



# Yield and Economics of Hybrid Maize (*Zea mays* L.) under Integrated Nutrient Management Practices in Odisha, India

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## 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 carried out at Regional Research and Technology Transfer Station, Odisha University of Agriculture and Technology, 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 yield and economics of hybrid maize. The experiment was laid out in randomized block design with three replications consisting of twelve treatments. The present investigation revealed that application of soil test fertilizer dose with green manure (cowpea), FYM @ 5 t ha<sup>-1</sup> and biofertilizer (*Azotobacter* + *Azospirillum* + *PSB* @ 4 kg ha<sup>-1</sup> each) resulted significantly higher seed yield of 7384 kg ha<sup>-1</sup> with a net monetary return of Rs. 50838 ha<sup>-1</sup> and benefit cost ratio of 1.97.

**Keywords:** 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<sup>-1</sup> [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<sup>-1</sup> [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%), high Al, Fe, and Mn saturation, and high P fixing capacity (80 to 91%) [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 hybrid maize in an *alfisol* under Eastern Ghat High Land (EGHL) zone of Odisha, India.

## 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°42'N latitude, 82°30'E longitude and an altitude of 884.0 m. The total rainfall received during the crop period is 864 mm. The soil of experimental site was red, sandy loam in texture and strongly acidic in reaction (pH= 5.06) with medium soil organic carbon (7.13 g kg<sup>-1</sup>), medium available N (472.0 kg ha<sup>-1</sup>), high available P (33.20 kg ha<sup>-1</sup>), high available K (313.0 kg ha<sup>-1</sup>), low available S (11.45 kg ha<sup>-1</sup>) and low available Ca (0.6 meq 100 g<sup>-1</sup>).

### 2.2 Experimental Design

The experiment consists of twelve treatments viz. T<sub>1</sub> - Soil test fertilizer dose (STFD); T<sub>2</sub> - STFD + Green Manure (GM) with cowpea; T<sub>3</sub> - STFD + FYM @ 5 t ha<sup>-1</sup>; T<sub>4</sub> - STFD + Lime

@ 0.1 LR; T<sub>5</sub> - STFD + Sulphur @ 30 kg ha<sup>-1</sup>; T<sub>6</sub> - STFD + Biofertilizer (*Azotobacter* + *Azospirillum* + *PSB* @ 4 kg ha<sup>-1</sup> each); T<sub>7</sub> - STFD + GM with cowpea + FYM @ 5 t ha<sup>-1</sup>; T<sub>8</sub> - STFD + GM with cowpea + Lime @ 0.1 LR; T<sub>9</sub> - STFD + FYM @ 5 t ha<sup>-1</sup> + Lime @ 0.1 LR; T<sub>10</sub> - STFD + GM with cowpea + FYM @ 5 t ha<sup>-1</sup> + Lime @ 0.1 LR; T<sub>11</sub> - STFD + GM with cowpea + FYM @ 5 t ha<sup>-1</sup> + Sulphur @ 30 kg ha<sup>-1</sup>; T<sub>12</sub> - STFD + GM with cowpea + FYM @ 5 t ha<sup>-1</sup> + Biofertilizer (*Azotobacter* + *Azospirillum* + *PSB* @ 4 kg ha<sup>-1</sup> each). The experiment was evaluated in randomized complete block design with three replications. Maize hybrid Kaveri as main crop and cowpea as green manure crop were sown during rainy season. Maize was sown with a spacing of 60cm x 30cm and seed rate of 15 kg ha<sup>-1</sup>. Cowpea was sown between two rows of maize as green manure crop with a spacing of 30cm x 15cm and seed rate of 10 kg ha<sup>-1</sup> taking into consideration that the cowpea plant population is 50 per cent of normal sole cowpea. In maize crop FYM @ 5 t ha<sup>-1</sup> was applied at the time of last ploughing as per the treatment. Soil test fertilizer dose, lime as CaCO<sub>3</sub> @ 5 t ha<sup>-1</sup>, sulphur @ 30 kg ha<sup>-1</sup>, biofertilizers [*Azotobacter* + *Azospirillum* + *PSB* (1:1:1) @ 4 kg ha<sup>-1</sup> each] were applied to the crop as per the treatments. Full dose of P, K and 25% N in form of DAP, MOP and Urea were applied as basal and rest 50% N and 25% N at first and 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<sup>-1</sup>. 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 + GM (cowpea) + FYM + Biofertilizers (T<sub>12</sub>) resulted significantly the tallest plant height of 213.7 cm at harvest followed by the application of STFD + GM (cowpea) + FYM + Sulphur (T<sub>11</sub>) (208.2 cm). The lowest plant height was recorded when the maize plant was grown with chemical Fertilizers only, T<sub>1</sub> (192.7 cm). The tallest plants due to conjunctive application of green 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 [8]. 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 + GM (cowpea) + FYM + Biofertilizers recorded significantly highest value of LAI (5.19) at 80 days after sowing followed by the application of STFD + GM (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 [9,10]. Treatment T<sub>12</sub> recorded the highest (250.5 g plant<sup>-1</sup>) dry matter accumulation followed by T<sub>11</sub> (241.9 g plant<sup>-1</sup>). The highest dry matter accumulation in T<sub>12</sub> 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 [9,11].

