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

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ABSTRACT

A field experiment was conducted to evaluate the effect of integrated nutrient management (INM) on growth, yield and quality of maize. The study was carried out at the agronomy research farm of IFTM University, Moradabad, Uttar Pradesh, India during the *kharif* season of 2023 and 2024. Twelve treatments comprising varying combinations of recommended doses of fertilizers with organic sources such as biogas slurry, vermicompost, farmyard manure, poultry manure, and green manuring with *Sesbania spp.* were evaluated in randomized block design (RBD) and replicated thrice. Maize variety *VHM-53* was planted with 50 × 20 cm spacing. The soil of experimental field was clay loam. Recommended dose of fertilizers (RDF) was used @ 120: 60: 40 kg/ha. Results revealed that different levels of nutrients and organic manures significantly improved the growth, yield attributes, yield and quality parameters of maize. Highest grain yield was recorded with T_9 (75 % RDF + 25 % N through Poultry manure) in which significantly increased all growth attributes *viz*., plant height, leaf area index and dry weight, as well as on yield attributing characters such as number of cobs/plant, number of grains/cob, seed index g. Maximum grain yield (5.28 and 5.30 t/ha) was recorded in T_9 which was significantly highest over rest of the treatments. Protein content (12.16 % and 12.33 %) and protein yield (642.04 kg and 653.13 kg/ha) was also highest in T9 which was significantly higher over rest of the treatments.

Keywords: *Growth, INM, Maize, Quality, Yield*

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crop which served as a staple food for a larger part of the world Dagar *et al*. (2022). It served as a source of fuel and raw material for the manufacture of food sweeteners, alcoholic beverages, protein, oil and starch. Because of its wider adaptability, the crop is flourishing across a wide range of climatic conditions of the world (Hartkamp, 2001 and Amanullah, *et al.* 2007). It is also essential for animals and poultry, constituting a high percentage of the ingredients in chicken feed and serving as the raw material for enterprises that produce medicines, gums, textiles, makeup, and products related to starch Naveenkumar *et al.* (2018).

Maize is the world's most leading cereal with respect to total annual harvest and the only crop that have global annual production more than one billion tonne (1.135 billion tonne) (FAOSTAT, 2019). With an output of 27.23 million tonnes and a productivity level of 2965 kg/ha, it occupies 9.18 million hectares in India and accounts for about 10.46% of the country's food basket (Agricultural Statistics, 2019). According to Joshi *et al.* (2017), it has 66.3% carbohydrates, 3.6% fat, 2.7% fiber, 11.1% protein, and 1.5% minerals (calcium, phosphorus, and iron) and vitamins (A, B, and E).

The INM refers to systems that are designed to maintain and improve soil fertility in order to sustain crop productivity. These systems include the use of chemical fertilizers in combination with organic manures, which are rich inputs produced through biological processes. The combination of chemical fertilizers and organic sources is effective in improving the physico-chemical properties of soil, increasing the availability of nutrients in the soil, and ultimately increasing crop productivity (Sharma, *et al.* 2020). For the development of all growth stages, maize needs more nitrogen and phosphorus than other essential elements. Essential nutrient elements should be supplied in sufficient amounts to maintain soil fertility and generate high yield. It has been demonstrated that integrating organic and inorganic fertilizers to apply plant nutrients in a balanced manner improves soil fertility and maize production (Almaz *et al.* 2017a). Mixing with farm yard manure might improve the availability of phosphorous Hussain *et al.* 2008).

Applying inorganic fertilizers in combination with varying amounts of organic manures from various sources can significantly increase maize production, improve plant nutrient uptake, and preserve the nutritional status of the soil in maize-based cropping systems (Almaz *et al.* 2017b). After sugarcane, maize is regarded as the most exhaustive crop and to achieve its high growth and productivity potential, it needs both macro and micronutrients. Actually, in addition to giving plants nutrients, organic manures help in maintain and enhance the soil health. For crop fields, integrated nutrient management (INM) refers to the judicious use of both organic and inorganic nutrient sources in order to sustain and maintain soil production (Bhandari *et al.* 2021). It is possible to address the issues of rising costs soil fertility and productivity can be sustained by applying these combinations in judicious manor (Sindhi *et al.* 2018). Therefore, the experiment was planned with the objective to assess the impact of recommended dose of fertilizers with integration of organic manures in maize.

