Pak. J. Bot., 52(4): 1289-1298, 2020. DOI: http://dx.doi.org/10.30848/PJB2020-4(6)

ANIMAL MANURES AND SOME CHEMICALS AS SOIL SUPPLEMENT TO IMPROVE GROWTH, YIELD AND FRUIT QUALITY OF TOMATO

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Abstract

The aim of current research was to determine the effects of two different animal manures (poultry and sheep manures) as base fertilizer and four different chemical supplements (foliar application of seaweed liquid fertilizer, humic acid, photosynthetic bacteria and plant growth regulator) on plant growth and yield of tomato. Tomato is among the most important crops worldwide and its yield is highly dependent on the soil fertility. Experimental studies were conducted in a modern polyethylene greenhouse, located in Yedidalga village in Northern Cyprus. The 'Halay' tomato variety was used in the current studies and the experiments were designed as a factorial combination of three manure applications (including "no manure application" as control) and five chemical foliar supplements (including "no foliar application" as control). The experiment was laid out in a split-plot design and each unique treatment in plots was arranged in a completely randomized block design with four replicates per treatment and each replication consist of five plants. The planting density was 2,800 plants da^{-1} with 25 cm distance between plants and 120 cm distance between rows. Results showed that both animal manure and chemical supplement applications, alone or in combination, have significant influence on the number of fruits $plant^{-1}$ and total yield (gr $plant^{-1}$) of the tomato plants, however no significant effect on the plant height, plant stem diameter and fruit firmness. Results suggested that the best combinations for the higher total yield are the HA/PM (humic acid/poultry manure) and HA/SM (humic acid/sheep manure) applications with 3,547.7 gr $plant^{-1}$, 3,496.7 gr $plant^{-1}$, respectively.

Key words: Poultry manure; Sheep manure; Seaweed liquid fertilizer; Humic acid; Photosynthetic bacteria; Plant growth regulator.

Introduction

Tomato (*Lycopersicon esculentum* Mill) fruits can be consumed as fresh or in other processed forms (i.e. paste, jams, etc.) and is among the most widely consumed vegetables worldwide. Tomato is the 10th most produced vegetable crop and 11th most produced crop in the world in 2017 (Anon., 2019). Tomato fruits are high in vitamin C, minerals and antioxidants (i.e. lycopene) and are known to be very beneficial for human health (Kanr *et al*., 2002). Tomato crop is suitable to grow on almost all types of soils, but due to its high yielding capacity, it is highly important to supply necessary nutrients to the growing media for higher yield (Pandey & Chandra, 2013). Chemical fertilizers are the most important contributors of agricultural production, but due to its potential negative effects on environment, its high acceptability in agricultural systems is decreasing (Peyvast *et al*., 2003; Jiménez *et al., 2019*). Agricultural production is directly related with nutrient availability and there are many factors affecting it, including: soil particle size, organic matter (humus) content, soil pH, aeration, parent material, water availability, temperature and mycorrhizal development (Jackson, 2008).

To increase crop yield, management of soil nutrients in the growing media is highly crucial. According to researchers, soil infertility might be accepted as the single most important factor reducing crop yields on the earth (Fageria & Baligar, 2005; Halka *et al.*, 2019). On the other hand, it is well known that the soil fertility and organic matter are highly important for the retention and availability of nutrients for plants growth (Adekiya & Agbede, 2009). Soil amendments generally aim to increase soil organic matter and the population of beneficial microbial populations to improve soil fertility and productivity. The use of animal manure, biosolids, compost and household wastes for maintaining soil fertility; and growth and yield of different crops including tomato had been previously reported (Elliot & Dempsey, 1991; Ewulo *et al*., 2008; Diacono & Montemurro, 2010; Toumpeli *et al*., 2013; Adekiya & Agbede, 2017). Previous studies showed that earthworm-processed sheep-manure (vermicompost) increased the tomato yield when tested as soil supplement (Gutierrez-Miceli *et al*., 2007; Sabijon & Sudarika, 2018). Some previous studies also noted that the aromatic plants can also be used as alternative sources for compost production (Chalkos *et al*., 2010; Kadoglidou *et al*., 2014). Soil amendments including bacterial cells were also reported to improve crops yield in some previous studies on different crop types (Schmidt, 1999; Ricci *et al*., 2019). Seaweed liquid fertilizers (Vasantharaja *et al*., 2017; Wang *et al*., 2018; Chanthini *et al*., 2019) and humic acid (Ciarkowska *et al*., 2017; Gholami *et al*., 2018; Gemin *et al*., 2019; Keabetswe *et al.,* 2019) were also reported to be very good soil amendments for improving soil fertility and crop yield. According to Authors' knowledge, no comprehensive study was previously conducted about the effects of those soil amendments and also the combined effects of them with animal manures on the growth of tomato. In the light of this information, the objective of present study was to determine the effects of two different animal manures (poultry and sheep) and four different chemical supplements (seaweed liquid fertilizer [SLF], humic acid [HA], photosynthetic bacteria [PB] and plant growth regulator [PGR]) on growth and yield of tomato.

Materials and Methods

Experimental field and cultivation: Experimental studies were conducted in a modern polyethylene greenhouse, located in Yedidalga village (35°08’33.68” N, 32°48’26.17” E) in Northern Cyprus. The climate of the area is Mediterranean climate which has relatively hot and dry summers and mild and rainy winters. The average minimum and maximum temperatures of the study site during the studies is: February: 7.82-17.47; March: 9.14-19.43; April: 11.64-22.78; May: 15.18-27.19; June: 19.12-31.55; July: 22.92-34.03 °C. Experimental site has a clay loam soil with a 7.7 pH and 1.2% organic matter (Table 1).

Table 1. Some physical and chemical properties of the experimental soil.

Characteristic	Result	Evaluation
Saturation (%)	56	Clay-loam
pH	7.7	Slightly alkaline
Lime (%)	3.6	Slightly lime
Total Salt (%)	0.11	Good
Organic matter (%)	1.2	Low
Available phosphorus (kg P_2O_5da^{-1})	24.8	High
Available potassium (kg K_2O da^{-1})	239	High

Present study was carried according to the completely randomized block design with 4 replicates and each replication formed from 5 tomato plants. The planting density was 2,800 plants/da with 25 cm distance between plants; and 120 cm distance between rows. Irrigation was performed by drip irrigation system with a single line in row (dripping volume: 4 L hour^{-1}). ‘Halay’ tomato variety was used in present study and transplanting was performed at 22nd of February, 2019. This variety is known to be suitable for spring and winter production. It is also resistant against cladosporium. The fruit colour is reddish and the shape is round. Applications of sheep and poultry manures were performed 3 weeks before transplanting and other chemical supplements were applied 1 week after the transplanting. The area was irrigated with 3 days intervals from transplanting to the beginning of May; with 2 days intervals during the May and then irrigation was performed daily until the end of the growing season. In each given date of irrigation, water volume was adjusted to 1 L plant^{-1}. Apart from the experimental fertilizer tests of the present study (described in following sections), regular fertilization was performed according to the nutrient rates given in Table 2. The nutrients were provided with every irrigation practices and the rates were adjusted according to the data given in table.

Weed management was done manually by hand and with hoe 3 times throughout the experiment. During the experimental studies, pests and diseases were regularly controlled and pesticide applications were done as needed. The list of the pesticides that applied was given in Table 3.

Experimental materials and applications: Plant materials of present study belong to the ‘Halay’ variety. The experimental studies were designed as a factorial combination of three manure applications (including control) and five chemical foliar supplements (including control). The experiment was laid out in a split-plot design. The main factor of the experiment was animal manure including 1) control, 2) sheep manure and 3) poultry manure. These two manures were collected from local farms and are 3-years old. Sub-factors of the experimental studies were the foliar applied chemical supplements (1-control, 2-seaweed liquid fertilizer, 3-humic acid, 4-photosynthetic bacteria and 5-plant growth regulator) and each unique treatment was arranged in a completely randomized block design with four replicates per treatment and each replication consist of five plants.

