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Integrated Nutrient Management of Sweet Pepper (*Capsicum annuum* L.) in the Mid Hills of Himachal Pradesh, India

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A B S T R A C T

The present investigation was conducted to develop integrated nutrient management system for higher productivity and profitability of sweet pepper on sustainable basis. The experiment laid out in RBD comprised of 15 different integrated combinations including a recommended practice, all replicated thrice. The study concluded that the conjoint use of 75 % recommended dose of NP + combined application of vermicompost and enriched compost @ 2.5 t/ha + PGPR (T_{14}) along with full recommended potash and FYM as basal application resulted in significantly maximum vegetative growth plant height (60.75 cm) and primary branches (4.07), earliest fruit harvest (62.67 days), fruit weight (54.92 g), number of fruits per plant (27.23) and consequently; the highest pepper fruit yield (367.68 q/ha) with a B:C (2.73:1). Beside this, the T_{14} also enhanced soil health as envisaged through the increased post-harvest availability of N, P and K by 25.35, 50.79 and 21.93, over the initial content.

Introduction

Sweet pepper (*Capsicum annuum* L.) was introduced in India by the Britishers in 19th century in Shimla hills (Greenleaf, 1986) and thus, named as 'Shimla mirch'.

Fruits are non-pungent with excellent aroma, hence called 'sweet pepper' and 'bell pepper' because of its bell shaped fruit.

It is commercially grown in Himachal Pradesh, Jammu and Kashmir, Uttarakhand, Arunachal Pradesh and Darjeeling district of West Bengal during summer and as an autumn crop in Maharashtra, Karnataka, Tamil Nadu and Bihar. In Himachal Pradesh, it is extensively grown as cash crop in the sub-temperate areas of Solan, Shimla, Mandi and Chamba districts during summer and rainy seasons over an area of 2.07 thousand hectares with production of 34.13 metric tonnes (Anonymous, 2016), fetching remunerative returns through 'off season' supplies to the adjoining plains.

For enhancing yield of vegetable crops, soil health is crucial factor. Enhancing soil fertility and crop productivity through use of chemical fertilizers has often negatively affected the complex system of biogeochemical cycles (Roberts, 2009).

The potential way to decrease this negative environmental impact is to follow integrated use of mineral fertilizers and organic manures including plant growth promoting rhizobacteria/bio-fertilizers. This will in turn help to meet out the nutrient requirement of the crops as well as maintaining sustainability in terms of productivity and soil fertility. Accordingly, the present study was aimed to evolve integrated plant nutrient system for cultivation of sweet pepper in the mid hills of Himachal Pradesh.

Materials and Methods

Experiment was carried out for two years (2015 and 2016) at Dr YSP University of Horticulture and Forestry, Nauni Solan, (HP) to evolve *INPS* system for higher productivity, profitability and soil health. The Experimental Farm is situated at 35°5' N latitude and 77°11' E longitude at an elevation of 1270 m (a m s l) at Nauni, on Rajgarh road, about 15 km away from the South East of Solan city (HP). The place is characterized by mild summers and cool winters. May and June are the hottest months, while December and January are the coldest. Agro-climatically, the farm area falls in the mid hill zone of HP and is characterized by sub-temperate to sub-tropical climate with moderate rainfall (1000-1300 mm).

The experiment was laid out in RBD with 03 replicates comprising 15 combinations of inorganic and organics including PGPR viz. T_1: RPF = (RDF (100 N: 75 P: 55 K kg/ha) + FYM 20 t/ha)), T_2: 75 % NP + VC@ 2.5 t/ha, T_3: 50 % NP + VC@ 2.5 t/ha, T_4: 75 % NP + EC@ 2.5 t/ha, T_5: 50 % NP + EC@ 2.5 t/ha, T_6: 75 % NP + PGPR, T_7: 50 % NP + PGPR, T_8: 75 % NP + VC@ 2.5 t/ha + PGPR, T_9: 50 % NP + VC@ 2.5 t/ha + PGPR, T_{10}: 75 % NP + EC@ 2.5 t/ha + PGPR, T_{11}: 50 % NP + EC@ 2.5 t/ha + PGPR, T_{12}: 75 % NP + VC and EC@ 2.5 t/ha, T_{13}: 50 % NP + VC and EC@ 2.5 t/ha, T_{14}: 75 % NP + VC and EC@ 2.5 t/ha + PGPR and T_{15}**:** 50 % NP + VC and EC@ 2.5 t/ha + PGPR.

