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# Effect of Organic Mulch and Mycorrhizal Inoculation on Growth and Yield of Tomato Plants

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author IIS designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors AAAB took the samples of soil and performed the statistical analysis of it made and. Author FSM performed the statistical analysis, wrote the protocol, and managed the analyses of the study. Author TMY managed the analyses of the study and managed the literature searches. Author EAS took over recorded the row data from filed. All authors read and approved the final manuscript.*

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## ABSTRACT

Net greenhouse experiment was conducted through the 2019/2020 and 2020/2021 seasons at Dokki protected cultivation experimental site, Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Ministry of Agriculture and Land Reclamation to investigate applied two factors organic mulch i.e., (bagasse, compost, palm fibers, mushroom spent, sawdust and control), mycorrhizal inoculation (with and without) and their interaction on growth and productivity of tomato plants. The seedlings of tomato cv. Super strain B was transplanted on the 15$^{th}$ October 2019 and 2020. The experimental design was split plot with three replicates. Results indicated that applied compost mulch treatment, without mycorrhizal inoculation and their interaction

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enhanced all vegetative growth characteristics i.e., (plant height, number of leaves, number of shoots, stem diameter, fresh and dry weights of plant). Whereas, applied compost mulch treatment, with mycorrhizal inoculation and their interaction improved chemical content of (N, P and K) in leaves and increased average fruit weight and total yield/m$^2$.

*Keywords: Tomato; organic mulch; compost; Mycorrhizal inoculation.*

## 1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is the most common vegetable crop in Egypt and is considered one of the most popular and economically important when used as fresh or processed. It spread around the globe bearing vigorously varied climatic conditions [1]. Its global production area reached 4.8 million hectares with an average of 37.6 tonnes/hectares and an overall production of more than 18 million tonnes in 2017 [2]. Furthermore, tomato cultivated area in Egypt was 413.67 thousand feddans [3], representing 22% of the total vegetable cultivated area which amounting to 1.9 million feddans during 2018-2020 [4]. Also, Egypt is considering the fifth largest producer of tomatoes globally.

Mulching is a regular practice in agricultural farming; it could be classified into inorganic and organic mulching. The type of mulching materials could benefit soil improvement and environmental protection, improve soil moisture, prevent soil nutrient loss and control crop pests and diseases [5,6]. Inorganic mulching is widely used in controlling weeds and as a water-saving means, especially in areas susceptible to drought. Although, inorganic mulching has a negative impact on soil quality and sustainability and may cause soil alkalization, due to its ability to change the soil's biological characteristics [7]. Organic mulching is mainly planting residues, which are proven to be better for soil health. The application of organic mulch on soils could not only inhibit weed germination but also improves plant growth and increases yield and quality, where it enhances soil health by providing moisture and mineral elements for plants and moderate soil temperature with a corresponding reduction in surface evaporation and nutrient loss [8,9].

It is well known that there is a relation between soil temperature and ambient climate including air temperature, where soil temperature varied from zero to 20 cm depth. The soil temperature is highest in the bare soil and is lower under the plant's cover, especially in the summer seasons. Moreover, in the summer, when the high air temperature is observed, high surface soil temperatures and large temperature differences in depth are also observed for uncovered soil [10,11]. These differences can be minimized by using mulch, especially during hot days, where the soil temperature at depth of 5 cm visibly differs in the mulched soil surface. It is on average 8°C lower on the mulched surface with plant residues, as the temperature is also affected by the amount of plant residue on the soil [12].

Mycorrhizae fungi are environmentally friendly bio-fertilizers, not only reduce the load of chemical fertilizers in the plants but also minimizing the pollution in the soil [13]. Mycorrhizal infection expands the absorbing area of roots from 10 to 100 times thereby greatly improving the ability of the plants to utilize the soil resources [14]. Application of mycorrhizae increases the number of microorganisms in the soil, Mycorrhizae enhance plant productivity by enhancing the biological nitrogen fixation, phosphate, solubilization, production of hormones and vitamins, and other growth factors required for plant growth [15]. Kumar and Sharma [16] reported that use of mycorrhizae combined with-mineral fertilizers increased yield and nutrient content. Hodge *et al*. [17] proved that the arbuscular mycorrhizal symbiosis can both enhance decomposition of and increase nitrogen capture from complex organic material in soil.

This study was aimed to investigate effects of organic mulch i.e., (bagasse, compost, palm fibers, mushroom spent, sawdust and control), with and without of mycorrhizal inoculation on growth and productivity of tomato plants.

## 2. MATERIALS AND METHODS

### 2.1 Experiment Layout

Net greenhouse experiment was conducted through 2019/2020 and 2020/2021 seasons at Dokki Protected Cultivation Experimental Site, Central Laboratory for Agricultural Climate

(CLAC), Agricultural Research Center (ARC), Ministry of Agriculture and Land Reclamation. The primary frame was a multi-span (five span) steel construction, and net greenhouse was employed. Net greenhouse was covered in an insect-proof white net.

## 2.2 Treatments

Two factors and their interaction were tested to investigate their effects on growth and productivity of tomato plants as follow:

a) Organic mulch: five kinds of organic mulch were applied i.e., (bagasse, compost, palm fibers, mushroom spent and sawdust) by 3cm thickness plus control (bar soil).
b) Mycorrhizal inoculation: inoculated mycorrhizal fungi was applied as (with or without inoculation).

The seedlings of tomato cv. Super strain B were transplanted on 15$^{th}$ of October 2019 and 2020 through both growing seasons with spacing of 0.5m between plants inside the same raw. Five raised beds were created at net greenhouse. Each ridge had a width of 100cm and a length of 40m. Drip irrigation system was used to watering the beds. Also, chemical fertilizers were used in accordance with the Ministry of Agriculture's recommendations (extension bulletin No. 13/2016). Some chemical analyses of soil at Dokki site (clay soil) were shown in Table 1.

## 2.3 Data Recorded

1. Vegetative growth as i.e., (plant height, number of leaves per plant, number of branches/plant, stem diameter, plant fresh and plant dry weights) was determined after 90 days from transplanting.
2. Chemical content in leaves (N, P and K) was measured by chosen four plants randomly from each plot. The nitrogen content was determined using the Kjeldahl technique, as defined by FAO [18], and the data was computed as a percentage. While, phosphorous concentration in acid digested decided by colorimeter method (ammonium molybdate) using spectrophotometer consistent with FAO [18]. Moreover, potassium content decided photometrically using Flame photometer as described by FAO [18]. Results of chemical content were calculated to be presented as percentage.
3. Average fruit weight was measured at fruit picking yielded representative samples of six fruits.
4. Total yield/m$^2$ was determined from the harvest's total collections.

