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INTEGRATED USE OF PSB AND ORGANIC FERTILIZERS TO IMPROVE YIELD AND QUALITY OF BELL PEPPER (*Capsicum Annum* L.) CV. GREEN WONDER

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ABSTRACT

Bell pepper is an important Solanaceous crop that is cultivated all around the globe for its economical and nutritional value. In Pakistan, it is cultivated mainly in Sindh and Punjab province of Pakistan. However, average yield ha^{-1} is quite low as compared to the rest of the world. One of the main reasons for this low yield is poor phosphorous status. The current study was conducted to estimate the effects of organic application combined with PSB biofertilizers (Phosphorus Solubilizing Bacteria) on growth and yield of bell pepper. Organic amendments included leaf compost (LC), farmyard manure (FYM) and poultry manure (PM). Bell pepper cultivar "Green Wonder" was used as test crop. FYM and PM showed better results as compared to LC in most of the measured parameters. Plant height in FYM and PM was 59.79 and 59.07 cm while PSB application produced 67.84 cm high plants. Maximum leaf area was 176.98 cm^2 that for FYM and was further increased up to 204.43 cm^2 when supplemented with PSB. Bell pepper yield was also maximum in FYM i.e. 1211.7 g while PM showed a value of 1077.6. g. However, when PSB was applied in combination with these treatments, yield $plant^{-1}$ was further increased up to 1393.4 and 1227.6 g, respectively. Total soluble solids were statistically at par among all the organic amendments but higher than control. Ascorbic acid was maximum in PM (58 mg 100 g^{-1}) and followed by FYM (55.53 mg 100 g^{-1}). PSB application showed a value of 72.46 mg 100 g^{-1}. It is recommended from these results that application of organic amendments and PSB should be practiced enhancing that yield and quality of bell pepper.

Keywords: Bell pepper, organic amendments, PSB, Growth, Yield greenhouse

INTRODUCTION

Bell pepper is an important solanaceous crop that originated from South and North America and spread worldwide (Igbokwe *et al*., 2015). China is considered as a largest producer of bell pepper followed by Mexico (FAOSTAT, 2016). Bell pepper is well known for its nutritional and medicinal value and is of great economic importance (Chavez-Mendoza *et al*., 2015). It contains significant amounts of antioxidants and oxygenated carotenoids (Deepa *et al*., 2006). The antioxidants like capsanthin, capsorubin and cryptocapsin present in bell pepper have the potential to act against the free radicals that might cause cell aging, mutagenesis and cancer (Hamid *et al*., 2010). Lycopene in bell pepper is also considered to be an anticancer compound. Moreover, it is an important source of folic acid, beta-carotene, fiber and various vitamins.

Bell pepper is considered as an important horticultural crop in Pakistan and is used as cooked vegetable, salad and dried condiment. It is cultivated as a "Rabi" crop during the months of September and October (NARC, 2015). Total area under cultivation reaches up to 0.0624 million hectares with a production of 0.14 million tons annually. Average yield of bell pepper rarely exceeds 2.5 tons' $hectare^{-1}$which is quite low as compared to the yield obtained in developed countries like America (376 cwt $heactare^{-1}$) and South Africa (6-10 tons' $hectare^{-1}$) (DAFF, 2013; Biswas *et al*., 2015; Chatterjee *et al*., 2016). Among various factors phosphorus and nitrogen deficiency are considered as important limiting factors (Aticho *et al*., 2014; Khan *et al*., 2010).

