Asian Research Journal of Agriculture

Volume 17, Issue 2, Page 123-133, 2024; Article no.ARJA.114835
ISSN: 2456-561X

Impact of Different Nutrient Management Strategies for Nitrogen, Phosphorous and Potassium Uptake and Availability in Chilli (*Capsicum annuum* var. *annuum* L.)

Sheetal [a], K.C. Sharma [a], Shivam Sharma [a*], Neha Sharma [a], D.R. Chaudhary [a], Sandeep Manuja [b] and Akhilesh Sharma [a]

[a] Department of Vegetable Science and Floriculture, CSK HPKV, Palampur, Himachal Pradesh-176062, India.
[b] Department of Agronomy, CSK HPKV, Palampur, Himachal Pradesh-176062, India.

Authors' contributions

This work was carried out in collaboration among all authors. Authors S and SS designed the manuscript. Authors KCS, NS, DRC, SM and AS helped to refine the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARJA/2024/v17i2430

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/114835

Original Research Article

Received: 24/01/2024
Accepted: 28/03/2024
Published: 30/03/2024

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 NPK uptake

**Corresponding author: E-mail: shivamsharma7154@gmail.com;*

and soil available N, P and K. The results revealed that treatment combination of 100% NPK + 10t vermicompost + *Azotobacter* + PSB recorded significantly the N (1.260%), P (0.156%) and K (1.387%) content in chilli stalk, N (1.870%), P (0.447%) and K (0.865%) content in chilli fruit, total uptake of N (132.34 kg ha^{-1}), P (26.32 kg ha^{-1}) and K (90.60 kg ha^{-1}) by chilli crop. At the end of the experiment, treatment combination of 100% NPK **+** 10t vermicompost + *Azotobacter* + PSB recorded maximum available N in the soil while maximum P and K was recorded in treatment combination of 100% NPK + 10t vermicompost + PSB. Natural farming practice recorded lowest soil available N, P, nutrient content and uptake while organic farming practice recorded lowest value of soil available. Therefore, it can be concluded that the combined application of NPK fertilizers and organic inputs coupled with biofertilizers proved the best for NPK uptake and soil available N, P and K.

Keywords: Chilli uptake; availability; azotobacter; vermicompost.

1. INTRODUCTION

Chilli (*Capsicum annuum* var*. annuum* L.), a member of Solanaceae family 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 [1]. It is a diploid (2n=24) species, genetically self-pollinated crop whose flowers open only after pollination and is consumed fresh, dried and in powdered form Lemma [2]. 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 [3]. Due to the chemical component capsaicin, it is valued economically for its red colour. In India, it occupies an area of about 400 thousand hectares with a production of 4221 thousand tonnes and productivity of 10.55 tonnes per hectare [4]. In Himachal Pradesh, chilli is grown in an area of 1.14 thousand hectares with a production of 13.48 thousand tonnes and productivity of 11.82 tonnes per hectare [5].

Indiscriminate use of synthetic fertilizers results in reduced nutritive value and sensory parameters whereas, conjoint use of organics and bio-fertilizers may reduce the recommended NPK dose and improve the soil health and plant nutrients availability resulting in higher crop yield, besides being environmentally safe. *Azotobacter chroococcum*, a non-symbiotic bacterium, is the potential bio-fertilizer and has the capability to contribute nitrogen to a number of non-legumes by tapping atmospheric nitrogen and can meet the nitrogen requirement of crop up to 15-20 kg, besides producing some growth promoting and antifungal substances and vitamins that help in increasing the yield. The Phosphorous Solubilizing Bacteria (PSB) in the rhizosphere is known to increase the solubility of insoluble phosphorus. Thus, full potential of a crop can only be judged when the nutrients supply system includes both organic sources and synthetic fertilizers. Based upon all these considerations, the present investigation was conducted on chilli variety 'Him Palam Mirch-2'.

2. MATERIALS AND METHODS

Composite soil samples from 0-15 cm depth were collected and then air-dried, ground and passed through 2 mm sieve. The soil was silty clay loam in texture (acrisols), neutral in pH, medium in organic carbon, low in available nitrogen and medium in available phosphorus and potassium **(Table 1)**. The experiment was laid out in randomized block design with three replications. In each block, 12 plots of size 1.8 x 1.8 m were prepared. Each plot consisted of four rows with row to row and plant to plant spacing of 45 cm and 45 cm. 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 farm yard manure (FYM) utilizing cowdung @20 t 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 of chilli variety 'Him Palam Mirch-2' were inoculated by dipping for 15 minutes in the culture of indigenous strain of *Azotobacter,* PSB and *Azotobacter* + PSB as per the treatments i.e., 10% *Azotobacter* in each T4 & T8, 10% PSB in each T5 & T9 and 5% *Azotobacter* + 5% PSB

