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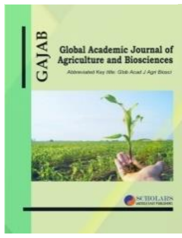


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Review Article

# Role of Intercropping some Aromatic and Medicinal Plants with Fruit Vegetables Crops, a Review

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**Abstract:** Crop diversification, need to maintain current levels of cropped area for food and other uses have made use of intercropping important. The trap nature of medicinal aromatic plants and has a great role for vegetable crops important for protecting damage of fruits from insect pest attack, extend the shelf life of it, maintain the quality during transportation to market like African marigold. Intercropping of medicinal and aromatic plants with different horticultural plants has a great role reducing the post-harvest yield loss, maintain the quality of fruits and increase its shelf life in storage. The aromatic nature and essential oil of MAPs enables to protect soil borne nematodes; they also protect these nematodes diseases by suppressing its adventus root system. The presence of other crops in intercropping the volatile oil is reduced because of shade. However, shading of the component crops has a negative effect on essential growth, biomass yield, oil content, composition and quality oil of MAPs. Medicinal aromatic plants are also significantly increase soil organic nitrogen, soil water content, decreased pH values and available nitrogen content. Intercropping of MAPs with other crops offers congenial conditions which it results the improvement in resource use efficiency in terms of productivity and net return per unit area.

**Keywords**: African marigold, Essential oil, Fruits, MAPs and Vegetables.



## INTRODUCTION

Plants with aromatic qualities contain volatile oils that may interfere with host plant location, feeding, distribution and mating in decreased pest abundance (Uvah and Coaker, 1984 and Lu *et al*., 2007). According to the experimental result of (Khafagy, 2015) intercropping of some aromatic plants with tomato protect the infestation of Tuta absoluta on tomato. The inclusion of rosemary with onion elevated yield advantage and competitiveness over sole planted crop per unit area as indicated by higher LER and relative crowding coefficient. This enables to prevent the insect pest attack on onion (Ashenafi, 2020). Planting marigolds between tomatoes protects the tomato plants from harmful root-knot nematodes in the soil and increase the marketable fruit yield of tomato by trapping different insects and pest attack and the like (Wondimkun and Ketema, 2019). Marigold repels nematodes, tomato worm, slugs and general garden pests. Gomez Rodriguez *et al*. (2003) found that intercropping of tomato with African marigold (*Tagetes erecta* L.) reduced early blight (*Alternaria solani*) of tomato in three ways: (1) allelopathic effect on *Alternaria solani* development, (2) reduced humidity levels below those conducive to the pathogen requirement, and (3) behaved as a physical barrier against spore dispersal (Gómez

Rodriguez *et al*., 2003; Zavaleta-Mejía and Gómez, 1995). Intercropping marigold for nematode management also appeared to reduce numbers of aphids and whiteflies, and resulted in lower levels of virus in tomato (Zavaleta-Mejía and Gómez, 1995).