The application of poultry and sheep manure was performed at a uniform rate of 3 t da^{-1} (Adekiya and Agbede, 2009). and just after, the study area was ploughed once with a tractor at 1st of February 2019. Three weeks later, on 22nd of February (#1), three weeks old tomato seedlings were transplanted to the field at a spacing of 25 cm x 120 cm. One week after transplanting, on 1st of March, foliar application of the chemical supplements was performed with hand atomizer. The Algawin fertilizer (Brand: Stoller) was used as a source of seaweed liquid fertilizer [SLF] supplement which consist of 40% total organic material content, 1% alginic acid, and 18% water-soluble potassium oxide. The test rate of the Algawin was 0.6 g L^{-1}. The foliar spray of humic acid [HA] was performed with a rate of 0.5 g L^{-1}. For the application of photosynthetic bacteria, the EM-1 (Brand: Agriton) was selected and used in a rate of 0.5 g L^{-1}.It contains photosynthetic bacteria [PA] (phototrophic bacteria), lactic acid bacteria, yeasts, actinomycetes and molds. Finally, plant growth regulator [PGR] (Atonikof NACL Industries Ltd.) was used at a rate of 0.5 g L^{-1}.

Table 2. Nutrient rates supplied to experimental plants during the studies.

Days from planting	mg plant^{-1} day^{-1}				
	N	P	K	Ca	Mg
1 to 15	20.4	5.0	33.2	2.5	0.0
16 to 30	21.4	4.6	33.2	2.5	2.5
31 to 40	21.4	7.1	32.1	3.6	0.0
41 to 60	42.9	10.7	67.9	3.6	1.8
61 to 80	42.9	14.3	64.3	7.1	0.0
81to 110	84.3	23.2	135.0	8.6	5.4
110 to 135	60.7	17.1	101.4	6.4	3.6

Table 3. Chemical control of pests and diseases during the experimental studies.

Date of application	Active ingredients	Against to
22nd of February	Acetamiprid + Kresoxim methyl	*Trialeurodes vaporariorum*, *Lyriomyza bryoniae*
2nd of March	Acetamiprid + Deltamethrin	*T. vaporariorum, Leveillula taurica, Heliothis armigera*
16th of March	Aluminium fosetyl	*Tuta absoluta*, *H. armigera*
3rd of April	Indoxacarb + Aluminium fosetyl	*T. vaporariorum*, *L. bryoniae*
20th of April	Acetamiprid + Chlorantraniliprole	*T. vaporariorum*, *T. absoluta*
10th of May	Kresoxim methyl + Boscalid	*Pseudomonas syringae*, *T. absoluta*
20th of May	Indoxacarb + Cyprodinil + Fludioxonil	*P. syringae*, *T. absoluta*
28th of May	Abamectin + Chlorantraniliprole	*T. vaporariorum*, *T. absoluta*
5th of June	Indoxacarb	*T. absoluta*
10th of June	Metaflumizone	*T. absoluta*

Data collection: Data collection was performed from the three mid-plants of each unique replication. Plant height and stem diameter data was collected with weekly measurements from 8th of March (#15) till 24th of May (#92) (until the appearance of 8th cluster). Plant height (cm) was measured with a measure and the stem diameter (mm) was measured with a digital caliper. The time of first flowering and first fruit set for each plant was also noted. One day after the last plant height and stem diameter measurements, first fruits were harvested. Harvesting was performed by hand according to the commercial maturity and it continued until 6th of July (#135) (totally 8 weeks and 8 harvests). During harvesting, number of harvested fruits for each plant and the total weight of the fruits were measured and noted. Thus, the yield (gr plant^{-1}), cumulative yield (gr plant^{-1}), yield (number of fruits plant^{-1}), cumulative yield (number of fruits plant^{-1}), and average fruit weight (gr) were calculated by using the obtained raw data. At the second harvest, one fruit was randomly selected from each plants (except the plants at the both edges of each replication) and soluble solids concentration (SSC) was measured with a hand refractometer as % and fruit firmness was measured with penetrometer (kg cm^{-2}). One day after the 8th (final) harvest, plants were uprooted to measure the fresh weights (gr). Hereafter, plant materials were chopped into small parts and oven-dried at 72°C to determine dry weight (gr).

Statistical analysis: Raw data of the experiments were summarized in Excel to calculate means and to prepare tables and figures from the mean values. The raw data was also subjected to the Analysis of Variance to determine if the treatments have significant influence on the parameters. In case of significant differences, Tukey's HSD (honestly significant difference) test was used to separate means. SPSS 22.0 (IBM Company, New York, USA) was used for the mentioned analysis.

Results and Discussions

Results of the present study showed that the different manure applications or chemical supplements do not have a significant influence on the flowering date (df within: 165, F:1.264, Sig.: 0.235) and thus earliness (df within: 165, F: 1.298, Sig.: 0.213) of the tomato crops (Fig. 1). After transplanting, tomato crops found to require from 20.7 to 24.9 days for first flowering. The number of flowers at the first day of flowering was also found to be between 3.4 - 4.5 unit plant^{-1}. Similar results were found for the fruit set and it was calculated for the different applications to require about 28.3 to 33.2 days from transplanting to first fruit set.

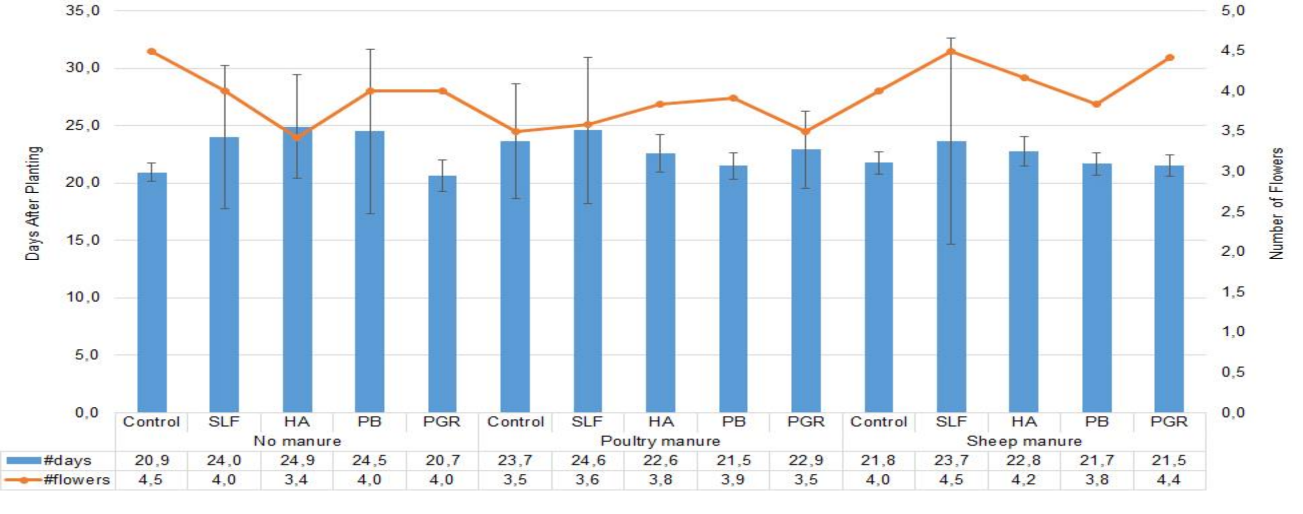


Fig. 1. Effects of different manures and chemical supplements on the flowering of tomato plants.

During the initial development periods of the crops, it was found that the crops planted on the soil with any of the manures (sheep manure [SM] or poultry manure [PM]) are smaller than the others. However, this result is only noted for the first week and the weeks after, no statistical difference was found among the plant height of the tomato crops. At the first week of the measurements, the smallest plants were noted from the combination of poultry manure & PB application with an average plant height of 26.2 cm (Table 4.). At the same date, the highest crops were noted from the control plants with an average height of 34.8 cm. It is known that the application of animal manures, i.e. poultry manure significantly influences soil chemical properties and this might cause a slight delay in the crops development (Adekiya & Agbede, 2017; Baranski *et al.*, 2019). Hereafter, measurements showed that there is not any significant difference among the treatments. When comparing the main- and sub-factors of the experiment, it was found that the poultry manure has higher negative effect than sheep manure on the plant height of tomato crops. However, as explained, this negative effect was only noted at the first week of the measurements, and then the crops began to develop rapidly. Similarly, HA and PB were found to cause some reductions in the plant height during the first days of the development. At the end of the experiments, it was noted that the manures and chemical supplements do not have significant influence on the plant height. These results are in conjunction with the findings of Chanthini *et al*., (2019) who noted that the rate of SLF is highly important for the determination of its effect on plant height. They reported that since lower doses could provide higher yield, it can be possible to not have any positive effects on the plant height. The beneficial impacts of humic acid on plant growth and yield was previously associated with the improved soil structure and soil fertility (Khan *et al*., 2014; Arjumend *et al*., 2015), which was noted to have higher impact on the plant roots than the plant height.

