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Effect of integrated nutrient management on the nutrient accumulation and status of post-harvest soil of brinjal (*Solanum melongena* L.) under Nadia conditions (West Bengal), India

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Abstract: A field experiment was carried out at the Central Research Farm, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India to study the effects of integrated nutrient management on the nutrient accumulation (dry weight recoveries) in brinjal and plant nutrient status of the post- harvest soil of brinjal under Nadia conditions. The results revealed that the treatment consisting of 75% RDF (RDF *i.e.* N:P:K:: 125:100:50) + *Azospirillum* + phosphate solubilising bacteria (PSB) + Borax @ 10 kg ha^{-1} recorded the highest oxidizable organic carbon (8.049 g kg^{-1}), total nitrogen (1.05 g kg^{-1}) , available nitrogen (212.67g kg^{-1}), available phosphorus (76.20g kg^{-1}) and available potassium (177.59 g kg^{-1}) in the post harvest soils of brinjal. On the other hand, 75% RDF + *Azospirillum* + PSB + $FeSO_4$ @ 50 kg ha^{-1} recorded the highest available iron (26.14 kg ha^{-1}) and the treatment consisting of 75% RDF + *Azospirillum* + PSB + $ZnSO_4$ @ 25 kg ha^{-1} recorded the highest soil available zinc (7.62 kg ha^{-1}) while 75% RDF + Azo + PSB + Borax @ 10 kg ha^{-1} recorded the highest available Boron content (0.78 kg ha^{-1}) of the post harvest soil of Brinjal. Highest brinjal yield (14.96 t ha^{-1}) was supported by the treatment consisting of 75% RDF + *Azospirillum* + PSB + Boron @ 10 Kg ha^{-1}. Meager information was available regarding the performance of integrated application of organics and micronutrient on brinjal in the experimental location. The present study may enlighten this unexplored section of nutrient management in brinjal.

Keywords: *Azospirillum*, Borax, Brinjal, PSB, Integrated Nutrient Management

INTRODUCTION

India is regarded as a horticultural paradise (Saravaiya and Patel, 2005), with a vast array of vegetables being cultivated in our country, brinjal is considered as one of the leading and the second major vegetable crops next to tomato. Brinjal (*Solanum melongena*) is also called as eggplant, a popular vegetable crop and is native to India (Kiran *et al*., 2010). India contributes about 28% of the total world production (*Daunay et al*., 2001). It is highly productive and usually finds a place as "poor man's crop". Purple fruits have higher amino acid content. Brinjal fruits have medicinal properties (Rajan and Markose, 2002). Some medicinal use of eggplant tissues and extract include treatment of diabetes, asthama, cholera, bronchitis and diarrhea, its fruit and leaves are reported to lower certain levels of blood cholesterol. The growth, yield and fruit quality of brinjal are largely dependent on a number of interacting factors.

Egg plant is a long duration crop with high yield which removes large quantities of nutrients from the soil. An egg-plant crop yielding 60 t ha^{-1} of fruit removes 190 kg N, 10.9 kg P and 128 kg K from soil (Hedge, 1997). Now-a-days demand for brinjal as a vegetable is increasing rapidly among the vegetable consumers in view of its better fruit color, size and taste. Average productivity of brinjal crop is quite low and there exists a good scope to improve its average productivity in India to fulfill both domestic and national needs.

The productivity of brinjal can be increased by using several techniques *viz.,* organic farming, integrated nutrient management and good hybrid seeds. Since the nutrient turnover in soil plant system is considerably high in intensive vegetable cultivation, neither the chemical fertilizer nor the organic manure alone can help achieve sustainable production (Khan *et al*., 2008). Moreover, the application of high input technologies such as chemical fertilizers, pesticides, herbicides improve the production but there is growing

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concern over the adverse effects of the use of chemicals on human health, soil productivity and environment quality.(Sharma *et al*., 2012). Bio fertilizers improve the quantitative and qualitative features of many plants (Yousefi *et al*., 2011). In addition, biofertilizers stimulate plant growth, improve both soil structure and conditions, restore natural soil fertility and provide protection against drought and some soil borne diseases (Bashan *et al*., 2004). On the other hand, application of organics improves the soil physical, chemical and biological properties and has direct impact on moisture retention, root growth and nutrient conservation etc. (Kumar *et al*., 2011). Many countries have already introduced the organic production system with specific logo to provide individuality to the organic products in commercial trade (Sharma, 2011).

Application of NPK, bio-fertilizers like *Azospirillum* and phosphate solubilizing bacteria (PSB) with micronutrients viz., ferrous sulphate, zinc sulphate and boron spray bring profound changes in various metabolic processes within the plant system, thereby influencing plant growth and yield considerably. In recent years, importance of combined use of these inorganic fertilizers, biofertilizers and micronutrients is being realized particularly in brinjal to boost up plant growth, productivity and also on seed quality. The application of high input technologies such as chemical fertilizers, pesticides, herbicides improve the production but there is growing concern over the adverse effects of the use of chemicals on human health, soil productivity and environment quality. The integrated management of nutrient, in its proper perspective, may be adopted to support enhanced productivity and quality of vegetables (Kiran *et al*., 2010). Keeping in view the present investigation was carried out to study the effect of integrated nutrient management on the nutrient status and uptake of brinjal (*Solanum melongena* L.) in an inceptisol of West Bengal.

