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Organic cultivation of medicinal plants: a review

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Abstract

Nowadays, organic products are being famous for all people around the world. Due to the great global market demand, production of organic foods has rapidly increased in the past decades. On this basis organic agriculture has become a great choice as means of organic product producing. As a staple product in the world, the high demand on organic medicinal plants has increased in last decades. Problems of the decline in the bio-environmental sustainability due to indiscriminative usage of chemical fertilizers and pesticides in conventional cropping system can solve under organic farming. Organic farming enhances soil organic carbon, available phosphorus content and microbial population / enzymatic activity of soil and thus making it sustainable for organic crop production. Application of different organic amendments in combinations and in a cumulative manner can supply the nutrient requirement of organic medicinal plants cropping system. The used main weed control strategies in organic cropping system is often the combination of cultural or husbandry techniques with direct mechanical and thermal methods. Pests are generally not a significant problem in organic system, since healthy plants living in good soil with the balanced nutrition are better able to resist against pest and disease attacks. However, commercial production of bio pesticides containing different bacteria, fungi and viruses has been undertaken to control certain insects, pests and diseases in organic crop production systems. Owing to positive influence of organic components in medicinal plants cropping system, it is therefore, be assumed that those farmers who adopted organic management practices, have found a way to improve the quality of their soil, or at least stemmed the deterioration ensuring productive capacity for future generations. From this review, technical aspects of medicinal plants organic farming shows modern concept and environmentally friendly. By these ways, the economic aspects in the agricultural sector are being better.

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Introduction

Organic agriculture (OA) is a production system which avoids or excludes the use of synthetic preparation-artificial fertilizers, pesticides, growth accelerators and fodder additives. As an alternative to these means, OA applies a number of modern preventive methods to maintain the natural soil fertility and non-chemical control of weeds, pests and diseases such as:

- Alternating sowing of crops (with leguminous crops inclusive)
- Suited use of manure
- Stimulating the populations of useful insects (entomophages and pathogens for the pests)
- Vegetation associations (combined cultivation of two or more crops in one and the same place)
- Use of mechanical methods for weed control
- Use of sustainable plant varieties and livestock breeds that are well adapted to the relevant environmental conditions.

These environment-friendly processes, above mentioned, are based on natural cycles and ensure the sustainability of soil life, its structure and the suitable balance of useful microorganisms.

However, negative aspects: the crop yields from OA generally are lower than those of conventional (industrial) agriculture and also, the conventional agriculture the prime cost of organic products is higher than those of industrial agriculture (IFOAM, 2007).

Organic agriculture means a farming system which produces healthful and quality products improve the quality of life, preserve the organic diversity, improvement of the soil structure and balance soil inhabiting microorganisms; without any application of synthetic product. The above mentioned principles and processes are followed as the main principles of International Federation of Organic Agriculture Movements (IFOAM), which are:

1. Production of enough high quality and nutritious food.
2. Organic farming, pastoral and wild harvest systems should fit the cycles and ecological balances in nature. Organic management must be adapted to local conditions, ecology, culture and scale.
3. Maintenance of natural soil fertility
4. Inputs should be reduced by reuse, recycling and efficient management of materials and energy in order to maintain and improve environmental quality and conserve resources.
5. Organic agriculture should provide everyone involved with a good quality of life, and contribute to food sovereignty and reduction of poverty
6. Practitioners of organic agriculture can enhance efficiency and increase productivity, but this should not be at the risk of health and well-being. Consequently, any harmful action should be stopped (IFOAM, 2007).

On the physical and chemical characteristics of the effective of medicinal plants, the climate and soil conditions are considered as two major factors. These plants require different climatic conditions to grow depending on their natural origin. Most medicinal plants require sunny, aerated places sheltered from strong winds and late winter frosts. The soil must be fertile and contains the required amounts in optimal combination of Na, P, Cu, minerals, organic and other elements needed for the crops to grow (Karlen *et al.,* 1997). Sustainability of agricultural systems has become an important issue throughout the world. Many of the sustainability issues are related to the quality and time dependent changes of the soil (Karlen *et al.,* 1997). It is well known that intensive cultivation has led to a rapid decline in organic matter and nutrient levels besides affecting the physical properties of soil. Conversely, the management practices with organic materials influence agricultural sustainability by improving physical, chemical and biological properties of soils (Saha *et al.,* 2008). The use of organic amendments has long been recognized as an effective means of improving the structure and fertility of the soil (Follet *et al.,* 1981), increasing the microbial diversity, activity and population, improving the moisture-holding capacity of soils and crop yield (Frederickson *et al.,* 1977).

