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RESEARCH ARTICLE

Developing an Economically Viable Nutrient Management Package that Sustains Growth, Yield and Quality of Chilli (*Capsicum annuum* L.)

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ABSTRACT

The field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore during 2021 to develop an economically viable nutrient management package for chilli that sustains growth, yield and quality of the produce at the same time. The experiment was laid out in randomized block design with six treatments and five replications. The treatments consisted of organic, inorganic and combined nutrient management practices. The results revealed that the state recommended practices (Farm yard manure @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + recommended dose fertilizers (RDF)) registered the highest plant height (71.7), number of branches per plant (24.7), leaf area (22.5 cm^2), number of fruits per plant (79.4) and yield per hectare (16589 kg). However, interms of economics the organic nutrient management practices performed well with 50 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + seedling treatment with Beejamrit + Ghanajeevamrit @ 250 kg ha^{-1}, Jeevamrit @ 500 litres ha^{-1} $time^{-1}$ twice a month with irrigation water fetching higher benefit cost ratio (2.40). The quality parameters like total soluble solids (TSS) and ascorbic acid content were also higher (5.84 °brix and 127.46 mg 100 g^{-1} respectively) under 50 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + seedling treatment with Beejamrit + Ghanajeevamrit @ 250 kg ha^{-1}, Jeevamrit @ 500 litres ha^{-1} $time^{-1}$ twice a month with irrigation water applied plots compared to other nutrient management practices. It can be concluded that the application of state recommended management practices had a positive effect on growth and yield. However for getting economically sustainable and quality chilli, the organic package – 50 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + seedling treatment with Beejamrit + application of Ghanajeevamrit @ 250 kg ha^{-1}, Jeevamrit @ 500 litres ha^{-1} $time^{-1}$ twice a month with irrigation water can be suggested.

Keywords: *Chilli; Organic; Integrated; Nutrient management; Jeevamrith.*

INTRODUCTION

Chilli is one of the important vegetable cum spices crop grown all over the world. In India, it is cultivated over an area of 4,00,000 ha for green chilli with annual production of 42,21,000 tonnes and grown over an area of 6,78,000 ha for red chilli with annual production of 18,74,000 tonnes (1st Adv. Est. 2020-21). Both green and red chillies are used in our daily diet for its pungency, color and flavor. The pungency of chilli is due to capsaicin, which has a great medicinal value. Chillies are also loaded with vitamin A and C as well as minerals like calcium, magnesium, potassium, iron, copper etc. (Chakrabarty *et al.,* 2017). However, number of factors limits the growth, yield and quality of chilli. One among them is imbalanced supply of nutrients. Hence developing a nutrient management package that is holistic and sustainable is most important for getting higher yield as well as higher income. The use of chemical fertilizers alone is not serving as a holistic approach towards achieving sustainable nutrient management practices. Hence, manures, vermicompost and other organic amendments like beejamrith, ghanajeevamrith and jeevamrith either alone or in combinations could be used to improve nutrient supplying capacity of the soil. Since organic manures not only provide nutrients, but also improve physical, chemical and biological properties of the soil, thus resulting in enhanced crop productivity along with better quality of crop produce (Premsekhar and Rajashree, 2009). The individual effects of organic manures and microbial formulations in chilli were well documented (Chandramohan *et al.,* 2017; Akshay *et al.,* 2018; Sujana *et al.,* 2019). Whereas, studies on combined effects of manures and liquid formulations on yield, economics and quality of the produce are scarce.

In this context, the present investigation was carried out to develop a workable and compatible nutrient management package that sustains crop productivity, soil health and at the same time fits to local conditions with economic viability.

MATERIAL AND METHODS

Experimental condition

The field experiment to develop a sustainable nutrient management package was carried out at Eastern Block Farm, TNAU, Coimbatore during Kharif season of 2021. The research farm is located at 11°N latitude, 77°E longitude and at an elevation of 427 m above mean sea level, which falls under western agro climatic zone of Tamil Nadu. The soil of the experimental field was clay loam in texture having pH of 7.8, EC of 0.86 dSm^{-1} and organic carbon (OC) of 0.82 %. Fertility of the soil was low (182 kg ha^{-1}), medium (18.0 kg ha^{-1}) and high (870 kg ha^{-1}) for N, P and K respectively. The experiment was laid out in a randomized block design with six treatments (Table 1) and five replications.

