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CONTENTS

Response of chilli (*Capsicum annuum* var. *annuum* L.) to different nutrient management practices

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ABSTRACT: A field investigation was carried out at the experimental farm of Krishi Vigyan Kendra, CSKHPKV, Bajaura (Kullu), Himachal Pradesh during *kharif*, 2022. The experiment was carried out in Randomized Block Design (RBD) with three replications comprising 12 treatment combinations of NPK fertilizers, biofertilizers (*Azotobacter* and PSB), organic and natural farming on chilli variety 'Him Palam Mirch-2'. Different nutrient management practices significantly influenced different horticultural traits. The results revealed that treatment combination of 100% NPK + 10 tonnes vermicompost + *Azotobacter* + PSB recorded maximum plant height (75.1 cm), number of primary branches per plant (4.90), number of secondary branches per plant (11.11), number of fruits per plant (173), fruit length (8.66 cm), fruit girth (3.60 cm), average green fruit weight (5.50 g), fruit yield (581.33 g), fruit yield plot^{-1} (9.30 kg), fruit yield ha^{-1}(258.37 q), number of seeds fruit-1(64.03), dry stalk weight (36.57 q ha^{-1}) and dry fruit yield (46.13 q ha^{-1}). The maximum B:C ratio of 4.24 was recorded with the application of 100% NPK + 10 tonnes vermicompost + *Azotobacter* + PSB and it also gave significantly the highest gross (₹5,16,740) and net (₹4,18,168.69) returns. Natural farming practice showed least performance for all the traits while organic farming practice found better than natural farming. Therefore, can be concluded that the combined application of NPK fertilizers and organic inputs coupled with biofertilizers proved the best for increasing fruit yield, quality and best utilization of nutrients supplied.

Key words: *Azotobacter*, biofertilizer, economics, PSB, vermicompost

Chilli (*Capsicum annuum* var. *annuum* L.), a member of family Solanaceae is the third most important crop after tomato and potato. Chilli is an important fruit vegetable and valuable spice grown throughout world for human consumption (Dias *et al.* 2013). It is rich in proteins, lipids, carbohydrates, fibers, minerals (Ca, P, Fe) and vitamins A, D3, E, C, K, B2 and B12 and mostly known for its green, aromatic fruits, which are used as an important ingredient in cooking (El-Ghorab *et al.* 2013).

Being a long duration crop, it requires proper manuring and fertilization in the surface soil for attaining high yield and quality produce because of its shallow root system (Bidari, 2000). Studies have also revealed that many nutrient deficits and decreased crop yield were caused by the use of sub-optimal amount of nutrients in an unbalanced proportion. Synthetic or chemical fertilizers comprising nitrogen, phosphorus and potassium increase the cost of agricultural production (Sharma *et al.,* 2022). Moreover, the imbalance and continuous use of chemical fertilizers has detrimental effects on soil physical, chemical and biological properties, there by affecting the sustainability of crop production, besides causing environmental pollution (Virmani, 1994). Organic manures can be used to meet the nutrient requirement of the crop as these not only enhance the physical, chemical and biological properties of the soil but also improve the moisture holding capacity of the soil.

Chemical fertilizers, organic manures, crop leftovers or bio-fertilizers alone cannot supply a crop with all the nutrients it requires. Therefore, there must be a balance between organic and inorganic fertilizers. The integrated supply and use of plant nutrients from chemical fertilizers and organic sources has shown to produce higher crop yields compared to their sole application (Kapse *et al.,* 2017). Though, chilli crop is grown over large area but per hectare fruit as well as seed yield is not up to the expectation. Lack of awareness among farmers about improved technologies like high yielding varieties, integrated nutrient management and proper plant protection measures are the main reasons for its low productivity in India.

MATERIALS AND METHODS

The present investigation was carried out at the experimental farm of Krishi Vigyan Kendra, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Bajaura, Kullu, Himachal Pradesh during *kharif*, 2022. The experimental material comprised of 12 treatment combinations i.e., (T_1) Recommended 100% NPK @100:75:55 kg ha^{-1} ($N:P_2O_5:K_2O$), (T_2) Recommended practice (100% NPK + 20 tonnes FYM ha^{-1}), (T_3) 100% NPK + 10 tonnes vermicompost, (T_4) 100% NPK + 10 tonnes vermicompost + *Azotobacter*, (T_5) 100% NPK + 10 tonnes vermicompost + PSB, (T_6) 100% NPK+10 tonnes vermicompost + *Azotobacter* + PSB, (T_7) 75% NPK @75:56.25:41.25 kg ha^{-1} ($N:P_2O_5:K_2O$) + 10 tonnes vermicompost, (T_8) 75% NPK + 10 tonnes vermicompost + *Azotobacter*, (T_9) 75% NPK + 10 tonnes vermicompost + PSB, (T_{10}) 75% NPK + 10 tonnes vermicompost + *Azotobacter* + PSB, (T_{11}) Organic farming practice: 10 tonnes vermicompost and Vermiwash spray @10% at 10 days interval, (T_{12}) Natural farming practice: Application of *Ghanjeevamrit* @ 10 q ha^{-1} at the time of transplanting, seedlings treatment with *Beejamrit* + *Jeevamrit* spray @10% 10 days interval.