2. MATERIALS AND METHODS

A field experiment was conducted during *kharif* 2023 and 2024 at the agronomy research farm of IFTM University, Moradabad, Uttar Pradesh, India. The experiment site lies between 28° 16´ to 28° 21´ N, 78° 4´ to 79° E and 193 meters above mean sea level. The soil of the experimental site was clay loam, slightly alkaline. The initial pH 8.0, electrical conductivity 1.03 dS/m, organic carbon 0.62%, available nitrogen 274.56 kg/ha, available phosphorus 18.27 kg/ha, available potassium 318.83 kg/ha were recorded before planting of maize. This location is characterized by a sub-tropical and semi-arid climate with hot and dry summer and cold winter.

The experiment consisted of 12 treatments, *viz.* T_1 - RDF (120: 60: 40 kg NPK), T_2 - 50% RDF + 50% N through Biogas slurry, T_3 - 50% RDF + 50% N through Vermicompost, T_4 - 50% RDF + 50% N through FYM, T_5 - 50% RDF + 50% N through Poultry manure, T_6 - 75% RDF + 25% N through Biogas slurry, T_7 - 75% RDF + 25% N through Vermicompost, T_8 - 75% RDF + 25% N through FYM, T_9 - 75% RDF + 25% N through Poultry manure, T_{10} - 50% RDF + Green manuring with S*asbania spp*., T_{11} - 75% RDF + Green manuring with *Sasbania spp. and* T_{12} - 100% RDF + Green manuring with *Sasbania spp.* These treatments were evaluated under randomized block design with 3 replications. Maize cv. *VHM-53* taken as test crop. The crop was sown in line with a spacing of 50 cm × 20 cm with the help of hand marker. Organic manure was incorporated before one month of crop sowing as per the treatment. Green manure was incorporated with the help of weeder at 45 days after sowing. All other agronomic practices were kept uniform for all the plots of the experiment.

The NPK, biogas slurry, vermicompost, FYM, poultry manure and green manuring were applied as per the treatment requirements. The sources of NPK taken were urea, diammonium phosphate and muriate of potash. Maize was sown in first fortnight of July in both of the experimental years. All plant attributes recorded were statistically analyzed using the Gomez and Gomez (1984), and the least significant difference (LSD) values (P=0.05) were used to determine the significance of the difference between treatment means. Online software OPSTAT (Sheoran *et al.,* 1998) was used to analyze the data.

3. RESULTS AND DISCUSSION

Growth Attributes

Integrated nutrient management significantly influenced the growth attributes of maize plants across the sampling periods in both of the experimental years (Table 1). Results showed a progressive increase in plant height throughout the sampling periods from 30 DAP to harvesting in both of the experimental years. T_9 (75% RDF + 25% N through poultry manure) produced the tallest plants of 191.99 cm, 193.78 cm and 192.88 cm height at harvesting stage in 2023, 2024 and on pooled analysis, followed by T_7 (75% RDF + 25% N through vermicompost) with 187.69 cm, 188.79 cm and 188.24 cm plant height in 2023, 2024 and pooled analysis respectively. Plant heights for the sole 100% RDF were 176.23 cm and 177.77 cm, respectively in both the years. T_{12} (100% RDF + Green manuring with *Sasbania spp*.) produced the plants of 179.79 and 181.23 cm height, followed by T_6 (75% RDF + 5% N through Biogas slurry) with 177.56 and 178.78 cm height in both of the years. It might be attributed due to the supply of poultry manure influences the availability of major plant nutrients with other micro nutrients required for plant growth and overall conditioning of the soil that can increase nutrient uptake compared to mineral fertilizers alone thereby boosting the vegetative growth of the plants. Same findings were also reported by Anjum, *et al*. (2017), Rohullah and Bubarai (2018), Prabhavathi, *et al.* (2021) and Essilfie, *et al.* (2024).