Diversification of crops, the need to maintain current levels of cropped area for food and other uses have made use of intercropping important. This Systems but also economy, equity and opportunities for knowledge based rural enterprise. Thus research has to be directed towards incorporating medicinal and aromatic crops (MACs) in existing cropping systems such as intercrop, crop rotations, under crops etc. there is an excellent body of literature on the improved cropping systems involving Medicinal Aromatic Crops (MACs) (Rao, 2009). Medicinal aromatic crops Short duration vegetables grown in-between the aromatic crops is the recent advancement to fulfill the requirement of vegetables without any reduction of production area. Performance of coriander (Chellaiah *et al.*, 2002), and other crops like vegetables, fodder, pulses and cereals (Verma *et al*., 2009; Singh *et al*., 2016; Rao Rajeswara, 2002) as intercrops under different cropping situation are well documented. Medicinal aromatic crop-based cropping systems in north and south India has shown that farmers gain significantly higher profit from their lands (Kumar and Patra 2000 and Rao *et al*., 2000). These systems have not only influenced the economics but also paved way for agro-based enterprises in the regions. Short duration vegetables grown in-between the aromatic crops is the recent advancement to fulfill the requirement of vegetables without any reduction of production area. Plants with aromatic qualities contain volatile oils that may interfere with host plant location, feeding, distribution and mating in decreased pest abundance (Uvah and Coaker, 1984 and Lu *et al*., 2007). Khafagy (2011) reported that, intercropping system of kidney bean with sweet basil, geranium, peppermint, spearmint and hot pepper showed highly reduction of Bemisia tabaci (Gennadius) (eggs, nymphs and adults) compared to kidney bean sole. Nan-host volatiles have been found to be repellent and/ or deterrent for a number of insect species in various insect orders: Coleoptera (Schroeder, 1992; Mauchline *et al.,* 2005), aphids (Homoptera: Aphididae) (Nottingham *et al*., 1991; Hardie *et al*., 1994; Pettersson *et al.,* 1994 and Agelopoulos *et al.,* 1999), Lepidoptera (Khan *et al.,* 2000; McNair *et al.,* 2000 and Liu *et al*., 2005), Diptera (Linn *et al.,* 2005) and Hymenoptera (Gohole *et al.,* 2003). The odors given off a non-host plant repel the searching insects. Aromatic plants have been suggested to be particularly repellent for host seeking insects (Uvah and Coaker, 1984). The experimental result of Wondimkun and Ketema (2018) which revealed that cropping system does not have significant effect on number of fruits per plant in tomato-African marigold intercropping.

Intercropping African marigold at 50% population density significantly increased tomato total fruit yield by 0.27% as compared to 25% population density of African marigold by 0.22%. The experimental result of Yayock (1979) that showed fruit yield of tomato was increased as population density increased, but after certain point it starts to decline its yield because the increasing of interspecific competition among the component crops (the demand crops for moisture, nutrient and solar ration might beyond the available resources on a given area) so it is better to know the optimum planting density among the component crops. This might be due to the risen of interspecific competition among the component crops. Plant density significantly affected the interspecies dynamics of the component crops in intercropping (Rena *et al*., 2016 and Pal *et al*., 1993) as it is a major factor affecting the intercropping system of the component crops in terms of yield. This related to interspecies competition for soil moisture, nutrients, light and other common resources. This experiment showed that yields of component crops in the intercropping system vary significantly with the components population density. This result was disagreed with the reported results of Tesfaye (2008); Law-Ogbomo and Egharevba (2009) they reported that highest total fruit yield per hectare of tomato was obtained from low plant density than at high plant density (fruit yield of tomato was decreased with increased population density).

The experimental result Ashraf *et al*., (2019) indicates that intercropping of pomegranate with aromatic plants (sweet basil and rosemary) at different intercropping systems affects growth and productivity of the three species (pomegranate and aromatic plants) and also the competitive indices of the cropping system. It also revealed that the combined yield advantages in terms of land equivalent ratio (LER), area time equivalent ratio (ATER) and land utilization efficiency (LUE) were greatest when pomegranate intercropped with some aromatic plants.

The cropping system of MAPs with other horticultural crops has a great impact of soil conservation, harvesting natural products, avoid environmental pollution and maintain the quality and shelf life of fruits and vegetables. So, the main objective of this review paper is to assess the intercropping system of some medicinal and aromatic plants with vegetable and fruits.

## LITERATURE REVIEW

### Review intercropping system of some medicinal aromatic plants with some vegetable fruit crops

### Intercropping chamomile with other vegetables

Chamomile (*Matricaria recutita* L.) is an annual species naturally distributed in the Mediterranean basin, but it also grows naturally in several areas of Europe, Asia, India, Algeria, Siberia, Australia, and the Americas. It is cultivated in temperate countries such as Germany, Hungary, Russia, Kashmir, Lebanon, Argentina, Colombia, and elsewhere. It thrives in all types of soil acidity, but performs better in soils with high pH values. It can also be grown in clayey, shallow, and moist soils, while it grows better in soils rich in organic matter and temperatures from 7 to 26° C (Singh *et al*., 2011).

