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Effect of Integrated Nutrient Management on Growth, Yield and Economics of Hybrid Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author MM carried out the experiment and performed statistical analysis. Further, author MM wrote the first draft of manuscript. Author SB helped author MM during the analysis and wrote the refined draft of manuscript. Author DD planned the experiment and guided as and when required. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out during summer season of 2018 at Instructional Farm, Jaguli, BCKV, West Bengal to study the effect of integrated nutrient management on growth, yield and economics in hybrid maize. The treatments were T_1-100% RDF (150:75:75 kg/ha N, P_2O_5 and K_2O) (control), T_2- 75% RDF+ Vermicompost @ 2t/ha, T_3-75% RDF+ Yeast Vinasse @ 2t/ha, T_4-75% RDF+ Vermicompost @ 2t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha, T_5-75% RDF+ Yeast Vinasse @ 2t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha, T_6-75% RDF+ Vermicompost @ 2t/ha+ Foliar application of $ZnSO_4$ @ 0.5% and T_7-75% RDF+ Yeast Vinasse @ 2t/ha+ Foliar application of $ZnSO_4$ @ 0.5% replicated thrice in RBD. The result of the experiment revealed that application of vermicompost @ 2 t/ha along with 75% RDF and 0.5% foliar application of $ZnSO_4$ (T_6) exhibited maximum plant height (250.97 cm), LAI (4.58), dry matter accumulation (1680.38 g/m^2), number of grains/cob (402.64), cob length (22.34 cm), grain yield (9.04 t/ha), stover yield (13.50 t/ha), net

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return (Rs.77112/ha), BCR (2.33) and uptake of N, P_2O_5 and K_2O (200.54, 66.45 and 119.12 kg/ha respectively) over application of 100% RDF. However, T_6 was statistically at par with the T_4 and T_7, which produced 8.94 and 8.75 t/ha grains respectively. Therefore, the study concluded that integrated application of vermicompost @ 2 t/ha along with 75% RDF and 0.5% foliar application of $ZnSO_4$ can be recommended for better grain yield and higher profit of summer maize.

Keywords: Economics; growth; INM; maize; nutrient uptake; yield.

1. INTRODUCTION

In India, maize is placed in 3rd position among the cereals in terms of its importance, after rice and wheat [1]. But from the last decade, the production peak of this crop is increasing very fast due to its demand as feed, better market price, wider adaptability and greater production potential of hybrids, and versatile uses in domestic, livestock and industrial sectors. Both production and consumption have grown at a compound annual growth rate of 5.5% and 4% respectively over the ten years from 2004-05 to 2013-14 [2]. Introduction of single cross hybrids have encouraged the farmers to keep the crop in the cropping system to maximize the profit. In the year of 2017-18 about 27.14 million metric tons production was recorded, contributing 9.7% of the total food-grain production of India [3]; but the productivity (2.5 mt/ha) lags behind the global average (5.5 mt/ha) [2]. One of main reasons of low productivity is the imbalance application of nutrients by the farmers. Indiscriminate and continuous application of macronutrients only through high analysis fertilizers causes micronutrients deficiencies, soil health deterioration and environmental pollutions [4]. Zinc deficiency is rated as the most wide spread problem in Indian soils due to less use of zinc by the farmers [5,6] and also in crops [7]. The beneficial effect of zinc on maize has already been reported by several Scientists [8,9]. Besides, in order to curtail down the environmental footprints and sharp rise of price associated with chemical fertilizers; organic sources of nutrients are now-a-days coming back as promising options which can be used in conjunction with inorganic fertilizer since they are balanced in nature. Integrated nutrient management (INM) with combination of organic manures and inorganic fertilizers may be beneficial to improve soil properties and higher productivity of crops. This could be achieved in sustainable manner without sacrificing soil health, environment safety and other natural resources [10]. Besides that, INM practices also helps in reduction of the production cost and increases the returns of the farmers [1]. Keeping these facts in mind, the present experiment was framed to study the effect of integrated nutrient management practices on hybrid maize during summer season.