### 3.2 Yield Attributes

The cob length was significantly higher (24.0 cm) in T<sub>12</sub> followed by T<sub>11</sub> (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<sub>12</sub>. Similar results were obtained in case of cob girth. The highest number (1.3) of cobs plant<sup>-1</sup> was recorded in T<sub>12</sub> whereas the lowest number of cobs plant<sup>-1</sup> (1.1) was recorded with soil test fertilizer dose (T<sub>1</sub>). 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<sup>-1</sup> (516.2) was the highest with application of (STFD + GM (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<sup>-1</sup> [12]. 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 [13]. The highest grain weight cob<sup>-1</sup> was 125.7 g cob<sup>-1</sup> which was exhibited by application of STFD + GM (cowpea) + FYM + Biofertilizers followed by the treatment of STFD + GM (cowpea) + FYM + Sulphur (110.1 g cob<sup>-1</sup>). The lowest grain weight cob<sup>-1</sup> of 63.9 g was recorded by the control treatment (T<sub>1</sub>) in the mean data of two years. The increase in grain weight cob<sup>-1</sup> might be due to increased availability of Zinc and phosphorous like nutrients [14]. Similar beneficial effect of organic manures on different growth and yield attributes were also reported by [15].

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 T<sub>12</sub> which was followed by T<sub>11</sub> (255.6 g). Similar observations were recorded by [16].

### 3.3 Grain and Stover Yield

The data presented in Table 3 showed that significantly highest grain yield (73.8 q ha<sup>-1</sup>) in hybrid maize was obtained with the application of STFD + GM (cowpea) + FYM + Biofertilizers. On the other hand the least grain yield (53.9 q ha<sup>-1</sup>) was registered with STFD alone. The percent increase of highest grain yield over the control is 36.9 %. Increase in grain yield of maize owing to integrated 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 [17,18]. 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 [19,20]. Similar trend was observed for stover yield too. The stover yield was 108.8 q ha<sup>-1</sup> with STFD + GM (cowpea) + FYM @ 5 t ha<sup>-1</sup> + Biofertilizers (*Azotobacter* + *Azospirillum* + *PSB* (1:1:1) @ 4 kg ha<sup>-1</sup> each), it was the lowest 97.1 q ha<sup>-1</sup> 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 [21]. 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 + GM (cowpea) + FYM @ 5 t ha<sup>-1</sup> + Biofertilizers (*Azotobacter* + *Azospirillum* + *PSB* (1:1:1) @ 4 kg ha<sup>-1</sup> each). 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 [22-24].

