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Assessment of Growth, Yield and Nutritional Parameters of Bell Pepper (*Capsicum annuum* L.) as Influenced by Conjoint Applications of Organic Manures, PGPR and Varying Levels of Inorganic Fertilizers

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A B S T R A C T

Sustainable agricultural production incorporates the idea that natural resources should be used to generate increased output and incomes, without depleting the natural resource base. Integrated nutrient management (INM) integrates the use of all natural and man-made sources of plant nutrients, so that productivity and nutrient status of food increases in an efficient and environmentally benefiting manner without sacrificing soil productivity of future generations. In the present study, various combination of organic manure (FYM, vermicompost and poultry manure), PGPR were used in combination with varying levels of NPK along with priming of seeds with GA_3 100ppm for 48 hrs during the year 2014 and 2015. The observations were recorded on different growth and yield contributing traits. Among different treatment combination T_4 gives maximum number of fruits (25.07), yield per plant (2.00kg), and yield per hectare (420.37q), longest harvest duration of 64.83 days and minimum days to flowering (44.25) and marketable maturity (69.33 days). This was closely followed by T_6 which results in larger sized fruits (28.78 cm2), more number of laterals (5.37) and vigorous plant (69.87cm). The benefit: cost ratio was obtained higher (2.27) in T_4 because of more yield potential and remunerative price. The plots receiving RDF (control) having minimum growth and yield potential and also having lower benefit: cost ratio.

Introduction

The basic concept underlying the INM principles is the maintenance and improvement of soil fertility for sustaining crop productivity on a long-term basis, which can be achieved through the combined use of various sources of nutrients and by managing them scientifically along with optimum time of planting for optimum growth, yield and quality of crop (Singh *et al.*,, 2015). Among the vegetable crop bell pepper (*Capsicum annuum* L.) is a popular crop belongs to the Solanaceous group. Bell pepper is also known as sweet pepper or green pepper. Sweet peppers differ from common hot peppers in

size and shape of the fruits, capsaicin content and usage. The fruits are non-pungent and have been widely used in immature or green stage as vegetable, for stuffing or for salads. Considered as high cash crop, it has occupied an important rank in world agriculture due to its high profit and nutritional values for human health. Sweet pepper fruits are a rich source of vitamin C, polyphenols, chlorophylls, carotenoids, sugars Flores *et al.*, (2009), magnesium, calcium, potassium, phosphorus and iron Jadczak *et al.*, (2010). It is a well-documented fact that increased dependence on agro-chemicals including fertilizer has led to several ill effects on the human health, so one should aware for eco-friendly organic products. Sustainable and eco-friendly agriculture which minimizes the use of harmful energy intensive inputs is available through the use of organic manures and biofertilizers. The organic nutrition for vegetables is especially important as they provide quality foods, which are very important for providing health security to people. Since the vegetables are mostly consumed as fresh or partially cooked, they should be devoid of residual effect of chemical fertilizers (kashyap *et al.*, 2014). The application of organic resources is essential for the balance of soil fertility status and crop productivity in agricultural systems. Crop yields is usually associated with the improvement of soil structure, soil fertility level, soil microbial population activity and moisture-holding capacity of the soil (Arancon *et al.*, 2004) and crop production. Several workers reviewed the significant role of FYM, vermicompost and biofertilizers in influencing the soil properties and enhancing the yield and quality of different vegetable crops like tomato (Prativa and Bhattarai, 2011), chilli (Naidu *et al.*, 2009), brinjal (Vijaya and Seethalakshmi, 2011) etc. Application of chemical fertilizers alone can supply only one or two nutrient elements to the crop. On the other hand, supplying only organic inputs can improve soil physical and biological environment but suffers from drawback of low content of plant nutrients as well as low production potential. However, in the modern days, when agriculture is motivated not only for production, but also accounts for the sustainability of all the resources including soil for the generations to come the use of inorganic fertilizers has been many-a-times reported for degrading soil and water resources (Adhikari *et al.*, 2016). Reviewing the fact, the present work was formulated to frame out a strategy for judicious combination of sources of nutrients both organic and inorganic, which will not only augment the efficiency of both the sources but will also minimize the ill effect of over use of chemicals in bell pepper cultivation.