2. MATERIALS AND METHODS

The field experiment was carried out in Instructional Farm (22°93' N latitude, 88°53' E longitude and 9.75 m above mean sea level) of Bidhan Chandra Krishi Viswavidyalaya, Jaguli, Nadia, West Bengal, India during summer season of 2018 to evaluate the effect of integrated nutrient management on growth, yield, nutrient uptake and economics of hybrid maize production. The experiment was conducted on medium land, Gangetic alluvial soil (order: *Inceptisol*), which belonged to the class of sandy loam with pH of 7.04, organic carbon of 0.60%, available nitrogen of 189.10 kg/ha, available phosphorus of 39.25 kg/ha and available potassium of 184.50 kg/ha and Zinc of 0.56 mg/kg of soil. Weather condition during the experimental period is represented in Figs. 1, 2 and 3. The experiment was laid out in randomized block design with three replication consisting of seven treatments (T_1: 100% RDF i.e. 150:75:75 kg/ha of N, P_2O_5, K_2O, T_2: 75% RDF+ vermicompost @ 2 t/ha, T_3: 75% RDF+ yeast vinasse @ 2 t/ha, T_4: 75% RDF+ vermicompost @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha, T_5: 75% RDF+ yeast vinasse @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha, T_6: 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% and T_7: 75% RDF+ yeast vinasse @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5%). Foliar application of $ZnSO_4$ @ 0.5% was done twice at 30 and 60 DAS. The crop was grown under irrigated condition with other standard agronomic and plant protection package of practices. The Medium duration hybrid maize variety 'P- 3396' was sown on 1st February, 2018 with 60 cm × 20 cm spacing in 4.8 m × 4 m size plot and the crop was harvested on 31st May, 2018. Nutrient contents of different organic sources as shown in Table 1 were applied during land preparation. Yeast vinasse, a by-product of bakery industries, can be a

potential source of organic as it contains a substantial amount of nutrients. It is prepared through evaporation and drying of semi-liquid rejected part derived from reverse osmosis after anaerobic and aerobic microbial digestion of residual liquid part of yeast fermentation [11]. The inorganic sources of nitrogen, phosphorus and potassium were supplied through urea, SSP and MOP respectively. As per the treatments, entire amount of P_2O_5, K_2O, 1/3rd of nitrogen and $ZnSO_4$ (soil application) were applied as basal and rest nitrogen was top dressed in two equal splits in 30 and 60 DAS.

Table 1. Nutrient contents (%) of the organic sources

Organic sources	N	P_2O_5	K_2O
Vermicompost	1.8	1	1.2
Yeast vinasse	1.92	0.24	9.02

Observations included plant height, leaf area index (LAI), dry matter accumulation, number of cobs/plant,.number of grains/cob, 100 grain weight, cob length, cob girth, grain yield, stover yield and nutrient uptake (N, P, K) of maize at harvest (120 DAS). Data collected from field as well in laboratory were statistically analyzed through analysis of variance method [12] and treatment means were compared according to critical differences (CD) at 5% level of significance as suggested by Gomez and Gomez [13]. Finally, cost of cultivation, gross and net returns and benefit-cost ratio (BCR) were calculated to investigate economic viability of maize production under various integrated nutrient management options.

3. RESULTS AND DISCUSSION

3.1 Growth Attributes

Experimental results revealed a significant variation of growth attributes of hybrid maize under different nutrient management options (Table 2). Application of 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_6) exhibited tallest maize plant (250.97 cm), followed by 75% RDF+ vermicompost @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha (T_4) (249.50 cm). Both the treatments remained statistically at par to each other, while the shortest plant (240.40 cm) was observed under application of 100% RDF (T_1). The result might be due to the fact that in INM, nitrogen from chemical fertilizer promoted the plant growth at early stages whereas organic sources of nutrition improved the growth at later stages. Use of vermicompost in INM exerted positive influence on plant growth due to presence of relatively readily available plant nutrients, growth enhancing substances and number of beneficial organisms [14]. Beneficial effect of inclusion of vermicompost as a part of INM on plant height was also observed by Kannan et al. [15] in maize, Mahapatra et al. [1] in babycorn, Kaur et al. [16] in wheat, Biswas et al. [17] in oat. Moreover, inclusion of Zn as a part of INM improved plant growth due to accelerated hormonal activity through its involvement in auxin metabolism.