The experiment was laid out in randomized block design with three replications with 12 plots each of size 1.8 x 1.8 m at a spacing of 45 × 45 cm were prepared. The inorganic fertilizers were applied as per treatments i.e., 100% NPK @100:75:55 kg ha^{-1} (N: P_2O_5: K_2O) and 75% NPK @75:56.25:41.25 kg ha^{-1} (N: P_2O_5: K_2O) through urea, single super phosphate and muriate of potash. The recommended dose of FYM @20 tonnes ha^{-1} was applied only in RDF treatment while vermicompost @10 t ha^{-1} was applied to different plots according to the treatments. Half dose of N, full dose of P and K was applied at the time of transplanting. The remaining half N was top dressed in two equal splits at an interval of 30 and 60 days after transplanting. Seedlings were inoculated by dipping for 15 minutes in the culture of indigenous strain of *Azotobacter,* PSB and *Azotobacter* + PSB as per the treatments. In organic farming treatment, application of vermiwash @10% (1:10 dilution) was sprayed at 10 days interval. The natural farming practice comprised of mixing of *Ghanzivamrit* @ 10 q ha^{-1} in the soil of respective treatment plots at transplanting. Besides, the seedlings were treated before transplanting with *Beejamrit* and *Jeevamrit* 10% was also sprayed at 10 days interval in natural farming treatment.

The observations were made on growth and development (days to 50% flowering, days to first harvest, plant height (cm), primary branches per plant, secondary branches per plant), yield contributing traits of chilli (number of fruits per plant, fruit length (cm), fruit girth (cm), average green fruit weight (g), green and dry fruit yield (green fruit yield per plant (g), green fruit yield per plot (kg), green fruit yield per ha (q), dry fruit yield per ha (q)), number of seeds per fruit and dry stalk weight (q ha^{-1}) and economic studies (Gross returns (₹ha^{-1}), Net returns (₹ha^{-1}) and B:C ratio). Analysis of variance was done as per the standards of Panse and Sukhatme (1984).

RESULTS AND DISCUSSION

Effect of different nutrient treatments on growth and development of chilli

Days to 50 % flowering and first harvest

The effect of different nutrient management practices could not significantly influence the number of days taken to 50 % flowering and days to first harvest (Table 1). It was quite expected because the fruit maturity in chilli is governed by the interactive effect of prevailing photoperiod and temperature.

Plant height (cm)

The analysis of variance revealed significant differences among different treatments for plant height (Table 1). The treatment combination T_6 (NPK @100% + 10 t vermicompost + *Azotobacter* + PSB) recorded significantly the tallest plants (75.1 cm) compared to rest of the treatments, however, it was statistically at par with the application of NPK

@100% + 10 t vermicompost + PSB (73.3 cm), NPK @100% + 10 t vermicompost + *Azotobacter* (72.9 cm), RDF @100% NPK + 20 tonnes FYM ha^{-1} (72.5 cm) and NPK @100% + 10 t vermicompost (72.4 cm). The application of NPK @ 100% (T_1) recorded significantly taller plants (71 cm) compared to organic (62.3 cm) and natural farming treatments (58.9 cm). However, this treatment was statistically at par with sole or combined application of biofertilizers (*Azotobacter* and PSB) @ 75 % NPK levels. Natural farming practice produced the lowest plant height (58.9 cm) which was statistically at par with organic farming treatment (62.3 cm).

The increase in plant height with higher doses of NPK could be due to enzymes, protein synthesis, root development, phosphoprotein, phospholipids formation and enhancing the translocation of assimilates. The increased plant height with the application of biofertilizers either alone or in

Table 1: Effect of different nutrient treatments on growth and development of chilli

Treatment	Treatment details	Days to 50% flowering	Days to first harvest	Plant height (cm)	Primary branches per plant	Secondary branches per plant
T_1	Recommended 100% NPK @100:75:55 kg ha^{-1} ($N:P_2O_5:K_2O$)	49.7	60.0	71.0	4.70	10.07
T_2	Recommended practice (100% NPK + 20 t FYM ha^{-1})	49.0	60.3	72.4	4.73	10.30
T_3	100% NPK + 10 t vermicompost	49.3	61.0	72.5	4.77	10.40
T_4	100% NPK + 10 t vermicompost + *Azotobacter*	50.0	61.3	72.9	4.80	10.70
T_5	100% NPK + 10 t vermicompost + PSB	49.7	61.3	73.3	4.82	11.03
T_6	100% NPK + 10 t vermicompost + *Azotobacter* + PSB	50.3	62.0	75.1	4.90	11.11
T_7	75% NPK @75:56.25:41.25 kg ha^{-1} ($N:P_2O_5:K_2O$) + 10 t vermicompost	48.0	61.7	68.8	4.50	9.73
T_8	75% NPK + 10 t vermicompost + *Azotobacter*	48.3	61.3	69.4	4.57	9.77
T_9	75% NPK + 10 t vermicompost + PSB	48.7	60.7	69.8	4.60	9.80
T_{10}	75% NPK + 10 t vermicompost + *Azotobacter* + PSB	49.0	61.3	70.0	4.62	9.93
T_{11}	Organic farming practice	50.7	62.7	62.3	4.26	9.37
T_{12}	Natural farming practice	51.3	63.0	58.9	4.04	8.87
SE(m) ±		0.78	0.72	1.3	0.09	0.15
CD (5%)		NS	NS	4.0	0.27	0.46
CV (%)		2.73	2.01	3.41	3.39	2.69

Table 2: Effect of different nutrient treatments on yield contributing traits of chilli

