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Research Paper

Influence of different organic and inorganic sources of nutrients on maize (*Zea mays*)

ANIKET KALHAPURE[1], BALASAHEB SHETE[2], MADHUKAR DHONDE[3] AND PRASHANT BODAKE[4]

Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra 413 722

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ABSTRACT

A field experiment was conducted at Breeder Seed Production farm of Mahatma Phule Krishi Vidyapeeth, Rahuri, during the rainy (*kharif*) seasons of 2011 and 2012, to find out most efficient and economic combination of different organic and inorganic sources of nutrients to increase the productivity of hybrid maize (*Zea mays* L.) without deteriorating the soil qualities. Integrated application of 25% recommended dose of fertilizers (RDF) with biofertilizers (*Azotobacter chroococcum* + phosphate-solubilizing bacteria), green-manuring with sunhemp (*Crotalaria juncea* L.) and incorporation of compost @ 10 tonnes/ha improved soil physico-chemical properties, *viz.* pH, bulk density and infiltration rate, and the nutrient status of soil in respect of organic carbon, available N and available P. Maize grain yield was increased by 252.38% over the control and 147.62% over application of 100% RDF with combined use of organic and inorganic fertilizers, which was 7.4 tonnes/ha with highest gross returns (₹95.9 × 10^3/ha) and net returns (₹54.2 × 10^3/ha). Maximum benefit: cost ratio (1.30) was also observed in combined use of 25% RDF, compost, biofertilizers and green manuring and it was followed by application of 100% RDF (1.26), which was responsible for deterioration of nutrient status of soil.

Key words: Biofertilizer, Crop Production, Compost, Green manuring, Inorganic fertilizers, Maize, Nutrient management, Physico-chemical properties, Productivity

Maize has better yield response to fertilizers due to which a trend of application of heavy doses of chemical fertilizers to crop is observed. Though these chemical sources of nutrients helps temporary increase in crop production; deterioration of natural resources (*viz.* land, water and air) is also the another side of such high-input intensive cultivation. Over reliance on use of chemical fertilizers has been associated with declines in soil physical and chemical properties and crop yield (Hepperly *et al.*, 2009). On the other hand, though organic sources of nutrients supplies different macro-and micro-nutrients to crop, the optimum yield level of maize production can not be achieved by using only organic manures because of their low nutrient content. Efficacy of organic sources to meet the nutrient requirement of crop is not as assured as mineral fertilizers, but the integrated use of chemical fertilizers along with various organic sources is capable to improve soil quality and higher crop productivity on long-term basis. Highest productivity of crops in a sustainable manner without deteriorating the soil and other natural resources could be achieved only by applying appropriate combination of different organic manures and inorganic fertilizers (Chandrashekara *et al.*, 2000). It is important to identify the best type of available organic resources which can be used as fertilizers and their best combination with appropriate proportion of inorganic fertilizers. Hence, present investigation was conducted to find out best combination of organic and inorganic fertilizers for maximum production of maize with higher income level in sustainable manner without affecting the soil qualities.

MATERIALS AND METHODS

A field experiment in randomized block design, consisting of 11 treatments with three replications, was conducted at the Breeder Seed Production Farm of Mahatma Phule Krishi Vidyapeeth, Rahuri (19^0 47’ N and 74^0 81’ E with average annual rainfall of 520 mm) during the rainy seasons of 2011 and 2012. The soil was deep with silty clay loam, slightly alkaline pH (8.2), medium in organic carbon (0.55%), available P (19.5 kg/ha), K (261.5 kg/ha) and low in available N (235.0 kg/ha). The bulk density and infiltration rate of soil were 1.38 Mg/m^3 and 3.09 cm/hr respec-

