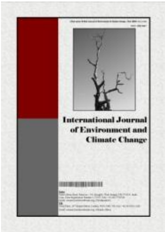

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Effect of Integrated Approach on Growth and Yield Attributes of Maize

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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

The investigation was carried out in sandy loam soils at college farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad during *kharif,* 2019. From results it can be concluded that growth parameters which were recorded at 30 days after sowing (DAS), Knee-high stage, 60 DAS and at harvest like SPAD, leaf area and at flowering parameters like days to 50% tasseling and silking were shown highest in treatment T_5-RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1} and also it was on par with T_7-RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages). Similar trends has been recorded in case of yield attributes like number of rows cob^{-1}, number of kernels row^{-1}, total no. of kernels cob^{-1}, kernels weight cob^{-1} and test weight.

Keywords: FYM; yield attributes; zinc; ZSB; $ZnSO_4$; SPAD.

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1. INTRODUCTION

Maize, also known as corn, is a cereal grain that was first grown in Central America. It is now the third most important cereal crop in the world and is called the 'Queen of Cereals' [1]. Fortification of staple foods is a globally accepted strategy to address micronutrient malnutrition in nutritionally vulnerable populations [2]. Being widely consumed, maize flour is a suitable vehicle for mass fortification [3].

Zinc is involved in a large number of enzymes as a cofactor. For example, it is involved in activation of different enzymes such as dehydrogenase, aldolase, isomerase, transphosphorase and DNA polymerase [4]. Zinc deficiency is a very important nutrient problem in the world's soils. Total Zn concentration is sufficient in many agricultural areas, but available Zn concentration is deficient because of different soil and climatic conditions. Soil pH, lime content, organic matter amount, clay type and amount and the amount of applied phosphorus fertilizer affect the available Zn concentration in soil [5]. Zinc deficiency rate was determined as a 30 % in the world [6]. In general attention towards the major nutrients is more than the secondary and micronutrients, but in maize zinc nutrition plays a major role in plant metabolism and yielding potential. However, less awareness about micronutrients application and indiscriminate use of major nutrients led to the imbalance in soil nutrient status and as a result micronutrient deficiency is noticed in many parts in general and among them zinc is particular. According to the recent survey, zinc deficiency in human nutrition is the most wide spread nutritional disorder, next to iron, vitamin 'A' and iodine. Nearly, 49% of the global population does not meet their daily-recommended intake of 15 mg day^{-1} of zinc for an adult and is one of the leading risk factors associated with diseases such as diarrhoea and retarded growth contributing to the death of 8,00,000 people each year [7]. Negative correlation between irrigation and phosphorous was observed with Zn uptake which leads to the reduction of Zn content in kernels, a major cause of Zn malnutrition among maize consumers.

This article briefs the nutrient bioavailability of added zinc. Target of maize enrichment for Zn contents could be achieved through different agronomic strategies. These strategies are discussed subsequently for usefulness to overcome the hidden hunger for Zn. Application of enriched compost with $ZnSO_4$, zinc solubilising bacteria (ZSB), zinc seed pelleting and foliar spray to growing plants react with native reserves of micronutrient elements and renders them available to the plants.

2. MATERIALS AND METHODS

The experiment was conducted during *Kharif*, 2019-2020 at College farm, Plot no. B-8, Block-B, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad. The geographical location of the experimental site was 17°19' 19.2" N Latitude, 78°24' 39.2" E Longitude with an altitude of 542.3 m above mean sea level. Agro-climatologically the area is classified as Southern Telangana Agro Climatic Zone of Telangana State. The total rainfall received during the cropping period was only 680.8 mm.