Plant stem diameter results of the present study are in accordance with the results of plant height. During the initial periods of the crop development, crops which were grown on the sheep manure was noted to have less stem diameter than the others (Table 5). However, this was not continued later on, and plants found to have statistically similar stem diameters until the end of the measurements. At the first week of the measurements, the lowest stem diameter was noted from the combination of sheep manure & HA as 7.3 mm; and the highest stem diameter was measured from the combination of no manure & control application as 9.9 mm. Comparison of the main- and sub-factors separately showed that the sheep manure application has the lowest stem diameter with 7.5 cm while the control treatment has the highest stem diameter with 9.3 mm. The negative influence of sheep manure on the stem diameter continued until 3rd week of the measurements (23th of May) and hereafter no statistical difference was noted for the stem diameter among the different treatments.

Table 4. Effects of different manures and chemical supplements on the tomato plant height.

Animal manures	Chemical supplements	Plant height (cm)					
		08.03 (#15)	23.03 (#30)	05.04 (#15)	19.04 (#43)	03.05 (#71)	19.05 (#87)
No manure	Control	34.8 a	66.2 a	91.5 a	121.5 a	148.3 ab	186.8 a
	SLF	30.3 ab	59.4 a	80.6 a	114.3 a	139.5 ab	177.8 a
	HA	30.0 ab	56.7 a	84.7 a	114.6 a	139.9 ab	174.7 a
	PB	27.3 ab	55.1 a	74.5 a	106.5 a	130.5 b	168.4 a
	PGR	30.0 ab	61.6 a	90.0 a	117.1 a	142.8 ab	177.1 a
Poultry manure	Control	29.7 ab	59.0 a	84.3 a	110.9 a	137.8 ab	181.3 a
	SLF	28.4 ab	57.1 a	81.9 a	111.3 a	140.8 ab	176.8 a
	HA	26.4 b	57.8 a	83.3 a	111.5 a	141.9 ab	181.0 a
	PB	26.2 b	57.8 a	83.0 a	112.1 a	141.9 ab	179.1 a
	PGR	27.7 ab	52.7 a	81.2 a	105.5 a	135.7 ab	175.8 a
Sheep manure	Control	29.7 ab	59.3 a	85.5 a	118.9 a	152.6 a	188.3 a
	SLF	30.4 ab	63.8 a	90.8 a	119.5 a	149.4 ab	180.8 a
	HA	26.7 b	54.8 a	79.5 a	111.3 a	149.0 ab	181.3 a
	PB	29.1 ab	55.8 a	80.4 a	114.9 a	148.6 ab	178.5 a
	PGR	29.7 ab	58.0 a	80.9 a	119.3 a	153.1 a	183.4 a
No manure		30.5 x	59.8 x	84.3 x	114.8xy	140.2 y	176.9 x
Poultry manure		27.7 y	56.9 x	82.7 x	110.3 y	139.6 y	178.8 x
Sheep manure		29.1xy	58.3 x	83.4 x	116.8 x	150.5 x	182.5 x
Control		31.4 A	61.5 A	87.1 A	117.1 A	146.2 A	185.4 A
SLF		29.7 AB	60.1 A	84.4 A	115.0 A	143.3 A	178.4 A
HA		27.7 B	56.4 A	82.5 A	112.4 A	143.6 A	179.0 A
PB		27.5 B	56.3 A	79.3 A	111.2 A	140.3 A	175.3 A
PGR		29.1 AB	57.4 A	84.0 A	114.0 A	143.9 A	178.8 A

Values followed by the same small or capital letter or letters in the same column (in between horizontal borders) are not significantly different at 5% significance level according to Tukey's HSD test. (SLF: seaweed liquid fertilizer, HA: humic acid, PB: photosynthetic bacteria and PGR: plant growth regulator)

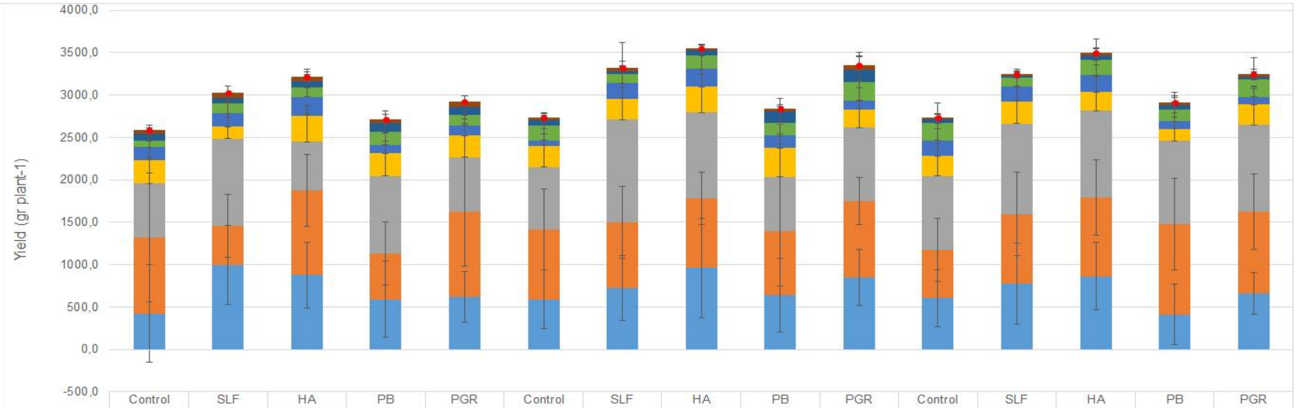
Table 5. Effects of different manures and chemical supplements on the tomato stem diameter.

Animal manures	Chemical supplements	Stem diameter (mm)					
		08.03 (#15)	23.03 (#30)	05.04 (#15)	19.04 (#43)	03.05 (#71)	19.05 (#87)
No manure	Control	9.9 a	10.6 ab	11.6 a	11.7 a	11.4 a	11.6 a
	SLF	8.9 ab	9.6 b	12.1 a	11.2 a	10.9 a	11.6 a
	HA	9.5 ab	11.6 ab	12.0 a	10.5 a	11.7 a	11.6 a
	PB	8.9 ab	10.3 ab	11.1 a	12.1 a	11.1 a	11.2 a
	PGR	9.4 ab	10.9 ab	11.6 a	10.9 a	10.8 a	11.2 a
Poultry manure	Control	9.0 ab	10.2 ab	10.8 a	10.5 a	10.8 a	11.0 a
	SLF	9.4 ab	10.2 ab	11.5 a	10.3 a	10.9 a	11.0 a
	HA	9.1 ab	10.8 ab	11.3 a	10.6 a	11.2 a	11.5 a
	PB	9.3 ab	10.6 ab	11.5 a	10.5 a	10.4 a	10.6 a
	PGR	8.9 ab	9.5 b	12.2 a	10.8 a	10.4 a	10.7 a
Sheep manure	Control	7.5 b	12.8 a	11.1 a	11.7 a	11.4 a	11.4 a
	SLF	7.5 b	12.7 a	12.5 a	11.3 a	11.3 a	11.1 a
	HA	7.3 b	11.6 ab	11.0 a	10.9 a	10.6 a	10.8 a
	PB	7.4 b	11.8 ab	10.8 a	11.1 a	10.9 a	10.5 a
	PGR	7.5 b	12.1 ab	11.2 a	11.5 a	11.4 a	11.2 a
No manure		9.3 x	10.6 y	11.7 x	11.3 x	11.2 x	11.4 x
Poultry manure		9.2 x	10.3 y	11.5 x	10.6 x	10.7 x	11.0 x
Sheep manure		7.5 y	12.2 x	11.3 x	11.3 x	11.1 x	11.0 x
Control		8.8 A	11.2 A	11.2 A	11.3 A	11.2 A	11.3 A
SLF		8.6 A	10.8 A	12.0 A	10.9 A	11.1 A	11.2 A
HA		8.6 A	11.3 A	11.4 A	10.7 A	11.1 A	11.3 A
PB		8.6 A	10.9 A	11.1 A	11.2 A	10.8 A	10.8 A
PGR		8.6 A	10.9 A	11.7 A	11.1 A	10.9 A	11.0 A

Values followed by the same small or capital letter or letters in the same column (in between horizontal borders) are not significantly different at 5% significance level according to Tukey's HSD test. (SLF: seaweed liquid fertilizer, HA: humic acid, PB: photosynthetic bacteria and PGR: plant growth regulator)

