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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(11): 318-322

www.thepharmajournal.com
Received: 04-08-2022
Accepted: 07-09-2022

Effect of integrated nutrient management on post-harvest soil nutrient status and economics of chilli in Typic Haplustert soils of Tamil Nadu

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Abstract
An experiment was conducted at farmer's field in Sivapuri village, Chidambaram taluk, Cuddalore district, Tamil Nadu, India, to study the effect of inorganic fertilizers, organic manures and biofertilizers on post-harvest soil nutrient status and economics of chilli var. K2. The treatments were imposed on a sandy clay loam soil. The field experiment was laid out in a randomized block design with three replications and eleven treatments. Among the different treatments experimented, the available nitrogen, phosphorus, exchangeable calcium in post-harvest soil and benefit cost ratio were significantly higher with the application of 75% recommended dose of fertilizers + poultry manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$. The findings also revealed that the maximum available potassium and exchangeable magnesium were registered in the treatment with application of 75% recommended dose of fertilizers + sheep manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$. Furthermore, the maximum content of available sulphur in post-harvest soil was recorded in the treatment which received 75% recommended dose of fertilizers + pressmud @ 10 t ha^{-1} + biofertilizers + 2% $MgSO_4$.

Keywords: Chilli, INM, soil nutrient status, economics

Introduction

Chilli is an important vegetable crop of India which belongs to Solanaceae family and also called Nightshade family. It is otherwise called as red pepper, hot pepper, cayenne pepper, capsicum, etc. Most of the cultivated varieties in India belong to the species *Capsicum annum* and regularly cultivated all over the world. Economically, chillies are grown as cash crop. Chilli is the excellent source of vitamins and minerals. The increased availability of oleoresins and spice oils of chilli has also enhanced its consumption in various food preparations. The chilli crop is very important for agricultural economy and is used in processing industries. In India, area under chillies is about 7.43 lakh hectares and production of 19.14 lakh tonnes with productivity of 2576 kg ha^{-1} in 2020-21. In Tamil Nadu, Chilli is grown in an area of 50.7 thousand hectares with a total production of 23.1 thousand tonnes and the productivity is 0.46 tonnes ha^{-1} (Geetha and Selvarani, 2017) [4].

In horticulture sector, usually imbalanced quantity of inorganic fertilizers is used, therefore highest yield could not be attained. Moreover, use of urea as chemical fertilizer by the farmers is being practiced without adding any organic fertilizer which causes hurdle for sustainable agricultural cropping system. Adequate and balanced fertilizer management along with organic manures is very much essential to exploiting the full yield potential and profit of chilli. After the green revolution, increase in production was achieved at the cost of soil health. Chilli, being a long duration crop, requires proper manuring and fertilizing in the surface soil. It is because of its shallow root system, for attaining high yield and quality produce (Bidari, 2000) [1].

It is necessary to adopt appropriate nutrient management practices which help to supply nutrients in adequate quantities to meet out the crop need based fertilizer management and urgent task in the present scenario to restore soil fertility. Due to escalating cost of fertilizers, their hazardous polluting effects on environment and quality of the produce, there is a growing awareness among the farming community about the advantages of organic fertilizers. Use of organic manures alone cannot fulfil the crop nutrients requirement. Organic sources for incorporation into the soil are becoming scarce.

Essential elements locked up in the organic manures are slowly mineralized and made available to the crops, which helps in increasing the yield and quality (Lal, 2004) [6], besides improving the fertility of the soil.

The integrated supply and use of plant nutrients from chemical fertilizers and organic manures has shown to produce higher crop yields than when they are applied alone (Kapse *et al*., 2017) [5]. Use of judicious combinations of integrated nutrient sources is essential, not only to maintain the soil health but also sustain the productivity. In view of this context a present investigation was carried out to find out the effect of integrated nutrient management on post-harvest soil and economics of chilli.

