Original Research Article

Integrated Nutrient Management strategies for Maize (*Zea mays* L.) production under Eastern Ghat High Land Zone of Odisha, India

ABSTRACT

A field experiment was carried out at Regional Research and Technology Transfer Station (OUAT), Semiliguda of Koraput district under Eastern Ghat High Land zone of Odisha in acidic soil during two consecutive *kharif* seasons of 2016 and 2017 to study the response of integrated nutrient management on growth and yield of maize. The experiment was laid out in randomized complete block design with three replications consisting of twelve treatments. The present investigation revealed that application of soil test Fertilizer dose with green leaf manure (cowpea), FYM @ 5 t ha^{-1} and biofertilizer (*Azotobacter + Azospirillum + PSB @ 4 kg ha^{-1} each*) resulted significantly higher seed yield of 7384 kg ha^{-1} with a net monetary return of Rs.50838 ha^{-1} and benefit cost ratio of 1.97.

Key words: Economics, growth, yield, INM, maize

1. INTRODUCTION

Maize (*Zea mays* L.) is the world's third most significant cereal crop after rice and wheat. It is an important cereal crop which has great production potential relative to other cereal crops and higher adaptation to a wide range of agro-climatic zones. It is also known as the "Queen of cereals" because of its great genetic yield potential. Maize crop has a larger production potential, which is partly dependent on nutrient supply capacity of soil. However, the full yield potential could not be realised due to lack of effective nutrient management in maize [1, 2]. 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 2018-19, it covered 2.71 lakh hectares in Odisha, with total production of 8.69 lakh tonnes and an average productivity of 3190 kg ha^{-1} [4]. In Odisha, where 80 percent of soils are acidic and low 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 CEC, low base saturation (16 to 67 percent), high Al, Fe, and Mn saturation, and high P fixing capacity (80 to 91 percent) [5]. 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 [6]. The dual use of organic and inorganic ameliorants reduces Al and Fe toxicity while also increasing nutrient availability [5], 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 Fertilizer doses in indigenous varieties resulting in low crop output. In order to achieve higher yields and lower production costs, balanced and efficient fertilizer application including inorganic and organic fertilizers 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. Soil and climate

A field experiment was conducted at Regional Research and Technology Transfer Station (OUAT), Semiliguda under Koraput district in Eastern Ghat High Land zone of Odisha during two consecutive *kharif* seasons in 2016 and 2017. The farm is located in the geographical parallels of $18^0$42'N latitude, $82^0$30'E longitude and an altitude of 884.0 m. The total rainfall received during the crop period is 864 mm. The soil of the experimental site was sandy to clay loam in texture, acidic in reaction (pH-5.8) with low in available N (170 kg ha^{-1}), low in available P (16 kg ha^{-1}) and low in available K (145 kg ha^{-1}).

2.2. Experimental Design

The experiment consists of twelve treatments*viz.*T_1 - Soil test fertilizer dose (STFD); T_2 - STFD + GLM with cowpea; T_3 - STFD + FYM @ 5 t ha^{-1}; T_4 - STFD + Lime; T_5 - STFD + Sulphur; T_6 - STFD + BioFertilizer;T_7 - STFD + GLM with cowpea + FYM @ 5 t ha^{-1}; T_8 -

STFD + GLM with cowpea + Lime; T_9 - STFD + FYM + Lime; T_{10} - STFD + GLM with cowpea + FYM @ 5 t ha^{-1} + Lime; T_{11} - STFD + GLM with cowpea + FYM @ 5 t ha^{-1} + Sulphur;T_{12} - STFD + GLM with cowpea + FYM @ 5 t ha^{-1} + Biofertilizer. The experiment was evaluated in randomized complete block design with three replications. Maize hybrid Kaveri as main crop and cowpea as green leaf manure crop were sown during rainy season. Maize was sown with a spacing of 60cm x 30cm and seed rate of 15 kg ha^{-1}. Cowpea was sown between two rows of maize as green leaf manure crop with a spacing of 30cm x 15cm and seed rate of 10 kg ha^{-1} taking into consideration that the cowpea plant population is 50 per cent of normal sole cowpea. In maize crop FYM @ 5 t ha^{-1} was applied at the time of last ploughing as per the treatment. Soil test-based fertilizer, lime as $CaCO_3$@ 10 q ha^{-1}, sulphur @ 30 kg ha^{-1}, bioFertilizers [*Azotobacter* + *Azospirillum* + *PSM* (1:1:1) @ 4 kg ha^{-1} each] were applied to the crop as per the treatments. Full dose of P, K & 25% N in form of DAP, MOP & Urea were applied as basal and rest 50% N and 25% N at first & second earthing up respectively were applied to the crop. The crop was harvested at physiological maturity. The periodical biometric and post harvest observations were taken at regular interval.

