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Integrated Nutrient Management in Maize (*Zea Mays* L.) for Increasing Production with Sustainability

A.H. Kalhapure[1], B.T. Shete[2] and M.B. Dhonde[3]

[1,2,3]Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ditrict- Ahmednagar, Maharashtra–413 722, India.

Abstract

Field experiment was conducted at Breeder Seed Production farm of Mahatma Phule Krishi Vidyapeeth, Rahuri for two consecutive kharif seasons of years 2010 and 2011 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. Application of 25% recommended dose of fertilizers (RDF) in combination with biofertilizers (Azotobacter chroococcum+ phosphate solubilizing bacteria), green manuring with sunhemp and incorporation of compost @10 t/ha improves soil physico- chemical properties (viz. decrease in alkaline pH by 0.4, bulk density by 0.04 g/cm^3 and increase in infiltration rate by 0.65 cm/hr). This was also responsible for improving the nutrient status of soil in respect of organic carbon, available N and available P_2O_5 which were increased by 0.14%, 4.4 kg/ha and 11.7 kg/ha, respectively over the initial nutrient status of soil. Maize grain yield was increased by 252.38% over control and 147.62% over application of 100% RDF with combined use of organic and inorganic fertilizers which was 7.4 t/ha with highest gross return (`95.9x10$^3$/ha) and net return (`54.2x10^3/ha). Maximum B:C ratio (1.30) was also observed in jointly 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.

Keywords: Biofertilizer, Compost, Green manuring, Inorganic fertilizers, Maize, Nutrient management, Physico- chemical properties, Productivity.

1. Introduction

Maize (*Zea mays* L.) has becoming very popular cereal crop in India because of the increasing market price and high production potential of hybrid varieties in both irrigated as well as rainfed conditions. More ever in irrigated areas farmers produce the income equal to the cash crops such as sugarcane, onion, cotton, etc. in comparatively short time period of 120-130 days by cultivating hybrid maize varieties. Hence the trend of replacing some cash crops with maize in intensive cultivation is observed in present condition.

For increasing the profitability of maize in only economic view, farmers are cultivating the crop intensively with the huge use of chemical fertilizers, pesticides, weedicides, etc. Maize crop has better yield response to chemical or inorganic fertilizers. Hence heavy doses of these fertilizers are applied to maize. Though these practices are helps to increase the temporary increase the production of crop; 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) and significant land problems, such as soil degradation due to over exploitation of land and soil pollution caused by high application rates of fertilizers and pesticide application (Singh, 2000).

The organic sources besides supplying N, P and K also make unavailable sources of elemental nitrogen, bound phosphates, micronutrients, and decomposed plant residues into an available form to facilitate to plant to absorb the nutrients. But, it is also the fact that optimum yield level of maize production can't 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 joint use of chemical fertilizers along with various organic sources is capable of improving soil quality and higher crop productivity on long- term basis. Highest productivity of crops in 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. Keeping this point in view, 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.

2. Materials and Methods

A field experiment in randomized block design which consists of 11 treatments with three replications was conducted at the Breeder Seed Production Farm of Mahatma Phule Krishi Vidyapeeth, Rahuri during two consecutive *kharif* seasons of year 2010 and 2011. The experimental site was located at 19^0 47' N latitudes and 74^0 81' E

longitudes with average annual rainfall of 520 mm. The soil of experimental field was deep with silty clay loam in texture, slightly alkaline pH (8.2), medium in organic carbon (0.55%), available P_2O_5 (19.5kg/ha), K_2O (261.5kg/ha) and low in available N (235.0kg/ha). Maize hybrid 'Rajershi' was sown at first fortnight of July for both years on flat bed at the spacing of 60cm x 20cm 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, biofertilizer, sunhemp green manuring) and their combinations with each other were arranged (Table- 1). RDF used in treatment was 120 kg N+ 60 kg P_2O_5+ 60 kg K_2O/ha out of which whole P_2O_5 and K_2O were applied at the time of sowing and N was applied in three split doses as- 20% at the time of sowing, 40% at 30 DAS and remaining 40% at the time of tassaling (i.e. at 60 DAS). Well decomposed compost which was prepared with cattle dung and farm residues was applied at the rate of 10 t/ha before sowing the crop. In the treatments where 25% RDF was used, 30 kg N+ 15 kg P_2O_5+ 15 kg K_2O/ha was applied as- 50% N and whole P_2O_5 and K_2O at the time of sowing and remaining 50% N was applied one month after sowing. Biofertilizers 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 (*Crotalaria juncea*) 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. Plant protection measures and irrigations whenever required were provided in same manner for all the treatments. Regular biometric observations were recorded at specific time intervals by selecting randomly five plants in each treatment. Crop was harvested at 130 days after sowing for both the years and yield observations were recorded from net plots. Randomly five soil samples from each plot were taken and examined for physico- chemical properties and nutrient status of soil after harvest of maize crop. The trend of observations was same for both the years, hence data was subjected to pooled analysis for interpreting the results.