Table 1. Initial physical and chemical properties of soil of experimental field

Particulars	Values in %	Analytical methods employed
A. Mechanical analysis		
Sand (%)	22.5	International pipette method [7]
Silt (%)	46.3	
Clay (%)	31.2	
Texture		Silty clay loam
B. Chemical properties		
pH	6.6	1:2.5 soil water suspension, Digital pH meter [8]
Organic carbon (%)	0.65	Walkey and Black's Rapid Titration Method [9]
C. Available nutrient (kg ha^{-1})		
Available N (kg/ha)	230	Alkaline potassium Permanganate Method [10]
Available P (kg/ha)	13.60	Olsen's Method [11]
Available K (kg/ha)	144	Flame-photometric method [8]

in each T6 & T10. In organic farming treatment, application of vermiwash @10% (1:10 dilution) was sprayed at10 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 this, 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 N, P and K content in chilli stalk (%), N, P and K content in chilli fruit (%), total N, P and K uptake by chilli crop (kg ha $^{-1}$), soil properties (organic carbon, pH, available N, P and K in soil after harvest (kg ha^{-1}). The data obtained for different parameters were subjected to statistical analysis using MS-Excel, OPSTAT and CPCS statistical package as per [6] and were tested at 5% level of significance to interpret the treatment differences.

3. RESULTS AND DISCUSSION

3.1 Effect of Different Nutrient Treatments on N, P and K Content in Stalk (%)

3.1.1 N content in stalk

The application of different nutrient management practices was found to be significant for N content in chilli stalk **(Table 2)**. The data showed that application of 100% NPK **+** 10t vermicompost + *Azotobacter* + PSB (1.260%) while remaining at par with 100% NPK + 10t vermicompost + PSB (1.254%), 100% NPK + 10t vermicompost + *Azotobacter* (1.258%), 100% NPK+ 10t vermicompost (1.248) and 100% NPK + 20t FYM ha^{-1} (1.242 % gave significantly the highest N content in chilli stalk compared to rest of the treatment combinations. Further, the differences among all the four combinations at 75 % NPK level and recommended 100% NPK were found to be non-significant among themselves but recorded significantly the higher N content in stalk compared to organic (1.077%) and natural farming practice (1.055%).

The increase in N content could be attributed to an adding supply of nutrients through NPK's coupled with biofertilizers and organic inputs that led to well-developed root system under balanced nutrient application resulting in better absorption of water and nutrients which in turn increase the dry matter as well as higher N, P and K concentration of plants [12]. Similar results were also reported by Naidu et al. [13-15].

3.1.2 P content in stalk

The conjoint application of NPK, biofertilizers and vermicompost was found to be significant for phosphorous content in chilli stalk **(Table 2)**. The results showed that the P content in stalk increased significantly with the increasing levels of NPK from 75% to 100% fertilizers. The data clearly depicted that the treatment T_6 (100% NPK **+** 10t vermicompost + *Azotobacter* + PSB) while remaining at par with 100% NPK + 10t vermicompost + PSB (0.149%) and 100% NPK + 10t vermicompost + *Azotobacter* (0.147%) recorded significantly the highest P content in stalk compared to rest of the treatment combinations. Furthermore, it was also observed that application of 100% NPK either in conjunction with vermicompost @10t ha^{-1} (0.138%) or with FYM @ 20 t ha^{-1} (0.136%) while remaining statistically at par with each other but gave significantly higher P content compared to the remaining seven treatment combinations (T_1, T_{10}, T_9, T_8, T_7, T_{11} and T_{12}). However, the differences among all the four combinations at 75% NPK level showed non- significant among themselves but recorded significantly the higher P content in stalk compared to organic (0.092%) and natural farming practice (0.071%).

The increase in P content might be due to use of inorganic fertilizers along with biofertilizer like PSB and *Azotobacter* [20]. The increase in phosphorus content also be attributable to the fact that organic manures in combination with synthetic fertilizers might have helped in the solubilization of fixed P to soluble form making it easily available to the plant. Similar findings were reported by Naidu et al. [13,14, 16]].

3.1.3 K content in stalk

An analysis of variance for K content in chilli stalk revealed significant differences with the application of different nutrient treatment combinations **(Table 2)**. The combined application of NPK @100% **+** 10t vermicompost + *Azotobacter* + PSB (T_6) while remaining statistically at par with all treatment combinations at 100% NPK level (T_5, T_4, T_3 and T_2) except T_1 recorded significantly the highest K content (1.387%) compared to rest of the combinations. At 75% NPK level, all the treatment combinations were found to be statistically at par among themselves but recorded significantly the higher K content in stalk compared to organic (1.119%) and natural farming practice (1.117%).

