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EFFECTS OF SEVERAL ORGANIC FERTILIZERS ON GROWTH, DEVELOPMENT AND QUALITY PROPERTIES OF TOMATOES OBTAINED IN ORGANIC SYSTEM: A REVIEW

Andreea ANTAL-TREMURICI, Alexandru BUTE, Daniela BOURUC, Creola BREZEANU, Petre Marian BREZEANU

Vegetable Research-Development Station Bacau, 220 Calea Barladului, Bacau, Romania

Corresponding author email: antal_andreea97@yahoo.com

Abstract

One of the main goals of today's agriculture is to produce healthy food and to increase the efficiency of plant production by protecting and conserving the environment. Organic tomatoes (Lycopersicon esculentum Mill.) represent one of the most valuable crops consumed widely either fresh or processed because for its sensory qualities, nutritional value and for its benefits on human health (reduce the risk of cardiovascular disease and certain types of cancer). Organic fertilizers are originated from plant and animal wastes and contain N, P, K and microelements. They are used to obtain the nutritional demands of plants for their growth and development, as well as improve the physical, biological and chemical properties in the soil. The objective of this study was to evaluate the effectiveness of organic fertilizers on quality characteristics (soluble solids contents, lycopene and carotenoids, titratable acidity, minerals and vitamins), on the growth and development of organically cultivated tomatoes based on the lasted valuable information.

Key words: *physico-chemical characteristics, vegetable growth, biofertilizers, sustainable agriculture.*

INTRODUCTION

The world population is reaching 9 billion by 2050, mankind will be facing the challenge of increasing food and energy production from crops by at least 70% to account for the increase in world population by adopting more sustainable farming methods and systems in a climate and environmental change scenario. The nutritional, organoleptic and nutraceutical quality of food also needs to be enhanced for improving the health in rural and urban communities. The enhanced vegetables production both in quantity and quality, needs to mitigate the changing climatic environment characterized by reduced and uneven distribution of rainfall, of extreme temperature fluctuation, of climatic events like flooding, storm, and drought, which reduces yields.

The use of pesticides and synthetic fertilizers in the process of fertilization provoke many health problems and environmental pollution (deterioration of soil characteristics and fertility) and lead to accumulation of heavy metals in plants (Dinu et al., 2015; Mahmoodi, 2017; Iosob et al., 2020).

The objective of decreasing the negative impact of agriculture on human and environment heath is a global challenge of interdisciplinary research. Organic agriculture is a new approach of farming aimed to develop production technology to obtain durable stability of the environmental protection and human safety. The implementation of organic farming principles is a tool featured by capacity to replace old practices and inputs that endanger the human health and environment.

The development and large-scale application of friendly environmental inputs and practices are strongly recommended by the new organic regulation (EU) 2018/848 and strategies such as: Farm to Fork, Green Deal, and Plant Protein Plan that highlight the importance of the development of new tools and solutions with the ability to limit the harmful effects.

Food production may be further reduced by the shift into low input systems due to local and global environmental concerns requiring governments to enact and enforce regulatory instruments for sustainable perspective for resilient, efficient, and sustainable farming systems and land use.

There are plenty studies in the international literature that demonstrates the quality of organic vegetables (Chassy et al., 2006; Kapoulas et al., 2011; Hallman, 2012; Araujo et al., 2015; Abdelkader et al., 2021; Doltu et al., 2021).

Tomato (*Solanum lycopersicum*) is a flagship species in the *Solanaceae* family, one of the most important and suitable vegetable crops grown throughout the world for its high nutritive value, antioxidant properties and for its aids on human health (Meena et al., 2017; Dūma et al., 2018; Shehata et al., 2018). Tomato fruit has a high content of water (94.52%) and a low caloric value, but it is a good source of vitamins: A, C, K, B1, B2, B3, PP (Viskelis et al., 2015; Tieman et al., 2017) and minerals (potassium, phosphorrous, magnesium, calcium, iron, sodium, copper, zinc (Dūma et al., 2018; Murariu et al., 2021) and contain organic acids, sugars, dietary fibre, many phenolic compounds, and carotenoids - lycopene and b-carotene (Nour et al., 2015; Ali et al., 2020).