Treatment	Treatment details	No. of fruits per plant	Fruit length (cm)	Fruit girth (cm)	Average green fruit weight (g)
T_1	Recommended 100% NPK @100:75:55 kg ha^{-1} ($N:P_2O_5:K_2O$)	166.6	7.84	3.50	5.00
T_2	Recommended practice (100% NPK + 20 t FYM ha^{-1})	170.7	8.02	3.52	5.10
T_3	100% NPK + 10 t vermicompost	171.2	8.14	3.53	5.17
T_4	100% NPK + 10 t vermicompost+ *Azotobacter*	171.7	8.22	3.55	5.23
T_5	100% NPK + 10 t vermicompost + PSB	172.1	8.34	3.56	5.37
T_6	100% NPK + 10 t vermicompost + *Azotobacter* + PSB	173.0	8.66	3.60	5.50
T_7	75% NPK @75:56.25:41.25 kg ha^{-1} ($N:P_2O_5:K_2O$) + 10 t vermicompost	150.9	7.85	3.46	4.82
T_8	75% NPK + 10 t vermicompost + *Azotobacter*	153.0	7.88	3.47	4.83
T_9	75% NPK + 10 t vermicompost + PSB	158.0	7.90	3.48	4.86
T_{10}	75% NPK + 10 t vermicompost + *Azotobacter* + PSB	160.7	7.96	3.49	4.92
T_{11}	Organic farming practice	131.3	7.27	3.40	4.54
T_{12}	Natural farming practice	122.5	7.10	3.33	4.44
SE(m) ±		1.07	0.15	0.04	0.10
CD (5%)		3.15	0.45	0.12	0.30
CV (%)		1.16	3.33	2.11	3.59

combinations may be ascribed to higher and continuous availability of atmospheric nitrogen by *Azotobacter*, phosphorus by the solubilizing. Similar results have also been reported by Narkhede *et al.* (2011), Talukder & Jana (2009), Rani *et al.* (2015) and Gokul *et al.* (2020).

Primary branches per plant

An analysis of variance for number of primary branches per plant revealed significant differences with the application of different nutrient treatment combinations (Table 1). The combined application of NPK @100% + 10 t vermicompost + *Azotobacter* + PSB (T_6) produced significantly the highest number of primary branches per plant (4.9) compared to the remaining combinations.

The increased number of primary branches with the conjoint application of inorganic fertilizers, biofertilizer, organic and natural farming practices may be due to effective absorption and utilization of available nutrients, better root growth and proliferation would have accelerated the production of growth regulators, which in turn increased cell division and elongation, leading to faster canopy growth and higher growth of the chilli plant with

Table 3: Effect of different nutrient treatments on green and dry fruit yield of chilli

Treatment	Treatment details	Fruit yield per plant (g)	Fruit yield per plot (kg)	Fruit yield per ha (q)	Dry fruit yield per ha (q)
T_1	Recommended 100% NPK @100:75:55 kg ha^{-1} ($N:P_2O_5:K_2O$)	467.90	7.47	207.58	40.37
T_2	Recommended practice (100% NPK) + 20 t FYM ha^{-1}	548.23	8.77	243.66	43.40
T_3	100% NPK + 10 t vermicompost	550.00	8.80	244.44	44.33
T_4	100% NPK + 10 t vermicompost + *Azotobacter*	567.08	9.07	252.04	44.50
T_5	100% NPK + 10 t vermicompost + PSB	572.47	9.16	254.43	45.53
T_6	100% NPK + 10 t vermicompost+ *Azotobacter* + PSB	581.33	9.30	258.37	46.13
T_7	75% NPK @75:56.25:41.25 kg ha^{-1} ($N:P_2O_5:K_2O$) + 10 t vermicompost	485.43	7.77	215.75	41.73
T_8	75% NPK + 10 t vermicompost + *Azotobacter*	517.55	8.30	230.67	42.30
T_9	75% NPK + 10 t vermicompost + PSB	522.93	8.37	232.41	42.40
T_{10}	75% NPK + 10 t vermicompost + *Azotobacter* + PSB	528.85	8.47	235.32	42.83
T_{11}	Organic farming practice	411.33	6.53	181.46	37.71
T_{12}	Natural farming practice	362.52	5.80	161.18	32.47
SE(m) ±		7.81	0.13	3.47	0.89
CD (5%)		23.00	0.37	10.26	2.64
CV (%)		2.66	2.67	2.66	3.70

Table 4: Effect of different nutrients treatments on no. of seeds per fruit and dry stalk weight

Treatment	Treatment details	No. of seeds per fruit	Dry stalk weight (q/ha)
T_1	Recommended 100% NPK @100:75:55 kg ha^{-1} ($N:P_2O_5:K_2O$)	58.3	33.02
T_2	Recommended practice (100% NPK) + 20 t FYM ha^{-1}	58.7	33.42
T_3	100% NPK + 10 t vermicompost	59.6	34.47
T_4	100% NPK + 10 t vermicompost+ *Azotobacter*	60.8	34.67
T_5	100% NPK + 10 t vermicompost + PSB	61.9	35.87
T_6	100% NPK + 10 t vermicompost+ *Azotobacter* + PSB	64.0	36.57
T_7	75% NPK @75:56.25:41.25 kg ha^{-1} ($N:P_2O_5:K_2O$) + 10 t vermicompost	55.3	30.65
T_8	75% NPK + 10 t vermicompost + *Azotobacter*	55.7	31.27
T_9	75% NPK + 10 t vermicompost + PSB	56.8	31.97
T_{10}	75% NPK + 10 t vermicompost + *Azotobacter* + PSB	57.3	32.28
T_{11}	Organic farming practice	51.0	29.66
T_{12}	Natural farming practice	48.5	26.45
SE(m) ±		1.10	1.05
CD (5%)		3.26	3.13
CV (%)		3.33	5.67