Crop cultivation

40 days old chilli seedlings (Hybrid Sierra) were transplanted at the spacing of 75 x 60 cm with net plot size of 5m x 4m. Seedling root dip treatment with Beejamrit was given for MP_1-II and MP_3-II treatments. FYM, Vermicompost, Jeevamrit, Ganajeevamrit were used as organic source of nutrients and urea, single super phosphate, muriate of potash were used as inorganic source of nutrients. The nitrogen content of the manures used were tested in the laboratory and according to the results, the doses of manures were set in such a way that it contains required amount of nitrogen. Jeevamrit was prepared by using following ingredients for 1 hectare; 25 kg desi cow dung, 25 litre desi cow urine, 5 kg jaggery, 5 kg pulse flour, 500 g rhizosphere soil and 500 litre water. All these ingredients were put in a 500 litres plastic drum, mixed thoroughly and volume was made up to 500 litres by adding water. The drum was covered with wet jute bag and kept under shade. The mixture was stirred well in clock and anti-clock wise direction thrice a day and it was used between 8th to 10th days after preparation. Beejamrit was prepared by the following procedure; A drum of 50 litres capacity was taken and filled with 20 litres of water. Then 5 kg of cow dung was taken in a cloth, bound it by tape and hung in the 20 liters of water in such a way that it was suspended in the middle of the water for overnight (12 hrs). Simultaneously, lime solution was prepared in another vessel by adding 50 g of lime in one litre of water and keeping it for overnight. Next day, the cloth bundle containing dung was squeezed twice in the container to extract the material and the residue was

removed. Then, the lime solution, 5 litres of cow urine and 500 g of soil from undisturbed bunds was added and stirred well and used for seedling treatment. Ganajeevamrith was prepared by the following procedure; 100 kg of cow dung (air dried for 4-5 days), 1 kg of jaggery, 1 kg of green gram flour,3 litres of cow urine and 250 g of soil from undisturbed bunds was taken in a plastic drum. After adding all the materials, it was mixed well and prepared like cakes. The cakes were shade dried for 10 days and applied in the field.

FYM and Ganajeevamrit were applied as basal, Vermicompost was applied as top dress, Jeevamrit was given through irrigation, inorganic fertilizers were applied as split in the respective treatments. Azadirachtin (10000 ppm), pheromone traps and yellow sticky traps @ 12 ha^{-1}, *Bacillus* buttermilk solution (10 %) and chemicals recommended in TNAU Crop Production Guide were used to manage pest and diseases in the organic and inorganic treatments respectively. Other cultural practices were followed as per the standard recommendations for tomato crop.

Data collection and analysis

Five plants per replication were selected at random; tagged and biometric observations like plant height, number of branches per plant and leaf area were recorded. Leaf area was calculated using the formula given by Meitei *et al.,* (2005), Y= 0.314 + 0.560 (X3), where X3 is the product of leaf length and breadth. The total numbers of fruits from five tagged plants were counted in all the pickings and the average numbers of fruits per plant in each treatment was calculated. Twenty numbers of fruits from each replication was selected from every harvest and used for measuring single fruit weight and fruit diameter. Fruit weight was measured with the help of electronic balance and fruit diameter was measured at the broad part of the fruit by using carbon fiber composites digital vernier caliper. The fresh fruit yield from the net plot area was taken to calculate the fruit yield per hectare. Quality parameter like ascorbic acid content was determined by titration method (Sadasivam and Manickam, 1996) and total soluble solids content (TSS) was measured by using the instrument Erma hand refractometer (0-32 °Brix). The economics of the system was worked out considering the prevailing cost of inputs and price of output. All the data obtained were then analyzed by analysis of variance using Agres software. The critical difference was reported at 5 per cent probability level.

