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Integrated Nutrient Management on Physiological, Yield and Quality Parameters of Chilli (*Capsicum annuum* L.) Genotypes

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ABSTRACT: The field experiment was conducted to study the integrated nutrient management on physiological yield and quality of chilli by using four different varieties. The experiment was laid in Split Plot Design with three replications five different treatments including different combinations of organic and inorganic fertilizers *i.e.* 100% RDF, 75% RDF + 25% vermicompost, 75% RDF + 25% vermicompost + VAM, 75% RDF + 25% vermicompost + Humic Acid, 75% RDF + 25% vermicompost + Azotobacter and four varieties of chilli were used *i.e.* VS455, SS841, Punjab Tej and Teja. By increasing the potential from all conceivable sources of inorganic, organic, and natural components in an integrated manner, Integrated Nutrient Management proposed to maintain soil fertility and plant nutrients at their most satisfying level for maintaining the preferred productivity. The main elements of INM include fertilizer, organic manures, legumes, agricultural leftovers, and bio fertilizers. The availability of nutrients is a crucial consideration when maximising output in any crop. According to the study, compared to other treatments, an integrated usage of 75% RDF + 25% vermicompost + VAM had the best yield (94.16 q/ha), chlorophyll index (58.84), and ascorbic acid (35.41 mg/100 g) were among the production and quality characteristics that were positively impacted by the treatment. Therefore, it can be said that VS455 and SS841 varieties responded better when integrated usage of 75% RDF + 25% vermicompost + VAM were used in terms of growth, yield, and quality.

Keywords: Azotobacter, FYM, Humic Acid, vermicompost and VAM.

INTRODUCTION

Chilli (*Capsicum annuum* L.) (2n=24) a member of the nightshade family *i.e*. Solanaceae is valued for its diverse commercial uses worldwide. Chilli peppers were originated in Mexico. It was first cultivated in central Mexico and parts of South America. Abundant cultivars of chilli peppers developed across the world are used as both traditional medicine and food. Chilli is a part of the human diet in the America since 7500 B.C. It was domesticated more than 6000 years ago in Mexico and in the region that extends across Northern Oaxaca, Southern Puebla and to South Eastern Veracruz. Peru is the centre of diversity where varieties of all five domesticated species were introduced, grown and consumed during pre- Columbian times.

The world trade of chilli accounts for 18 per cent of the whole spice traded in the world securing second position after black pepper. Chilli is the largest grown spice item exported from India and it also occupies first position in terms of prices. 100 g of ripe and dry chilli contains protein (15.8 g), fat (6.2 g), carbohydrates (31.7 g), fiber (30.6 g), mineral matter (6.2 g), calcium (0.16 g), phosphorus (0.36 g), vitamin C (50 mg) and vitamin A (575 I.U.). Capsaicin ($C_{18}H_{27}NO_3$) is an active component of chilli peppers and has analgesic properties. It is a euro peptide releasing agent selective for primary sensory peripheral neurons. This agent has been used experimentally to manipulate substance P and other tachykinins. It is utilized to make drugs for heart diseases and also used in cosmetics like skin protectant, antidandruff agent, antimicrobial agent, antiperspirant agent, artificial nail builder, antioxidant, anti caries.

Adequate and balanced fertilizer management in association with manures is very much essential to exploit the full yield potential of Chilli. After the green revolution, increase in production was achieved at the cost of soil health. It has been proved that indiscriminate use of inorganic fertilizers results in decrease in soil fertility and increase in soil acidity with depletion of organic humus content in addition to poor crop quality. Use of organic manures to meet the nutrient requirements of crop would be an inevitable practice in the years to come for sustainable agriculture since organic manures not only improve the physical, chemical and biological properties of soil (Kapse *et al*., 2017; Heitkamp *et al*., 2011**)** but also improves the moisture holding capacity of soil, Chilli crop requires a balanced fertilizer management without which growth and development of the crop will be impaired leading to substantial reduction in yield of the chilli.