Table 5: Economics of different treatment

Treatment	Treatment details	Gross returns₹ha^{-1}	Net returns₹ha^{-1}	B:C ratio
T_1	Recommended 100% NPK @100:75:55 kg ha^{-1}(N:P_2O_5:K_2O)	415160	335388.69	4.20
T_2	Recommended practice (100% NPK + 20 t FYM ha^{-1})	487320	394108.69	4.22
T_3	100% NPK + 10 t vermicompost	488800	393668.69	4.13
T_4	100% NPK + 10 t vermicompost + *Azotobacter*	504080	405938.69	4.14
T_5	100% NPK + 10 t vermicompost + PSB	508860	410718.69	4.18
T_6	100% NPK + 10 t vermicompost+ *Azotobacter* + PSB	516740	418168.69	4.24
T_7	75% NPK @75:56.25:41.25 kg ha^{-1} (N:P_2O_5:K_2O) + 10 t vermicompost	431500	337374.91	3.58
T_8	75% NPK + 10 t vermicompost + *Azotobacter*	461340	364714.91	3.77
T_9	75% NPK + 10 t vermicompost + PSB	464820	368194.91	3.81
T_{10}	75% NPK + 10 t vermicompost + *Azotobacter* + PSB	470640	374014.91	3.87
T_{11}	Organic farming practice	362920	259380.00	2.50
T_{12}	Natural farming practice	322360	227310.00	2.39

more primary branches. The results are in line with the findings of Pariari and Khan (2013), Vitkar *et al.* (2007) and Rani *et al.* (2015). Application of vermicompost increases the nutrient supply and microbial population that significantly increases the number of primary branches per plant as reported by Singh *et al.* (2014).

Secondary branches per plant

Number of secondary branches per plant was significantly influenced by different treatment combinations of nutrient sources. The treatment combination T_6 (100% NPK + 10 t vermicompost + *Azotobacter* + PSB) recorded significantly the highest number of secondary branches per plant (11.11) compared to rest of the treatment combinations. However, it was statistically at par with application of NPK @100% + 10 t vermicompost + PSB (11.03) and NPK @100% + 10 t vermicompost + *Azotobacter* (10.70). Further, it was also observed that application of 100% NPK either in conjunction with vermicompost @10 t ha^{-1} (10.40) and FYM @20 tonnes ha^{-1} (10.30) or alone (10.07) while remaining statistically at par among themselves but produced significantly higher number of secondary branches per plant compared to the six treatment combinations. (Table 1). At 75% NPK level, all the treatment combinations were statistically at par among themselves.

The increase in number of secondary branches per plant could be attributed to increased nutrient availability. Further, the application of biofertilizers, organic and natural farming practices had the positive role on plant growth and development that led to increased branches per plant. Similar findings were also reported by Ranjitha (2016).

Effect of different nutrient treatments on yield contributing traits of chilli

Number of fruits per plant

The observations significantly depicted that the treatment T_6 (100% NPK + 10 t vermicompost + *Azotobacter* + PSB) recorded significantly the maximum number of fruits per plant (173) compared to other nutrient practices (Table 2). However, it was statistically at par with treatment T_5 (100% NPK + 10 t vermicompost + PSB), T_4 (100% NPK + 10 t vermicompost + *Azotobacter*), T_3 (100% NPK + 10 t vermicompost) and T_2 (100% NPK + 20 tonnes FYM ha^{-1}). Furthermore, it was observed that application of 100% NPK gave significantly higher number of fruits per plant (170.7) compared to remaining combinations either at 75% NPK level or organic and natural farming treatments. Further, it was also observed that the organic farming treatment gave significantly higher number of fruits) per plant (131.3) compared to natural farming practice (122.5).

The increased number of fruits per plant with the application of chemical fertilizers, organic inputs including biofertilizers that might be due to the synergistic physiological effects of these nutrients as well as growth promoting substances on growth and development in chilli. Moreover, these inputs also have a critical function in cell expansion that has a direct impact on the quality of fruits. Similar findings were also recorded by Kashem *et al.* (2015).

Fruit length (cm)

The results significantly revealed that application of 100% NPK + 10 t vermicompost + *Azotobacter* + PSB (8.66 cm) while remaining at par with 100% NPK + 10 t vermicompost + PSB (8.34 cm) and 100% NPK + 10 t vermicompost + *Azotobacter* (8.22 cm) gave significantly the highest fruit length compared to rest of the treatment combinations (Table 2). Almost similar findings have also been reported by Singh *et al.* (2010), Vitkar *et al.* (2007), Kumar *et al.* (2016), Islam *et al.* (2018) and Sharma *et al.* (2022) in chilli owing to the beneficial effects of NPK when integrated with biofertilizers and organic inputs.

Fruit girth (cm)

The fruit girth was significantly influenced by different nutrient combinations (Table 2). The treatment, 100% NPK + 10 t vermicompost + *Azotobacter* + PSB recorded significantly the highest fruit girth (3.60 cm) over organic (3.40 cm) and natural farming treatment (3.33 cm), however it was statistically at par with treatment combinations of 100% NPK + 10 t vermicompost + PSB (3.56 cm), 100% NPK + 10 t vermicompost + *Azotobacter* (3.55 cm), 100% NPK + 10 t vermicompost (3.53 cm), 100% NPK + 20 tonnes FYM ha^{-1} (3.52 cm) and recommended 100% NPK (3.50 cm) and 75% NPK + 10 t vermicompost + *Azotobacter* + PSB (3.49 cm). The above findings are in confirmation with the finding of Kumar *et al.* (2016), Islam *et al.* (2018), Shabir *et al.* (2016) and Behera *et al.* (2020) who found that fruit girth of chilli increased significantly with increase in the NPK levels, biofertilizers and organic inputs. These inputs improved the nutrient availability thereby, resulted in enhanced growth and yield attributes of the crop.

