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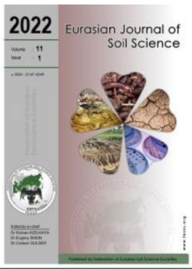

Integrated use of bio-organic and chemical fertilizer to enhance yield and nutrients content of tomato

Shoaib Ahmed [a], Matiullah Khan [a], Taqi Raza [a,*], Rizwan Ahmad [a], Javid Iqbal [b], Neal S. Eash [c]

[a] Land Resources Research Institute, National Agricultural Research Centre Islamabad, Pakistan
[b] Animal Science Institute, National Agricultural Research Centre Islamabad, Pakistan
[c] Biosystems Engineering & Soil Science, The University of Tennessee, USA

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Author(s)

S. Ahmed
M. Khan
T. Raza *
R. Ahmad
J. Iqbal
N.S. Eash

* Corresponding author

Abstract

Excessive use of chemical fertilizers causing a serious threat to the agro-ecological system, developing resistance to pest and declining food safety. Under current scenario, the application of bio-organic nutrients sources become imperative to sustain the productivity of arable farming. Thus to study the possible use of bio-organic sources of nutrients in soil fertility, crop quality and saving the application cost of chemical fertilizer, a pot experiment was conducted in green-house at Land Resources Research Institute, NARC Islamabad. Integrated effects of bio-organic fertilizers such as phosphate solubilizing bacteria (PSB), vermicompost (VC) along with chemical fertilizer was investigated on soil-plant nutrients contents, growth and yield of tomato. Post-harvest results showed that the integrated use of bio-organic fertilizers with chemical fertilizer significantly increased the agronomic yield (Plant height and chlorophyll content) and fruit yield (Number of fruits, fruit weight, fruit diameter and yield) in tomato. The maximum plant height (161.24cm), chlorophyll contents (61.2), number of fruits (19), fruit weight (55g), fruit diameter (45.6a) and fruit yield (1.39 Kg/plant) were recorded in the treatment T5 where VC+PSB+75%RD were applied and minimum in treatment T1 (control). Treatment T5 has increased 117% fruit yield over control. The highest N (2.05% and 2.89%), P (0.33% and 0.50%) and K (2.32% and 6.67%) concentration in shoot and fruit of tomato respectively were found in treatment T5 (VC+PSB+75%RD). Similarly, in soil the highest N (4 mg Kg^{-1}), P (0.66mg Kg^{-1}) and K (3.53mg Kg^{-1}) was recorded in treatment T6 (VC+PSB+100RD). Thus, study results recommend that the integrated use of bio-organic sources with appropriate proportion of chemical/synthetic fertilizers is best option of fertilizer savings and to achieve maximum benefits regarding quality and yield.

Keywords: Tomato, phosphate solubilizing bacteria, vermicompost, chemical fertilizer, greenhouse conditions.

Introduction

Tomato (*Solanum lycopersicum*) is an important crop and is grown throughout the year in different parts of Pakistan. The average yield is 10.3 tons ha^{-1} (Malik et al., 2018), which is quite low as compared to other countries. While 44-65 tons ha^{-1} is commercial yield under good management and production practices (FAO, 2020). Bulging population demands increase in the production of tomatoes, which can be met by increasing per unit production. Tomato cultivars are much sensitive to hot climate which is one of the limitations in the optimum production of the summer tomato crop in the plains of Pakistan (Khan et al., 2020). Chemical fertilizers contain salts of ammonium, nitrate, phosphate, potassium and heavy metals in a specific concentration. For better crop production qualitatively and quantitatively, the efficiency of fertilizer use has increased many folds. In Pakistan, formers consider over application of fertilizer only way to

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increase the crop yield. In such a scenario, globally the fertilizer application increased which causing serious environmental issues. Fertilizers not only improve crop production but also increase the accumulation of salts and heavy metals in the soil-plant system. In such conditions, plant also uptake the salts and heavy metals along with the fertilizer absorption from the soil and enter into the food chain. Consequently, fertilization causes soil, water and environmental pollution.