## 2.4 Experimental Design and Data Analysis

The experimental design was split plot with three replications. The mycorrhizal inoculation treatments were putted at main plots, whereas, organic mulch treatments were putted in sub main plots**.** The analysis of variance approach was used to statistically assess the data obtained. Duncan's multiple range tests were performed to compare the treatment means at a 5% level of probability [19].

**Table 1. Some chemical analyses of soil**

| Chemical analyses | Value |
|---|---|
| pH | 8.1 |
| Organic matter (O. M) % | 0.53 |
| ECE (dS/m) | 2.2 |
| Available N mg/kg | 235.45 |
| Available P mg/kg | 9.35 |
| Available K mg/kg | 124.78 |
| Cations meq/L | |
| $Ca^{++}$ | 6.2 |
| $Mg^{++}$ | 3.1 |
| $Na^{+}$ | 20.07 |
| $K^{+}$ | 1.17 |
| Anions meq/L | |
| $CO_3^{-}$ | 0.0 |
| $HCO_3^{-}$ | 2.4 |
| $Cl^{-}$ | 12.9 |
| $So_4^{-}$ | 8.26 |

## 3. RESULTS

### 3.1 Vegetative Growth

Illustrated data in Tables 2, 3, 4, 5, 6 and 7 reflected the positive role of applying organic mulch, mycorrhizal inoculation and their interaction on vegetative growth characteristics of tomato plants (plant height, number of leaves, number of shoots, stem diameter, fresh and dry weights of plant).

#### 3.1.1 Plant height

Presented data in Table 2 indicated the effect of applying organic mulch, mycorrhizal inoculation and their interaction on plant height of tomato plants. The positive effect on plant height, in general, was obtained with plants which applied organic mulch, without mycorrhizal inoculation and their interaction.

The greatest values of applying organic mulch on plant height were indicated with applied compost treatment as organic mulch. When the lowest effect of applying organic mulch on plant height of tomato plants were observed with control and palm fibers treatments, respectively, without any significant difference.

Regarding mycorrhizal inoculation noticed that plants inoculated by mycorrhizal had recorded the lowest value of plant height compared to those without mycorrhizal inoculation which gave the highest value.

Moreover, the interaction had significant influences on plant height all over both growing seasons. The greatest interaction values were observed with applied organic mulch plus without mycorrhizal inoculation more than organic mulch plus mycorrhizal inoculation. Plants cultivated under compost organic mulch without mycorrhizal inoculation treatment obtained the highest plant height, while, control + mycorrhizal inoculation treatment show the lowest values compared with other treatments. These results were true in two tested seasons.

#### 3.1.2 Number of leaves/plant

Data in Table 3 the great effect of applied organic mulch on the number of leaves per plant. The highest number of leaves values was recorded with compost mulch treatment, in the first season, while obtained with compost and mushroom spent treatments, respectively, without any significant difference, in the second season. While, the lowest number of leaves was detected with the control treatment.

On other hand, plants which inoculated by mycorrhizal gave the lowest values from number of leaves more than without mycorrhizal inoculation.

Considering the interaction between organic mulch and mycorrhizal inoculation noticed that, applied compost mulch treatment plus without mycorrhizal inoculation obtained highest number of leaves, when, control treatment + with or without mycorrhizal inoculation and palm fibers + with mycorrhizal inoculation, respectively, indicated the lowest values. These results were true in both growing seasons.

**Table 2. Effect of applying organic mulch and mycorrhizal inoculation on plant height (cm) of tomato plants during the 2019/2020 and 2020/2021 seasons**

| Organic mulch treatments | With mycorrhizal inoculation | Without mycorrhizal inoculation | Mean |
|---|---|---|---|
| | **First season** | | |
| **Bagasse** | 165.0g | 171.0e | 168.0C |
| **Compost** | 179.0c | 186.6a | 182.8A |
| **Palm fibers** | 163.0h | 168.0f | 165.5D |
| **Mushroom spent** | 176.0d | 184.0b | 180.0B |
| **Sawdust** | 168.0f | 172.0e | 170.0C |
| **Control** | 160.0i | 167.0f | 163.5D |
| **Mean** | 168.5B | 174.8A | |
| | **Second season** | | |
| **Bagasse** | 171.2i | 177.5e | 174.3C |
| **Compost** | 185.1c | 194.0a | 189.5A |
| **Palm fibers** | 166.9j | 175.4f | 171.2D |
| **Mushroom spent** | 182.4d | 189.7b | 186.1B |
| **Sawdust** | 173.7g | 177.5e | 175.6C |
| **Control** | 165.7k | 172.4h | 169.1D |
| **Mean** | 174.2B | 181.1A | |

**Table 3. Effect of applying organic mulch and mycorrhizal inoculation on the number of leaves per plant of tomato plants during the 2019/2020 and 2020/2021 seasons**

| Organic mulch treatments | With mycorrhizal inoculation | Without mycorrhizal inoculation | Mean |
|---|---|---|---|
| | | **First season** | |
| **Bagasse** | 76.00h | 77.00g | 76.50D |
| **Compost** | 86.70c | 90.60a | 88.65A |
| **Palm fibers** | 75.00i | 75.67h | 75.34D |
| **Mushroom spent** | 84.50d | 87.67b | 86.09B |
| **Sawdust** | 79.50f | 81.00e | 80.25C |
| **Control** | 75.00i | 75.00i | 75.00D |
| **Mean** | 79.45B | 81.16A | |
| | | **Second season** | |
| **Bagasse** | 76.40f | 77.40f | 76.90BC |
| **Compost** | 85.50b | 91.30a | 88.40A |
| **Palm fibers** | 73.60hi | 75.20g | 74.40C |
| **Mushroom spent** | 84.20c | 86.50b | 85.35A |
| **Sawdust** | 78.56e | 81.30d | 79.93B |
| **Control** | 72.80i | 72.90i | 72.85D |
| **Mean** | 78.51B | 80.77A | |

#### 3.1.3 Number of shoots/plant

Table 4 showed a significant difference in number of shoots/plants was obtained as a result of applied organic mulch, mycorrhizal and their interaction treatments.

Tomato plants grown in compost and mushroom spent treatments as organic mulch, respectively, produced the highest number of shoots/plant without any significant difference compared to other treatments. Where, control treatment observed as lowest.

Plants that were inoculated by mycorrhizal indicated the lowest values from the number of shoots/plant more than without mycorrhizal inoculation.

Regarding interaction found that application compost mulch treatment + without mycorrhizal inoculation obtained the highest number of shoots/plant, while, control treatment + with or without mycorrhizal inoculation, respectively, gave the lowest values. These results were true in both growing seasons.

#### 3.1.4 Stem diameter

As for the effect of applied organic mulch Table 5 noticed that the greatest values of stem diameter were recorded with compost mulch treatment followed by mushroom spent treatment. When, control treatment reduced it.

Concerning the inoculation with or without mycorrhizal had no significant effect on stem diameter.