2.3. Observation recorded

Plant height was recorded using a wooden meter scale and average plant height was expressed in centimeter. The leaf area index was calculated using formula leaf area to land area. The dry matter was recorded by taking destructive sampling and expressed as g $plant^{-1}$. The yield and yield attributes were recorded using standard procedures and the economics were calculated using standard formula.

2.4. Statistical Analysis

The experimental data collected during the crop growth and harvest were analyzed statistically following the standard procedure [7]. Treatment differences were tested at 5% level of significance by F test and using analysis of variance (ANOVA) for making comparison among treatment means for various yield and yield components of maize. Critical difference (CD) was done at P=0.05.

3. RESULTS AND DISCUSSION

3.1. Growth parameters

Plant height of hybrid maize was influenced by different treatments of organic and inorganic fertilizers combinations. The pooled analysis over two years data (Table 1) indicated that plant height increased gradually as the growth stages of plant advances. Application of STFD + GLM (cowpea) + FYM + Biofertilizers (T_{12}) resulted significantly the tallest plant height of 213.7 cm at harvest followed by the application of STFD + GLM (cowpea) + FYM + Sulphur (T_{11}) (208.2 cm). The lowest plant height was recorded when the maize plant was grown with chemical Fertilizers only, T_1 (192.7 cm). The tallest plants due to conjunctive application of green leaf manure (cowpea), FYM and biofertilizer along with STFD might be due to the more availability of plant nutrients, enzymes, vitamins and congenial soil characters which helped the plant to uptake more soil nutrient along with water. Similar result was found in baby corn [9]. Similar trend was observed for leaf area index (Table 1). Combined application of organic and inorganic sources of nutrient recorded higher values of leaf area index in comparison with the sole application of chemical fertilizers. Treatment receiving STFD + GLM (cowpea) + FYM + Biofertilizers recorded significantly highest value of LAI (5.19) at 80 days after sowing followed by the application of STFD + GLM (cowpea) + FYM + Sulphur (4.97). The highest leaf area index might be due to greater availability of soil nutrient throughout the growth period from the combined application of organic and inorganic sources of nutrient. Similar result was confirmed by the findings of other workers [10, 11]. Treatment T_{12} recorded the highest (250.5 g plant^{-1}) dry matter accumulation followed by T_{11} (241.9 g plant^{-1}). The highest dry matter accumulation in T_{12} might be attributed to the greater availability of applied nutrients and higher uptake of primary nutrients by maize from the combined application of organic and inorganic sources of nutrients. Similar result was found by various authors [10, 12].

3.2. Yield attributes

The cob length was significantly higher (24.0 cm) in T_{12} followed by T_{11} (22.3 cm). The control treatment resulted in least length (16.8 cm) which was 30 % less than the lengthiest cob i.e. 24.20 cm in T_{12}. Similar results were obtained in case of cob girth. The highest number (1.3) of cobs plant^{-1} was recorded in T_{12} whereas the lowest number of cobs plant^{-1} (1.1) was recorded with soil test Fertilizer dose (T_1). The length of cob, girth of cob and number of cob are primarily attributed due to better growth of plants in terms of plant height and dry matter accumulation due to integration application of organic and inorganic fertilizer. The yield attributing characters (Table 2) *i.e.* number of grains cob^{-1} (516.2) was the highest with application of (STFD + GLM

(cowpea) + FYM + Biofertilizers) which was significantly higher among all other treatments. The conjunctive application of chemical nitrogen and biofertilizer has been reported to increase in chlorophyll content causing increase in the production of photosynthesis materials, duration of flowering and flowers fertility and therefore increase in number of grains cob^{-1} [13]. This improvement in yield components of maize with integral application of organic and inorganic might be because of higher availability of macro and micronutrients with the combined application of inorganic and organic sources of nutrients [14]. The highest grain weight cob^{-1} was 125.7 g cob^{-1} which was exhibited by application of STFD + GLM (cowpea) + FYM + Biofertilizers followed by the treatment of STFD + GLM (cowpea) + FYM + Sulphur (110.1 g cob^{-1}). The lowest grain weight per cob of 63.9 g cob^{-1} was recorded by the control treatment (T_1) in the mean data of two years. The increase in grain weight cob^{-1} might be due to increased availability of Zinc and phosphorous like nutrients [15]. Similar beneficial effect of organic manures on different growth and yield attributes were also reported by Sujatha et al., 2008 [16].