Table 2. Effect of integrated nutrient management on growth attributes of hybrid maize

Treatments	Growth attributes		
	Plant height (cm)	LAI	Dry matter accumulation(g/m^2)
T_1: 100% RDF (150:75:75 kg/ha of N, P_2O_5, K_2O)	240.40	3.64	1219.27
T_2: 75% RDF+ vermicompost @ 2 t/ha	246.83	3.91	1360.99
T_3: 75% RDF+ yeast vinasse @ 2 t/ha	241.90	3.78	1351.31
T_4: 75% RDF+ vermicompost @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha	249.50	4.43	1582.30
T_5: 75% RDF+ yeast vinasse @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha	248.03	4.10	1484.27
T_6: 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5%	250.97	4.58	1680.38
T_7: 75% RDF+ yeast vinasse @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5%	248.93	4.39	1544.14
S.Em(±)	0.62	0.07	47.50
CD at 5%	1.81	0.20	140.11

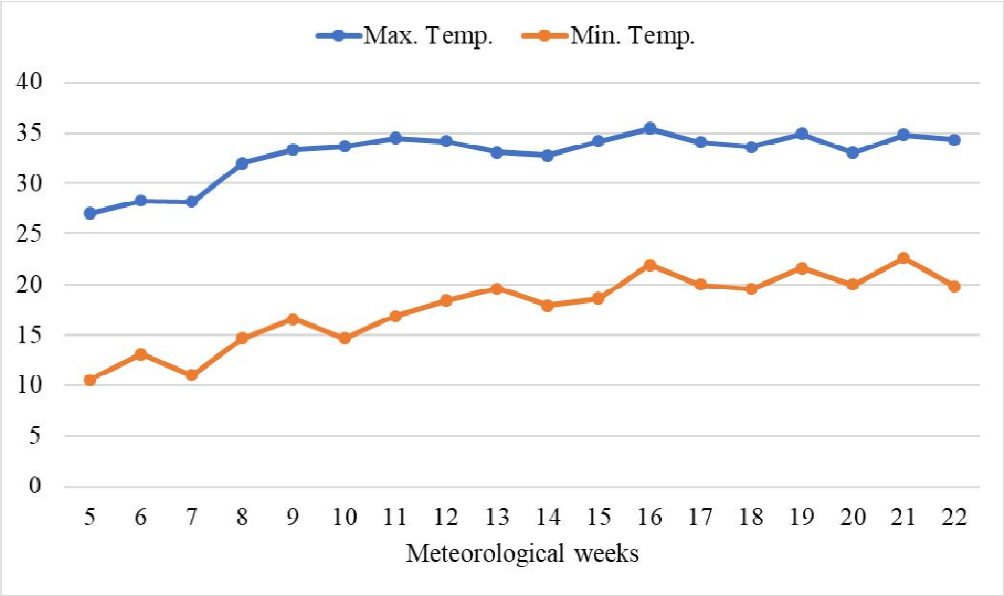

Fig. 1. Weekly variation in temperature (°C) during experiment (Feb-May, 2018)