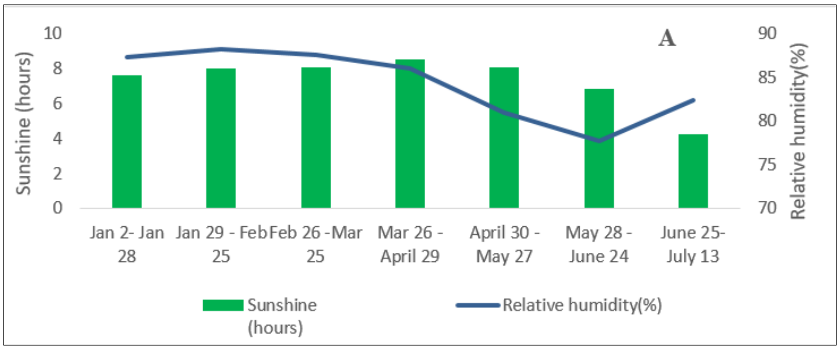
Materials and Methods

The present investigation was conducted at farmer's field in Sivapuri village, Chidambaram taluk, Cuddalore district, Tamil Nadu with chilli variety K2 as test crop. The meteorological data for growing periods of crop were presented in fig.1. The experimental soil was sandy clay loam and comes under the taxonomic class of Typic Haplustert with a pH of 7.40, EC of 0.7 dS m^{-1} and CEC of 16.30 c mol (p^{+}) kg^{-1}. The available N, P and K contents of soil were 212.0 (low), 10.7 (low) and 232.0 (medium) kg ha^{-1} respectively. The treatments consisted of application of inorganic fertilizers, organic manures and biofertilizers in different combinations. The treatments were T_1 - 100% recommended dose of fertilizers (control), T_2 (100% recommended dose of fertilizers + FYM @ 25 t ha^{-1})- farmer's practice, T_3 (75% recommended dose of fertilizers + sheep manure @ 5 t ha^{-1}), T_4 (75% recommended dose of fertilizers + sheep manure @ 5 t ha^{-1} + biofertilizers), T_5 (75% recommended dose of fertilizers + sheep manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$), T_6 (75% recommended dose of fertilizers + pressmud @ 10 t ha^{-1}), T_7 (75% recommended dose of fertilizers + pressmud @ 5 t ha^{-1} + biofertilizers), T_8 (75% recommended dose of fertilizers + pressmud @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$), T_9 (75% recommended dose of fertilizers + poultry manure @ 5 t ha^{-1}), T_{10} (75% recommended dose of fertilizers + poultry manure @ 5 t ha^{-1} + biofertilizers), T_{11} (75% recommended dose of fertilizers + poultry manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$). The experiment was laid out in randomized block design and replicated three times. The experimental plots received the fertilizers according to the treatment schedule. The N, P, K fertilizers, FYM, poultry manure, pressmud, sheep manure and biofertilizers (*Azospirillum* and *Phosphobacteria*) were applied as basal according to the treatments.

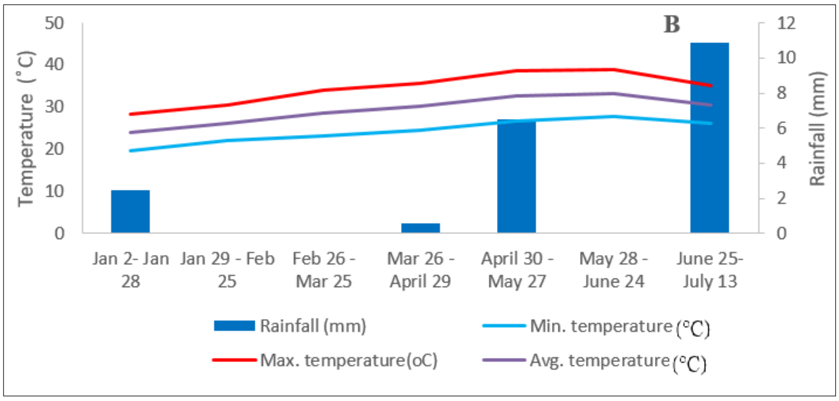
Table 1: Properties of organic manures

Parameters	FYM	Sheep manure	Pressmud	Poultry manure
pH (1:2.5)	7.87	7.9	7.72	7.5
EC (dS m^{-1}) (1:2.5)	0.19	0.70	1.65	1.8
Organic carbon (%)	11.25	20.37	14.53	23.45
Nitrogen (%)	0.61	2.97	1.44	3.20
Phosphorus (%)	0.25	1.13	0.82	2.03
Potassium (%)	0.54	2.01	0.74	1.57
Calcium (%)	0.83	0.74	0.63	2.99
Magnesium (%)	0.25	0.98	0.42	0.67
Sulphur (%)	0.29	0.46	0.81	0.59
Zinc (mg kg^{-1})	149	98.5	128	258
Iron (mg kg^{-1})	138	354.2	220	1219
Copper (mg kg^{-1})	3.1	45	78	113
Manganese (mg kg^{-1})	92.2	156.4	112	410

The properties of organic manures used in this study were presented in table 1. The $MgSO_4$ was applied as 2% foliar spray at 30, 60 and 90 DAT. The available nutrient status of post-harvest soil and economics were analysed after harvest of the chilli crop.