In changing scenario, our interest is towards sustainable agriculture by using biological and organic source for crop production. Biofertilizers increase biological nitrogen fixation and enhance the availability of nutrients to plant (Kaur et al., 2017). Phosphorus plays a key role in plant growth and development. The majority of the soils throughout the world are phosphorus-deficient (Shahid et al., 2012). When chemical fertilizer applies, phosphorus rapidly transformed into less available form by forming a complex with Al or Fe in acid soils with Ca in calcareous soils and become unavailable to plants (Namli et al., 2017). Phosphate solubilizing microorganisms (PSMs) convert insoluble phosphate to soluble forms by acidification, exchange reaction and chelation (Olanrewaju et al., 2017). PSB provide sustained phosphorus supply (Park et al., 2016) along with stimulation of nitrogen fixation and enhance the accessibility of trace elements by synthesizing important growth promoting substances like antibiotics, side spores, etc (Amanullah and Khan, 2015).

Vermicompost (organic manure) supply macro and micronutrients and ultimately improve physical, chemical and biological properties of soil (Chatterjee and Bandyopadhyay, 2014). Vermicompost also helps in nutrients uptake, disease and pest control, and productivity (Barrios-Masias et al., 2011). Several workers reviewed the significant role of vermicompost and PSB, which enhance the yield and at the same time quality of different vegetable crops like tomato (Bihari et al., 2018), chilli (Anggraheni et al., 2019) by influencing the soil properties. So by the application of PSB and vermicompost, we can reduce the hazardous effect of chemical fertilizer by reducing their use, which ultimately turns towards good soil health.

Material and Methods

This research pertained to study the effect of integrated use of bio-organic and chemical fertilizers on growth, yield and nutrients contents of the tomato plant. A pot experiment was conducted in a greenhouse at National Agricultural Research Center (NARC) Islamabad during fall 2015-2016. NARC is situated at Latitude (33.420 North) and Longitude (73.080 East). The climate of the region varies from semi-arid to subtropical with extreme winter and summer. Vermicompost (VC) and phosphate solubilizing bacteria (PSB), and di-ammonium phosphate (DAP) were applied as sources of bio-organic and as a chemical fertilizer respectively. Soil samples were collected from the vegetable research farm and vermicompost from Soil Biology Program at NARC, Islamabad. Soil samples were pulverized, air-dried and mixed thoroughly. Before sowing, each experimental pot was filled with 10 Kg soil. Vermicompost was applied @ 05 ton ha^{-1} and DAP @ rate of 125 Kg ha^{-1}. Before the experimental setting, soil and vermicompost were analyzed for physio-chemical characteristics and given in Table 2 and 3. The two months old tomato seedlings (CV≈ Rio Grande; 15-25cm tall with 3-4 true leaves) were taken from the vegetable program and transplanted in the pots by dipping in PSB solution. The experiment was laid out in a completely randomized design (CRD) with three replications. The treatments detail is given in Table 1.

Table 1. Treatment plan

Treatments	Descriptions
T_1	Control
T_2	VC+75% RD
T_3	PSB Inoculation+75% RD
T_4	75% RD
T_5	VC+PSB+75%Rd
T_6	VC+PSB+RD
T_7	RD

Table 2. Physiochemical Analysis of Vermicompost.

Characteristics	Unit	Value
pH	---	7.5
EC (1:1)	dSm^{-1}	3.0
Total N	(%)	2.3
Total K	(%)	2.0
Total P	(%)	0.3
C:N		15.0
Organic Matter	(%)	25.0

Table 3. Physio-chemical analysis of soil.

Soil Characteristics	Unit	Value
pH	---	7.80
EC (1:1)	dSm^{-1}	1.70
Total NO_3-N	mg/kg	3.20
Total P	mg/kg	2.33
Extractable K	mg/kg	101.00
Organic matter	%	0.81
Clay	%	20.00
Sand	%	35.00
Silt	%	45.00
Textural Class	---	Loam

Soil and plant chemical analysis

Post-harvest chemical analysis of soil and plant are given in Table 4 and 5. The Hydrometric method was used to determine the soil texture. Soil pH and EC was determined by 1:1 soil-water past using dual pH-EC meter. Soil NO_3-N, total P and available K was determined by the ammonium Bicarbonate-Diethylene Triamine Penta Acetic Acid (AB-DTPA) method (Soltanpour and Workman, 1979). While concern plant analysis: total nitrogen was measured by Kjeldahl method (Kjeldahl, 1883), P and K were measured by Di-acid (Nitric acid and perchloric acid) digestion method using a spectrophotometer.

