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Integrated Nutrient Management for Sustainable Maize (*Zea mays* L.) Production in Acidic Soil of Senapati District, Manipur, India

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A B S T R A C T

Field experiment was conducted at Krishi Vigyan Kendra- Senapati, Manipur for two consecutive kharif seasons of years 2014 and 2015 to find out most efficient and economic combination of different organic and inorganic sources of nutrients to increase the productivity of maize (*Zea mays* L.) without deteriorating the soil qualities. Application of 100% NPK recommended dose of fertilizers in combination with biofertilizers (Azotobacter) and incorporation of vermicompost @5 t/ha improved soil physico-chemical properties (*viz.* decrease in acidic pH). This was also responsible for improving the nutrient status of soil in respect of available N and available P_2O_5 which were increased by 87 kg/ha and 14.08 kg/ha, respectively over the initial nutrient status of soil. Maize grain yield was also increased by 181.90 % (under application of 100% NPK+ vermicompost @ 5 t ha^{-1}) over control. Combined use of vermicompost along with inorganic fertilizers were efficiently used by maize crop and had maximum values of yield attributes, yields as well as highest average net return of about Rs 57,716/ha and also maintained soil fertility.

Introduction

The NER of India has geographical area of 26.3 million hectors and population of 45 million. Almost 85% of soils in this region are moderate to strongly acidic (Das *et al*., 2016). Maize is globally the top ranking cereal in potential grain productivity. In India, maize is the third most important food crops after rice and wheat. Maize (*Zea mays* L.) is 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. Maize has high production potential compared to any other cereal crop. Hence it is called as ‘miracle crop’ and also as ‘queen of cereals because it has the highest genetic yield potential among the cereals. Maize is a crop par excellence for food, feed and industrial utilization.

The productivity of maize is largely dependent on its nutrient management. Maize can be grown successfully in variety of soils ranging from loamy sand to clay loam. However, soils with good organic matter content having high water holding capacity with neutral pH are considered good for higher productivity. The average productivity of Maize in the north-east hill region of India is very low (1.50 t/ha) mainly owing to cultivation under nutrient-starved condition Continuous use of only chemical fertilizers in intensive cropping system is leading to imbalance of nutrients in soil, which has an adverse effect on soil health and also on crop yields. 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). But, use of organics alone does not result in spectacular increase in crop yields, due to their low nutrient status. The conjunctive application of organics with inorganic sources of nutrients reduces the dependence on chemical inputs (Vanlanwe *et al.*, 2002). Integrated nutrient management (INM) is a flexible approach to minimize the use of chemical fertilizer along with maximization of their efficiency and farmer's profit. The vermicompost along with inorganic fertilizers were efficiently used by maize crop for their growth and development and also maintained soil fertility and increased yield of the crop (Sanjivkumar, 2014). Therefore, Integrated Nutrient Supply/management (INS) aims at maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of benefit from all possible sources of plant nutrients in an integrated manner (Roy and Ange, 1991). 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). Integrated use of organic and inorganic fertilizers not only recorded significantly greater root-shoot dry matter but also accelerated their growth compared to inorganic fertilizer application (Ghosh *et al.*, 2003).

Materials and Methods

A field experiment was conducted during kharif season of 2013-14 & 2014-15 at farmers field of Krishi Vigyan Kendra - Senapati, Manipur, India with objective to establish Integrated nutrient management for increasing production of maize with sustainability and residual fertility status in acidic soil of Senapati District, Manipur. The geographical area of the district is 3271 sq. km with 14.56% of the total geographical area of the state. The average temperature ranges from 4°C to 32°C and average annual rainfall varies from 671 to 1454 mm. It is located between 24° 30′N latitude and 93° 30′E longitude over the globe. The altitude of the district ranges from 800 to 4000 m above MSL. Senapati district has alluvium, lateritic black regur and ferruginous type of soil (Anonymous, 2009). The soil of the experimental site was clayey soil (Fluvaquentic Humaquepts) of 18.10 % sand, 14.60 % silt and 67.30 % clay, strongly acidic (pH 5.10) in reaction, medium in available nitrogen (412 Kg ha^{-1}), phosphorus (20 kg ha^{-1}) and potassium (128 kg ha^{-1}), low in sulphur (0.047 mg kg^{-1}) while high in zinc (3.35 mg kg^{-1}) (Table 1).