Phosphorus plays important role in vegetative and reproductive growth of plants. Its most important

function is the formation of ATPs and energy transfer while other functions include cell division, signal transduction, photosynthesis, respiration, and biosynthesis of macromolecules (Shenoy and Kalagudi, 2005; Khan *et al*., 2014). Out of the total phosphorus (0.02 to 0.5%) present in soil only a minute fraction i.e 0.1% is available for plant uptake (Fernandez *et al*., 2007; Zou *et al*., 1992) therefore almost of 99 % of the applied chemical fertilizers is converted to plant unavailable fractions while drastically reducing fertilizer use efficiency (Mehta *et al*., 2014). The processes that render phosphorus unavailable for plants include mainly precipitation with cationic fractions of soil (Khan *et al*., 2009) and fixation of primary and secondary orthophosphates in interlayer spaced of silicate clays (Melenya *et al*., 2015). Different approaches can be implied to improve the availability of phosphorus to the plants. These might include application of relatively higher fertilizers rates, band placement of the fertilizer, application through complex phosphatic fertilizers like commercially available humic substances or slow release fertilizers, application of complex phosphatic fertilizers and balancing phosphorus with other nutrients. However, these approaches are expensive, laborious and might result in addition of organic and inorganic pollutants in the soil (Hopkins and Ellsworth, 2015). Another important approach to solve this problem is the application of phosphorus solubilizing bacteria (PSB) which is reported to be an economical, convenient and effective way to mobilize the insoluble phosphorus present in the soil (Abbasi *et al*., 2015). PSB increases phosphorus availability by producing organic acids (Kpomblekou and Tabatabai, 2003; Chen *et al*., 2006) chelation and production of ammonia and plant hormones (Rangarajan *et al*., 2003).

Another approach that has positive effects on plant growth and phosphorus availability is the application of organic matter. High temperatures and low rainfall results in rapid organic matter decomposition therefore soils of Pakistan contain less than 1% organic matter (Sarwar *et al*., 2005). Organic fertilizers not only have good phosphorus content but also release the precipitated phosphorus as acids are produced upon their decomposition (Nishanth and Biswas, 2008). Moreover, soil biological properties are enhanced due to organic matter application that also enhances phosphorus availability (Fankem *et al*., 2006). Therefore, integrated use of PSB and organic fertilizers could be a viable approach to improve phosphorus availability (Abbasi *et al.*, 2015). Many studies have reported increased phosphorus availability after application of organic amendments. Different organic amendments that have the potential to improve phosphorus availability include composts (Nishanth and Biswas, 2008; Wickramatilake *et al*., 2010; Saleem *et al*., 2013), animal manure and plant residues (Alloush, 2003; Toor, 2009; Aria *et al*., 2010). Present study was conducted to evaluate the impact of PSB and organic amendments application on growth and yield of bell pepper.

MATERIALS AND METHODS

Study area description: A greenhouse experiment was conducted at the Department of horticulture, University research farm Koont, Chakwal, Pakistan. Soil was collected from a depth of 15 cm, processed properly and filled into pots. Leaf compost (LC), poultry manure (PM) and farmyard manure (FYM) were selected as organic fertilizers these were dried, grinded and stored in plastic containers for further use. PSB biofertilizers (Phosphorus Solubilizing Bacteria) was collected from National Agriculture Research Center, Islamabad, Pakistan. Nursery of bell pepper variety "Green Wonder" was raised in plastic trays and then transferred to plastic bags after application of organic amendments and PSB. Recommended dose of NPK was also applied.

Treatments included: control, leaf compost, poultry manure, farmyard Manure, control+PSB, Leaf compost +PSB, poultry manure + PSB and farmyard manure + PSB. Each pot contains one bell pepper plant and three bags pots were considered as one replication. Each treatment was replicated thrice

Measurements: During the course of the experiment bell pepper plants were analyzed for different growth and yield parameters including plant height, leaf area, number flowers fruit plant-1, fruit length and diameter, fruit wall thickness and fruit weight plant-1. Total soluble solids and titrateable acidity were measured by method described by AOAC, (1990) while ascorbic acid content in bell pepper fruit was analyzed by method described by Hans *et al*. (1990).

Statistical Analysis: Two-way analysis of variance (ANOVA) was used to analyze the data for variations among treatments while least significant difference test (LSD) at 5% level of probability was used to compare the means obtained for the treatments used in the experiment (Steel *et al*., 1980).

