Effect of organic mulch and mycorrhizal inoculation on growth and yield of tomato plants

Abstract

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 to investigate applied two factors organic mulch i.e., (bagasse, compost, palm fibers, mushroom spent, sawdust and control), mycorrhizal inoculation (with, without) and their interaction on growth and productivity of tomato plants. The seedlings of tomato cv. Super strain B were transplanted in 15th of 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 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.

Key words: Tomato, Organic mulch, Compost, Mycorrhizal inoculation

1. Introduction:

Tomato (*Lycopersicon esculentum* Mill.) is the most commonly vegetable crop in Egypt and is considered one of the most popular and economically important which used as fresh or processed. It spread around the globe bearing vigorously varied climatic conditions (Kacsjan-Marsic *et al*., 2005). Its globally 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 (FAO, 2019). Furthermore, tomato cultivated area in Egypt was 413.67 thousand feddans (MALR, 2020), representing 22% of the total vegetable cultivated area which amounting 1.9 million feddans during 2018-2020 (Faied and Elshater, 2022). 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 (Zhang *et al*., 2020; Chai, *et al*., 2014). Inorganic mulching is widely used in controlling weeds and as 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, according to Ni *et al*. (2016). 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 yields 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 (Montenegro *et al*., 2013; Mulumba and Lal, 2008).

It is well known that there is a relation between soil temperature and ambient climate including air temperature, where soil temperature varied from zero up to 20 cm depth. The soil temperature is highest in the bare soil and is lower under the plant's cover especially in 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 (Mikova, 2004; Prunty and Bell, 2005). 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 (Yordanova and Gerassimova, 2015).

Mycorrhizae fungi are environmentally friendly bio-fertilizers, not only reduce the load of chemical fertilizers in the plants but also minimize the pollution in the soil (Abul Hossain *et al*., 2012). 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 (Pal and Pandey, 2017). 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 (Bhattacharya *et al*., 2000). Kumar and Sharma (2004) reported that using of mycorrhizae combined with the mineral fertilizers increased yield and nutrient content. Hodge *et al*. (2001) proved that the arbuscular mycorrhizal symbiosis can both enhance decomposition of and increase nitrogen capture from complex organic material in soil.

This study aims to investigate applied two factors organic mulch i.e., (bagasse, compost, palm fibers, mushroom spent, sawdust and control), mycorrhizal inoculation (with, without) and their interaction 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 in 15th 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 water 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).

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

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 (2008), 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 (2008). Moreover, potassium content decided photometrically using Flame photometer as described by FAO (2008). Results of chemical content was 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 (SAS, 2005).

3. Results and discussion:

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, were obtained with plants which applied by 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 to mycorrhizal inoculation noticed that plants which inoculated by mycorrhizal had recorded the lowest value of plant height compared to without mycorrhizal inoculation which gave the highest value.

Moreover, the interaction had significant influences on plant height all over the 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.

Table (2): Effect of applying organic mulch and mycorrhizal inoculation on plant height (cm) of tomato plants during 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	

3.1.2. Number of leaves par plant:

Data in Table (3) reflected the great effect of applied organic mulch on number of leaves per plant. The highest number of leaves values recorded with compost mulch treatment, in first season, while obtained with compost and mushroom spent treatments, respectively, without any significant difference, in second season. While, lowest number of leaves was detected with 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, application 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 (3): Effect of applying organic mulch and mycorrhizal inoculation on number of leaves par plant of tomato plants during 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:

In Table (4) shown a significant differences in number of shoots/plant were obtained as a result of applied organic mulch, mycorrhizal and their interaction treatments.

Tomato plants which grown at 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 the lowest.

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

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

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.

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

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	

3.1.5. Plant fresh weight:

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

On other word, mycorrhizal inoculation had 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 first season), and control plus with or without, respectively, without any significant difference (in second season) led to reduced it. Those results are true in two growing season.

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

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	

3.1.6. Plant dry weight:

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

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

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

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

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	

These enhanced of 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 (Awodoyin *et al*., 2007; Sadek *et al*., 2019), 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*. (2011), the organic mulch had a greater impact on the number of leaves/plant than the control (bare soil) treatment. Hong *et al*. (2001) 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, according to Matsenjwa (2006), boosted vegetative growth. According to Kumar and Lal (2012), greater plant dry weight for mulched plants is attributable to 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 (Gupta *et al*., 2009).

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 (Tilander and Bonzi, 1997), moderate decomposers like paper, hay, straw, and other crop wastes, and slow decomposers like bark and woody chips have all been tested (Downer and Hodel, 2001). 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 (Barman *et al*., 2005; Chawla, 2006).