Nutrient management is most important factor for higher productivity (Patil, 1998). Higher cost of cultivation or chemical fertilizers is posing a major challenge to fully meet out the nutrient requirement of the crop. This problem can be managed through adoption of integrated nutrient management. Present investigation is carried out to identify/ screening suitable genotype with better management practices for getting good quality fruits and higher fruit yield of chilli. Now the government and policy makers are seriously considering alternative methods to intensive agriculture such as organic farming practices, natural farming, INM, biodynamic practices etc. Adoption of organic farming practice alone may not address the food and nutritional requirement of our country as evident from several cases. Hence the blend of organic farming practices and modern agriculture needs to be developed. It is found that integrated nutrient management with FYM, vermicompost, poultry manures and oil cakes showed a significant positive response on chilli (Pariari and Khan 2013). Particularly chilli needs heavy manuring for better plant growth and high yield. Use of judicious combinations of organic and inorganic fertilizer sources is essential not only to maintain the soil health but also sustain the productivity (Malewar *et al*., 1998). With respect to management, nutrient management is most important factor for higher productivity (Patil, 1998).

MATERIALS AND METHODS

The present investigation conducted during the year August 2018 – May 2019 at the Agriculture Research Farm of the School of Agriculture, Lovely Professional University, Phagwara, Punjab (India).

Experimental Design and Treatments. The experimental trial carried out in split plot design with three replications.

Treatments Notation	Treatments
T_1	100% RDF
T_2	75% RDF + 25% Vermicompost
T_3	75% RDF + 25% Vermicompost + VAM
T_4	75% RDF + 25% Vermicompost + Humic acid
T_5	75% RDF + 25% Vermicompost + Azotobacter

There are treatments involving various proportions of organic and inorganic fertilisers and four varieties of chilli were used in the experimental trial. The treatments are given in table.

Combination of nutrient sources (T_1, T_2, T_3, T_4 and T_5 as described in Main plot).

Varieties of chilli described as Sub-Plot of the experimental trial. There are four varieties were used in experiment as follows:

Varieties	Description
V_1- VS455	Cylindrical long shaped and high pungency with deep red colour
V_2- SS841	Short in length and having more diameter with medium pungency
V_3- Punjab Tej	Medium sized fruit and more diameter with mild pungency
V_4- Teja	Cylindrical long shaped and high pungency with deep purple colour

Parameters of Study

A. Physiological Parameters

Chlorophyll index (SPAD value). The chlorophyll content of leaf at the time of final harvesting was measured with help of the SPAD meter.

B. Yield Parameters

Average Fruit length (cm). Five fruits from each variety per replication were selected randomly and fruit length was measured with help of the measuring scale and then mean value was calculated and expressed in centimetres.

Fruit diameter (mm). Five fruits from each variety per replication were selected randomly and fruit diameters was measured with help of the digital Vernier calliper and then mean value was calculated and expressed in centimetres.

Number of seeds per fruit. The seeds were removed from five randomly selected fruits from five plants in each treatment. The number of seeds per fruit were counted and average was worked out to get number of seeds per fruit.

1000 seed weight (g). Weight of 100 dried seeds was taken from seed bulk of each genotype and in treatment. The weight was measured by digital weighing balance and then 1000 seed weight was calculated by multiplying the values obtained with 10 and then averaged.

Yield per hectare (q). Based on the green fruit yield obtained from the net plot area, the yield per hectare was computed and expressed in quintals.

C. Quality parameters

Total soluble solids (^{o}Brix). Total soluble solids were measured from each variety from each replication by pouring few drops of juice over designated platform of the refractometer between ranged from 0-32 °Brix at room temperature and then allowing the light to pass through the prism. The TSS was directly recorded from the scale, separately for five fruits and then average TSS was calculated.

Ascorbic acid (mg/100g). Ascorbic acid content in green chilli fruits was estimated by using 2,6-

dichlorophenol indophenols visual titration method given by Ranganna (2009).

RESULTS AND DISCUSSION

The results with respect to the mean performance of four varieties grown under different treatments fertilizer combinations under the following heading:

A. Physiological Parameters

Chlorophyll index (SPAD value): Among the various treatments, the maximum leaf chlorophyll index (58.84) was obtained in T_3 (75% RDF + 25% vermicompost + VAM) which was at par with T_1 (58.76), T_4 (58.62) and T_2 (58.17) while the minimum leaf chlorophyll index was observed in T_5 (46.61). Among the different varieties, V_2 (SS841) resulted in maximum leaf chlorophyll index (60.06) which was at par with V_3 (58.73) while the minimum leaf chlorophyll index (52.85) was observed in V_4 (Teja).