MATERIALS AND METHODS

Characterization of experimental site: Field trials were conducted in the new alluvial zone (Inceptisol) of Central Research Farm of Bidhan Chandra Krishi Viswavidyalaya at Gayeshpur Nadia district of West Bengal, India. The field is situated at in $22^0 58'162''$N latitude, $88^0 30'651''$E longitude, experiencing hot and humid climate with mean annual rainfall of 1310 mm, minimum and maximum temperature of 21 ± 1 and 32 ± 2° C, respectively. The soil was typic endoaquepts with silty clayey loamy texture, slightly alkaline in reaction. The experimental soils were non-saline (EC 0.278 dS/m), sandy-clay loam in texture, neutral in reaction (pH 6.7), low in organic carbon (4.5 g/kg), available N (178 kg/ha), high in available P (51 kg/ha) and medium in available K contents (137 kg /ha). The soils were high in DTPA extractable Fe (25.3 kg/ ha) and low in DTPA extractable Zn and B (4.56 and 0.43 kg/ ha, respectively).

Experimental details: The experiment was laid out in two factor factorial randomized block design with each treatment being replicated three times and with Brinjal (cv F_1- hybrid VNR -60) as the test crop. So there were 48 (4 × 4 × 3) plots (size 5m × 2m).The experiment consisted of sixteen treatments combinations comprising of four levels of fertilizers and biofertilizers viz; F_1= recommended dose of fertilizer (RDF)N:P:K:: 125:100:50kg ha^{-1}, F_2= 75% RDF + *Azospirillum* (root dipping) @ 250 g ha^{-1}, F_3= 75% RDF +PSB (root dipping) @ 250 g ha^{-1}, F_4= 75% RDF +*Azospirillum* + PSB (root dipping) each @ 125 g ha^{-1} and four levels of micronutrients viz; S_1= control, S_2= $ZnSO_4$ @ 25 kg ha^{-1} (Soil application), S_3= $FeSO_4$ @ 50 kg ha^{-1} (Soil application) and S_4= Borax @ 10 kg ha^{-1} (Soil application).

The recommended dose of inorganic fertilizers @ 125:100:50 (N:P:K) kg ha^{-1} were applied in the experimental plot. The entire amount of phosphorus (SSP), potassic fertilizer (MOP) and half of total nitrogenous fertilizer (urea) were applied at final land preparation. The rest half of the nitrogenous fertilizers were applied in two equal split doses (one quarter each) at 20-25 DAS and at 40-45 DAS respectively. Bio-fertilizers like *Azospirillum* and PSB @ 250 g ha^{-1} and *Azospirillum* + PSB each @125g ha^{-1} were applied in the selected plots as root dip treatment before transplanting of brinjal seedling. Micronutrient fertilizers were applied as soil application (SA) 4 days before transplanting of brinjal seedling. Fruits were harvested at their edible maturity stage i.e. when they are not fully ripened and have a bright purple colour and harvested at 3 days interval at peak fruiting stage.

Analytical methodologies: The methods involved in analyses of soil (both initial and post-harvest) and plant samples are depicted in Table 1.

Statistical interpretation: The experimental layout was set to be a 4×4 factorial design with three replications. Statistical conclusions were drawn by factorial analysis of the database. All statistical computations were done through SPSS V.16.0.

RESULTS AND DISCUSSION

Nutrient uptake in brinjal: The nutrients status of brinjal fruit, leaf and shoot (estimated in dry weight basis) obtained through different systems of integrated management have been recorded in tables 2 and 3. N accumulations (g kg^{-1} dry weight basis) in brinjal leaf, fruit and shoot were observed to vary within a range of 17.40, 16.36 and 9.47 (control) to 25.33, 23.72 and 15.77 (75% RDF+ PSB+ Borax @ 10 kg ha^{-1}) respectively. The changes in the fruit protein content followed the same trend as observed in total N content. P accumulation (g kg^{-1} dry weight basis) in brinjal leaf, fruit and shoot were observed to vary within a range of 3.95, 3.81 and 3.65 (control) to 8.83, 7.00 and 8.16 (75% RDF+ PSB+ Borax @ 10 kg ha^{-1}), respectively. Potassium accumulations (g kg^{-1} dry weight) in brinjal

Table 1. Analytical methodologies parameters.