The interaction between applied organic mulch and mycorrhizal inoculation reflected that applied compost mulch treatment + without mycorrhizal inoculation gave the highest stem diameter value, whereas, control treatment with or without mycorrhizal inoculation and palm fibers + with mycorrhizal inoculation, respectively, reduced stem diameter value. This trend is true through all tested seasons.

#### 3.1.5 Plant fresh weight

Results in Table 6 noticed that there were insignificant differences in plant fresh weight with applied organic mulch treatments. Plants which applied compost mulch treatment produced highest plant fresh weight followed by mushroom spent and sawdust treatments, respectively, compared to the control treatment that reduced plant fresh weight.

In other word, mycorrhizal inoculation had a negative effect on plant fresh weight rather than without inoculation.

Interaction obtained that applied compost much treatment + without mycorrhizal inoculation increased plant fresh weight, while, control treatment plus with mycorrhizal inoculation (in the first season), and control plus with or without, respectively, without any significant difference (in the second season) led to reduced it. Those results are true in two growing seasons.

**Table 4. Effect of applying organic mulch and mycorrhizal inoculation on number of shoots/plant of tomato plants during 2019/2020 and 2020/2021seasons**

| Organic mulch treatments | With mycorrhizal inoculation | Without mycorrhizal inoculation | Mean |
|---|---|---|---|
| | | **First season** | |
| **Bagasse** | 9.33d | 10.33c | 9.83B |
| **Compost** | 11.67b | 12.67a | 12.17A |
| **Palm fibers** | 8.33e | 9.33d | 8.83C |
| **Mushroom spent** | 12.00b | 11.44b | 11.72A |
| **Sawdust** | 8.85de | 10.56c | 9.71B |
| **Control** | 7.33f | 7.67f | 7.5D |
| **Mean** | 9.59B | 10.33A | |
| | | **Second season** | |
| **Bagasse** | 12.00cd | 13.00bc | 12.50B |
| **Compost** | 14.00ab | 15.00a | 14.50A |
| **Palm fibers** | 11.00de | 12.00cd | 11.50C |
| **Mushroom spent** | 15.00a | 14.00ab | 14.50A |
| **Sawdust** | 11.00de | 13.00bc | 12.00BC |
| **Control** | 10.00ef | 9.00f | 9.50D |
| **Mean** | 12.17B | 12.67A | |

**Table 5. Effect of applying organic mulch and mycorrhizal inoculation on stem diameter (cm) of tomato plants during 2019/2020 and 2020/2021 seasons**

| Organic mulch treatments | With mycorrhizal inoculation | Without mycorrhizal inoculation | Mean |
|---|---|---|---|
| | | **First season** | |
| **Bagasse** | 1.15f | 1.17f | 1.16D |
| **Compost** | 1.50b | 1.70a | 1.60A |
| **Palm fibers** | 1.04gh | 1.09g | 1.07E |
| **Mushroom spent** | 1.40cd | 1.43bc | 1.42B |
| **Sawdust** | 1.29e | 1.33de | 1.31C |
| **Control** | 1.00h | 1.02gh | 1.01F |
| **Mean** | 1.23A | 1.29A | |
| | | **Second season** | |
| **Bagasse** | 1.17e | 1.19e | 1.18 |
| **Compost** | 1.53b | 1.73a | 1.63 |
| **Palm fibers** | 1.07fg | 1.10f | 1.09 |
| **Mushroom spent** | 1.43c | 1.46c | 1.45 |
| **Sawdust** | 1.31d | 1.36d | 1.34 |
| **Control** | 1.02g | 1.04fg | 1.03 |
| **Mean** | 1.26A | 1.31A | |

### 3.1.6 Plant dry weight

Illustrated data in Table 7 indicated that the dry weight of plant affected by applied organic mulch treatments. Compost mulch treatment recorded the highest values of plant dry weight followed by mushroom spent and sawdust treatments, respectively, compared to the control treatment which reduced plant dry weight.

Applied mycorrhizal inoculation decreased plant dry weight value rather than without inoculation.

Regarding interaction observed that applied compost much treatment + without mycorrhizal inoculation produced the highest plant dry weight, while, control plus with or without, respectively, without any significant difference (in the first season), and control treatment plus with mycorrhizal inoculation (in the second season), reduced it. Those results are true in two growing season.

## 3.2 Chemical Components in Leaves

Data presented in Tables 8, 9 and 10 reflected the effect of organic mulch treatments, mycorrhizal inoculation, and their interaction on N, P, and K contents in leaves.

### 3.2.1 Nitrogen and phosphorus contents

Obtained results indicated that N and P were influenced by the tested factors and their interaction Tables (8 and 9). Applied compost mulch treatment increased leaves content from N and P followed by mushroom spent and sawdust treatments as second and third place, respectively, compared to the control treatment which recorded the lowest content.

In the same way, plants inoculated by mycorrhizal obtained the greatest leaves content from N and P rather than plants without inoculation.

The best treatment as interaction for increasing N and P in leaves was indicated with compost mulch plus with mycorrhizal inoculation, whereas, control + without mycorrhizal inoculation decreased it.

**Table 6. Effect of applying organic mulch and mycorrhizal inoculation on plant fresh weight (g) of tomato plants during 2019/2020 and 2020/2021 seasons**

| Organic mulch treatments | With mycorrhizal inoculation | Without mycorrhizal inoculation | Mean |
|---|---|---|---|
| | | **First season** | |
| **Bagasse** | 1200.00h | 1206.40g | 1203.20D |
| **Compost** | 1271.50b | 1278.90a | 1275.20A |
| **Palm fibers** | 1200.00h | 1195.00i | 1197.50E |
| **Mushroom spent** | 1242.00d | 1245.60c | 1243.80B |
| **Sawdust** | 1232.00f | 1236.00e | 1234.00C |
| **Control** | 1110.00k | 1115.00j | 1112.50F |
| **Mean** | 1209.25B | 1212.82A | |
| | | **Second season** | |
| **Bagasse** | 1219.20f | 1226.60e | 1222.90D |
| **Compost** | 1291.50b | 1299.00a | 1295.25A |
| **Palm fibers** | 1218.80f | 1213.80f | 1216.30E |
| **Mushroom spent** | 1261.50c | 1265.20c | 1263.35B |
| **Sawdust** | 1251.30d | 1255.40d | 1253.35C |
| **Control** | 1127.40g | 1132.50g | 1129.95F |
| **Mean** | 1228.28B | 1232.08A | |