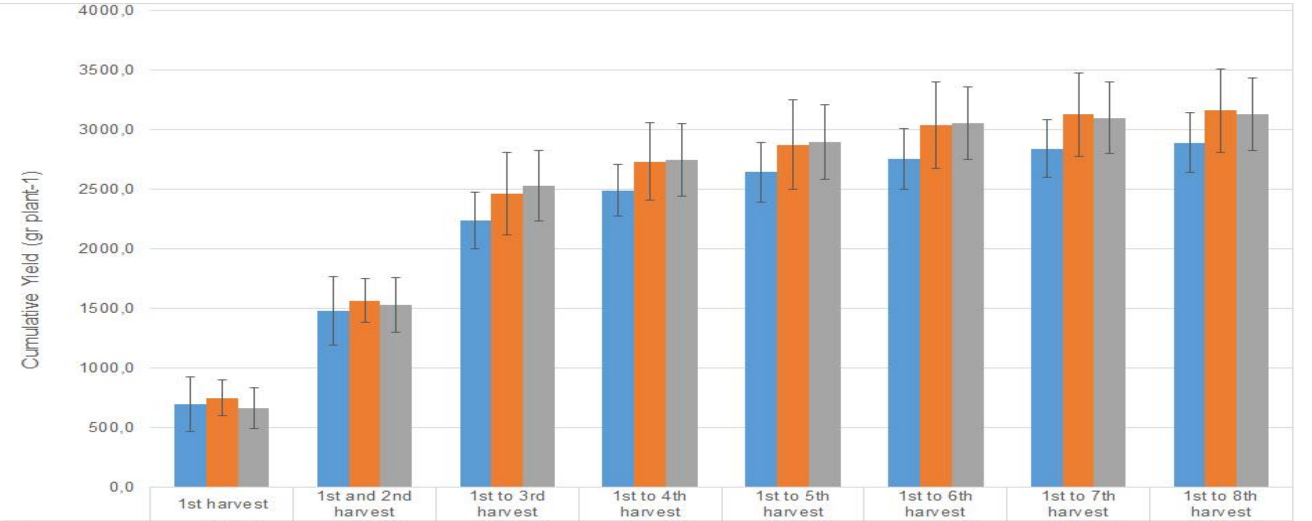
First harvest of the tomato fruits was carried 92 days after the transplanting on 25th of May, 2019. Since the beginning of the harvest, it was noted that the treatments have significant influence on the crop yield (Fig. 2). It was found that fruits treated with SLD and HA have higher yield than the other treatments. Results showed that at the first day of harvest, the highest fruit yield was obtained from the combination of SLF and no manure (NM) application with 993.4 gr and was followed by the combination of HA and poultry manure (PM) application with 961.7 gr. No statistical difference was noted for these two treatments. Moreover, the lowest fruit yield was obtained from PB/SM application as 414.2 gr and was followed by Control/NM application with 428.8 gr. Similar results continued until the end of the harvesting period. Results also showed that the fruit yield decreased after the 4th harvest (15th of June). According to the total yields of the plants, application of HA either on PM or SM was found to provide higher efficacy on the total yield. Highest yield was collected from the HA/PM application with 3,547.7 gr plant^{-1} and was followed by the HA/SM application with 3,496.7 gr plant^{-1}. No statistical difference was obtained among these two treatments. In a previous study, Adekiya and Agbede (2017) reported that the poultry manure is highly effective in increasing the tomato yield and the best time of application is 3 weeks before transplanting. Chanthini *et al*., (2019) was also reported similar results about the positive effects of SLF on the tomato plant growth and fruit yield. They reported that the bio-stimulant of *Chaetomorpha antennina* derived seaweed liquid fertilizers, can be applied to soil for improving soil fertility as is an economic, renewable, efficient and eco-friendly bio-stimulant. The results of present study are also in agreement with the previous works which reported an increase in the crop yield of pea (Ramamoorthy *et al*., 2006) and tomato (Zodape *et al*., 2008), when treated with seaweed liquid fertilizers. The effects of humic acid and farmyard manure were previously tested, as a combination, on the celery and leek crops, and high positive influence was reported (Ciarkowska *et al*., 2017).

Among the two factors of the experimental study, it was found out that the manure application has significant influence on the cumulative yield of the tomato crops. As can be seen from the Fig. 3, the crops which are grown on either sheep manure (SM) or poultry manure (PM) applied soils, have higher cumulative yields than the crops planted on soils with no manure (NM). Results also showed that, during the first harvest, there was no significant difference among the manure applications. It was also noted that the crops grown on SM applied soils have less yield than the other crops at the first harvest. This result is in accordance with the plant height and stem diameter data of this experiment. During the development of the crops, manures started to have positive impact on both crop growth and fruit yield. Numerous studies have previously noted that the manure amendments (Carrera *et al*., 2007) grape compost (Saison *et al*., 2006), mushroom compost (Perez-Piqueres *et al*., 2006), turkey manure (Calbrix *et al*., 2007) and poultry manure (Demir *et al*., 2010) positively affect soil microbial community and increase the crop yield due to better nutrition of the crops.



	No manure					Poultry manure					Sheep manure				
	Control	SLF	HA	PB	PGR	Control	SLF	HA	PB	PGR	Control	SLF	HA	PB	PGR
3-Jul (#135)	42,6 b	57,8 a	54,8 a	42,2 b	54,5 a	30,7 b	35,1 b	13,0 b	27,3 b	59,0 a	19,3 b	26,2 b	25,0 b	31,8 b	33,7 b
3-Jul (#132)	82,7 b	61,4 b	72,7 b	106,1 a	100,4 a	64,2 b	32,9 b	71,4 b	132,1 a	138,3 a	49,8 b	22,5 b	56,6 b	51,4 b	32,3 b
29-Jun (#128)	68,9 b	118,5 b	112,3 b	150,6 a	119,7 b	178,5 a	108,6 b	151,4 a	154,5 a	226,0 a	205,2 a	97,8 b	177,7 a	140,4 b	200,6 a
22-Jun (#121)	154,0 a	159,8 a	218,5 a	102,5 b	121,3 b	61,5 b	182,9 a	214,1 a	142,2 b	100,5 b	183,8 a	175,9 a	200,7 a	91,7 b	88,3 b
15-Jun (#114)	280,3 a	141,7 b	308,8 a	264,8 a	259,3 a	253,6 a	244,3 b	302,8 a	341,0 a	217,3 b	233,7 b	261,8 a	221,8 b	137,9 b	242,3 b
8-Jun (#108)	633,2 b	1030,0 a	573,7 b	913,4 a	640,7 b	732,8 b	1217,8 a	1014,5 a	646,1 b	863,3 a	873,5 a	1072,1 a	1022,7 a	979,9 a	1025,4 a
1-Jun (#100)	897,3 a	463,2 c	1001,4 a	541,2 b	1004,5 a	826,2 a	773,2 b	818,8 a	754,7 b	905,5 a	568,2 b	819,7 a	928,8 a	1067,8 a	965,1 a
25-May (#93)	424,8 b	993,4 a	876,2 a	592,2 b	619,8 b	590,6 b	723,6 a	961,7 a	636,9 b	845,7 a	604,8 b	774,6 a	863,4 a	414,2 b	659,7 b
Total	2583,8 c	3025,6 b	3218,4 b	2712,9 bc	2920,0 b	2738,1 bc	3318,4 ab	3547,7 a	2834,7 b	3355,6 ab	2738,2 bc	3250,4 b	3496,7 a	2915,1 b	3247,4 ab

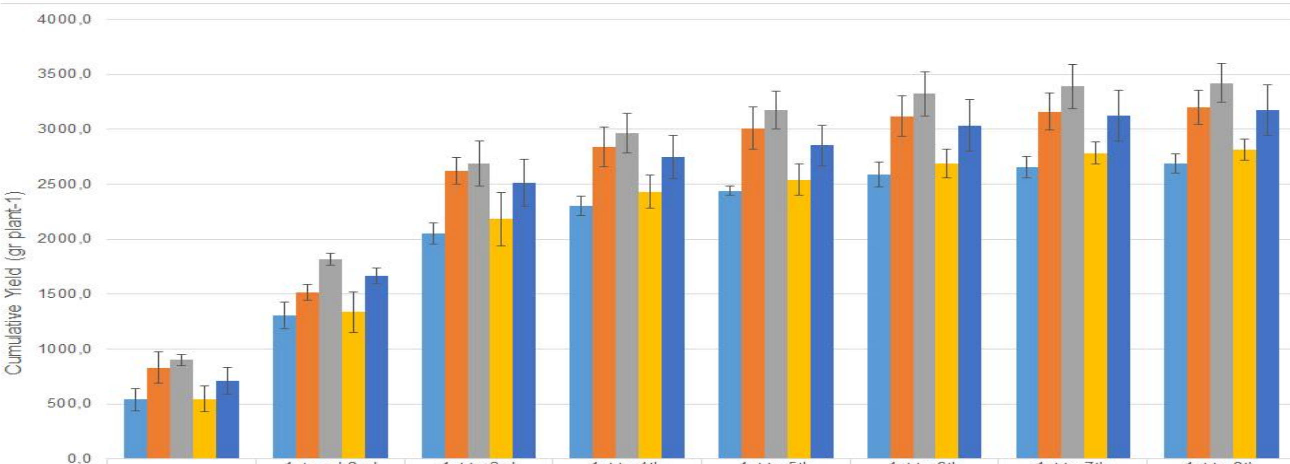
Fig. 2. Effects of different manures and chemical supplements on the yield (gr plant^{-1}) of tomato plants. Values followed by the same small letter or letters in the same row are not significantly different at 5% significance level according to Tukey's HSD test. (SLF: seaweed liquid fertilizer, HA: humic acid, PB: photosynthetic bacteria and PGR: plant growth regulator)