RESULTS

Effect of organic amendments and PSB biofertilizers (Phosphorus Solubilizing Bacteria) application on morphology of bell pepper: It was evident from the data that application of organic amendments and PSB had positive effects on growth and yield of bell pepper as well as on its fruit quality. Maximum Plant height (Table 1) was obtain by the application of farmyard manure but was found statistically at par with the plant height recorded in poultry manure application. On the other hand average plant height of bell pepper was 59.79 cm where PSB was applied which was significantly higher from 48.89 cm in uinoculated plants. Similar trend was observed for leaf area where the minimum value was observed for control i.e. 92.66 cm2which increased 176.98 cm2 in the treatment where farmyard manure was applied. It was significantly

higher than leaf area of 161.82 and 138.32 cm2for poultry manure and leaf compost application. Uninoculated plants had an average leaf area of 122 cm2 which was increased up to 162.88 cm2 after PSB application. Number of flowers and fruits plant^{-1} were affected in the same way by the application of organic amendments and PSB. Application of farmyard manure and poultry manure produced statistically similar results for both parameters while the values for leaf compost were significantly lower. PSB application also increased number of flowers and fruits significantly over the control treatment.

Table 1. Effect of organic amendments and PSB on morphology of bell pepper.

Main Effect of Organic Amendment on Morphology of bell pepper					
Organic Amendment	**Plant height (cm)**	**Leaf area (cm^2)**	**Number of flowers plant^{-1}**	**Number of fruits plant^{-1}**	
Control	37.19 c	92.66 d	11.67 c	7.83 c	
Leaf Compost	53.42 b	138.32 c	19.67 b	12.67 b	
Farmyard Manure	59.79 a	176.98 a	23.17 a	14.83 a	
Poultry Manure	59.07 a	161.82 b	23.67 a	14.67 a	
LSD	2.6742*	12.736*	2.4766*	1.8026*	
Main Effect of PSB Inoculation on Morphology of Bell Pepper					
Inoculation level					
Uninoculated	48.89 b	122 b	17.58 b	11.42 b	
Inoculated	57.84 a	162.8 a	21.5 a	13.58 a	
LSD	1.8910*	9.0059*	1.7512*	1.2746*	
Interactive Effect of Organic Amendments and Inoculation Levels on Morphology of Bell Pepper					
Organic Amendment X inoculation interaction					
Control	X Uninoculated	33.61 g	80.88 f	9.67 d	6.33 d
Leaf Compost		44.80 e	115.9 e	17.00 c	10.67 c
Farmyard Manure		51.71 d	149.5 cd	21.33 b	13.33 b
Poultry Manure		57.44 c	141.67 d	22.33 ab	14.00 ab
Control	X Inoculated	40.77 f	104.43 e	13.67 c	9.33 c
Leaf Compost		62.03 b	160.70 c	22.33 ab	14.67 ab
Farmyard Manure		67.87 a	204.43 a	25.00 a	16.33 a
Poultry Manure		60.7 bc	181.97 b	25.00 a	15.33 ab

*LSD values showed a significant difference among applied treatment

Effect of organic amendments and PSB on the yield of bell pepper: It was clear from the data that organic amendments and PSB application not only enhanced plant growth but also improved fruit yield and quality of bell pepper (Table 2). Fruit length and diameter were improved by the application of farmyard manure but for previous the value was statistically at par with the fruit length observed for poultry manure. However, in case of fruit diameter farmyard manure application increased the value significantly over all other treatments. PSB application also enhanced fruit length and diameter significantly over control with values of 6.38 and 6.63 cm, respectively. Application of FYM and PM also produced fruits with thickest walls and the results of both treatments were statistically at par but significantly higher from those observed for LC application. Uninoculated plants produced fruits with an average thickness of 0.344 cm that was significantly lower from 0.43 cm produced in the plants where PSB was applied.