Bio-inoculated/un-inoculated seeds/seedlings of sweet pepper cv. 'Solan Bharpur' were soaked in culture broth of bacterium (*Bacillus subtilis*)/sterilized water in sterilized Petri-plates for 3-4 hours before sowing/transplanting in different growing media as per treatment. Seeds were sown in the nursery on 10th and 7th March, and subsequently; seedlings transplanted on 21st & 17th April during 2015 and 2016, respectively in the treatment plots each measuring 3.0 m x 1.8 m, following a spacing of 60 cm x 45 cm. The NPK fertilizers were applied through – Urea, SSP and MOP, respectively. N and P as per treatments and full K were given to all the plots as basal dressing. N was given in three spilt doses, 1/3rd as basal dressing and rest further at one month interval. Recommended dose of FYM to all the plots and the other manures (vermicompost (VC) and enriched compost (EC)) as per treatments were incorporated at the time of preparation of individual plot manually. The data were recorded on important growth; yields attributes and yield along with post-harvest soil fertility status (available NPK).

Statistical Analysis

The data recorded on various parameters were analyzed for RBD design as suggested by Gomez and Gomez (1984). The results have been interpreted on the basis of 'F' test value and critical difference (CD) was calculated at 5 % level of significance

The standard error of mean (SEm) and critical difference (CD) for comparing the mean of any two treatments were computed as follows:

SEm = (Me/r)1/2

SE (d) = (2 Me/r)1/2

CD = SE (d) "t" value at error degree of freedom.

Results and Discussion

Plant growth and flowering

Perusal of pooled over years data in Table 1 exhibited significantly tallest plants (60.75 cm) in a plot fertilized with recommended package of fertilization (RPF) i.e. 100 N: 75 P: 55 K kg/ha + 20 t FYM/ha (T_1). Similarly, significantly highest number of branches (4.07) were also observed by the same treatment (T_1) which determined tallest plants (60.75 cm) followed by statistically equal branching (4.02) in an integrated module T_{14} (75 % NP + VC and EC@ 2.5 t/ha + PGPR).

Overall, next to RPF, the modules comprising of 75 % of recommended inorganic (NP) with or without bio-inoculation and addition of any of the organic manures (VC, EC), recorded significantly or at least numerically higher vegetative growth vis-à-vis their counter modules receiving inorganic NP @ 50 % of RPF. The enhancement of vegetative growth with higher inorganic (100 or 75 % NP) may be ascribed to increased activities through organic manures and bio-inoculation, which resulted in production of growth promoting substances and improved nutrient availability for longer period throughout the crop growth and resulted in better photosynthetic activities and ultimately high biomass production (Kumar and Dhar, 2010).

In an INM study in tomato by Bagale *et al.*, (2014), a module comprising 50 % RDN + FYM 20 t/ha + 25 % RDN through VC + 25 % RDN through neem cake + PSB + VAM showed maximum plant height (90.37 cm) and number of branches per plant (15.37) as compared to the values of 74.47 cm and 9.27, respectively recorded in 100 % RDF + FYM @ 20 t/ha. Similarly, according to Kondappa *et al.,* (2009), significantly maximum branches/ plant (33.98) in chilli were recorded through 50 % RDN + 50 % N through FYM + bio-fertilizer + Panchagavya and it was at par with 100 % RDF + Panchagavya (30.38/plant). Besides the above studies, our results are also in concordance with the findings reported earlier by Fawzy *et al.*, (2012), Escalona and Pire (2008) and Flores *et al.*, (2007) in sweet pepper.

The days for inducing flowering varied from 26.90 days in T_{14} (75 % NP + VC and EC @ 2.5 t/ha + PGPR) to 35.79 days (RPF). Overall, addition of new organics (VC, EC) and/or bio-inoculation with *Bacillus subtilis* or both as substitution for reduced inorganic (NP) significantly or at least numerically led to advancement of flowering through such modules in bell pepper. Treatment T_{14} which induced early flowering also harvested at least one fruit in 50 % of plants in minimum number of days (62.67) along with T_{15} (50 % NP + VC and EC@ 2.5 t/ha + PGPR) which also harvested at least one fruit from 50 % of plant population in statistically similar minimum days (64.33). Overall, majority of the treatments involving inorganic (NP) at reduced concentration (75 or 50 %) in integration with new organics (VC, EC) or PGPR or both attained Ist fruit harvesting in at least 50 % plant population significantly or numerically earlier than RPF (T_1) which attained this mark in as many as 75.50 days after transplanting. The earliness in flowering and subsequent Ist fruit harvesting in integrated modules as above could be attributed to the faster enhancement of vegetative growth and storing sufficient reserved food materials for differentiation of buds into flower buds whereas, the delayed flowering by the RPF utilizing 100 % NPK could be due to extended vegetative phase of the plant by the availability of inorganic nitrogen as advocated by Renuka and Sankar (2001) in tomato.