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*., (2014), who found that applied mycorrhizal inoculation had no significant effect on growth. Low P availability/addition resulted in stronger growth responses (Douds Jr. *et al*., 2016). Extensive cropping systems (Ryan and Kirkegaard, 2012) and high P soils are two examples of situations where they may not have a role (Ryan and Graham, 2002). The reaction of plants to mycorrhizal fungi is often inversely related to the amount of accessible P in the soil (Koide, 1991). 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 (Douds *et al*., 2012 a and b). Valentine *et al*. (2001) 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 a 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 with mycorrhizal inoculation infection are the product of intricate interplay between phosphorus supply and other important nutrients. According to Dasgan *et al*. (2008), mycorrhizal inoculation had no effect on vegetative plant growth. During a similar experiment with tomatoes, Maboko *et al*. (2013) discovered that mycorrhizal inoculation had no significant influence on plant development. Bowles *et al*. (2016) 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 (Bryla and Koide, 1998).

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 control treatment which recorded the lowest content.

In the same way, plants which inoculated by mycorrhizal obtained 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 (8): Effect of applying organic mulch and mycorrhizal inoculation on content N (%) in leaves of tomato plants during 2019/2020 and 2020/2021seasons.

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 2020/2021seasons.

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	

3.2.2. Potassium content:

The statistical analysis in Table (10) indicated that organic mulch treatments had 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, control treatment which reduced it.

On other hand, mycorrhizal inoculation had not 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.

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

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	

The contributed of increasing chemical content of (N, P and K) in tomato leaves by applied organic mulch, especially, compost as mulch are harmony with (Muhammad *et al*., 2009; Borthakur *et al*., 2012; Kumar *et al*., 2014; Sadek *et al*., 2018; Sadek *et al*., 2019). 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 (Opara-Nadi, 1993). 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 (Sadek *et al*., 2019).

On the other hand, mycorrhizal inoculation greatly boosted tomato root colonisation, resulting in higher phosphorus absorption in an optimal water supply (Bakr *et al*., 2018). Sallaku *et al*. (2019) 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 (Latef and Chaoxing, 2011). Mycorrhizal inoculation enhanced Ca and K absorption via plants, according to Jamiokowska *et al*. (2020). Tomatoes with mycorrhizal inoculation had a higher rise in K content (Ordookhani *et al*., 2010). The concentration of macro and microelements in leaves was changed by mycorrhizal inoculation (Sas-Paszt *et al*., 2014). Other studies have noticed higher absorption of macro and microelements like potassium, nitrogen, calcium, and magnesium (Jamiokowska *et al*., 2018). Cimen *et* *al*. (2010) 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.

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 (George *et al*., 1992). 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 (Kothari *et al*., 1990). Root hydraulic conductivities are greater in mycorrhizal plants than in non-mycorrhizal species (Ruiz-Lozano *et al*., 1996).

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 reduction both of their.

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 interaction between two tested factors increased two tested parameters compared other treatments. While, control treatment + without mycorrhizal inoculation reduced both of average fruit weight and total yield/m^2. These are true through tested seasons.

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

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	

Those result is agree with (Alenazi *et al*., 2015; Sadek *et al*., 2019). They mentioned that mulching increased fruit output, which, 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 (Kumar and Lal, 2012). Mulch increased the amount of vegetation and productivity of several crops, according to Chen and Katan (1980). Increased yields can be attributable to improved soil moisture and fertiliser utilisation. 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 (Sadek *et al*., 2019). Mulches changed the microclimate by changing soil temperature, moisture, and evaporation, according to Gandhi and Bains (2006), 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*., (2006), 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*. (2008) 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*. (2007), 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 (Subramanian *et al*., 2006). However, a large body of evidence suggests that mycorrhizal inoculation boosts tomato output (Nzanza *et al*., 2012; Colella *et al*., 2014; Candido *et al*., 2015). 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 (Conversa *et al*., 2013). Furthermore, even in a high P soil, utilising mycorrhizal inoculation generated on-farm resulted in a moderate but considerable increase in tomato fruit output with minimum changes in farm management (Douds Jr. *et al*., 2016). According to Damaiyanti *et al*. (2015), 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*. (2015), the beneficial benefits of 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 (Gosling *et al*., 2006; Guillermo *et al*., 2009).

4. Conclusion:

Organic mulch is consider 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 increasing 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 encouraging average fruit weight and total yield/m^2 of tomato plants.