Application of organic amendments showed marked increase in the yield of bell pepper where maximum yield of 1211.7 g plant^{-1} was produced by FYM followed by 1077.6 g plant^{-1} for PM application and then by 786.3 g plant^{-1} for LC. These values were significantly higher from control. On the other hand, PSB application increased fruit yield plant^{-1}upto 1032.1 kg plant^{-1} that was significantly higher than 669.1 g plant^{-1} for uninoculated plants.

The present study revealed that ositive effect of organic amendments on fruit has been reported by other researcher also increases in fruit length after application of organic amendments and PBS is well documented. Ikeh *et al*. (2012) reported that application of poultry manure increased pepper fruit length upto 8.33 cm as compared to 6.11 cm in control. Hiraguli and Allolli (2011) also reported similar results where FYM+NPK produced 11.75 cm long chili fruits and the value was increased further to 13.85 cm for FYM+NPK+PSB application.

Table 2: Effect of organic amendments and PSB on yield characteristics of bell pepper

Main Effect of Organic Amendment on Yield of bell pepper					
Organic Amendment	**Fruit length (cm)**	**Fruit diameter (cm)**	**Fruit wall thickness (cm)**	**Fruit Yield plant^{-1} (g)**	
Control	4.85 c	4.70 d	0.256 c	326.9 d	
Leaf Compost	5.41 b	5.41 c	0.364 b	786.3 c	
Farmyard Manure	6.38 a	6.63 a	0.471 a	1211.7 a	
Poultry Manure	6.35 a	5.92 b	0.456 a	1077.6 b	
LSD	0.3667*	0.2576*	0.0609*	105.34*	
Main Effect of PSB Inoculation on Yield of Bell Pepper					
Inoculation level					
Uninoculated	5.26 b	4.97 b	0.344 b	669.1 b	
Inoculated	6.19 a	6.35 a	0.430 a	1032.1 a	
LSD	0.2593*	0.1821*	0.0430*	74.484*	
Interactive Effect of Organic Amendments and Inoculation Levels on Yield of Bell Pepper					
Organic Amendments x PSB interaction					
Control	x uninoculated	4.31 e	4.26	0.251 d	193.8 e
Leaf Compost		5.18 d	4.82 d	0.303 d	525.2 d
Farmyard Manure		5.65 cd	5.75 c	0.410 c	1030.0 c
Poultry Manure		5.92 c	5.06 d	0.413 c	927.5 c
Control	x inoculated	5.40 cd	5.14 d	0.262 d	460.0 d
Leaf Compost		5.65 cd	5.99 c	0.425 bc	1047.4 c
Farmyard Manure		7.13 a	7.50 a	0.532 a	1393.4 a
Poultry Manure		6.60 b	6.78 b	0.500 ab	1227.6 b

*LSD values showed a significant difference among applied treatments

Effect of organic amendments and PSB biofertilizers (Phosphorus Solubilizing Bacteria) on quality of bell pepper fruit: Fruit quality of bell pepper was also affected significantly by the application of various treatments. The highest total soluble solids were obtained the by application of PM but these were found statistically at par with those produced by FYM and LC. PSB application also increased TSS significantly over control with a value of 6.42 brix. Titrate able acidity, on the other hand, was significantly reduced by the application of organic amendments. Lowest value was observed for FYM where it was 0.8%. PM and LC produced statistically similar values of 0.94which was significantly lower than control. PSB application also affected significantly on acidity of bell pepper and reduced it to a value of 0.89% compared to observed for uninoculated plants. The highest value of ascorbic acid was 65.23 mg 100 g^{-1} produced by PM which was significantly higher than all other organic amendments. For FYM and LC its values were 60.4 and 51.8 mg 100 g^{-1}respectively that shows positive effects of organic amendments on ascorbic acid contents of bell pepper.PSB application also improved ascorbic acid content and it was found to be 61.78 mg 100 g-$^{1.}$ It was proved that application of PSB has the potential to improve not only the yield but also the quality of bell pepper fruit
.