3. Results and Discussion

3.1 Effect on physico- chemical properties of soil

Various treatments found to be effective for changing the different physico- chemical properties of soil (Table 1). Significantly lowest pH was observed in application of 25% RDF+ biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost. Also the decrease in pH over initial value is more in treatments which included either sole application of biofertilizers, green manuring and compost or their combination 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 has been earlier reported by Mohammadi and Sohrabi (2012).

Table 1: Effect of different treatments on physico- chemical properties of soil after harvest of maize and comparison between initial and after harvest status of these properties (pooled)

Treatment	pH (pHa)	Bulk density (g/cm3) (BDa)	Infiltration rate (cm/hr) (IRa)	Increase or decrease of soil property status as the effect of treatment (after harvest)		
				pH (pHa- pHb*)	Bulk density (g/cm3) (BDa- BDb*)	Infiltration rate (cm/hr) (IRa- IRb*)
T1: 100% RDF	8.1	1.33	3.17	-0.1	-0.01	0.08
T2: 25% RDF	8.2	1.33	3.17	0.0	-0.01	0.08
T3: compost	7.8	1.31	3.58	-0.4	-0.03	0.49
T4: green manuring with sunhemp	7.9	1.32	3.54	-0.3	-0.02	0.45
T5: Biofertilizers (Azotobacter+ PSB)	7.8	1.33	3.27	-0.4	-0.01	0.18
T6: 25% RDF+ biofertilizers (Azotobacter+ PSB)+ green manuring with sunhemp+ compost	7.8	1.30	3.74	-0.4	-0.04	0.65
T7: 25% RDF+ compost	7.8	1.31	3.58	-0.4	-0.03	0.49
T8: 25% RDF+ green manuring with sunhemp	7.9	1.32	3.55	-0.3	-0.02	0.46
T9: 25% RDF+ Biofertilizers (Azotobacter+ PSB)	7.8	1.33	3.29	-0.4	-0.01	0.20

T10: biofertilizers (Azotobacter+ PSB)+ green manuring with sunhemp+ compost	7.8	1.30	3.74	-0.4	-0.04	0.65
T11: control	8.2	1.33	3.10	0.0	-0.01	0.01
SEm±	0.05	0.01	0.14	--	--	--
CD (P=0.05)	0.15	0.03	0.42	--	--	--

pH_b^* = Initial soil pH = 8.2, BD_b^* = Initial bulk density of soil= 1.34 gm/cm^3, IR_b^* = Initial Infiltration rate of soil= 3.09 cm/hr.

The lower values of bulk density and higher values of infiltration rate were observed in the treatments where green manuring and compost are applied as organic fertilizers. Application of 25% RDF+ biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost resulted in lowest bulk density (1.30g/cm^3) and highest infiltration rate (3.74cm/hr) after harvesting the maize crop. This treatment also recorded maximum values of decrease in bulk density and increase in infiltration rate, respectively over the initial values of these parameters. The main reason of decreasing bulk density was aggregation of soil particle due to increasing organic matter as well as stability of aggregates which leads to increase the total pore space in soil. Islam *et al.* (2012) has been also concluded that addition of organic matter through organic fertilizers decreases the bulk density of soil. Higher bulk density (1.33g/cm^3) was observed in application of 100% RDF, 25 % RDF and control treatment.

The infiltration rate of soil is depends upon the arrangement of soil particles, porosity and stability of soil aggregates. Also there is inverse relation in bulk density and infiltration rate of soil. The soils of the treatments in which biofertilizer, green manuring with sunhemp and compost were applied in combination recorded higher infiltration rate which might be due to the better soil particle aggregation, microbial respiration, increase 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) and Rasoulzadeh and Yaghoubi (2010) in no cropped field.

