized as innovative and not only as traditional.

Keywords: climate change, innovative crops, Mediterranean conditions, Organic Agriculture, retrovative crops

Introduction

Climate change consists the greatest environmental threat facing humanity worldwide. It is a natural process but, in the light of recent surveys, this dramatic change is mainly due to the increase of various greenhouse gases (GHG) emissions as a result of anthropogenic reasons. Agriculture is actually affected by climate change but also plays a part in the rise of problem. Agriculture is the third largest contributor of greenhouse gas emissions, mainly including methane (CH4), nitrous oxide (N2O) and carbon dioxide (CO2). The Intergovernmental Panel on Climate Change (IPCC, 2007). In addition, agriculture contributes about half of global emissions of methane and nitrous oxide (World Bank, 2008). It has to be noted that emissions due to the production of agricultural inputs such as synthetic fertilizers and pesticides, fossil fuels used in the production of agrochemicals and agricultural machinery and irrigation are not included and should also be taken into account (El-Hage Scialabba and Müller-Lindenlauf, 2010). Regarding the high contribution of agriculture to greenhouse gas emissions, the choice of alternative agricultural practices is the only solution to cope with problem of climate change.

Agriculture is highly depended on climate conditions. Changing environmental conditions such as rising temperatures, changes in precipitation patterns and an increase of extreme weather phenomena have the potential to affect productivity in agriculture, making it even more prone to failure (El-Hage and Müller-Lindenlauf, 2010).
Innovative Crops: General Information and First Results of their Cultivation

Quinoa
Quinoa (Chenopodium quinoa Willd.) has a significant potential for increased production as a new cultivated crop in the Mediterranean region and in other areas of the world including North America, Europe and Asia (Jacobsen, 2003). It is characterized as one of the crops that could provide food security, especially in the future climate scenario of increasing salinization and aridity (Jacobsen, 2003; Ruiz et al., 2014). Quinoa, a member of Chenopodiaceae family, is a pseudocereal crop well adapted to grow under unfavourable soil and climatic conditions (García et al., 2003) and has been traditionally cultivated for thousands of years in the Andean highlands of Bolivia, Peru, and Ecuador for its nutritious grains and leaves (Pearsall, 1992). Archaeological findings in northern Chile have shown that quinoa is cultivated there for more than 7000 years (Jancurová et al., 2009). Over the last thirty years, quinoa seed has become an extremely popular food product, especially in Europe and North America (Jellen et al., 2015), because of its exceptional nutritional value (Repo-Carrasco et al., 2003). Quinoa grain is gluten-free and therefore can be eaten by people who have celiac disease (Pulvento et al., 2010). It has a high protein content (14-20%) containing essential amino acids such as lysine, methionine and threonine which are limiting in cereals (Bhargava et al., 2007). Moreover, quinoa is rich in vitamins C, E and B complex, minerals, isoflavones and lipids (Koziol, 1992).

The saponins, constituted up to 6% of seed coat, can be exploited for industrial and biomedical purposes (Vega-Gilvez et al., 2010). The aerial biomass of quinoa has been used as green fodder for animals such as cattle, pigs and poultry (Bhargava et al., 2006). Therefore, this species is considered as a multi-purpose agricultural crop with potential uses for both human and animal consumption and nutrition. The Food and Agriculture Organization of the United Nations (FAO) has declared the year 2013 as the international year of quinoa (FAO, 2012).