Parameter	Methodology	Citation	Equipment used
Soil analyses			
Sand-Silt-Clay	Hydrometer method	Bouyoucos (1962)	Hydrometer
pH	(in 1:2.5:: Soil : Water)	Jackson (1967)	m-processor based pH-EC-Ion meter
EC	(in 1:2.5:: Soil : Water)	Jackson (1967)	
Organic carbon	Wet oxidation method	Jackson (1973)	-
Available N	Hot alkaline $KMnO_4$ Method	Subbiah and Asija (1956)	Kjeldahl apparatus
Available P	0.5 M $NaHCO_3$ extraction	Olsen *et al.*(1954)	Spectrophotometer
Available K	Neutral N NH_4OAc extraction	Brown and Warncke (1988)	Flame photometer
Available Fe	DTPA extraction	Lindsay and Norvell (1978)	Atomic Absorption Spectrophotometer
Available Zn	DTPA extraction	Lindsay and Norvell (1978)	Atomic Absorption Spectrophotometer
Available B	Hot water extraction	Berger and Truog (1939)	Spectrophotometer
Analyses of plant samples			
Total N	Concentrated H_2SO_4 digestion	AOAC, 1995	Micro-Kjeldahl's method
Protein percentage	Accounted by multiplying total nitrogen content by 6.25	Sadasivam and Manickam, 1996	-
Total P	Tri-acid mixture (HNO_3:H_2SO_4:$HClO_4$:: 9:1:4) digestion	Jackson, 1973	Spectrophotometer
Total K	Tri-acid mixture (HNO_3:H_2SO_4:$HClO_4$:: 9:1:4) digestion	Jackson, 1973	Flame photometer
Total Fe and Zn	Tri-acid mixture (HNO_3:H_2SO_4:$HClO_4$:: 9:1:4) digestion	Jackson, 1973	Atomic Absorption Spectrophotometer
Total B	Dry ashing	Gaines and Mitchell (1979)	Spectrophotometer

leaf, fruit and shoot were observed to vary within a range of 17.03, 15.14 and 11.42 (control) to 31.64, 23.81 and 16.60 (75 % RDF + *Azospirillum* + PSB + Borax @ 10 kg ha^{-1}). Maximum concentration of N, P and K in leaf, shoot and fruit was observed in 75 % RDF + *Azospirillum* + PSB + Borax @ 10 kg ha^{-1} treatment. Our observations in this regard have been substantiated by findings of several earlier workers like Srijaya and Sitaramayya (2006) who found highest nitrogen (2.28%), P(0.224%), K(1.17%) against treatment RDF + gypsum and RDF + Zn (soil application), respectively. The range of N was 1.92 to 2.10%, 0.122 to 0.244% for P and 1.10 to 1.17% for K in plant while in fruits the P and K concentrations were more than N as compared to plant. Patil and Patil (2000) recorded N, P and K contents in different cultivars of brinjal fruits which ranged from 2.04 to 3.26, 0.35 to 0.55 and 1.50 to 3.89 per cent, respectively.

Positive impact of biofertilizers on nutrient uptake and quality of vegetables has already been reported (Choudhury *et al.*, 2005; Kadlag *et al.*, 2007). Singh *et al.*, (2004) also reported that the integrated use of organic and inorganic sources of nutrients and biofertilizers increased the N, P and K concentration in the plants (including fruits of okra, pea and tomato under cropping system in a Mollisols while higher higher protein and ascorbic acid in cauliflower with 60 kg N and *Azotobacter* has been reported by Bashyal (2011). Iron accumulations (g kg^{-1} dry weight) in brinjal leaf, fruit and shoot were observed to vary within a range of 121.87, 125.67, 124.67 (control) to 316.72 (75% RDF + PSB + $FeSO_4$ @ 50 kg ha^{-1}), 265.83 (75% RDF + *Azospirillum* + $FeSO_4$ @ 50 kg ha^{-1}), 251.50 (75% RDF + Azo + PSB + $FeSO_4$ @ 50kg ha^{-1}), respectively. Zinc accumulations (g kg^{-1} dry weight) in brinjal leaf, fruit and shoot were observed to vary within a range of 25.50, 25.43 and 25.00 (control) to 43.10, 42.60 and 39.86 (75% RDF + *Azospirillum* + PSB + $ZnSO_4$ @ 25kg ha^{-1}), respectively. Boron accumulations (g kg^{-1} dry weight) in brinjal leaf, fruit and shoot were observed to vary within a range 0.70, 0.34 and 0.27 (control) to 1.19, 0.51 and 0.46 (75% RDF + *Azospirillum* + PSB + Borax @ 10 kg ha^{-1}), respectively. Integrated nutrient management and plant uptake or accumulation of micronutrient elements have been studied by several workers in a no. of crops and cropping system. Working with brinjal cv. "CVK" in Coimbatore, Selvi *et al.*, (2004) recorded that a Zn uptake ranging from 278 to 493 g/ha. They further noticed that the content of zinc in Brinjal fruits ranged from 42.8 to 154.4 ppm. Selvi *et al*. (2004) recorded that Fe uptake ranged from 2.16 to 3.49 kg/ha as well as iron content in brinjal fruit ranged from 313 – 401 ppm. Singh *et al*., (2012) reported that Zn content in

Table.2: Nutrient accumulation (dry weight recoveries) in brinjal plant.