The application of 100% NPK with organic fertilizers and biofertilizers had a positive impact on K content in chilli stalk. The increased potassium content in chilli stalk might be due to better mineralization of nutrients [17]. The present findings are in agreement with those reported by Naidu et al. [13-15].

Table 2. Effect of different nutrient treatments on N, P and K content in stalk (%)

Treatment	Treatment details	Nitrogen content (%)	Phosphorous content (%)	Potassium content (%)
T_1	Recommended 100% NPK @100:75:55 kg ha^{-1} ($N:P_2O_5:K_2O$)	1.214	0.118	1.360
T_2	Recommended practice (100% NPK + 20t FYM ha^{-1}	1.242	0.136	1.370
T_3	100% NPK **+** 10t vermicompost	1.248	0.138	1.375
T_4	100% NPK **+** 10t vermicompost + *Azotobacter*	1.258	0.147	1.378
T_5	100% NPK + 10t vermicompost + PSB	1.254	0.149	1.382
T_6	100% NPK **+** 10t vermicompost + *Azotobacter* + PSB	1.260	0.156	1.387
T_7	75% NPK @75:56.25:41.25 kg ha^{-1} ($N:P_2O_5:K_2O$) + 10t vermicompost	1.218	0.120	1.330
T_8	75% NPK + 10t vermicompost + *Azotobacter*	1.226	0.121	1.339
T_9	75% NPK + 10t vermicompost + PSB	1.222	0.124	1.342
T_{10}	75% NPK + 10t vermicompost + *Azotobacter* + PSB	1.228	0.125	1.347
T_{11}	Organic farming practice	1.070	0.092	1.119
T_{12}	Natural farming practice	1.055	0.071	1.117
SE(m) ±		0.010	0.004	0.008
F test		*	*	*
CD (5%)		0.031	0.010	0.025
CV (%)		1.482	4.892	1.097

*Note: *= Significant at P=.05, CV= Coefficient of Variation*

3.2 Effect of Different Nutrient Treatments on N, P and K Content in Chilli Fruit (%)

3.2.1 N content in chilli fruit (%)

The analysis of variance showed significant differences among different treatment combination with respect to N content in chilli fruits as presented in **Table 3**. The data clearly depicted that the application of 100% NPK **+** 10t vermicompost + *Azotobacter* + PSB (1.870 %) recorded significantly the maximum N content in chilli fruit compared to rest of the nutrient practices, however, it was statistically at par with treatment T_5 (100% NPK + 10t vermicompost + PSB), T_4 (100% NPK **+** 10t vermicompost + *Azotobacter*), T_3 (100% NPK **+** 10t vermicompost), T_2 (100% NPK + 20t FYM ha^{-1}) and T_{10} (75% NPK + 10t vermicompost + *Azotobacter* + PSB). Further, it was also observed that the differences among all the combinations at 75% NPK level (T_{10}, T_9, T_8, T_7) and T_1 (100 % NPK alone) were not significant among themselves but recorded significantly the higher N content in fruit compared to organic (1.670%) and natural farming practice (1.651%). The increase in N content in chilli fruit might be due to addition of nitrogen through inorganic and organic fertilizers [17]. *Azotobacter* a non-symbiotic bacterium taps the atmospheric nitrogen and make it available to plant. Similar results were also reported by Naidu et al. [13,14,16].

3.2.2 P content in chilli fruit (%)

A perusal of the data presented in **Table 3** revealed significant differences among the different nutrient treatment combinations for P content in chilli fruit. The conjoint application of 100% NPK **+** 10t vermicompost + *Azotobacter* + PSB recorded significantly the highest P content (0.447%) in chilli fruit compared to rest of the treatment combinations, though it remained at par with combinations of NPK @100% + 10t vermicompost + PSB (0.439%) and NPK @ 100% **+** 10t vermicompost + *Azotobacter* (0.436%, thereby clearly indicating the impact of combined application of biofertilizers (*Azotobacter* + PSB) with NPK and vermicompost. 100% NPK **+** 10t vermicompost (0.429%) and 100%NPK+ 20t FYM ha^{-} (0.427%). Further, the differences among all the

Table 3. Effect of different nutrient treatments on N, P and K content in chilli fruit (%)