The findings on earliness concluded in the present study are in conformity of earlier researchers *viz.* Despande *et al.*, (2010), who through the inoculation of chilli seedling with *Azospirillum* and 16.17 % reduction in nitrogen (N 125 kg/ha + FYM @ 10 t/ha) observed earliest flowering (39.96 days) and fruits maturity (66.12 days) over their RPF (N 150 kg/ha + FYM @ 10 t/ha). In tomato, Bagale *et al.*, (2014) recorded minimum days for 50 % flowering (43.67) and first harvesting (79.10 days) from transplanting with module 50 % RDN + FYM 20 t/ha + 25 % RDN through vermicompost + 25 % RDN through neem cake + PSB + VAM while, maximum days for 50 % flowering (61.10) and first harvesting (100.10 days) were recorded in 100 % RDF + FYM @ 20 t/ha. According to Shiva *et al.*, (2015), application of 75 % N + *Azospirillum* sp. + 75 % P + Phosphobacteria + 100 % K reduced the number of days to flowering (51.28 days) in paprika. However, control recorded the maximum number of days to 50 % flowering (57.81 days).

According to them, the bio-fertilizers facilitate the continuous availability of nutrients during the entire life cycle of the plant. These nutrients are important constituents of nucleotides, protein, chlorophyll and enzymes involved in various metabolic activities and have direct impact on vegetative and reproductive phases of the plants.

Yield attributes and yield

The yield attributes viz. size, weight and number of fruits was significantly influenced by different INM modules under study as depicted in Table 2.

The module T_{14} recorded maximum fruit length (6.10 cm), along with other four integrated modules namely; T_{15} (6.06 cm), T_6 (6.00 cm), T_2 (5.88 cm) and T_{12} (5.87 cm) having statistically at par fruit length. Similarly, the maximum fruit breadth (5.26 cm) was also recorded by the same treatment (T_{14}) which measured maximum fruit length and closely followed by T_{15} (5.12 cm) vis-à-vis RPF which measured 4.81 cm mean width of the fruits. This increase in fruit size may be ascribed to better solubilization of insoluble or fixed P by the bacteria and uptake of soluble P by the plant (Wu *et al.*, 2005), which accelerates the secretion of growth promoting substances resulting into elongation of fruit. Similar are the findings of Bagale *et al.*, (2014), who reported the maximum fruit diameter (5.50 cm) in tomato through the combination 50 % RDN + 20 t FYM/ha + 25 % RDN through vermicompost + 25 % RDN through neem cake + PSB + VAM while, their RPF (100 % RDF + 20 t/ha FYM) recorded minimum fruit diameter of 3.83 cm. Deshpande *et al.*, (2010) also reported that fruit size in chilli through integrated module N 125 kg/ha + FYM @ 10 t/ha + *Azospirillum* was as effective as their RPF (N 150 kg/ha + FYM 10 t/ha).

The treatment T_{14} which produced highest fruit size, also observed maximum fruit weight (54.92 g) as presented in Table 2. The fruits harvested from T_{12} and T_6 also observed statistically similar fruit weight potential (52.39 g and 51.51 g, respectively) as above with T_{14}. Overall, all the treatment modules with reduced NP (75 or 50 %), organic (VC, EC) and/or PGPR or both registered statistically higher or similar fruit weight to that of RPF (T_1) which recorded 47.92 g weight per fruit.

As for fruit number, significantly maximum fruits per plant (27.23) were also harvested from the plant grown under the organic, inorganic and bio-inoculated combination T_{14}. The other module which scored significantly more number of fruits over the RPF was T_6 (75 % NP + PGPR), with a score of 24.59 fruits per plant.