The treatment details include recommended dose of fertilizer Recommended Dose of Fertilizer (RDF) 200: 60: 50-N: P_2O_5: K_2O kg ha^{-1}) N was applied in three equal splits (at sowing, knee-high and tasseling stage), total P was applied as basal and K was applied in two equal splits (at sowing and tasseling stage). FYM was enriched with zinc solubilising bacteria (ZSB) @ 1 kg per 100 kg FYM for about 22 days before sowing i.e., T_2& T_7.Seed pelleting (1kg seed) was done by adding water with 3.6 g of $ZnSO_4$, after proper dissolving, polymer was added to above solution and made into slurry by thorough stirring. The slurry was added to 1 kg seed in a polythene cover and thoroughly mixed for 4-5 minutes and shade dried i.e., T_4& T_9.FYM is enriched with $ZnSO_4$ @ 50 kg ha^{-1} with 25 t FYM ha^{-1} for about 22 days before sowing i.e., T_5 & T_{10}.

2.1 Experimental Details

The field was ploughed twice with tractor drawn cultivator followed by levelling with rotavator. FYM alone was applied to $T_3$and T_8 treatments, FYM enriched with ZSB was applied to $T_2$and T_7treatments and FYM enriched with $ZnSO_4$ @ 50 kg ha^{-1} was applied to $T_5$and T_{10}treatments. Crop was sown on ridges. The recommended dose of fertilizers applied (N, P, and K @ 200: 60: 50 kg ha^{-1}). Maize hybrid nk-6240 @ 20 kg $ha^{-1}$was sown. In present experiment the spacing was 60 cm × 20 cm. Pre-emergence herbicide like atrazine 50% WP was sprayed @ 2-2.5 kg ha^{-1}. Intercultural operations like gap filling, thinning and weeding was done timely. Crop was entirely grown under rainfall. The crop was harvested at proper stage of maturity as determined by visual observations. Border rows from all sides of each plot were first harvested followed by net plot. Fresh and dry weights of cobs and stover were weighed separately. Shelling of cobs was done by tractor operated maize sheller machine. Biometric observations recorded were plant height, dry matter production, cob length, cob girth, grain and stover yield.

3. RESULTS AND DISCUSSION

3.1 Leaf Area (cm^2)

Leaf area is an important parameter that could affect crop response to added nutrients. Like total number of leaves, leaf area also has direct effect on growth and yield parameters of plant. It expresses the capacity of plants to trap solar energy for photosynthesis. It was observed that the rate of increase in leaf area was very slow in the initial stages of growth and thereafter increased up to crop harvest. The data related to leaf area at 30 DAS, knee high stage, 60 DAS and at harvest is presented in Table 1.

Leaf area was significantly influenced by integrated approach for zinc enrichment at knee high stage, 60 DAS and at harvest except at 30 DAS.

At 30 DAS, highest leaf area (979.33 cm^2) was recorded with T_9 {RDF +Seed pelleting + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)} while, the lowest leaf area (740.92 cm^2) was registered with T_3 {RDF + FYM (25 t ha^{-1})}.

At knee high stage, highest leaf area (1094.43 cm^2) was recorded with T_{10} {RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1} + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)} and it was on par with all other treatments but differed significantly with T_1 and T_6.The lowest leaf area (816.59 cm^2) was registered with T_1 {RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}} treatment.

At 60 DAS, highest leaf area (6850.73 cm^2) was recorded with T_5 {RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}} and was on par with T_7 (6497.34 cm^2) {RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)} while, the lowest leaf area (4784.29 cm^2) was registered with T_1{RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}} treatment. Similar trend was observed at harvest stage also.

Results showed an increasing trend in leaf area expansion at all stages of crop growth period similar to that of plant height and dry matter production. Increased in leaf area might be due to Zn application which led to increase in tryptophan amino acid and indole acetic acid hormone which are two main factors in leaf area expansion. Zinc had positive effect on biological activity, metabolism and stimulating the photosynthetic pigments and enzyme activity encouraged the vegetative growth of the plants, consequently increased the leaf area. The results are in conformity with findings of Wailare and Kesarwani [8], Anees et al. [9] and Mohsin et al. [10].