Globally, tomato is a major consumed fruit vegetable with per capita consumption of either fresh or processed type of about 21 kg in 2017 or around 19% of the total vegetable consumption per year (FAOSTAT, 2020). According to the Food and Agriculture Organization of the United Nations, in 2020, the area cultivated with tomatoes worldwide was 5,051,983 ha with a production of 186,821,216 tons, and in Europe, in the same year, the area harvested was 424,449 ha with a production of 22,810,698 tons.

In Romania, in 2020, the total area harvested with tomatoes was 22 470 ha with a production of 449 460 tones. Compared to the previous year, the production of tomatoes increased by 12 910 tones.

The tomatoes consumption is associated with decreasing risk of developing digestive tract, prostate cancer (Giovannucci et al., 1995; Maguer, 2000), chronic degenerative diseases such as certain types of cancer (Giovanucci, 1999) and cardiovascular diseases (Agarwa and Rao, 2000).

The application of organic farming practices and input imprints benefits on the environment: contributes to the increasing of biodiversity and resistance to disease and pests (improving the soil quality makes plants healthier), commits to soil conservation (cover crops, mulching, intercropping), contributes to the reduction of eutrophication and water pollution, reduced energy use and some benefits on human health (reduce air pollution, makes food healthier due to its nutritional value) (Djokoto, 2015; Muller et al., 2016). Organic farming largely relies on organic materials instead of chemical fertilizers, pesticides, herbicides, or other synthetics. High-efficiency organic fertilizers may increase crop yield, does not affect soil quality, making it a support tool balance long-term food security and environmental protection (Angadi et al., 2017; Cen et al., 2020).

The differences between organic and conventional management practices include: the use/non-use of chemical pesticides; the use/non-use of chemical fertilizers; and the need for a long and varied crop rotation (Bengtsson et al., 2005).

The goal of this review analysis was to investigate and determine the potential impact and efficiency of organic amendments on quality essences and on the growth and development of organically cultivated tomatoes.

MATERIALS AND METHODS

This assessment is based on a comprehensive evaluation of materials available in the international literature. The information for this analysis was gathered from open access sources on the internet through sites like Google School, Google Academic, Free Full PDF, Research Gate, and Science Direct. To find work content, we utilized the following keywords and phrases such as "organic manure," "biofertilizer," "quality of organic tomatoes," "growth," and "development." This study comprised studies on organic fertilizer that were connected to effects (advantages and downsides) on organically cultivated tomatoes and were available as free full papers in English. According to the analysis of the selected documents, the results show that organic farming, fertilizer application, and their effects on the quality and quantity characteristics of organic tomatoes are extremely broad and extensive internationally. Two inclusion criteria were considered: thematic focus (referring to the effect of natural fertilizer on growth, development and quality parameters of organically tomato) and document type (journal and books chapters). Following these guidelines, 82 studies and experiments were chosen that have both positive and negative features, such as increased vitamin C content, soluble solids, titratable acidity, fruit per plant, and overall yield, as well as negative elements, such as the fact that some organic fertilizers have limitations.

RESULTS AND DISCUSSIONS

Biofertilizers have been recognized as a possible technique for achieving a more sustainable agricultural system by improving food output while also improving ecosystem functionality (Swapna et al., 2016; Mahanty et al., 2017). Ecological fertilizers contain living or inert microorganisms or bioactive components obtained from organisms such as bacteria, algae, and fungi that can aid in soil fertility and plant growth (Abdel-Raouf et al., 2012).

Bacteria or fungi capable of nitrogen fixation, phosphate solubilization, sulphur oxidation, plant hormone synthesis, or organic compound decomposition are commonly used as biofertilizers (Verma et al., 2018; Pirttilä et al., 2021). Rashid et al., 2015, demonstrate that by affecting the aggregation of soil particles, microbial biofertilizers play an important role in preserving soil fertility and improving its structure. Inoculation with biofertilizers boosted crop yield by 16.2 percent on average when compared to non-inoculated controls, according to a study by Schütz et al. (2018).