**Table 7. Effect of applying organic mulch and mycorrhizal inoculation on plant dry weight (g) of tomato plants during 2019/2020 and 2020/2021 seasons**

| Organic mulch treatments | With mycorrhizal inoculation | Without mycorrhizal inoculation | Mean |
|---|---|---|---|
| | | **First season** | |
| **Bagasse** | 254.00f | 261.00e | 257.50D |
| **Compost** | 289.00b | 300.00a | 294.50A |
| **Palm fibers** | 145.00h | 149.40g | 147.20E |
| **Mushroom spent** | 280.00c | 292.00b | 286.00B |
| **Sawdust** | 274.00d | 283.00c | 278.50C |
| **Control** | 129.00i | 131.60i | 130.30F |
| **Mean** | 228.50B | 236.17A | |
| | | **Second season** | |
| **Bagasse** | 253.20g | 260.30f | 256.75D |
| **Compost** | 290.80b | 301.00a | 295.90A |
| **Palm fibers** | 143.40i | 147.70h | 145.55E |
| **Mushroom spent** | 280.60d | 284.20c | 282.40B |
| **Sawdust** | 273.50e | 281.70d | 277.60C |
| **Control** | 126.10k | 130.40j | 128.25F |
| **Mean** | 227.93B | 234.22A | |

### 3.2.2 Potassium content

The statistical analysis in Table 10 indicated that organic mulch treatments had a significant effect on K content in leaves. The greatest value of K content in leaves was found with applied compost mulch treatment more than other treatments, especially, the control treatment which reduced it.

On other hand, mycorrhizal inoculation had not any significant effect on K content in leaves.

Interaction obtained that compost mulch treatment plus with or without mycorrhizal inoculation and mushroom spent treatment + with mycorrhizal inoculation, respectively, recorded the highest values of K content in leaves without any significant difference. Whereas, control treatment + with mycorrhizal inoculation gave the lowest content of K in leaves.

## 3.3 Average Fruit Weight and Total Yield

Presented data in Tables (11 and 12) indicated the effect of applied organic mulch, mycorrhizal inoculation, and their interaction on average fruit weight (g) and total yield/m$^2$ (Kg).

The greatest average fruit weight (g) and total yield/m$^2$ (Kg) were noticed applied compost mulch treatment followed by mushroom spent and sawdust treatments which pleased second and third places, respectively. When control treatment reduces both of heirs.

In the same way, mycorrhizal inoculation enhanced and increased average fruit weight and total yield/m$^2$ more than without mycorrhizal inoculation.

Moreover, applied compost mulch treatment plus mycorrhizal inoculation as the interaction between two tested factors increased two tested parameters compared to other treatments. While, control treatment + without mycorrhizal inoculation reduced both average fruit weight and total yield/m$^2$. These are true through tested seasons.

## 4. DISCUSSION

From the aforementioned data on plant growth, it could be concluded that enhanced vegetative growth characteristics i.e., (plant height, number of leaves, number of shoots, stem diameter, fresh and dry weights of plant) due to applied organic mulch [20, 21], who mentioned that mulching the soil surface increased plant height significantly when compared to bare soil, which could be due to the increased and moderated soil temperature, and observations on plant growth revealed that the mulched plots' plants were generally taller and more vigorous than the un-mulched plots. According to Norman *et al*. [22], the organic mulch had a greater impact on the number of leaves/plant than the control (bare soil) treatment. Hong *et al*. [23] discovered that when mulching materials were used, the leaf weight was greater than when no mulching materials were used. Foliage growth is stimulated by mulching with wastes and reflective film. Organic mulches boosted vegetative growth [24]. According to Kumar and Lal [25], greater plant dry weight for mulched plants is attributable to the mulch's ability to preserve soil moisture as well as enhanced plant water absorption efficiency. Organic mulch also promotes soil aggregation by supplying a significant amount of organic matter in the form of leaf biomass [26].

Furthermore, organic materials are the greatest mulches for overall plant performance, frequently rated as the best or second best in comparative field studies. Rapid decomposers like grass clippings, leaves, and compost [27], moderate decomposers like paper, hay, straw, and other crop wastes, and slow decomposers like bark and woody chips have all been tested [28]. The impacts of mulches on plants are mediated through their effects on soil water and temperature structure. Mulch helps to reduce evaporation, which is one of the main reasons for plant development. Mulching creates an ideal growing environment. Plants that are more vigorous and healthier are the consequence of a mix of the aforementioned, as well as maybe additional variables. Mulched plants, on the other hand, tend to grow and develop more consistently than un-mulched plants. Different mulching materials were shown to have a significant impact on growth characteristics. Increased moisture content and moderate soil temperature enhance root development, which leads to increased plant growth [29,30].

Despite the fact that the mycorrhizal inoculation had no effect on vegetative growth for the course of the trial, this funding supports the findings of Sas-Paszt *et al*. [31], who found that applied mycorrhizal inoculation had no significant effect on growth. Low P availability/addition resulted in stronger growth responses [32]. Extensive cropping systems [33] and high P soils are two examples of situations where they may not have a role [34]. The reaction of plants to mycorrhizal fungi is often inversely related to the amount of accessible P in the soil [35]. As a result, farmers of high P soils with *Solanum lycopersicum* should not rule out the use of mycorrhizal inoculation, as other crops with on-farm production and usage of mycorrhizal inoculation have shown [36,37]. Valentine *et al*. [38] investigated the effects of mycorrhizal inoculation infection on cucumber growth, photosynthesis, and nutrient concentrations and found that plants grown at low phosphorous with high concentrations of other nutrients had the highest mycorrhizal inoculation infection, as well as higher biomass due to a higher maximum net photosynthetic rate. There was a growth slump in mycorrhizal inoculation plants with high phosphorus and high concentrations of the other nutrients, but this was not related to a loss in photosynthesis or an increase in leaf dark respiration rate. However, it was linked to a decrease in photosynthetic nitrogen usage efficiency. As a result, any benefits or drawbacks related to mycorrhizal inoculation infection are the product of the intricate interplay between phosphorus supply and other important nutrients. According to Dasgan *et al*. [39], mycorrhizal inoculation had no effect on vegetative plant growth. During a similar experiment with tomatoes, Maboko *et al*. [40] discovered that mycorrhizal inoculation had no significant influence on plant development. Bowles *et al*. [41] discovered that mycorrhizal inoculation had no effect on tomato plant shoot biomass. Furthermore, the response to mycorrhizal inoculation has been shown to be cultivar-specific [42].

The static analysis presented the contribution of increasing chemical content of (N, P and K) in tomato leaves by applied organic mulch, especially, compost as mulch are harmony with [43-46] and [21]. They claim that organic mulches absorb substantially more nitrogen, phosphate, and potassium than un-mulched soil. This is due to the immobilization of soil N by soil microorganisms as a result of the high C:N ratio. Organic mulches increased the nutrients and structure of the soil [47]. The organic mulch breakdown results in enhanced nutrient availability and soil organic matter for the plants. Organic mulches also resulted in higher nutrient levels in the soil and canopy [21].