The analysis of variance was calculated as follows

Source of Variation	df	Sum of Square	Mean Sum of Square	Variance Ratio ("F" Value)
Replication (r)	(r-1)	Sr	Sr/(r-1) = Mr	Mr/Me
Treatment (t)	(t-1)	St	St/(t-1) = Mt	Mt/Me
Error	(r-1) (t-1)	Se	Se/(r-1)(t-1) = Me	

Where,
r = Number of replications
t = Number of treatments
Me = Mean sum of square due to error
df = Degree of freedom

Table.1 Effect of different INM treatments on plant growth and flowering

Treatment Code	Plant height (cm)			No of primary branches			Days to 50 % flowering			Days to 1st harvest		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	65.10	56.40	**60.75**	4.53	3.60	**4.07**	34.84	36.73	**35.79**	78.67	72.33	**75.50**
T_2	60.79	52.40	**56.60**	3.87	3.47	**3.67**	29.50	32.87	**31.18**	69.33	65.67	**67.50**
T_3	54.57	50.52	**52.54**	2.87	3.13	**3.00**	30.73	34.87	**32.80**	71.00	68.00	**69.50**
T_4	52.35	51.15	**51.75**	3.47	3.13	**3.30**	30.97	35.53	**33.25**	71.33	69.33	**70.33**
T_5	49.23	50.15	**49.69**	3.00	3.33	**3.17**	33.23	36.73	**34.98**	76.67	70.00	**73.33**
T_6	62.81	53.00	**57.91**	3.73	3.33	**3.53**	27.27	33.93	**30.60**	66.00	65.33	**65.67**
T_7	59.33	50.30	**55.12**	3.93	3.13	**3.53**	28.17	34.17	**31.17**	67.67	67.67	**67.67**
T_8	60.26	51.52	**55.89**	3.07	3.27	**3.17**	31.43	32.83	**32.13**	73.00	66.33	**69.67**
T_9	55.77	47.99	**51.88**	3.00	2.87	**2.93**	29.83	34.47	**32.15**	71.00	69.00	**70.00**
T_{10}	56.95	50.96	**53.95**	3.60	3.53	**3.57**	28.33	28.33	**28.33**	69.33	64.67	**67.00**
T_{11}	50.29	48.90	**49.59**	2.80	3.27	**3.03**	33.73	30.87	**32.30**	75.00	69.33	**72.17**
T_{12}	60.59	54.41	**57.50**	3.33	3.57	**3.45**	30.73	30.90	**30.82**	71.00	69.00	**70.00**
T_{13}	53.22	51.98	**52.60**	3.20	3.32	**3.26**	30.13	31.57	**30.85**	69.33	68.00	**68.67**
T_{14}	63.15	54.83	**58.99**	4.47	3.57	**4.02**	25.90	27.90	**26.90**	66.00	59.33	**62.67**
T_{15}	54.46	52.68	**53.57**	3.87	3.53	**3.70**	26.53	28.33	**27.43**	67.67	61.00	**64.33**
Mean	57.26	51.81	**54.56**	3.52	3.34	**3.43**	30.09	32.67	**31.38**	70.87	67.00	**68.93**
$C.D_{(0.05)}$	**3.08**	**2.03**	**1.44**	**0.34**	**0.25**	**0.23**	**2.96**	**1.83**	**1.92**	**5.82**	**3.93**	**3.65**

