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Residual Effect of Integrated Nutrient Management in *Kharif* Maize (*Zea mays* L.) on Growth and Yield of Toria (*Brassica campestris* L. var. Toria) during *Rabi* Season 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 (OUAT), Semiliguda of Koraput district under Eastern Ghat High Land zone of Odisha in acidic soil during two consecutive *rabi* seasons of 2016-17 and 2017-18 to study the residual effect of integrated nutrient management in maize on succeeding toria crop. 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 based fertilizer with green leaf manure (cowpea), FYM @ 5 t ha^{-1} and biofertilizer (*Azotobacter* + *Azospirillum* + *PSB* @ 4 kg ha^{-1} each) to maize crop registered maximum residual effect thereby resulted significantly highest seed yield (6.3 q ha^{-1}) and stover yield (11.1 q ha^{-1}) of toria with a net monetary return of Rs. 7025 ha^{-1} and benefit cost ratio of 1.38.

Keywords: Residual; growth; yield; INM; toria.

1. INTRODUCTION

"Oilseeds are the second-most significant crop after cereals for the agricultural economy. They supply vital fatty acids requirement, oil cakes used to make cattle feed and are also popular in pharma, biofuel and oleochemical industries. In India, rapeseed and mustard are the second most valuable edible oilseed crops. Toria (*Brassica campestris* var. toria) is a short-duration crop used as a catch crop in the tarai region of Uttar Pradesh, Assam and Odisha" [1]. "The rapeseed-mustard, which contributes nearly 80% of the total *rabi* oilseed production, is a vital component in edible oil sector. Brassica crops are grown in a rainfed, resource-poor environment. Rapeseed mustard contributes greatly to small and marginal farmers' livelihoods as they rely heavily on it, especially in rainfed areas" [2]. "India is the biggest producer in the world, with 6.32 million hectares of land used to grow Brassica, which accounts for about 7.39 million tonnes of total world production" [3].

"Toria is an important oilseed crop of Odisha after harvest of *kharif* paddy. The rapeseed-mustard crops are diverse in their agro-climatic requirements and crop management practices. In Odisha, rapeseed and mustard is grown in an area of about 0.116 million hectares that produces 0.049 million tonnes with a productivity of 422 kg ha^{-1} which is much below the national average of 1176 kg ha^{-1}" [4,5].

"The soils of Odisha are mostly deficient in nitrogen, phosphorus and micronutrients like boron, zinc and molybdenum where 80 percent of soils are acidic in nature". [6] "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)" [7]. "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" [8,9]. "The dual use of organic and inorganic ameliorants reduces Al and Fe toxicity while also increasing nutrient availability, resulting in superior crop growing conditions in these soils. Toria 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" [7].

"Since toria is cultivated mainly in the rainfed regions, the productivity of this crop depends on the amount of rainfall and its distribution pattern as well as residual soil moisture during the crop

growing season. Cultivation of toria becomes less remunerative to the farmers under marginal resource situations, which results in a big gap between requirement and production of toria in India. Therefore, integrated nutrient management approach can be a key in stabilizing and increasing the production and productivity of toria. Integrated nutrient management has always been found to be a better option in intensive cropping system compared to chemical-based fertilizer management practices. Additionally, the organic component of INM also helps in soil moisture conservation by increasing the water holding capacity of the soil and moderating soil temperature" [10]. The present investigation was, therefore, conducted to study the residual effect of integrated nutrient management in *kharif* maize on growth and yield of toria during *rabi* season in Odisha, India.

2. MATERIALS AND METHODS

2.1 Experimental Site

To achieve the objectives of the programme, a field experiment was conducted at Regional Research and Technology Transfer Station, Odisha University of Agriculture and Technology, Semiliguda under Koraput district in Eastern Ghat High Land zone of Odisha during two consecutive *rabi* seasons of 2016-17 and 2017-18. 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 region is marked by its warm and humid climate with an average annual rainfall of 1500 mm, most of which is received from middle of June to middle of October.