Materials and Methods

The research was carried out in the Experimental Farm of Krishi Vigyan Kendra and Training Station, kandaghat of DR YS Parmar University of Horticulture and Forestry Nauni -Solan Himachal Pradesh at an altitude of 1425m msl in the year 2014 and 2015. The treatments comprised of 7 combinations of different nutrient sources and two factors (priming and non-priming) and were laid out in factorial RBD with three replications. The treatments consisted of combined application of varied levels of vermicompost (VC), poultry manures (PM) and FYM along with 75% and 50% of recommended dose of inorganic fertilizers in the presence of PGPRs. The treatment combinations are as follows: T_1: RDF (Control) ; T_2: 75% N + remaining 25% N through FYM + VC + full FYM, P and K + PGPR; T_3: 50% N + remaining 50% N through FYM + VC + full FYM, P and K + PGPR ; T_4: 75% N + remaining 25% through FYM + PM + full FYM, P and K + PGPR; T_5: 50% N + remaining 50% N through FYM +

PM + full FYM, P and K + PGPR; T_6: 75% N + remaining 25% N through VC + PM + full FYM, P and K + PGPR; T_7: 50% N + remaining 50% N through VC + PM + full FYM, P and K + PGPR. Before sowing the seeds in the nursery they were primed with GA_3 100 ppm for 48 hrs for enhancing germination and vigour. The bell pepper seedlings were transplanted in 2.7x2.4cm^2 plots with a spacing of 65x45cm between and within row, respectively. Vermicompost, poultry manures and FYM were applied to the respective plots at field preparation. PGPRs (*Bacillus subtilis*) were applied as seedling dip treatment for 30 min just before transplanting. The crop was raised using standard cultural practices. Various growth and yield attributes were examined at various times of crop cycle. The statistical analysis was carried out for each observed character under the study using MS-Excel and SPSS. The mean values of data were subjected to analysis of variance as described by Panse and Sukhatme (1987) for factorial RBD.

Results and Discussion

Growth parameters

Among different plant growth parameters days to first flowering and marketable maturity, number of laterals and plant height are the important traits which influence the yield potential of any crop (Table 1). Both flowering and marketable maturity of bell pepper was significantly affected by different nutrient combination as well as by seed priming treatments. Early maturity is desirable since it fetches good returns to the growers. Both these parameters are directly related to each other. An application of 75% N + FYM + PM + P and K + PGPR (T_4) will initiate flowering in 44.25 days and fruits was mature 5 days earlier (69.33) than control which takes 48.00 days to flower and 74.08 days to mature. The present findings are in line with those of Goo *et al.,* (2000) and Gu and Blank (2008) as they observed lesser number of days to maturity in egg plant under organic regime. Further flowering was initiated in 44.74 days and the fruits got matured in 69.86 days in those plants which were raised from primed seeds. Whereas the plants raised from the non-primed seeds get flowering in 46.12 days and reach to market after 5 days (73.21). The results are endorsed by Harris *et al.,* (2000) who reported direct benefits of seed priming in all crops which include faster emergence, more vigorous plants, earlier flowering and harvest and by Kumar *et al.,* (2010) who reported less number of days to 50 percent flowering as a result of pre sowing priming treatment in brinjal.

Height of plant is the dominant characters regulating more number of laterals, flowers, fruits and consequently more yield. Plant height and vigour of bell pepper plant was positively affected by different organic and inorganic nutrient combinations as well as by seed priming. Maximum height of plants 69.87cm was recorded in T_6 as compared to control which results minimum plant height i.e; 60.99cm. Similar increase in plant growth due to organic manures application was noticed by Rafi *et al.,* (2002) in tomato. Increase in growth and height can be attributed due to the synergistic effect of organic manures in making essential nutrients available to plants by improving the soil physical condition, solubilisation and mobilization of nutrients in soil. In addition to this, the plant height was significantly more (66.34cm) in primed seeds as compared to non-primed seeds (64.73cm). This is probably due to the reason that primed seeds resulted into healthy seedlings which created cooperative competition among plants for light and nutrients resulting into taller plants. Identical results have also been reported by Harris *et al.,* (2000). The plants having more

number of laterals are healthy and vigorous and directly affect the yield potential of any crop. It is clear from the results that maximum number of laterals (5.37) was obtained in T_6. In addition to this; the treatment which produced more number of laterals per plant had also produced vigorous and tall plants indicating direct and positive correlation. Increased number of laterals as a result of more N content has been ascribed the involvement of N in physiological process of plant which stimulated vegetative growth and thus there was more number of laterals per plant. Moreover, the presence of vermicompost involve in the production of plant growth regulators such as IAA, Kinetin and gibberellins associated with humic and fulvic acid which further enhance the growth of plant (Edward *et al.,* 2004). There is non-significant effect of priming on number of laterals per plant.