Treatment	Protein (%)	N content (g kg^{-1})			P content (g kg^{-1})			K content (g kg^{-1})		
		Leaf	Fruit	Shoot	Leaf	Fruit	Shoot	Leaf	Fruit	Shoot
Fertilizers and Bio-fertilizers										
F_1	10.68^{b}	20.02^{b}	17.09^{b}	16.90^{b}	5.69^{d}	5.38^{d}	5.29^{d}	20.69^{b}	16.90^{b}	11.84^{b}
F_2	11.89^{ab}	22.51^{a}	19.02^{ab}	19.13^{ab}	6.65^{c}	5.76^{c}	6.30^{c}	23.84^{ab}	19.13^{ab}	14.04^{a}
F_3	13.34^{a}	23.94^{a}	21.34^{a}	18.80^{ab}	8.00^{a}	6.52^{a}	7.49^{a}	23.11^{ab}	18.80^{ab}	13.11^{ab}
F_4	12.71^{a}	23.98^{a}	20.34^{a}	20.33^{a}	7.69^{b}	6.47^{b}	7.12^{b}	25.96^{a}	20.33^{a}	14.58^{a}
Micronutrients										
S_1	11.25^{a}	21.75^{a}	18.00^{a}	17.26^{a}	6.22^{c}	5.37^{c}	5.89^{d}	20.78^{b}	17.26^{a}	12.92^{a}
S_2	12.54^{a}	23.28^{a}	20.06^{a}	19.12^{a}	7.08^{b}	6.15^{b}	6.24^{c}	23.19^{ab}	19.12^{a}	13.21^{a}
S_3	12.56^{a}	22.94^{a}	20.10^{a}	18.94^{a}	7.11^{b}	6.13^{b}	6.85^{b}	25.36^{a}	18.94^{a}	13.17a
S_4	12.27^{a}	22.49^{a}	19.63^{a}	19.84^{a}	7.62^{a}	6.48^{a}	7.23^{a}	24.27^{ab}	19.84^{a}	14.27^{a}
Interaction (F X S)										
F_1S_1	10.23^{bc}	17.40^{b}	16.36^{bc}	15.14^{b}	3.95^{g}	3.81^{h}	3.65^{g}	17.03^{c}	15.14^{b}	11.42^{b}
F_1S_2	10.40^{bc}	21.48^{ab}	16.64^{bc}	17.64^{ab}	6.06^{f}	6.05^{e}	5.45^{f}	21.52^{abc}	17.64^{ab}	11.79^{b}
F_1S_3	11.75^{abc}	20.49^{ab}	18.80^{abc}	17.47^{ab}	6.29^{ef}	5.43^{g}	5.93^{e}	22.74^{abc}	17.47^{ab}	11.68^{b}
F_1S_4	10.35^{bc}	20.70^{ab}	16.57^{bc}	17.35^{ab}	6.48^{def}	6.22^{d}	6.12^{de}	21.46^{abc}	17.35^{ab}	12.45^{ab}
F_2S_1	11.66^{abc}	21.88^{ab}	18.66^{abc}	17.92^{ab}	5.99^{f}	5.44^{g}	6.15^{de}	23.18^{abc}	17.92^{ab}	13.73ab
F_2S_2	11.92^{abc}	23.58^{ab}	19.07^{abc}	19.61^{ab}	6.84^{cde}	5.66^{f}	6.17^{de}	24.43^{abc}	19.61^{ab}	14.10ab
F_2S_3	11.92^{abc}	23.66^{ab}	19.08^{abc}	19.54^{ab}	6.92^{cd}	6.20^{d}	6.35^{de}	27.25^{abc}	19.54^{ab}	13.76ab
F_2S_4	12.04^{abc}	20.92^{ab}	19.26^{abc}	19.47^{ab}	6.86^{cde}	5.75^{f}	6.53^{cd}	20.49^{bc}	19.47^{ab}	14.58ab
F_3S_1	13.14^{abc}	23.64^{ab}	21.01^{abc}	18.19^{ab}	7.53^{b}	6.08^{e}	6.93^{bc}	21.32^{abc}	18.19^{ab}	12.59ab
F_3S_2	14.53^{ab}	24.80^{a}	23.24^{ab}	19.23^{ab}	8.27^{a}	6.65^{b}	7.03^{b}	23.88^{abc}	19.23^{ab}	13.54ab
F_3S_3	13.84^{abc}	24.32^{a}	22.16^{abc}	19.05^{ab}	7.58^{b}	6.36^{c}	7.85^{a}	23.76^{abc}	19.05^{ab}	12.86ab
F_3S_4	11.85^{abc}	23.00^{ab}	18.97^{abc}	19.71^{ab}	8.63^{a}	7.00^{a}	8.16^{a}	23.48^{abc}	18.71^{ab}	13.46ab
F_4S_1	9.97^{c}	24.07^{a}	15.95^{c}	17.80^{ab}	7.42^{bc}	6.15^{de}	6.82^{bc}	21.58^{abc}	17.80^{ab}	13.93ab
F_4S_2	13.32^{abc}	23.26^{ab}	21.31^{abc}	20.00^{ab}	7.16^{bc}	6.24^{d}	6.29^{de}	22.94^{abc}	20.00^{ab}	13.41ab
F_4S_3	12.74^{abc}	23.27^{ab}	20.38^{abc}	19.69^{ab}	7.64^{b}	6.54^{b}	7.26^{b}	27.68^{ab}	19.69^{ab}	14.39^{ab}
F_4S_4	14.83^{a}	25.33^{a}	23.72^{a}	23.81^{a}	8.52^{a}	6.93^{a}	8.09^{b}	31.64^{a}	23.81^{a}	16.60^{a}