2.2 Soil Characteristics

The soil samples collected from field were air dried, grounded with mortar pestle and sieved in 2 mm sized mesh. The soil of experimental site was red, sandy loam in texture and strongly acid in reaction (pH= 5.06) with medium soil organic carbon (7.13 g kg^{-1}), medium available N (472.0 kg ha^{-1}), high available P (33.20 kg ha^{-1}), high available K (313.0 kg ha^{-1}), low available S (11.45 kg ha^{-1}) and low available Ca (0.6 meq $100g^{-1}$).

2.3 Experimental Design

The experiment consists of twelve treatments *viz.* T_1 - Soil test based fertilizer (STBF); T_2 - STBF + Green Leaf Manure (GLM) with cowpea; T_3 - STBF + FYM @ 5 t ha^{-1};T_4 - STBF + Lime; T_5 - STBF + Sulphur; T_6 - STBF + Biofertilizer; T_7 - STBF + GLM with cowpea + FYM @ 5 t ha^{-1}; T_8 - STBF + GLM with cowpea + Lime; T_9 - STBF + FYM + Lime; T_{10} - STBF + GLM with cowpea + FYM @ 5 t ha^{-1} + Lime; T_{11} - STBF + GLM with cowpea + FYM @ 5 t ha^{-1} + Sulphur; T_{12} - STBF + GLM with cowpea + FYM @ 5 t ha^{-1} + Biofertilizer (Table 1). The experiment was evaluated in randomized block design with three replications for statistical analysis. Maize hybrid Kaveri as main crop and cowpea as green leaf manure crop were sown during *kharif* 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 the 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 and 25% N in form of DAP, MOP and Urea were applied as basal and rest 50% N and 25% N at first & second earthing up respectively were applied to maize crop. Toria (var. Anuradha) was sown in the same plot with a row spacing of 30 cm using a seed rate of 7.5 kg ha^{-1} after harvest of maize. Plant to plant spacing of 10 cm was maintained by thinning operation at 21 DAS. The periodical biometric and post harvest observations were taken at regular interval.

2.4 Statistical Analysis

"The experimental data collected during the crop growth and harvest were analysed statistically following the procedure as described by" Gomez et al. [11]. 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 toria. Critical difference (CD) was done at P=0.05.

3. RESULTS AND DISCUSSION

3.1 Effect on Growth Parameters

Plant height of toria was influenced by different treatments of organic and inorganic fertilizers combinations (Table 1). Residual effect of treatment with STBF + GLM (cowpea) + FYM +

Biofertilizers resulted significantly the tallest plants of 87.5 cm at harvest followed by the treatment with STBF + GLM (cowpea) + FYM + Sulphur which resulted in plant height of 81.7 cm. The lowest plant height was recorded in control where only Soil Test Fertilizer Dose (STBF) was applied (63.4 cm). "The tallest plants due to conjunctive application of green leaf manure (cowpea), FYM and biofertilizer along with STBF 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" [12].

"Leaf area index of toria was influenced by different treatments of organic and inorganic fertilizers combinations applied in maize" [13]. The data presented in Table 1 revealed that 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 STBF + GLM (cowpea) + FYM + Biofertilizers recorded significantly highest value of LAI (2.45) at 40 days after sowing followed by the application of STBF + GLM (cowpea) + FYM + Sulphur (2.28). "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" [13].

Number of branches per plant of toria was influenced by different treatments of organic and inorganic fertilizers combinations (Table 1). Residual effect of treatment STBF + GLM (cowpea) + FYM + Biofertilizers resulted significantly highest number of both primary (4.3) and secondary (4.8) branches per plant at harvest. The least number of both primary and secondary branches per plant (2.5 and 3.3 respectively) was recorded in control at harvest where only chemical Soil Test Based Fertilizer was applied. The highest number of branches per plant with conjunctive application of green leaf manure (cowpea), FYM and biofertilizer along with STBF 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.