**Table 8. Effect of applying organic mulch and mycorrhizal inoculation on content N (%) in leaves of tomato plants during 2019/2020 and 2020/2021 seasons**

| Organic mulch treatments | With mycorrhizal inoculation | Without mycorrhizal inoculation | Mean |
|---|---|---|---|
| | **First season** | | |
| **Bagasse** | 3.02e | 2.97e | 3.00D |
| **Compost** | 5.77a | 2.56f | 4.17A |
| **Palm fibers** | 2.50f | 2.30g | 2.40E |
| **Mushroom spent** | 4.07b | 4.05b | 4.06B |
| **Sawdust** | 3.57c | 3.47d | 3.52C |
| **Control** | 2.20g | 2.01h | 2.11F |
| **Mean** | 3.52A | 2.89B | |
| | **Second season** | | |
| **Bagasse** | 3.05d | 3.03d | 3.04D |
| **Compost** | 5.81a | 2.58e | 4.20A |
| **Palm fibers** | 2.58e | 2.40f | 2.49E |
| **Mushroom spent** | 4.08b | 4.06b | 4.07B |
| **Sawdust** | 3.62c | 3.59c | 3.61C |
| **Control** | 2.31g | 2.02h | 2.17F |
| **Mean** | 3.58A | 2.95B | |

**Table 9. Effect of applying organic mulch and mycorrhizal inoculation on content P (%) in leaves of tomato plants during 2019/2020 and 2020/2021 seasons**

| Organic mulch treatments | With mycorrhizal inoculation | Without mycorrhizal inoculation | Mean |
|---|---|---|---|
| | **First season** | | |
| **Bagasse** | 0.65e | 0.63e | 0.64D |
| **Compost** | 0.77a | 0.74b | 0.76A |
| **Palm fibers** | 0.54f | 0.50g | 0.52E |
| **Mushroom spent** | 0.74b | 0.69d | 0.72B |
| **Sawdust** | 0.70c | 0.63e | 0.67C |
| **Control** | 0.48h | 0.45i | 0.47F |
| **Mean** | 0.65A | 0.61B | |
| | **Second season** | | |
| **Bagasse** | 0.66e | 0.64e | 0.65D |
| **Compost** | 0.78a | 0.75b | 0.77A |
| **Palm fibers** | 0.55f | 0.51g | 0.53E |
| **Mushroom spent** | 0.75b | 0.70d | 0.73B |
| **Sawdust** | 0.71c | 0.64e | 0.68C |
| **Control** | 0.49h | 0.46i | 0.48F |
| **Mean** | 0.66A | 0.62B | |

**Table 10. Effect of applying organic mulch and mycorrhizal inoculation on content K (%) in leaves of tomato plants during 2019/2020 and 2020/2021 seasons**

| Organic mulch treatments | With mycorrhizal inoculation | Without mycorrhizal inoculation | Mean |
|---|---|---|---|
| | **First season** | | |
| **Bagasse** | 3.87de | 3.84e | 3.86D |
| **Compost** | 4.42a | 4.42a | 4.42A |
| **Palm fibers** | 3.56f | 3.50g | 3.53E |
| **Mushroom spent** | 4.38ab | 4.34b | 4.36B |
| **Sawdust** | 3.95c | 3.92cd | 3.94C |
| **Control** | 3.10h | 3.08h | 3.09F |
| **Mean** | 3.88A | 3.85A | |
| | **Second season** | | |
| **Bagasse** | 3.92de | 3.89e | 3.91D |
| **Compost** | 4.48a | 4.48a | 4.48A |
| **Palm fibers** | 3.61f | 3.55g | 3.58E |
| **Mushroom spent** | 4.44ab | 4.40b | 4.42B |
| **Sawdust** | 4.00c | 3.97cd | 3.99C |
| **Control** | 3.14h | 3.12h | 3.13F |
| **Mean** | 3.93A | 3.90A | |

In the other hand, mycorrhizal inoculation greatly boosted tomato root colonization, resulting in higher phosphorus absorption in an optimal water supply [48]. Sallaku *et al*. [49] found that inoculating cucumber seedlings with mycorrhizal increased their nutrient intake and stand establishment rate by expanding their root system and increasing their photosynthetic rate. Phosphorus and potassium concentrations were greater in mycorrhizal inoculated plants than in non-inoculated plants cultivated in the same conditions [50]. Mycorrhizal inoculation enhanced Ca and K absorption via plants [51]. Tomatoes with mycorrhizal inoculation had a higher rise in K content [52]. The concentration of macro and microelements in leaves was changed by mycorrhizal inoculation [31]. Other studies have noticed higher absorption of macro and microelements like potassium, nitrogen, calcium, and magnesium [53]. Cimen *et al*. [54] found an increase in mineral nutrient content (P, K, Mg, Fe, Mn, Zn, and Cu) in the leaves of tomato plants infected with mycorrhizal inoculation.

**Table 11. Effect of applying organic mulch and mycorrhizal inoculation on average fruit weight (g) of tomato plants during the 2019/2020 and 2020/2021seasons**

| Organic mulch treatments | With mycorrhizal inoculation | Without mycorrhizal inoculation | Mean |
|---|---|---|---|
| | **First season** | | |
| **Bagasse** | 87.90f | 84.35g | 86.13D |
| **Compost** | 121.40a | 118.65b | 120.03A |
| **Palm fibers** | 87.06f | 82.98gh | 85.02D |
| **Mushroom spent** | 110.80c | 107.75d | 109.28B |
| **Sawdust** | 92.50e | 89.56f | 91.03C |
| **Control** | 81.80h | 78.75i | 80.28E |
| **Mean** | 96.91A | 93.67B | |
| | **Second season** | | |
| **Bagasse** | 90.28g | 86.54i | 88.41D |
| **Compost** | 124.74a | 120.88b | 122.81A |
| **Palm fibers** | 88.5h | 84.89j | 86.70D |
| **Mushroom spent** | 113.75c | 111.23d | 112.49B |
| **Sawdust** | 95.13e | 91.98f | 93.56C |
| **Control** | 84.34j | 80.32k | 82.33E |
| **Mean** | 99.46A | 95.97B | |

**Table 12. Effect of applying organic mulch and mycorrhizal inoculation on total yield/m$^2$ (Kg) of tomato plants during 2019/2020 and 2020/2021 seasons**

| Organic mulch treatments | With mycorrhizal inoculation | Without mycorrhizal inoculation | Mean |
|---|---|---|---|
| | **First season** | | |
| **Bagasse** | 29.14f | 27.85g | 28.50D |
| **Compost** | 42.41a | 40.72b | 41.57A |
| **Palm fibers** | 27.15h | 25.03j | 26.09E |
| **Mushroom spent** | 38.25c | 37.88c | 38.07B |
| **Sawdust** | 30.67d | 29.98e | 30.33C |
| **Control** | 26.19i | 23.03k | 24.61F |
| **Mean** | 32.30A | 30.75B | |
| | **Second season** | | |
| **Bagasse** | 31.52f | 30.04g | 30.78D |
| **Compost** | 45.75a | 42.95b | 44.35A |
| **Palm fibers** | 28.59h | 27.60i | 28.10E |
| **Mushroom spent** | 41.36c | 41.20c | 41.28B |
| **Sawdust** | 33.30d | 32.40e | 32.85C |
| **Control** | 28.25h | 26.49j | 27.37F |
| **Mean** | 34.80A | 33.45B | |

