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Integrated Nutrient Management in Rainfed Maize (*Zea mays* L.) under Eastern Ghat High Land Zone of Odisha

Amit Phonglosa [a*], Bibhuti Bhusan Dalei [b], Paritosh Murmu [c], Biman Behera [d], Biswajit Sinha [e], Subhashis Saren [f], Lalatendu Nayak [d] and Manoj Kumar Meena [g]

[a] Directorate of Extension Education, Bhubaneswar, Odisha University of Agriculture and Technology, Bhubaneswar- 751003, Odisha, India.
[b] All India Co-ordinated Research Project on Niger, Odisha University of Agriculture and Technology, Semiliguda-763002, Odisha, India.
[c] Krishi Vigyan Kendra, Odisha University of Agriculture and Technology, Umerkote-764073, Odisha, India.
[d] Regional Research and Technology Transfer Sub-Station, Odisha University of Agriculture and Technology, Umerkote-764073, Odisha, India.
[e] College of Agriculture, Bhawanipatna, Odisha University of Agriculture and Technology, Bhawanipatna-766001, Odisha, India.
[f] College of Agriculture, Department of Soil Science and Agricultural Chemistry, Odisha University of Agriculture and Technology, Bhubaneswar-751003, Odisha, India.
[g] S. K. N. College of Agriculture, Sri Karan Narendra Agriculture University, Jobner-303329, Rajasthan, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *kharif* season of 2016 and 2017 at Regional Research and Technology Transfer Sub-Station, Umerkote of Odisha University of Agriculture and Technology comes under Eastern Ghat High Zone of Odisha, India to assess the response of integrated nutrient

**Corresponding author: E-mail: soilamit12@rediffmail.com;*

management on yield and economics of rainfed maize. The experiment was laid out in randomized block design with six treatments replicated four times. The experimental soils were strongly acidic, non-saline, loamy sand, low in organic carbon, available N, P, B, Zn and medium in available K contents. The maximum 100 seeds weight (38.86 g), stover yield (9.57 t ha^{-1}), grain yield (7.65 t ha^{-1}), net return (INR 50,711 ha^{-1}) and B:C ratio (1.98) were recorded in soil test based N:P:K:B:Zn (i.e. N:P_2O_5:K_2O:S:B:Zn @ 150:75:60:1.25:6.25 kg ha^{-1}) + lime @ 0.1 LR + FYM @ 5 t ha^{-1} (T_6) followed by soil test based N:P:K:Zn @ 150:75:60:1.25: 6.25 kg ha^{-1} + lime @ 0.1 LR (T_5) over control (i.e Farmers Practice N:P:K:Zn @ 160:80:45:0:0 kg ha^{-1}). Hence, it could be concluded that application of soil test based N:P:K:B:Zn @ 150:75:60:1.25:6.25 kg ha^{-1} + lime 0.1 LR + FYM @ 5 t ha^{-1} recorded better yield (7.65 t ha^{-1}) and income (INR 50,711 ha^{-1}) as compared to other treatments as well as farmers practice.

Keywords: Maize; INM; lime; yield; economics.