Medicinal and aromatic plants are of prime economic importance because of the continuous and increasing demand for their products by local and foreign markets (Khalid, 2006). German chamomile (*Chamomilla recutita* (L) Rauschert is one of the most important plants in this regard (Salamon, 1992). Nowadays, in phytotherapy, flower anthodia are mainly used. Pharmacological properties include anti-inflammatory, antiseptic, carminative, healing, sedative and spasmolytic activity (Salamon, 1992). According to Ahmadian *et al.,* (2011) essential oil content and composition of essential oil in plant varies and is due to the genetic and environment factors, such as water stress and nutrient fertilizers. According to the experimental result of Darbaghshahi *et al.,* (2012) chamomile and Saffron has similar agroecology requirement in mixed culture. Generally, the trapping nature of chamomile eanbles to protect the very sensitive vegetable crops like tomato, cabbage and potable as push-pool technology in intercropping.

### Effects of intercropping of MAPs on soil pH and organic matter

Intercropping with certain species of aromatic plants can improve soil quality. It is also significantly increase soil organic nitrogen, soil water content, decreased pH values and available nitrogen contents in our previous study (Chen *et al*., 2014). However, intercropping vegetables with aromatic medicinal plants is not well studied and known in different parts of the world like pulse with. Cereals. Intercropping of MAPs had more positive effect on soil pH in medicinal aromatic plants with vegetable fruit crops. The experimental results of Sujatha *et al*., (2011), revealed that the soil pH was increased from 0.9-5.6 in 2004 units due to the presence of medicinal aromatic plants. Soil organic carbon (SOC) content is also varied significantly due to intercropping of MAPs at the end of this experiment. The soil organic carbon (SOC) content increased in *Aloe vera*, *A. pallens*, *P. longum* and *B. monnieri*, while it depleted in grasses and rhizomatic MAPs. The demand and marketing opportunities for MAPs, farmers are advised to grow aromatic plants in large areas on a community basis to meet huge industrial demand and variety of medicinal crops in small areas to meet the requirement of traditional systems of medicine.

### Intercropping African marigold with tomato

Members of the genus *Tagetes* have a long history of human use as beverages, condiments, ornamentals, and medicinal purpose such as analgesics, antiseptics, carminative, diuretic, antispasmodic, anthelmintic, stimulants, vermin repellents, and for treatment of stomach and intestinal diseases (Singh *et al*., 2016; Leung, 1980). *Tagetes minuta* L., commonly known as African marigold, is a highly aromatic annual perennial herb growing. It is cultivated for '*Tagetes* oil' (Singh *et al., 2016)*. *Tagetes minutia* s used in indigenous medicines as a natural source of raw material due to its anti-microbial, anti-inflammatory, anti-fungal and insecticidal and acaricidal activities (Chamorro *et al*., 2008; Singh and Singh, 2002). Marigold and tomato companion planting is a tested and true technique used by gardeners for hundreds of years. Research studies have indicated that planting marigolds between tomatoes protects the tomato plants from harmful root-knot nematodes in the soil. Although scientists tend to be skeptical, many gardeners are convinced that the pungent scent of marigolds also discourages a variety of pests such tomato hornworms, whiteflies, thrips, and maybe even rabbits. Allow 45 to 60 cm between the marigold and the tomato plant, which is close enough for the marigold to benefit the tomato, but allows plenty of space for the tomato grow (https://www.gardeningknowhow.com/ornamental /flowers/marigold/marigoldtomatocomanio ns.htm). Marigold repels nematodes, tomato worm, slugs and general garden pests. Gomez Rodriguez *et al.,* (2003) found that intercropping of tomato with African marigold (*Tagetes erecta* L.) reduced early blight (*Alternaria solani*) of tomato in three ways: (1) allelopathic effect on *Alternaria solani* development, (2) reduced humidity levels below those conducive to the pathogen requirement, and (3) behaved as a physical barrier against spore dispersal (Gómez Rodriguez *et al.,* 2003; Zavaleta-Mejía and Gómez, 1995). Intercropping marigold for nematode management also appeared to reduce numbers of aphids and whiteflies, and resulted in lower levels of virus in tomato (Zavaleta and Gómez, 1995).