Data obtained from several studies conducted in areas of Mediterranean basin demonstrate the beneficial effects of organic farming in quinoa crop (table 1). Bilalis et al. (2012) conducted a two-year experiment in western Greece to investigate the influence of soil tillage [conventional tillage (CT) and minimum tillage (MT)] and organic fertilization [fertilization treatments: control, cow manure (200 kg ha\(^{-1}\)) and seaweed compost (250 kg ha\(^{-1}\))] on growth, yield and quality of quinoa and found that the highest saponin yield (7.70-12.05 kg ha\(^{-1}\)) was observed in soils subjected to minimum soil tillage. Also, there were significant differences between the fertilization treatments with the highest values of seed yield (2485-2643 kg ha\(^{-1}\)) and saponin content (0.42-0.45%) observed in manure and compost treatments. Papastylianou et al. (2014) studied the response of quinoa and amaranth to different fertilization regimes ([control, inorganic fertilization (fertilizer 26-0-0 with 100 kg N ha\(^{-1}\)), compost (2000 kg ha\(^{-1}\)) and cow manure (2000 kg ha\(^{-1}\)]) and found that fertilization with compost showed higher values in yield (8430 kg ha\(^{-1}\)) and quality traits (18.8% total...
ash, 2.87% crude fat and 14.7% crude protein) of quinoa biomass. They suggested that quinoa could be used as an alternative feed crop for substitution of spring legume species in Mediterranean semi-arid areas.

**Chia**

Chia (Salvia hispanica L.) is an annual plant of the Lamiaceae family and originated from southern Mexico and northern Guatemala (Ayerza and Coates, 2005). In pre-Columbian period, chia seeds were one of the four main components in the diet of Mesoamerican civilizations (Bochicchio et al., 2015). Currently, it has been rediscovered (Ayerza and Coates, 2009) and received remarkable attention due to its exceptional nutritional value (Borneo et al., 2010; Ixtaina et al., 2011). Seeds are great sources of polyunsaturated fatty acids, antioxidants, vitamins and minerals (Ayerza and Coates, 2009). The oil content of chia seeds ranges from 25 to 40%, consisting 60% ω-3 alpha-linolenic acid and 20% ω-6 linoleic acid (Mohd Ali et al., 2012). Both of these essential fatty acids are required by the human body for its health and they cannot be artificially synthesized (Pizarro et al., 2013). Several studies reported that chia consists one of the richest natural sources of ω-3 fats and hence chia seeds were successfully used to increase the ω-3 fatty acid content of animal products such as eggs, poultry and pork meat (Ayerza, 2011). In Europe, the use of chia for human consumption has been approved by the European Parliament and the European Council according to the directive 2009/827/EC (European Commission, 2009).

Bilalis et al. (2016) established a field experiment to determine the effect of plant densities (row spacing: 60 and 40 cm) and organic fertilization [fertilization treatments: control, organic fertilizer (fertilizer 6-8-10 at a rate of 1000 kg ha⁻¹) and sheep manure (1800 kg ha⁻¹)] on growth and fodder quality of quinoa crop under Mediterranean conditions. According to the results, there was a positive effect of increasing row spacing on biomass production (5587 and 14190 kg ha⁻¹ for 40 and 60 cm, respectively). Fodder quality parameters were actually affected by organic fertilization. The highest crude protein (13.25%) and acid detergent fiber (ADF) content (42.45%) were observed in organic fertilizer treatment, while, the highest neutral detergent fiber (NDF) (49.57%) content was recorded under manure treatment. According to the authors, these high values can meet the requirements of lactating animals. Moreover, they emphasized that chia biomass is produced during the summer which is very important for the nutrition of ruminants since there is a lack of natural vegetation during this period.