Longer harvest duration is a desirable trait for providing continuous supply of fresh fruits to the market over long period and to avoid glut in the market. Maximum harvest duration of 64.75 days was recorded in T_4 and minimum of 56.83 days were recorded in control (RDF). The present findings are in line with those of Chattoo *et al.,* (2011). The harvest duration was also affected by priming and harvest duration of 62.60 days was observed priming treatment than that of the non-priming treatment (59.40 days). The longer harvest duration may be due to early and continuous flowering and subsequently healthy crop growth.

Yield and contributing traits

Significantly more number of fruits (25.07) was obtained by applying 75% N + FYM + PM + P& K + PGPR and lesser number of fruits (20.07) were recorded in control. Similar were the findings of Gopinath *et al.*, (2008) and Jaipaul *et al.,* (2011) in capsicum. The increase in number of fruits per plant may be due to higher organic sources, higher organic matter build-up, balanced C: N ratio, efficient microbial activity, synergistic interaction between organic manures and PGPR resulting in more supply and availability of nutrients. Similar observations were also made by other workers like Dash *et al.,* (2005) and Chattoo *et al.,* (2011). Different combinations of organic and inorganic nutrients significantly affect the fruit size and weight resulted into higher yield. It is evident from the data (Table 2) that larger fruits (28.78cm^2) with more weight (68.02g) were obtained in T_4 and it was closely followed by T_6 whereas, smaller fruits (23.74cm^2) with less weight (59.31g) were obtained in control (T_1). This increase may be due to greater accumulation of solid matter in the fruits. It appear from the findings of Suthar (2009), that supply of nutrients by conjoint application of organic and inorganic sources i.e. vermicompost, poultry manures and chemical fertilizer improved the portioning of photo-assimilates from source to sink (leaf to fruit) thereby increased fruit weight and size. Similar are the findings of Adhikary *et al.,* (2016) and Kiestu and Heri (2014) in tomato.

Yield is responsible for commercial viability of a variety and is a key factor attaining highest consideration in the entire research programme. In the present study, maximum yield (Table 2) of 2.00kg per plant and 420.37q per hectare was obtained by the application of 75% N + remaining 25% N through FYM + PM + full FYM, P and K + PGPR (T_4) which was closely followed by T_6. Minimum yield potential of 1.65kg per plant and 347.05q per hectare was resulted (Fig-1) in the plots receiving only RDF (T_1). These results are in line with Jaipaul *et al.,* (2011) and Alam *et al.,* (2016).

Table.1 Effect of seed priming and organic manures in combination with inorganic fertilizers on growth parameters of bell pepper (Pooled data of 2 years)