Interaction among the five fertilizer combinations and the four varieties showed that the maximum leaf chlorophyll index (85.80) was observed in T_2V_2 *i.e*. SS841 variety grown under 75% RDF + 25% vermicompost which was at par with T_3V_3 (84.93) and T_4V_4 (83.56) while the minimum leaf chlorophyll index (25.66) was observed in T_2V_1.

Nitrogen is a component of chlorophyll molecule and it is available in the rhizosphere increase nitrogen uptakes that use chlorophyll synthesis, which is evident from increase in chlorophyll content with nitrogen application. Application of nitrogen through RDF and vermicompost increased nitrogen uptake leading to higher chlorophyll synthesis. The results are in conformity with the findings of Singh *et al.* (2004).

B. Yield Parameters

Average Fruit Length (cm): Among the various treatments, the maximum average fruit length (14.30 cm) was obtained in T_1 (100% RDF) which was statistically significant over the other treatments while the minimum average fruit length (8.14 cm) was observed in T_3 (75% RDF + 25% vermicompost + VAM). Among the different varieties, V_1 (VS455) resulted in maximum average fruit length (11.16 cm) which was statistically significant over the other treatments while the minimum average fruit length (9.72 cm) was observed in V_3 (Punjab Tej).

Interaction among five fertilizer combinations and the four varieties showed that the maximum average fruit length (15.20 cm) was observed in T_1V_3 *i.e*. Punjab Tej variety grown under 100% RDF which was at par with T_1V_4 (14.70 cm) while, the minimum average fruit length (7.26 cm) was obtained in T_3V_3.

Among the major nutrients, P and K are known to influence quality aspects and N is better utilized only in the presence of P and K. When the RDF were added to soil, even though the initial available nitrogen content was low, the complex nitrogenous compounds slowly released N and it was steadily applied throughout the growth period of the crop. This might have attributed to more N availability and subsequent uptake by the crop, thus increasing the length of fruit. Similar results have been reported by Nair and Peter (1990).

Fruit Diameter (mm): Among the various treatments the maximum average fruit diameter (10.59 mm) was obtained in T_5 (75% RDF + 25% vermicompost + Azotobacter) which was at par with T4 (10.11 mm) while, the minimum average fruit diameter (8.69 mm) was observed in T_2 (75% RDF + 25% vermicompost). Among the different varieties, V_1 (VS455) resulted in maximum average fruit diameter (10.29 mm) which was statistically significant over the other treatments while the minimum average fruit diameter (9.22 mm) was observed in V_2 (SS841).

Interaction among the five fertilizer combinations and the four varieties showed that the maximum average fruit diameter at 4^{th} harvesting (13.04 mm) was observed in T_3V_4 *i.e.* Teja variety grown under 75% RDF + 25% Vermicompost + VAM which was at par with T_4V_1 (12.96 mm) while the minimum average fruit diameter at 4^{th} harvesting (5.35 mm) was obtained in T_4V_4.

Maximum fruit diameter was observed in T5 might be due to the application of inorganic fertilizers along with organic and bio-fertilizers as a source of nutrients. This may be due to better availability and higher absorption of essential elements as well as their effective utilization by the plants. Presence of higher amount of vermicompost along with biofertilizers has encouraged greater uptake of N, P and K as well as micronutrients. The increased uptake of essential plant nutrients increased the production of assimilates and the rate of biosynthesis of various metabolic physiological pathways in the plant system leading to increased fruit diameter in chilli.

Increased fruit diameter might be due to the soil microbial activities, high absorption of nutrients from the soil which also affected the photosynthesis process leading to maximum fruit diameter. Application of vermicompost and bio-fertilizers together might have influenced the plant metabolism by increasing the availability of applied nutrients and moisture retention capacity. A similar result has been reported Habibi *et al.* (2011).