Treatment	Treatment details	Nitrogen content (%)	Phosphorous content (%)	Potassium content (%)
T_1	Recommended 100% NPK @100:75:55 kg ha^{-1} ($N:P_2O_5:K_2O$)	1.824	0.417	0.844
T_2	Recommended practice (100% NPK + 20t FYM ha^{-1})	1.852	0.427	0.850
T_3	100% NPK **+** 10t vermicompost	1.858	0.429	0.856
T_4	100% NPK **+** 10t vermicompost+ *Azotobacter*	1.868	0.436	0.858
T_5	100% NPK + 10t vermicompost + PSB	1.864	0.439	0.861
T_6	100% NPK **+** 10t vermicompost+ *Azotobacter* + PSB	1.870	0.447	0.865
T_7	75% NPK @75:56.25:41.25 kg ha^{-1} ($N:P_2O_5:K_2O$) + 10t vermicompost	1.828	0.410	0.833
T_8	75% NPK + 10t vermicompost + *Azotobacter*	1.836	0.411	0.835
T_9	75% NPK + 10t vermicompost + PSB	1.832	0.414	0.836
T_{10}	75% NPK + 10t vermicompost + Azotobacter + PSB	1.837	0.415	0.838
T_{11}	Organic farming practice	1.670	0.398	0.811
T_{12}	Natural farming practice	1.651	0.384	0.800
SE(m) ±		0.011	0.006	0.007
F test		*	*	*
CD (5%)		0.033	0.017	0.020
CV (%)		1.081	2.443	1.397

*Note: *= Significant at P=.05 CV= Coefficient of Variation* four combinations at 75 % NPK level and recommended 100% NPK (T_1) showed non-significant among themselves but recorded significantly the higher P content in chilli fruit compared to organic (0.398%) and natural farming practice (0.384%). The increase in P content in fruit might be due to use of vermicompost and biofertilizers along with inorganic fertilizers [17]. The increase in P uptake might be due to the chelating effect of organic materials resulted in reduced phosphorus fixation, enhanced solubilization of insoluble P fractions and released available phosphorus as reported by Naidu et al [13,14,16] in different crops.

3.2.3 K content in chilli fruit (%)

The application of different nutrient management practices on K content in chilli fruit was found to be significant **(Table 3)**. The results showed that application of 100% NPK **+** 10t vermicompost + *Azotobacter* + PSB (0.865%) while remaining at par with 100% NPK + 10t vermicompost + PSB (0.861%), 100% NPK + 10t vermicompost + *Azotobacter* (0.858%), 100% NPK+ 10t vermicompost (0.856%) and 100% NPK + 20 t FYM ha^{-1} (0.850%) recorded significantly the highest K content in chilli fruit compared to rest of the treatment combinations. Further, the differences among all the four combinations at 75% NPK level and recommended 100% NPK (T_1) showed non- significant among themselves but gave significantly the higher K content in chilli fruit compared to organic (0.811%) and natural farming practice (0.800%).

The application of inorganic and organic fertilizers along with biofertilizers had a positive impact on K content in chilli fruit. The increased potassium content in chilli fruit might be due to better mineralization of nutrients [18]. The present findings are in agreement with those reported by Naidu et al [13,14,16].

3.3 Effect of Different Nutrient Treatments on Total N, P and K Uptake by Chilli Crop (kg ha^{-1})

3.3.1 Total N uptake by chilli crop

The analysis of variance showed significant differences among different treatment combination with respect to total nitrogen uptake as tabulated in **Table 4**. Significantly maximum total nitrogen uptake (132.34 kg ha^{-1}) was recorded in treatment combination T_6 (100% NPK **+** 10t vermicompost + *Azotobacter* + PSB) compared to rest of the treatment combinations, however, it was statistically at par with application of 100% NPK + 10t vermicompost + PSB (129.86 kg ha^{-1}), 100% NPK **+** 10t vermicompost + *Azotobacter* (126.75 kg ha^{-1}) and 100% NPK + 10t vermicompost (125.38 kg ha^{-1}). Further, the differences among 100% NPK + 20t FYM ha^{-1} (122.65 kg ha^{-1}), 75% NPK + 10t vermicompost + *Azotobacter* + PSB (118.32 kg ha^{-1}), 75% NPK + 10t vermicompost + PSB (116.74 kg ha^{-1}) and 75% NPK + 10t vermicompost + *Azotobacter* (115.97kg ha^{-1}) were not significant among themselves but significantly superior over organic (94.71 kg ha^{-1}) and natural farming practice (81.51 kg ha^{-1}), thereby indicating the beneficial role of conjoint application of biofertilizers with NPK fertilizers besides saving the 25% chemical fertilizers.