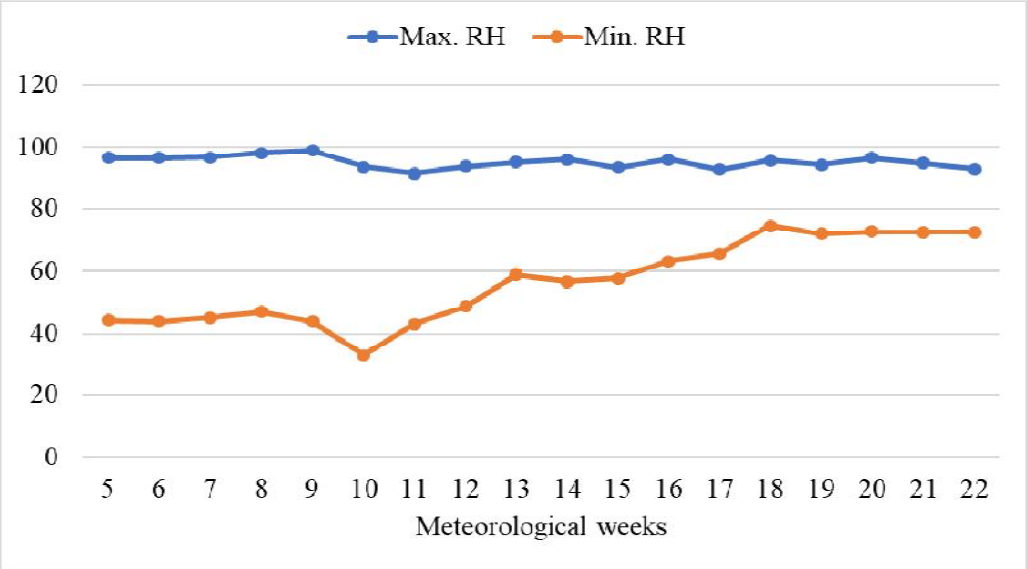

Fig. 2. Weekly variation in relative humidity (%) during experiment (Feb-May, 2018)

Leaf area index (LAI) and dry matter accumulation (DMA) at harvest also followed the similar trend of plant height (Table 2). Highest LAI (4.58) and DMA (1680.38 g/m^2) were recorded under soil application of 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_6). However, it was statistically at par with 75% RDF+ vermicompost @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha (T_4) (LAI: 4.43 and DMA: 1582.30 g/m^2) and soil application of 75% RDF+ yeast vinasse @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_7) (LAI: 4.39 and DMA: 1544.14 g/m^2). Application of 100% RDF (T_1) recorded lowest LAI (3.64) and DMA (1219.27 g/m^2). Application of vermicompost resulted in synthesis of phytohormones, vitamins and chlorophyll and helped the crop to intercept more solar radiation reflected on higher leaf area index in maize. Moreover, the use of Zn improved LAI of maize by synthesizing tryptophan which is a precursor of growth hormones like auxin and indole acetic

acid (IAA) and thereby, promoting enzyme activity and cell membrane integrity [18]. Increment of LAI was earlier reported by Mahapatra et al. [1] in babycorn under of vermicompost along with biofertilizers and micronutrients, Kaur et al. [16] in wheat under application of 75% NPK + vermicompost @ 2.5 t/ha+ *azotobacter* and Biswas et al. [17] in oat under application of 75% inorganic and 25% organic (vermicompost) sources of nutrients. Improved plant height and LAI under INM increased the light interception, absorption and utilization of solar radiation and thus enhanced photosynthesis which was reflected in dry matter production. Further, the slow release of nutrients associated with vermicompost might have resulted in higher concentration of nutrients in plant cells resulting in higher dry matter accumulation. The results were in conformity with the findings of Kumar et al. [19] in maize, Mahapatra et al. [1] in babycorn, Kaur et al. [16] in wheat and Biswas et al. [20] in oat.

3.2 Yield Attributes and Yield

The results showed that nutrient management practices significantly influenced all the yield attributes and yield of hybrid maize except no. of cobs/plant and 100 grain weight (Table 3). However, the maximum no. of cobs/plant (1.11) and 100 grain weight (28.78 g) were obtained with the application of 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_6) and 75% RDF+ vermicompost @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha (T_4) respectively, while minimum no. of cobs/plant (1.03) and 100 grain weight (28.37 g) were recorded under application of 100% RDF (T_1). Kumar et al. (2007) observed high cob numbers/plant and 100 grain weight in maize with 100% RDF and 2.5 t/ha vermicompost under rainfed condition. Kannan et al. [15] also found high 100 seed weight of maize under INM practice comprising RDF and vermicompost. Later, Mahapatra et al. [1] noticed high cob numbers/plant with the use of INM covering chemical fertilizers along with vermicompost, biofertilizers and micronutrients in babycorn. Similarly, maximum no. of grains/cob (402.64) was exhibited under application of 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_6) which remained statistically at par with 75% RDF+ vermicompost @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha (T_4) (388.22) and 75% RDF+ yeast vinasse @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_7) (382.13). Minimum no. of grains/cob (326.59) was observed under application 100% RDF (T_1). The result corroborated the findings of Kumar et al. [19] and Kannan et al. [15]. Cob length and girth also showed positive response under INM. Maximum cob length (22.34 cm) was observed with 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_6), which did not show statistically any variation with 75% RDF+ vermicompost @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha (T_4) (21.53 cm) and 75% RDF+ yeast vinasse @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_7) (20.93 cm). Conversely,