The main objective of this review is to provide information to help in future research and development in organic medicinal plants cultivation.

Effect of compost on medicinal plants

Composting is a biological process in which organic biodegradable wastes are converted into hygienic, hums rich product (compost) for using as a soil conditioner and an organic fertilizer (Popkin, 1995). These are also used to provide biological control against various plant pathogens (Hoitink & Grebus, 1994). Aqueous extracts of compost have also been suggested to replace synthetic fungicides (Zhang *et al.*, 1998). The addition of municipal solid waste compost to agricultural soils has beneficial effects on crop development and yield by improving soil physical and biological properties (Zheljazkov and Warman, 2004).

Application of compost to improve soil structure, fertility and consequently development and productivity of medicinal plants were studied in several cases. In Sweet Marjoram (*Majorana hortensis*) when soil treated with 15 and 30% aqueous extracts of compost, essential oil percentage and yield per plant and herbage biomass have been increased. The highest values of essential oil percentage were increased significantly about 39.0 and 52.0% with the application of 15 and 30% aqueous extracts of compost, while the chemical composition of marjoram essential oil did not change due to the compost treatment or level (Fatma *et al.,* 2008). Similar results were obtained from marjoram (Edris *et al.*, 2003) and *Cymbopogon winterianus* plants (Adholeya and Prakash, 2004). Also, in chamomile (*Matricaria chamomilla* L.), effect of chemical fertilizer and compost on soil productivity were studied and results showed that all compost + liquid compost treatments overcame the chemical fertilizers and improved the flower heads growth characters [i.e. fresh or dry weights of flower heads and flower head diameter] and essential oil contents [% and g/plant] (Hendawy and Khalid, 2011).

Effect of vermicomposting on medicinal plants yield and secondary metabolite synthesis

Vermicompost contains most nutrients in plant-available forms such as nitrates, phosphates, and exchangeable calcium and soluble potassium (Edwards, 1998). Vermicompost has large particulate surface area that provides many microsites for the microbial activity and strong retention of nutrients. It is rich in microbial population and diversity, particularly fungi, bacteria and actinomycetes (Edwards, 1998). It contains plant growth regulators and other growth-influencing materials produced by microorganisms (Atiyeh *et al.,* 2002). Krishnamoorthy and Vajrabhiah (1986) reported the production of cytokinins and auxins in organic wastes that were produced by earthworms. Vermicompost also contains large amounts of humic substances and some of the effects of these substances on plant growth have been shown to be very similar to those of soil-applied plant growth regulators or hormones (Muscolo *et al.,* 1999). As a result, most nutrients are easily available such as; nitrates, phosphates, and exchangeable calcium and soluble potassium (Edwards, 1998), which are responsible to increase the plant growth and crop yield. Vermicompost has been shown to increase the dry weight (Edwards, 1995), and nitrogen uptake efficiency of plants (Tomati, 1994). The beneficial effects of vermicompost have been observed in horticultural (Atiyeh *et al.,* 2000a; Atiyeh *et al.,* 2000b; Goswami *et al.,* 2001) and agronomical crops (Pashanasi *et al.,* 1996; Roy *et al.,* 2002). Haj Seyed Hadi *et al.,* (2011) reported that vermicompost have no detrimental but rather stimulatory effects on the growth, flower yield and essential oil content of chamomile and have thus considerable potential for providing nutritional elements in chamomile production, especially for the sustainable production systems. Vermicompost is rich in macro and microelements, which are responsible for increased qualitative and quantitative yields of many crops (Atiyeh *et al.*, 2002; Roy *et al.,* 2002). Azizi *et al.,* (2009) have found the positive influence of vermicompost on the essential oil and chamazulene contents of chamomile (Azizi *et al.,* 2009). In sweet fennel, the highest anethole content and the lowest contents of fenchone, limonene and estragole of essential oil were obtained in a treatment contained vermicompost (Moradi *et al.,* 2011). The application of vermicompost favorably affects soil pH, microbial population and soil enzyme activities (Maheswarappa *et al.,* 1999) which all of them can affect biosynthesis of compounds. Phenolic compounds are a large group of plant secondary metabolites. Increasing in the levels of phenols have been reported in strawberries and marionberries treated with organic fertilizers (Asami *et al.,* 2003). Chand *et al.,* (2012) reported that growth parameters and herb yield of mint marginally enhanced with the application of 7.5 ton/ha vermicompost. Several studies have indicated the same results on some medicinal plants (Darzi *et al.,* 2007; Hadj Seyed Hadi *et al.,* 2004).