The most common leaf disease in tomato is tomato early blight, caused by *Alternaria solani*. This disease is considered one of the main diseases affecting tomato production in different area of the world. According to different authors (Koocheki *et al*., 2008; Gómez Rodríguez *et al.,* 2003; Zavaleta and Gomez, 1995), the effects of marigold intercropped with tomato on *Alternaria solani* on tomato leaf damage was observed in farm condition. Three reasons were given for this. The first was the allelopathic effects of marigold on *Alternaria solani* conidia germination. The second was by altering the microclimatic conditions around the canopy, particularly by reducing the number of hours per day with relative humidity > 92%, thus diminishing conidial development. The third mechanism was to provide a physical barrier against conidia spreading. For intercropped with tomato, African marigold plants serves as a physical barrier and promoted reductions in the maximum relative humidity surrounding the canopy, but to a lesser extent than marigold (Koocheki *et al*., 2008; Gomez Rodríguez *et al.,* 2003). The experimental results of Wondimkun and Ketema (2021); Wondimkun and Desta (2021) which revealed that intercropping of African marigold varieties at 50% population density with tomato gave effective land utilization efficiency and more profitability. Intercropping of African marigold with tomato adds extra income and warrants insurance against a risk to the farmers, intercropping of tomato component was found to be advantageous than single cropping of tomato as there is a scarcity of land and a need to diversify production. They also conclude that intercropping of African marigold and other aromatic and medicinal plants with other known crops like tomato is one of the best options to increase the production of African marigold in Ethiopia (Wondimkun and Ketema, 2021).

**Intercropping Basil with tomato**

Tomato and basil are common pairs that are intercropped (Midekesa and Chala 2022). Several studies reported the performance of inter-cropping of aromatic and medicinal plant species with selected major horticultural crops in different countries as cited by Midekesa and Chala (2022), the experimental results of (Neelam and Lokho, 2009; Nigussie *et al*., 2017). Girma (2015) reported inter-cropping of onion with basil at a 1:1-row arrangement could provide farmers with the best yield advantage and income over sole planting of component (onion) crops. Basil and tomato are companion plants that have similar lighting and watering needs, some even say tomatoes taste better when they neighbour basil (Bomford, 2004). According to Lulie. (2017), higher tomato yields have been observed under intercropping with Aromatic plants as compared to tomato alone, so it is a more profitable system. Previous research has also observed that Basil can attract the positive bacteria, Arbuscular mycorrhizal fungi (AMF), and helps prevent diseases in tomatoes, and increases the biomass of tomato (Hage-Ahmed *et al*., 2013). The efficiency of intercropping tomato with basil was significantly affected by basil population density and row arrangement. Intercropping of basil with tomato enables to obtained the highest economic value (Midekesa and Chala 2022). Medicinal and aromatic plants (MAPs) play a significant role in the uplifting rural economy and thus, their demand is increasing all over the world (Rao 2002; Mishra *et al*., 2020). However, they are less cultivated by farmers, because their cultivation as a mono-crop involves certain risk and their economic returns are uncertain. The productivity of tomato and basil intercrops requires improving the interspecies complementary action or reducing the competition effects. Planting density is one of the most important agronomic management decisions to be considered when deciding to practice intercropping. The experimental results of Sattler and Bartelheimer (2018), revealed that poor management of planting density could be detrimental to intercropping. They also stated that the lowest plant densities may limit the potential yield of the main crop but the highest plant densities may lead to increased stress on the plants, and increased interplant competition for light, water and nutrients finally it results decreased the yield (Adeniyi and Omotunde 2001).

**Intercropping Rosemary with carrot and onion**

The experimental Nibret (2019) revealed that intercropping rosemary with carrot showed that intercropping 25% and 50% of rosemary with 100% carrot gave significantly higher in terms of monetary advantage index. These experimental results also showed that carrot rosemary cropping system enables to obtained the additional income generation for small scale farmers and intensive agriculture system. Intercropping of rosemary with onion has also a great role for additional income generation of the component crops. Intercropping onion with the vegetables reduced both the total and marketable bulb yield. The highest bulb yield and other agronomic traits to obtained from the highest plant population density of rosemary in rosemary onion intercropping (Ashenafi *et al*., 2017). Similar results were reported by Talukder *et al*., (2015), Trdan *et al*., (2006), Kabura *et al*., (2008) and Kucharczyk and Legutowska (2003), who revealed that intercropping onion with coriander increase bulb yield and carrot yield with the increased population density. The experimental results of Ofosu-Animand Limbani, (2007) who reported that the lowest bulb yield was obtained with the increased rosemary population density, this may due to the highest plant density per plot area of rosemary and intercrop competition for nutrients, water and light. The increasing pressures on agricultural land arisen out of population growth, farmers have to explore new ways to intensify production per unit area of land (Nibret, 2019).