Number of Seeds per Fruit: Among the various treatments, the maximum number of seeds per fruit (55.33) were obtained in T_5 (75% RDF + 25% vermicompost + Azotobacter) which was at par with T_1 (54.58) while, the minimum number of seeds per fruit (42.25) were observed in T_3 (75% RDF + 25% vermicompost + VAM). Among the different varieties, V_4 (Teja) resulted in maximum number of seeds per fruit (49.26) which was at par with V_2 (VS455) (48.86) and V_3 (Punjab Tej) (48.80) while, the minimum number of seeds per fruit (46.66) were observed in V_1 (VS455).

Interaction among the five fertilizer combinations and the four varieties showed that the maximum number of seeds per fruit (65.33) were observed in T_5V_3 *i.e*. Punjab Tej variety grown under 75% RDF + 25% vermicompost + Azotobacter which was at par with T_1V_4 (65.31) and T_1V_3 (64.0) while, the minimum number of seeds per fruit (24.66) were observed in T_3V_3.

The increase in seeds per fruit may be due to increase in length and diameter of the fruit. Hasan *et al.* (2014) also reported the higher number of seeds per fruits in chilli (69.00).

1000 Seed Weight (g): Among the various treatments the maximum weight of 1000 seeds (4.08 g) was obtained in T_5 (75% RDF + 25% vermicompost + Azotobacter) which was statistically significant over the other treatments while the minimum weight of 1000 seeds (3.58 g) was observed in T_2 (75% RDF + 25% vermicompost). Among the different varieties, V_4 (Teja) resulted in maximum weight of 1000 seeds (3.97 g) which was statistically significant over the other treatments while the minimum weight of 1000 seeds (3.51 g) was observed in V_3 (Punjab Tej).

Interaction among the five fertilizers combinations and the four varieties showed that the maximum weight of 1000 seeds (4.70 g) was observed in T_5V_4 *i.e.* Teja variety grown under 75% RDF + 25% vermicompost + Azotobacter which was at par with T_3V_1 (4.46 g), T5V2 (4.40 g) and T_1V_4 (4.33 g) while the minimum weight of 1000 seeds (3.23 g) was observed inT_1V_1.

Increase in seed weight in T5 which included 75% RDF+ 25% vermicompost + Azotobacter might be due to higher number of seeds per fruit. Kodalli (2006) also reported maximum weight of 1000 seeds (4.14g).

Yield per hectare (q/ha): Among the various treatments, the maximum fruit yield (94.16 q/ha) was obtained in T_3 (75% RDF + 25% vermicompost + VAM) which was statistically significant over the other treatments while, the minimum fruit yield (64.09 q/ha) was observed in T_4 (75% RDF + 25% vermicompost + humic acid). Among the different varieties, V_1 (VS455) resulted in maximum fruit yield (87.76 q/ha) which was at par with V_2 (82.01 q/ha) while, the minimum fruit yield (62.99 q/ha) was observed in V_3 (Teja).

Interaction among the five fertilizer combinations and the four varieties showed that the maximum fruit yield (129.70 q/ha) was observed in T_3V_4 *i.e.* Teja variety grown under 75% RDF + 25% vermicompost + VAM which was at par with T_5V_1 (123.92 q/ha), T_2V_3 (123.70 q/ha), T_1V_2 (120.06 q/ha) and T_3V_2 (119.11 q/ha) while, the minimum fruit yield (26.66 q/ha) was observed in T_3V_3.

The significant improvement and increment in yield might be due to the addition of vermicompost along with VAM which led to the uptake of nutrients from soil and increased the rate of photosynthesis which further increased the vegetative growth and thus resulted in more accumulation of photosynthates with an ultimate increase in yield. Similar results were recorded by Haque (2011).

C. Quality parameters

Total soluble solids (ºBrix): Among the various treatments, the maximum total soluble solids (5.93 ºBrix) was obtained in T_2 (75% RDF + 25% Vermicompost) which was statistically significant over the other treatments while the minimum total soluble solids (4.16 ºBrix) was observed in T_5 (75% RDF + 25% vermicompost + Azotobacter). Among the different varieties, V_3 (Punjab Tej) resulted in higher total soluble solids (5.60 ºBrix) which was statistically significant over the other treatments while the minimum total soluble solids (4.21 ºBrix) was observed in V_4 (Teja).