RESULTS AND DISCUSSION

Growth characters

Plant height

The appraisal of data revealed that the plant height was significantly influenced by the different management practices. The highest plant height (71.7 cm) at 90 DAT was recorded in plots applied with FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF. However, it was on par with 50% N requirement through organic manures + 50% N requirement through inorganic fertilizers applied plots (68.5 cm). The readily available macro nutrients from chemical fertilizers accompanied with growth enhancing factors from manures might have accelerated the growth in both the treatments. The lowest plant height of 60.8 cm was noted in recommended dose of fertilizers alone applied plots (Figure 1). The less effectiveness of application of RDF alone as compared to combined application of organic and inorganic fertilizers was also reported by Gokul *et al.,* 2020 in chilli.

Number of branches

From the data, it was found that the plants grown under different management practices significantly differed with respect to number of fruiting branches per plant. Among the treatments experimented, the application of FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF recorded the maximum number of branches (24.7) per plant. However, it was comparable with 50% N requirement through organic manures + 50% N requirement through inorganic fertilizers applied plots (22.4). The increased number of branches might be attributed to the combined application of manures, inorganic fertilizers and biofertilizers that could have encouraged more number of auxiliary buds and resulted in more number of productive branches. Lesser number of branches per plant (17.2) was observed in plants grown in RDF alone applied plots (MP_2-I) (Figure 1). Chouhan *et al.,* 2017 observed that the application of organic manures coupled with RDF has produced higher number of branches (9.1, 21.2 and 24.7 @ 30, 60 and 90 DAT respectively) in chilli as compared to application of RDF alone.

Leaf area

Leaf area is an important growth contributing factor. Higher leaf area leads to higher interception of light and higher photosynthesis. During the investigation, a gradual increase in leaf area was observed from vegetative to harvest. The plants grown under state recommended management practices (FYM @ 25

t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF) exhibited a significantly higher leaf area (22.5 cm^2) than all other management practices (Figure 1). It was followed by plants grown under 50% N requirement through organic manures + 50% N requirement through inorganic fertilizers management practices (MP_3-I) (20.0 cm^2) . The significant variation of leaf area in MP_2-II was presumably due to better nutrient uptake and increased physiological and biochemical activities. Altaf *et al.,* 2019 noticed that the nutrient uptake of chilli was maximum in 100% RDF + FYM applied treatment compared to other treatments.

Yield attributing characters

Number of fruits per plant

The plots applied with state recommended management practices (FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF) had produced significantly more number of fruits per plant (79.4) than all other management practices. It was followed by 100 % of nutrient source as organic manures (50 % FYM + 50 % Vermicompost) (13.9) and 50 % of nutrient source as organic manures + 50 % as inorganic fertilizers (13.1) applied plots (Table 2). The exceptionally higher number of fruits in MP_2-II can be ascribed to increased availability of nutrient from RDF and FYM which had contributed to higher number of branches and eventually higher number of fruits. Anburani and Manivannan (2003) also observed that the application of FYM at 25 t ha^{-1} along with 100 % NPK + biofertilizers produced higher number of fruits per plant compared to other treatments in brinjal.

Fruit weight

Statistical analysis of data revealed that the fruit weight was found to be non significant among the treatments (Table 2). However, the fruits harvested from plants grown under state recommended management practices (MP_2-II) showed higher fruit weight (7.56 g) compared to other treatments. It was followed by fruits harvested from MP_3-I, MP_1-I, MP_3-II, MP_1-II MP_2-I with average fruit weight of 7.45 g, 7.30 g, 7.05 g, 6.94 g, 6.90 g respectively (Table 2).

Fruit girth

Perusal of data revealed that the fruit girth was not significantly influenced by the management practices (Table 2). However, the maximum fruit girth of 12.23 mm was recorded in plots applied with state recommended management practices (MP_2-II) which was followed by 50% of nutrient source as organic manures and 50% as inorganic fertilizers (MP_3-I) (11.86 mm) and 100% of nutrient source as organic manures (MP_1-I) (11.68 mm). Fruit girth was minimum (11.11 mm) in recommended dose of inorganic fertilizers alone applied plots (MP_2-I). The results were in agreement with the findings of Sharma *et al*. (2012) in broccoli in which the different management practices did not exhibit any differences in broccoli diameter.