3.2 SPAD Readings (Chlorophyll Content)

Nitrogen status of plant can be determined by knowing the chlorophyll content in leaves, which can be measured by using a non-destructive simple portable device, SPAD meter. The data related to SPAD readings at 30 DAS, knee high stage, 60 DAS, and at harvest is presented in Table 2. Data revealed that, SPAD readings were significantly influenced by integrated approach at 60 DAS and at harvest only.

Keen observation of SPAD meter readings reveals that treatments were significantly influenced by SPAD meter readings at 60 DAS and at harvest. Observing data at 60 DAS, T_5 {RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}} treatment recorded highest (52.99) reading closely followed by T_7 {RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)}. However, both are on par with each other and other treatments except T_1, T_6 and T_8. Lowest reading (38.00) were recorded with T_1 {RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}} treatment. Similar trend was observed at harvest also.

It was observed that SPAD readings were high at all the stages of crop period and showed static decrease at harvest. This may be due to integrated application of nutrients that supplied more quantity of nitrogen which enhanced production of leaf N concentration and chlorophyll content that ultimately resulted in more SPAD reading. The synergistic effect of both nitrogen and zinc helped in rapid growth and development of plants as they help in photosynthesis and various plant biochemical processes which responds towards growth. Khidrapure et al. [11] and Priya et al. [12] reported the same.

3.3 Days to 50% Tasseling and Silking

The data related to days to 50 % tasseling and silking were significantly influenced by integrated approach due to treatments (Table 3). Data indicates that less number of days (55.67) was taken to attain 50 % tasseling with T_5 {RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}} and T_7 {RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)} and it was on par with T_2, T_3, T_9 and T_{10} treatments while, more number of days (58.33) taken to attain 50 % tasseling recorded with T_1 {RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}} treatment.

Table 1. Leaf area (cm^2 $plant^{-1}$) as influenced by integrated approach for zinc enrichment in maize

Treatments		Leaf area (cm^2 $plant^{-1}$)			
		30 DAS	Knee-high stage	60 DAS	At harvest
T_1 -	RDF alone (Control) [N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}]	771.13	816.59	4784.29	4992.42
T_2 -	RDF + Zinc Solubilising Bacteria (ZSB @ 1kg/100 kg FYM)	779.05	1066.16	5729.08	6671.48
T_3 -	RDF + FYM (25 t ha^{-1})	740.92	1041.48	5375.32	6300.43
T_4 -	RDF + Seed pelleting (3.6 g $ZnSO_4$ kg^{-1} seed)	946.29	1066.27	5548.09	6388.94
T_5 -	RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}	839.85	1037.63	6850.73	8651.05
T_6 -	RDF + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	772.91	826.58	5035.42	5469.57
T_7 -	RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	977.11	1054.78	6497.35	7779.08
T_8 -	RDF + FYM (25 t ha^{-1}) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	769.52	1007.22	5278.89	5688.26
T_9 -	RDF +Seed pelleting + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	979.33	1039.43	5340.84	5727.98
T_{10} -	RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1} + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	895.47	1094.43	6178.65	7558.41
SEm±		70.50	77.79	166.44	344.90
CD (p=0.05)		NS	232.90	498.35	1,032.70

Table 2. SPAD readings as influenced by integrated approach for zinc enrichment in maize

Treatments		SPAD readings			
		30 DAS	Knee-high stage	60 DAS	At harvest
T_1 -	RDF alone (Control) [N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}]	30.78	33.11	38.00	35.94
T_2 -	RDF + Zinc Solubilising Bacteria (ZSB @ 1kg/100 kg FYM)	27.75	40.05	49.30	46.31
T_3 -	RDF + FYM (25 t ha^{-1})	28.99	37.94	48.13	47.75
T_4 -	RDF + Seed pelleting (3.6 g $ZnSO_4$ kg^{-1} seed)	25.36	37.70	48.32	45.52
T_5 -	RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}	31.11	38.33	52.99	54.36
T_6 -	RDF + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	28.51	34.68	40.14	39.79
T_7 -	RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	30.02	38.66	50.56	47.93
T_8 -	RDF + FYM (25 t ha^{-1}) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	26.15	37.79	46.16	44.29
T_9 -	RDF +Seed pelleting + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	28.66	38.07	48.06	47.52
T_{10} -	RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1} + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	28.54	38.96	49.19	45.97
SEm±		2.08	1.58	1.90	1.78
CD (p=0.05)		NS	NS	5.69	5.34