Results

Dynamics of soil and plant chemical analysis

Among different values, treatment comparison showed that soil pH, N, P and K was statistically affected by the different treatments. However, maximum pH 7.67 was recorded in T1 (control) and after that, it was decreased in all treatments and minimum pH (7.27) was recorded in treatment T6 where both organic and inorganic fertilizer applied (Table 4). In the case of soil P content, the highest P was observed in combining the application of T6 (VC +PSB+RD) followed by T5 (VC +PSB +75% of RD) and minimum in treatment T1. Overall soil P contents were increased with PSB, VC and fertilizer application. Similarly, soil N and K content were also improved in all treatments. Maximum N and K Contents was recorded in T6 and minimum in treatment T1 (Control). The decrease in pH is due to the release of organic acids by the reactions of VC and PSB. Likewise, the nutrient concentration of NPK also improved in soil due to the production of organic acids which results in more release of nutrient from the soil. The results are in line with the findings of Kumar et al. (2001), who reported that biofertilizers have the ability to increase nutrient bioavailability through a biological process which ultimately increases yield. Many studies clearly concluded that the application of biofertilizer and vermicompost improved soil health and nutrient availability (Maji, 2013; Rani and Jha, 2020).

Table 4. Chemical analysis of soil on experiment harvest.

Treatments	pH	Total phosphorus ($mg\ kg^{-1}$)	Total nitrogen ($mg\ kg^{-1}$)	Extractable potassium ($mg\ kg^{-1}$)
T1	7.67 a	0.053 c	3.20 e	2.40 a
T2	7.63 a	0.074 c	3.80 bc	3.00 bc
T3	7.57 ab	0.125 bc	3.60 cd	3.17 ab
T4	7.37 cde	0.058 c	3.40 d	2.71 ab
T5	7.43 cd	0.134 b	3.90 b	3.40 abc
T6	7.27 efg	0.066 b	4.20 a	3.53 c
T7	7.47 bc	0.059 c	3.90 b	2.80 b

Effect of vermicompost, PSB and chemical fertilizers on nutrient contents of tomato

In tomato, whole shoot and fruit analysis of nitrogen, phosphorus and potassium showed that their concentration was significantly affected by treatments given in Table 5. In the case of tomato shoot analysis, the mean highest nitrogen (2.05%), phosphorus (0.33%) and potassium (2.32%) were recorded in T5 (VC+PSB+75% RD), followed by T6 (VC+PSB+RD). Meanwhile, the mean lowest value of N (1.45%), P (0.15%) and K (1.81%) was noted in T1 (control). It was recorded that all the treatment significantly influence the NPK contents of the tomato shoot but the influence of treatment T5 was recorded clearly at par as compared to all other treatments. Similarly, in the case of tomato fruit analysis, the mean maximum nitrogen (2.89%) phosphorus (0.50%) and potassium (6.67%) was recorded in treatment T5 (VC+PSB+75% RD), followed by treatment T6 (VC+PSB+RD) and mean the lowest value of N, P and K were recorded in T1 (control).

Table 5. Effect of treatments on tomato plant nutrients (Nitrogen, phosphorus and potassium)

Treatments	Tomato whole shoot analysis			Tomato Fruit analysis		
	N, %	P, %	K, %	N, %	P, %	K, %
T1	1.45 i	0.15 g	1.83 h	2.12 h	0.25 g	4.01 c
T2	1.94 fg	0.31 bc	2.20 f	2.65 d	0.46 c	4.83 bc
T3	1.86 g	0.33 de	1.91 g	2.48 e	0.36 e	5.91 a
T4	1.99 ef	0.20 f	2.24 ef	2.27 g	0.30 f	5.01 b
T5	2.05 cde	0.33 b	2.32 d	2.89 c	0.50 b	6.67 a
T6	2.03 def	0.30 bc	2.27 de	2.66 d	0.41 d	6.01 a
T7	1.69 h	0.18 fg	2.29 de	2.38 f	0.30 f	4.65 bc

Effect of vermicompost, PSB and chemical fertilizers on agronomic parameters of tomato