1. INTRODUCTION

After rice and wheat, maize (*Zea mays* L.) is the world's third most significant cereal crop. Because of its great production potential relative to other cereal crops and higher adaptation to a wide range of settings, maize is an important cereal crop. The crop is known as the "Queen of Cereals" because of its great genetic yield potential. Maize, being a C4 plant, has a larger production potential, which is partly dependent on the soil's nutrient supply capacity. However, due to a lack of effective nutrient management procedures, its full potential was not realised [1, 2]. It may be grown in every soil type (excluding sandy soil) and under any agro-climatic conditions. Maize has been grown in various seasons and places, with crop durations ranging from <90-130 days [2], due to its photo insensitivity. In India, it is cultivated over an area of 92.32 lakh hectares with an annual production of 236.73 lakh tonnes having an average productivity of more than 2564 kg ha^{-1} [3]. In 2013-14, it covered 2.80 lakh hectares in Odisha, with total production of 7.79 lakh tonnes and an average productivity of 2.78 tha^{-1} [4]. The state of Odisha covering geographical area of 15.57 m ha lies in the tropical belt in the eastern regions of India between 17^0.47'- $22^0$33' N latitude and $81^0$31'- $87^0$30' E longitudes. The climate is characterized by high temperature and medium rainfall. The average annual rainfall of the state is 1500 mm and the mean annual temperature is 26.20 °C. The soils are deficient in nitrogen, phosphorus and micronutrients like boron, zinc and molybdenum [5] (About 44 percent of soils of Odisha are deficient in B [6]. Maize has been previously considered to have a relatively low B requirement compared with other cereals [7]. Deficiency of B in field grown maize was first observed in the 1960s in the United States [8]. Crop yield increases more than 10% was observed in response to B application [9]. In B deficient maize, poor grain setting can result in barren cobs as reported by Vaughan [10]. In Zn deficient soils, Zn application was increased maize grain yield due to increase of kernel numbers and kernel weight. An adequate Zn supply in maize plants maintained high pollen viability and a sufficient carbohydrate source as reported by Liu et al. [11]. Therefore, Zn fertilization can improve inferior grains, because a positive relationship between kernel number and Zn content in the maize stem, whereas the absence of Zn induced barren ear tips [12]. In Odisha, where 80 percent of soils are acidic, poverty and soil acidity are synonymous. Low crop productivity in acidic soils of Odisha is due to low water holding capacity, high bulk density, and soil crusting, as well as chemical constraints such as low pH, low CEC, low base saturation (16 to 67 percent), high Al, Fe, and Mn saturation, and high P fixing capacity (80 to 91 percent) [13]. Applications of lime along with other management practices are needed to correct soil acidity. Apart from its manifested role in increasing crop yield, application of lime enhances the efficiency of applied fertilizers, protects the environment and increases the net profit of the farmers [14]. The dual use of organic and inorganic ameliorants reduces Al and Fe toxicity while also increasing nutrient availability [13], resulting in superior crop growing conditions in these soils. Maize is commonly grown on marginal lands in Odisha and it is frequently given with sub-optimal fertiliser doses in indigenous varieties resulting in low crop output. In order to achieve higher yields and lower production costs, balanced and efficient fertiliser application including inorganic and organic fertilisers as well as the use of soil ameliorants, is required. Therefore, combination of chemical and organic sources and their management have shown promising results not only in sustaining the productivity but also in maintaining soil health.

Keeping this in view, the present experiment was undertaken to assess the response of integrated nutrient management on yield and economics of maize in an alfisol under Eastern Ghat High Land (EGHL) zone of Odisha.

2. MATERIALS AND METHODS

2.1 Site Description and Experimental Design

The field experiment was conducted for two consecutive years (2016 and 2017) during *kharif* season at Regional Research and Technology Transfer Sub-Station, Umerkote of Nabarangpur district in Odisha, India to assess the response of integrated nutrient management on yield and economics of rainfed maize. The field is situated at 19° 39’10.67” N latitude, 82°12’01.39” E longitude, experiencing warm and humid climate during maize growing periods. The average maximum and minimum temperature during the maize growing period varied from 26.4 to 30.3°C and 17.3 to 20.6°C, respectively in 2016; and from 26.3 to 29.8°C and 19.4 to 21.8°C, respectively in 2017. Average maximum and minimum relative humidity (RH) during the experimentation fluctuated from 92 to 94% and 74 to 91%, respectively in 2016; and from 85 to 93% and 77 to 85%, respectively in 2017. Monthly average rainfall during the experimental period varied from 12.4 to 42.1 cm in 2016 and from 9.2 to 47.0 cm, respectively in 2017. The soil was *Typic Haplustalfs* with loamy sand texture (Sand: 85.4%, Silt: 10.4% and Clay: 4.0%) and strongly acidic (pH 4.96) in reaction. The experimental soils were non-saline (EC- 0.007dSm^{-1}), low in organic carbon (2.7 g kg^{-1}), available N (126.0 kg ha^{-1}), available P (5.4 kg ha^{-1}), available B (0.37 mg kg^{-1}), available Zn (0.44 mg kg^{-1}), Ca (1.7 cmol kg^{-1}), Mg (0.6 cmol kg^{-1}) and medium in available K (170.0 kg ha^{-1}) contents, respectively. A composite soil sample analysis was done to know the physico-chemical properties before conducting the experiment. The methods involved in analysis of initial soil samples are depicted in Table 1.