The data pertaining to the dry matter accumulation presented in Table 1 showed that the treatment receiving STBF + GLM (cowpea) + FYM + Biofertilizers recorded the highest (16.2 g plant^{-1}) dry matter accumulation followed by the treatment with STBF + GLM (cowpea) + FYM + Sulphur (15.5 g plant^{-1}). "The highest dry matter accumulation due to application of STBF + GLM (cowpea) + FYM + Biofertilizers might be attributed to the greater availability of applied nutrients and higher uptake of primary nutrients by toria from the residue of combined application of organic and inorganic sources of nutrients" [14].

The data presented in Table 1 revealed that the treatment receiving STBF + GLM (cowpea) + FYM + Biofertilizers recorded highest value of crop growth rate (18.5 g m^{-2} day^{-1}) at 40-55 days after sowing followed by the application of STBF + GLM (cowpea) + FYM + Sulphur (17.9 g m^{-2} day^{-1}). The highest crop growth rate might be due to greater availability of soil nutrient throughout the growth period from the combined application of organic and inorganic sources of nutrient.

3.2 Yield Attributes

The data presented in Table 2 revealed that highest values for yield attributes such as number of siliqua per plant (137.4), length of siliqua (5.5 cm), number of seeds per siliqua (12.5) and 1000 seed weight (3.8 g) were recorded in toria with residual effect of the treatment STBF + GLM (cowpea) + FYM + Biofertilizers. Least values for yield attributes such as number of siliqua per plant (56.9), length of siliqua (3.7 cm), number of seeds per siliqua (7.4) and 1000 seed weight (2.9 g) were recorded with residual effect of the control i.e. soil test fertilizer dose only. Similar result was also reported by Sau [1]. The number of siliqua per plant, length of siliqua, number of seeds per siliqua and 1000 seed weight 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 perusal of pooled data of 2016 and 2017 presented in Table 2 indicated that the days to 50% flowering (31.2) and days to maturity (70.1) were recorded maximum with application of STBF + GLM (cowpea) + FYM + Biofertilizers and minimum with application of soil test based fertilizer (25.7 and 63.0). When the required fertilizer doses were applied both in form of organic and inorganic sources in maize enhanced the maturity duration of succeeding toria crop mostly because of the slow release of nutrients from the organic sources and registering required soil fertility.

Table 1. Residual effect of integrated nutrient management in maize on growth parameters of toria in maize-toria cropping system during 2016-17 and 2017-18 (2 years pooled data)

Treatment	Plant Height (cm)	No. of branches plant^{-1}		Leaf Area Index (40 DAS)	Dry matter production (g plant^{-1})	CGR at 40-55 DAS (g m^{-2}day^{-1})
		Primary	Secondary			
T_1: STBF	63.4	2.5	3.3	1.65	12.4	16.8
T_2: STBF + GLM (cowpea)	68.3	2.7	3.4	1.84	13.8	16.7
T_3: STBF + FYM @ 5t ha^{-1}	70.7	2.9	3.6	1.93	14.4	17.2
T_4: STBF + Lime @ 0.1 LR	68.6	2.9	3.5	1.84	13.9	16.9
T_5: STBF + Sulphur @ 30 kg ha^{-1}	66.6	2.5	3.4	1.76	12.9	16.6
T_6: STBF + Biofertilizers	67.1	2.6	3.4	1.80	13.4	16.5
T_7: STBF + GLM (cowpea) + FYM @ 5t ha^{-1}	75.6	3.3	3.9	2.04	14.9	17.4
T_8: STBF + GLM (cowpea) + Lime @ 0.1 LR	73.3	3.1	3.7	1.93	14.5	17.3
T_9: STBF + FYM @ 5t ha^{-1} + Lime @ 0.1 LR	78.1	3.5	4.0	2.14	14.6	17.6
T_{10}: STBF + GLM (cowpea) + FYM + Lime @ 0.1 LR	80.3	3.9	4.2	2.19	15.4	17.7
T_{11}: STBF + GLM (cowpea) + FYM @ 5t ha^{-1}+ Sulphur @ 30 kg ha^{-1}	81.7	4.0	4.3	2.28	15.5	17.9
T_{12}: STBF + GLM (cowpea) + FYM @ 5t ha^{-1} + Biofertilizers	87.5	4.3	4.8	2.45	16.2	18.5
SEm (±)	3.8	0.24	0.20	0.121	0.67	1.62
CD (p=0.05)	11.2	0.7	0.5	0.34	1.9	4.5