Application of N might have resulted in vigorous vegetative as well as profused root growth which might have led to better absorption of nutrients from the soil [18]. Mixing of N fertilizers with vermicompost and biofertilizers might have reduced the nitrogen loss, improved the fertilizer use efficiency and thus increased the nitrogen uptake by plant. The above findings are in confirmation with the finding of Sharma et al. [15,14,16]

3.3.2 Total P uptake by chilli crop (kg ha^{-1})

The total uptake of phosphorous was significantly influenced by different treatment combinations as depicted in **Table 4**. The results showed that the treatment combination of T_6 i.e., 100% NPK **+** 10t vermicompost + *Azotobacter* + PSB (26.32 kg ha^{-1}) while remaining statistically at par with 100% NPK + 10t vermicompost + PSB (25.32 kg ha^{-1}) recorded significantly the maximum total P uptake compared to rest of the nutrient combinations. At 75% NPK level, all the treatment combinations were found to be statistically at par among themselves but gave significantly higher total P uptake over organic (17.70 kg ha^{-1}) and natural farming practice (14.33 kg ha^{-1}).

The increase in P uptake with the increasing fertility levels may be because of increasing trend in the productivity and dry matter accumulations. PSB application with N and P fertilizers resulted in significant increase in phosphorous uptake. The increase in P uptake may be due to the chelating effect of organic materials resulted in reduced phosphorus fixation, enhanced solubilization of insoluble P fractions and released available phosphorus [19]. Organic

Table 4. Effect of different nutrient treatments on total N, P and K uptake by chilli crop (kg ha^{-1})

Treatment	Treatment details	N uptake by stalk	N uptake by fruit	Total N uptake	P uptake by stalk	P uptake by fruit	Total P uptake	K uptake by stalk	K uptake by fruit	Total K uptake
T_1	Recommended 100% NPK @100:75:55 kg ha^{-1} ($N:P_2O_5:K_2O$)	40.08	73.65	113.72	3.88	16.86	20.74	44.95	34.08	79.03
T_2	Recommended practice (100% NPK + 20t FYM ha^{-1})	41.54	81.12	122.65	4.54	18.53	23.07	45.81	37.24	83.06
T_3	100% NPK **+** 10t vermicompost	43.02	82.36	125.38	4.75	19.03	23.78	47.39	37.96	85.35
T_4	100% NPK **+** 10t vermicompost + *Azotobacter*	43.61	83.14	126.75	5.09	19.40	24.49	47.76	38.18	85.93
T_5	100% NPK + 10t vermicompost + PSB	44.96	84.90	129.86	5.35	19.98	25.32	49.57	39.18	88.75
T_6	100% NPK **+** 10t vermicompost + *Azotobacter* + PSB	46.08	86.26	132.34	5.69	20.63	26.32	50.72	39.88	90.60
T_7	75% NPK @75:56.25:41.25 kg ha^{-1} ($N:P_2O_5:K_2O$) + 10t vermicompost	37.34	76.27	113.61	3.66	17.10	20.76	40.78	34.78	75.55
T_8	75% NPK + 10t vermicompost + *Azotobacter*	38.33	77.64	115.97	3.78	17.38	21.17	41.83	35.32	77.15
T_9	75% NPK + 10t vermicompost + PSB	39.06	77.68	116.74	3.98	17.55	21.53	42.91	35.45	78.35
T_{10}	75% NPK + 10t vermicompost + *Azotobacter* + PSB	39.62	78.70	118.32	4.03	17.79	21.82	43.47	35.89	79.36
T_{11}	Organic farming practice	31.77	62.94	94.71	2.71	14.99	17.70	33.17	30.57	63.74
T_{12}	Natural farming practice	27.90	53.61	81.51	1.87	12.46	14.33	29.54	25.97	55.51
SE(m) ±		1.57	1.57	2.41	0.18	0.43	0.50	1.64	0.77	1.89
F test		*	*	*	*	*	*	*	*	*
CD (5%)		4.63	4.63	7.10	0.53	1.28	1.48	4.85	2.27	5.58
CV (%)		6.867	3.556	3.591	7.623	4.258	3.992	6.558	3.772	4.161

*Note: *= Significant at P=.05 CV= Coefficient of Variation* manures in combination with synthetic fertilizers might have helped in the solubilization of fixed P to soluble form making it easily available to the plant [18]. Similar reports were shared by Sharma et al. [15,14,16].