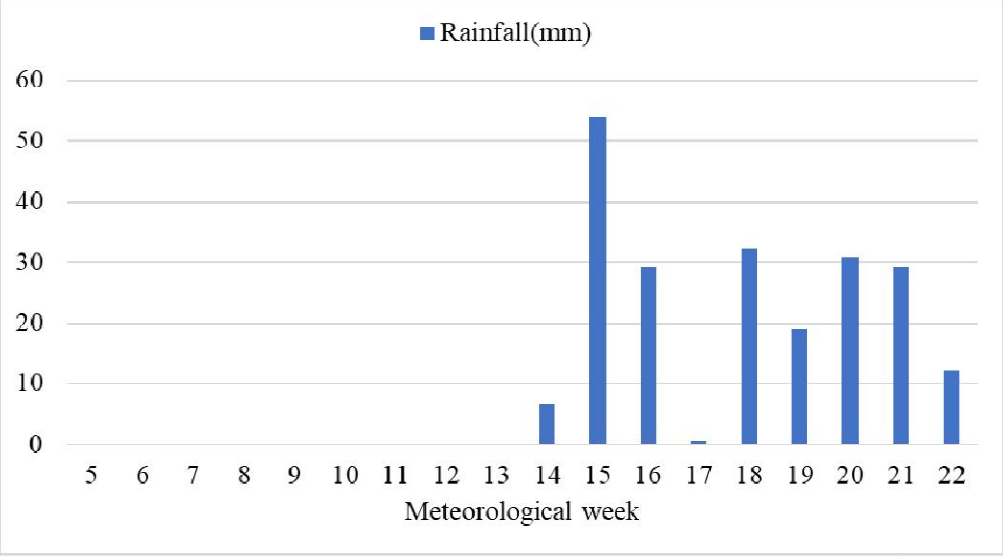

Fig. 3. Weekly variation in rainfall (mm) during experiment (Feb-May, 2018)

Table 3. Effect of Integrated Nutrient Management (INM) on yield attributes and yields of hybrid maize

Treatments	No. of cobs/plant	No. of grains/cob	100 grain weight (g)	Cob length (cm)	Cob girth (cm)	Grain yield (t/ha)	Stover yield (t/ha)
T_1: 100% RDF (150:75:75 kg/ha of N, P_2O_5, K_2O)	1.03	326.59	28.37	19.04	15.20	7.38	10.86
T_2: 75% RDF+ vermicompost @ 2 t/ha	1.07	343.18	28.40	20.63	15.59	8.09	11.93
T_3: 75% RDF+ yeast vinasse @ 2 t/ha	1.06	342.41	28.39	20.11	15.17	7.93	11.69
T_4: 75% RDF+ vermicompost @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha	1.12	388.22	28.78	21.53	18.21	8.94	13.36
T_5: 75% RDF+ yeast vinasse @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha	1.10	359.17	28.42	20.62	16.96	8.63	12.89
T_6: 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5%	1.11	402.64	28.63	22.34	18.14	9.04	13.50
T_7: 75% RDF+ yeast vinasse @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5%	1.08	382.13	28.46	20.93	17.94	8.75	13.22
S.Em(±)	0.023	8.39	0.20	0.51	0.14	0.10	0.12
CD at 5%	NS	26.16	NS	1.51	0.42	0.31	0.36

the minimum length of cob (19.04 cm) was noticed under application of 100% RDF (T_1). The results were in line with the findings of Kumar et al. [19], Mahapatra et al. [1], Ashoka et al. [21] and Patra and Biswas [22]. Cob girth was highest (18.21 cm) under use of 75% RDF+ vermicompost @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha (T_4), which was however statistically at par with soil application of 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_6) (18.14 cm) and soil application of 75% RDF+ yeast vinasse @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_7) (17.94 cm). On the other hand, application of 75% RDF+ yeast vinasse @ 2 t/ha produced lowest cob girth of hybrid maize (15.17 cm). Application of chemical fertilizers and vermicompost/yeast vinasse improved yield attributes of hybrid maize by supplying nutrients in a balanced form which reflected on high photosynthetic efficiency and consequently translocation of assimilates towards reproductive parts. Further, application of Zn imparted positively in increment of growth-regulating substances, oxidation and metabolic activities, chlorophyll content and thereby improved photosynthesis activity, partitioning and translocation of photosynthates, resulting in overall development of crop and improved yield attributes.