Bacterial fertilizers are appropriate for use in agricultural fields because of their high humic acid concentration and low hazardous element content.

Vegetable, mineral, and animal matter are used to make organic fertilizers. In this case, a short classification can be done:

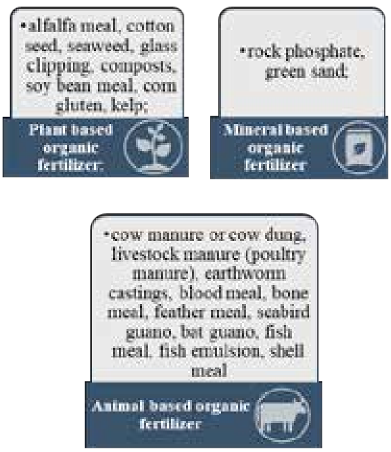

Figure 1. Classification of organic fertilizer

When biofertilizers are applied to seeds, plant surface or soil, living cells of different types of microorganisms from these products colonize the interior of plant and promotes growth by converting N and P from unavailable to available form (El-Yazid et al., 2007; El-Yazeid et al., 2011). Many researchers studied the role of organic manures and, also, shown that the use of compost in horticulture is beneficial because increase the quality, grown and yield of fruits (Adekiya, 2009; Khan et al., 2017; Bilalis et al., 2018). Youssef and Eissa, (2017) demonstrated that the combination of rock phosphate, feldspar, and rabbit manure with Microbine (Bio-N), Phosphorin (Bio-P) and Potassiumag (Bio-K) significantly enhanced vegetative growth, yield, and fruit quality of tomato plants.

The influence of organic fertilizer application on GROWTH and DEVELOPMENT of tomatoes plants

From planting to harvest, open-field tomato plants have a long production cycle that necessitates the use of supplemental fertilizer to maintain vegetative and reproductive growth (Choi, 2020). Natural fertilizers contain N, P, K and microelements in different rates depending to the source of the fertilizer. Organic fertilizer originated from molasses containing 7% N, 7% P and 7% K and from this point of view, Ulusu et al. (2017) demonstrated that the organic fertilizer from molasse increased the mineral and organic matter content of the soil while also developing the soil reaction for microorganism activity and represent a good alternative to synthetic fertilizers for tomato production under greenhouse conditions. Tiwari et al. (2016) discovered that foliar spraying tomato plants with vermiwash offers all of the necessary nutrients for growth, early flowering, and increased yield.

Organic fertilizers are environmentally friendly and provide nutritional requirements, suppress plant pest populations, and increase the yield and quality of agricultural crops (Tonfac et al., 2009; Souri et al., 2018; Laily et al., 2021). In a study conducted in Japan was concluded that organic fertilizer increased microbial biomass and enhanced nutrient circulation such as N and P circulation activity (Kai et al., 2020).

Nutrient is one of supporting factors of optimum growth and development of tomato plant (Tittarelli et al., 2017). Tomatoes require proper and sufficient nutrients for good fruiting and subsequent quality, and as a heavy feeder of nitrogen, phosphorus, and potassium, they respond well to manure and fertilizer application (Gideon, 2012 and Singh et al., 2014).

In research conducted by Basilio, 2021 two biofertilizers composed of two different bacterial consortia were used in order to study their effects in the production and productivity of tomato plants: biofertilizer 1, constituted by the consortium *Bacillus* + *Pseudomonas*, and biofertilizer 2, constituted by the consortium *Azospirillum* + *Pseudomonas*. Biofertilizer 1 provide more benefits to the plant in greenhouse soils with higher levels of organic matter composed of higher concentrations of labile C fractions, whereas biofertilizer 2 provide more benefits to the plant in greenhouse soils with low organic matter and low total P content, resulting in a high P plant demand.

According to the findings of Mahmood et al. (2020) adding organic fertilizer to the soil and spraying garlic extract, whey, and bread yeast in tomato has increased the concentrations of N, P, and K in the soil and leaves, as well as a substantial improvement in plant dry weight, chlorophyll content, fruit number, fruit weight, and plant yield

El-Yazeid (2011) showed that growth parameters such as stem diameter, number of leaves, branches per plant, and leaf area/plant had significantly higher values when phosphate solubilizing microorganisms were combined with rock phosphate treatments.