Table 3. Days to 50% tasseling and silking as influenced by integrated approach for zinc enrichment in maize

Treatments		Days to 50 % tasselling	Days to 50 % silking
T_1 -	RDF alone (Control) [N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}]	58.33 d	65.00
T_2 -	RDF + Zinc Solubilising Bacteria (ZSB @ 1kg/100 kg FYM)	57.00	62.67
T_3 -	RDF + FYM (25 t ha^{-1})	57.33	63.00
T_4 -	RDF + Seed pelleting (3.6 g $ZnSO_4$ kg^{-1} seed)	57.67	64.00
T_5 -	RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}	55.67	61.00
T_6 -	RDF + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	58.00	64.33
T_7 -	RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	55.67	61.33
T_8 -	RDF + FYM (25 t ha^{-1}) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	57.67	63.67
T_9 -	RDF +Seed pelleting + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	56.00	62.33
T_{10} -	RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1} + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	56.33	62.33
SEm±		0.58	0.66
CD (p=0.05)		1.75	1.98

Data indicates that less number of days (61.00) required to reach 50 % silking was recorded with T_5 {RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}} and was on par with T_2, T_7, T_9 and T_{10} treatments. While more number of days (65.00) taken to 50 % silking with T_1 {RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}} treatment.

Advancements of phenological events like tasseling and silking in maize were recorded due to integrated application of organic and inorganic sources of plant nutrient. Because of readily available plant nutrients in balance form along with favourable soil environment resulted in faster growth and development of plants. Low availability of primary nutrients namely N, P,K and micronutrients in soil for plant absorption probably has slow down the growth rate in control plot was the possible reason for attaining all these developmental stages very late. Similar results were earlier reported by Halecha et al. [13], Wanniang and Singh [14].

3.4 Yield Attributes

Higher yield attributing characters like no. of rows cob^{-1}, no. of kernels row^{-1}, total no. of kernels cob^{-1}, kernel weight cob^{-1} and test weight (g) were recorded with treatments containing Zn along with organic manures like FYM and inorganic fertilizers. The increase in yield attributes due to application of zinc was caused by higher chlorophyll contents, and this had apparently a positive effect on photosynthetic activity, synthesis of metabolites and growth-regulating substances, oxidation and metabolic activities and ultimately better growth and yield of crop, which led to increase in yield attributes [9].

The above observations were recorded by using appropriate tools and implements. Data on yield attributes were presented in Table 4.

3.5 No. of Rows Cob^{-1}

The highest no. of rows per cob (14.80) was observed with T_7 {RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)} and was on par with T_2, T_5 and T_{10} treatments. The lowest no. of rows per cob (11.00) was recorded with T_1 {RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}} and T_6 {RDF + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)} treatments.

3.6 No. of Kernels Row^{-1}

Data on number of kernels per row were significantly influenced by integrated approach for zinc enrichment. The highest no. of kernels per row (35.60) was observed with T_5 {RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}} followed by T_7 which were on par with each other and with T_2 and T_{10} treatments. The lowest no. of kernels per row (25.07) was registered with T_1 {RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}} treatment.