As a consequence of improvement of yield components, the highest grain yield (9.04 t/ha) of hybrid maize was achieved under T_6 treatment (75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5%) which was however statistically on a par with 75% RDF+ vermicompost @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha (T_4) (8.94 t/ha) and 75% RDF+ yeast vinasse @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_7) (8.75 t/ha). Lowest grain yield (7.38 t/ha) of hybrid maize was found under application of 100% RDF (T_1) (Table 3). The result was in agreement with the findings of Kannan et al. [15], Mahapatra et al. [1], Sanjivkumar [23] and Singh et al. [24]. Verma et al. [25] explained the effect of INM practice in maize under maize-wheat cropping system that improvement of grain yield under application of vermicompost might be due to the betterment in soil physico-chemical properties (viz., pH, bulk density, infiltration rate and microbial biomass carbon) and availability of nutrients and organic carbon in optimum way, which reflected on growth and yield enhancing characters of maize. Besides vermicompost, the positive effect of yeast vinasse on nutrient uptake and yield was reported by Biswas and Dutta [11] in potato. Enhancement of yield might be due to the effective utilization of applied nutrients which increased sink capacity and higher nutrients

uptake by crop. Mahapatra et al. [1] confirmed the beneficial role of application of micronutrients (Zn and B) on growth, yield attributes and yield of maize as those micronutrients influenced nutrient uptake, utilization and helped in partitioning and translocation of food materials to reproductive parts of the plant. Stover yield of hybrid maize also followed the identical trend of grain yield (Table 3) with maximum of 13.50 t/ha obtained from soil application of 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_6) which remained statistically indifferent with 75% RDF+ vermicompost @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha (T_4) (13.36 t/ha) and soil application of 75% RDF+ yeast vinasse @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_7) (13.22 t/ha). On the other hand, 100% RDF (T_1) showed poorest values of stover yield (10.86 t/ha). Integrated application of Zn along with organic and inorganic sources of nutrients might have increased the protoplasmic constituents and accelerated the process of cell division and elongation which in turn, resulted in increased growth attributes and stover yields. Similar types of result were earlier reported by Kumar et al. [19], Mahapatra et al. [1] and Rani [26] in maize.

3.3 Nutrient Uptake and Economics

Nutrient uptake by hybrid maize significantly varied with different nutrient management options (Table 4). Maximum N (200.54 kg/ha) and P (66.45 kg/ha) uptake by the crop were obtained with application of 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_6), which was however statistically at par with T_4 and T_7 treatments. Likewise, the maximum K uptake (119.12 kg/ha) was found in T_6 treatment, which at par with T_4. Lowest N, P and K uptake was noticed under 100% RDF (T_1). The higher uptakes of N, P and K with the combined application of organic and inorganic sources of nutrients compared to sole inorganic source was attributed to greater availability of nutrients over a long period of the crop growth and increase in dry matter production with the increase in total biological yield (grain + stover yield), which ultimately increased the total uptake of nutrients. The increase of total nitrogen uptake induced by zinc application might be due to its primary effect on main physiological processes relating to nutrients uptake [27,28]. The result was supported by the findings of Kumar et al. [19].