	1st harvest	1st and 2nd harvest	1st to 3rd harvest	1st to 4th harvest	1st to 5th harvest	1st to 6th harvest	1st to 7th harvest	1st to 8th harvest
No manure	701,3 a	1482,8 a	2241,0 a	2492,0 a	2643,2 a	2757,2 b	2841,8 b	2892,2 b
Poultry manure	751,7 a	1567,4 a	2462,3 a	2734,1 a	2874,3 a	3038,1 a	3125,9 a	3158,9 a
Sheep manure	663,3 a	1533,2 a	2528,0 a	2747,5 a	2895,5 a	3057,5 a	3100,0 a	3127,2 a

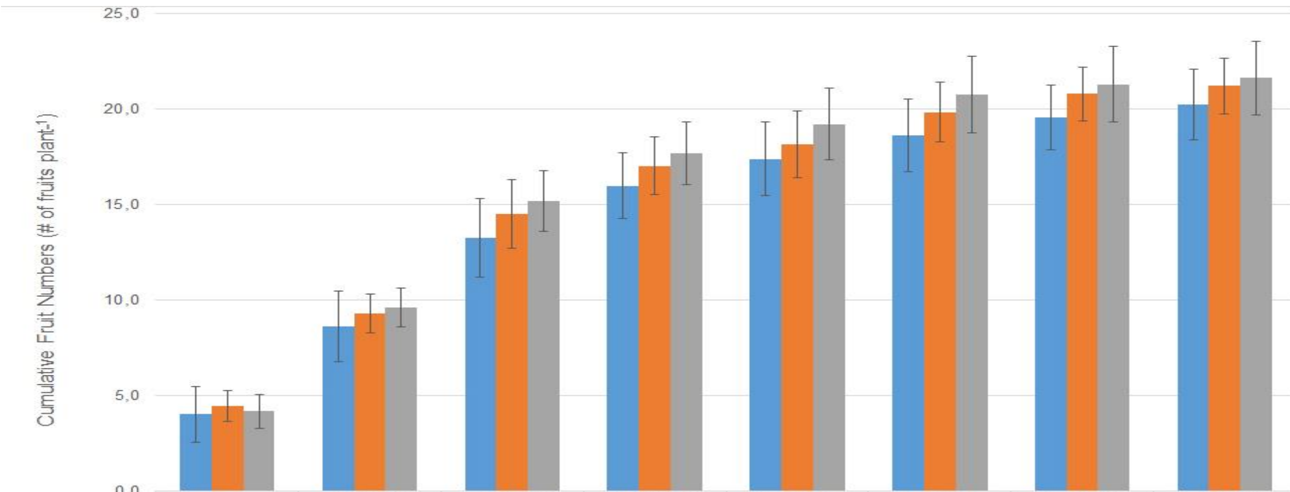
Fig. 3. Effects of different manures on the cumulative yield (gr plant^{-1}) of tomato plants. Values followed by the same small letter or letters in the same column are not significantly different at 5% significance level according to Tukey's HSD test.

Comparison of the sub-factors of the present experiment, resulted with a very important finding, which revealed that the application of HA, SLF and PGR have high positive influence on the cumulative and total yield of tomato (Fig. 4). From the first harvest, till the end, these three applications were found to have higher yield than the others. Among these three applications, HA was the most effective application which resulted with a total of 3,420.9 gr plant^{-1} yield at the end of the experiments. The total yield of the crops treated with SLF and PGR were found to be 3,198.1 and 3,174.4 gr plant^{-1}, respectively; and no statistical difference was obtained among these two treatments. The lowest yield, not surprisingly, was noted from the control treatment with 2,686.7 gr plant^{-1}. The % increase in the total yield of crops treated with HA, SLF, PGR and PB applications were found to be as 27.3%, 19.0%, 18.2% and 4.8%, respectively. The higher positive effect of humic acid on the crop yield was previously reported for different crops. In a very recent study, Gemin *et al*. (2019) reported that the humic acid application promotes the growth of onions at the early states, improved bulb caliber and increase the crop yield. Humic acid is reported to improve plant growth (Silva *et al*., 2011), root growth (Bettoni *et al*., 2016) and increase crop yield (Canellas *et al*., 2015). In another study, Ahmed *et al*., (2020) reported that the rhizobacteria is effective for improving the growth of mungbean under salinity stress conditions when it is combined with silicon. The photosynthetic bacteria have different mode of action as compared with rhizobacteria and is tested alone in present study, which supports the findings (ineffectiveness or less effectiveness of PB).



	1st harvest	1st and 2nd harvest	1st to 3rd harvest	1st to 4th harvest	1st to 5th harvest	1st to 6th harvest	1st to 7th harvest	1st to 8th harvest
Control	540,0 b	1303,9 b	2050,5 b	2306,3 b	2439,4 c	2590,3 b	2655,8 b	2686,7 b
SLF	830,5 a	1515,9 ab	2622,5 a	2838,4 ab	3011,3 ab	3119,5 ab	3158,5 ab	3198,1 ab
HA	900,4 a	1816,7 a	2687,0 a	2964,8 a	3176,0 a	3323,1 a	3390,0 a	3420,9 a
PB	547,8 b	1335,7 b	2182,1 ab	2430,0 ab	2542,2 bc	2686,8 b	2783,3 b	2817,0 b
PGR	708,4 ab	1666,8 ab	2509,9 ab	2749,5 ab	2852,9 abc	3035,0 ab	3125,3 ab	3174,4 ab

Fig. 4. Effects of different chemical supplements on the cumulative yield (gr plant^{-1}) of tomato plants. Values followed by the same small letter or letters in the same column are not significantly different at 5% significance level according to Tukey's HSD test. (SLF: seaweed liquid fertilizer, HA: humic acid, PB: photosynthetic bacteria and PGR: plant growth regulator).

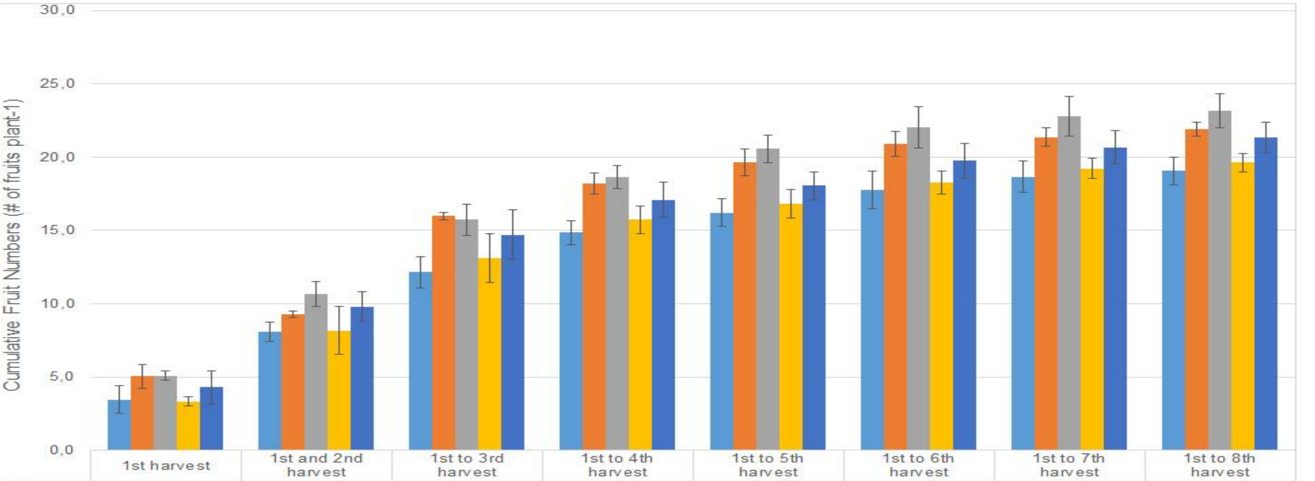


	1st harvest	1st and 2nd harvest	1st to 3rd harvest	1st to 4th harvest	1st to 5th harvest	1st to 6th harvest	1st to 7th harvest	1st to 8th harvest
No manure	4,1 a	8,6 a	13,3 a	16,0 a	17,4 a	18,6 a	19,6 a	20,2 a
Poultry manure	4,5 a	9,3 a	14,5 a	17,0 a	18,2 a	19,8 a	20,8 a	21,2 a
Sheep manure	4,2 a	9,6 a	15,2 a	17,7 a	19,2 a	20,8 a	21,3 a	21,6 a

Fig. 5. Effects of different manures on the cumulative number of fruits (# plant^{-1}) of tomato plants. Values followed by the same small letter or letters in the same column are not significantly different at 5% significance level according to Tukey's HSD test.