Table.2 Effect of different INM treatments on yield attributes and yield

Treatment Code	Fruit length (cm)			Fruit breadth (cm)			Fruit weight (g)			Number of fruits per plant			Yield per hectare		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	4.75	5.91	**5.33**	17.94	21.80	**19.87**	43.53	52.30	**47.92**	17.94	21.80	**19.87**	230.60	290.63	**260.62**
T_2	5.73	6.03	**5.88**	19.55	24.13	**21.85**	48.27	52.23	**50.25**	19.55	24.13	**21.85**	290.68	324.68	**307.68**
T_3	5.11	5.90	**5.51**	17.44	21.60	**19.52**	45.47	49.17	**47.32**	17.44	21.60	**19.52**	228.71	285.47	**257.09**
T_4	4.94	5.72	**5.33**	17.05	23.20	**20.13**	44.10	54.40	**49.25**	17.05	23.20	**20.13**	232.44	309.51	**270.98**
T_5	4.40	5.66	**5.03**	15.72	21.60	**18.66**	43.06	52.20	**47.63**	15.72	21.60	**18.66**	221.21	280.82	**251.02**
T_6	6.04	5.96	**6.00**	23.77	25.40	**24.59**	48.98	54.03	**51.51**	23.77	25.40	**24.59**	329.30	314.61	**321.95**
T_7	5.85	5.76	**5.81**	19.61	20.60	**20.11**	47.68	49.53	**48.61**	19.61	20.60	**20.11**	281.13	256.26	**268.70**
T_8	5.59	5.96	**5.78**	20.83	20.07	**20.45**	47.33	47.57	**47.45**	20.83	20.07	**20.45**	305.69	341.81	**323.75**
T_9	5.23	5.68	**5.46**	18.72	19.67	**19.20**	46.14	46.30	**46.22**	18.72	19.67	**19.20**	248.28	277.45	**262.87**
T_{10}	5.28	5.90	**5.59**	16.72	22.87	**19.79**	46.98	50.83	**48.91**	16.72	22.87	**19.79**	235.38	311.25	**273.31**
T_{11}	4.46	5.81	**5.14**	15.83	19.67	**17.75**	43.70	52.20	**47.95**	15.83	19.67	**17.75**	203.58	251.64	**227.61**
T_{12}	5.63	6.10	**5.87**	18.55	24.07	**21.31**	47.67	57.10	**52.39**	18.55	24.07	**21.31**	267.85	335.38	**301.62**
T_{13}	4.96	5.96	**5.46**	16.39	23.80	**20.09**	44.69	53.20	**48.95**	16.39	23.80	**20.09**	229.60	308.25	**268.93**
T_{14}	6.06	6.13	**6.10**	26.05	28.40	**27.23**	50.37	59.47	**54.92**	26.05	28.40	**27.23**	371.01	364.34	**367.68**
T_{15}	6.04	6.08	**6.06**	21.05	24.40	**22.73**	48.54	52.20	**50.37**	21.05	24.40	**22.73**	311.88	315.44	**313.66**
Mean	5.34	5.90	**5.62**	19.01	22.75	**20.89**	46.34	52.18	**49.31**	19.01	22.75	**20.89**	265.82	304.50	**285.16**
$C.D_{(0.05)}$	**0.43**	**0.28**	**0.26**	**2.74**	**2.66**	**1.90**	**1.70**	**6.63**	**3.42**	**2.74**	**2.66**	**1.90**	**26.47**	**28.12**	**20.43**

Table.3 Effect of different INM treatments on available NPK

Treatment Code	Available nitrogen (kg/ha)			Available phosphorus (kg/ha)			Available potassium (kg/ha)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
T_1	314.59	317.54	**316.07**	34.27	35.71	**34.99**	399.54	390.59	**395.07**
T_2	333.46	338.67	**336.07**	39.75	42.32	**41.04**	412.10	418.60	**415.35**
T_3	298.97	293.67	**296.32**	36.63	36.31	**36.47**	409.45	400.80	**405.13**
T_4	296.16	305.16	**300.67**	29.24	35.21	**32.23**	400.57	407.51	**404.04**
T_5	297.92	290.56	**294.24**	21.36	23.02	**22.19**	384.77	357.81	**371.29**
T_6	390.82	349.71	**370.27**	43.94	45.39	**44.67**	447.47	419.15	**433.31**
T_7	380.44	338.25	**359.35**	40.80	44.41	**42.61**	431.06	398.99	**415.03**
T_8	375.89	371.56	**373.73**	44.10	48.64	**46.37**	417.40	420.53	**418.97**
T_9	311.49	317.83	**314.66**	39.09	42.15	**40.63**	401.49	409.62	**405.56**
T_{10}	313.59	322.10	**317.85**	40.14	44.84	**42.49**	402.84	415.08	**408.96**
T_{11}	286.56	271.55	**279.06**	23.84	24.07	**23.96**	383.65	395.70	**389.68**
T_{12}	379.45	352.52	**365.99**	42.43	43.98	**43.36**	421.88	424.00	**423.44**
T_{13}	310.47	300.23	**305.35**	37.68	37.90	**37.79**	407.76	405.82	**406.79**
T_{14}	418.13	382.42	**400.28**	51.87	53.36	**52.61**	464.37	447.78	**456.07**
T_{15}	378.17	344.82	**361.49**	43.88	42.71	**43.30**	443.68	411.25	**427.47**
Mean	339.07	326.44	**332.76**	37.93	40.00	**38.98**	415.20	408.22	**411.74**
$CD_{(0.05)}$	**23.58**	**17.60**	**15.65**	**5.45**	**6.68**	**4.80**	**13.53**	**15.44**	**8.23**