Effect of bio-fertilizers on essential oil and yield of medicinal plants

a) Mycorrhizal fungi

In cultivation of medicinal plants, the real value is given to the quality while yield quantity comes in the second step of importance. Some studies in concern of medicinal plants in natural and agro-ecosystems showed that sustainable agricultural approaches are the best methods in which these plants revealed better performance on the account of the harmony with nature, therefore global approach to medicinal plant production is leading toward sustainable agricultural systems (Sharifi *et al.,* 2002). In addition, environmental impacts which are caused by over application of chemical fertilizers, energies, expenses of their production and etc. are the reasons for global tendering toward application of bio-fertilizers (Kannayan, 2002).

Mycorrhizal fungi are beneficial microorganisms and hence, have been considered as bio-fertilizer. Most terrestrial ecosystems depend on mycorrhiza, which promote the establishment, growth and health of plants. The improved productivity of AM (AM=VAM: Vesicular Arbuscular Mycorrhiza) plants was attributed to enhanced uptake of immobile nutrients such as Phosphorus, Zinc and Copper. Resistance against biotic and abiotic stresses has been argued to be due to the effects of AM fungi on inducing plant hormones production (Sharma, 2003). Phosphate solubilizing microorganisms are another sort of bio-fertilizers which have the ability to solubilize organic and inorganic phosphorus compounds by producing organic acid or phosphatase enzyme (Rashid *et al.,* 2004). Many studies showed that these bacteria have a synergistic effect with mycorrhizal fungi and coinoculation of them leads to more absorption of water and soil minerals and increases growth of host plant (Ratti *et al.,* 2001). The effect of mycorrhizal symbiosis on 76 medicinal plants in Azad Jamma and Kashmir had been studied. Results showed different mycorrhizal root colonization. Plants at vegetative growth stage exhibited more VAM root colonization percentage compared to those at flowering and fruiting stages. Herbaceous plant showed more root colonization in comparison with shrubby and woody plants as well (Sadiq Gorsi, 2002). In two distinct researches which were carried out on lemon grass (*Symbopogon martini*) (Qupta *et al.,* 1990) and on mint (*Mentha arvensis*) (Khaliq and Janardhanan, 1997), results showed that mycorrhizal inoculation caused increasing in percentage of essence and essence yield in comparison with non-inoculated. Their studies revealed that the improvement of mineral nutrition resulted in the enhancement of the essence percentage and essence yield in inoculated plants. Kapoor *et al.,* (2004) reported that fennel root symbiosis with two species of mycorrhizal fungi, including *Glomus macrocarpum* and *Glomus fasiculatum* significantly improved properties as are followed the number of umbels in plant, seed weight, phosphorus concentration, biomass, percentage of AM root colonization and amount of essence (concentration of essential oil). Among two fungal species, *G.fasiculatum* showed the highest performance at both levels of phosphorus up to 78% increase in essential oil concentration of fennel seed over non- mycorrhizal control. Saedi- Farkoosh *et al.,* (2011) reported that establishment of an effective symbiotic relationship between *Matricaria* *chamomilla* and arbuscular myccorrhizal fungi and efficient inoculation with phosphate solubilizing bacteria resulted in augmentation in essential oil yield (28%) and its components (kamuzulen and bisabolen compounds). A research concerning the effects of mycorrhizal association on the concentration and composition of essential oil in coriander (Coriandrum sativum), showed that VAM inoculation increased the concentration of the essential oil in seeds up to 43% and caused improvement of essence quality, therefore the amount of consequential components like Geranial (19.99%) linalool (61.73%) significantly increased in mycorrhizal treatments in comparison with non-inoculated control (Kapoor *et al.,* 2002).

b) Bacterial biofertilizers

Some bacteria provide plants with growth promoting substances and play major role in phosphate solubilizing (Abou-Aly *et al.,* 2006). An advantageous of phosphate solubilizing microorganisms is related to their propagation rate that can relatively remove the plant requirements to phosphorus at the root region (Sharma, 2002). Belimov *et al.,* (1995) demonstrated that, inoculation of soil with bacterial mixtures caused a more balance nutrition for plants and improved the root uptake of nitrogen and phosphorus in a main mechanism of interaction between phosphate solubilizing and bacteria nitrogen fixing. Ratti *et al.,* (2001) investigated the effect of some varieties of phosphate solubilizing bacteria on the yield of Lemon Grass and concluded that the plant height and biomass were increased compared to the control treatment.