The pest occurrence is a severe problem in vegetable cultivation. There is growing public concern about the non-target effects of pesticides on humans and other organisms, and many pests have evolved resistance to some of the most commonly-used pesticides. Monoculture farms do not provide the resources for natural enemies to provide natural control services (Rusch *et al*., 2010) and intensive cropping of carrot and indiscriminate use of pesticides are annihilating natural enemies. The synergetic effect of MAPs and carrots, have led to increasing interest in non-chemical, ecologically sound ways to manage pests. So, this cropping system the best pest-management alternative because the diversification of agricultural fields by establishing polycultures (mixed cropping, intercropping, under sowing, etc.) that include one or more different crop varieties or species within the same field, to more-closely match the higher species richness typical of natural systems (Jankowska and Elizbeth, 2016). The percentage of plants damaged by the carrot rust fly Psila rosae (F), root aphids Pemphigus phenax Band B, haworth carrot aphid Dysaphis crataegi Kalt and nematodes was reduced due to the presence of medicinal aromatic plants (Rusch *et al*., 2010). Intercropping of MAPs had a significant effect on the decrease in the number of fruits, roots and leaf damaged rust fly Psila rosae, aphid, fungi and other soil born nematodes (Jankowska, 2016). The experimental results of different authors suggested revealed that during harvest the least number of damaged roots were observed in combination with of MAPs with other vegetable and fruit crops. The experimental results of Jankowska (2016) showed that the number of carrot psyllid T. viridula Zett. and aphids on carrot leaves and roots damaged by nematodes was significantly lower on plots where carrot was intercropped. In all years the highest number of Coccinellidae and Syrphidae was also observed on plots where carrot was intercropped with coriander.

**Intercropping of Mint with other fruit crops**

As cited by Paulus *et al*., (2019) which revealed that agroforestry contributes through the intentional incorporation of woody vegetation with agricultural crops, grasses, or livestock in the same land unit, to produce ecological financial and social benefits (Armengot *et al*., 2016). Intercropping of medicinal plants in agroforestry systems has become a best choice for the integration of forest species with species of agricultural use. The presence of aromatic and medicinal they allow sustainable production, avoiding contamination of the soil with agrochemicals that can alter the composition of the active components of medicinal plants (Sartorio *et al*., 2017). The inclusion of aromatic and medicinal plants in agricultural farms is important for sustainable use and management technologies that reduce environmental impacts and that can make this production system socially and economically feasible. The Mentha (Lamiaceae) family comprises plants such as mint which are highly cultivated due to the production of essential oils produced by glandular trichomes present in the leaves and stems of plants (Paulus *et al*., 2019). Besides of the trapping nature and increase the soil nutrients, the essential oils of mint are directly used as food flavourings, flavouring agents, cosmetics, perfumes, and medications (Poovaiah *et al*., 2006). The Mint family like pepper mint, spear mint, Japan mint and others which enables to produces essential oils that rich in monoterpenes, such as linalool. This component is of great economic interest because it is widely used to fix fragrances, about 70% of the cosmetics produced in the perfume industry have linalool in its formula (Paulus *et al*., 2019).

The cultivation of medicinal aromatic plants in agroforestry silvoarable systems is possible with high quality products of the component crops in the intercropping system (Katsoulis *et al*., 2022). The cultivation of MAPs has multiple advantages over various other crops. Medicinal aromatic plants (MAPs) offer higher yield per unit area and are less likely to be attacked by insects and diseases. The inclusion of this plants can upgrade poor and unprofitable soils, yield long-term products, and ensure profit for farmers (Sujath *et al*., 2011). The most suitable MAPs for intercropping with trees are those that develop a deep root system and are shade-resistant (Katsoulis *et al*., 2022). This may because of the competition that will be developed between the trees and the understory crop for sunlight and soil moisture. Intercropping some MAPs with trees produce better yields when grown in agroforestry systems, such as species of the genus Mentha, Cymbopogon martini (Roxb.) W. Watson, Cymbopogon flexuosus (Nees ex Steud) Wats and Piper longum L. in avocado, papaya, coffee plantation farms (Ashenafi *et al*., 2019). However, the population density of tree affects the growth, biomass yield chemical composition and quality of some medicinal aromatic plants. So, the appropriate choice of the understory MAP species has a significant impact on the success of the agroforestry system (Katsoulis *et al*., 2022).