Table 3: Effect of organic amendments and PSB biofertilizers (Phosphorus Solubilizing Bacteria) on quality of bell pepper fruits

Main Effect of Organic Amendment on Quality of bell pepper			
Organic Amendment	Total soluble solids	Titratable acidity	Ascorbic acid
	(brix)	(%)	(mg 100 g^{-1})
Control	5.15 b	1.13 a	49.77 c
Leaf Compost	6.05 a	0.942 b	51.8 c
Farmyard Manure	6.40 a	0.802 c	60.4 b
Poultry Manure	6.70 a	0.948 b	65.23a
LSD	0.7095*	0.1061*	3.45*
Main Effect of PSB Inoculation on Quality of Bell Pepper			
Inoculation level			
Uninoculated	5.72 b	1.015 a	51.86 b
Inoculated	6.42 a	0.894 b	61.78 a
LSD	0.5017*	0.0749*	2.44*
Interactive Effect of Organic Amendments and Inoculation Levels on Quality of Bell Pepper			
Organic amendment x PSB interaction			
Control	x uninoculated	4.93 d	1.183 a	47.02 e

Leaf Compost		5.80 bcd	0.967 bcd	47.17 e
Farmyard Manure		6.00 bc	0.883 cd	55.27 cd
Poultry Manure		6.17 bc	1.03 bc	58.00 c
Control	x inoculated	5.30 cd	1.07 ab	52.53 d
Leaf Compost		6.30 abc	0.917 cd	56.6 cd
Farmyard Manure		6.80 ab	0.720 e	65.53 b
Poultry Manure		7.23 a	0.87 d	72.46 a

*LSD values showed a significant difference among applied treatment

DISCUSSION

Stunted plant growth is usually caused by nutrient deficiency and especially nitrogen and phosphorous (Leghari, *et al*., 2016). Results of the present study are confirmed by Baiyeri *et al*. (2017) who found that application of poultry manure increased plant height of aromatic pepper with increasing application rate. This was attributed to enhanced supply of plant nutrients to pepper plants at higher application rates. Ewulo *et al*. (2007) also reported that application of 7.5 t $ha^{-1}$of cow dung along with NPK produced tallest plants due to provision of all necessary nutrients to pepper plants. Ikeh *et al*. (2012) also reported significant increase in pepper height with poultry manure application at it was argued in the study that manures provide essential plant nutrients that are associated with higher photosynthetic rates and hence result in enhanced plant growth. Bashir *et al*. (2017) found that application of PSB significantly enhanced height of chili as more solubilized phosphorus was available due to its application along with mineral phosphorus source. In their study Abbasi *et al*. (2015) reported that combined application of poultry manure and PSB along with different mineral phosphorus sources significantly enhanced plant height over control within a range of 7-53 %. It was argued in the study that combined application of rock phosphate, poultry manure and PSB released highest amounts of plant available phosphorus that had positive effects on plant growth. Increase in the plant height of bell pepper after integrated application of organic amendments and PSB is due to the supply of essential plant nutrients from organic amendments and production of phosphorus solubilizing compounds and consequent increase in P availability.