5. References:

Abul Hossain, M., M. M. Hagque, M. A. Haque and G. N. M. Ilias. 2012. Trichoderma – enriched biofertilizer enhances production and nutritional quality of tomato (*Lycopericon esculentum* Mill.) and minimizes NPK fertilizer use. Agric. Res. 1(3): 265-272.

Alenazi, M., H. Abdel-Razzak, A. Ibrahim, M. Wahb-Allah and A. Alsadon. 2015. Response of muskmelon cultivars to plastic mulch and irrigation regimes under greenhouse conditions. The J. Animal & Plant Sci. 25(5): 1398-1410.

Awodoyin, R. O., F. I. Ogbeide and O. Oluwole. 2007. 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. 10: 53-60.

Bakr, J., Z. Pék, L. Helyes and K. Posta. 2018. Mycorrhizal inoculation alleviates water deficit impact on field-grown processing tomato. Pol. J. Environ. Stud. 27(5): 1949-1958.

Barman, D., K. Rajni, R. Pal, R. Upadhyaya. 2005. Effect of mulching on cut flower production and corm multiplication in gladiolus. J. Ornamental Horticulture. 8: 152-154.

Bhattacharya, P., R. K. Jain and M. K. Paliwal. 2000. Biofertilizers for vegetable. Indian Hort. 12-13.

Borthakur, P. K., S. W. Tivelliand and L.F.V. Purquerio. 2012. Effect of green manuring, mulching, compost and microorganism inoculation on size and yield of lettuce. ActaHorticulturae. 933: 165-171.

Bosco, M., G. Giovannetti, C. Picard, E. Baruffa, A. Brondolo and F. Sabbioni. 2007. 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, 268-271.

Bowles, T. M., F. H. Barrios-Masias, E. A. Carlisle, T. R. Cavagnaro and L. E. Jackson. 2016. 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. 566–567: 1223–1234.

Bryla, D. R. and R. T. Koide. 1998. Mycorrhizal response of two tomato genotypes relates to their ability to acquire and utilize phosphorus. Ann. Bot. 82: 849–857.

Candido, V., G. Campanelli, T. D'Addabbo, D. Castronuovo, M. Perniola and I. Camele. 2015. Growth and yield promoting effect of artificial mycorrhization on field tomato at different irrigation regimes. Sci. Hortic. 187: 35-43.

Chai, Q., Y. T. Gan, N. C. Turner, R. Z. Zhang, C. Yang, Y. N. Niu and K. H. M. Siddique. 2014. Chapter two - water-saving innovations in Chinese agriculture. Adv. Agron. 126: 149–201.

Chawla, S. L. 2006. 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.

Chen, Y. and J. Katan. 1980. Effect of solar heating of soils by transparent polyethylene mulching on their chemical properties. Soil Science. 130: 271-277.

Cimen, I., V. E. D. A. Pirinc, I. Doran and B. Turgay. 2010. Effect of soil solarization and arbuscular mycorrhizal fungus (*Glomus intraradices*) on yield and blossom-end rot of tomato. Int. J. Agric. Biol. 12: 551-555.

Conversa, G., C. Lazzizera, A. Bonasia and A. Elia. 2013. 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. 49(6): 691-703.

Colella, T., V. Candido, G. Campanelli, I. Camele and D. Battaglia. 2014. Effect of irrigation regimes and artificial mycorrhization on insect pest infestations and yield in tomato crop. Phytoparasitica. 42(2): 235-246.

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

Dasgan, H. Y., S. Kusvuran and I. Ortas. 2008. Responses of soilless grown tomato plants to arbuscular mycorrhizal fungal (*Glomus fasciculatum*) colonization in recycling and open systems. African Journal of Biotechnology. 7(20): 3606-3613.

Douds, D. D., G. Nagahashi and J. E. Shenk. 2012a. 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. 27: 251–255.

Douds, D. D., J. Lee, L. Rogers, M. E. Lohman, N. Pinzon and S. Ganser. 2012b. 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. 28: 129–145.

Douds Jr., D. D., J. Lee, L. McKeever, C. Ziegler-Ulsh and S. Ganser. 2016. 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. 207: 89–96.

Downer, J. and D. Hodel. 2001. 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. 87: 85–92.

FAO. 2008. Guide to laboratory establishment for plant nutrient analysis. Fertilizer and Plant Nutrition Bulletin 19.

FAO. 2019. Global tomato production in 2017, Rome, Italy.