3.2 Effect on nutrient uptake by maize

The statistical data in Table- 2 reveals that there was significant effect of various sources of nutrients over control on the nutrient uptake of maize. Highest uptake of N, P_2O_5 and K_2O was observed in application of 25% RDF+ biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost. In case of N uptake treatments 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 on par with each other. The uptake of N, P_2O_5 and K_2O was

found higher to the tune of 70, 293.6 and 123.4 percent in application of 25% RDF+ biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost over control. This might be due to the combined effect of rapid release of nutrients by decomposition of green manuring crop and compost and also due to the increased availability of N and P_2O_5 which added in the soil through organic and inorganic resources by *Azotobacter* and phosphate solubilizing bacteria. Satish *et al.* (2011) has been also reported that the combination of organic and inorganic fertilizer showed higher uptake values of all the three nutrients, which is in close conformity with the results obtained in present investigation.

Table 2: Effect of different treatments on nutrient uptake of maize, soil nutrient status and comparison between initial and after harvest status of these soil nutrients (pooled data)

Treatment	Nutrient uptake by maize			Organic carbon % (OCa)	Available N (kg/ha) (Na)	Available P2O5 (kg/ha) (Pa)	Available K2O (kg/ha) (Ka)	Gain of nutrients in soil as the effect of treatment (after harvest)			
	N	P2O5	K2O					Organic carbon % (OCa-OCb*)	Available N (kg/ha) (Na-Nb*)	Available P2O5 (kg/ha) (Pa-Pb*)	Available K2O (kg/ha) (Ka-Kb*)
T1	164.2	19.3	132.9	0.38	111.3	22.7	144.5	-0.17	-123.7	3.2	-117.0
T2	146.9	9.8	88.3	0.34	118.7	10.6	165.4	-0.21	-116.3	-8.9	-96.1
T3	158.0	15.5	115.7	0.61	139.8	23.3	197.1	0.06	-95.2	3.8	-64.4
T4	147.6	8.6	87.8	0.59	131.6	10.6	142.4	0.04	-103.4	-8.9	-119.1
T5	145.4	9.5	124.6	0.37	121.4	13.5	158.5	-0.18	-113.6	-6.0	-103.0
T6	192.8	24.4	181.4	0.69	239.4	31.2	234.6	0.14	4.4	11.7	-26.9
T7	171.7	13.9	120.4	0.61	155.8	20.6	206.8	0.06	-79.2	1.1	-54.7
T8	164.1	11.1	96.4	0.59	152.1	11.0	140.9	0.04	-82.9	-8.5	-120.6
T9	151.3	16.6	124.6	0.38	147.2	14.9	156.9	-0.17	-87.8	-4.6	-104.6

T10	172.0	21.6	162.1	0.69	219.6	26.9	188.3	0.14	-15.4	7.4	-73.2
T11	113.4	6.2	81.2	0.34	101.9	9.1	114.0	-0.21	-133.1	-10.4	-147.5
SEm±	2.9	0.6	2.1	0.07	2.43	0.4	2.73	--	--	--	--
CD (P=0.05)	8.8	1.8	6.3	0.22	7.3	1.1	8.2	--	--	--	--

OC_b^*= Initial organic carbon in soil= 0.55%, N_b^*= Initial available N in soil= 235.0 kg/ha, P_b^*= Initial available P_2O_5 in soil= 19.5 kg/ha, K_b^*= Initial available K_2O in soil= 261.5 kg/ha.

3.3 Effect on soil nutrient status after harvest

Significantly higher values of organic carbon percentage, available N, P_2O_5 and K_20 content in soil were recorded in application of 25% RDF+ biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost (Table- 2). 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 phosphorous fixed in soil and made it available for absorbtion 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 percent availability of organic carbon, N, P_2O_5 and K_2O under 25% RDF+ biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost was higher to the tune of 102.9%, 134.9 kg/ha, 242.9 kg/ha and 113.7 kg/ha over control, respectively. However in respect of organic carbon percent in soil, treatment 25% RDF+ biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost, treatment biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost, treatment 25% RDF+ compost, treatment only compost application and treatment application of only green manuring were found to be on par with each other. The lowest availability of these nutrients was observed in 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 numerical data in Table-2 reveals that, Application of 25% RDF+ biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost made maximum addition amongst all the other treatments of organic carbon, available N and P_2O_5 by 0.14%, 4.4 kg/ha and 11.7 kg/ha, respectively over the initial status of soil available nutrients. Highest decreased values in organic carbon and soil available N, P_2O_5 and K_2O over initial soil status were recorded in control which were 0.21%, 133.1 kg/ha, 10.4 kg/ha and 147.5 kg/ha, respectively.