F_1- 125:100:50 (RDF), F_2-75% RDF + *Azotobacter*, F_3-75% RDF + PSB, F_4-75% RDF + *Azotobacter* + PSB; S_1- Control, S_2- $ZnSO_4$ @ 25 kg/ha, S_3- $FeSO_4$ @ 50 kg/ha, S_4- Borax @10 kg/ha; a, b different superscriptions against means denote significant differences (otherwise statistically at par) at P<0.05 by Tukey's Honest significant Difference Test

brinjal stem, leaf and fruits to the tune of 87, 102 and 29 (kg/g dry wt.), respectively. Karuppaiah (2005) stated that foliar application of borax (0.5%) at 35, 50 and 65 DAT was found to be best in terms of no. of flowers per plant, no. of fruits per plant.

Nutrient status of post-harvest soil of brinjal: The organic matter and nutrient status of post harvest soil of brinjal obtained under different INM treatments as recorded. The oxidizable organic carbon content (g kg^{-1}) of post harvest soil of brinjal has been observed to vary within a range of 4.46 (control) to 8.049 (75% RDF+ *Azospirillum* + PSB + Borax @10 kg ha^{-1}). Since chemical NPK could not, any way, contribute to soil organic fraction, it is presumably the bacterial fertilizers which contributed to increased oxidizable organic C pool through greater mineralization of soil organic matter by enhanced microbial population and in such the performance of combined addition of *Azospirillum + PSB* remained most pronounced (Table 4).

Total nitrogen (g kg^{-1}) of post harvest soil of brinjal has been observed to vary within a range of 0.49 (control) to 1.05 (75 % RDF + *Azospirillum* + PSB + Borax @ 10 kg ha^{-1}) (Table 4). The significant increase in total N of post harvest soils receiving NPK and *Azospirillum* remained quite imperative due to further N addition through biological fixation. Ladha *et al.,* (2014) reported that the increase in the nitrogen content of the post-harvest soil sample treated with biofertilizer might be due to the release of more of nitrogenous substance in the soil. Application of micronutrient fertilizers also observed to increase total soil N significantly over the control counterparts for reasons could not be explained through available findings obtained from the present investigation. Available nitrogen kg ha^{-1} have been ranged from

Table 3. Micronutrient accumulation (dry weight recoveries) in brinjal plant.

Treatment	Fe content (g kg^{-1})			Zn content (g kg^{-1})			B content (g kg^{-1})		
	Leaf	Fruit	Shoot	Leaf	Fruit	Shoot	Leaf	Fruit	Shoot
Fertilizers and Bio-fertilizers									
F_1	142.03^{c}	143.57^{c}	152.67^{b}	27.51^{b}	30.40^{c}	29.84^{c}	0.73^{b}	0.37^{a}	0.33^{a}
F_2	210.45^{ab}	166.54^{b}	210.78^{a}	33.32^{a}	32.73^{bc}	32.41^{bc}	0.95^{a}	0.41^{a}	0.34^{a}
F_3	229.52^{a}	188.88^{a}	201.75^{a}	34.25^{a}	35.40^{ab}	34.40^{ab}	0.91^{a}	0.42a	0.35^{a}
F_4	189.26^{b}	197.54^{a}	201.61^{a}	37.33^{a}	38.99^{a}	37.05^{a}	1.04^{a}	0.45^{a}	0.35^{a}
Micronutrients									
S_1	160.37^{b}	153.63^{b}	164.44^{b}	30.30^{b}	28.57c	28.83^{b}	0.83^{b}	0.39^{ab}	0.31^{b}
S_2	183.10^{b}	160.08^{b}	193.75^{ab}	37.71^{a}	38.76^{a}	37.19^{a}	0.91^{ab}	0.40^{ab}	0.33^{b}
S_3	249.00^{a}	219.50^{a}	236.60^{a}	33.06^{ab}	35.27^{ab}	33.60^{a}	0.92^{ab}	0.39^{b}	0.32^{b}
S_4	178.78^{b}	163.32^{b}	172.02^{b}	31.34^{b}	34.92^{b}	34.07^{a}	0.99^{a}	0.47^{a}	0.40^{a}
Interaction (F X S)									
F_1S_1	121.87^{e}	124.67^{g}	125.67^{c}	25.50^{b}	25.43^{e}	25.00^{e}	0.70^{b}	0.34^{a}	0.27^{d}
F_1S_2	144.12^{e}	127.00^{g}	145.33^{abc}	31.43^{ab}	34.16^{abcde}	34.59^{abcde}	0.74^{b}	0.36^{a}	0.36^{abcd}
F_1S_3	157.45^{e}	152.50^{defg}	163.68^{abc}	26.33^{b}	30.13^{cde}	28.58^{cde}	0.77^{b}	0.38^{a}	0.30^{cd}
F_1S_4	144.67^{e}	170.10^{cd}	176.00^{abc}	26.79^{b}	31.88^{bcde}	31.21^{abcde}	0.72^{b}	0.41^{a}	0.37^{abcd}
F_2S_1	145.62e	135.83^{fg}	141.60^{bc}	35.19^{ab}	30.50^{cde}	31.83^{abcde}	0.90^{ab}	0.40^{a}	0.35^{abcd}
F_2S_2	251.82^{abc}	168.50^{cde}	255.83^{ab}	38.93^{ab}	38.83^{abcd}	36.19^{abcd}	0.98^{ab}	0.38^{a}	0.32^{bcd}
F_2S_3	265.68^{a}	224.67^{ab}	265.83^{a}	33.60^{ab}	32.77^{abcde}	29.49^{bcde}	0.93^{ab}	0.38^{a}	0.31^{bcd}
F_2S_4	178.67^{cde}	137.17^{efg}	179.83^{abc}	25.67^{b}	28.83^{de}	32.10^{abcde}	1.00^{ab}	0.46^{a}	0.38^{abc}
F_3S_1	189.55^{bcde}	158.50^{def}	194.00^{abc}	29.33^{ab}	26.50^{e}	27.00^{de}	0.82^{ab}	0.40^{a}	0.32^{bcd}
F_3S_2	165.17^{e}	141.33^{defg}	165.17^{abc}	37.48^{ab}	39.46^{abc}	38.11^{abc}	0.82^{ab}	0.41^{a}	0.31^{bcd}
F_3S_3	316.72^{a}	249.33^{a}	261.70^{ab}	35.74^{ab}	37.81^{abcd}	37.50^{abc}	0.96^{ab}	0.39^{a}	0.36^{abcd}
F_3S_4	246.67^{abcd}	206.33^{b}	186.15^{abc}	34.44^{ab}	37.83^{abcd}	35.00^{abcd}	1.04^{ab}	0.48^{a}	0.41^{ab}
F_4S_1	184.43^{bcde}	195.50^{bc}	196.50^{abc}	31.17^{ab}	31.83^{bcde}	31.50^{abcde}	0.91^{ab}	0.42^{a}	0.32^{bcd}
F_4S_2	171.32^{de}	203.50^{b}	208.67^{abc}	43.10^{a}	42.60^{a}	39.86^{a}	1.08^{ab}	0.44^{a}	0.35^{abcd}
F_4S_3	256.17^{ab}	251.50^{a}	255.18^{ab}	36.58^{ab}	40.37^{abc}	38.84^{ab}	1.00^{ab}	0.40^{a}	0.30^{cd}
F_4S_4	145.13^{e}	139.67^{defg}	146.08^{abc}	38.49^{ab}	41.14^{ab}	37.19^{abc}	1.19^{a}	0.51^{a}	0.45^{a}