The higher nutrient absorption caused by mycorrhizal inoculation might be caused by two different processes. By boosting the absorption of extraradical hyphae, mycorrhizal hyphae acquire nutrients directly, shortening the transit path of nutrients from the soil to the roots. The extraradical hyphae of mycorrhizal inoculation impact the direct absorption and transport of organic and inorganic N, as well as K and Ca to the plant [55]. The increased water absorption, which hastens the flow of these nutrients via the plant roots colonized by mycorrhizal inoculation, is the second mechanism responsible for mycorrhizal plants' uptake of K, Ca, and Mg [56]. Root hydraulic conductivities are greater in mycorrhizal plants than in non-mycorrhizal species [57].

From the above-mentioned tomato fruits characteristics, it could be that result agrees with [58, 21]. They mentioned that mulching increased fruit output, which, is an indicator that mulching is more helpful to crop performance. Mulches consistently improved yield attributes when compared to non-mulch applications.

Improved average fruit weight and total production might be attributable to enhanced plant development, which is influenced by stable soil temperatures and soil moisture. Enhanced soil moisture retention, the establishment of a suitable soil temperature, improved soil structure, raised nutritional status in soil, and well-developed root systems all contributed to a considerable increase in production [25]. Mulch increased the amount of vegetation and productivity of several crops [59]. Increased yields can be attributable to improved soil moisture and fertilizer utilization. Mulch's most prevalent reaction is an increase in overall yield. The mulched area produced significantly more marketable fruit than the bare-soil plot. Moisture conservation, higher and moderate soil temperature, and enhanced mineral nutrient absorption in the mulched plot due to improved root temperatures can all be ascribed to this difference [21]. Mulches changed the microclimate by changing soil temperature, moisture, and evaporation [60], and the tailored microclimate influenced yield contributing features. When a crop was grown with straw mulch, the fruit weight and overall yield were greater than when the same was grown without it. According to Khurshid *et al*. [61], crop residue mulching improved both the physical and chemical qualities of the soil while also preserving yield. The difference in development and yield attributes observed between the mulched and un-mulched plots could be attributed to the mulched plots' higher soil moisture reserves, as higher soil moisture is known to improve fertilizer efficiency, while excellent solar radiation during the growth seasons encouraged higher photosynthetic rates, resulting in higher yields.

In the same way, mycorrhizal inoculation increased average fruit weight and total yield. Dasgan *et al*. [39] indicated that mycorrhizal-infected tomato plants could successfully employ photo assimilates for fruit development rather than vegetative growth, resulting in an increase in fruit output. Overall, mycorrhizal inoculation increased fruit output and size. According to Bosco *et al*. [62], commercial mycorrhizal formulations had little effect on increasing total or marketable tomato yields. The inherent organic soil richness was the reason for this. It has also been hypothesized that increased pollen quantity and quality in mycorrhizal plants might be linked to increased fruit output [63]. However, a large body of evidence suggests that mycorrhizal inoculation boosts tomato output [64-66]. Tomato plants infected with a commercial formulation of mycorrhizal and cultivated in the field generated bigger inflorescences, more flowers, and a greater total and marketable yield [67]. Furthermore, even in a high P soil, utilizing mycorrhizal inoculation generated on-farm resulted in a moderate but considerable increase in tomato fruit output with minimum changes in farm management [32]. According to Damaiyanti *et al*. [68], the fresh weight of tomato fruit without mycorrhizal inoculation was lower than that of tomato fruit with mycorrhizal inoculation, which improved the plant's nutritional state. Mycorrhizal association can also alter the hosts and environment at the rhizosphere level, affecting soil architecture, carbon deposition, and microbial variability. According to Candido *et al*. [66], the beneficial benefits of the mycorrhizal inoculation were extended to marketable yield, owing to an increase in the quantity and weight of fruits. Plant inoculation with mycorrhizal fungi can be a long-term strategy for increasing output [69,70].

## 5. CONCLUSION

Organic mulch considered the best way to enhance vegetative growth characteristics i.e., (plant height, number of leaves, number of shoots, stem diameter, fresh and dry weights of plant) and increase average fruit weight and total yield/m$^2$ of tomato plants, especially compost as mulch, mushroom spent and sawdust treatments, respectively. Furthermore, without mycorrhizal inoculation is improving vegetative growth characteristics and with mycorrhizal inoculation encourage average fruit weight and total yield/m$^2$ of tomato plants.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Kacjan-Maršič N, Osvald J, Jakše M. Evaluation of ten cultivars of determinate tomato (*Lycopersicum esculentum* Mill.) grown under different climatic conditions. Acta Agriculturae Slovenica. 2005;85:321-328.
2. FAO. Global tomato production in 2017, Rome, Italy; 2019.
3. MALR. Agriculture statistics bulletin. Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Central Administration of Agricultural Economy, Cairo; 2020.