Leaf area is important in plant growth as it affects total canopy, hence net photosynthesis rate of a plant. The results of the present study are confirmed by Ikeh *et al*. (2012) who found that application of organic amendments significantly enhanced leaf area of pepper in a field experiment. He attributed this increase the availability of nitrogen, phosphorus and other nutrients and therefore development of aerial parts was stimulated. Improvement in soil physical properties like aeration, bulk density, water retention, and nutrient holding capacity by the application of organic amendments could be another reason that ultimately was have positive effects on plant growth. Castellanos *et al*. (2017) also reported significant increase in leaf area of hot pepper after application of FYM, PM and vermicompost. In their study Hiraguli and Allolli (2011) concluded that application of farmyard manure in combination with recommended fertilizer dose and PSB significantly enhanced leaf area of chili. Increase in leaf area of bell pepper after application of PSB could be due to higher availability of phosphorus which is reported for the production of ATPs for plant growth.PSB might also have contributed to increase the leaf area by producing plant growth promoting hormones (Sood *et al*., 2018). In the present study, increase in the number of flowers after application of organic amendments and PSB might be credited to the availability of nitrogen, phosphorus and other nutrients due to combined effect of amendments and PSB application. The results of the present study are confirmed by Surapat *et al*. (2013) who found that application of PSB increased the number of flower significantly when applied to chili. Moreover, integrated application of organic amendments and PSB increased soil proliferation, nutrient and water uptake and produced plant growth promoting hormones that resulted in higher number of flowers $plant^{-1}$. Beside, increase in leaf area also results in higher photosynthesis that could enhance food accumulation and plant growth compared to control and uninoculated treatments (Palagani *et al*., 2013).

Many researchers have reported positive effects of organic amendments and PSB application on number of fruits $plant^{-1}$. Baiyeri *et al*. (2017) reported that application of poultry manure to aromatic pepper increased number of fruits $plant^{-1}$significantly over the control. Ewulo *et al*. (2007) found that application of FYM+NPK to pepper increased number of fruits $plant^{-1}$upto 70 as compared to 35 fruits in control. Application of poultry manure @ 10 t ha^{-1} produced 44 fruits on pepper plants as compared to 9 fruits in control (Ikeh *et al*., 2012). Bashir *et al*. (2017) also reported significant increase in number of fruits $plant^{-1}$ in pepper that was inoculated with potassium and phosphorus solubilizing bacteria. The production of fruits depends largely on supply of nutrients. In the present study the higher number of fruits $plant^{-1}$ with application of organic amendments and PSB might be due to better provision of all the required nutrients by organic amendments and supportive role of PSB in providing higher amounts of phosphorus resulting in higher number of fruits $plant^{-1}$ (Dhillon, *et al*. 2011). Increase in plant height after organic amendment and PSB application might have resulted in higher number of branches that provided more room for fruit setting and hence number of fruits was increased. On the

other hand, more leaf area resulted in increased photosynthesis and higher net assimilation that also played positive role in fruit setting and hence number of fruits plant^{-} . Hiraguli and Allolli (2011) also reported similar results where FYM+NPK produced 11.75 cm long chili fruits and the value was increased further to 13.85 cm for FYM+NPK+PSB application. Castellanos *et al*. (2017) also reported increase in fruit length after application of different doses of farmyard manure, poultry manure and vermicompost to three genotypes of hot pepper. These results are also supported by Abbasi *et al*. (2015) who found that chili fruit length was increase from 6.1 cm in control to 7.6 cm for rock phosphate +poultry manure application while further increased to 9.5 cm for rock phosphate+ poultry manure+ phosphorus solubilizing bacteria. Increase in fruit length of bell pepper after application of PSB and organic amendments can be attributed to improved soil conditions, higher nutrient availability and increased photosynthesis due to more leaf area. All these factors have contributed to more biomass production, therefore fruit size was significantly enhanced due to application of PSB and organic amendments (Abbasi *et al*., 2015).

Fruit size is important parameter when economic value is considered. Increase in the fruit size after application of organic amendments and PSB in the present study can be attributed to the availability of nutrients especially phosphorus and nitrogen to the plants. Nitrogen plays an important role in the assimilation of photosynthates in the fruits and phosphorus starts early maturity and fruit setting. Results of the present study are confirmed by Hiraguli and Allolli (2011) who reported that fruit diameter of chili was 0.78 cm in FYM+NPK application and increased upto 0.95 with the addition of PSB in the same treatment. Abu-Zehra. (2011) also had similar findings and reported that application of animal manure significantly enhanced fruit size. Increase in fruit size of bell pepper due to application of PSB and organic amendments are due to higher nutrients availability. Provision of nitrogen, potassium and phosphorus resulted in higher biomass production and improved transportation of photosynthates to the sink i.e. fruit, hence increasing its size and weight. PSB application increased phosphorus availability to bell pepper plants that is essential for cell elongation and cell division which enhanced the diameter of fruits over the uninoculated treatments.