[1]**Corresponding author Email:** aniketmpkv@gmail.com
[1]Junior Research Assistant of Agronomy; [2]Assistant Professor of Agronomy; [3]Professor of Agronomy; [4]Associate Professor of Agronomy, Seed Cell, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra 413 722

tively. Maize hybrid 'Rajershi' was sown on 6 July and 14 July in 2011 and 2012 respectively, on flat bed at the spacing of 60 cm × 20 cm with seed rate of 15 kg/ha. Different treatments of application of inorganic sources of nutrients (*viz*. recommended dose of fertilizers (RDF) and 25% RDF) and organic sources of nutrients (*viz*. application of compost, biofertilizers, sunhemp green manuring) and their combinations with each other were arranged (Table 1). The RDF used in treatment was 120–60–60 kg NPK/ha out of which whole P and K were applied at the time of sowing and N was applied in 3 split doses as 20% at the time of sowing, 40% at 30 days after sowing (DAS) and remaining 40% at the time of tassaling (i.e. at 60 DAS). In the plots where the treatment of compost application was arranged, well-decomposed compost which was prepared with cattle dung and farm residues was applied @ 10 tonnes/ha before sowing the crop and its composition was 0.52% N, 0.18% P and 0.53% K. In the treatments where 25% RDF was used, 30–15–15 kg NPK/ha was applied 50% N and whole P and K at the time of sowing and remaining 50% N was applied one month after sowing. Biofertilizer inoculants of *Azotobacter chroococcum* and phosphate-solubilizing bacteria (*Bacillus megaterium*) were used @ 250g/10 kg of maize seed as seed treatment before sowing. For the application of green manuring, sunhemp seed was sown with seed rate of 30 kg/ha at the row spacing of 60 cm by bullock-drawn seed drill before sowing of maize, but at the same day. Then maize seed was sown in these plots in between the rows of sunhemp. Sunhemp crop was then incorporated into soil by bullock-drawn plough without damaging the maize crop at 40 days after sowing, when the N, P and K content of green-manuring crop was 2.30, 0.26 and 1.60% respectively, on air-dry basis and total dry matter added at this stage by sunhemp was 3.88 tonnes/ha. Plant-protection measures and irrigations as and when required were provided in same manner for all the treatments. Regular biometric observations were recorded at specific time intervals by selecting randomly 5 plants in each treatment. After harvesting the maize crop of first year the experimental field was kept fallow for both winter (*rabi*) and summer seasons and in next rainy (*kharif*) season the experiment was continued for second year. Crop was harvested on 13 November and 21 November in 2011 and 2012 respectively, and yield observations were recorded from net plots. Five random soil samples from each plot were taken and examined for physico-chemical properties and nutrient status of soil after completing 2 cycles of maize crop.

RESULTS AND DISCUSSION

Physico-chemical properties of soil

Various treatments were found effective in changing the different physico-chemical properties of soil after completing 2 cycles of maize crop (Table 1). Significantly lowest pH was observed in treatments which included either combined application of biofertilizers, green-manuring and compost or their integration with inorganic nutrient sources. When manures and chemical fertilizers are applied to soil, nitrification and decomposition processes produce various acids. Nitrification process releases H^+ into soil solution. The organic matter added with green-manuring and compost application acts as a pH buffer, releasing H^+ which are responsible for reducing alkalinity of the soil (Antil and Singh, 2007). Application of *Azotobacter* and phosphate-solubilizing bacteria as biofertilizers are also responsible for decreasing soil pH with producing organic acids which was earlier reported by Mohammadi and Sohrabi (2012).

The lower values of bulk density and higher values of infiltration rate were observed in the treatments where green-manuring and compost were applied as organic fertilizers as compaired to control and application of 100% RDF and 25% RDF. Application of biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost and their combination with 25% RDF resulted in lowest bulk density and highest infiltration rate after harvesting the maize crop. The main reason of lower bulk density was aggregation of soil particle due to increasing organic matter as well as stability of aggregates, which lead to increase the total pore space in soil. Islam *et al.* (2012) also concluded that addition of organic matter through organic fertilizers decreases the bulk density of soil. Higher bulk density was observed in application of 100% RDF, 25 % RDF and control treatment. The soils of the treatments in which biofertilizer, green-manuring with sunhemp and compost were applied in combination recorded higher infiltration rate, might be owing to the better soil particle aggregation, microbial respiration, increased pore space and decreased soil bulk density. Similar results regarding the decrease of bulk density and increase in infiltration rate as the effect of addition of organic and inorganic fertilizers in soil were reported by Martens and Frankenberger (1992).