A) Sunshine (hours), Relative Humidity (%)



B) Rainfall (mm), Max. temperature (°C), Min. temperature (°C), Avg. temperature (°C)

Fig 1: Meteorological data during the experimental period (Jan 2-July 13, 2019)

Results and Discussion

Nutrient status of post-harvest soil (Table 2)

Available Nitrogen

Among the different treatments experimented, application of 75% recommended dose of fertilizers + poultry manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$ (T_{11}) recorded the highest available nitrogen content of 204.4 kg ha^{-1}. This was followed by the application 75% recommended dose of fertilizers + sheep manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$ (T_5) which recorded available nitrogen content of 199.8 kg ha^{-1} in post-harvest soil. These treatments were followed by T_8, T_{10}, T_4, T_7, T_2, T_9, T_3 and T_6. However, the treatments T_8 and T_{10}; T_7 and T_2; T_3 and T_6 were statistically not different from each other. This might be due to the synergistic effect of nitrogen fixing bacteria which resulted in higher accumulation of N in the soil. The mineralization of native organic matter along with applied poultry manure might also have increased the N. The significant effect due to organo mineral application could be attributed to easy dissolution effect of released plant nutrient leading to improved soil available nitrogen status. The increase in available N might be attributed to the direct addition of nitrogen through inorganic fertilizer, poultry manure and multiplication of soil microbes through *Azospirillum*, which could convert organically bound N to inorganic form to the available N pool of the soil and *Azospirillum*, helps to fix the atmospheric nitrogen in to the soil which increased the available nitrogen status. The increase in nitrogen content might also be attributed to addition of organic material *viz*., poultry manure with balanced chemical fertilizers. These results are in close conformity with the findings of Sarangthem *et al*. (2011) [8]. The lowest available nitrogen content of 170.8 kg ha^{-1} was noticed with application of 100% recommended dose of fertilizers alone (T_1).

Available phosphorus

It was quite clear from the data that the available phosphorus in post-harvest soil significantly differed with different treatments. The result confirmed that the application of 75% recommended dose of fertilizers + poultry manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$ (T_{11}) registered the highest available phosphorus content of 10.01 kg ha^{-1}. This treatment was followed by the treatments T_{10}, T_5, T_4, T_8, T_7, T_2, T_9, T_3, T_6 and T_1. The treatments T_{11} and T_{10} were not significantly different from each other. The treatments T_5 and T_4; T_8 and T_7 were on par with each other. The application of organic and inorganic fertilizers marginally increased the available phosphorus. The increase in available P content in post-harvest soil might be also due to the incorporation of organic manure namely poultry manure which enabled the direct addition of P as well as release of various organic acids on their decomposition, chelating with Fe and Al and helped in solubilization of native P. The organic materials also form a cover on sesquioxides and thus reduce the phosphate fixing capacity of the soil. Another reason might be that *Phosphobacteria* applied in this treatment have enhanced the availability of phosphorus in soil (Chetri *et al*., 2012) [2].

Available potassium

The appraisal of data revealed that the application of 75% recommended dose of fertilizers + sheep manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$ (T_5) significantly increased the available potassium content of post-harvest soil from 164.13 kg ha^{-1} (T_1) to 206.63 kg ha^{-1} (T_5). This might be due to the fact that application of organic manures like sheep manure in bulk quantity and subsequently their slow mineralization resulted in gradual build-up of available K (Chetri *et al*., 2012) [2]. Another possible reason might be due to reduced solubility of Al and Fe and improved the CEC of the soil and thus increased the retention of K in exchangeable form by a mass action effect. The beneficial effect of sheep manure on available K might 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. The minimum potassium, availability in control treatment might be due to either high removal of K by capsicum or addition of K only through chemical fertilizer to the crop. These results are in consonance with the findings of Sharma (2018) [9].