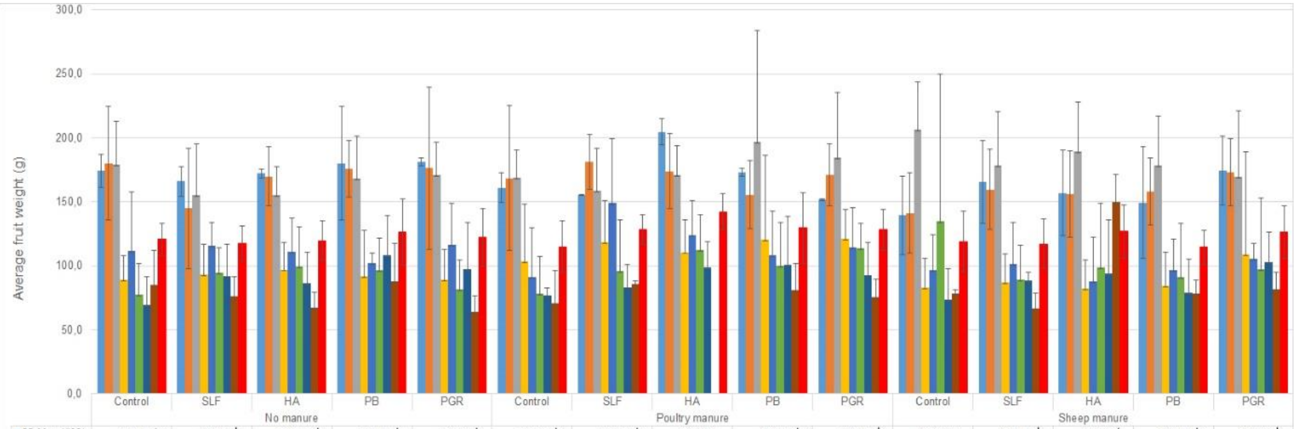
Results of present study showed that manure applications have slight but not significant effects on the number of fruits plant^{-1}. It was found that the number of harvested fruits was 4.1 at the control treatment in the first harvest; and it was 4.2 and 4.5 at the sheep manure (SM) and poultry manure (PM), respectively (Fig. 5).

No significant difference was obtained for the fruit numbers among the different manure applications. From the second harvest till the end, it was found out that the number of harvested fruits plant^{-1} is highest at the SM and lowest at control application. However, no significant difference was calculated for the different manure treatments. Contrary to the manure application, the tested chemical supplements of the present study are found to have significant influence on the number of fruits plant^{-1}. This significant difference began to appear at the first harvest and it continued until the end of the experiments. At the first day of harvest, the highest number of fruits plant^{-1} was noted from the SLF and HA applications with a same number of 5.1, and was followed by the PGR application with 4.3 fruits plant^{-1}. Number of fruits at the control and PB applications was noted as 3.4 and 3.3, respectively. During the entire harvesting period, similar effects were observed for the chemical supplements. At the end of the experimental studies, the HA application was found to the most effective one in terms of number of fruits plant^{-1}. Total number of harvest fruits plant^{-1} was found to be 23.2 for HA application and 21.9 for SLF application. When comparing with the control treatment, the HA application was found to cause about 21.5% increase in the number of fruits plant^{-1}. These results, in line with the average fruit weight results (Fig. 6) suggested that the positive effects of the treatments on the total yield is closely related with the number of fruit set, rather than the average fruit weight.



	1st harvest	1st and 2nd harvest	1st to 3rd harvest	1st to 4th harvest	1st to 5th harvest	1st to 6th harvest	1st to 7th harvest	1st to 8th harvest
Control	3,4 b	8,1 b	12,1 b	14,9 b	16,2 c	17,8 b	18,7 b	19,1 b
SLF	5,1 a	9,3 ab	16,0 a	18,2 a	19,6 ab	20,9 ab	21,4 ab	21,9 ab
HA	5,1 a	10,7 a	15,7 a	18,6 a	20,6 a	22,1 a	22,8 a	23,2 a
PB	3,3 b	8,2 b	13,1 ab	15,7 ab	16,8 bc	18,3 b	19,2 ab	19,6 ab
PGR	4,3 ab	9,8 ab	14,7 ab	17,1 ab	18,1 abc	19,8 ab	20,7 ab	21,3 ab

Fig. 6. Effects of different chemical supplements on the cumulative number of fruits (# plant^{-1}) of tomato plants. Values followed by the same small letter or letters in the same column are not significantly different at 5% significance level according to Tukey's HSD test. (SLF: seaweed liquid fertilizer, HA: humic acid, PB: photosynthetic bacteria and PGR: plant growth regulator).



	Control	SLF	HA	PB	PGR	Control	SLF	HA	PB	PGR	Control	SLF	HA	PB	PGR
	No manure					Poultry manure					Sheep manure				
25-May (#93)	174,2 abc	165,9 ab	172,1 ab	180,0 ab	181,3 ab	161,1 ab	155,1 ab	204,6 a	173,0 abc	151,6 ab	139,5 c	165,6 ab	156,9 ab	149,4 ab	174,4 ab
1-Jun (#100)	180,2 a	144,8 a	169,7 a	175,9 a	176,2 a	168,5 a	181,2 a	174,1 a	155,5 a	171,0 a	141,1 a	159,5 a	156,0 a	158,0 a	172,8 a
8-Jun (#108)	179,1 a	155,6 a	155,5 a	168,5 a	171,3 a	169,2 a	158,5 a	171,0 a	197,1 a	184,6 a	206,3 a	178,8 a	189,1 a	178,2 a	169,4 a
15-Jun (#114)	89,1 a	93,3 a	97,0 a	91,6 a	89,3 a	103,3 a	118,7 a	110,6 a	120,6 a	121,1 a	83,1 a	87,2 a	82,0 a	84,3 a	108,9 a
22-Jun (#121)	111,4 ab	115,5 ab	110,8 ab	101,9 ab	116,2 ab	91,5 b	149,2 a	124,1 ab	108,5 ab	114,5 ab	96,4 ab	101,1 ab	88,1 b	96,4 ab	105,2 ab
29-Jun (#128)	77,5 a	94,9 a	99,6 a	96,3 a	81,6 a	78,4 a	96,0 a	112,2 a	99,8 a	113,9 a	134,6 a	89,3 a	98,3 a	91,2 a	97,0 a
3-Jul (#132)	69,5 a	92,1 a	86,6 a	108,1 a	97,3 a	76,7 a	83,1 a	98,4 a	100,8 a	92,7 a	73,5 a	88,4 a	94,0 a	79,1 a	103,0 a
3-Jul (#135)	85,1 a	76,5 a	67,2 a	88,0 a	64,1 a	70,4 a	86,0 a		80,9 a	75,6 a	78,0 a	66,5 a	149,8 a	78,5 a	81,7 a
Average	120,8 a	117,3 a	119,8 a	126,3 a	122,1 a	114,9 a	128,5 a	142,1 a	129,5 a	128,1 a	119,1 a	117,1 a	126,8 a	114,4 a	126,5 a

Fig. 7. Effects of different manures and chemical supplements on the average fruit weight (gr) of tomato plants. Values followed by the same small letter or letters in the same row are not significantly different at 5% significance level according to Tukey's HSD test. (SLF: seaweed liquid fertilizer, HA: humic acid, PB: photosynthetic bacteria and PGR: plant growth regulator)

Results of present study showed that the animal manure and chemical supplement applications do not have a significant influence on the average fruit weight. At the 1st harvest (25th of May (#93)) and 5th harvest (22nd of June (#121)), the application of HA/PM found to provide higher average fruit weight as compared with treatments (Fig. 7).