The influence of different treatment composition on agronomic parameters of tomato is shown in Table 6. The maximum mean plant height was 161.24 cm was recorded in T5 (VC+PSB+75% RD), followed by 154.16 cm in T6 (VC+PSB+RD). The mean lowest plant height was 102.23 cm was recorded in T1 (control), followed by 115.10 cm in T7 (RD). The mean maximum chlorophyll content was 61.2 was noted in T5 (VC+PSB+75% RD), followed by 59.0 in T6 (VC+PSB+RD). On the other hand mean lowest chlorophyll content was 39.7 in T1 (control), followed by 55.2 in T2 (75% RD). Similarly, the mean maximum number of fruits was 19 in T5 (VC+PSB+75% RD), followed by 18 in T6 (VC+PSB+RD). Mean lowest fruits were recorded 10 in T1 (control), followed by 13 in T2 (VC+75% RD). The fruit diameter was measured in milli meters (mm). The mean highest diameter of fruit was 45.6 mm in T5 (VC+PSB+75% RD), followed by 42.2 mm in T6 (VC+PSB+RD). While the lowest recorded diameter was 29.4 mm in T1 (control), followed by 35.1 mm in T3 (PSB Inoculation+75% RD). Fruit weight was measured in g kg^{-1}. The mean maximum fruit weight was 55.0 g kg^{-1} was recorded in T5 (VC+PSB+75% RD), followed by 52.9 g kg^{-1} in T6 (VC+PSB+RD). On the other hand, the minimum mean value of 17.5 g kg^{-1} was recorded in T1 (Control). In the case of fruit yield, the mean maximum yield was 1.39 ton ha^{-1} recorded in T5 (VC+PSB+75% RD), followed by 1.32 ton ha^{-1} in T6 (VC+PSB+RD). On the other hand mean minimum value was 0.64 ton ha^{-1} in T1 (control), followed by 0.96 ton ha^{-1} in T2 (VC+75% RD) shown in Table 6.

Table 6. Effect of treatments on agronomic parameter of tomato

Treatments		Plant Height (cm)	Chlorophyll content	No. of fruits	Fruit weight (g)	Fruit diameter (mm)	Yield (Kg)
T1	Control	102.23 j	39.7 i	10 f	17.5 i	29.4 h	0.64 h
T2	75% RD	124.16 h	55.2 f	13 de	39.0 f	39.2 c	0.96 e
T3	PSB+75%RD	140.85 de	56.4 de	16 b	49.6 cd	35.1 efg	1.13 d
T4	VC+75% RD	144.16 cd	56.5 cd	15 bc	48.3 de	36.2 ef	1.14 d
T5	VC+PSB+75%RD	161.24 a	61.2 a	19 a	55.0 a	45.6 a	1.39 a
T6	VC+PSB+RD	154.16 b	59.0 b	18 a	52.9 ab	42.2 b	1.32 b
T7	RD	115.10 i	56.5 d	14 cd	39.3 f	38.7 cd	1.26 c

Discussion

It has been recorded that not only tomato growth and yield but also the soil properties (physical and chemical) were significantly affected by the addition of organic and inorganic sources to the soil. Tomato has high production ability 44-65 tons ha^{-1} under good management and production practices (FAO, 2020). But due to imbalance in soil nutrients and extreme environmental changes, production cannot be achieved at the expected rate. However, with the addition of external nutrients sources to soil through organic and inorganic amendment and using integrated nutrient management practices, soil health can be improved (Jack and Thies, 2006). Micronutrients also supplied to soil by organic source which cannot be supplied by chemical fertilizers (Umar et al., 2008). The use of biofertilizers as an alternate of chemical input can be ensured the bioavailability of nutrients through biological processes, and increase vegetable yield (Kumar et al., 2014) and fruits production (Maji and Das, 2008). Proper use of organic and inorganic amendment will help to maintain sustainability in quality and production by maintaining soil fertility by reducing health hazards (Pal et al., 2015; Palaniappan and Annadurai, 2018), at the same time help to control insect-pest diseases (El-Gleel Mosa et al., 2014; Maji, 2013). Evidences showed that the PGPR application increases the availability of nutrients in the rhizosphere for the plant uptake (Kumar et al., 2015; Etesami and Adl, 2020).