Average green fruit weight (g)

The application of 100% NPK + 10 t vermicompost + *Azotobacter* + PSB (5.50 g) while remaining at par with 100% NPK+10 t vermicompost + PSB (5.37 g) and 100% NPK + 10 t vermicompost + *Azotobacter* (5.23 g) produced significantly the highest green fruit weight over the rest of the treatment combinations (Table 2). The above findings corroborated with the reports of Singh *et al.* (2010), Jamir *et al.* (2017), Chauhan *et al.* (2018) and Islam *et al.* (2018) who revealed that integrated application of chemical fertilizers, biofertilizers along with incorporation of vermicompost significantly improved the fruit weight of solanaceous vegetables.

Effect of different treatments on green and dry fruit yield of chilli

Fruit yield per plant of chilli (g)

Fruit yield per plant increased significantly with increment in fertility levels from 75 to 100 % NPK irrespective of any combinations (Table 3). The application of NPK @ 100% + 10 t vermicompost + *Azotobacter* + PSB (581.33 g) while remaining statistically at par with NPK @100% + 10 t vermicompost + PSB (572.47 g) and NPK @ 100% + 10 t vermicompost + *Azotobacter* (567.08 g) gave significantly the highest fruit yield per plant compared to rest of the treatment combinations (Fig. 1). It was also observed that treatment combination of 100% NPK + 10 t vermicompost produced significantly higher fruit yield per plant (550.00 g) compared to remaining treatment combinations, however it was statistically at par with 100% NPK + 20 tonnes FYM ha^{-1} (548.23 g) and 75% NPK + 10 t vermicompost + *Azotobacter* + PSB (528.85 g). The increase in fruit yield per plant of chilli could be due to higher and continuous availability of nutrients from combined source (NPK + Vermicompost + *Azotobacter* + PSB) at vital growth period that might have enhanced the growth and yield contributing traits. This resulted in better photosynthetic activities of the plant that helped in better translocation of carbohydrates to the storage organs and ultimately enhanced biomass production. Similar results were also reported by Kattimani & Yadahalli (2009), Singh *et al.* (2010) and Chauhan *et al.* (2018) in chilli crop.

Fruit yield per plot of chilli (kg)

Significantly the highest fruit yield per plot (9.30 kg) was found in treatment T_6 (100% NPK + 10 t

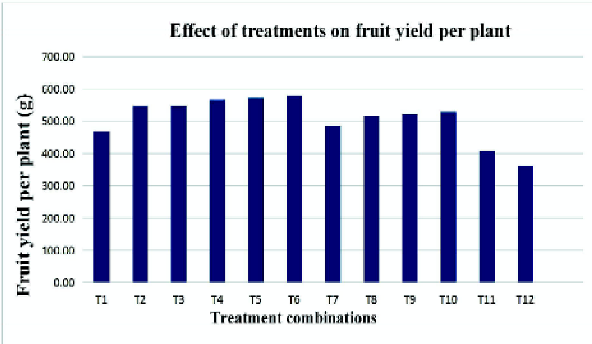

Fig. 1: Effect of treatments on fruit yield per plant

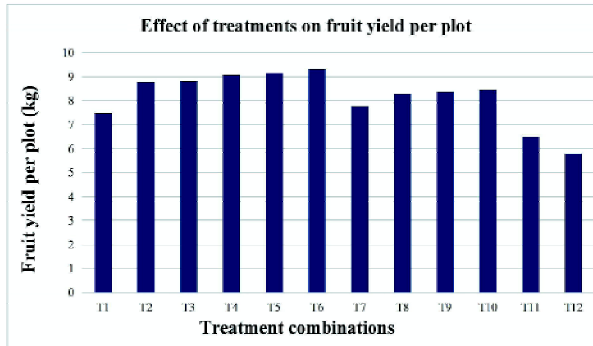

Fig. 2: Effect of treatments on fruit yield per plot

vermicompost + *Azotobacter* + PSB) which was statistically at par with T_5 (100% NPK + 10 t vermicompost + PSB) and T_4 (100% NPK + 10 t vermicompost + *Azotobacter*) but significantly superior over rest of the treatment combinations (Table 3). The application of NPK @ 100% + 10 t vermicompost + *Azotobacter* + PSB and NPK @100% + 20 tonnes FYM ha^{-1} recorded an increased fruit yield per plot to the tune of 24.50 and 16.47 per cent, respectively, over NPK @ 100% (Fig. 2).

The increased fruit yield with conjoint application of NPK, biofertilizers and organic inputs could be ascribed to increase in yield attributes (number of fruits/plants, fruit length, average fruit weight) and well-developed root system that ultimately resulted in a healthy plant growth and development and in turn to yield. Deepika *et al.* (2010), Kumar *et al.* (2016), Talukder and Jana (2009) and Islam *et al.* (2018) also found the similar results with the integrated application of chemical and organic sources of fertilizers in chilli.