### 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<sup>-1</sup>, net return of Rs. 50,838 ha<sup>-1</sup> were recorded with application of soil test fertilizer dose with green manure (cowpea), FYM @ 5 t ha<sup>-1</sup> and biofertilizer (*Azotobacter* + *Azospirillum* + *PSB* @ 4 kg ha<sup>-1</sup> each). Similar result was also reported by [25]. But, the highest return rupee<sup>-1</sup> invested (1.99) was obtained with soil test fertilizer dose with green manure (cowpea) and lime. This might be due to lower cost of cultivation. Some workers [26-28] reported increase in gross expenditure due to high cost of organic manures.

**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 <sup>-1</sup> )
T <sub>1</sub> - Soil Test Fertilizer Dose (STFD)	192.7	4.2	191.4
T <sub>2</sub> - STFD + GM (cowpea)	200.8	4.7	203.0
T <sub>3</sub> - STFD + FYM @ 5 t ha <sup>-1</sup>	205.6	4.7	205.3
T <sub>4</sub> - STFD + Lime @ 0.1 LR	205.9	4.7	209.2
T <sub>5</sub> - STFD + Sulphur @ 30 kg ha <sup>-1</sup>	199.6	4.4	202.1
T <sub>6</sub> - STFD + Biofertilizers [ <i>Azotobacter</i> + <i>Azospirillum</i> + <i>PSB</i> (1:1:1) @ 4 kg ha <sup>-1</sup> each]	202.7	4.7	204.5
T <sub>7</sub> - STFD + GM (cowpea) + FYM @ 5 t ha <sup>-1</sup>	205.3	4.8	217.5
T <sub>8</sub> - STFD + GM (cowpea) + Lime @ 0.1 LR	206.3	4.8	213.9
T <sub>9</sub> - STFD + FYM + Lime @ 0.1 LR	205.8	4.8	225.3
T <sub>10</sub> - STFD + GM (cowpea)+ FY M @ 5 t ha <sup>-1</sup> + Lime @ 0.1 LR	207.2	4.9	234.3
T <sub>11</sub> - STFD + GM (cowpea) + FYM @ 5 t ha <sup>-1</sup> + Sulphur @ 30 kg ha <sup>-1</sup>	208.2	5.0	241.9
T <sub>12</sub> - STFD + GM (cowpea) + FYM @ 5 t ha <sup>-1</sup> + Biofertilizers [ <i>Azotobacter</i> + <i>Azospirillum</i> + <i>PSB</i> (1:1:1) @ 4 kg ha <sup>-1</sup> each]	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 <sup>-1</sup>	No. of grains cob <sup>-1</sup>	1000 grain wt (g)	Grain weight (g cob <sup>-1</sup> )
T <sub>1</sub> - Soil Test Fertilizer Dose (STFD)	16.8	13.3	12.9	293.5	232.8	63.9
T <sub>2</sub> - STFD + GM (cowpea)	18.1	14.2	13.9	330.7	244.8	76.5
T <sub>3</sub> - STFD + FYM @ 5 t ha <sup>-1</sup>	18.7	14.4	14.6	361.4	247.1	84.6
T <sub>4</sub> - STFD + Lime @ 0.1 LR	18.9	14.6	14.8	372.2	247.5	86.5
T <sub>5</sub> - STFD + Sulphur @ 30 kg ha <sup>-1</sup>	18.0	13.6	13.5	320.0	244.2	74.6
T <sub>6</sub> - STFD + Biofertilizers [ <i>Azotobacter</i> + <i>Azospirillum</i> + <i>PSB</i> (1:1:1) @ 4 kg ha <sup>-1</sup> each]	18.5	14.3	14.2	347.7	246.5	81.0
T <sub>7</sub> - STFD + GM (cowpea) + FYM @ 5 t ha <sup>-1</sup>	19.5	14.9	15.3	397.0	250.7	94.6