		Days to first flowering			Days to marketable maturity			Harvest duration (days)			Plant height (cm)			Number of laterals/plant		
		Pr	**NPr**	**Mean**	**Pr**	**NPr**	**Mean**	**Pr**	**NPr**	**Mean**	**Pr**	**NPr**	**Mean**	**Pr**	**NPr**	**Mean**
T_1: RDF (Control)		47.00	49.00	**48.00**	71.17	77.00	**74.08**	58.83	54.83	**56.83**	61.41	60.57	**60.99**	4.92	4.88	**4.90**
T_2: 75% N + remaining 25% N through FYM + VC + full FYM, P & K + PGPR		44.83	46.33	**45.58**	71.00	73.50	**72.25**	63.17	60.50	**61.83**	67.18	65.69	**66.43**	5.02	4.92	**4.97**
T_3: 50% N + remaining 50% N through FYM + VC + full FYM, P& K + PGPR		44.83	45.67	**45.25**	69.17	75.17	**72.17**	59.50	59.00	**59.25**	60.63	61.56	**61.10**	5.12	5.03	**5.08**
T_4: 75% N + remaining 25% through FYM + PM + full FYM, P & K + PGPR		43.67	44.83	**44.25**	69.33	69.33	**69.33**	67.00	62.67	**64.83**	69.58	66.52	**68.05**	5.08	4.92	**5.00**
T_5: 50% N + remaining 50% N through FYM + PM + full FYM, P & K + PGPR		44.33	46.17	**45.25**	68.83	73.00	**70.92**	59.00	56.50	**57.75**	65.03	63.67	**64.35**	5.12	5.08	**5.10**
T_6: 75% N + remaining 25% N through VC + PM + full FYM, P & K + PGPR		44.17	46.33	**45.25**	70.50	73.83	**72.17**	63.67	60.50	**62.08**	70.74	69.00	**69.87**	5.30	5.43	**5.37**
T_7: 50% N + remaining 50% N through VC + PM + full FYM, P& K + PGPR		44.33	44.50	**44.42**	69.00	70.67	**69.83**	67.00	61.83	**64.42**	69.82	66.08	**67.95**	5.08	4.77	**4.93**
Mean		44.74	46.12		69.86	73.21		62.60	59.40		66.34	64.73		5.09	5.00	
CD $_{(0.05)}$	**Treatment (T)**	1.56			NS			3.14			2.17			15.77		
	Priming (P)	0.83			2.27			1.68			1.16			NS		
	T X P	NS			NS			NS			NS			NS		

Table.2 Effect of seed priming and organic manures in combination with inorganic fertilizers on yield and contributing traits of bell pepper (Pooled data of 2 years)

		Number of fruits/plant			Fruit size (cm2)			Fruit weight (g)			Fruit yield/plant (kg)			Fruit yield/hectare (q)		
		Pr	**NPr**	**Mean**	**Pr**	**NPr**	**Mean**	**Pr**	**NPr**	**Mean**	**Pr**	**NPr**	**Mean**	**Pr**	**NPr**	**Mean**
T_1: RDF (Control)		19.58	20.55	**20.07**	23.49	23.98	**23.74**	60.45	58.17	**59.31**	1660	1650	**1650**	348.74	345.35	**347.05**
T_2: 75% N + remaining 25% N through FYM + VC + full FYM, P & K + PGPR		20.37	23.53	**21.95**	29.28	28.28	**28.78**	69.23	66.81	**68.02**	1730	1760	**1740**	362.74	369.49	**366.11**
T_3: 50% N + remaining 50% N through FYM + VC + full FYM, P& K + PGPR		24.93	23.82	**24.38**	24.33	24.38	**24.35**	63.67	64.93	**64.30**	1980	1890	**1930**	415.21	396.32	**405.76**
T_4: 75% N + remaining 25% through FYM + PM + full FYM, P & K + PGPR		25.63	24.50	**25.07**	25.50	26.45	**25.98**	64.76	64.86	**64.81**	2050	1950	**2000**	430.95	409.78	**420.37**
T_5: 50% N + remaining 50% N through FYM + PM + full FYM, P & K + PGPR		22.85	21.60	**22.23**	25.50	25.50	**25.50**	61.69	60.56	**61.13**	1770	1910	**1840**	371.83	400.86	**386.35**
T_6: 75% N + remaining 25% N through VC + PM + full FYM, P & K + PGPR		25.88	23.83	**24.86**	29.66	27.79	**28.73**	69.00	67.12	**68.06**	2030	1880	**1950**	425.00	395.09	**410.05**
T_7: 50% N + remaining 50% N through VC + PM + full FYM, P& K + PGPR		21.93	20.80	**21.37**	28.53	27.35	**27.94**	67.34	66.06	**66.70**	1800	1810	**1810**	378.13	380.79	**379.46**
Mean		23.03	22.66		**26.61**	**26.25**		65.16	64.07		1860	1840		390.37	385.38	
CD $_{(0.05)}$	**Treatment (T)**	1.19			1.97			3.22			0.11			15.77		
	Priming (P)	NS			NS			NS			NS			NS		
	T X P	1.68			NS			NS			0.16			22.3		