Tognetti et al. (2005) reported that vermicompost highly tended to lower the pH of soil than simple compost. Maximum pH was recorded in control and reduced in all the other treatment of the experiment because in the presence of the biofertilizer and activities of PSB, acids were produced in close area that reduce the pH of the medium. Similar results were stated by El-Tarabily et al. (2006) that application of oxidizing bacteria enriched biofertilizer reduced the pH of the soil as compared to control. Similar results were recorded by the Berger et al. (2013) and Lima et al. (2010), application of biofertilizer with microorganism comparatively reduced the pH of the soil over control. In soil, phosphorus is present in an insoluble form, which is not available to plants (Tognett et al., 2007). Same time, in the rhizosphere many organism's present i.e. PSB (Nautiyal et al**.,** 2000) which secretes acids (amino) for the bioavailability of phosphorus (Kim et al**.,** 1998; Richardson, 2001). Organic acids and hormones increase the soil phosphorus availability and ultimately plant growth increase (Chatterjee and Bandyopadhyay, 2014). Fertilizers, organic manures and PSB when applied in combination were shown best result and increase phosphorus availability (Ughade et al**.,** 2016). Vermicompost contains a significant amount of nitrogen and which is easily mineralized and available for uptake of plants (Barani and Anburani, 2004). Application beneficial microorganisms enhanced the bioavailability of nutrients in brinjal (Prabhu et al**.,** 2004), in cucumber (Mali et al**.,** 2005). Vermicompost contains nitrogen in nitrate form instead of ammonia (Chatterjee and Bandyopadhyay, 2014). In current study, combined application of chemical fertilizers, organic manures and PSB increased nitrogen availability (Ughade et al., 2016). In vermicompost considerable amount of potassium is present which easily available to plants. In results, bio-fertilizers application also increased the availability of potassium to plants. A field study stated that application of PGPR and inorganic fertilizer increased the uptake of K in plant by 58% while N and P three times as compared to control in wheat (Abbasi et al., 2011). Khaliq et al. (2006) stated that a significant increase in the uptake of K (10-15%) recorded in cotton plant on the application of PSB containing PGPR amended with bioorganic and chemical fertilizers over control. Application of vermicompost and PSB together greatly improved the efficiency nutrients availability (Chatterjee and Bandyopadhyay, 2014). Result showed that plant height and number of leaves increased significantly because in the rhizosphere bacteria produced plant growth regulators which increased chlorophyll contents. So increase in plant height, the number of leaves and chlorophyll content was due to the nitrogen fixation of bacteria (Douds et al., 2006). An increase in plant height, number of leaves, number of flowers, stem girth and chlorophyll content were reported by use of vermicompost and PSB (Nazir et al**.,** 2006; Tripathi et al**.,** 2014; Damse et al**.** 2014). It has been reported that combined application of vermicompost and PSB along with lower fertilizer dose increased the numbers of flowers, chlorophyll content, numbers of leaves and fruits (diameter, weight and number (Singh et al*.,* 2015b; Soni et al., 2018). Fertilizers, organic manures and PSB when applied in combination were shown the best result and plant yield and growth in tomato (Singh et al**.,** 2015a). The same results were obtained in chilli by Khan et al**.** (2012). Yeptho et al. (2012) recorded that 50% NPK + PM + biofertilizer application increases the leaf area, the number of leaves, fruit weight and yield.. By the combined application of vermicompost and PSB increase plant height, flowering and fruit yield in chilli (Vimera et al*.,* 2012); in radish (Deepika et al**.,** 2010) and in strawberry (Singh et al**.**, 2008).

Conclusion

The results of the present study concluded that the application of PSB enriched bio-organic (vermicompost) fertilizer could help to reduce the overuse of costly synthetic fertilizers. Application of PSB and vermicompost significantly reduce the cost of production without affecting the yield. Moreover, the use of PSB and vermicompost with a lower rate of chemical fertilizer lead to improvement of tomato growth and yield traits as well as soil and plants nutrients status. Therefore, it is concluded that the application of bio-organic fertilizers as a supplement can reduce the rate as well as the cost of synthetic fertilisers. Thus, through the integrated use of organic and inorganic sources of nutrients, the expected yield of tomatoes can be achieved keeping in view the healthy soil and environmental aspects.

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