Mutale-joan et al. (2020) studied the effects of 18 crude bio-extracts (CBEs) derived from microalgae and cyanobacteria on tomato plants (*Solanum lycopersicum*) at three different biomass concentrations: 0.1, 0.5, and 1 g L-1. The application of CBEs to tomato plants improved chlorophyll content, nutrient uptake, and, in many cases, root and shoot length and dry weight. According to Ordookhani et al., (2010) inoculating tomato plants with *Pseudomonas putida*, *Azotobacter chroococcum*, *Azospirillum lipoferum*, and a mixture of arbuscular mycorrhiza fungi (*Glomus lipoferum*, *Glomus mossea*, and *Glomus etunicatum*) increased lycopene antioxidant levels.

According to several studies, plots treated with a combination of organic and inorganic fertilizers produced more fruits per plant, heavier fruits per plant, and, ultimately, a higher total yield (Anwar et al., 2012; Ferdous et al., 2017). Similar, Laily et al., (2021) in a study conducted in Bangladesh obtained the highest yield due to fruit per plant and weight of fruit per plant from plants treated with chemical fertilizer in combination with organic fertilizer. Islam et al., (2017) reported that the application of mixed fertilizers, organic 2/3 + inorganic 1/3 produced the highest number of flower clusters, fruit clusters, fruit yield and plant height.

Heeb et al., (2006) sustained that the organic fertilizers have limited effects on plant growth and yield as compared to chemical fertilizer. Several researchers proved in their studies that higher yields were obtained from chemical fertilizer treatment (Mahmood et al., 2017; Turhan and Özmen, 2021).

The influence of organic fertilizer application on QUALITY PROPERTIES of tomatoes plants

Tomato (*Solanum lycopersicum*) is an adaptable and one of the most cultivated vegetables throughout the world for taste, colour and diversified use. Tomato fruits contains carotenoids which include β-carotene and lycopene. β-carotene is a pro vitamin and is responsible for orange coloration and lycopene has antioxidant properties and is responsible for redness (Sidhu, 2017; Dobrin, 2019; Salehi et al., 2019). Stoleru et al. (2020) sustain that the organic fertilization has a positive effect on the lycopene accumulation and antioxidant activity of tomato.

Some studies report better taste, higher vitamin C content, and higher levels of other quality-related compounds for organically grown tomatoes (Mitchell et al., 2007; Murtic et al., 2018; Peralta et al., 2020). Coppens et al. (2016) demonstrated that microalgal fertilizers improve the quality of tomato fruits through an increase in the sugar and carotenoid content. In a meta-analysis, Worthington (2001) concluded that organic crops contained more vitamin C, iron, magnesium, and phosphorus and significantly less nitrates than conventional crops. Similarly, Vinha et al. (2014) reported that the organic tomatoes were healthier than those produced by conventional practices. Ochoa-Velasco et al. (2016) compared the total antioxidant content of tomato fruits after biofertilization with *Bacillus licheniformis* and different nitrogen fertilizer doses. In general, they describe an improvement in tomato fruit quality in terms of total hydrophilic antioxidant compounds (vitamin C and total phenols) after inoculation with *B. licheniformis*, as well as a reduction in nitrogen dosing.

Soluble sugars (glucose, fructose and sucrose) and organic acids (mainly malic and citric acids) are major osmotic compounds accumulated in tomato fruit (Heuvelink, 2018). Pieper et al. (2008) studied the differences between production systems and identified that total and soluble solid were significantly higher and consistency was greater in organic tomatoes than in conventional ones.

Turhan (2021) exposed that the highest lycopene, total carotenoid, vitamin C contents and, also, fruit soluble solids and dry matter contents were obtained as reaction of application of organic fertilizers, especially from poultry manure.