However, this impact did not significantly appear on the average results. Although the results are not statistically significant, it is clear from the data that the application of HA improves the fruit weight. Another important result of present study is that, among the test factors, chemical supplements found to have no significant influence on the soluble solids concentration (SSC) of the fruits, while manure application significantly affected the fruit SSC (Table 6). Results suggested that the fruits grown on SM applied soils have higher SSC than the fruits grown on PM or NM applied soils. Average SSC of the fruits grown on SM, PM and NM soils were calculated as 4.7%, 4.5% and 4.3%, respectively. On the other hand, none of the test conditions were found to have a significant influence on the fruit firmness.

The fresh weight and dry weight results of present study are found to be in agreement, as expected (Table 7). According to the obtained data, similar with the plant height results, manure applications found to have no significant influence on the fresh and dry weight of the plants. On the other hand, chemical supplements, found to improve the fresh and dry weight of the plants. Highest fresh weight was noted from the HA application with 322.41 gr, while the lowest was measured from control treatment with 251.93 gr. The positive effect of humic acid application on the crop biomass was previously associated with the pathways which stimulate the accumulation of biomass (i.e. releasing auxin-like molecules and causing an increase in H^+ ATPase enzyme activity). This was reported to result in increase in the biomass as a consequence of cell expansion (Canellas *et al*., 2009). Results of current work are also in agreement with the reported of Fan *et al*., (2014), who noted an increase in the fresh and dry weight of chrysanthemum with the application humic acid. Similar effects of humic acid on the fresh and dry root weight of Iranian chicory were reported by Gholami *et al*., (2018).

Table 6. Effects of different manure and chemical supplement combinations on the soluble solids concentration (SSC) and firmness of tomato fruits.

Chemical supplements	SSC (%)				Firmness (kg cm^{-2})			
	No. manure	Poultry manure	Sheep manure	Averages	No manure	Poultry manure	Sheep manure	Averages
Control	4.3 a	4.4 a	4.8 a	4.5 A	0.41 a	0.46 a	0.45 a	0.44 A
SLF	4.2 a	4.5 a	4.7 a	4.5 A	0.48 a	0.49 a	0.44 a	0.47 A
HA	4.3 a	4.5 a	4.7 a	4.5 A	0.50 a	0.45 a	0.46 a	0.47 A
PB	4.5 a	4.4 a	4.6 a	4.5 A	0.46 a	0.46 a	0.46 a	0.46 A
PGR	4.4 a	4.6 a	4.7 a	4.5 A	0.47 a	0.46 a	0.44 a	0.45 A
Averages	**4.3 B**	**4.5 B**	**4.7 A**		**0.46 A**	**0.46 A**	**0.45 A**	

Values followed by the same small letter or letters (within the same row or column) are not significantly different at 5% significance level according to Tukey's HSD test. Capital letters were used for the comparison of the average values of chemical supplements or animal manures. (SLF: seaweed liquid fertilizer, HA: humic acid, PB: photosynthetic bacteria and PGR: plant growth regulator)

Table 7. Effects of different manure and chemical supplement combinations on the fresh and dry weights of tomato plants.

Chemical supplements	Fresh weight (gr)				Dry weight (gr)			
	No. manure	Poultry manure	Sheep manure	Averages	No manure	Poultry manure	Sheep manure	Averages
Control	251.13 a	245.76 a	258.90 a	251.93 B	63.62 a	65.93 a	63.11 a	64.22 B
SLF	303.99 a	288.53 a	280.83 a	291.12 AB	62.78 a	63.55 a	60.88 a	62.40 B
HA	376.88 a	324.68 a	265.68 a	322.41 A	80.20 a	69.68 a	57.05 a	68.98 A
PB	310.78 a	272.42 a	279.65 a	287.62 AB	69.53 a	66.03 a	67.45 a	67.67 A
PGR	287.52 a	269.69 a	297.73 a	284.98 AB	60.74 a	62.88 a	71.06 a	64.89 B
Averages	**303.06 A**	**280.21 A**	**276.56 A**		**67.37 A**	**65.62 A**	**63.91 A**	

Values followed by the same small letter or letters (within the same row or column) are not significantly different at 5% significance level according to Tukey's HSD test. Capital letters were used for the comparison of the average values of chemical supplements or animal manures. (SLF: seaweed liquid fertilizer, HA: humic acid, PB: photosynthetic bacteria and PGR: plant growth regulator)

Conclusions

To sum up, results of present study showed that neither the manure applications nor the chemical supplements of present study are affective in providing earliness on the tomato fruits cv. 'Halay'. Results of present study showed that the manure applications (SM or PM) alone have slight effect on the number of fruits $plant^{-1}$ and total yield (gr $plant^{-1}$) of the tomato plants; and the positive effect of the manure applications increases with the combination of chemical supplements. Therefore, the highest tomato yield was noted from the HA/PM application with 3,547.7 gr $plant^{-1}$ and was followed by the HA/SM application with 3,496.7 gr $plant^{-1}$. These yields were found to be 37.3% and 35.3% higher than the control treatment. It was discussed from the results that the manure and chemical supplement applications are not significantly affecting the average fruit weight of the tomato, except humic acid. Results also suggested that the test materials of present study do not have any significant influence on the plant height, plant stem diameter and fruit firmness.

References

Adekiya, A.O. and T.M. Agbede. 2009. Growth and yield of tomato (*Lycopersicon esculentum* Mill) as influenced by poultry manure and NPK fertilizer. *Emir. J. Food Agric*., 21(1): 10-20.

Adekiya, A.O. and T.M. Agbede. 2017. Effect of methods and time of poultry manure application on soil and leaf nutrient concentrations, growth and fruit yield of tomato (*Lycopersicon esculentum* Mill). *J. Saudi Society of Agri. Sci.*, 16: 383-388.

Ahmed, N., S. Ahsen, M.A. Ali, M.B. Hussain, S.B. Hussain, M.K. Rasheed, B. Butt, I. Irshad and S. Danish. 2020. Rhizobacteria and silicon synergy modulates the growth, nutrition and yield of mungbean under saline soil. *Pak. J. Bot.*, 52(1): 9-15.

Anonymous. 2019. Food and Agriculture Organization of the United Nations (FAO). Statistics web page: http://www.fao.org/faostat/en/#data/QC (Accessed on 16th of October, 2019).

Arjumend, T., M.K. Abbasi and E. Rafique. 2015. Effects of lignite-derived humic acid on some selected soil properties, growth and nutrient uptake of wheat (*Triticuma estivum* L.) grown under greenhouse conditions. *Pak. J. Bot*., 47(6): 2231-2238.

Baranski, R., M. Klimek-Chodacka and A. Lukasiewicz. 2019. Approved genetically modified (GM) horticultural plants: A 25-year perspective. *Folia Hort.*, 31(1): 3-49.

Bettoni, M.M., A.F. Mógor, J.F. Kogerastki and Pauletti. 2016. Onion (*Allium cepa* L.) seedling growth using humic substances. *Idesia,* 34: 57-62.

Calbrix, R., S. Barray, O. Chabrerie, L. Fourrie and K. Laval. 2007. Impact of organic amendments on the dynamics of soil microbial biomass and bacterial communities in cultivated land. *Appl. Soil Ecol.,* 35: 511-522.

Canellas, L.P., F.L. Olivares, N.O. Aguiar, D.L. Jones, A. Nebbioso, P. Mazzei and A. Piccolo. 2015. Humic and fulvic acids as biostimulants in horticulture. *Sci. Hort*., 196: 15-27.

Canellas, L.P., R. Spaccini, A. Piccolo, L. Dobbss, A. Okorokova-Façanha, G.A. Santos, F.L. Olivares and A.R. Façanha. 2009. Relationships between chemical characteristics and root growth promotion of humic acids isolated from Brazilian oxisols. *Soil Sci.*, 174: 611-620.

Carrera, L.M., J.S. Buyer, B. Vinyard, A.A. Abdul-Baki, L.J. Sikora and J.R. Teasdale. 2007. Effects of cover crops, compost, and manure amendments on soil microbial community structure in tomato production systems. *Appl. Soil Ecol*., 37: 247-255.