3.3.3 Total K uptake by chilli crop (kg ha^{-1})

The total uptake of K was significantly influenced by different nutrient management combinations **(Table 4)**. Application of 100% NPK **+** 10t vermicompost + *Azotobacter* + PSB recorded significantly the maximum total K uptake (90.60 kg ha^{-1}) compared to rest of the treatment combinations, however, it was statistically at par with application of NPK @ 100% NPK + 10t vermicompost + PSB (88.75 kg ha^{-1}), 100% NPK **+** 10t vermicompost + *Azotobacter* (85.93 kg ha^{-1}) and 100% NPK + 10t vermicompost (85.35 kg ha^{-1}). The application of 100% NPK + 20t FYM ha^{-1} gave significantly higher K uptake (83.06 kg ha^{-1}) compared to organic (63.74 kg ha^{-1}) and natural farming practice (55.51 kg ha^{-1}), however, it was statistically at par with treatments T_1 (79.03 kg ha^{-1}), T_{10} (79.36 kg ha^{-1}), T_9 (78.35 kg ha^{-1}), T_8 (77.15 kg ha^{-1}) and T_7 (75.55 kg ha^{-1}).

As nutrient uptake is a product of dry matter accumulation and nutrient content. Therefore, higher dry matter due to higher application of NPK fertilizer coupled with microbial inoculants may resulted into more dry matter accumulation [20]. The nutrient supply resulted in stimulated microbial and root and shoot growth owing to the improvement in the soil conditions with the addition of nutrients and ultimately increase the nutrient uptake. Similar reports were shared by Sharma et al. [15,14,16].

3.4 Effect of Different Nutrient Treatments on Soil Properties

3.4.1 Soil organic carbon (%) and pH

The data with respect to organic carbon and soil pH is presented in **Table 5**. The data showed that different treatment combinations did not significantly influence the soil organic carbon and pH.

3.4.2 Available Nitrogen in soil (kg ha^{-1})

The analysis of variance revealed significant differences among different nutrient management treatments for available soil N in post-harvest soil as tabulated in Table 5. Significantly the highest available N was found in 100% NPK **+** 10t vermicompost + *Azotobacter* + PSB (242.31 kg ha^{-1}) which was statistically at par with 100% NPK **+** 10t vermicompost + *Azotobacter* (238.24 kg ha^{-1}). Further, it was also observed that application of 100% NPK **+** 10t vermicompost (234.73 kg ha^{-1}) while remaining statistically at par with 100% NPK + 20t FYM ha^{-1} (232.32 kg ha^{-1}) recorded significantly higher available N compared to remaining treatment combinations. At 75 % NPK level all the combinations showed non-significant differences among themselves with respect to available N in post-harvest soil.

The increase in available N in soil could be due to conjoint application of NPK, biofertilizer and organic inputs. The presence of vermicompost might have resulted in release of more nitrogenous substances in the soil and might have increased the efficiency and effectiveness of soil to hold the nutrients as reported by [21,22]. Mixing of N fertilizer with organic manures might have reduced the nitrogen losses, improved the fertilizer use efficiency thus, increasing the availability of N. Similar results were also reported by Singh et al. [23,24,15].

3.4.3 Available phosphorous in soil (kg ha^{-1})

A cursory glance at the data in **Table 5** showed significant differences among different nutrient management practices for available soil P in post-harvest soil The data revealed that application of 100% NPK + 10t vermicompost + PSB (15.35 kg ha^{-1}) while remaining statistically at par with 100% NPK + 10t vermicompost+ *Azotobacter* + PSB (15.28 kg ha^{-1}), 100% NPK + 10t vermicompost+ *Azotobacter* (14.68 kg ha^{-1}) and 100% NPK + 10t vermicompost (14.42 kg ha^{-1}) recorded significantly the highest available P over rest of treatment combinations.

Further, it was also observed that the differences among 100% NPK + 20t FYM ha^{-1} (13.97 kg ha^{-1}), 75% NPK + 10t vermicompost + *Azotobacter* + PSB (13.50 kg ha^{-1}), 100% NPK (12.96 kg ha^{-1}) and 75% NPK + 10t vermicompost + PSB (13.08 kg ha^{-1}) remained statistically at par among themselves but recorded significantly higher available P compared to other remaining treatment combinations. Natural farming practice recorded lowest available P (10.45 kg ha^{-1}) in post-harvest soil.

The increase in phosphorus is belongs to the fact that organic manures in combination with synthetic fertilizers might have helped in the solubilization of fixed P to soluble form making it easily available to the plant [21]. The organic materials form a cover on sesquioxides and thus, reduce the phosphate fixing capacity of the soil. Similar results were reported by Singh et al. [23,24,15].