Table 4. Effect of integrated nutrient management on nutrients uptake and economics of hybrid maize

Treatments	Nutrients uptake (Kg/ha)			Economics			
	N	P	K	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	BCR
T_1: 100% RDF (150:75:75 kg/ha of N, P_2O5, K_2O)	136.54	45.29	85.43	48,240	1,10,268	62,028	2.28
T_2: 75% RDF+ vermicompost @ 2 t/ha	154.78	49.92	99.23	56,168	1,20,884	64,716	2.15
T_3: 75% RDF+ yeast vinasse @ 2 t/ha	147.47	47.74	90.36	60,168	1,18,492	58,324	1.96
T_4: 75% RDF+ vermicompost @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha	186.33	62.99	109.36	59,918	1,33,638	73,720	2.23
T_5: 75% RDF+ yeast vinasse @ 2 t/ha+ soil application of $ZnSO_4$ @ 25 kg/ha	164.23	60.05	96.99	63,918	1,29,002	65,084	2.02
T_6: 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5%	200.54	66.45	119.12	58,018	1,35,130	77,112	2.33
T_7: 75% RDF+ yeast vinasse @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5%	178.65	64.27	100.92	61,093	1,30,841	69,748	2.14
S.Em(±)	9.08	2.02	3.89	-	1495	801	0.01
CD at 5%	26.78	5.95	10.25	-	4086	2242	0.03

Prices: Selling price: Grain- Rs.14.50 /Kg and Stover- Rs.30 /q, Input price: Urea- Rs.7/ Kg, SSP- Rs.8/ Kg, MOP-Rs.14 /Kg, Vermicompost-Rs.5 /Kg, Yeast Vinasse-Rs.7 /Kg, $ZnSO_4$-Rs.150 /Kg, Mandays-Rs.275

Economic analysis of hybrid maize production showed that integrated application of nutrients increased the gross and net returns compare to sole inorganic nutrition (Table 4). The highest gross return (Rs. 1,35,130/ha) and net return (Rs. 77,112/ha) were recorded under application of 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_6) due to production of highest yields. The lowest gross return (Rs. 1,10,268/ha) and net return (Rs. 58,324/ha) were recorded under application of 100% RDF (T_1) and 75% RDF+ yeast vinasse @ 2 t/ha (T_3) respectively. Similarly, the maximum benefit-cost ratio (BCR) (2.33) was realized under T_6, while the minimum BCR (1.96) under application T_3 (75% RDF+ yeast vinasse @ 2 t/ha). The superiority of economic viability under the application of 75% RDF+ vermicompost @ 2 t/ha+ foliar application of $ZnSO_4$ @ 0.5% (T_6) was due to increase in grain and stover yields coupled with appreciable cost of cultivation resulting in higher return as compared to others. The similar results were reported by Ashoka et al. [21] and Mahapatra et al. [1].

4. CONCLUSION

The study concluded that the integrated application of vermicompost 2t/ha along with 75% RDF and 0.5% foliar application of $ZnSO_4$ at 30 and 60 DAS can be recommended for better grain yields and higher profits of summer maize and also be considered as a measure for maintaining sustainable production by substituting chemical fertilizers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Mahapatra A, Barik AK, Mishra GC. Integrated nutrient management on babycorn (*Zea mays* L.). International Journal of Bio-resource and Stress Management. 2018;9(1):044-048.
2. India maize summit. Maize in India; 2014. Available:www.ficci.in/spdocument/20386/India-Maize-2014_v2.pdf
3. Directorate of Economics and Statistics Report (2018-19). Department of Agriculture Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Govt. of India.
4. Biswas BC, Tewatia RK. Nutrient balance in Agro- Climatic regions of India- An overview. Fertilizer News. 1991;36:13-17.
5. Rakshit A, Abhilash PC, Singh HB, Ghosh S. Adaptive soil management: From Theory to Practices. Springer-Verlag Singapore. 2017;571.
6. Meena SK, Mundra SL, Singh P. Response of maize (*Zea mays*) to nitrogen and zinc fertilization. Indian Journal of Agronomy. 2013;58:127-128.
7. Takkar PN, Singh MV, Ganeshmurthy AN. In plant nutrient needs, supply, efficiency and policy issues: 2000-2025, (J.S. Kanwar and J.C. Katyal, Eds.) National Academy of Agricultural Sciences, New Delhi. 1997;238-264.
8. Dwivedi SK, Singh RS, Dwivedi KN. Effect of sulphur and zinc nutrition on yield and quality of maize in typic ustochrept soil of Kanpur. J. Indian Soc. Soil Sci. 2002; 50(1):70-74.
9. Hosseini SM, Maioun M, Karimian N, Rounaghi A, Emam Y. Effect of zinc and boron interaction on plant growth and tissue nutrient concentration of corn. J. Plant Nutr. 2007;30:773-781.
10. Chandrashekara CP, Harlapur SI, Murlikrishna S, Girijesh GK. Response of maize (*Zea maize* L.) to organic manures with inorganic fertilizers. Karnataka J. Agric. Sci. 2000;13(1):144-146.
11. Biswas S, Dutta D. Effect of integrated nutrient management (INM) on nutrient uptake, yield and quality of potato (*Solanum tuberosum* L.). International Journal of Chemical Studies. 2020;8(1): 436-442.
12. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. Indian Council of Agricultural Research Publication. New Delhi. 1985;87-89.
13. Gomez KA, Gomez AA. Statistical procedures for agricultural research. John Wiley & Sons, New York; 1984.
14. Nehra AS, Hooda IS, Singh KP. Effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum*). Indian Journal of Agronomy. 2001;46:112-117.
15. Kannan RL, Dhivya M, Abinaya D, Lekshmi Krishna R, Krishnakumar S. Effect of integrated nutrient management on soil fertility and productivity in Maize. Bulletin of Environment, Pharmacology and Life Sciences. 2013;2(8):61-67.