Nutrient uptake by maize, soil nutrient status after harvest and nutrient balance

There was significant effect of different sources of nutrients over the control on the nutrient uptake of maize (Table 1). Highest uptake of N, P and K was observed with application of 25% RDF + biofertilizers (*Azotobacter* + PSB) + green manuring with sunhemp + compost. In case of N uptake, application of biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost, 25% RDF + compost, 100% RDF and 25% RDF + green-manuring with sunhemp were found to be at par with each other. The uptake of N, P and K was found higher to the tune of 70, 293.6 and 123.4%, where 25% RDF + biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost were applied over the control. This might be owing to the combined effect of rapid release of nutrients by decomposition of green-manuring crop and compost and also owing because of the increased availability of N and P which added in the soil through organic and inorganic resources by *Azotobacter* and phosphate-solubilizing bacteria. Satish *et al.* (2011) also reported the similar findings.

Significantly higher values of organic carbon percentage, available N, P and K content in soil after completing two cycles of maize crop were recorded in treatment having 25% RDF + biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost (Table 1). Green-manures and compost are the rich sources of organic carbon, nitrogen, phosphorus, potassium and some other micronutrients also. *Azotobacter chroococcum* fixes the environmental nitrogen asymbiotically and phosphate-solubilizing bacteria (*Bacillus megaterium*) are responsible for solubilization of phosphorus fixed in soil and made it available for absorption by plant roots in elemental form. These all the sources of organic fertilizers were found to be effective for addition of the various nutrients into soil in available form. The per cent availability of organic carbon, N, P and K under 25% RDF + biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost was higher to the tune of 23.4, 134.9, 242.9 and 113.7% over the control respectively. The lowest availability of these nutrients was observed in the control. The similar effects of different organic and inorganic sources of nutrients on the nutrient status of soil after harvest of the crop were revealed by Tetarwal *et al.* (2011) in rainfed maize.

The negative values of actual gain/loss of nutrients in Table 2 of nutrient balance data indicate that, all treatments were responsible for mining of N from soil, except integrated application of 25% RDF with biofertilizers, green-manuring with sunhemp and compost, which added 4.4 kg/ha N into soil over initial status. It was also found that, treatments 100% RDF, application of only compost and its combination with 25% RDF, biofertilizers and green-manuring were added P into soil, while in case of K, all the treatments were responsible for nutrient mining.

Table 1. Effect of different treatments on soil physico- chemical properties, nutrient uptake by maize and soil-nutrient status after harvest

Treatment	Physico-chemical properties of soil (after completing 2 cycles of maize crop)			Nutrient uptake by maize(pooled data of 2 years)			Nutrient status in soil (after completing 2 cycles of maize crop)			
	pH	Bulk density (Mg/m^3)	Infiltration rate (cm/hr)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Organic carbon %	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
100% RDF	8.1	1.37	3.17	164.2	19.3	132.9	0.48	111.3	22.7	144.5
25% RDF	8.2	1.37	3.17	146.9	9.8	88.3	0.48	118.7	10.6	165.4
Compost	7.9	1.35	3.58	158.0	15.5	115.7	0.57	139.8	23.3	197.1
Green-manuring with sunhemp	8.0	1.36	3.54	147.6	8.6	87.8	0.56	131.6	10.6	142.4
Biofertilizers (*Azotobacter* + PSB)	7.9	1.37	3.27	145.4	9.5	124.6	0.51	121.4	13.5	158.5
25% RDF + biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost	7.8	1.34	3.74	192.8	24.4	181.4	0.58	239.4	31.2	234.6
25% RDF + compost	7.9	1.35	3.58	171.7	13.9	120.4	0.57	155.8	20.6	206.8
25% RDF + green-manuring with sunhemp	7.9	1.36	3.55	164.1	11.1	96.4	0.56	152.1	11.0	140.9
25% RDF + Biofertilizers *Azotobacter* + PSB)	7.9	1.37	3.29	151.3	16.6	124.6	0.51	147.2	14.9	156.9
Biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost	7.8	1.34	3.74	172.0	21.6	162.1	0.58	219.6	26.9	188.3
Control	8.2	1.37	3.10	113.4	6.2	81.2	0.47	101.9	9.1	114.0
SEm±	0.05	0.01	0.14	2.9	0.6	2.1	0.03	2.43	0.4	2.73
CD (P=0.05)	0.15	0.03	0.42	8.8	1.8	6.3	0.09	7.3	1.1	8.2