Another study guided in Turkey, demonstrate that three different dosses (1, 3 and 5 g L^{-1}) of bacterial fertilizers which include *Azotobacter* spp., *Bacillus subtilis* and *Bacillus megatarium* affected the plants by increasing the mineral content (N, P, K, Ca, Mg) of fruits (Dursun et al., 2019).

Cyanobacteria can be used as a biofertilizer for enhance the qualitative and quantitative characteristic of tomatoes. In this regard Hussain et al. (2019) showed that the interaction of cyanobacteria with Marwa var. (a variety of tomatoes) gave the highest rate of yield traits, as well as total soluble solids, total acidity, vitamin C and fruit content of carotene and lycopene.

A two years experiment during 2013 and 2014 season demonstrate that the quality and quantitative parameters of tomatoes was higher when the biofertilizers was applied (Table 1). The biofertilizers used was *Azospirillum* sp. and *Azotobacter* sp. (nitrogen fixing bacteria) under the commercial name of Nitrobein and a mixture of P dissolving bacteria (*B. megatherium*) and N fixing bacteria *Azospirillium* sp. and *Azotobacter* sp. under the commercial name of Microbein (Mesallam et al., 2017).

Microalgae are a high potential source of biofertilizers and one of these microalgae is *Chlorella vulgaris*. Coban et al., (2020) investigated the effect of microalgae on nutrient saving in soilless greenhouse tomatoes. The algae used to have a major improvement impact on average tomato fruit production, expanded vitamin C levels, and increased mineral content P, Mg, and Na in tomato fruit. Furthermore, Suchitra et al. (2020) demonstrated that the foliar spraying of *Chlorella vulgaris*, as well as the combination of this algae with cow manure, have gained the highest soluble solids, total soluble sugar, ascorbic acid, total protein and moisture of tomato fruits.

Table 1. Effects of biofertilizer on quantitative and qualitative on fruit tomato during 2013 and 2014 season

Treatment	Effect of biofertilizers on fruit yield of tomato					
	Fruit weight (gm)		Fruits yield/plant (kg)		Fruits yield/fed (ton)	
	2013	2014	2013	2014	2013	2014
With biofertilizers	178.75	136.06	3.68	3.49	25.76	24.43
Without biofertilizers	154.06	132.94	3.49	3.30	24.43	23.10
Treatment	Effect of biofertilizers on quality of tomato					
	TSS%		Ascorbic acid (mg/100 g FW)		Titratable acidity (mg/100 ml juice)	
	2013	2014	2013	2014	2013	2014
With biofertilizers	3.42	3.68	17.06	22.69	0.96	0.86
Without biofertilizers	3.17	3.66	15.86	22.12	0.89	0.91

In a recent study Carricondo-Martínez et al. (2022) comparison between waste-derived amendments and inorganic fertilization on tomato yield, chemical and physical properties of tomato fruit was observed. The treatments with fresh crop residue, goat manure and composted vegetable waste showed significant lower yields compared with the inorganic fertilizer. In this experiment the highest value of fruit colour was obtained with conventional fertilization, but regarding to beta-carotene content, this was higher in organically cultivated tomato.

CONCLUSIONS

The reduction of chemical fertilizers in favour of products based on yard waste animal manure, products based on microorganisms or bioactive compounds, is a good alternative, not only to reduce the overuse of chemical fertilizers and pollution of the environment, but also to ensure food quality. On numerous occasions, green product application has been shown to improve crop output, reduce disease, and promote plant nutrient coordination.

In this review, we have discussed several examples of plant bacteria that, when used as biofertilizers, promote plant growth, increase yield, and improve some quality parameters (soluble solids contents, lycopene and carotenoids, titratable acidity, minerals, and vitamins) of organic tomatoes. On the other hand, we have described how the combination of some organic fertilizers contributes to preserving soil fertility and improving its structure.

It is also observed that there are a lot of studies comparing the amounts of secondary metabolites, growth and development of plant in organically farmed to those in conventionally grown vegetables.

Moreover, the application of fertilizer, whether organic or inorganic, boosted tomato growth, yield, and quality. It was discovered that combining organic and inorganic fertilizers was better than utilizing each separately.

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