**Nigella**

Nigella (Nigella sativa L.) is an annual medicinal plant of the Ranunculaceae family and is native to areas of southern Europe, North Africa, South and West Asia (Tuncturk et al., 2005). It is cultivated from the countries of the southern and eastern areas of the Mediterranean basin to Iran, Pakistan and India for seed yield and oil production (Gharby et al., 2015). Its seeds, the only part of the plant harvested and exploited, have been subjected to a series of pharmacological studies over the last three decades. The studies have shown that nigella seed oil and extracts have diuretic, antihypertensive, anti diabetic, anticancer, anthelmintic, analgesic, antimicrobial, anti-inflammatory, spasmyolytic, hepatoprotective, gastroprotective, nephron-protective, antihypertensive and antioxidant effects (Riaz et al., 1996; Ahmad et al., 2013). The seeds are rich in unsaturated essential fatty acids, among which linoleic, oleic and palmitic acids are the most abundant (Kizil et al., 2008). In addition, the nigella seeds are also a source of minerals, including Fe, Na, Cu, Zn, P, Ca and vitamins such as ascorbic acid, thiamin, niacin, pyridoxine, and folic acid (Takruri and Dameh, 1998). Nigella seeds contain 30-35% oil and 0.5-1.5% essential oil which have several uses for pharmaceutical and food industries (Üstun et al., 1990; Ashraf et al., 2006). Thymoquinone is the major active compound in the crude extract of nigella oil and is characterized for antioxidant and anti-inflammatory effects in models of in vitro and in vivo studies as well as asthma, diabetes, encephalomyelitis, neurodegeneration, and carcinogenesis (Woo et al., 2012).
During the spring and summer of year 2016, Roussis et al. (2017) set up an experiment at Agricultural University of Athens to investigate the effects of different seed rates (50 and 60 kg ha$^{-1}$) and fertilization (fertilization regimes: control, compost (2000 kg/ha), sheep manure (2750 kg/ha), inorganic fertilizer (15-15-15+5 S, 400 kg/ha)) on growth, yield and yield components of nigella crop (Fig. 1). They found that the different seed rates significantly affected the plant height with the highest values (18.2-22.7 cm) recorded with 60 kg ha$^{-1}$. Moreover, they observed that seed yield and biological yield were significantly affected, maximum parameters (911-1066 kg ha$^{-1}$ and 3864-4063 kg ha$^{-1}$ for seed yield and biological yield, respectively) were recorded with inorganic fertilization followed by compost (828-881 kg ha$^{-1}$ and 3239-3455 kg ha$^{-1}$ for seed yield and biological yield, respectively). They eventually demonstrated that there is a clear need for further studies on performance of nigella under Mediterranean conditions.

Teff

*Teff* (*Eragrostis tef* (Zucc.) Trotter), a member of the Poaceae family, originated in Ethiopia around 4000-1000 BC and is mainly grown for its grain mainly used in human consumption (Stallknecht et al., 1993; Tesfahunegn, 2014). It is a warm season C$^4$ annual plant (Bedane et al., 2015) and is intermediate between tropical and temperate grass (Stallknecht et al., 1993). Teff has the potential to be one of those crops with beneficial health effects as it contains very low gluten, making it an extremely important component for the diet of people with either gluten intolerance or celiac disease (Roseberg et al., 2006). Teff makes excellent quality straw and has various uses mainly as fodder for cattle, and secondarily as bedding material, mulch and domestic fuel source (Assefa et al., 2001). In addition, teff is also gaining the interest of the people of Western world and serious efforts are being made to expand its cultivation in Europe and America (Belay et al., 2009).

Chroni (2016) established a field experiment in Greece during the summer of 2015 to investigate the effect of different plant densities (row spacing treatments: 20, 40 and 60 cm) and fertilization (control, organic fertilizer (Bokashi) at a rate of 4200 kg ha$^{-1}$ and inorganic fertilizer (34.5-0-0) at a rate of 60 kg N ha$^{-1}$) on agronomic characteristics and yield of teff crop under Mediterranean conditions (Fig. 2). According to the results of this study, plant densities had no significant effect in teff measurements. On the contrary, fertilization had significant effect on number of grains per panicle but it did not affect the seed yield. The highest value (approx. 840 seeds per panicle) was recorded in organic fertilization treatment, followed by inorganic (approx. 590 seeds per panicle) and control (approx. 170 seeds per panicle). Furthermore, she reported that among fertilization treatments, dry weight per stem was actually affected. The highest dry weight per stem (approx. 5 g) obtained in organic fertilization, while the lowest were found under inorganic fertilization (approx. 3.2 g) and control (approx. 2.6 g). Finally, she demonstrated that organic fertilization had better impact on some agronomic characteristics, especially on plant biomass, and argued that further research is necessary to provide safe conclusions on the adaptability and performance of teff under Mediterranean conditions.