RDF, Recommended dose of fertilizer; PSB, Phosphate-solubilizing bacteria

Table 2. Nutrient balance data (kg/ha) after completing 2 cycles of maize crop

Treatment	Initial soil nutrient status (a)			Nutrients added by treatment (b)			Nutrient uptake by maize (c)			Soil nutrient status after harvest (d)			Actual gain/loss of nutrients in soil over initial status (d-a)		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
100% RDF	235.0	19.5	261.5	120.0	60.0	60.0	164.2	19.3	132.9	111.3	22.7	144.5	–123.7	3.2	–117
25% RDF	235.0	19.5	261.5	30.0	15.0	15.0	146.9	9.8	88.3	118.7	10.6	165.4	–116.3	–8.9	–96.1
Compost	235.0	19.5	261.5	52.0	18.0	53.0	158.0	15.5	115.7	139.8	23.3	197.1	–95.2	3.8	–64.4
Green-manuring with sunhemp	235.0	19.5	261.5	89.2	10.0	62.1	147.6	8.6	87.8	131.6	10.6	142.4	–103.4	–8.9	–119.1
Biofertilizers (*Azotobacter* + PSB)	235.0	19.5	261.5	0.0	0.0	0.0	145.4	9.5	124.6	121.4	13.5	158.5	–113.6	–6	–103
25% RDF + biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost	235.0	19.5	261.5	171.2	43.0	130.1	192.8	24.4	181.4	239.4	31.2	234.6	4.4	11.7	–26.9
25% RDF + compost	235.0	19.5	261.5	82.0	33.0	68.0	171.7	13.9	120.4	155.8	20.6	206.8	–79.2	1.1	–54.7
25% RDF + green-manuring with sunhemp	235.0	19.5	261.5	119.2	25.0	77.1	164.1	11.1	96.4	152.1	11	140.9	–82.9	–8.5	–120.6
25% RDF + Biofertilizers (*Azotobacter* + PSB)	235.0	19.5	261.5	30.0	15.0	15.0	151.3	16.6	124.6	147.2	14.9	156.9	–87.8	–4.6	–104.6
Biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost	235.0	19.5	261.5	141.2	28.0	115.1	172.0	21.6	162.1	219.6	26.9	188.3	–15.4	7.4	–73.2
Control	235.0	19.5	261.5	0.0	0.0	0.0	113.4	6.2	81.2	101.9	9.1	114	–133.1	–10.4	–147.5
SEm±	–	–	–	–	–	–	2.9	0.6	2.1	2.43	0.4	2.73	–	–	–
CD (P=0.05)	–	–	–	–	–	–	8.8	1.8	6.3	7.3	1.1	8.2	–	–	–

RDF, Recommended dose of fertilizer; PSB, Phosphate-solubilizing bacteria

Growth and yield-attributing characters

All the growth and yield-attributing characters were affected by different treatments (Table 3). Significantly taller plants and highest total plant dry matter were recorded in treatment of 25% RDF + biofertilizers (*Azotobacter* + PSB) + green manuring with sunhemp + compost. However the treatments–application of 100% RDF and biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost were found to be on a par with each other in respect of these growth-attributing characters. Treatment 25% RDF + biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost also produced highest number of cobs/plant, grains/cob and weight of 1,000-grains over rest of the treatments; however, it was on a par with application of biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost for cobs/plant, which was at par with application of 100% RDF. Treatments 25% RDF + biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost, application of biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost, 25% RDF and 100% RDF were on par with each other for grains/cob. This might be owing to the maize crop better responded to improved soil pH, bulk density and infiltration rate and optimum availability of major nutrients. Sujatha *et al.* (2008) also reported similar positive effects of combination of sunhemp green manuring, use of biofertilizers and compost with inorganic fertilizers on growth and yield-attributing characters of rainfed maize.