Exchangeable calcium

The exchangeable calcium content was statistically influenced by application of different sources of nutrients. The maximum exchangeable calcium content was registered in the treatment with application of 75% recommended dose of fertilizers + poultry manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$ (T_{11}) with the value of 9.51 c mol (p^+) kg^{-1}. The treatments next in order were T_9, T_{10}, T_2, T_5, T_4, T_3, T_8, T_6, T_7 and T_1 of 9.27, 9.14, 8.75, 8.47, 8.11, 8.02, 7.73, 7.48,7.39 and 7.16 c mol (p^+) kg^{-1} respectively. But, the treatments T_9 and T_{10}; T_4 and T_3; T_6 and T_7 were on par with each other. Superiority of this might be due to higher percentage of calcium in poultry manure which increase the soil pH and exchangeable calcium in post-harvest soil more effectively as compared to other organic manures. Thus, these integrated applications were found to be effective to enhance the exchangeable calcium in post-harvest soil. Thirunavukkarasu and Balaji (2015) and Vinod Kumar (2016) [10, 11] reported similar findings.

Exchangeable magnesium

The various treatment combinations significantly differed in the exchangeable magnesium content of post-harvest soil. The maximum was recorded with application of 75% recommended dose of fertilizers + sheep manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$ (T_5). The minimum was observed in control (T_1). This might be attributed to the supply of magnesium from sheep manure which leads to maximization of exchangeable magnesium after harvest of the crop. The release of those nutrients from added sheep manure with inorganic fertilizers to the soil after mineralization released magnesium. Foliar application of $MgSO_4$ might be another reason responsible for increment of minimum quantity of exchangeable magnesium in post-harvest soil. Further, the organic acids released from the decomposition of sheep manure might have released magnesium from exchange sites in the soil. The present results are in close consonance with the findings of Muthuraju *et al.* (2005) [7].

Available Sulphur

The data on available sulphur revealed that there was a significant effect in post-harvest soil by the addition of different combination of application of inorganic fertilizers, organic manures and biofertilizers.

Table 2: Effect of integrated nutrient management on post-harvest soil status of chilli

Treatment details	Available N	Available P	Available K	Exch. Ca	Exch. Mg	Available S
	(kg ha^{-1})			(c mol (p$^+$) kg^{-1})		(mg kg^{-1})
T_1 - 100% RDF alone (Control)	170.8	7.16	164.13	7.16	5.26	5.53
T_2 - 100% RDF + farm yard manure @ 25 t ha^{-1} (Farmer's practice)	184.8	8.68	168.42	8.75	5.59	5.79
T_3 - 75% RDF + sheep manure@ 5 t ha^{-1}	175.3	7.98	200.51	8.02	6.64	6.09
T_4 - 75% RDF + sheep manure@ 5 t ha^{-1} + biofertilizers	190.4	9.40	199.06	8.11	6.56	6.22
T_5 - 75% RDF + sheep manure@ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$	199.8	9.51	206.63	8.47	7.44	7.08
T_6 - 75% RDF + pressmud @ 10 t ha^{-1}	174.9	7.44	173.11	7.48	5.84	6.81
T_7 - 75% RDF + pressmud @ 10 t ha^{-1} + biofertilizers	185.3	8.95	175.48	7.39	5.92	6.90
T_8 - 75% RDF + pressmud @ 10 t ha^{-1} + biofertilizers + 2% $MgSO_4$	195.7	9.08	181.04	7.73	6.87	7.52
T_9 - 75% RDF + poultry manure @ 5 t ha^{-1}	179.8	8.31	188.21	9.27	6.18	6.54
T_{10}- 75% RDF + poultry manure @ 5 t ha^{-1} + biofertilizers	195.1	9.93	189.32	9.14	6.23	6.42
T_{11}- 75% RDF + poultry manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$	204.4	10.01	194.47	9.51	7.19	7.29
SE_d	1.960	0.126	2.036	0.108	0.094	0.076
CD (p=0.05)	4.089	0.262	4.247	0.226	0.195	0.161

The highest available sulphur content was registered in the treatment T_8 (75% RDF + pressmud @ 10 t ha^{-1} + biofertilizers + 2% $MgSO_4$ and this was followed by the treatment T_{11} (75% recommended dose of fertilizers + poultry manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$. The treatments next in order were T_5, T_7, T_6, T_9, T_{10}, T_4, T_3, T_2 and T_1. But, the treatments T_7 and T_6; T_9 and T_{10}; T_4 and T_3 were comparable with each other. This might be due to mineralization of sulphur from native as well as from added organic source. The organic manure *viz*., pressmud acts as an energy source for sulphur oxidizing microorganisms which in turn make in their activities and increased the sulphur mineralization rate in post-harvest soil. Application of pressmud might have released sulphur during cropping period and some effect of foliar spray of magnesium sulphate which improved the available sulphur (Dilmaghani *et al*., 2012) [3].