Studies on symbiotic relationship between bacteria and plants have been mainly on cereals and grassy plants and only a few studies have been carried out on medicinal plants. In a study on the medicinal plant *Scutellaria integrifolia*, inoculation of mycorrhiza increased root length and general plant growth in low phosphorous soils (Joshee *et al.,* 2007). Inoculation of Azotobacter in *Rosmarinus officinalis* increased concentration of plant essence (Leithy *et al.,* 2006). Application of bio-fertilizers Azospirillum and Azotobacter in the medicinal plant of *Salvia officinalis* was reported to increase the plant height and shoot dry and wet weights (Vande broek, 1999). In another study, plant biomass and alkaloids levels inoculation of *Caharanthus roseus* were enhanced as plantlets inoculated with *Pseudomonas florescence* bacteria under water stress (Abdul-Jaleel *et al.,* 1991). Ratti *et al.,* (2001) reported that simultaneous application of mycorrhiza fungus with Azospirillum and bacillus increased the biomass of *Cymbopogon maritinii*. Also, application of biological fertilizers made a significant increase in the plant growth of *Thymus vulgaris* (Youssef *et al.,* 2004). Moreover, some researchers showed that the increase in growth characters of medicinal plants might be due to the fact that phosphate solubilizing bacteria inoculated plants were able to absorb nutrients from solution at faster rates than un-inoculated plants resulting in accumulation of more N, P and K in the leaves (Rai, 2006; Premsekhar and Rajashree, 2009; El- Tantawy and Mohamed, 2009; Castagno *et al.,* 2011; Saharan and Nehra, 2011). Studies of El-Ghandour *et al.,* (2009) demonstrated that growth parameters of *Majorana hortensis* L. were positively affected by bacterial inoculation as well as organic phosphorus sources. Abo-Baker and Mostafa (2011) showed that the inoculation of *Hibiscus sabdariffa* with the mixture of bio-fertilizers improved the growth characters. Similar results were observed on some plants such as *Nigella sativa*, *Ammi visnaga* and *Salvia officinalis* (Yuonis *et al.,* 2004; Shaalan, 2005; Abd El-Latif, 2006).

Fallahi *et al.,* (2008) reported that the highest essential oil and kamauzolen yield per hectare of chamomile were obtained in phosphate solubilizing bacteria (8600g) and nitroxin (923g) treatments, respectively and they mentioned that bio-fertilizers can consider as a replacement for chemical fertilizers in chamomile medicinal plant production. Fatma *et al.,* (2006) reported a favorable result for the effect of Azospirillum and Azotobacter, and also phosphate solubilizing bacteria on the medicinal plant, *Majorana Hortensis*. Similarly, Krishna *et al.,* (2008) reported an improvement in germination indexes such as percentage and speed of germination, viability, and also the length of roots and stems of *Ocimum sanctum* and *Withania somniferum* treated with Azospirillum and Azotobacter bio-fertilizers, phosphate solubilizing bacteria, nitrogen fixation bacteria, and a combination of these fertilizers. Many research studies have mentioned the positive effects of microorganisms on improving the growth and performance of medicinal plants. In addition to nitrogen fixation, Azospirillum improves root growth through generation of stimulating compounds and these results in an increasing in water and nutrients uptake and the general performance of the plant (Tilak *et al.,* 2005). Subba Rao (1979) reported that the most important growth stimulating bacteria are Azospirillum, Azotobacter, and *Pseudomonas* which in addition to biological fixation of nitrogen and solubilizing the soil phosphate, considerably affect plant growth regulators especially auxin, gibberellin and cytokinin and hence improve the plant performance. Azotobacter is able to produce antifungal compounds that fight plant diseases and increase viability and germination of the plantlets and, as a result, improve the overall plant growth (Chen, 2006).