3.4.4 Available Potassium in soil (kg ha^{-1})

Analysis of variance revealed significant differences among different nutrient management treatments for available soil K in post-harvest soil as presented in **Table 5**. The results showed that the application of 100% NPK + 10t vermicompost +PSB gave significantly the highest soil available K (149.91 kg ha^{-1}) which remained at par with 100% NPK **+** 10t vermicompost (149.72 kg ha^{-1}), 100% NPK **+** 10t vermicompost+ *Azotobacter* (149.64 kg ha^{-1}),100% NPK **+** 10t vermicompost+ *Azotobacter* + PSB (149.33 kg ha^{-1}) and 100% NPK + 20t FYM ha^{-1} (148.02 kg ha^{-1}). Further, it was also observed that all treatment combination at 75% NPK level and 100% NPK (T_1) and natural farming practice showed non-significant among themselves for available K in post-harvest soil. The available K content increased due to addition of organic manure and biofertilizers along with NPK which helped in the release of unavailable form of potassium to available form in the soil solution and increased the potassium content in the soil [21]. The beneficial effect of vermicompost and farm yard manure on available K may be ascribed to the direct potassium addition to the potassium pool of the soil besides the reduction in potassium fixation and its release due to interaction of organic matter with clay particles [25]. Similar results were reported by Singh et al. [23,24,15].].

Table 5. Effect of different treatments on soil properties

Treatment	Treatment details	Organic carbon (%)	Soil pH	Available N in soil (kg ha^{-1})	Available P in soil (kg ha^{-1})	Available K in soil (kg ha^{-1})
T_1	Recommended 100% NPK @100:75:55 kg ha^{-1} ($N:P_2O_5:K_2O$)	0.69	6.80	220.70	12.96	141.51
T_2	Recommended practice (100% NPK + 20t FYM ha^{-1}	0.73	6.83	232.32	13.97	148.02
T_3	100% NPK **+** 10t vermicompost	0.73	6.83	234.73	14.42	149.72
T_4	100% NPK **+** 10t vermicompost+ *Azotobacter*	0.73	6.87	238.24	14.68	149.64
T_5	100% NPK + 10t vermicompost + PSB	0.74	6.87	233.12	15.35	149.91
T_6	100% NPK **+** 10t vermicompost+ *Azotobacter* + PSB	0.75	6.88	242.31	15.28	149.33
T_7	75% NPK @75:56.25:41.25 kg ha^{-1}($N:P_2O_5:K_2O$) + 10t vermicompost	0.72	6.77	215.74	12.06	143.74
T_8	75% NPK + 10t vermicompost + *Azotobacter*	0.72	6.79	217.72	11.98	143.32
T_9	75% NPK + 10t vermicompost + PSB	0.73	6.79	214.71	13.08	142.90
T_{10}	75% NPK + 10t vermicompost + *Azotobacter* + PSB	0.74	6.80	210.29	13.50	142.71
T_{11}	Organic farming practice	0.64	6.75	212.70	11.18	139.03
T_{12}	Natural farming practice	0.65	6.74	196	10.45	142.02
SE(m) ±		0.09	-	1.75	0.35	1.45
F test		NS	-	*	*	*
CD (5%)		NS	-	5.18	1.05	3.28
CV (%)		9.836	-	1.369	4.684	1.328

*Note: *= Significant at P=.05, NS= Non-Significant, CV= Coefficient of Variation*

4. CONCLUSION

The application of 100% NPK **+** 10t vermicompost + *Azotobacter* + PSB proved to be statistically superior in N, P and K uptake and content in chilli stalk and fruit. The application of 100% NPK + 10t vermicompost + Azotobacter + PSB recorded significantly the highest soil available N. Treatment combination of 100% NPK + 10t vermicompost + PSB recorded significantly the highest soil available P. Significantly the highest soil available K was recorded in Treatment combination of 100% NPK + 10t vermicompost + PSB. Natural farming practice recorded lowest soil available N, P, nutrient content and uptake while organic farming practice recorded lowest value of soil available K.