Quality characters

Total Soluble Solids (TSS)

Total soluble solids represent total sugar content and a small portion of soluble proteins, amino acids and other organic materials (Bexiga *et al.,* 2017). TSS is a key fruit quality parameter as it directly indicates the level of sweetness of the fruit. Among the treatments, TSS was maximum (5.84 °brix) in fruits harvested from 50 % of nutrient source as organic manures + Ghanajeevamrith & Jeevamrith (MP_1-II) applied plots (Table 2). It was on par with fruits harvested from 100 % of nutrient source as organic manures (50% FYM + 50% Vermicompost) applied plots (MP_1-I) (5.62 °brix). The lowest TSS (4.66 °brix) was noted in fruits harvested from inorganic management practices (MP_2-I). The substantial increase of TSS in organic management practices as compared to integrated or inorganic management practices was possibly due to increased activity of hydrolytic enzymes that converts complex polysaccharides into simple sugars. The results were also in line with Karale *et al*., (2020) in chilli and Sharpe *et al.,*(2020) in tomato.

Ascorbic acid

Ascorbic acid is one of the subjective fruit quality traits. Nutrient management practices greatly influences ascorbic acid content in the fruit. Among the treatments, the fruits obtained from 50% of nutrient source as organic manures + Ghanajeevamrith & Jeevamrith applied plots (MP_1-II) registered the highest ascorbic acid content of 127.46 mg 100 g^{-1}. It was followed by fruits obtained from 100 % of nutrient source as organic manures (50 % FYM + 50 % Vermicompost) (MP_1-I) (27.46 mg 100 g^{-1}) applied plots. Lowest ascorbic acid content (116.97 mg 100 g^{-1}) was noted in fruits obtained from RDF alone applied plots (Table 2). The results implicit that the application of organic management practices has either encouraged the ascorbic acid synthesis or protected the oxidation of synthesized ascorbic acid by the enzyme *AA oxidase* which augments the ascorbic acid content in the fruit.

Yield and Economics

Yield

With respect to yield, the plots applied with FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF (MP_2-II) registered the highest fruit yield of 16589 kg ha^{-1} which was followed by 50 % as organic + 50 % as inorganic sources of nutrients (MP_3-I) and 100 % of nutrient source as organic manures applied plots (MP_1-I) with fruit yield of 14193 kg ha^{-1} and 13865 kg ha^{-1} respectively. The yield was lowest (12095 kg ha^{-1}) in plots applied only with 100 % inorganic sources of nutrients (MP_2-1) (Table 3). The higher fruit yield in MP_2-II is not contentious as it produced a sound source interms of plant height, leaf area and number of branches which led to increase in number of fruits, fruit weight and eventually yield. The results are in line with the findings of Nanthakumar and Veeraragavathatham (2003) who observed that combining 12.5 t ha^{-1} of farmyard manure and 2 kg each of Azospirillum and phosphobacteria with inorganic fertilizers favourably influenced the yield of brinjal than other treatments.

Economics

Cost of cultivation

The cost of cultivation incurred per hectare was more (Rs. 183294) in state recommended management practices (MP_2-II) as it involved higher quantity of inputs. The next higher cost of cultivation was seen in 100 % of nutrient source as organic manures (MP_1-I) (Rs. 153765) applied treatment. The lowest cost of cultivation per hectare (Rs. 116534) was recorded in RDF alone applied treatment (MP_1-I) (Table 3).

Gross return

Fruits harvested from inorganic (MP_2-I) and integrated management practices (MP_2-II, MP_3-I and MP_3-II) were sold with normal price whereas fruits harvested from 100 % organic management practices (MP_1-I and MP_1-II) were sold with premium price (25 % higher). This led to higher gross return per hectare (Rs. 346625) in organic management practices (MP_2-I) followed by state recommended management practices (Rs. 331780). The lowest gross return of Rs. 241900 ha^{-1} was noticed in RDF alone applied treatment (MP_1-I) (Table 3).