Interaction among the five fertilizer combinations and the four varieties showed that the maximum total soluble solids (9.63 ºBrix) was observed in T_2V_3 *i.e.* Punjab Tej variety grown under 75% RDF + 25% vermicompost which was statistically significant over the other treatments while the minimum total soluble solids (3.36 ºBrix) was observed in T_4V_4 (Teja variety grown under 75% RDF + 25% vermicompost + humic acid).

TSS was comparatively higher in the treatments which included both vermicompost and NPK. This might be due to influence on the physiological activity of enzymes which increased vegetative growth, solubilised native and applied nutrients and thus increased their subsequent uptake. Nchang *et al.* (2018) also reported higher amount of TSS per fruit in chilli (5.10 ºBrix).

Ascorbic acid (mg/100g): Among the various treatments, the maximum ascorbic acid content (35.41 mg/100 g) was obtained in T_3 (75% RDF + 25% vermicompost + VAM) and which was at par with T_2 (26.25 mg/100 g) while the minimum ascorbic acid content (14.58 mg/100 g) was observed in T_1 (100% RDF). Among the different varieties, V_2 (SS841) resulted in high ascorbic acid content (27.33 mg/100 g) which was statistically at par with V_3 (23.33 mg/100 g) while the minimum ascorbic acid content (22 mg/100 g) was observed in V_1 (VS455).

Interaction among the five fertilizers and the four varieties showed that the maximum ascorbic acid content (41.67 mg/100 g) was observed in T_3V_2 *i.e.* SS841 variety grown under 75% RDF + 25% vermicompost + VAM which was at par with T_3V_1 (41.66 mg/100 g), T2V3 (40 mg/100 g) T_3V_4 (40 mg/100 g) and T_4V_2 (36.67 mg/100 g) while the minimum ascorbic acid content (11.66 mg/100 g) was observed in T_1V_1.

Maximum ascorbic acid content was observed in the in T_3 which included 75% RDF + 25% vermicompost + VAM might be due to action of specific soil nutrients which may be made more readily available into the soil for plant absorption. Integration effect which in term may activate specific enzymes for the synthesis of these compounds. Similar results were recorded by Nchang *et al.* (2018).

Table 1: Mean Performance of Integrated Nutrient Management on Physiological and Yield Parameters of Chilli.

Sr. No.	Treatments	Chlorophyll Index (SPAD value)					Average Fruit Length (cm)					Average Fruit Diameter (mm)				
		V1	V2	V3	V4	Mean	V1	V2	V3	V4	Mean	V1	V2	V3	V4	Mean
1.	T_1 (100% RDF)	77.83	65.23	56.33	35.66	58.76	12.96	14.33	15.20	14.70	14.30	8.24	8.80	10.48	10.79	9.58
2.	T_2 (75% RDF + 25% Vermicompost)	25.66	85.80	65.23	56.00	58.17	13.46	8.43	8.86	8.76	9.88	10.16	5.84	9.12	9.64	8.69
3.	T_3 (75% RDF + 25% Vermicompost + VAM)	53.60	43.53	84.93	53.30	58.84	7.83	8.23	7.26	9.23	8.14	9.18	8.91	5.86	13.04	9.25
4.	T_4 (75% RDF + 25% Vermicompost + Humic acid)	54.80	52.70	43.43	83.56	58.62	8.23	9.03	8.36	9.36	8.75	12.96	11.21	10.93	5.35	10.11
5.	T_5 (75% RDF + 25% Vermicompost + Azotobacter)	53.93	53.06	43.73	35.73	46.61	13.33	8.73	8.90	9.03	10.00	10.91	11.32	10.63	9.49	10.59
	Mean	53.16	60.06	58.73	52.85		11.16	9.75	9.72	10.22		10.2	9.22	9.40	9.66	

Factors	Chlorophyll CD at 5%	SE (d)	SEm±	Fruit Length CD at 5%	SE (d)	SEm±	Fruit Diameter CD at 5%	SE (d)	SEm±
Fertilizer combinations	2.66	1.13	0.80	0.63	0.27	0.19	0.44	0.19	0.13
Varieties	1.71	0.83	0.59	0.31	0.15	0.10	0.33	0.16	0.11
Interaction	4.01	1.87	1.61	0.74	0.34	0.38	0.78	0.36	0.26

Table 2: Mean Performance of Integrated Nutrient Management on Yield Parameters of Chilli.