The twelve treatments, viz. 100% NPK, 100 % NPK + Zn,100% NPK + S + Zn, 100 % NPK + S, 100 % NPK + seed treatment with *Azotobacter*, vermicompost @ 5 tonnes /ha + 100 % NPK (excluding NPK content of vermicompost), 100 % NPK + vermicompost @ 5 tonnes /ha, vermicompost @ 10 tonnes /ha, 150 % NPK, 100 % NP, 100% N and absolute control were replicated four times in randomized block design. The sources used for applying N,P and k were urea, di-ammonium phosphate (adjusted for its N content) and muriate of potash, respectively. Gypsum and zinc sulphate ($ZnSO_4$. 7 H_2O) were used to supply S and Zn. The other sources of nutrients were vermicompost and biofertilizer (*Azotobacter* sp.). The dose of the NPK for maize was worked out according to the soil test fertilizer recommendation. The 100 % NPK dose in Kg ha^{-1} worked out was 80:60:40 for maize crop. The doses for sulphur and zinc were framed as 40 kg S ha^{-1} and 5 kg Zn ha^{-1}, respectively while vermicompost was applied as per the treatments. Maize local variety was sown at the seed rate of 25 kg ha^{-1} at the inter row of 60 cm and plant to plant spacing of 20 cm. Soil samples, 0-15 cm depth from each plot were drawn after harvest of the crop and air dried in shade, ground with wooden pestle and mortar and passed through 2 mm sieve and analysed for N, P_2O_5 and K_2O as per standard procedures. Statistical analysis of the data was carried out using standard analysis of variance (Panse and Sukhatme, 1989).

Results and Discussion

The data presented in table 2 indicate that all the treatments improved the available NPK status over unfertilized control after harvest of maize crop. Maximum available nitrogen (499.00 kg ha^{-1}), phosphorus (34.08 kg ha^{-1}) was observed under treatment receiving 100 % NPK + Vermicompost 5 t $ha^{-1,}$ while maximum potassium (338 kg ha^{-1}) was observed under the treatment receiving 150 % NPK. Tetarwal *et al.*, (2011) also observed similar results in respect of N, P and K status of soil (Fig. 1).

The data (Table 3) show that application of only 100% recommended N significantly increased weight of cob but the efficiency was further improved by adding phosphorus and potassium to the fertilization schedule. Data further show that nutrient stress (unfertilized control) had minimum cob weight (58.00 g) and all the nutrient application treatments resulted in significantly higher cob weight. The heaviest cob (131.10 g cob^{-1}) was produced under the application of 100 % NPK + Vermicompost 5 t ha^{-1}. It clearly evidence from the research finding that application of plant nutrients in the form of chemical fertilizer, organic sources or integrated way resulted in significantly higher cob length as compared with unfertilized control.

Table.1 Some major physical and chemical characteristics of the soil in experimental site

Soil characteristic	Value
pH	5.10
Organic carbon(g kg^{-1})	21.3
Available N (kg ha^{-1})	412
Available P_2O_5 (kg ha^{-1})	20
Available K_2O (kg ha^{-1})	128
Sulphur (mg kg^{-1})	0.047
Zinc (mg kg^{-1})	3.35
Clay (%)	67.30
Silt (%)	14.60
Sand (%)	18.10

Table.2 Effect of integrated nutrient management practices on nutrients status of soil after harvesting of maize crop

Treatments	**pH**	**Available N (kg ha^{-1})**	**Available P_2O_5 (kg ha^{-1})**	**Available K_2O (kg ha^{-1})**
100 % NPK	4.98	390	28.00	222
100 % NPK + Zn	4.99	399	27.50	247
100 % NPK + S + Zn	5.01	376	26.00	228
100 % NPK + S	5.04	382	27.00	234
100 % NPK + *Azotobacter*	5.05	412	29.00	253
Vermicompost 5t ha^{-1} + 100 % NPK (- NPK of Vermicompost)	5.6	435	28.77	278
100 % NPK + Vermicompost 5 t ha^{-1}	5.7	499	34.08	266
Vermicompost 10 t ha^{-1}	5.7	392	30.50	250
150 % NPK	5.2	483	27.95	338
100 % NP	4.99	377	28.00	167
100 % N	5.01	384	21.60	176
Control	5.0	303	19.00	120

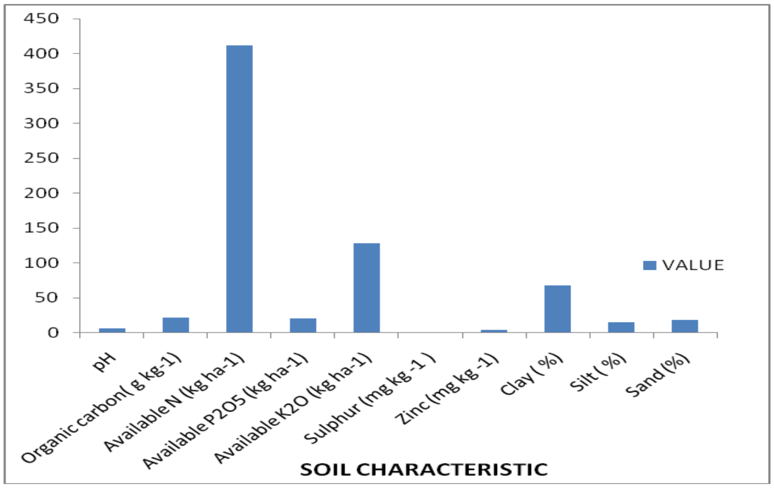
Table.3 Effect of integrated nutrient management practices on Yield parameters of maize