Table.4 Effect of different treatments on economics of sweet pepper

Treatment code	Yield (t/ha)	Gross return (Rs. in lacs)	Cost of cultivation (Rs in lacs)	Net return (Rs. in lacs)	B: C ratio
T_1	26.06	4.64	1.30	3.18	2.16
T_2	30.77	5.43	1.67	3.61	1.96
T_3	25.71	4.57	1.63	2.78	1.51
T_4	27.01	4.84	1.37	3.32	2.13
T_5	25.10	4.47	1.24	3.02	2.05
T_6	32.20	5.62	1.32	4.14	2.79
T_7	26.87	4.67	1.31	3.21	2.20
T_8	32.38	5.71	1.71	3.84	2.04
T_9	26.29	4.64	1.69	2.79	1.49
T_{10}	27.33	4.88	1.41	3.31	2.06
T_{11}	22.76	4.04	1.38	2.50	1.58
T_{12}	30.16	5.36	1.52	3.69	2.17
T_{13}	26.89	4.80	1.51	3.15	1.86
T_{14}	36.77	6.43	1.56	4.71	2.73
T_{15}	31.36	5.49	1.51	3.81	2.25
$C.D_{(0.05)}$	2.04	3.63		3.63	0.22

* The gross return were worked out on the basis of sale price of Rs. 15/- kg fixed by the University

The module T_{14} statistically excelled the RPF (260.62 q/ha) as well as all the other integrated modules with an yield outlay of 367.68 q/ha. The treatment combination T_6 (75 % NP + PGPR) even without any compensation by way of any organics for reduced synthetic content seems to have worked well as evident through its 3rd highest record of yield (321.95 q/ha) after T_{14} and T_8. In general, the increase in yield was more pronounced primarily in vermicompost related modules vis-a-vis those supplemented with enriched compost with or without bio-inoculation. Overall, six integrated modules *viz.* T_{14}, T_8, T_6, T_{15}, T_2, and T_{12} exerted highest positive influence on yield and yielding attributes which significantly surpassed RPF comprising 100 % inorganic (NPK) along with 20 t FYM/ha (T_1). The increased yield of 41.08, 24.22, 23.53, 20.35, 18.06, and 15.73 per cent, respectively observed by above modules was primarily on account of increase in components of yield *viz.* fruit size, weight, numbers as well as early harvest. The findings suggested that by the end of 2nd year of crop raising, reduction of at least 25 % recommended inorganic (NP) is possible through their substitution primarily with VC and/or bio-inoculation of planting material with *Bacillus subtilis*.

The higher yielding attributes and yield of capsicum through treatments supplemented with vermicompost alone or along with enriched compost in the present study could also be the result of regulated liberalization and balanced supply of nutrients, tilting microbial dynamics in favour of growth and creation of salutary soil environmental conditions for crop growth. In addition, besides its better nutrient contents, it could have increased the efficiency of added chemical fertilizers by its temporary immobilization, which reduces leaching of plant nutrients (Das *et al.*, 2006). Further, the PGPR can provide biologically fixed nitrogen to plants by meeting requirement up to 15-20 kg N/ha and secretes beneficial growth promoting substances like IAA, GA, kinetin, riboflavin, and thiamine, which can result in better plant growth (Malik *et al.*, 2005).

Corroborating with the results of present investigation, Khan *et al.*, (2008) showed that use of *Azotobacter*, *Azospirillum* in conjunction with 75 % RDN recorded significant increase in growth and yield of chillies as compared to control and concluded that N-fixing bio fertilizers could reduce the use of inorganic nitrogen by 25-50 per cent. Dass *et al.,* (2008) observed higher number as well more fruit weight of bell pepper and consequently the significantly higher yield from the plot treated with 50 % RPF + 5 t/ha VC and 50 % RPF + VC @ 2.5 t/ha + CM @ 5t/ha than recommended rate of synthetic fertilizers(NPK). Rani *et al.,* (2015) also recorded higher green chilli yield on account of higher fruit number and weight when 150 % of recommended dose of nitrogenous fertilizer was sourced half through inorganic and another half from organic sources *viz.* FYM (25 %) and Neem Cake (25 %) as basal and vermicompost as top dressing (50 %).

The reasons for increased fruit yield in chilli were attributed to the increased solubilization effect and availability of nutrient by the addition of organics and increased physiological activity leading to the build up of sufficient food reserves for the developing sinks and better portioning towards the developing fruits.

The advantage on yield by following different combinations of treatments by the integrated nutrition have also been reported in sweet pepper/chilli by Singh *et al.,* (2009), Talukder and Jana (2009) and Lal and Kanaujia (2013).