16. Kaur R, Kumar S, Kaur R, Kaur J. Effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.) under irrigated conditions. International Journal of Chemical Studies. 2018;6(4): 1800-1803.
17. Biswas S, Jana K, Agrawal RK, Puste AM. Effect of integrated nutrient management on growth attributing characters of crops under various oat-lathyrus intercropping system. The Pharma Innovation Journal. 2019a;8(9):368-373.
18. Havlin JL, Beaton JD, Tisdale SL, Nelson WL. Soil fertility and fertilizer- An introduction to nutrient management (7th Edition). PHI Learning Private Limited, New Delhi. 2010;514.
19. Kumar P, Halepyati AS, Pujari BT, Desai BK. Effect of Integrated nutrient management on productivity, nutrient uptake and economics of maize (*Zea mays* L.) under rainfed condition. Karnataka J. Agric. Sci. 2007;20(3):462-465.
20. Biswas S, Jana K, Khan R, Agrawal RK, Puste AM. Periodic dry matter accumulation and crop growth rate of oat and lathyrus as influenced by integrated nutrient management in intercropping systems. International Journal of Current Microbiology and Applied Sciences. 2019b; 8(08):2675-2686.
21. Ashoka P, Pujari BT, Hugar PS, Desai BK. Effect of micronutrients with or without organic manures on yield of babycorn (*Zea mays* L.)–Chickpea (*Cicer artietinum* L.) sequence. Karnataka Journal of Agricultural Science. 2008;21(4):485−487.
22. Patra PS, Biswas S. Integrated nutrient management on growth, yield and economics of maize (*Zea mays* L.) under terai region. Journal of Crop and Weed. 2009;5(1):136-139.
23. Sanjivkumar V. Effect of integrated nutrient management on soil fertility and yield of maize crop (*Zea mays*) in entic haplustart in Tamil Nadu, India. Journal of Applied and Natural Science. 2014;6(1):294-297.
24. Singh L, Kumar S, Singh K, Singh D. Effect of integrated nutrient management on growth and yield attributes of maize under winter season (*Zea mays* L.). Journal of Pharmacognosy and Phytochemistry. 2017; 6(5):1625-1628.
25. Verma K, Bindra AD, Singh J, Negi SC, Datt N, Rana U, Manuja S. Effect of integrated nutrient management on growth, yield attributes and yield of maize and wheat in maize-wheat cropping system in mid hills of Himachal Pradesh. Int. J. Pure App. Biosci. 2018;6(3):282-301.
26. Rani UI, Padmaja G, Chandrasekhar Rao P. Integrated effect of organic manures and inorganic fertilizers on soil urease activity and yield of maize-spinach cropping system. Agric. Sci. Digest. 2013; 34(1):31-35.
27. Alloway B. Zinc in soils and crop nutrition. Areas of the World with Zinc Deficiency Problems; 2004.
Available:http://www.zinc-crops.org/Crops/Alloway-all.php
28. Cakmak I. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? Plant and Soil. 2008;302: 1–17.

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