STBF: Soil Test Based Fertilizer; Biofertilizers: Azotobacter + Azospirillum + PSM (1:1:1) @ 4 kg ha^{-1} each; GLM: Green Leaf Manure

Table 2. Residual effect of integrated nutrient management in maize on yield attributes of toria in maize-toria cropping system during 2016-17 and 2017-18 (2 years pooled data)

Treatment	No. of siliqua plant^{-1}	Length of siliqua (cm)	No. of seeds siliqua^{-1}	Days to 50% flowering	Days to maturity	1000 seed wt. (g)
T_1: STBF	56.9	3.7	7.4	25.7	63.0	2.9
T_2: STBF + GLM (cowpea)	67.9	4.0	8.5	27.0	64.0	3.0
T_3: STBF + FYM @ 5t ha^{-1}	75.2	4.4	9.4	27.7	64.8	3.3
T_4: STBF + Lime @ 0.1 LR	70.9	4.3	8.7	27.3	64.3	3.2
T_5: STBF + Sulphur @ 30 kg ha^{-1}	61.7	3.8	8.0	26.5	63.8	3.0
T_6: STBF + Biofertilizers	65.1	3.9	8.3	26.8	63.7	3.0
T_7: STBF + GLM (cowpea) + FYM @ 5 t ha^{-1}	87.0	4.9	10.3	28.5	66.9	3.5
T_8: STBF + GLM (cowpea) + Lime @ 0.1 LR	79.5	4.6	9.7	28.2	65.6	3.4
T_9: STBF + FYM @ 5 t ha^{-1} + Lime @ 0.1 LR	94.3	5.1	10.5	29.2	67.8	3.6
T_{10}: STBF + GLM (cowpea) + FYM + Lime @ 0.1 LR	105.2	5.2	11.1	29.8	68.6	3.7
T_{11}: STBF + GLM (cowpea) + FYM @ 5 t ha^{-1}+ Sulphur @ 30 kg ha^{-1}	111.2	5.3	11.3	30.2	69.0	3.6
T_{12}: STBF + GLM (cowpea) + FYM @ 5 t ha^{-1} + Biofertilizers	137.4	5.5	12.5	31.2	70.1	3.8
SEm (±)	6.79	0.35	0.66	1.49	1.26	0.19
CD (p=0.05)	18.9	1.0	1.8	4.2	3.5	0.5

STBF: Soil Test Based Fertilizer; Biofertilizers: Azotobacter + Azospirillum + PSM (1:1:1) @ 4 kg ha^{-1} each; GLM: Green Leaf Manure

Table 3. Residual effect of integrated nutrient management in maize on seed yield and economics of toria in maize-toria cropping system during 2016-17 and 2017-18 (2 years pooled data)