F_1- 125:100:50 (RDF), F_2-75% RDF + *Azotobacter*, F_3-75% RDF + PSB, F_4-75% RDF + *Azotobacter* + PSB; S_1- Control, S_2- $ZnSO_4$ @ 25 kg/ha, S_3- $FeSO_4$ @ 50 kg/ha, S_4- Borax @10 kg/ha; a, b different superscriptions against means denote significant differences (otherwise statistically at par) at P<0.05 by Tukey's Honest significant Difference Test

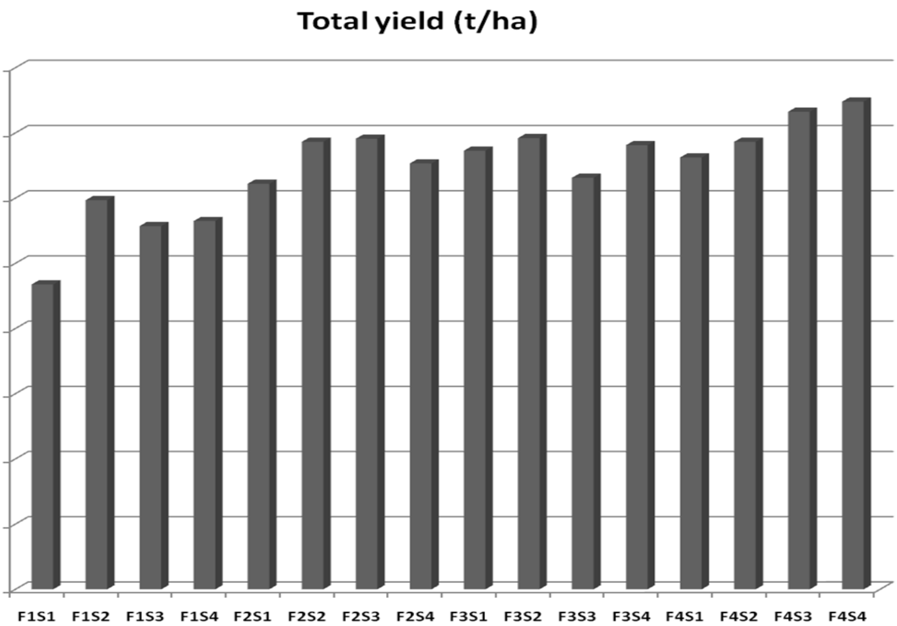

Fig. 1. *Yield of Brinjal observed under different nutrient management protocols.F_1- 125:100:50 (RDF), F_2-75% RDF + Azotobacter, F_3-75% RDF + PSB, F_4-75% RDF + Azotobacter + PSB; S_1- Control, S_2- $ZnSO_4$ @ 25 kg/ha, S_3- $FeSO_4$ @ 50 kg/ha, S_4- Borax @10 kg/ha.*

Table 4. Organic matter and nutrient status of the post-harvest soil of brinjal under varying protocols of integrated nutrient management.