Table.3 Effect of seed priming and organic manures in combination with inorganic fertilizers on nutritional parameters of bell pepper (Pooled data of 2 years)

Treatments		**Ascorbic acid content (mg/100g)**			**Total soluble solids (^{o}brix)**			**Shelf life (days)**		
		Pr	**NPr**	**Mean**	**Pr**	**NPr**	**Mean**	**Pr**	**NPr**	**Mean**
T_1: RDF (Control)		121.73	113.37	**117.55**	4.23	4.18	**4.21**	11.17	10.83	**11.00**
T_2: 75% N + remaining 25% N through FYM + VC + full FYM, P & K + PGPR		126.84	131.53	**129.18**	4.33	4.32	**4.33**	13.00	12.50	**12.75**
T_3: 50% N + remaining 50% N through FYM + VC + full FYM, P& K + PGPR		155.70	144.48	**150.09**	4.80	4.65	**4.73**	13.67	14.17	**13.92**
T_4: 75% N + remaining 25% through FYM + PM + full FYM, P & K + PGPR		130.53	158.27	**144.40**	4.32	4.43	**4.38**	12.17	12.67	**12.42**
T_5: 50% N + remaining 50% N through FYM + PM + full FYM, P & K + PGPR		154.43	152.44	**153.44**	4.42	4.67	**4.54**	14.83	15.17	**15.00**
T_6: 75% N + remaining 25% N through VC + PM + full FYM, P & K + PGPR		152.33	142.01	**147.17**	4.62	4.70	**4.66**	13.50	12.17	**12.83**
T_7: 50% N + remaining 50% N through VC + PM + full FYM, P& K + PGPR		134.87	128.32	**131.60**	4.20	4.25	**4.23**	13.50	14.50	**14.00**
Mean		139.49	138.63		4.42	4.46		13.12	13.14	
CD $_{(0.05)}$	**Treatment (T)**	10.59			0.20			1.37		
	Priming (P)	NS			1.16			NS		
	T X P	NS			NS			NS		

Fig.1 Fruit yield per plant and per hectare as affected by different treatment combinations

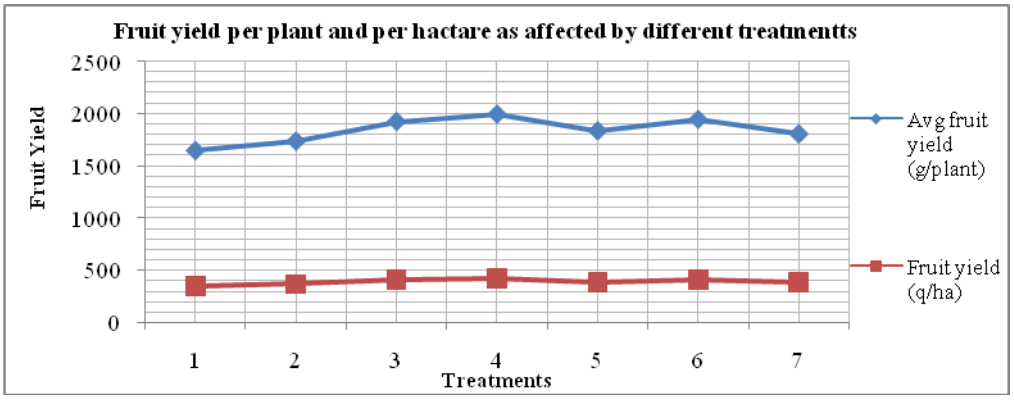
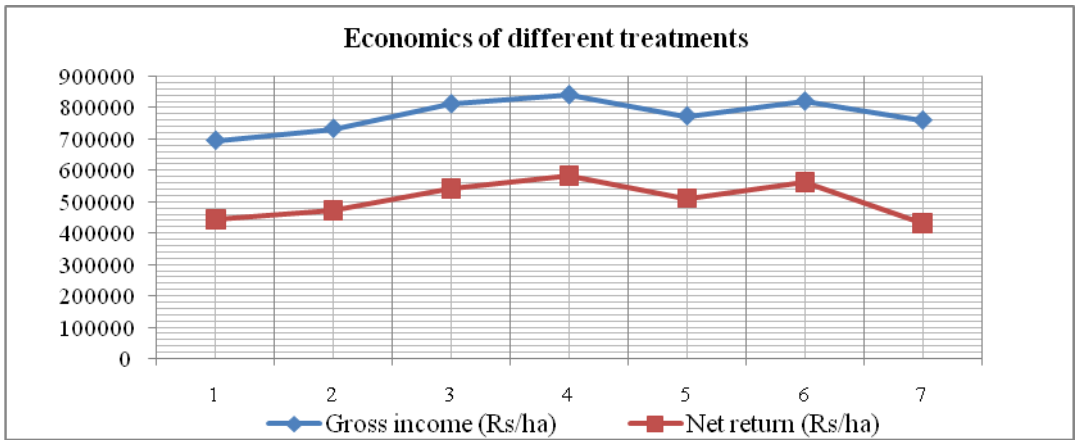