4. Faied EK, Elshater AAM. Socioeconomics study of tomato production in Egypt: A case study. Middle East Journal of Agriculture Research. 2022;11(1):312-323.
5. Zhang S, Wang Y, Sun L. Organic mulching positively regulates the soil microbial communities and ecosystem functions in tea plantation. BMC Microbiology. 2020;20(1):1-13.
6. Chai Q, Gan YT, Turner NC, Zhang RZ, Yang C, Niu YN, Siddique KHM. Chapter two - water-saving innovations in Chinese agriculture. Adv. Agron. 2014;126:149–201.
7. Ni X, Song WT, Zhang HC, Yang XL, Wang LG. Effects of mulching on soil properties and growth of tea olive (*Osmanthus fragrans*). PLOS One. 2016;11(8): 1-11.
8. Montenegro AAA, Abrantes JRCB, de Lima JLMP, Singh VP, Santos TEM. Impact of mulching on soil and water dynamics under intermittent simulated rainfall. Catena. 2013;109:139–149.
9. Mulumba LN, Lal R. Mulching effects on selected soil physical properties. Soil Tillage Res. 2008;98:1: 106-111.
10. Mikova A. Influence of the vegetation cover on the soil temperature. Plant Science. 2004;41: 216-219.
11. Prunty L, Bell J. Soil temperature change over time during infiltration. Soil Science Society of America Journal. 2005;69(3):766-775.
12. Yordanova M, Gerasimova N. Influence of different organic mulches on soil temperature during pepper (*Capsicum annuum* L.) cultivation. Scientific Papers. Series B, Horticulture. 2015;285-292.
13. Abul Hossain M, Hagque MM, Haque MA, Ilias GNM. Trichoderma – enriched biofertilizer enhances production and nutritional quality of tomato (*Lycopericon esculentum* Mill.) and minimizes NPK fertilizer use. Agric. Res. 2012;1(3):265-272.
14. Pal A, Pandey S. A study on pearl millet (*Pennisetum glaucum* L.) plant Biochemical and histochemical changes inoculated with indigenous AM fungi under Barren soil. Journal Plant Biotechnology. 2017;44(2):203–206.
15. Bhattacharya P, Jain RK, Paliwal MK. Biofertilizers for vegetable. Indian Hort. 2000;12-13.
16. Kumar P, Sharma SK. Integrated nutrient management for sustainable cabbage-tomato cropping sequence under mid hill conditions of Himachal Pradesh. Indian J. Hortic. 2004; 61(4):331-334.
17. Hodge A, Campbell CD, Fitter AH. An arbuscular mycorrhizal fungus accelerates decomposition and acquires nitrogen directly from organic material. Nature. 2001;413:297–299.
18. FAO. Guide to laboratory establishment for plant nutrient analysis. Fertilizer and Plant Nutrition Bulletin 19; 2008.
19. SAS Institute. The SAS system for Microsoft Windows. Release 9. 1. SAS Inst, Cary, NC; 2005.
20. Awodoyin RO, Ogbeide FI, Oluwole O. Effects of three mulch types on the growth and yield of tomato (*Lycopersicon esculentum* Mill.) and weed suppression in Ibadan, rainforest-savanna transition zone of Nigeria. Tropical Agricultural Research and Extension. 2007;10:53-60.
21. Sadek II, Youssef MA, Solieman NY, Alyafei MAM. Response of soil properties, growth, yield and fruit quality of cantaloupe plants (*Cucumis melo* L.) to organic mulch. Merit Research Journal of Agricultural Science and Soil Sciences. 2019;7(9):106-122.
22. Norman JC, Opata J, Ofori E. Growth and yield of okra and hot pepper as affected by mulching. Ghana Journal of Horticulture. 2011;9:35-42.
23. Hong SJ, Kim HK, Park SW. Effect of mulching materials on growth and flowering of oriental hybrid lilies in alpine area. Korean J. Horticultural Sci. Technol. 2001;19:585-590.
24. Matsenjwa NV. Influence of mulch on ecological and agronomic characteristics of field bean (*Phaseolus vulgaris* L.) in Luyengo. Unpublished BSc. Agriculture Dissertation, University of Swaziland, Luyengo, Swaziland; 2006.
25. Kumar DK, Lal BR. Effect of mulching on crop production under rainfed condition: a review. International Journal of Research in Chemistry and Environment. 2012;2(2):8-20.
26. Gupta N, Kukal SS, Bawa SS, Dhaliwal GS. Soil organic carbon and aggregation under poplar based agroforestry system in relation to tree age and soil type. Agroforest. Syst. 2009;76:27-35.
27. Tilander Y, Bonzi M. Water and nutrient conservation through the use of agroforestry mulches, and sorghum yield

response. Plant and Soil. 1997;197:219–232.

28. Downer J, Hodel D. The effects of mulching on establishment of *Syagrus romanzoffiana* (Cham.) Becc, *Washingtonia robusta* H. Wendl. and *Archontophoenix cunninghamiana* (H. Wendl.) H. Wendl. & Drude in the landscape. Scientia Hortic. 2001;87: 85–92.
29. Barman D, Rajni K, Pal R, Upadhyaya R. Effect of mulching on cut flower production and corm multiplication in gladiolus. J. Ornamental Horticulture. 2005;8:152-154.
30. Chawla SL. Effect of irrigation regimes and mulching on vegetative growth, quality and yield of flowers of African marigold. Ph. D. Thesis, Department of Horticulture, Maharana Pratap University of Agriculture and Technology, Udaipur; 2006.
31. Sas-Paszt L, Pruski K, Żurawicz E, Sumorok B, Derkowska E, Gluszek S. The effect of organic mulches and mycorrhizal substrate on growth, yield and quality of gold milenium apples on M.9 rootstock. Can. J. Plant Sci. 2014;94:281-291.
32. Douds Jr DD, Lee J, McKeever L, Ziegler-Ulsh C, Ganser S. Utilization of inoculum of AM fungi produced on-farm increases the yield of *Solanum lycopersicum*: A summary of 7 years of field trials ona conventional vegetable farm with high soil phosphorus. Scientia Horticulturae. 2016; 207:89–96.
33. Ryan MH, Kirkegaard JA. The agronomic relevance of arbuscular mycorrhizas in the fertility of Australian extensive cropping systems. Agric. Ecosys. Environ. 2012;163:37–53.
34. Ryan MH. and J. H.Graham. Is there a role for arbuscular mycorrhizal fungi inproduction agriculture? Plant Soil. 2002;244:263–271.
35. Koide RT. Nutrient supply, nutrient demand and plant response to mycorrhizal infection. New Phytol. 1991;117:365–386.
36. Douds DD, Nagahashi G, Shenk JE. Frequent cultivation prior to planting to prevent weed competition results in an opportunity for the use of arbuscular mycorrhizal fungus inoculum. Sustain. Agric. Food Syst. 2012a;27:251–255.
37. Douds DD, Lee J, Rogers L, Lohman ME, Pinzon N, Ganser S. Utilization of inoculum of AM fungi produced on-farm for the production of *Capsicum annuum*: a summary of seven years of field trials on a conventional vegetable farm. Biol. Agric. Hortic. 2012b;28:129–145.
38. Valentine AJ, Osborne BA, Mitchell DT. Interactions between phosphorus supply and total nutrient availability on mycorrhizal colonization, growth and photosynthesis of cucumber. Scientia Horticulturae. 2001;88:177-189.
39. Dasgan HY, Kusvuran S, Ortas I. Responses of soilless grown tomato plants to arbuscular mycorrhizal fungal (*Glomus fasciculatum*) colonization in recycling and open systems. African Journal of Biotechnology. 2008;7(20):3606-3613.
40. Maboko MM, Bertling I, Du Plooy CP. Effect of arbuscular mycorrhiza and temperature control on plant growth, yield, and mineral content of tomato plants grown hydroponically. HortScience. 2013;48(12):1470–1477.
41. Bowles TM, Barrios-Masias FH, Carlisle EA, Cavagnaro TR, Jackson LE. Effects of arbuscular mycorrhizae on tomato yield, nutrient uptake, water relations, and soil carbon dynamics under deficit irrigation in field conditions. Science of the Total Environment. 2016;566–567:1223–1234.
42. Bryla DR, Koide RT. Mycorrhizal response of two tomato genotypes relates to their ability to acquire and utilize phosphorus. Ann. Bot. 1998;82:849–857.
43. Muhammad AP, Muhammad I, Khuram S, Hassan AUL. Effect of mulch on soil physical properties and NPK concentration in Maize (*Zea mays*) shoots under two tillage system. Int. J. Agric. Biol. 2009;11:120-124.
44. Borthakur PK, Tivelliand SW, Purquerio LFV. Effect of green manuring, mulching, compost and microorganism inoculation on size and yield of lettuce. Acta Horticulturae. 2012;933:165-171.
45. Kumar R, Sood S, Sharma S, Kasana RC, Pathania VL, Singh B, Singh RD. Effect of plant spacing and organic mulch on growth, yield and quality of natural sweetener plant stevia and soil fertility in western Himalayas. International Journal of Plant Production. 2014;8(3):311-333.
46. Sadek II, Aboud FS, Moursy FS, Ahmed NM. Influence of substrate types and mulch application on growth, yield and quality of lettuce plants (*Lactuca sativa* L.). International Journal of Science and Research Methodology. 2018;9(2): 90-117.
47. Opara-Nadi OA. Effect of elephant grass and plastic mulch on soil properties and