Treatment	Organic C (g/kg)	Total N (g/kg)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Available Fe (kg/ha)	Available Zn (kg/ha)	Available B (kg/ha)
Fertilizers and Bio-fertilizers								
F_1	4.95^{c}	0.66^{b}	180.75^{b}	60.08^{c}	147.77^{a}	22.17^{d}	4.51^{d}	0.50^{c}
F_2	7.05^{b}	0.89^{a}	197.82^{a}	65.09^{b}	157.18^{a}	24.64^{b}	5.58^{c}	0.60^{b}
F_3	6.74^{b}	0.75^{b}	192.14^{ab}	73.17^{a}	152.60^{a}	25.58^{a}	6.50^{b}	0.61^{b}
F_4	7.73^{a}	0.95^{a}	199.79^{a}	68.60^{b}	164.48^{a}	23.94^{c}	6.77^{a}	0.70^{a}
Micronutrients								
S_1	6.34^{a}	0.71^{b}	186.93^{a}	63.22^{b}	151.51^{a}	23.27^{d}	4.77^{c}	0.52c
S_2	6.60^{a}	0.81^{a}	192.48^{a}	68.27^{a}	148.88^{a}	23.50^{c}	6.34^{a}	0.60^{b}
S_3	6.69^{a}	0.82^{a}	195.46^{a}	66.63^{ab}	159.57^{a}	25.44^{a}	6.18^{ab}	0.60^{b}
S_4	6.84^{a}	0.90^{a}	195.63^{a}	68.81^{a}	162.07^{a}	24.13^{b}	6.07^{b}	0.69^{a}
Interaction (F X S)								
F_1S_1	4.46^{d}	0.49^{e}	173.16^{b}	53.79^{c}	129.14^{a}	20.55^{k}	3.03^{g}	0.40^{f}
F_1S_2	4.95^{d}	0.54^{de}	181.66^{ab}	61.21^{bc}	148.10^{a}	22.07^{i}	4.32^{e}	0.52^{de}
F_1S_3	5.13^{cd}	0.73^{bcde}	187.94^{ab}	62.85^{bc}	160.16^{a}	24.10^{g}	5.40^{d}	0.48^{ef}
F_1S_4	5.25^{bcd}	0.88^{abc}	180.24^{b}	62.45^{bc}	153.67^{a}	21.95^{i}	5.30^{d}	0.60^{cd}
F_2S_1	6.76^{ab}	0.82^{abcd}	198.66^{ab}	65.62^{abc}	168.23^{a}	24.36^{f}	3.72^{f}	0.53^{de}
F_2S_2	7.05^{a}	0.87^{abc}	190.70^{ab}	67.49^{ab}	149.00^{a}	24.63^{e}	6.83^{b}	0.57^{de}
F_2S_3	7.13^{a}	0.91^{abc}	201.23^{ab}	61.76^{bc}	150.08^{a}	25.24^{c}	5.45^{d}	0.62^{bcd}
F_2S_4	7.24^{a}	0.94^{abc}	200.71^{ab}	65.50^{abc}	161.41^{a}	24.34^{f}	6.30^{c}	0.68^{abc}
F_3S_1	6.63^{abc}	0.68^{cde}	188.00^{ab}	71.44^{ab}	150.66^{a}	24.84^{d}	5.74^{d}	0.55^{de}
F_3S_2	6.70^{ab}	0.84^{abc}	198.15^{ab}	72.68^{ab}	149.88^{a}	26.14^{b}	6.60^{bc}	0.57^{de}
F_3S_3	6.83^{a}	0.75^{bcde}	193.53^{ab}	72.35^{ab}	154.26^{a}	26.08^{b}	7.41^{a}	0.60^{cd}
F_3S_4	6.81^{a}	0.73^{bcde}	188.91^{ab}	76.20^{a}	155.61^{a}	25.28^{c}	6.26^{c}	0.71^{ab}
F_4S_1	7.51^{a}	0.83^{abc}	187.91^{ab}	62.06^{bc}	158.00^{a}	23.31^{h}	6.59^{bc}	0.60^{cd}
F_4S_2	7.68^{a}	1.01^{ab}	199.43^{ab}	71.69^{ab}	148.54^{a}	21.15^{j}	7.62^{a}	0.74^{a}
F_4S_3	7.67^{a}	0.90^{abc}	199.15^{ab}	69.55^{ab}	173.80^{a}	26.34^{a}	6.45^{bc}	0.69^{abc}
F_4S_4	8.04^{a}	1.05^{a}	212.67^{a}	71.08^{ab}	177.59^{a}	24.94^{d}	6.43^{bc}	0.78^{a}

F_1- 125:100:50 (RDF), F_2-75% RDF + *Azotobacter*, F_3-75% RDF + PSB, F_4-75% RDF + *Azotobacter* + PSB; S_1- Control, S_2- $ZnSO_4$ @ 25 kg/ha, S_3- $FeSO_4$ @ 50 kg/ha, S_4- Borax @10 kg/ha; a, b different superscriptions against means denote significant differences (otherwise statistically at par) at P<0.05 by Tukey's Honest significant Difference Test

173.16 (control) to 212.67 (75% RDF + *Azospirillum* + PSB + Borax @10 kg ha^{-1}). The significant increase in total N of post harvest soils receiving NPK and *Azospirillum* remained quite imperative due to further N addition through biological fixation (Table 4).