The perusal of pooled data of 2016 and 2017 presented in Table 2 indicated that the highest test weight (274.9 g) of maize was found in T12 which was followed by T_{11} (255.6 g). Similar observations were recorded by Nasrolahzadeh et al., 2007 [17].

3.3. Grain and stover yield

The data presented in Table 3 showed that significantly highest grain yield (73.8 q ha^{-1}) in maize was obtained with the application of STFD + GLM (cowpea) + FYM + Biofertilizers. On the other hand the least grain yield (53.9 q ha^{-1}) was registered with STFD alone. The percent increase of highest grain yield over the control is 36.9 %. Increase in maize grain yield owing to integration application of chemical fertilizer and organic manures might be attributed to steady release of nutrients to soil for longer duration after decomposition resulting in better plant growth and yield attributing characters. The higher yield in maize due to integrated application of organics and inorganics source of fertilizer [18,19]. The higher grain yield with integrated nutrient management treatments might be due to remarkable increase in yield components such as number of grains and grain weight. This is also due to adequate supply of photosynthates for development of sink and balanced nutrition with integrated nutrient management. These findings are alike with those reported by other researchers [20, 21]. Similar trend was observed for stover yield too. The stover yield was 108.8 q ha^{-1} in T_{12}, it was the lowest 97.1 q ha^{-1} with STFD alone. The improvement in stover yield might be due to significant increase in yield components like

length of cob, girth of cob and grains per cob which ultimately resulted into higher productivity. The result was supported by Mahato et al., 2020 [22]. The experimental pooled data of 2016 and 2017 on harvest index perused in Table 3 indicated that significantly highest harvest index (40.4%) was found with the application of STFD + GLM (cowpea) + FYM + Biofertilizers. The lowest harvest index (35.7%) was found in the control treatment of soil test fertilizer dose. Highest harvest index might be due to better partitioning of photosynthates from the vegetative part to the reproductive part of the crop in the combined application of organic with inorganic Fertilizer which could able to supply nutrients to meet its requirement for long time as well as quick requirement at various stages. This result was in conformity with the findings of several other workers [23, 24, 25].

3.4. Economics

Data on economics as influenced by integrated nutrient management in hybrid maize (Table 3) revealed that the highest gross return of Rs.1,03,371 ha^{-1}, net return of Rs.50,838 ha^{-1} were recorded with application of soil test fertilizer dose with green leaf manure (cowpea), FYM @ 5 t ha^{-1} and biofertilizer (*Azotobacter + Azospirillum + PSB @ 4* kg ha^{-1} *each*). Similar result was also reported by Yadav et al., 2016 [26]. But, the highest return $rupee^{-1}$ invested (1.99) was obtained with soil test fertilizer dose with green leaf manure (cowpea) and lime. This might be due to lower cost of cultivation. Some workers [27, 28] reported increase in gross expenditure was due to high cost of organic manures.

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Table 1. Effect of integrated nutrient management on plant growth parameters of hybrid maize during 2016-17 and 2017-18 (Pooled data)

Treatment	Plant height (cm)	Leaf Area Index (80 DAS)	Dry matter production (g plant^{-1})
T_1-Soil Test Fertilizer Dose (STFD)	192.7	4.2	191.4
T_2-STFD + GLM (cowpea)	200.8	4.7	203.0
T_3-STFD + FYM @ 5t/ha	205.6	4.7	205.3
T_4-STFD + Lime	205.9	4.7	209.2
T_5-STFD + Sulphur @ 30 kg ha^{-1}	199.6	4.4	202.1
T_6-STFD + Biofertilizers [Azoto.+Azosp.+PSM (1:1:1) @ 4 kg ha^{-1}each]	202.7	4.7	204.5
T_7-STFD + GLM (cowpea) + FYM	205.3	4.8	217.5
T_8-STFD + GLM (cowpea) + Lime	206.3	4.8	213.9
T_9-STFD + FYM + Lime	205.8	4.8	225.3
T_{10}-STFD + GLM (cowpea)+ FY M + Lime	207.2	4.9	234.3
T_{11}-STFD + GLM (cowpea) + FYM + Sulphur	208.2	5.0	241.9
T_{12}-STFD + GLM (cowpea) + FYM + Biofertilizers	213.7	5.2	250.5
SEm (±)	11.00	0.24	10.24
CD (p=0.05)	30.6	0.7	28.5