Fruit yield quintal per ha

The fruit yield per hectare in chilli was significant influenced with the application of all the nutrient management practices (Table 3). The application of 100 %NPK + 10 t vermicompost + *Azotobacter* + PSB produced significantly the highest fruit yield of 258.37 q ha^{-1} over rest of the treatment combinations, however, it was statistically at par with 100% NPK + 10 t vermicompost + PSB (254.43 q ha^{-1}) and 100% NPK + 10 t vermicompost + *Azotobacter* (252.04 q ha^{-1}). The next best treatment was T_3 i.e., 100% NPK + 10 t vermicompost (244.44 q ha^{-1}) that gave significantly the higher fruit yield compared to the other combinations but it remained statistically at par with the combinations of 100% NPK + 20 tonnes FYM ha^{-1} (243.66 q ha^{-1}) and 75% NPK + 10 t vermicompost + *Azotobacter* + PSB (235.32 q ha^{-1}). The application of NPK @ 100% + 10 t vermicompost + *Azotobacter* + PSB recorded an increased fruit yield to the tune of 6.03 per cent over recommended dose of fertilizer (NPK @100% + 20 tonnes FYM ha^{-1}).

The differences among biofertilizers (*Azotobacter* and PSB) applied either alone or in combined form at 75% NPK level were found to non-significant but recorded significantly higher fruit yield over 75% NPK + 10 t vermicompost, thereby exhibiting that *Azotobacter* and PSB applied either individually or in combined form could mobilize plant nutrients in more efficient way. The organic farming practices (181.46 q ha^{-1}) produced significantly higher fruit yield over natural farming (161.18 q ha^{-1}).

This increase could be ascribed to higher and continuous availability of nutrients from combined source (NPK, biofertilizers and organic inputs) during critical growth period that might have increased the growth parameters which finally resulted into higher fruit yield. The results are in conformity with the findings of Kattimani and Yadahalli (2009), Singh *et al.* (2016), Chauhan *et al.* (2018), Bilal *et al.* (2019) and Islam *et al.* (2018).

Dry fruit yield (q ha^{-1})

The combination 100% NPK + 10 t vermicompost + *Azotobacter* + PSB) gave significantly the highest dry fruit yield (46.13 q ha^{-1}) over rest of the treatment combinations, however, it was statistically at par with 100% NPK + 10 t vermicompost + PSB (45.53 q ha^{-1}), 100% NPK + 10 t vermicompost + *Azotobacter* (44.50 q ha^{-1}) and 100 % NPK + 10 t vermicompost (44.33 q ha^{-1}). The recommended dose of fertilizers @100% NPK + 20 tonnes ha^{-1} FYM (43.40 q ha^{-1}) while remaining at par with different combinations at 75% NPK levels (T_{10}, T_9, T_8, T_7) also produced significantly higher dry fruit yield over the remaining combinations (T_1, T_{10} and T_{11}), thereby resulting in net saving of 25 % chemical fertilizers. The organic treatment also recorded significantly increased dry yield to the tune of 16.13 per cent over natural farming treatment (Table 3).

These results may be due to the role of NPK fertilizers on promotion of vegetative growth and the role of biofertilizers in increasing the availability of nutrients (nitrogen, phosphorus and potassium) to plant absorption which finally resulted in improving the vegetative growth and quality of fruits. The presence of beneficial microorganism in organic inputs like, vermicompost and *vermiwash* may be due to their constituents, which contain both macro and micro nutrients, vitamins, essential amino acids, growth promoting substances such as indole acetic acid (IAA), gibberellic acid and beneficial microorganism that directly aid in the plant's growth and development. Ranjitha (2016) also reported the similar results in chilli.

Effect of different nutrient treatments on no. of seeds per fruit and dry stalk weight

Number of seeds per fruit

Application of 100% NPK + 10 t vermicompost + *Azotobacter* + PSB (64.0) significantly recorded the highest number of seeds per fruit compared to rest of the treatment combinations, however, it remained statistically at par with T_5 (100% NPK + 10 t vermicompost + PSB) and T_4 (100% NPK + 10 t vermicompost + *Azotobacter*). Thereby indicating the role of integrated use of fertilizers besides saving 25% NPK (Table 4). The increase could be due to higher and continuous availability of nutrients from combined source (NPK, *Azotobacter* + PSB + vermicompost) at vital growth period that might have enhanced the growth and yield parameters. This resulted in better photosynthetic activities of the plant that helped in better translocation of carbohydrates to the storage organs and ultimately enhanced biomass production Mallika *et al.* (2022) and Hasan *et al.* (2014).

Dry stalk weight (q ha^{-1})

Application of treatment combination T_6 (100% NPK + 10 t vermicompost + *Azotobacter* + PSB) recorded significantly the highest dry stalk weight (36.57 q ha^{-1}) over rest of the combinations (Table 4), however, it was statistically at par with 100% NPK + 10 t vermicompost + PSB (35.87 q ha^{-1}), 100% NPK + 10 t vermicompost + *Azotobacter* (34.67 q ha^{-1}) and 100 % NPK + 10 t vermicompost (34.47 q ha^{-1}). Further, the application of RDF (100% NPK + 20 tonnes FYM) gave significantly higher stalk weight (33.42 q ha^{-1}) compared to organic (29.66 q ha^{-1}) and natural farming practice (26.45 q ha^{-1}) but it remained statistically at par with 100% NPK @100:75:55 kg ha^{-1} (33.02 q ha^{-1}), 75% NPK + 10 t vermicompost + *Azotobacter* + PSB (32.28 q ha^{-1}), 75% NPK + 10 t vermicompost + PSB (31.97 q ha^{-1}), 75% NPK + 10 t vermicompost + *Azotobacter* (31.27 q ha^{-1}) and 75% NPK @75:56:25:41:25 kg ha^{-1} ($N:P_20_5:K_2O$) + 10 t vermicompost (30.65 q ha^{-1}).