Camelina

*Camelina sativa* (L.) Crantz (Fig. 3), also known as false flax or gold of pleasure, is a cruciferous annual or summer oil seed plant originated from the Mediterranean and Central Asia (Zubr, 1997; Ionescu and Roman, 2009). It has been cultivated in Europe for centuries and is used as the most important oil crop from the Bronze and Iron Ages until the beginning of the Industrial Revolution (Ionescu and Roman, 2009). Recently, the interest in camelina has been renewed due to its very low requirements for tillage and weed control.
Alpha-linolenic acid is a nutritionally valuable omega-3 fatty acid which is generally found in significant quantities only in linseed and fish oils (Crowley and Fröhlich, 1998) and can reduce the incidence of cardiovascular disease as well as various health risks in humans (Ruxton et al., 2007). Camelina oil also is high in omega-6 fats (linoleic acid, approx. 15-20%), vitamin E (approx. 110 mg/100g) and natural antioxidants such as tocopherols (Ionescu and Roman, 2009). Therefore, camelina offers an opportunity to supply the growing demand for high quality edible oils (Zurb, 1997).

In Greece, a field trial was conducted with the aim of investigating the effect of different fertilization regimes [control, inorganic fertilization (fertilizer 34.5-0-0 with 200 kg N ha⁻¹), compost (8000 kg ha⁻¹) and farmyard manure (18000 kg ha⁻¹)] on growth and yield of camelina crop (Kobilakou, 2017). The results revealed that fertilization had a significant effect on yield and yield parameters such as thousand-seed weight. The maximum values (approx. 1820 kg ha⁻¹ and 1.35 g for seed yield and thousand-seed weight, respectively) were recorded with compost, followed by inorganic fertilization (approx. 1350 kg ha⁻¹ and 0.81 g), control (approx. 1150 kg ha⁻¹ and 0.80 g) and farmyard manure (approx. 830 kg ha⁻¹ and 0.73 g). In the conclusions of this study, she mentioned that compost increased the yield of camelina and suggested further studies on the performance of camelina under different types and rates of fertilizers.

**Flax**

Flax or linseed (*Linum usitatissimum* L.) is the only species of Linaceae family that has economic as agronomic values (Copur et al., 2006) and is one of the oldest cultivated crops that continues to be widely grown for oil, fiber and food (Berglund, 2002). It originates from Europe and Southern Asia (Casa et al., 1999). The fiber, obtained from stems, is used to make fine linen and paper. Flax seed is a rich source of oil (41%), proteins (20%) and total dietary fiber (28%) and contains 7.7% moisture and 3.3% ash (Morris, 2007). In the past, the main use of flax oil was as a raw material for varnish, paints, linoleum and oilcloth industry, inks, leather and soaps (Laza and Pop, 2012). Flax oil has become popular for its nutritional and pharmaceutical values (Zhang et al., 2011). Nowadays, it is used in human consumption, medical purposes and animal feed (Laza and Pop, 2012). Flax oil is commonly known as the richest source of omega-3 fatty acid, α-linolenic acid, which is one of the essential fatty acids (Madhusudhan, 2009). Several studies have shown that flax oil has a positive impact on many diseases, such as hyperlipidemia, colon tumor, mammary cancer and atherosclerosis (Zhang et al., 2011).

In a 2-year field experiment in the experimental field of Agricultural university of Athens, Greece, the influence of different tillage systems [conventional tillage (CT), minimum tillage (MT), no-tillage] and organic fertilization (vetch as green manure, faba bean as green manure and compost at a rate of 2500 kg ha⁻¹) on growth and yield of flax were determined (Bilalis et al., 2010). It was observed that tillage system had significant effect on seed yield and oil yield. The highest values (1761 and 670 kg ha⁻¹ for seed yield and oil yield, respectively) were obtained under minimum tillage system. The fertilization and especially the vetch and faba bean green manure had a significant influence on the oil content of the flax. Oil content (39.34%) was significantly higher in plots fertilized with faba bean green manure. Finally, the researchers of this study reported that conservation tillage systems could increase the oil yield of flax.