Chalkos, D., K. Kadoglidou, K. Karamanoli, C. Fotiou, A.S. Pavlatou-Ve, I.G. Eleftherohorinos, H.I.A. Constantinidou and D. Vokou. 2010. Menthaspicata and Salvia fruticosa as soil amendments in tomato cultivation. *Plant Soil*, 332: 495-509.

Chanthini, K.M.P., S. Senthil-Nathan, V. Stanley-Raja, A. Thanigaivel, S. Karthi, H. Sivanesh, N.S. Sundar, R. Palanikani and R. Soranam. 2019. *Chaetomorpha antennina* (Bory) Kützing derived seaweed liquid fertilizers as prospective bio-stimulant for *Lycopersicon esculentum* (Mill). *Biocatalysis & Agri. Biotechnol.*, 20: 101190.

Ciarkowska, K., K. Sołek-Podwika, B. Filipek-Mazur and M. Tabak. 2017. Comparative effects of lignite-derived humic acids and FYM on soil properties and vegetable yield. *Geoderma*, 303: 85-92.

Demir, K., O. Sahin, Y. K. Kadioglu, D.J. Pilbeam and A. Gunes. 2010. Essential and non-essential element composition of tomato plants fertilized withpoultry manure. *Sci. Hort.,* 127: 16-22.

Diacono, M. and F. Montemurro. 2010. Long-term effects of organic amendments on soil fertility. A review. *Agron. Sustain. Dev.,* 30:401-422.

Elliot, H.A. and B.A. Dempsey. 1991. Agronomic effects of land application of water treatment sludges. *J. AWWA.,* 83: 126.

Ewulo, B.S., S.O. Ojeniyi and D.A. Akanni. 2008. Effect of poultry manure on selected soil physical and chemical properties, growth, yield and nutrient status of tomato. *Afr. J. Agri. Res.*, 3(9): 612-616.

Fageria N.K. and V.C. Baligar. 2005. Nutrient availability. In: Encyclopedia of soils in the environment (Ed. Hillel, D.), *Academic Press*, 2200p.

Fan, H.M., X.W. Wanga, X. Sun, Y.Y. Li, X.Z. Sun and C.S. Zheng. 2014. Effects of humicacid derived from sediments on growth, photosynthesis and chloroplast ultrastructure in chrysanthemum. *Sci. Hort.,* 177: 118-123.

Gemin, L.G., A.F. Mógor, J.D.O. Amatussi and G. Mógor. 2019. Microalgae associated to humic acid as a novel biostimulant improving onion growth and yield. *Sci. Hort.*, 256: 108560.

Gholami, H., F.R. Fard, M.J. Saharkhiz and A. Ghani. 2018. Yield and physicochemical properties of inulin obtained from Iranian chicory roots under vermicompost and humic acid treatments. *Indust. Crops & Prod.*, 123: 610-616.

Gutierrez-Miceli, F.A., J. Santiago-Borraz, J.A.M. Molina, C.C. Nafate, M. Abud-Archila, M.A.O. Llaven, R. Rincon-Rosales and L. Dendooven. 2017. Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (*Lycopersicum esculentum*). *Bioresour. Technol.,* 98: 2781-2786.

Halka, M., S. Smoleń, I. Ledwożyw-Smoleń and W. Sady. 2019. Iodosalicylates and iodobenzoates supplied to tomato plants affect the antioxidative and sugar metabolism differently than potassium iodide. *Folia Hort.*, 31(2): 385-400.

Jackson, R.S. 2008. Site Selection and Climate. In: Wine Science (3rd Edition) Principles and Applications Food Science and Technology (Ed.): Jackson, R.S., Academic Press, pp. 239-269.

Jiménez, M. R., L. Casanova, T. Saavedra, F. Gama, M.P. Suárez, P.J. Correia and M. Pestana. 2019. Responses of tomato (*Solanum lycopersicum* L.) plants to iron deficiency in the root zone. *Folia Hort.*, 31(1): 223-234.

Kadoglidou, K., D. Chalkos, K. Karamanoli, I.G. Eleftherohorinos, H.I.A. Constantinidou and D. Vokou. 2004. Aromatic plants as soil amendments: Effects of spearmint and sage on soil properties, growth and physiology of tomato seedlings. *Sci. Hort.,* 179: 25-35.

Kanr, R., G.P. Savage and P.C. Diatta. 2002. Antioxidants vitamins in four commercially grown tomato cultivars. *Nutr. Soc. Newzealand*, 27: 69-74.

Keabetswe, L., G.C. Shao, J. Cui, J. Lu and T. Stimela. 2019. A combination of biochar and regulated deficit irrigation improves tomato fruit quality: A comprehensive quality analysis. *Folia Hort.*, 31(1): 181-193.

Khan, M.Z., M.E. Akhtar, S. Ahmad, A. Khan and R.U. Khan. 2014. Chemical composition of lignitic humic acid and evaluating its positive impacts on nutrient uptake, growth and yield of maize. *Pak. J. Chem.,* 4(1): 19-25.

Pandey, S.K. and K.K. Chandra. 2013. Impact of integrated nutrient management on tomato yield under farmers field conditions. *J. Environ. Biol.,* 34(6): 1047-1051.

Perez-Piqueres, A., V. Edel-Hermann, C. Alabouvette and C. Steinberg. 2006. Response of soil microbial communities to compost amendments. *Soil Biol. Biochem*., 38: 460-470.

Peyvast, Gh., R.P. Kharazi, S. Tahernia, Z. Nosratierad and J.A. Olfati. 2003. Municipal solid waste compost increased yield and decreased nitrate amount of broccoli (*Brassica oleracea* var. Italica). *J. Appl. Hort.,* 10(2): 129-131.

Ramamoorthy, K., K. Sujatha, K. Sivasubramaniam and K. Subburamu. 2006. Organic priming with *Sargassum polycystum* extracts on vigour and viability in cowpea *Vigna unguiculata* L. *Seaweed Res. Util.,* 28: 85-88.

Ricci, E., T. Schwinghamer, D. Fan, D.L. Smith and V. Gravel. 2019. Growth promotion of greenhouse tomatoes with *Pseudomonas* sp. and *Bacillus* sp. bioflms and planktonic cells. *Appl. Soil. Ecol*., 138: 61-68.

Sabijon, J. and M.A. Sudarika. 2018. Effect of vermicompost amendment and nitrogen levels on soil characteristics and growth and yield of tomato (*Solanumlycopersicum* cv. Diamante max). *Int. J. Agri. For. Life Sci*., 2(2): 145-153.

Saison, C., V. Degrange, R. Oliver, P. Millard, C. Commeaux, D. Montange and X. Le Roux. 2006. Alteration and resilience of the soil microbial community following compost amendment: effects of compost level and compost-borne microbial community. *Environ. Microbiol*., 8: 247-257.

Schmidt, W. 1999. Mechanisms and regulation of reduction-based iron uptake in plants. *New Phytol*., 141(1): 1-26.

Silva, A.C., L.P. Canellas, F.L. Olivares, L.B. Dobbss, N.O. Aguiar, D.A.R. Frade, C.E. Rezende and L.E.P. Peres. 2011. Root growth of tomato seedlings intensified byhumic substances from peat bogs. *Rev. Bras. Ciênc. Sol.,* 35: 1609-1617.

Toumpeli, A., A.K. Pavlatou-Ve, S.K. Kostopoulou, A.P. Mamolos, A.S. Siomos and K.L. Kalburtji. 2013. Composting Phragmitesaustralis Cav. plant material and compost effects on soil and tomato (*Lycopersicon esculentum* Mill.) growth. *J. Environ. Manag*., 128: 243-251.

Vasantharaja, R., L.S. Abraham, D. Inbakandan, R. Thirugnanasambandam, T. Senthilvelan, S.K. Ayesha Jabeen and P. Prakash. 2017. Influence of seaweed extracts on growth, phytochemical contents and antioxidant capacity of cowpea (*Vigna unguiculata* L. Walp). *Biocatalysis & Agri. Biotechnol*., 17: 589-594.

Wang, M., L. Chen, Y. Li, L. Chen, Z. Liu, X. Wang, P. Yan and S. Qin. 2018. Responses of soil microbial communities to a short-term application of seaweed fertilizer revealed by deep amplicon sequencing. *Appl. Soil Ecol*., 125: 288-296.

Zodape, S.T., V.J. Kawarhe, J.S. Patolia and A.D. Warade. 2008. Effect of liquid seaweed fertilizer on yield and quality of okra *Abelmoschuss esculentus*. *Seaweed. Res. Util.*, 67: 1115-1117.

(Received for publication 20 December 2018)