The experiment was laid out in randomized block design (RBD) with six treatments *viz.* T_1: Farmers practice NPKBZn ($N:P_2O_5K_2O:B:Zn$ @ 160:80:45:0:0 kg ha^{-1} i.e. control), T_2: Farmers practice + lime @ 0.1 lime requirement (LR), T_3: Farmers practice + lime @ 0.1 LR + FYM @ 5 t ha^{-1}, T_4: Soil test based NPKBZn ($N:P_2O_5:K_2O:B:Zn$ @ 150:75:60:1.25:6.25 kg ha^{-1}), T_5: Soil test based NPKBZn + lime @ 0.1 LR, T_6: Soil test based NPKBZn + lime @ 0.1 LR + FYM @ 5 t ha^{-1}] replicated four times taking maize (cv. Kaveri, 25K55) as test crop. Crop was sown with a spacing of 60 cm x 30 cm in the last week of June during both years of experimentation. Lime was applied at 0.1 LR in the form of paper mill sludge (PMS) locally available liming material (60% calcium carbonate equivalent) below the seed zone at the time of sowing. The farmers’ practice was considered as control treatment and it was widely adopted in the locality of rainfed upland maize ecosystems under Eastern Ghat High Land Zone of Odisha. Urea, Diammonium Phosphate (DAP), Muriate of Potash (MOP), Borax and Zinc sulphate were used as source of N, P, K, B and Zn respectively. The entire amount of P and K were applied as basal during final land preparation (before sowing of maize seeds). Nitrogen was applied in three split doses i.e. 25% as basal, 50% at first hoeing (three weeks after sowing) and 25% at second hoeing (six to seven weeks after sowing). Top dressings of fertilizers were applied at the time of hoeing/intercultural and earthing up operations to incorporate fertilizer into the soil. Borax fertilizer was applied as basal soil application before sowing in each respective treatment except T_1, T_2 and T_3, respectively. Zinc sulphate fertilizer was also applied as basal soil application before sowing in respective treatment except T_1, T_2 and T_3, respectively. Well decomposed FYM (containing 0.45% N, 0.21% P_2O_5 and 0.32% K_2O on a dry-weight basis) @ 5 t ha^{-1} was applied 10 days prior to sowing in respective treatments (i.e. T_3 and T_6). All the other cultural practices were followed uniformly throughout the growing period of crop. The yield attributes were recorded at harvest and grain yield at 14% moisture content. Hundred seed weight was recorded after sun drying of seeds. Net return (INR ha^{-1}) and benefit:cost (B:C) ratio of maize were calculated based upon the prevailing local market prices.

2.2 Statistical Analysis

The data on growth and yield attributes were subjected to an analysis of variance (ANOVA) using randomized block design and statistical analysis was carried out using the SPSS statistical package (version 18.0, Chicago, USA). Probabilities of significance (p= 0.05) was used to test the significance of nutrient effects.