**Emmer Wheat**

Emmer (*Triticum turgidum* L. ssp. *diocon* (Schrank) Thell.) is a primitive hulled allotetraploid wheat species developed from its correspondent wild form [*Triticum dicoccoides* (Koern. ex Asch. et Graebn.) Schweinf.] (Pagnotta et al., 2009; Özbek et al., 2012). It originates from Middle East (Iran, Iraq, Jordan, Syria, Palestine) and during the last century, the introduction of high-yielding and free-
threshing wheats led to the decline of emmer cultivation in mountain regions and small areas of Mediterranean basin (Italy, Spain), Ethiopia, Iran, Transcaucasia, Central Europe, India and the Volga Basin (Marino et al., 2009; Pagnotta et al., 2009; Zaharieva et al., 2010). Nowadays, emmer accounts for 1% of the total world area cultivated with wheats. In ancient times, it was the main crop of Babylon, ancient Egypt and Greece (Zaharieva et al., 2010). Emmer is rich in protein (18-23%), minerals and fiber (Marino et al., 2011). The findings of recent surveys demonstrated that emmer is a very healthy cereal, suitable for diets of people suffering from allergies, colitics, and high blood cholesterol (Marino et al., 2011). Moreover, it is characterized by the resistance to pest and disease, the tolerance to abiotic and biotic stress, the quality of seed protein and the high concentration of micronutrients such as Zn, Fe, and Mn (Marino et al., 2009; Zaharieva et al., 2010).

In Italy, a research study was carried out to evaluate the influence of olive pomace compost [fertilization treatments (each of them at a rate 80 kg N ha⁻¹): commercial organic mineral fertilizer (control), olive pomace compost A1 (OPC-A1) (composting mixture with C/N ratio of 45 stopped at the end of active phase of bio-oxidation), olive pomace compost A2 (OPC-A2) (composting mixture with C/N ratio of 45 processed until maturation), olive pomace compost B1 (OPC-B1) (composting mixture C/N ratio of 30 stopped at the end of active phase) olive pomace compost B2 (OPC-B2) (composting mixture with C/N ratio of 30 processed until maturation)] on growth, yield and quality of emmer wheat (Diacono et al., 2012). They observed that different fertilization treatments had no significant effect on growth and yield of emmer, however, they found that olive pomace compost showed an increase of 9.8% in grain yield compared to commercial mineral fertilizer treatment. The emmer grain protein was significantly affected by fertilization with the highest values obtained in the commercial mineral fertilizer (12.30%) and matured compost with low C/N ratio (12.25%) treatments. Finally, they demonstrated that more experiments and data are needed to evaluate the possible long-term effects of olive pomace compost in the emmer crop.

Conclusions

Several studies, conducted under Mediterranean semi-arid conditions and organic cropping system, have proved that innovative crops can also be grown for alternative uses. Quinoa and chia could be successfully used in animal feed. Moreover, quinoa could be exploited as a medicinal plant due to saponins extracted from seed coats. Nigella and camelina seeds contain oils which can have several uses in pharmaceutical and food industries. Flax seed oil is rich in omega-3 fatty acids and can be accepted in the diets designed for specific health benefits. Emmer wheat has the potential for developing new health food products. According to the literature, it has been observed that innovative crops cultivated under organic system present better quality and similar yields as with those cultivated under conventional system, and in some cases, even higher. Taking all these into account, organic agriculture could also be characterized as innovative and not only as traditional.

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<td>Oil</td>
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<tr>
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<td>Greece</td>
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<td>Camellina</td>
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<td>Emmer Wheat</td>
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Table 1. Innovative crops cultivated under Mediterranean conditions and their uses

References