Grain and stover yields

All the treatments significantly affected the grain and stover yields of maize (Table 3). Application of 25% RDF + biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost resulted in the highest grain and stover yield being was 252.4 and 77.46% more over the control treatment. Application of biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost was found to be the next superior treatment, while treatment control resulted in the lowest grain and stover yields. The yield advantage observed in combination of inorganic fertilizers with application of biofertilizers, green-manuring and compost might be due to the increased growth and yield-

Table 3. Effect of different treatments on growth and yield-attributing characters (at harvest), grain and stover yield and economics of maize (pooled data of 2 years)

Treatment	Plant height (cm)	Total dry matter (g/plant)	Cobs/ plant	Grains/ cob	1,000-grain weight (g)	Grain yield (tonnes/ ha)	Stover yield (tonnes/ ha)	Cost of cultivation (×10³ ₹/ha)	Net returns (×10³ ₹/ha)	Benefit: cost ratio
100% RDF	162.5	224.2	1.4	220.2	204.3	5.2	10.4	30.5	38.4	1.26
25% RDF	136.7	170.4	0.9	185.1	207.8	3.0	8.0	24.2	17.6	0.73
Compost	152.2	177.9	1.1	189.9	239.4	4.2	8.9	34.2	22.0	0.64
Green-manuring with sunhemp	149.3	178.6	1.1	164.8	205.2	3.0	8.4	27.6	14.6	0.53
Biofertilizers (*Azotobacter* + PSB)	147.1	170.1	0.9	162.3	205.9	2.5	7.9	22.3	13.7	0.61
25% RDF + biofertilizers (*Azotobacter* + PSB) + green manuring with sunhemp + compost	172.6	256.6	1.6	223.5	249.0	7.4	12.6	41.7	54.2	1.30
25% RDF + compost	155.9	187.2	1.3	217.5	235.1	5.8	9.8	36.2	38.9	1.07
25% RDF + green manuring with sunhemp	151.8	182.1	1.2	182.7	234.7	4.3	8.2	29.6	27.0	0.91
25% RDF + Biofertilizers (*Azotobacter* + PSB)	149.5	180.0	1.1	160.8	206.7	3.1	8.4	24.3	19.0	0.78
Biofertilizers (*Azotobacter* + PSB) + green manuring with sunhemp + compost	164.6	232.9	1.5	221.3	239.2	6.7	10.7	39.7	46.4	1.17
Control	123.8	153.3	0.8	155.8	198.8	2.1	7.1	22.2	8.5	0.38
SEm±	1.9	3.2	0.06	3.66	1.5	0.07	0.09	–	0.68	–
CD (P=0.05)	5.8	9.5	0.18	10.9	4.4	0.22	0.27	–	2.04	–

RDF, Recommended dose of fertilizer; PSB, Phosphate-solubilizing bacteria

attributing characters in maize. Shanwad *et al*. (2010) also reported the enhancement in maize productivity with combined application of nutrients through organic and inorganic resources.

Economics

Highest gross returns, net returns and benefit: cost ratio were found in application of 25% RDF+ biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost, which were 212.38, 537.6 and 242.1% more than that of control treatment respectively. Treatment application of biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost was at second place in respect of gross and net returns with producing ₹86.1 × 10^3/ha and ₹46.4 × 10^3/ha respectively. With considering benefit: cost ratio, application of 100% RDF is the second best treatment (1.26). Lowest gross returns, net returns and benefit: cost ratio were recorded in control. These results are in close conformity with the findings reported by Sujatha *et al.* (2008).

It can be concluded that, application of 25% RDF + biofertilizers (*Azotobacter* + PSB) + green-manuring with sunhemp + compost is the best combination of organic and inorganic fertilizers for increasing hybrid maize productivity with maximum benefit: cost ratio. This treatment is also helpful to improving soil physico-chemical properties without deteriorating the nutrient status of soil.

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