T_9 (75% RDF + 25% N through Poultry manure) achieved the maximum leaf area index (3.63, 3.66 and 3.65) respectively, in both the years of experimentation and in pooled analysis. T_7 (75% RDF + 25% N through Vermicompost) and T_{12} (100% RDF + Green manuring with *Sasbania spp*.) were found at par and followed by T_6 (75% RDF + 25% N through Biogas slurry). The application of poultry manure may have contributed to the significantly enhanced the plant height, number of leaves and stem diameter, which in turn led to the increased number of leave and leaf area index. The results are in conformity with those already reported by Jjagwe *et al.* (2020) and Essilfie *et al.* (2024).

Maximum dry weight (289.98 g, 295.13 g and 292.56 g/plant) in 2023, 2024 and pooled analysis was observed under T_9 (75% RDF + 25% N through Poultry manure) followed by T_7 (75% RDF + 25% N through Vermicompost). One possible explanation for the higher dry weight in this treatment is the continuous, steady release of vital plant nutrients, which may

raise plant height, number of leaves/plant and the leaf area index. Consequently, plants are able to accumulate more dry matter since photosynthesis is prolonged. Same findings also reported by Ponmozhi *et al.* (2019), Jjagwe*et al.* (2020) and Esssilfie *et al.* (2024).

Table 1: Growth attributes of maize as influenced by integrated nutrient management

Treatments	Growth attributes (at harvesting)								
	Plant height (cm)			LAI			Dry weight (g/plant)		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
T1	176.23	177.77	177.00	3.58	3.60	3.59	276.86	279.67	278.26
T2	169.24	170.13	169.68	3.41	3.44	3.43	266.07	269.75	267.91
T3	172.23	173.40	172.81	3.50	3.53	3.52	270.56	275.07	272.81
T4	171.97	172.46	172.22	3.48	3.51	3.50	269.23	274.75	271.99
T5	174.90	175.31	175.11	3.51	3.54	3.53	272.30	275.20	273.75
T6	177.56	178.78	178.17	3.59	3.62	3.61	279.85	283.47	281.66
T7	187.69	188.79	188.24	3.60	3.63	3.62	285.45	291.50	288.48
T8	175.68	176.44	176.06	3.53	3.57	3.55	275.38	279.30	277.34
T9	191.99	193.78	192.88	3.63	3.66	3.65	289.98	295.13	292.56
T10	168.29	169.30	168.80	3.27	3.32	3.29	259.63	265.64	262.64
T11	168.42	170.15	169.29	3.40	3.44	3.42	263.77	268.47	266.12
T12	179.79	181.23	180.51	3.59	3.61	3.60	283.38	285.86	284.62
C.D. at 5%	2.546	3.433	2.06	0.031	0.031	0.02	1.293	3.999	2.03
SE(m)±	0.863	1.163	1.02	0.011	0.010	0.01	0.438	1.355	1.01

Yield Attributes

Results revealed that integrated nutrient management (INM) practice significantly enhanced the yield attributing characters. Number of cobs/plants (1.52, 1.63 and 1.57), number of grains/cob (495.45, 501.57 and 498.51) and seed index (27.42, 27.75 and 27.59) respectively, was recorded significantly superior with the application of 75% RDF + 25% N through poultry manure in both of the experimental years and pooled analysis (Table 2). Seed index was recorded at par with the treatment T_1, T_6, T_7 and T_{12}. It may be attributed due to the poultry manure and vermicompost activate several plant enzymes that are involved in carbohydrate metabolism, protein synthesis and pollen formation ultimately increase in number of grains/cob and increased cob length has positively influenced the number of grains/cobs. The slow release of nutrients from the poultry manure may have complemented the application of NPK in improving nutrient availability that promotes the yield components of the maize. The maximum number of leaves and leaf area index may be able the plants to intercept more solar radiation and therefore produce more photosynthates for partitioning to the cob and grains. The results are in conformity with those already reported by Anjum *et al*. (2017), Ali *et al.* (2019) and Arthy *et al.* (2020).