Economic analysis (Table 3)

It is important to study economics of the experiment as no technology can be recommended without knowing its profit and loss. The perusal of the data indicated with respect to economic status of chilli cultivation, the highest gross return (Rs. 352926), net return (Rs. 250640.20) and return repee^{-1} (3.45) invested was registered under the treatment with combined application of 75% inorganic recommended dose of fertilizers + poultry manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$ (T_{11}). This was followed by T_5 and T_{10} which recorded the net income of Rs. 235356.20 ha^{-1} and Rs. 221970.70 ha^{-1} with 3.29 and 3.18 return rupee^{-1} invested respectively. The treatments next in order were T_4, T_8, T_1, T_9, T_7, T_3 and T_2. The highest benefit cost ratio compared to other treatments because of the use of bio inputs in the field along with chemical fertilizers. The treatment T_6 (75% recommended dose of fertilizers + pressmud @ 10 t ha^{-1}) recorded the minimum net return Rs. 158361.20 ha^{-1} with 2.46 return rupee^{-1} invested (Fig. 2).

Table 3: Effect of integrated nutrient management on economics of chilli

Treatment details	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net return (Rs. ha^{-1})
T_1 - 100% RDF alone (Control)	87623.18	252861	165237.80
T_2 - 100% RDF + farm yard manure @ 25 t ha^{-1} (Farmer's practice)	112623.20	294462	181838.80
T_3 - 75% RDF + sheep manure@ 5 t ha^{-1}	102069.80	267645	165575.20
T_4 - 75% RDF + sheep manure@ 5 t ha^{-1} + biofertilizers	102475.30	310149	207673.70
T_5 - 75% RDF + sheep manure@ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$	102785.80	338142	235356.20
T_6 - 75% RDF + pressmud @ 10 t ha^{-1}	108569.80	266931	158361.20
T_7 - 75% RDF + pressmud @ 10 t ha^{-1} + biofertilizers	108975.30	297003	188027.70
T_8 - 75% RDF + pressmud @ 10 t ha^{-1} + biofertilizers + 2% $MgSO_4$	109285.80	324807	215521.20
T_9 - 75% RDF + poultry manure @ 5 t ha^{-1}	101569.80	280812	179242.20
T_{10}- 75% RDF + poultry manure @ 5 t ha^{-1} + biofertilizers	101975.30	323946	221970.70
T_{11}- 75% RDF + poultry manure @ 5 t ha^{-1} + biofertilizers + 2% $MgSO_4$	102285.80	352926	250640.20

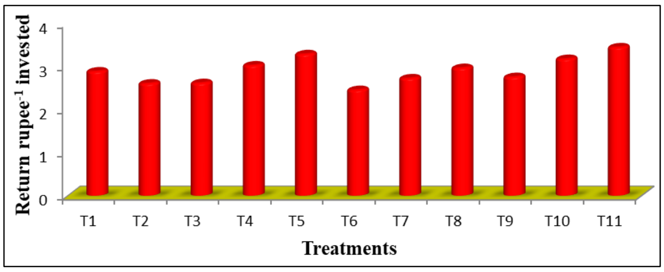


Fig 2: Effect of integrated nutrient application on benefit cost ratio in chilli

Conclusion

The integrated nutrient management is essential for maintaining soil health and quality. The results clearly emphasized that the application of organic manures, biofertilizers *Azospirillum* and *Phosphobacteria*) and foliar spray of $MgSO_4$ combined with 75% recommended dose of fertilizers resulted in higher nutrient availability over a long period of time and remunerative return to farmers. It also helped in building up soil health and fertility by improving the soil physical and chemical properties during cropping period. Therefore, application of organic manure should be considered as an alternative source to substitute inorganic fertilizers partially.

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