ACKNOWLEDGEMENT

The authors would like to thank Krishi Vigyan Kendra, Bajaura (Kullu) and CSK HPKV, Palampur for providing all the research facilities to conduct this research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Dias GB, Gomes VM, Moraes TM, Zottich UP, Rabelo GR, Carvalho AO, Moulin M, Goncalves LS, Rodrigues R, Cunha M. Characterization of *Capsicum species* using anatomical and molecular data. Genetics and Molecular Research. 2023;12:6488-6501.
2. Lemma D. Seed production guideline for tomatoes, onion and hot pepper. IARI, Addis Ababa; 1998.
3. El-Ghorab AH, Javed Q, Anjum FM, Hamed SF, Shaaban HA. Pakistani bell pepper (*Capsicum annuum* L.) chemical compositions and its antioxidant activity. International Journal of Food Properties. 2013;16:18-32.
4. Anonymous. Food and Agriculture organization of United Nations. FAOSTAT; 2021a.
5. Anonymous. Ministry of Agriculture and Farmers Welfare, Government of India. FAOSTAT; 2021b.
6. Panse VG and Sukhatme PV. 1984. Statistical Methods for Agricultural Workers, ICAR, New Delhi. 1984;359.
7. Piper CS. Soil and plant analysis (Asia Edition), Hans Publishers, Bombay, India; 1966.
8. Jackson ML. Soil Chemical Analysis. Prentice Wall. Inc. Englewood Chiffs. New Jersey, USA. Journal of Ecology. 1973;63: 995-1001.
9. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science. 1934;37:29-38.
10. Subbiah BV, Asija GL. A rapid procedure for the estimation of available nitrogen in soils. Current Sciences. 1956;25:259-260.
11. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA circular No. 939;1954.
12. Bam R, Mishra SR, Khanal S, Ghimire P, Bhattarai S. Effect of biofertilizers and nutrient sources on the performance of mungbean at Rupandehi, Nepal. Journal of Agriculture and Food Research. 2022;10: 100404.
13. Naidu DK, Radder BM, Patil PL, Hebsur NS and Alagundagi SC. Effect of integrated nutrient management on nutrient uptake and residual fertility of chilli cv. Byadgi Dabbi in a vertisol. Karnataka Journal of Agricultural Sciences. 2009;22:306-309.
14. Yugvinder, Kumar K, Kumar N, Gill V, Yadav M, Singh S. Effect of integrated nutrient management on quality of chilli (*Capsicum annuum* L.). The Pharma Innovation. 2021;10(10):645-648.
15. Sharma N, Shukla YR, Sigh K, Mehta DK. Soil fertility, nutrient uptake and yield of bell pepper as influenced by conjoint application of organic and inorganic Fertilizers. Communications in Soil Science and Plant Analysis. 2020;51:1626-1640.
16. Dhopavakar R, Gokhale NB, Dodake SB, Khandekar RG, Joshi MS, Dhekale JS, Kapse VD. Effect of different levels of N and P fertilizers with biofertilizers on yield and nutrient uptake by chilli (*Capsicum annuum* L.) in lateritic soils of Konkan. The Pharma Innovation Journal. 2021;10:428-437.
17. Zakharchenko E, Datsko O, Mishchenko Y, Melnyk A, Kriuchko L, Rieznik S, Hotvianska A. Efficiency of biofertilizers when growing corn for grain. Modern Phytomorphology. 2023;17:50-56.
18. Moskalenko AM, Volkohon VV. Economic grounding for ecologically safe strategy of

mineral fertilizers use. Actual Problems of Economics. 2015;171: 286−293.

19. Chetri DA, Singh AK, Singh VB. Effect of integrated nutrient management on yield, quality and nutrient uptake by capsicum (*Capsicum annuum* L.) cv. California Wonder. Journal of Soils and Crops. 2012;22:44-48.
20. Dmytruk Y, Dent D. (eds) Soils Under Stress. Springer, Cham. 2022;255 DOI: 10.1007/978-3-030-68394-8
21. Bielashov O, Rozhkov A, Kalenska S, Karpuk L, Marenych M, Kuts O, Muzafarov N. Influence of pre-sowing application of mineral fertilizers, root and foliar nutrition on productivity of winter Tritical Plants. Ecological Engineering & Environmental Technology. 2022;23(6): 1-14.
22. Vijaya KS, Seethalakshmi S. Response of eggplant (*Solanum melongena* L.) to integrated nutrient management amended soil. International Journal of Scientific & Engineering Research. 2011;2:1-8.
23. Singh M, Deokaran, Bhatt BP. Effect of integrated nutrient management on soil fertility status, productivity and profitability of garden pea. Journal of Krishi Vigyan. 2016;5:29-33.
24. Raturi HC, Uppal GS, Singh SK, Kachwaya DS. Effect of organic and inorganic nutrient sources on growth, yield and quality of bell pepper (*Capsicum annuum* L.) grown under polyhouse condition. Journal of Pharmacognosy and Phytochemistry. 2019; 8:1788-1792.
25. Wang F, Wang Z, Kou C, Ma Z, Zhao D. Responses of wheat yield, macro- and micronutrients, and heavy metals in soil and wheat following the application of manure compost on the north China plain. Public Library of Science. 2016;11:e01 46453.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/114835