Table 4. Yield attributes as influenced by integrated approach for zinc enrichment in maize

Treatments		Yield attributes				
		No. of rows cob^{-1}	**No. of kernels row^{-1}**	**Total no. of kernels cob^{-1}**	**Kernels weight cob^{-1} (g)**	**Test weight (g)**
T_1 -	RDF alone (Control) [N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}]	11.27	25.07	340.88	70.78	21.25
T_2 -	RDF + Zinc Solubilising Bacteria (ZSB @ 1kg/100 kg FYM)	13.80	32.53	433.20	105.28	26.14
T_3 -	RDF + FYM (25 t ha^{-1})	13.13	30.93	420.58	95.54	24.65
T_4 -	RDF + Seed pelleting (3.6 g $ZnSO_4$ kg^{-1} seed)	13.33	31.20	426.83	99.03	25.76
T_5 -	RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}	14.67	35.60	470.36	118.81	32.29
T_6 -	RDF + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	11.00	26.40	371.80	83.24 f	28.09
T_7 -	RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	14.80	33.93	436.73	117.50	30.70
T_8 -	RDF + FYM (25 t ha^{-1}) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	12.67	28.67	383.67	87.73	30.47
T_9 -	RDF +Seed pelleting + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	12.93	30.07	409.59	92.77	29.71
T_{10} -	RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1} + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	14.13	32.13	439.83	110.50	26.99
SEm±		0.44	1.07	15.14	3.68	1.76
CD (p=0.05)		1.31	3.21	45.34	11.02	5.26

The number of kernels row^{-1} emergence and development depends on environmental factors like vigour, nutrient provision in proper proportions that induce it, therefore different sources of fertilizers and their combinations create statistically significant differences in the treatments [15].

3.7 Total no. of Kernels Cob^{-1}

Number of kernels per cob is a vital yield determining factor and had direct influence on grain yield.

The highest total no. of kernels cob^{-1} (470.36) was observed with T_5 {RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}} followed by T_{10}, T_7, T_4 and T_2 which are on par with each other. The lowest total no. of kernels cob^{-1} (340.88) was registered with T_1 {RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}} treatment.

Results indicated that due to continuous supply of nutrients to plants under integrated approach management over plots with recommended dose of fertilizer alone was significantly influenced to yield attributes. Foliar application of zinc exerted significant influence when integrated with other application methods than applied alone. This is because that zinc application on foliage will increase the number of grains per cob due to better enzymes activity that might helped for easy translocation of assimilates from leaf to grain. Wailare and Kesarwani [8] and Anees et al. [9] were on same line of result.

3.8 Kernels Weight Cob^{-1} (g)

The highest kernel weight cob^{-1} (118.81 g) was observed with T_5 {RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}} closely followed by T_7 which were also on par each other and with T_{10} but significantly higher over all other treatments. The lowest kernel weight per cob (70.78 g) was registered with T_1 {RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}} treatment.

Higher kernel weight might be due to more availability of zinc by foliar spray which increases the enzyme activation and result in easily assimilate partitioning from leaf to grain. Maize grain weight was increased due to foliar application along with recommended dose of NPK and release of nutrients from FYM which also increased nutrient use efficiency. Similar findings were also earlier reported by Kumar et al. [15].

3.9 Test Weight (g)

The highest test weight (32.29 g) was observed with T_5 {RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}} closely followed by T_7 and was on par each other and other treatments except T_2, T_3, T_4 and T_{10} treatments. The lowest test weight (21.25 g) was registered with T_1 {RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}} treatment.

It was observed that there was linear relationship between test weight and maize grain yield. However, the minimum test weight was observed in control where biological yield recorded lowest. Due to the application of macro as well as micro nutrients, particularly $ZnSO_4$, plants received maximum nutrients throughout their growth period and nourished properly which resulted in maximum 100 kernel weight. Similar results were also earlier reported by Khan et al. [16].

4. CONCLUSION

The growth and yield attributes of maize were significantly high with the integrated application of chemical fertilizers, enriched FYM with ZSB or $ZnSO_4$ along with foliar spray @ 0.2 % $ZnSO_4$. Inspite of going for alone application of any of the above mentioned inputs it can be concluded from the study that integration of organics along with inorganics may be more beneficial to maize growers.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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