0Weight of fruit improves its economic importance. Increase in fruit weight after application of organic amendments and PSB can be credited to the secretion of growth promoting hormones and increased availability, mobility and uptake of plant nutrients. Chatterjee *et al*. (2016) confirms the findings of our study by reporting increase in single fruit of bell pepper from 63.41 g in uninoculated treatment to 69.21 g in the plants that were treated with PGPR. Increase in fruit weight after application of organic amendments was due to improved soil conditions that resulted in higher water and nutrient uptake. Release of nitrogen, phosphorus, potassium and other nutrients not only increased plant biomass but also improved the transport of these nutrients to growing parts and higher biomass was produced. PSB application also supplemented this effect by increasing phosphorus availability and balancing the levels of hormones. Phosphorus is known to improve cell division, elongation and growth therefore it is very important for improved fruit weight and yields. Availability of different nutrients not only favors production of biomass but also improves translocation and synthesis of different growth regulators that result in higher fruit weight (Mishra &Tripathi, 2011)

Fruit yield is the most important parameter when the economic value and farmer's profit is taken into account. Increase in the fruit yield after application of organic amendments and PSB is well established. Baiyeri *et al*. (2016) reported that application of poultry manure gave higher yield as compared to control. Increase in the fruit yield of bell pepper in the present study could due to enhanced yield parameters including fruit length, fruit diameter and individual fruit weight. Increased number of fruits plant^{-1} in the plants treated with organic amendment and PSB was also an important parameter that resulted in increased fruit yield plant^{-1}). Tariq *et al.* (2014) found that bell pepper yield was significantly enhanced after PGPR application and it was credited to overall enhancement in the performance of plants due to PGPR application. Ewulo *et al*. (2007) reported that application of FYM+NPK increased pepper yield to 380 g plant^{-1} from 259 g plant^{-1} in control. Ikeh *et al*. (2012) also found that application of poultry manure produced 22.75 g plant^{-1} pepper as compared to 8.22 g plant^{-1} in control. It was argued in the study that higher nutrient availability from poultry manure caused higher net assimilation in the fruits resulting in higher yields. Experiment work of Hiraguli and Allolli (2011) also reported results of the present study. They reported that application of FYM+NPK in different combinations produced chili yields in a range of 3.83 to 5.2 q ha^{-1} whereas application of PSB along with the same combinations resulted in a production ranging between 4.86 to 7.42 q ha^{-1}. It was argued that the combined application of organic amendments and PSB accelerated the respiratory processes increased cell membrane permeability and provided with plant growth promoting hormones and more available nutrients while improving the soil properties that ultimately resulted in higher yields. Castellanos *et al*. (2017) also reported significant increase in yield of three different genotypes of hot pepper after application of poultry manure, farmyard manure and vermicompost. Chatterjee *et al*. (2016) observed increase in yield of bell pepper after application of PGPR. The main reason behind this increase in yield with organic amendments and PSB application was the higher nutrient availability due to acidic condition created during decomposition by microbial activity,

chelation and higher mobility and uptake of these nutrients by the soil due to improved physical, chemical and biological properties. Moreover, secretion of plant growth promoting hormones from PGPRs might also have contributed to the higher yields as well.