Sr. No.	Treatments	Number of Seeds Per Fruit					Weight of 1000 Seeds (g)					Fruit Yield (q/ha)				
		V1	V2	V3	V4	Mean	V1	V2	V3	V4	Mean	V1	V2	V3	V4	Mean
1.	T_1 (100% RDF)	33.00	56.00	64.00	65.31	54.58	3.23	3.46	3.33	4.33	3.59	39.11	120.06	57.40	75.63	73.05
2.	T_2 (75% RDF + 25% Vermicompost)	55.33	32.33	43.66	45.00	44.08	3.66	3.46	3.63	3.56	3.58	79.81	43.55	123.70	79.33	81.60
3.	T_3 (75% RDF + 25% Vermicompost + VAM)	52.66	45.66	24.66	46.00	42.25	4.46	3.66	3.40	3.66	3.80	101.18	119.11	26.66	129.70	94.16
4.	T_4 (75% RDF + 25% Vermicompost + Humic acid)	46.00	56.66	46.33	34.00	45.75	3.73	3.40	3.63	3.60	3.59	94.81	71.78	54.07	35.70	64.09
5.	T_5 (75% RDF + 25% Vermicompost + Azotobacter)	46.33	53.66	65.33	56.00	55.33	3.66	4.40	3.56	4.70	4.08	123.92	55.55	53.11	56.00	72.14
	Mean	46.66	48.86	48.80	49.26	46.66	3.75	3.68	3.51	3.97		87.76	82.01	62.99	75.27	

Factors	Seeds Per Fruit CD at 5%	SE (d)	SEm±	1000 Seed Weight CD at 5%	SE (d)	SEm±	Fruit Yield CD at 5%	SE (d)	SEm±
Fertilizer combinations	1.48	0.63	0.44	0.15	0.06	0.04	4.84	2.07	1.46
Varieties	1.01	0.49	0.34	0.15	0.07	0.05	5.11	2.49	1.76
Interaction	2.35	1.10	0.89	0.35	0.16	0.09	11.69	5.57	2.92

Table 3: Mean Performance of Integrated Nutrient Management on Quality Parameters of Chilli.

Sr. No.	Treatments	Total Soluble Solids (°Brix)					Ascorbic Acid Content (mg/100 g)				
		V1	V2	V3	V4	Mean	V1	V2	V3	V4	Mean
1.	T_1 (100% RDF)	4.03	4.33	4.46	4.40	4.30	11.66	18.33	11.67	16.66	14.58
2.	T_2 (75% RDF + 25% Vermicompost)	3.66	5.53	9.63	4.90	5.93	16.66	21.66	40.00	26.67	26.25
3.	T_3 (75% RDF + 25% Vermicompost + VAM)	4.93	5.86	4.00	4.66	4.86	41.66	41.67	18.33	40.00	35.41
4.	T_4 (75% RDF + 25% Vermicompost + Humic acid)	5.50	5.10	5.50	3.36	4.86	20.00	36.67	28.33	13.33	24.58
5.	T_5 (75% RDF + 25% Vermicompost + Azotobacter)	4.30	4.23	4.40	3.73	4.16	20.00	18.33	18.33	18.33	18.75
	Mean	4.48	5.01	5.60	4.21		22.00	27.33	23.33	23.00	

Factors	CD at 5%	SE (d)	SEm±	CD at 5%	SE (d)	SEm±
Fertilizer combinations	0.43	0.18	0.10	10.50	4.48	3.17
Varieties	0.50	0.24	0.17	3.93	1.92	1.35
Interaction	1.14	0.55	0.26	9.54	4.29	6.34

CONCLUSION

On the basis of results obtained from the investigation it may be concluded that application of 75% RDF + 25% vermicompost + VAM increased the Chlorophyll Index, produced higher fruit yield and enhanced the quality of chilli. So, it may be concluded that VS455 and SS841 variety showed better response in terms of growth, yield and quality when integrated use of 75% RDF + 25% vermicompost + VAM were applied. It may be better option for the formers having adequate resources.

FUTURE SCOPE

Chili was best grown in an ecologically friendly manner with the use Integrated nutrient management which also reduces production costs and improve the growth yield and quality of chilli cultivars.

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