cowpea yield. In: Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture. 1993;351-360.

48. Bakr J, Pék Z, Helyes L, Posta K. Mycorrhizal inoculation alleviates water deficit impact on field-grown processing tomato. Pol. J. Environ. Stud. 2018;27(5):1949-1958.
49. Sallaku G, Sandén H, Babaj I, Kaciu S, Balliu A, Rewald B. Specific nutrient absorption rates of transplanted cucumber seedlings are highly related to RGR and influenced by grafting method, AMF inoculation and salinity. Scientia Horticulturae. 2019;243:177–188.
50. Latef AAHA, Chaoxing H. Effect of arbuscular mycorrhizal fungi on growth, mineral nutrition, antioxidant enzymes activity and fruit yield of tomato grown under salinity stress. Scientia Horticulturae. 2011;127:228–233.
51. Jamiołkowska A, Thanoon AH, Skwaryło-Bednarz B, Patkowska E, Mielniczuk E. Mycorrhizal inoculation as an alternative in the ecological production of tomato (*Lycopersicon esculentum* Mill.). Int. Agrophys. 2020;34:253-264.
52. Ordookhani K, Khavazi K, Moezzi A, Rejali F. Influence of PGPR and AMF on antioxidant activity, lycopene and potassium content in tomato. Afr. J. Agric. Res. 2010;5(10):1108-1116.
53. Jamiołkowska A, Księżniak A, Gałązka A, Hetman B, Kopacki M, Skwaryło-Bednarz B. Impact of abiotic factors on development of the community of arbuscular mycorrhizal fungi in the soil. Int. Agrophys. 2018;32:133-140.
54. Cimen I, Pirinc VEDA, Doran I, Turgay B. Effect of soil solarization and arbuscular mycorrhizal fungus (*Glomus intraradices*) on yield and blossom-end rot of tomato. Int. J. Agric. Biol. 2010; 12: 551-555.
55. George E, Häussler K, Vetterlein D, Gorgus E, Marschner H. Water and nutrient translocation by hyphae of *Glomus mosseae*. Can. J. Botany. 1992;70:2130-2137.
56. Kothari SK, Marschner H, George E. Effect of VA mycorrhizal fungi and rhizosphere microorganisms on root and shoot morphology, growth and water relations in maize. New Phytologist. 1990;116:303-311.
57. Ruiz-Lozano JM, Azcon R, Gomez M. Alleviation of salt stress by arbuscular-mycorrhizal *Glomus* species in *Lactuca sativa* plants. Physiol. Plantarum. 1996;98(4):767-772.
58. Alenazi M, Abdel-Razzak H, Ibrahim A, Wahb-Allah M, Alsadon A. Response of muskmelon cultivars to plastic mulch and irrigation regimes under greenhouse conditions. The J. Animal & Plant Sci. 2015;25(5):1398-1410.
59. Chen Y, Katan J. Effect of solar heating of soils by transparent polyethylene mulching on their chemical properties. Soil Science. 1980;130:271-277.
60. Gandhi N, Bains GS. Effect of mulching and date of transplanting on yield contributing characters of tomato. Journal Research Punjab Agriculture University India. 2006;43:6-9.
61. Khurshid K, Iqbal M, Arif MS, Nawaz A. Effect of tillage and mulch on soil physical properties and growth of maize. Int. J. Agric. Biol. 2006;8:593–596.
62. Bosco M, Giovannetti G, Picard C, Baruffa E, Brondolo A, Sabbioni F. Commercial plant-probiotic microorganisms for sustainable organic tomato production systems. In: Improving sustainability in organic and lowinput food production systems (Eds U. Niggli, C. Leifert, T. Alföldi, L. Lück, H. Willer) . Proc. 3rd QLIF Congress, Stuttgart, FiBL, Frick. 2007;268-271.
63. Subramanian KS, Santhanakrishnan P, Balasubramanian P. Responses of field grown tomato plants to arbuscular mycorrhizal fungal colonization under varying intensities of drought stress. Sci. Hortic. 2006;107(3):245-253.
64. Nzanza B, Marais D, Soundy P. Effect of arbuscular mycorrhizal fungal inoculation and biochar amendment on growth and yield of tomato. Int. J. Agric. Biol. 2012;14:965-969.
65. Colella T, Candido V, Campanelli G, Camele I, Battaglia D. Effect of irrigation regimes and artificial mycorrhization on insect pest infestations and yield in tomato crop. Phytoparasitica. 2014;42(2):235-246.
66. Candido V, Campanelli G, D'Addabbo T, Castronuovo D, Perniola M, Camele I. Growth and yield promoting effect of artificial mycorrhization on field tomato at different irrigation regimes. Sci. Hortic. 2015;187:35-43.
67. Conversa G, Lazzizera C, Bonasia A, Elia A. Yield and phosphorus uptake of a processing tomato crop grown at different phosphorus levels in a calcareous soil as

affected by mycorrhizal inoculation under field conditions. Biol. Fert. Soils. 2013;49(6): 691-703.

68. Damaiyanti DRR, Aini N, Soelistyono R. Effects of arbuscular mycorrhiza inoculation on growth and yield of tomato (*Lycopersicum esculentum* Mill.) under salinity stress. Journal of Degraded and Mining Lands Management. 2015;3(1):447 – 452.

69. Gosling P, Hodge A, Goodlass G, Bending GD. Arbuscular mycorrhizal fungi and organic farming. Agric. Ecosyst. Environ. 2006;113:17–35.

70. Guillermo AG, Parádi I, Burger K, Baar J, Kuyper TW, Scholten OE, Kik C. Molecular diversity of arbuscular mycorrhizal fungi in onion roots from organic and conventional farming systems in the Netherlands. MYCORRHIZA. 2009;19(5):317-328.



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