3.4 Effect on 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 content were recorded in application 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 par with each other in respect of plant height and total dry matter content of plant. Treatment 25% RDF+ biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost also produced highest number of cobs per plant, number of grains per cob and weight of 100 grains over rest of the treatments, however it was on par with application of biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost in respect of number of cobs per plant which was on 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 in respect of number of grains per cob. This might be due to the improvement in soil physico- chemical properties (*viz.* pH, Bulk density and infiltration rate) and optimum availability of major nutrients and organic carbon which acted as the growth and yield enhancing factors for maize crop. Sujatha *et al.* (2008) has been also reported similar results of 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.

Table 3: Effect of different treatments on growth, yield and economics of maize (pooled).

Treatment	Plant height (cm) (at harvest)	Dry matter per plant (g) (at harvest)	Number of cobs per plant	Number of grains per cob	100 grain weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Gross return (x103`/ha)	Net return (x103`/ha)	B:C ratio
T1	162.5	224.2	1.4	220.2	20.4	5.2	10.4	68.9	38.4	1.26
T2	136.7	170.4	0.9	185.1	20.8	3.0	8.0	41.8	17.6	0.73
T3	152.2	177.9	1.1	189.9	23.9	4.2	8.9	56.2	22.0	0.64
T4	149.3	178.6	1.1	164.8	20.5	3.0	8.4	42.2	14.6	0.53
T5	147.1	170.1	0.9	162.3	20.6	2.5	7.9	36.0	13.7	0.61
T6	172.6	256.6	1.6	223.5	24.9	7.4	12.6	95.9	54.2	1.30
T7	155.9	187.2	1.3	217.5	23.5	5.8	9.8	75.1	38.9	1.07

T8	151.8	182.1	1.2	182.7	23.5	4.3	8.2	56.6	27.0	0.91
T9	149.5	180.0	1.1	160.8	20.7	3.1	8.4	43.3	19.0	0.78
T10	164.6	232.9	1.5	221.3	23.9	6.7	10.7	84.1	44.4	1.12
T11	123.8	153.3	0.8	155.8	19.9	2.1	7.1	30.7	8.5	0.38
SEm±	1.9	3.2	0.06	3.66	0.15	0.07	0.09	0.71	0.68	--
CD (P=0.05)	5.8	9.5	0.18	10.9	0.44	0.22	0.27	2.12	2.04	--

3.5 Effect on yield

All the treatments has been significantly affected the grain and stover yield of maize (Table-3). Application of 25% RDF+ biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost produced highest grain(7.4 t/ha) and stover 12.6 t/ha) yield which was 252.4 and 77.46 percent more over control treatment. Application of biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost was found to be the next superior treatment which produced 6.7 and 10.7 t/ha grain and stover yield per hectare, respectively. Treatment control produced lowest grain (2.1 t/ha) and stover (7.1 t/ha) yield. 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 attributing characters in maize. Shanwad *et al*. (2010) also has been reported the enhancement in maize productivity with combined application of nutrients through organic and inorganic resources.

3.6 Effect on economics

Highest gross return (`95.9x$10^3$/ha), net return (`54.2x10^3/ha) and B:C ratio (1.30) were found in application of 25% RDF+ biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost, which were 212.38, 537.6 and 242.1 percent more than that of control treatment, respectively (Table-3). Treatment application of biofertilizers (*Azotobacter*+ PSB)+ green manuring with sunhemp+ compost was at second place in respect of gross and net return with producing `84.1x$10^3$/ha and `44.4x10^3/ha, respectively. With considering B:C ratio, application of 100% RDF is the second best treatment (1.26). Lowest gross return (`30.7x$10^3$/ha), net return (`8.5x10^3/ha) and B:C ratio (0.38) were recorded in control. These results are in close conformity with the findings reported by *Sujatha et al.* (2008).

4. Conclusion

From the tow years experimentation 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 for increasing productivity of hybrid maize with sustainability. This treatment is also responsible for improving physico- chemical properties and nutrient status of soil.

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