Available NPK

The significantly maximum available N (400.28 Kg/ha) was through the module comprising of 75 % NP + VC and EC @ 2.5 t/ha + PGPR (T_{14}) which was followed by T_8 (75 % NP + VC@ 2.5 t/ha + PGPR) and T_6 (75 % NP + PGPR), recording 373.73 and 370.27 kg N/ha, respectively. The gain in nitrogen availability in soil through above three treatment modules was to the tune of 26.64, 18.24 and 17.15 per cent, respectively over the RPF i.e. T_1 (316.07 kg/ha). As far phosphorus, T_{14} and T_8 again registered significantly maximum mean P i.e. 52.61 and 46.37 kg/ha, respectively, among all modules including RPF (34.99 kg P/ha). The availability of these macro-nutrients was more pronounced when reduction in recommended inorganic application was substituted primarily with vermicompost, PGPR or both. The mean content of K was also maximum (456.07 kg/ha) with T_{14} closely followed by $T_{6,}$ $T_{15,}$ and T_2 which recorded 433.31, 427.47 and 423.44 kg P/ha, respectively (Table 3).

Concluding, in our study, conjoint use of organic manures particularly vermicompost, PGPR and chemical fertilizers could result in saving of at least 25 % of synthetic fertilizers (NP) which is in conformity with conclusion drawn by many earlier researchers as below.

Prativa and Bhattarai (2011) obtained the maximum available N, P and K to be 382.80, 100.40 and 230.80 kg/ha, respectively after harvesting tomato, when half of recommended NPK was integrated with 15 t/ha vemicompost as compared to ½ NPK + 30 t/ha FYM which recorded 350.80, 88.70 and 193.60 kg of N, P and K, respectively or absolute recommended synthetic fertilizer (340.00, 89.30 and 184.10 kg, respectively).

They explained that mixing of N fertilizer with organic manures (more importantly VC) might have reduced the nitrogen losses, improved the fertilizer use efficiency thus increasing the availability of N.

The increase in phosphorus is attributable to the fact that vermicompost in combination with synthetic fertilizers might have helped in the solubilization of fixed P to soluble form making it easily available to the plant whereas, high availability of K might be due to enhancement in K availability by shifting the equilibrium among the form of K from relatively exchangeable K to soluble K forms in the soil.

Economic

The economic analysis showed that the highest net return of Rs 4.71 lacs by incurring Rs.1.56 lacs towards cost of cultivation per hectare was obtained from treatment T_{14} (75 % NP + VC and EC @ 2.5 t/ha + PGPR) on account of highest yield (36.77 t/ha) with a benefit: cost ratio of 2.73.

However, the benefit: cost ratio was highest (2.79) through module T_6 (75 % NP + PGPR) which otherwise recorded lesser yield (32.20 t/ha) as well as net returns (Rs. 4.14 lacs) vis-à-vis to the former module i.e. T_{14}.

This was 'in fact' on account of additional cost incurred on organic inputs (VC, EC) used in $T_{14.}$

However, it is pertinent to mention here that T_{14} vis-a-vis T_6 also resulted in good build-up of nutrient status (NPK) in soil as envisaged through Table 4.

Patil *et al.*, (2016), noticed the highest B: C ratio (7.77) case of 100 % RDF treatment vis-à-vis 50 % RDF + 25 % N through FYM and 25 % as through VC (5.93) to a carrot crop, yet the net returns were almost comparable between the former (Rs 1,24,286/-) and later one (Rs 1,23,738/-).

Similar returns through conjoint use of organic manures, PGPR/biofertilizers and chemical fertilizers has also been reported by Talukder and Jana (2009), Vimera *et al.*, (2012) in chilli and Lal and Kanaujia (2013) and Rani *et al.*, (2015) in capsicum.

Concluding, the integrated module T_{14} (75 % NP + VC and EC @ 2.5 t/ha + PGPR) along with full recommended potash and FYM as basal application which resulted in saving of 25 % fertilizers (NP), better growth, higher yield and net returns along with enhanced soil health, can be suggested as a cost effective combination for getting higher yield of sweet pepper on sustainable basis.

References

Anonymous. NHB. 2016. National Horticulture Board Database. www.nhb.gov.in

Bagale, M. M., Kale, V. S., Khardeand, R. P. and Alekar, A. N. 2014. Integrated nutrient management studies in tomato. *Bioinfolet* 11: 1054-7.

Das, A., Prasad, M., Gautam, R. C. and Shivay, Y. S. 2006. Productivity of cotton (*Gossypium hirsutum)* as influenced by organic and inorganic sources of nitrogen. *Indian Journal of Agricultural Sciences* 76: 354-7.

Dass, A., Lenka, N. K., Patnaik, U. S. and Sudhishri, S. 2008. Integrated nutrient management for production, economics and soil improvement in winter vegetables. *Int J Veg Sci* 14: 104-20.