Table 2. Effect of integrated nutrient management on yield attributes of hybrid maize during 2016-17 and 2017-18 (Pooled data)

Treatment	Length of cob (cm)	Cob girth (cm)	No. of rows cob^{-1}	No. of grains cob^{-1}	1000 grain wt (g)	Grain weight (g cob^{-1})
T_1-Soil Test Fertilizer Dose (STFD)	16.8	13.3	12.9	293.5	232.8	63.9
T_2-STFD + GLM (cowpea)	18.1	14.2	13.9	330.7	244.8	76.5
T_3-STFD + FYM @ 5t/ha	18.7	14.4	14.6	361.4	247.1	84.6
T_4-STFD + Lime	18.9	14.6	14.8	372.2	247.5	86.5
T_5-STFD + Sulphur @ 30 kg ha^{-1}	18.0	13.6	13.5	320.0	244.2	74.6
T_6-STFD + Biofertilizers [Azoto.+Azosp.+PSM (1:1:1) @ 4 kg ha^{-1}each]	18.5	14.3	14.2	347.7	246.5	81.0
T_7-STFD + GLM (cowpea) + FYM	19.5	14.9	15.3	397.0	250.7	94.6
T_8-STFD + GLM (cowpea) + Lime	20.9	15.5	16.1	436.8	254.6	103.7
T_9-STFD + FYM + Lime	20.2	15.2	14.8	385.9	252.1	91.6
T_{10}-STFD + GLM (cowpea) + FY M + Lime	22.0	16.4	16.5	452.1	255.0	106.5
T_{11}-STFD + GLM (cowpea) + FYM + Sulphur	22.3	16.7	16.8	462.2	255.6	110.1
T_{12}-STFD + GLM (cowpea) + FYM + Biofertilizers	24.0	17.7	18.0	516.2	274.9	125.7
SEm (±)	1.72	0.93	0.99	34.63	13.12	8.51
CD (p=0.05)	4.8	2.6	2.9	96.5	36.6	23.7

Table 3. Effect of integrated nutrient management on yield and economics of hybrid maize during 2016-17 and 2017-18 (Pooled data)

Treatment	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest Index (%)	Gross Return (Rs. ha^{-1})	Net Return (Rs. ha^{-1})	Return $rupee^{-1}$ invested (Rs.)
T_1-Soil Test Fertilizer Dose (STFD)	53.9	97.1	35.7	75437	31919	1.73
T_2-STFD + GLM (cowpea)	59.8	100.4	37.3	83655	37972	1.83
T_3-STFD + FYM @ 5t/ha	61.4	102.4	37.5	85923	37405	1.77
T_4-STFD + Lime	61.6	103.2	37.4	86296	40748	1.89
T_5-STFD + Sulphur @ 30 kg ha^{-1}	58.8	103.1	36.3	82269	36601	1.80
T_6-STFD + Biofertilizers [Azoto.+Azosp.+PSM (1:1:1) @ 4 kg ha^{-1}each]	61.0	102.8	37.2	85395	40027	1.88
T_7-STFD + GLM (cowpea) + FYM	64.6	101.8	38.8	90393	39710	1.78
T_8-STFD + GLM (cowpea) + Lime	67.8	103.6	39.5	94855	47142	1.99
T_9-STFD + FYM + Lime	66.0	102.3	39.2	92335	41787	1.83
T_{10}-STFD + GLM (cowpea) + FY M + Lime	69.6	105.2	39.8	97384	44671	1.85
T_{11}-STFD + GLM (cowpea) + FYM + Sulphur	69.9	105.7	39.8	97893	45060	1.85
T_{12}-STFD + GLM (cowpea) + FYM + Biofertilizers	73.8	108.8	40.4	103371	50838	1.97
SEm (±)	4.41	6.06	0.01	6171	6171	0.131
CD (p=0.05)	12.9	17.8	0.03	18098	17190	0.36