3. RESULTS AND DISCUSSION

3.1 Yield and Yield Attributes of Maize

The experimental results of two years (2016 and 2017) on maize (Table-2) revealed that 100 seeds weight, grain yield and stover yield were significantly increased in soil test based NPKBZn (i.e. $N:P_2O_5:K_2O:S:B:Zn$ @ 150:75:60:1.25:6.25 kg ha^{-1}) + lime @ 0.1 LR + FYM @ 5 t ha^{-1} as compared with all other treatments. The maximum 100 seeds weight (38.86 g), grain yield (7.65 t ha^{-1}) and stover yield (9.57 t ha^{-1}) were obtained in soil test based NPKBZn + lime @ 0.1 LR + FYM @ 5 t ha^{-1} followed by soil test based NPKBZn + lime @ 0.1 LR (T_5), where farmers practice showed the lowest 100 seeds weight (35.50 g), grain yield (4.61 t ha^{-1}) and stover yield (7.19 t ha^{-1}), respectively (Table-2). This result also corroborated with the findings of Borase et al. [3]; Phonglosa et al. [23]; Thinghujam et al. [24]. Combined application of inorganic, organic and lime i.e. soil test based NPKBZn + lime @ 0.1 LR + FYM @ 5 t ha^{-1} increased 65.94% (Fig. 1) grain yield of maize over control (i.e. Farmers practice NPKBZn). Similar results were reported by Borase et al. [3]; Phonglosa et al. [23]. The improvement in grain, stover and biological yield of maize is mainly attributed to complementary role of boron in the reproduction and vegetative stage of plants as reported by Tahir et al. [25]. The present investigation confirmed that significantly lowest values of yield attributes were recorded in control (farmers practice) plots. The favorable effect of integrated application of inorganic fertilizers, FYM and lime on yield attributes might be due to better absorption and availability of nutrients to the crop. Samantaray et al. [26] reported that integrated application of 75% soil test-based fertilizer recommendation (STBFR) + FYM @ 5 t ha^{-1} + lime @ 0.2 LR + sulphur @ 20 kg ha^{-1} recorded maximum yield attributes and yield in pigeon pea crop [27].

Table 1. Analytical methodologies for different soil parameters

Parameter	Methodology	Citation	Equipment used
		Soil analyses	
Sand-Silt-Clay	Hydrometer method	Bouyoucos [15]	Hydrometer
pH	(in 1:2.5:: Soil : Water)	Jackson (1967) [16]	m-processor based pH-EC-Ion meter
EC	(in 1:2.5:: Soil : Water)	Jackson (1967) [16]	
Organic carbon	Wet oxidation method	Jackson (1973) [17]	
Available N	Hot alkaline $KMnO_4$ Method	Subbiah and Asija [18]	Kjeldahl apparatus
Available P	0.03 N NH_4F + 0.025 N HCl (pH 3.5)	Bray and Kurtz [19]	Spectrophotometer
Available K	Neutral N NH_4OAc extraction	Brown and Warncke [20]	Flame photometer
Available B	Hot water extraction	Berger and Truog [21]	Spectrophotometer
Available Zn	DTPA extraction	Lindsay and Norvell [22]	Atomic Absorption Spectrophotometer

Table 2. Effect of integrated nutrient management on yield and yield attributes of maize (mean data of 2 years)

Treatments	100 seeds wt. (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})
T_1: Farmers practice NPKBZn[#]	35.50	4.61	7.19
T_2: Farmers practice NPKBZn + lime @ 0.1 LR	37.37	5.46	7.78
T_3: Farmers practice NPKBZn + lime @ 0.1 LR + FYM 5 t ha^{-1}	37.77	5.84	7.86
T_4: Soil test based NPKBZn[##]	38.54	6.49	8.66
T_5: Soil test based NPKBZn + lime @ 0.1 LR	38.65	6.82	9.44
T_6: Soil test based NPKBZn + lime @ 0.1 LR + FYM @ 5 t ha^{-1}	38.86	7.65	9.57
SEm (±)	0.701	0.083	0.068
CD (p=0.05)	2.111	0.250	0.206

[#]Farmers practice NPKBZn i.e. $N:P_2O_5:K_2O:S:B:Zn$ @160:80:45:0:0 kg ha^{-1};
[##]Soil test based NPKBZn i.e. $N:P_2O_5:K_2O:S:B:Zn$ @ 150:75:60:1.25:6.25 kg ha^{-1}

Table 3. Effect of integrated nutrient management on economics of maize cultivation (mean data of 2 years)

Treatments	Cost of cultivation (INR ha^{-1})	Gross Return (INR ha^{-1})	Net Return (INR ha^{-1})	B:C ratio
T_1: Farmers practice NPKBZn#	43391	61640	18249	1.42
T_2: Farmers practice NPKBZn + lime @ 0.1 LR	43657	72981	29324	1.67
T_3: Farmers practice NPKBZn + lime @ 0.1 LR + FYM 5 t ha^{-1}	48657	78115	29457	1.61
T_4: Soil test based NPKBZn##	46398	86869	40471	1.87
T_5: Soil test based NPKBZn + lime @ 0.1 LR	46664	91163	44499	1.95
T_6: Soil test based NPKBZn + lime @ 0.1 LR + FYM @ 5 t ha^{-1}	51664	102375	50711	1.98

#Farmers practice NPKBZn i.e. $N:P_2O_5:K_2O:S:B:Zn$ @160:80:45:0:0 kg ha^{-1};
##Soil test based NPKBZn i.e. $N:P_2O_5:K_2O:S:B:Zn$ @ 150:75:60:1.25:6.25 kg ha^{-1};
INR: Indian Rupee; B:C ratio:: Benefit: Cost ratio.