Treatment	Seed 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: STBF	3.1	6.8	31.1	12058	-5443	0.68
T_2: STBF + GLM (cowpea)	3.9	7.9	32.7	15106	-2394	0.85
T_3: STBF + FYM @ 5 t ha^{-1}	4.4	8.5	34.0	17063	-438	0.96
T_4: STBF + Lime @ 0.1 LR	4.0	8.1	33.2	15652	-1848	0.88
T_5: STBF + Sulphur @ 30 kg ha^{-1}	3.7	7.7	32.3	14424	-3077	0.81
T_6: STBF + Biofertilizers	3.8	7.9	32.7	14879	-2622	0.84
T_7: STBF + GLM (cowpea) + FYM @ 5 t ha^{-1}	5.1	9.6	34.5	19838	2338	1.12
T_8: STBF + GLM (cowpea) + Lime @ 0.1 LR	4.8	9.1	34.4	18655	1155	1.05
T_9: STBF + FYM @ 5 t ha^{-1} + Lime @ 0.1 LR	5.2	9.7	34.9	20293	2793	1.14
T_{10}: STBF + GLM (cowpea) + FYM + Lime @ 0.1 LR	5.8	10.4	35.7	22477	4977	1.27
T_{11}: STBF + GLM (cowpea) + FYM @ 5 t ha^{-1} + Sulphur @ 30 kg ha^{-1}	5.9	10.5	35.6	22887	5387	1.29
T_{12}: STBF + GLM (cowpea) + FYM @ 5 t ha^{-1} + Biofertilizers	6.3	11.1	36.2	24525	7025	1.38
SEm (±)	0.38	0.50	2.16	1492	1492	0.084
CD (p=0.05)	1.1	1.4	6.0	4156	4156	0.23

STBF: Soil Test Based Fertilizer; Biofertilizers: Azotobacter + Azospirillum + PSM (1:1:1) @ 4 kg ha^{-1} each; GLM: Green Leaf Manure

3.3 Seed and Stover Yield

The data presented in Table 3 showed that significantly highest seed yield (6.3 q ha^{-1}) in toria was obtained with the residual effect of STBF + GLM (cowpea) + FYM + Biofertilizers applied to hybrid maize. On the other hand the least seed yield of 3.1 q ha^{-1} was registered with soil test based fertilizer treatment. "The percent increase of highest seed yield over the control is 103%. Increase in seed yield of toria 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" [1]. "The higher seed yield with integrated nutrient management treatments might be due to remarkable increase in yield components such as number of siliquae $plant^{-1}$ and number of seeds $siliquae^{-1}$. This is also due to adequate supply of photosynthates for development of sink and balanced nutrition with integrated nutrient management" [15].

"The experimental pooled data pertaining to the stover yield presented in Table 3 revealed that the highest stover yield (11.1 q ha^{-1}) was with the application of STBF + GLM (cowpea) + FYM + Biofertilizers. The lowest stover yield of 6.8 q ha^{-1} was recorded with control where soil test fertilizer dose had been applied. The improvement in stover yield might be due to significant increase in yield components like length of siliqua, number of siliqua per plant and number of seeds per siliqua which ultimately resulted into higher productivity" [16,17].

"The experimental pooled data of 2016 and 2017 on harvest index perused in Table 3 indicated that significantly highest harvest index was found with the application of STBF + GLM (cowpea) + FYM + Biofertilizers (36.2). The lowest harvest index was found in the control treatment of soil test fertiliser dose (31.1). Highest harvest index might be due to the combined application of organic with inorganic fertiliser which could able to supply nutrients to meet its requirement for long time as well as quick requirement at various stages" [18,19].

3.4 Economics

Data on economics as influenced by the residual effect of integrated nutrient management in hybrid maize on toria (Table 3) revealed that the highest gross return of Rs. 24,525 ha^{-1}, net return of Rs.7025 ha^{-1} were recorded with application of soil test based fertilizer recommendation 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 Samant and Pal [5,20]. The highest return $rupee^{-1}$ invested (1.38) was obtained with soil test based fertilizer 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 Udgata, Phonglosa and Dalei et al. [19,21,22].

4. CONCLUSION

It is not economical to grow toria crop under residual soil fertility without application of any fertilizer. However, residual effect of soil test based fertilizer with green leaf manure (cowpea), FYM @ 5 t ha^{-1} and biofertilizer (*Azotobacter* + *Azospirillum* + *PSB* @ 4 kg ha^{-1} each) applied in hybrid maize on toria recorded significantly highest seed yield of 6.3 q ha^{-1} with net return of Rs.7025 ha^{-1} and return $rupee^{-1}$ invested 1.38.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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