The increased dry weight in chilli may be due to the role of NPK fertilizers on promotion of vegetative growth and the role of biofertilizers and organic inputs on increasing the availability of nutrients (N, P & K) to plant absorption which finally resulted in improving the vegetative growth that led to more plant height, primary and secondary branches per plant. The results are similar with the findings of Ranjitha (2016).

Effect of different nutrient treatments on economics of chilli

The application of treatment combination T_6 (100% NPK + 10 t vermicompost + *Azotobacter* + PSB) gave the highest gross returns of ₹5,16,740 ha^{-1} (Table 5) followed by 100% NPK + 10 t vermicompost + PSB (₹5,08,860), 100% NPK + 10 t vermicompost + *Azotobacter* (₹5,04,080), 100%

NPK + 10 t vermicompost (₹4,88,800) and 100% NPK + 20 tonnes FYM ha^{-1} (₹4,15,160). Treatment combination T_{10} (75% NPK + 10 t vermicompost + *Azotobacter* + PSB) also recorded higher gross returns of ₹4,70,640 followed by T_9 (75% NPK + 10 t vermicompost + PSB) and T_8 (75% NPK + 10 t vermicompost + *Azotobacter*). The minimum gross returns (₹3,22,360) were found in natural farming practice.

Net returns (₹ha^{-1})

The maximum net returns (₹4,18,168.69 ha^{-1}) were recorded in treatment combination T_6 (Table 5) followed by 100% NPK + 10 t vermicompost + PSB (₹4,10,718.69), 100% NPK + 10 tonnes vermicompost + *Azotobacter* (₹40,59,38.69), 100% NPK + 10 tonnes vermicompost (₹393668.69) and 100% NPK + 20 tonnes FYM ha^{-1} (₹3,94,108.69). Application of 75% NPK + 10 t vermicompost + *Azotobacter* + PSB) also gave higher net returns of ₹3,74,014.91 ha^{-1} followed by 75% NPK + 10 tonnes vermicompost + PSB (Rs 3,68,194.91) and 75% NPK + 10 t vermicompost + *Azotobacter* (Rs 3,64,714.91). The application of natural farming practice recorded the lowest net returns (₹2,27,310.00).

B:C Ratio

The highest B:C ratio of 4.24 was recorded, when the plots were supplemented with 100% NPK + 10 tonnes vermicompost + *Azotobacter* + PSB (Table 5) closely followed by 100% NPK + 20 tonnes FYM ha^{-1} (4.22), 100% NPK (4.20), 100% NPK + 10 tonnes vermicompost + PSB (4.18), 100% NPK + 10 tonnes vermicompost + *Azotobacter* (4.14) and 100% NPK + 10 tonnes vermicompost (4.13). At 75% NPK level, the combination of 75% NPK + 10 tonnes vermicompost + *Azotobacter* + PSB gave higher B:C ratio (3.87). The lowest B:C ratio was registered in natural farming practice (2.39).

CONCLUSION

Based on the results, it was concluded that 'Him Palam Mirch-2' variety of chilli produced significantly the maximum green fruit yield of 258.37 q ha^{-1} with the application of 100% NPK + 10 t vermicompost + *Azotobacter* + PSB. In addition, the application of 100% NPK + 10 t vermicompost+ *Azotobacter* + PSB gave maximum gross returns of ₹5,16,740, net returns of ₹4,18,168.69 and B:C ratio of 4.24. Therefore, combined application of inorganic and organic source of nutrients coupled with biofertilizers proved to be the best for increasing fruit yield, quality and best utilization of nutrient supplied. Natural farming practice showed least performance for all the traits while organic farming practice found better than natural farming. Gross returns, net returns and B:C ratio in natural farming was less than organic farming practice.

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REFERENCES

Behera, S., Pradhan, P. P., Sahu, G. and Santra G. H. (2020). Integrated nitrogen management in growth and yield of chilli (*Capsicum annuum* L.) under red and lateritic soils of Odisha. *International Journal of Plant & Soil Science*, 32: 28-34.

Bidari, B. I. (2000). Assessment of yield and quality of Byadagi Chillies (*Capsicum annuum* L.) in relation to soil and management practices in Dharwad district. Doctoral dissertation, University of Agricultural Sciences, Dharwad.

Bilal, H., Aman, F., Ullah, I., Awan, A. A., Ullah, S., Khan, S., Aamir, M., Khan, M. A. and Rome, B. (2019). Response of chilli varieties to various sources of organic fertilizers. *ARPN Journal of Agricultural Biological Sciences*, 13: 15-24.

Chauhan, K. S., Baghel, S. S., Mishra, K., Singh, A. K. and Singh, V. (2018). Effect of integrated nutrient management on yield, quality and economic of chilli (*Capsicum annuum* L.). *Current Horticulture*, 6: 37-40.

Deepika, A., Singh, A. K., Kanaujia, S. P. and Singh, V. B. (2010). Effect of integrated nutrient management on growth, yield and economics of capsicum (*Capsicum annuum* L.) cv. California Wonder. *Journal of Soils and Crops*, 20: 33-38.

Dias, G. B., Gomes, V. M., Moraes, T. M., Zottich, U. P., Rabelo, G. R., Carvalho, A. O., Moulin M., Goncalves, L. S., Rodrigues, R. and Cunha, M. (2013). Characterization of *Capsicum species* using anatomical and molecular data. *Genetics and Molecular Research*, 12: 6488-6501.

El-Ghorab, A. H., Javed, Q., Anjum, F. M., Hamed, S. F. and Shaaban, H. A. (2013). Pakistani bell pepper (*Capsicum annuum* L.) chemical compositions and its antioxidant activity. *International Journal of Food Properties*, 16: 18-32.