Faied, E.K. and A.A.M. Elshater. 2022. Socioeconomics study of tomato production in Egypt: A case study. Middle East Journal of Agriculture Research. 11(1): 312-323.

Gandhi, N. and G. S. Bains. 2006. Effect of mulching and date of transplanting on yield contributing characters of tomato. Journal Research Punjab Agriculture University India. 43: 6-9.

George, E., K. Häussler, D. Vetterlein, E. Gorgus, and H. Marschner. 1992. Water and nutrient translocation by hyphae of *Glomus mosseae*. Can. J. Botany. 70: 2130-2137.

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

Guillermo, A. G., I. Parádi, K. Burger, J. Baar, T. W. Kuyper, O. E. Scholten and C. Kik. 2009. Molecular diversity of arbuscular mycorrhizal fungi in onion roots from organic and conventional farming systems in the Netherlands. MYCORRHIZA 19: 5 pp. 317-328.

Gupta, N., S. S. Kukal, S. S. Bawa and G. S. Dhaliwal. 2009. Soil organic carbon and aggregation under poplar based agroforestry system in relation to tree age and soil type. Agroforest. Syst. 76: 27-35.

Hodge, A., C. D. Campbell and A. H. Fitter. 2001. An arbuscular mycorrhizal fungus accelerates decomposition and acquires nitrogen directly from organic material. Nature. 413: 297–299.

Hong, S. J., H. K. Kim and S. W. Park. 2001. Effect of mulching materials on growth and flowering of oriental hybrid lilies in alpine area. Korean J. Horticultural Sci. Technol. 19: 585-590.

Jamiołkowska, A., A. Księżniak, A. Gałązka, B. Hetman, M. Kopacki and B. Skwaryło-Bednarz. 2018. Impact of abiotic factors on development of the community of arbuscular mycorrhizal fungi in the soil. Int. Agrophys. 32: 133-140.

Jamiołkowska, A., A. H. Thanoon, B. Skwaryło-Bednarz, E. Patkowska and E. Mielniczuk. 2020. Mycorrhizal inoculation as an alternative in the ecological production of tomato (*Lycopersicon esculentum* Mill.). Int. Agrophys. 34: 253-264.

Kacjan-Maršič, N., J. Osvald and M. Jakše. 2005. Evaluation of ten cultivars of determinate tomato (*Lycopersicum esculentum* Mill.) grown under different climatic conditions. Acta Agriculturae Slovenica. 85: 321-328.

Khurshid, K., M. Iqbal, M. S. Arif and A. Nawaz. 2006. Effect of tillage and mulch on soil physical properties and growth of maize. Int. J. Agric. Biol. 8: 593–596.

Koide, R. T. 1991. Nutrient supply, nutrient demand and plant response to mycorrhizal infection. New Phytol. 117: 365–386.

Kothari, S. K., H. Marschner and E. George. 1990. Effect of VA mycorrhizal fungi and rhizosphere microorganisms on root and shoot morphology, growth and water relations in maize. New Phytologist. 116: 303-311.

Kumar, P. and S. K. Sharma. 2004. Integrated nutrient management for sustainable cabbage-tomato cropping sequence under mid hill conditions of Himachal Pradesh. Indian J. Hortic. 61(4): 331-334.

Kumar, D. K. and B. R. Lal. 2012. Effect of mulching on crop production under rainfed condition: a review. International Journal of Research in Chemistry and Environment. 2(2): 8-20.

Kumar, R., S. Sood, S. Sharma, R. C. Kasana, V. L. Pathania, B. Singh and R. D. Singh. 2014. 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. 8(3): 311-333.

Latef, A. A. H. A. and H. Chaoxing. 2011. Effect of arbuscular mycorrhizal fungi on growth, mineral nutrition, antioxidant enzymes activity and fruit yield of tomato grown under salinity stress. Scientia Horticulturae. 127: 228–233.

Maboko, M. M., I. Bertling and C. P. Du Plooy. 2013. Effect of arbuscular mycorrhiza and temperature control on plant growth, yield, and mineral content of tomato plants grown hydroponically. HortScience. 48(12): 1470–1477.

MALR. 2020. Agriculture statistics bulletin. Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Central Administration of Agricultural Economy, Cairo.

Matsenjwa, N. V. 2006. 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.

Mikova, A. 2004. Influence of the vegetation cover on the soil temperature. Plant Science. 41: 216-219.

Montenegro, A. A. A., J. R. C. B. Abrantes, J. L. M. P. de Lima, V. P. Singh and T. E. M. Santos. 2013. Impact of mulching on soil and water dynamics under intermittent simulated rainfall. Catena. 109: 139–149.