Treatments	Weight of Cob^{-1} (g)	Weight of grain Cob^{-1} (g)	Test weight (g)	Cob length (cm)	Grain yield (q ha^{-1})
100 % NPK	117.85	82.87	192.05	17.88	32.00
100 % NPK + Zn	118.15	83.00	192.92	17.48	32.24
100 % NPK + S + Zn	123.19	84.18	187.20	18.10	35.40
100 % NPK + S	119.23	83.45	186.88	17.00	33.09
100 % NPK + *Azotobacter*	118.80	84.22	189.11	17.14	32.60
Vermicompost 5t ha^{-1} + 100 % NPK	118.50	87.54	195.22	17.58	35.10
(-NPK of Vermicompost)	56.00				
100 % NPK + Vermicompost 5 t ha^{-1}	131.10	92.25	198.14	18.85	38.00
Vermicompost 10 t ha^{-1}	110.01	81.85	183.00	15.60	26.80
150 % NPK	123.00	88.12	189.00	18.00	35.25
100 % NP	100.05	74.20	177.12	16.28	28.30
100 % N	97.00	61.15	173.40	15.14	18.69
Control	58.00	32.67	162.48	13.74	13.48

Table.4 Economic impact for the application of 100% NPK+ Vermicompost @ 5 t/ ha

Sl.No.	Average cost of cultivation (Rs /ha)	Average gross return (Rs/ha)	Average net return (Profit) (Rs/ha)	B.C Ratio
1.	94,284	152,000	57,716	1.61:1

Fig.1 Some major physical and chemical characteristics of the soil in experimental site



Maximum cob length (18.85 cm) was found when crop was supplied with 100 % NPK + Vermicompost 5 t ha^{-1}. Maximum weight of grains cob^{-1} (92.25 g) was observed when crop was supplied with 100 % NPK + Vermicompost 5 t ha^{-1} which was at par with seed treatment with *Azotobacter*, Vermicompost 5t ha^{-1} + 100 % NPK (-NPK of Vermicompost) and 150 % NPK. The 1000 grain weight of maize was significantly improved by application of various nutrients through different sources. Maximum 1000 grain weight (198.14 g) was produced under the application of 100 % NPK + Vermicompost 5 t ha^{-1} (Table 3). The highest grain yield (38.00 q ha^{-1}) was produced by application of 100 % NPK + Vermicompost 5 t ha^{-1} and its performance was at par with 100 % NPK + S + Zn and 150 % NPK (Table 3). The treatment receiving 100 % NPK and its combination with Zn, S, Zn + S, *Azotobacter* seed treatment and Vermicompost 5 t ha^{-1} + 100 % NPK (- NPK of Vermicompost) showed statistically equivalent results in increasing grain yield over the other treatments. Though application of 100 % N, 100 % NP, and Vermicompost 10 t ha^{-1} increased the yield significantly over control but provided inferior results in comparison to aforesaid treatments. Similarly application of Vermicompost 10 t ha^{-1} and 100 % N alone were statistically at par with other but statistically superior over unfertilized control but provided inferior results in comparison to aforesaid treatments (Table 4). The increase in yield varied from 13.48 to 78 q ha^{-1}.

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In conclusion, INM practice including vermicompost and recommended dose of NPK showed its best results with respect to yield parameters like number of grains per cob, cob length, 1000 seed weight, weight of the cob and yield. The present study concluded that vermicompost along with inorganic NPK fertilizers and Biofertilizers (*Azotobacter*) were efficiently used by maize crop for their growth and development and also maintained soil fertility and increased yield of the crop.

From the two years experimentation it can be concluded that, application of 100% NPK+ vermicompost @ 5 t ha^{-1} is the best combination of organic and inorganic fertilizers for increasing productivity of maize with sustainability. This treatment is also responsible for improving physico- chemical properties and nutrient status of soil as well as highest average net return of about Rs 57,716/ha. Thus the combined use of organic manure and chemical fertilizer holds great promise in meeting the growing nutrient demands of intensive agriculture and maintaining the crop productivity at higher levels with overall improvement of soil fertility.

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