Gokul, D., Poonkodi, P. and Angayarkanni, A. (2020). Effect of integrated nutrient management on the growth and nutrient content of chilli (*Capsicum annuum* L.). *International Journal of Chemical Studies*, 8: 2647-2651.

Hasan, M., Haider, T., Choudhary, M. S. N. and Ferdous, M. (2014). Study on morpho-physiological and yield performance of four chilli (*Capsicum sp*.) lines. *Journal of Bioscience and Agriculture Research*, 2: 1-7.

Islam, M. R., Sultana, T., Haque, M. A., Hossain, M. I., Sabrin, N. and Islam, R. (2018). Growth and yield of chili influenced by nitrogen and phosphorus. *Journal of Agriculture and Veterinary Science*, 11: 54-68.

Jamir, T., Rajwade, V. B., Prasad, V. M. and Lyngdoh, C. (2017). Effect of organic manures and chemical fertilizers on growth and yield of sweet pepper (*Capsicum annuum* L.) hybrid Indam Bharath in shade net condition. *International Journal of Current Microbiology and Applied Sciences*, 6: 1010-1019.

Kapse, V. D., Puranik, U. Y., Bhosale, A. R., Gokhale, N. B. and Kasture, M. C. (2017). Effect of integrated nutrient management on yield of chilli (*Capsicum annuum* L.) and physicochemical properties of soil in Kongan region of Maharashtra. *International Journal of Chemical Studies*, 5: 106-109.

Kashem, M. A., Sarkar, A., Hossain, I. and Islam, M. S. (2015). Comparison of the effect of vermicompost and inorganic fertilizers on vegetative growth and fruit production of tomato. *Open Journal of Soil Science*, 5: 53-58.

Kattimani, S. R. and Yadahalli, G. S. (2009). Effect of integrated nutrient management on yield and nutrient uptake of chilli genotypes. *Journal of Ecotoxicology & Environmental Monitoring*, 19: 119-123.

Kumar, V., Sachan, C. P., Singh, S. and Sinha, A. K. (2016). Effect of INM practice on plant growth, fruit yield and yield attributes in chilli (*Capsicum annuum* L.). *International Journal of Plant, Animal and Environment Science*, 6: 170-173.

Mallika, A., Kumar, D., Singh, N., Gangwar, V., Pal, O. and Rawat, M. (2022). Integrated nutrient management on physiological, yield and quality parameters of chili (*Capsicum annuum* L.) genotypes. *Biological Forum - An International Journal*, 14: 1506-15011.

Narkhede, S. D., Attarde, S. B. and Ingle, S. T. (2011). Study on effect of chemical fertilizer and vermicompost on growth of chilli pepper plant (*Capsicum annuum* L.) *Journal of Applied Sciences in Environmental Sanitation*, 6: 327-332.

Panse, V. G. and Sukhatme, P. V. (1984). Statistical Methods for Agricultural Workers, ICAR, New Delhi, 359p.

Pariari, A. and Khan, S. (2013). Integrated nutrient management of chilli (*Capsicum annuum* L.) in gangetic alluvial plains. *Journal of Crop and Weed*, 9: 128-130.

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.). *International*

Journal of Bio-resource and Stress Management, 6: 76-80.

Ranjitha, B. M. (2016). Effect of soil test based INM practices on the performance of chilli (*Capsicum annuum* L.). Doctoral dissertation, University of Horticulture Sciences, Bagalkot.

Shabir, A., Wani, S. H., Khan, S. H., Praveen, K. and Ali, T. (2016). Integrated nutrient management on yield of chilli (*Capsicum annuum* L.) and physiochemical properties of Kashmir region. *International Journal of Fauna and Biological Studies*, 3: 140-142.

Sharma, S., Chauhan, M. and Bijalwan, P. (2022). Plant growth promoting rhizobacteria, organic manures and chemical fertilizers: Impact on crop productivity and soil health of capsicum (*Capsicum annuum* L.) in North Western Himalayan Region. *Journal of Plant Nutrition*, 23: 110-115.

Singh, B., Pathak, K., Boopathi, T. and Deka, B. (2010). Vermicompost and NPK fertilizer effects on morpho-physiological traits of plants, yield and quality of tomato fruits: (*Solanum lycopersicum* L.). *Vegetable Crops Research Bulletin*, 73: 77-86.

Singh, C. K., John, S. A. and Jaiswal, D. (2014). Effect of organics on growth, yield and biochemical parameters of chilli (*Capsicum annuum* L.). *IOSR Journal of Agriculture and Veterinary Science*, 7: 27-32.

Singh, M., Deokaran and Bhatt. B. P. (2016). Effect of integrated nutrient management on soil fertility status, productivity and profitability of garden pea. *Journal of Krishi Vigyan*, 5: 29-33.

Talukder, B. and Jana, J. C. (2009). Integrated nutrient management for better growth, yield and quality of green chilli (*Capsicum annuum*) in Terai region of West Bengal. *Indian Journal of Agricultural Sciences*, 79: 600-603.

Virmani, S. M. (1994). UNCTAD Agenda-21: The new challenges for soils research. *Journal of the Indian Society of Soil Science*, 42: 516-524.

Vitkar, M. N., Manolikar, R. R., Vasmate, S. D., Kalalbandi, B. M. and Patil, M. F. (2007). Effect of organic and inorganic fertilizers on growth and green fruit yield of chilli (*Capsicum annuum* L.). *Asian Journal of Horticulture* 2: 273-276.

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