Available P content (kg ha^{-1}) of post harvest soil of brinjal has been observed to vary within a range of 53.79 (control) to 76.20 (75% RDF + *Azospirillum* + PSB + Borax @ 10 kg ha^{-1}) (Table 4).The maximum recoveries of available P has been found to be associated with brinjal seedling inoculation through PSB which might be contributed to available P pool of the soil through enhanced microbe-mediated dissolution of not -so-available soil P fractions (non-exchangeable, adsorbed etc.). It has been earlier noted by several workers that it was also observed that the biological fertilizer application releases certain chemical compounds which in turn increases the phosphorus solubility (Yousefi *et al.,* 2011)

Available potassium (kg ha^{-1}) of the post harvest soil of brinjal has been observed to vary within a range of 129.04 (control) to 177.59 (75 % RDF + *Azospirillum* + PSB + Borax @ 10 kg ha^{-1}) (Table 4). The availabilities of P and K were found higher with bacterial fertilizers (N-fixers), since the build-up of available P and K in the soil could be due to the organic acids which were released during microbial decomposition of native soil organic fractions increasing the available P and K in soil (Choudhury *et al*., 2005). Available iron (kg ha^{-1}) in the post harvest soil of brinjal ranged from 20.55 (control) to 26.14 (75% RDF + *Azospirillum* + PSB + $FeSO_4$ @ 50 kg ha^{-1}). The maximum recoveries of available Fe has been found to be associated with application of iron fertilizers ($FeSO_4$ @ 50 kg ha^{-1}) along with NPK and bacterial fertilizers. Such increases [% over control (RDF)] have also been supported by Fe-fertilizer application over NPK + Bacterial fertilizers (Table 4). Available zinc content (kg ha^{-1}) of the post harvest soil of brinjal ranged from 3.03 (control) to 7.62 (75% RDF + *Azospirillum* + PSB + $ZnSO_4$ @ 25 kg ha^{-1}). The maximum recoveries of available Zn has been found to be associated with application of iron fertilizers ($ZnSO_4$ @ 25 kg ha^{-1}) along with NPK and bacterial fertilizers. Such increases [% over control (RDF)] have also been supported by Zn-fertilizer application over NPK + bacterial fertilizers (Table 4). Available boron content (kg ha^{-1}) of the post harvest soil of brinjal ranged from 0.40 (control) to 0.78 (75% RDF + *Azospirillum* + PSB + Borax @ 10 kg ha^{-1}). The maximum recoveries of available B has been found to be associated with application of boron fertilizers (Borax @ 10 kg/ha) along with NPK and bacterial fertilizers. Such increases [% over control (RDF)] have also been supported by borax application over NPK + Bacterial fertilizers (Table 4).

The yield of brinjal cultivated with interventions of the selected nutrient management practices are shown in Fig. 1. Brinjal yields supported by different INM protocols ranged from 9.35 (control) to 14.96 t ha^{-1} (75% recommended dose of fertilizer NPK (RDF *i.e.* N:P:K:: 125:100:50) + *Azospirillum* + PSB + Boron @ 10 Kg ha^{-1})(Fig 1). Results revealed that integrated management of nutrients through supplementation of chemical fertilizers with bacterial fertilizers along with micronutrient fertilizers brought significant enhancement in Brinjal fruit yields over the control counterparts (RDF only). Managing the nutrient requirement of Brinjal through a combined application of 75% RDF + *Azospirilum* + PSB + Boron @10kg ha^{-1} recorded the highest yield followed by the treatment combination of 75% RDF + *Azospirillum* + PSB + $FeSO_4$ @50 Kg ha^{-1}. Maximum increments in Brinjal yields obtained remained to the tune of 60 % over control. Such results are in good agreement with Yadav *et al.* (2006).

Conclusion

It is concluded that the treatment consisting of 75% RDF (RDF *i.e.* N:P:K:: 125:100:50) + *Azospirillum* + PSB + Borax @ 10 kg ha^{-1} recorded the highest brinjal yield, oxidisable organic carbon (8.049 g kg^{-1}), total nitrogen (1.05 g kg^{-1}) , available nitrogen (212.67g kg^{-1}), available phosphorus (76.20g kg^{-1}) and available potassium(177.59 g kg^{-1}) in the post harvest soils of brinjal. Integrated management of nutrients through supplementation of chemical fertilizers by bacterial fertilizers along with micronutrients inputs was found to significantly increase available micro-nutrient status of the post harvest soil.

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