Fig.2 Economics analysis for gross income (Rs/ha) and net return (Rs/ha) for different treatment combinations



The increased fruit yield with combined application of organic manures and inorganic fertilizers may be due to large uptake and effective utilization of nutrients for increased synthesis of carbohydrates, more vegetative growth and subsequently better partitioning and remobilization of accumulated assimilates towards developing fruits (sink) Dass *et al.*, (2008) and Chaterjee (2013). Besides this, application of PGPR are also known to activate growth promoting substances like auxins, cytokinins and gibberellins as root inducing substrates as well as for increasing the nitrogen and phosphorus turnover in the soil through N –fixation and mobilizing native soil phosphorus which resulted in better plant growth and yield. Similar are the findings of Dhruba *et al.*, (2011) and Vimera *et al.*, (2012). The priming did not influence final yield potential but facilitates early yield which ultimately beneficial for farmers.

Nutritional parameters

High ascorbic acid content improves the nutrition and also helps in better retention of natural colour and flavour of bell pepper. It is apparent from the data (Table 3) that maximum ascorbic acid (153.44mg/100g) content was recorded in T_5 which was statistically at par with T_6 (147.17mg/100g) and T_4 (144.40mg/100g). Similar are the observation of Jaipaul *et al.*, (2011). Minimum ascorbic acid content

(117.55mg/100g) was recorded in control. The priming and its interaction with different combination didn't influence the ascorbic acid content. Further, the TSS was obtained maximum (4.73^{o}brix) in T_3 which was closely followed by T_6 (4.66 ^{o}brix). According to Laxmi *et al.,* (2015) increase in quality parameters with the combined application of inorganic fertilizers and organic manures might be due to increased availability of major as well as minor nutrients especially N and K as they play a vital role in enhancing the fruit quality. Similar are the findings of Patil *et al.,* (2004) and Singh *et al.,* (2010).

Fruits having longer shelf life can be transported to distant markets whereas fruits with poor shelf life are vulnerable to long distance transport and disease injury. In country like India, it assesses greater importance because more than 30 per cent produce goes waste during post-harvest handling (Verma and Joshi, 2000). In our study (Table 3), maximum shelf life (15.00 days) was recorded in T_5 (50% N + FYM + PM + P and K +PGPR) which was statistically at par with T_7 (14.00 days) and T_3 (13.92 days). The possible reason for better shelf life may be attributed to better and vigorous growth resulting into fruits with more pericarp thickness. Being a climacteric fruit, ethylene release is obvious to start fruit ripening as the water content and ethylene concentration plays an important role in post-harvest life of fruits.

Economics

The gross returns, net returns and benefit: cost ratio was affected by different treatment combinations (Fig. 2). An examination of the data revealed that highest gross income, net return and benefit: cost ration were recorded in T_4 and followed by T_6. This might be owing to higher production of bell pepper and more remunerative price under these treatments. Among different treatment combinations the minimum benefit: cost ratio was observed with control due to high price of chemicals and lower yield potential. Similar are the findings of Meena *et al.,* (2012) and Pandey and Chandra (2012).

Based on the 2 years findings of this experiments it can be concluded that reduced dose of chemical fertilizers upto 25-50% can give higher yield and better quality fruits with more benefit cost ratio as compared to solely use of inorganic fertilizers. Further the sustainability in yield and soil can be achieved by conjoint application of organic and inorganic fertilizers which benefit the farmers on long run.

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