**The Effects of intercropping Aromatic Medicinal plants with other horticultural crops on its essential oil content and oil yield**

The results of different intercropping researches showed that increased essential oil content in aromatic plants with increased essence rate of the oil (Costa *et al*., 2010). This may due to the low volatile rate of essential oils due to the presence component crops (shade). The transpiration rate influences concentration as well as the composition of essential oils this is directly related to the volatile aromatic oil of the plants from solar radiation. The development of glandular trichomes, plant structures that biosynthesize and store essential oils, is a light-dependent processes (Morais. 2009). The low light intensity and low temperatures cause significant variations in the amount of essential oil constituents and total yield (Paulus *et al*., 2019). According to Costa *et al*. (2012) the ratio of light quality and composition of peppermint oil (Mentha piperita) may be associated with the biosynthetic route of the compounds, as the conversion of menthone to menthol is influenced by low light and short photoperiod conditions. The cultivation of mint with bananas showed the lowest production of biomass and essential oil, possibly due to excessive shading, because the bananas had large leaves that provided greater shading than the other evaluated fruit species (Meira *et al*., 2012). The essential oil of lemon balm was also (Melissa officinalis L.) reduced when intercropped with black mesh due to shading presented less fresh and dry weight development and lower essential oil content. The desired characteristics in therapeutic plants are the Phyto mass and the active component, and if intercropping increases the productivity of the agroecosystem and maintains local biodiversity, favoring the natural control of pests and diseases, as well as the recycling of nutrients (Innis, 1997). The cultivation of medicinal plants associated with fruit, becomes a viable alternative.

### Role of medicinal and aromatic plants for post-harvest yield loss

Cultivation of medicinal and aromatic plants (MAPs) has several advantages like higher net returns per unit area, low incidence of pests and diseases, improvement of degraded and marginal soils, longer shelf life of end products and foreign exchange earning potential Sujatha *et al*., 2011). Regardless of this, the lack of standardized cultivation aspects, supply of good quality planting material and marketing facilities are identified as major limitations in cultivation of MAPs (Rao *et al*., 2004). The quality of the economic products of MAPs is an absolute necessity. As the demand for organic products is increasing rapidly in the world market, adoption of organic farming approach would be a feasible option. The experimental results of different researches showed that MAPs maintain the quality of the fruits and vegetables of the component crops in the intercropping system. African marigold flower maintains the quality of tomato fruit in storage and transportation.

## SUMMERY AND CONCLUSION

Medicinal and aromatic plants are of prime economic importance because of the continuous and increasing demand for their products by local and foreign markets. Intercropping of medicinal and aromatic plants with different horticultural plants has a great role reducing the post-harvest yield loss, maintain the quality of fruits and increase its shelf life in storage. The essential oil content, oil yield and composition of MAPs is also affected by interspecific competition of the component crops intercropping system. The inclusion of MAPs enables to prevent the damaged of fruits, insect pest attack of vegetables fruits. Plants with aromatic qualities contain volatile oils that may interfere with, host plant location, feeding, distribution and mating, resulting in decreased pest abundance. Intercropping of medicinal plants with horticultural crops; Enables to expand the area coverage and production of MAPs increase the adoption rate of different research technologies from such type of crops. Hence the insect trap nature of some MAPs it has a great role for vegetable crops like tomato, cabbage, potato, onion and other fruit crops. Intercropping with certain species of aromatic plants can improve soil quality. It is also significantly increase soil organic nitrogen, soil water content, decreased pH values and available nitrogen content. Intercropping of MAPs with other crops offers congenial conditions which it results the improvement in resource use efficiency in terms of productivity and net return per unit area.

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