Deshpande, R. P., Tamgadge, S., Deshmukh, A. and Deshmukh, S. 2010. Effect of organic and inorganic manures on growth and yield of chilli. *Int J Forestry & Crop Improvement* 1: 146-8.

Escalona, A. and Pire, R. 2008. Growth and N-P-K removal in chicken manure fertilized bell pepper (*Capsicum annuum* L.) plants in Quibor, Lara State, Venezuela. *Revista de la Faculated de Agronomia, Universidad del Zulia*. 25: 243-60.

Fawzy, Z. F., El-Bassiony, A. M., Yunsheng, Li., Zhu, O. and Ghoname, A. A. 2012. Effect of mineral, organic and bio-N fertilizers on growth, yield and fruit quality of sweet pepper. *J Applied Sci Res* 8(8): 3921-33.

Flores, P., Castellar, I., Hellin, P., Fenoll, J. and Navarro, J. 2007. Response of pepper plants to different rates of mineral fertilizers after soil biofumigation and solarization. *J Plant Nutrition* 30: 367-79.

Greenleaf, W. H. 1986. Pepper breeding. (*In*) Breeding Vegetable Crops. AVI, West Port, pp. 67-134.

Khan, M. A., Zarghar, Y. and Ara, S. 2008. Performance of carrier-based inoculants in some vegetable crops grown in Srinagar, Kashmir. *J Plant Sci Res* 24(2): 215-7.

Kondapa, D., Radder, B. M., Patil, P. L., Hebsur, N. S. and Alagundagi, S. C. 2009. Effect of integrated nutrient management on growth, yield and economics of chilli (cv. Byadgi Dabba) in a vertisol. *Karnataka J Agri Sci* 22: 438-40.

Kumar, A. and Dhar, S. 2010. Evaluation of organic and inorganic sources of nutrients in maize (*Zea mays*) and their residual effect on wheat (*Triticum aestivum*) under different fertility levels. *Indian J Agri Sci* 80: 364-71.

Lal, S. and Kanaujia, S. P. 2013. Integrated nutrient management in capsicum under low cost polyhouse condition. *Annals of Hort* 6: 170-7.

Malik, B. S., Paul, S., Sharma, R. K., Sethi, A. P. and Verma, O. P. 2005. Effect of *Azotobacter chroococcum* on wheat (*Triticum aestivum*) yield and its attributing components. *Indian J Agri Sci* 75: 600-2.

Prativa, K. C. and Bhattarai, B. P. 2011. Effect of integrated nutrient management on the growth, yield and soil nutrient status in tomato. *Nepal J Sci & Tech* 12: 23-8.

Rani, P. L., Balaswamy, K., Rao, A. R. and Masthan. S. C. 2015. Evaluation of integrated nutrient management practices on growth, yield and economics of green chilli cv. Pusa Jwala (*Capsicum annuum* L.). *Int J Bio-resource & Stress Management* 6: 076-80.

Renuka, B. and Ravi Shankar, C. 1998. Effect of organic manures on growth and yield of tomato. *South Indian Horti* 49: 216-7.

Roberts, T. L. 2009. The role of fertilizer in growing the world's food. Better Crops 93: 12-5.

Shiva, K. N., Srinivasan, V., Zachariah, T. J. and Leela, N. K. 2015. Integrated nutrient management on growth, yield and quality of paprika alike chillies (*Capsicum annuum* L.). *J Spices & Aromatic Crops* 24: 92-7.

Singh, A., Singh, K. G. and Gosal, S. K. 2009. Integrated nutrient management in sweet pepper (*Capsicum annuum* L. *var. grossum*) grown in naturally ventilated polyhouse. *Department of Microbiology, PAU, Ludhiana* 36: 171-4.

Taludker, B. and Jana, J. C. 2009. Integrated nutrient management for better growth, yield and quality of green chilli (*Capsicum annuum* L.) in Tarai region of West Bengal. *Indian J Agri Sci* 79: 600-3.

Vimera, K., Kanaujia, S. P., Singh, V. B. and Singh, P. K. 2012. Effect of integrated nutrient management on growth and yield of king chilli under foothill condition of Nagaland. *J Indian Soci of Soil Sci* 60: 45-9.

Wu, S. C., Cao, Z. H., Li, Z. G., Cheung, K. C. and Wong, M. H. 2005. Effects of biofertilizer containing N-fixer, P and K solubilizers and AM fungi on maize growth: a greenhouse trial. *Geoderma* 125: 155-66.

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