Intercropping of medicinal plants

The term "intercropping" refers to the special cropping system obtained by the simultaneous growing of two or more species (Caporali *et al.,* 1987). Agricultural specialists suggest intercropping, as a useful means for enhancing yields for one or all the consociated species, thanks to the ability of the consociated systems to reduce weeds and pests (Baumann *et al.,* 2000; Hatcher and Melander, 2003; Kenny and Chapman, 1988; Poggio, 2005) and to improve the exploitation of the available environmental resources with respect to monocropping systems (Arnon, 1992; Caporali *et al.,* 1987; Park *et al.,* 2002). Therefore, the intercropping technique is thought to minimize the risks of production and improve strategies for food production. A given intercropping system may be advantageous when there is a mutualistic relationship between the partners or when the interspecific competition is weaker than intraspecific competition. When either species, or the most productive species, is affected more by intraspecific competition than interspecific competition, the optimal plant population may be higher when intercropped than when grown separately (Willey, 1979b; Fordham, 1983). To date, experimental reports about intercropping between medicinal and aromatic plants are rare: some of them, focused on the evaluation of their yields and quality traits when cultivated in various agroforestry systems, come to the conclusion that the introduction of such herbs into agroforestry systems could be a useful way to increase biodiversity and to gain an improvement significant income (Becker, 2004; Huang *et al.,* 2002; *Rao et al.,* 2004). Some further interest in the potential role of medicinal and aromatic plants in intercropping systems has arisen from the widespread trend toward the cultivation of such species with organic and, generally speaking, sustainable methods. An attempt to utilize some aromatic oil-bearing plants, namely *Artemisia annua* L., *Coriandrum sativum* L., *Chamomilla recutita* Rausch., *Foeniculum vulgare* Mill. and *Anethum sowa* Kurtz., as intercrops to manage aphid infestation on mustard (*Brassica juncea* L.) was performed in India by Singh and Kothari (1997), who obtained the lowest aphid population when mustard was intercropped with fennel, and the highest one when it was cultivated in mixture with coriander. Other experiments have involved the association of palmarosa (*Cymbopogon martinii* Stapf.) with redgram (*Cajanus cajan* L.) (Maheshwari *et al.,* 1996) and scented geranium (*Pelargonium* spp.) with mint (*Mentha arvensis* L.) (Rajeswara Rao, 2002). Especially interesting are the experiments performed on species with a different production cycle, intercropped for one year or more; such an arrangement has been tested on some industrial crops (Callan and Kennedy, 1996), and when this multiple cropping involves an annual and a perennial, the overall results of the obtained cropping system seem to be strongly dependent upon the reactivity of the perennial, considered the "primary" crop, to the competition with the annual.

Intercropping between dill (*Anethum graveolens* L.), an annual, and clary sage (*Salvia sclarea* L.), a perennial, may improve the overall efficiency of the cropping system, allowing some marketable production even in the year in which the main species, namely clary sage, does not have any yield (Catizone et al., 1986). With the same objective, interesting experiments on intercropping between licorice (*Glycyrrhiza glabra* L.) and cereals, such as wheat (*Triticum* spp.) or barley (*Hordeum vulgare* L.), have been conducted in southern Italy; the results of such experiments are variable, but they are generally unfavorable for the yield of fresh licorice roots, that from 22.8 t/ha in pure stand cropping to 14 t/ha for intercropping (De Mastro *et al.,* 1993; Marzi, 1996). In the cultivation of medicinal and aromatic plants the aspect of bare productivity, although important, is not the only one to be considered; in such special crops, as a matter of fact, particular attention must be paid to the quality features of the products. Various results have been obtained regarding the qualitative aspect of production with intercropping, and much research has demonstrated that in some cases such a technique may affect the chemical features of the consociated species, causing variations both in yield of essential oil and in composition of the extracts. For example, the alkaloid content of jimsonweed (*Datura stramonium* L.) plants seems to be affected by the cultivation of other species nearby, showing, respectively, an enhancement with lupine (*Lupinus albus* L.) or a decrease with peppermint (*Mentha piperita* L.) (Morelli, 1981). The essential oil content of peppermint is furthermore positively affected by intercropping with soybean (*Glycine max* Merr.), which also increases the menthol content of peppermint oil (Maffei and Mucciarelli, 2003). Naderidarbaghshahi *et al.,* (2013) reported that all mixed culture treatments in German chamomile and saffron intercropping cultivation, had significantly higher land equivalent ratio than pure saffron. Considering higher ratios of all mixed culture treatments, there was higher use efficiency in mixed culture of these plants for soil and other inputs. This is in agreement with results of other researchers (Kaafi *et al.,* 2002; Farhoudi and Esmaeilzaadeh, 2003; Banitaba *et al.,* 2009; Koucheki *et al.,* 2009).

Conclusion

According to the effect of wide spread demand to use of organic products as well as medicinal and aromatic plants, as a suitable substitution of industrial agriculture products and synthetic drugs, it is necessary to serious attention of organic cultivation of medicinal and aromatic plants. Based on the above results, it is concluded that the application of organic cultivation system was found more beneficial and significantly improved morpho-physiological traits, growth parameters, biochemical constituents, yield and yield components and essential oil yield in medicinal plants. Totally, the obtained results revealed that using Organic system significantly improved the quantity and quality characters compared to control. Organic farming enhances soil organic carbon, available phosphorus content and microbial population / enzymatic activity of soil thus making it sustainable for organic medicinal plants production. Owing to positive influence of organic components medicinal plants cropping system, it is therefore, be assumed that those farmers who adopted organic management practices found a way to improve the quality of their soil, or at least stemmed the deterioration. The system is became long term productive by protecting soils and enhancing their fertility ensuring productive capacity for future generations.

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