Muhammad, A. P., I. Muhammad, S. Khuram, A. U. L. Hassan. 2009. Effect of mulch on soil physical properties and NPK concentration in Maize (*Zea mays*) shoots under two tillage system. Int. J. Agric. Biol. 11: 120-124.

Mulumba, L. N. and R. Lal. 2008. Mulching effects on selected soil physical properties. Soil Tillage Res. (98)1: 106-111.

Ni, X., W. T. Song, H. C. Zhang, X. L. Yang and L. G. Wang. 2016. Effects of mulching on soil properties and growth of tea olive (*Osmanthus fragrans*). PLOS One. 11(8): 1-11.

Norman, J.C., J. Opata and E. Ofori .2011. Growth and yield of okra and hot pepper as affected by mulching. Ghana Journal of Horticulture. 9:35-42.

Nzanza, B., D. Marais and P. Soundy. 2012. Effect of arbuscular mycorrhizal fungal inoculation and biochar amendment on growth and yield of tomato. Int. J. Agric. Biol. 14: 965-969.

Opara-Nadi, O. A. 1993. Effect of elephant grass and plastic mulch on soil properties and cowpea yield. In: Soil organic matter dynamics and sustainability of tropical agriculture. 351-360.

Ordookhani, K., K. Khavazi, A. Moezzi and F. Rejali. 2010. Influence of PGPR and AMF on antioxidant activity, lycopene and potassium content in tomato. Afr. J. Agric. Res. 5(10): 1108-1116.

Pal, A. and S. Pandey. 2017. A study on pearl millet (*Pennisetum glaucum* L.) plant Biochemical and histochemical changes inoculated with indigenous AM fungi under Barren soil. Journal Plant Biotechnology. 44(2): 203–206.

Prunty, L. and J. Bell. 2005. Soil temperature change over time during infiltration. Soil Science Society of America Journal. 69(3): 766-775.

Ruiz-Lozano, J. M., R. Azcon and M. Gomez. 1996. Alleviation of salt stress by arbuscular-mycorrhizal *Glomus* species in *Lactuca sativa* plants. Physiol. Plantarum. 98(4): 767-772.

Ryan, M. H. and J. H.Graham. 2002. Is there a role for arbuscular mycorrhizal fungi inproduction agriculture? Plant Soil. 244: 263–271.

Ryan, M. H. and J. A. Kirkegaard. 2012. The agronomic relevance of arbuscular mycorrhizas in the fertility of Australian extensive cropping systems. Agric. Ecosys. Environ. 163: 37–53.

Sadek, I. I., F. S. Aboud, F. S. Moursy, N. M. Ahmed. 2018. 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. 9(2): 90-117.

Sadek, I. I., M. A. Youssef, N. Y. Solieman and M. A. M. Alyafei. 2019. 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. 7(9): 106-122.

Sallaku, G., H. Sandén, I. Babaj, S. Kaciu, A. Balliu and B. Rewald. 2019. Specific nutrient absorption rates of transplanted cucumber seedlings are highly related to RGR and influenced by grafting method, AMF inoculation and salinity. Scientia Horticulturae. 243: 177–188.

SAS Institute. 2005. The SAS system for Microsoft Windows. Release 9. 1. SAS Inst., Cary, NC.

Sas-Paszt, L., K. Pruski, E. Żurawicz, B. Sumorok, E. Derkowska, and S. Gluszek. 2014. 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. 94: 281-291.

Subramanian, K.S., P. Santhanakrishnan and P. Balasubramanian. 2006. Responses of field grown tomato plants to arbuscular mycorrhizal fungal colonization under varying intensities of drought stress. Sci. Hortic. 107(3): 245-253.

Tilander, Y. and M. Bonzi. 1997. Water and nutrient conservation through the use of agroforestry mulches, and sorghum yield response. Plant and Soil. 197: 219–232.

Valentine, A. J., B. A. Osborne and D. T. Mitchell. 2001. Interactions between phosphorus supply and total nutrient availability on mycorrhizal colonization, growth and photosynthesis of cucumber. Scientia Horticulturae. 88: 177-189.

Yordanova, M. and N. Gerasimova. 2015. Influence of different organic mulches on soil temperature during pepper (*Capsicum annuum* L.) cultivation. Scientific Papers. Series B, Horticulture. 285-292.

Zhang, S., Y. Wang and L. Sun. 2020. Organic mulching positively regulates the soil microbial communities and ecosystem functions in tea plantation. BMC Microbiology. 20(1):1-13.