Fruit wall thickness plays a vital role in increasing the weight of individual fruit which in turn improves fruit yield. Increase in fruit wall thickness of bell pepper after application of organic amendments and PSB could be due to higher availability of nitrogen, phosphorus and other plant nutrients that play vital role in biomass accumulation and vegetative growth while increasing pod yield and quality (Fawzy *et al*., 2012). The results of the present study are also supported by Reyes *et al*. (2008), Flores *et al*. (2007) and Akande *et al*., (2007). Organic amendments improved the nutrients especially nitrogen, phosphorus and potassium. Nitrogen and phosphorus produce structural constituents that increase dry matter production while potassium, being the primary nutrient to control solute transport can increase translocation of nutrients and photosynthates to the fruits while increasing flesh thickness. PSB application also played important role in this case by increasing availability of phosphorus in the soil. Moreover, production of plant growth regulators from PSB might also have improved fruit development by enhancing its flesh thickness. Total soluble solids are important when taste of the fruit is considered. Increase in the total soluble solids due to the applied treatments might be due to higher photosynthesis rate and then higher net assimilation of these photosynthates in the fruits as nitrogen and phosphorus plays important role in fruit formation. Castellanos *et al*. (2017) found increase in total soluble solids of pepper after application of farmyard manure, poultry manure and vermicompost. Abu-Zehra (2011) also reported that application of animal manures including cattle manure, poultry manure and sheep manure increased availability of nutrients and improved soil properties that resulted in higher total soluble solids in sweet pepper fruit. Increase in total soluble solids due to PSB application can be attributed to increased root growth that resulted in higher nutrient uptakes. Moreover, increased phosphorus availability and production of plant growth promoting hormones might also have increased photosynthesis and carbohydrate synthesis which resulted in an increase in total soluble solids of bell pepper. Baksh *et al*. (2009) also reported increase in total soluble solids of guava after application of PSB.

The results of the present study are confirmed by Aminifard (2013) and Llaven *et al*. (2008) who reported a decrease in titratable acidity of pepper when organic amendments were applied. Decrease in the titratable acidity of bell pepper after application of organic amendments and PSB was due to increased nitrogen and phosphorus supply as both are known to decrease titratable acidity of fruit. The possible mechanism behind reduction in the titratable acidity of the fruit could be the production of greater biomass with steady nutrient supply that were readily used for synthesis of sugar molecules. Fandi *et al*. (2010) reported that application of higher phosphorus and nitrogen rates resulted in reduced acidity of tomato while reduction in their application rates, especially of phosphorus produced fruits with more titratable acidity. El-Araby *et al*. (2003) reported reduction in the titratable acidity of strawberry with PSB inoculation.

Organic amendments and PSB application improved the vitamin C contents in bell pepper. Castellanos *et al*. (2017) reported increase in ascorbic acid contents in three genotypes of bell pepper amended with farmyard manure and poultry manure. Abu-Zehra (2011) reported that sheep manure application increased ascorbic acid content upto 168.75 mg 100 g^{-1} as compared to control where it was 137.25 mg 100 g-1. Jadczak *et al*. (2010) also reported increase in ascorbic acid after application of organic amendments. Chatterjee *et al*. (2016) reported that application of PGPR increased ascorbic acid upto 136.73 mg 100 g-1 as compared to uninoculated plants of bell pepper where it was 125.21 mg 100 g-1. Aminifard and Bayat (2017) observed ascorbic acid content of 165 mg 100 g^{-1} in bell pepper amended with vermicompost as compared to 102 mg 100 g-1 in control. It was argued that higher vitamin C/ ascorbic acid contents are linked with a steady supply of zinc and manganese resulting from the application of organic amendments and PSB in sufficient amounts hence increasing their content in bell pepper.

CONCLUSIONS

It was clear from the results of the study that application of organic amendments has the potential to increase crop growth and yield by providing essential plant nutrients while integrated use of PSB and organic amendments boost up the yield therefore PSB biofertilizers (Phosphorus Solubilizing Bacteria) and organic amendments should be applied in combination to exploit full potential of bell pepper plants in terms of growth and yield. It is recommended that PSB biofertilizers (Phosphorus Solubilizing Bacteria) and organic amendments should be applied in combination to exploit full potential of bell pepper plants in terms of growth and yield.

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