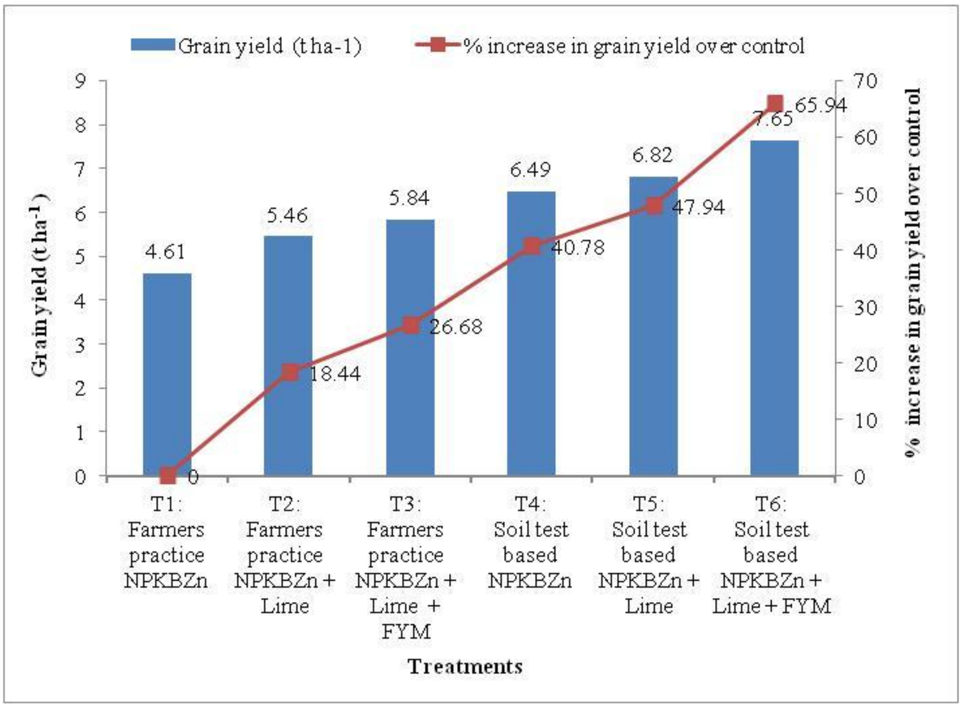

Fig. 1. Effect of integrated nutrient management on grain yield and percent increase over control (i.e. farmers practice NPKBZn only)

3.2 Economics

The cost of cultivation of maize varied from INR 43,391 ha^{-1} to INR 51,664 ha^{-1} (Table 3). Average data of economics of maize showed that maximum gross return (INR 1,02,375 ha^{-1}), net return (INR 50,711 ha^{-1}) and B:C ratio (1.98) were recorded from the treatments with soil test based NPKBZn (i.e. $N:P_2O_5:K_2O:S:B:Zn$ @ 150:75:60:1.25:6.25 kg ha^{-1}) + lime @ 0.1 LR + FYM @ 5 t ha^{-1} followed by T_5 (soil test based NPKBZn + lime @ 0.1 LR) over control (i.e. farmers practice NPKBZn).

4. CONCLUSION

The results of the investigation revealed that integrated nutrient management i.e. soil test based $N:P_2O_5:K_2O:S:B:Zn$ @ 150:75:60:1.25:6.25 kg ha^{-1} + lime @ 0.1 LR + FYM @ 5 t ha^{-1}) could be effective in maximizing the productivity and economics of maize crop in acidic soils under continuous maize growing areas of Eastern Ghat High Land zone of Odisha. Application of FYM and lime amelioration in acidic soils had strong economic impact when applied in combination with soil test based fertilizer (N, P, K, B and Zn) recommendation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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