Table 2: Yield attributes of maize as influenced by integrated nutrient management

Treatments	Yield attributes								
	No. of cobs/plant			No. of grains/cob			Seed Index (g)		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
T1	1.36	1.43	1.40	465.60	472.66	469.13	26.55	26.88	26.72
T2	1.27	1.34	1.30	390.03	398.20	394.11	26.23	26.40	26.31

T3	1.33	1.39	1.36	425.53	431.72	428.63	26.38	26.57	26.48
T4	1.33	1.38	1.36	407.39	409.11	408.25	26.34	26.54	26.44
T5	1.33	1.41	1.37	437.83	441.59	439.71	26.40	26.73	26.56
T6	1.41	1.45	1.43	469.69	476.30	472.99	26.60	26.94	26.77
T7	1.46	1.54	1.50	489.07	494.41	491.74	26.86	27.19	27.03
T8	1.35	1.42	1.38	449.11	456.14	452.62	26.46	26.58	26.52
T9	1.52	1.63	1.57	495.45	501.57	498.51	27.42	27.75	27.59
T10	1.00	1.20	1.10	339.44	342.79	341.12	25.06	25.39	25.22
T11	1.06	1.26	1.16	370.77	373.60	372.19	26.23	25.66	25.95
T12	1.43	1.49	1.46	475.67	478.20	477.43	26.74	27.08	26.91
C.D. at 5%	0.237	0.151	0.14	4.408	5.768	2.97	0.901	0.879	0.61
SE(m)±	0.080	0.051	0.07	4.493	1.954	1.47	0.305	0.298	0.30

Yield

Application of nutrients through combination of inorganic fertilizers and organic manures increased the grain yield 15.53 %, 15.66 % and 15.66 %, biological yield 10.51 %, 10.71 % and 10.65 % respectively, in both of the experimental years and in pooled analysis over the treatment T_1 100 % RDF @ 120: 60: 40 kg NPK (Table 3). Application of T_9 (75% RDF + 25% N through Poultry manure) resulted in highest grain yield (5.28 t, 5.30 t and 5.29 t/ha), biological yield (12.37 t, 12.42 t and 12.40 t/ha) and harvest index (42.67, 42.67 and 42.67) in the experimental years of 2023, 2024 and in pooled analysis respectively, followed by T_7 (75% RDF + 25% N through Vermicompost). Increased development and production were the results of the integrated use of fertilizers, which promoted the mineralization of nutrients in the manure due to their readiness. Moreover, the poultry manure may have played a significant role in preventing the leaching of nitrogen fertilizer by enhancing the soil structure and anchoring mineral nutrients. All these benefits of the INM in conditioning the soil in addition to readily accessibility of nutrients from mineral fertilizer accounts for the complementary and synergistic effects in improving growth and yield of maize. The results are in conformity with those already reported by Shah and Wani (2017), Ali *et al.* (2019), Geng *et al.* (2019), Chandrashekara *et al.* (2000), Arthy *et al.* (2020) and Essilfie *et al.* (2024).

Table 3: Yield of maize as influenced by integrated nutrient management

Treatments	Grain yield (t/ha)			Biological yield (t/ha)			HI (%)		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
T1	4.46	4.47	4.47	11.07	11.09	11.08	40.32	40.30	40.31
T2	4.06	4.10	4.08	10.03	10.08	10.06	40.47	40.63	40.55
T3	4.20	4.23	4.21	10.48	10.51	10.49	40.08	40.23	40.16
T4	4.11	4.13	4.12	10.33	10.40	10.37	39.74	39.70	39.72
T5	4.24	4.28	4.26	10.77	10.82	10.80	39.33	39.53	39.43
T6	4.54	4.57	4.55	11.15	11.20	11.18	40.71	40.78	40.74
T7	4.82	4.84	4.83	11.62	11.66	11.64	41.48	41.45	41.47
T8	4.28	4.30	4.29	10.86	10.90	10.88	39.43	39.45	39.44
T9	5.28	5.30	5.29	12.37	12.42	12.40	42.67	42.67	42.67
T10	3.07	3.10	3.08	8.02	8.09	8.06	38.24	38.26	38.25
T11	3.80	3.82	3.81	9.72	9.76	9.74	39.06	39.07	39.07