Net return

The organic management practices MP_1-I and MP_1-II have fetched the highest net return of Rs. 1,92,860 and Rs. 1,88,011 per ha respectively which were followed by state recommended management practices (Rs. 148486 ha^{-1}) (Table 3). The lowest net return of Rs. 125366 ha^{-1} was observed in MP_2-I as it produced lowest yield among the management practices.

Benefit Cost Ratio

The highest benefit cost ratio of 2.40 and 2.25 was observed in organic management practices MP_1-II (50 % of nutrient source as organic manure + Ghanajeevanrith & Jeevamrith) and MP_1-I (100 % of nutrient source as organic manure) respectively. This was obvious as the management practices fetched higher gross return and incurred lower cost of cultivation as compared to state recommended management practices. The lowest benefit cost ratio was (1.81) was noted in state recommended management practices (MP_2-II) (Table 3).

CONCLUSION

Based on the experimental results, the following conclusion may be drawn that the application of state recommended management practices had a positive effect on growth and yield. However for getting economically sustainable and quality chilli, the organic nutrient management package – 50 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + seedling treatment with Beejamrit + application of Ghanajeevamrit @ 250 kg ha^{-1}, Jeevamrit @ 500 litres ha^{-1} $time^{-1}$ twice a month with irrigation water can be suggested.

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Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Originality and plagiarism

This is entirely original work, any work or words of others have been appropriately cited.

Consent for publication

All the authors agreed to publish the content.

Competing interests

There was no conflict of interest in the publication of this content.

Data availability

All the data of this manuscript are included in the MS. No separate external data source is required.

Author contributions

Research fund - ICAR-IIFSR, Idea conceptualization - MS, SM, Experiment - GR, Guidance - MS, SM, Writing original draft - GR, Writing- reviewing & editing - MS, MS, GR.

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Table 1. Treatments details

MP_1-I	:	50 % N requirement through FYM + 50 % N requirement through Vermicompost
MP_1-II	:	50 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + seedling treatment with Beejamrit + application of Ghanajeevamrit @ 250 kg/ha, Jeevamrit @ 500 litres ha^{-1} $time^{-1}$ twice a month with irrigation water
MP_2-I	:	Recommended Dose of Fertilizers (RDF) alone
MP_2-II	:	State recommended practices (FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF)
MP_3-I	:	50 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + 50 % N requirement through inorganic fertilizers
MP_3-II	:	25 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + 25 % N requirement through inorganic fertilizers + seedling treatment with Beejamrit + application of Ghanajeevamrit @ 250 kg ha^{-1} + Jeevamrit @ 500 litres ha^{-1} $time^{-1}$ twice a month with irrigation water

MP - Management Practice, RDF – 120:80:80 kg of NPK ha^{-1}

Table 2. Effect of treatments on yield and quality characters of chilli

Treatments	Number of fruits plant^{-1}	Fruit weight (grams)	Fruit girth (mm)	TSS (°Brix)	Ascorbic acid (mg 100 g^{-1})
MP_1-I	70.1	7.30	11.68	5.62	125.23
MP_1-II	67.9	6.94	11.21	5.84	127.46
MP_2-I	64.0	6.90	11.11	4.66	116.97
MP_2-II	79.4	7.56	12.23	5.23	123.58
MP_3-I	69.4	7.45	11.86	5.42	120.47
MP_3-II	68.8	7.05	11.59	5.54	123.72
SEd	1.70	0.49	0.41	0.18	0.30
CD(P=0.05)	3.54	NS	NS	0.38	0.63

Table 3. Effect of treatments on yield and economics* of chilli

Treatments	Fruit Yield (Kg ha^{-1})	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
MP_1-I	13865	153765	346625	192860	2.25
MP_1-II	12896	134389	322400	188011	2.40
MP_2-I	12095	116534	241900	125366	2.08
MP_2-II	16589	183294	331780	148486	1.81
MP_3-I	14193	140550	283860	143310	2.02
MP_3-II	13386	129213	267720	138507	2.07
SEd	213.54	-	-	-	-
CD(P=0.05)	445.45	-	-	-	-

*Data not statistically analysed

Figure 1. Effect of treatments on growth characters of chilli