T <sub>8</sub> - STFD + GM (cowpea) + Lime @ 0.1 LR	20.9	15.5	16.1	436.8	254.6	103.7
T <sub>9</sub> - STFD + FYM + Lime @ 0.1 LR	20.2	15.2	14.8	385.9	252.1	91.6
T <sub>10</sub> - STFD + GM (cowpea)+ FY M @ 5 t ha <sup>-1</sup> + Lime @ 0.1 LR	22.0	16.4	16.5	452.1	255.0	106.5
T <sub>11</sub> - STFD + GM (cowpea) + FYM @ 5 t ha <sup>-1</sup> + Sulphur @ 30 kg ha <sup>-1</sup>	22.3	16.7	16.8	462.2	255.6	110.1
T <sub>12</sub> - STFD + GM (cowpea) + FYM @ 5 t ha <sup>-1</sup> + Biofertilizers [ <i>Azotobacter</i> + <i>Azospirillum</i> + <i>PSB</i> (1:1:1) @ 4 kg ha <sup>-1</sup> each]	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 <sup>-1</sup> )	Stover yield (q ha <sup>-1</sup> )	Harvest Index (%)	Gross Return (Rs. ha <sup>-1</sup> )	Net Return (Rs. ha <sup>-1</sup> )	Return rupee <sup>-1</sup> invested (Rs.)
T <sub>1</sub> - Soil Test Fertilizer Dose (STFD)	53.9	97.1	35.7	75437	31919	1.73
T <sub>2</sub> - STFD + GM (cowpea)	59.8	100.4	37.3	83655	37972	1.83
T <sub>3</sub> - STFD + FYM @ 5 t ha <sup>-1</sup>	61.4	102.4	37.5	85923	37405	1.77
T <sub>4</sub> - STFD + Lime @ 0.1 LR	61.6	103.2	37.4	86296	40748	1.89
T <sub>5</sub> - STFD + Sulphur @ 30 kg ha <sup>-1</sup>	58.8	103.1	36.3	82269	36601	1.80
T <sub>6</sub> - STFD + Biofertilizers [ <i>Azotobacter</i> + <i>Azospirillum</i> + <i>PSB</i> (1:1:1) @ 4 kg ha <sup>-1</sup> each]	61.0	102.8	37.2	85395	40027	1.88
T <sub>7</sub> - STFD + GM (cowpea) + FYM @ 5 t ha <sup>-1</sup>	64.6	101.8	38.8	90393	39710	1.78
T <sub>8</sub> - STFD + GM (cowpea) + Lime @ 0.1 LR	67.8	103.6	39.5	94855	47142	1.99
T <sub>9</sub> - STFD + FYM + Lime @ 0.1 LR	66.0	102.3	39.2	92335	41787	1.83
T <sub>10</sub> - STFD + GM (cowpea)+ FY M @ 5 t ha <sup>-1</sup> + Lime @ 0.1 LR	69.6	105.2	39.8	97384	44671	1.85
T <sub>11</sub> - STFD + GM (cowpea) + FYM @ 5 t ha <sup>-1</sup> + Sulphur @ 30 kg ha <sup>-1</sup>	69.9	105.7	39.8	97893	45060	1.85
T <sub>12</sub> - STFD + GM (cowpea) + FYM @ 5 t ha <sup>-1</sup> + Biofertilizers [ <i>Azotobacter</i> + <i>Azospirillum</i> + <i>PSB</i> (1:1:1) @ 4 kg ha <sup>-1</sup> each]	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

#### 4. CONCLUSION

Application of soil test fertilizer dose with green manure (cowpea), FYM @ 5 t ha<sup>-1</sup> and biofertilizer (*Azotobacter* + *Azospirillum* + PSB @ 4 kg ha<sup>-1</sup> each) in hybrid maize produced the significantly highest grain yield of 73.8 q ha<sup>-1</sup> with net return of Rs. 50838 ha<sup>-1</sup> and return rupee<sup>-1</sup> invested 1.97.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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