T12	4.58	4.61	4.60	11.21	11.27	11.24	40.88	40.95	40.91
C.D. at 5%	0.021	0.015	0.01	0.094	0.119	0.07	0.454	0.458	0.31
SE(m)±	0.007	0.005	0.01	0.032	0.040	0.04	0.154	0.155	0.15

Quality Parameters

Integrated nutrient management (INM) in maize cultivation has a positive impact on both protein content and protein yield. Treatment T_9 (75% RDF + 25% RDN through Poultry manure) resulted in significantly higher protein content (5.92 %, 6.33% and 6.13 %) more in grain during 2023-24, 2024-25 and pooled analysis respectively, over the treatment T_1 - 100 % RDF @ 120: 60: 40 kg NPK (Table 4). This might be possible owing to the higher content of nitrogen in grains because of adequate and perpetual availability of nitrogen throughout the growth period under treatment T_9, because of protein content in seed increased with N from organic and inorganic sources because N is a principal constituent of protein. The principal use of inorganic N is (ammonium or nitrate) that the plant takes it up in the formation of protein contents. Increasing N supply by integrated application of nutrients increased the amount of protein formed. Similar results were obtained by Pinjari, (2007), Iqbal *et al*., (2014), Nagavani and Subbian, (2014).

Table 4: Quality parameters of maize as influenced by integrated nutrient management

Treatments	Quality parameters					
	Protein Content in Grain (%)			Protein Yield (kg/ha)		
	2023	2024	Pooled	2023	2024	Pooled
T1	11.44	11.55	11.49	510.53	516.32	513.42
T2	10.85	10.93	10.89	440.49	448.03	444.26
T3	11.20	11.29	11.25	470.58	477.61	474.09
T4	10.89	10.94	10.91	447.12	452.31	449.71
T5	11.38	11.46	11.42	482.14	490.26	486.20
T6	11.70	11.77	11.73	531.18	537.33	534.26
T7	12.02	12.11	12.07	579.56	585.47	582.52
T8	11.40	11.47	11.43	488.30	493.20	490.71
T9	12.16	12.33	12.24	642.04	653.13	647.59
T10	10.03	10.23	10.13	307.62	317.06	312.34
T11	10.84	10.92	10.88	411.70	416.57	414.14
T12	12.00	12.08	12.04	549.97	557.36	553.66
C.D. at 5%	0.908	0.766	0.57	40.079	44.099	28.77
SE(m)±	0.308	0.260	0.28	13.578	14.939	14.27

The combination of mineral fertilizer nutrient sources and organic manures have shown to results in synergistic effects and improved protein yield of maize crop (Table 4). The highest protein yield in 2023-24, 2024-25 and on pooled analysis (642.4, 653.13 and 647.59 kg/ha) was recorded with the application of T_9 (75% RDF + 25% N through Poultry manure) followed by T_7 (75% RDF + 25% N through Vermicompost) and T_{12} (100% RDF + Green manuring with *Sasbania spp.*). Studies show that INM can increase protein content in maize grains and lead to higher overall protein yields compared to relying solely on chemical fertilizers, Nagappa and Biradar, (2007) also reported the similar trends of protein yield.

4. CONCLUSION

This study clearly demonstrated the significant beneficial effects of INM in maize on enhanced growth, yield and quality of maize grain. Application of 75% RDF + 25% N through poultry manure was found a better combination of nutrient integration with respect to growth, productivity and quality of maize. This is an important finding for increased nutrient

availability and sustaining soil fertility for long term productivity of maize. For future research, it is essential to gain a deeper understanding of the INM in maize will provide valuable insights for advancing sustainable agricultural practices.

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