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Effect of Integrated Nitrogen Management Practices on Growth and Yield of *Kharif* 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

Aims: This field experiment was conducted to find out the effect of integrated nitrogen management on growth and yield of kharif maize.
Study Design: In the experiment, five nitrogen management treatments were taken in Randomized Block Design (RBD).
Place and Duration of Study: This field experiment was conducted for consecutive two kharif seasons in 2022 and 2023 at Agronomy Farm of B. A. College of Agriculture, Anand Agricultural University, Anand.

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Methodology: In the experiment, five nitrogen management treatments were taken in Randomised Block Design (RBD) *viz* T1:100% Recommended Dose of Nitrogen (RDN) through chemical fertilizer, T2:100% RDN through farm yard manure (FYM), T3:75% RDN through FYM + 25% through chemical fertilizer, T4:50% RDN through FYM + 50% through chemical fertilizer and T5:50% RDN through FYM + 25% through chemical fertilizer + Bio NPK consortium with four replications.

Results: The various nitrogen management treatments significantly affected growth plant height at 30, 60 DAS and at harvest, grain yield and straw yield. Application 100% RDN through inorganic fertilizer (T1) to recorded significantly higher grain yield and straw yield, it was remained statistically at par with T4 (50% RDN through FYM + 50% RDN through chemical fertilizer) and T5 (50% RDN through FYM + 25% RDN through chemical fertilizer + Bio NPK consortium) in both the years and in pooled analysis.

Conclusion: Application 100% RDN through inorganic fertilizer (T1) gave the highest plant height, grain yield and straw yield, closely followed by a 50% RDN from FYM + 50% from chemical fertilizer.

Keywords: Nitrogen; nitrogen management; maize; Bio NPK Consortia.

1. INTRODUCTION

India's Green Revolution significantly increased food grain production from 50.82 million tonnes in 1950-51 to 314.51 million tonnes in 2021-22. However, current surpluses are insufficient to meet the food demand posed by rapid population growth and unsustainable farming practices. By 2050, food demand is expected to rise to 400 million tonnes, requiring an additional 4-5 million tonnes of grain production annually. While chemical fertilizers drove past growth, they have degraded soil health, threatening future agricultural sustainability. Cereals, particularly maize, play a crucial role in India's food security, with maize ranking third in importance after rice and wheat (Bahar et al., 2009). Grown on nearly 10 million hectares in India, maize production has surged due to its growing demand for feed, adaptability, and hybrid production potential. However, India's maize productivity (3.39 tonnes per hectare) lags behind the global average (5.72 tonnes per hectare) due to issues like poor nutrient management, climate variability, and limited technology adoption.

The intensive use of chemical fertilizers, instrumental in the Green Revolution, has caused long-term damage to soil quality, making it unsustainable for future agricultural development in India (Santhosh et al., 2019). To bridge this future gap and overcome the negative impact of the Green Revolution, a balanced approach to resource management and combining chemical fertilizer-based technology with organic manure are needed (Ghosh, 2004, and Aguilar-Rivera et al., 2019).

Among nutrients, nitrogen is critical for plant growth and productivity, yet nitrogen use efficiency remains low, with significant losses due to excess application and poor practices (Jat et al., 2014). A more balanced approach is needed, combining chemical fertilizers with organic sources like farmyard manure (FYM) and biofertilizers (Jat et al., 2023; Shukla et al., 2023). FYM, an affordable and efficient organic manure, enhances soil properties, nutrient availability, and microbial activity, improving long-term soil health.

Integrated nutrient management (INM), which blends organic and inorganic fertilizers, is essential for improving crop productivity while safeguarding environmental and soil health (Kumar et al., 2008). Maize, being nutrient-intensive, responds well to both chemical and organic inputs. Implementing INM practices can reduce costs, enhance soil fertility, and ensure sustainable maize production, helping to meet future food demands while minimizing environmental impact. So keeping this fact on mind the experiment was conducted to find out the effect of integrated nitrogen management on growth and yield of maize.

2. MATERIALS AND METHODS

This field experiment was conducted for consecutive two *kharif* seasons in 2022 and 2023 at Agronomy Farm of B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat to find out the effect of integrated nutrient management in *kharif* maize under middle Gujarat conditions. In the experiment, five nitrogen management treatments (Table 1) were

Table 1. Details of treatment (*Kharif*- Maize)

T_1	100% RDN through chemical fertilizer
T_2	100% RDN through FYM
T_3	75% RDN through FYM + 25% RDN through chemical fertilizer
T_4	50% RDN through FYM + 50% RDN through chemical fertilizer
T_5	50% RDN through FYM + 25% RDN through chemical fertilizer + Bio NPK consortium

taken in Randomised Block Design (RBD) T_1:100% Recommended Dose of Nitrogen (RDN) through chemical fertilizer, T_2:100% RDN through farm yard manure (FYM), T_3:75% RDN through FYM + 25% through chemical fertilizer, T_4:50% RDN through FYM + 50% through chemical fertilizer and T_5:50% RDN through FYM + 25% through chemical fertilizer + Bio NPK consortium with four replications. The soil of experimental plot was loamy sand in texture, low in available nitrogen (210.23 kg/ha), medium in organic carbon (0.522%), available phosphorus (43.61 kg/ha) and potassium (225.30 kg/ha), with 8.55 soil pH and normal electric conductivity (0.255 dS/m). The meteorological conditions were favourable for the normal growth and development of the crops throughout the season. During the *kharif* seasons of the years 2022 and 2023, seeds of the maize variety GAYMH 1 were manually sown at a depth of approximately 4-5 cm in furrows previously prepared and treated with fertilizer according to the respective treatments. The recommended seed rate of 20 kg/ha was followed, with sowing conducted under dry conditions on June 21st, 2022, and June 20th, 2023. Inter-row spacing of 60 cm was maintained by using a tractor-drawn furrow opener, while intra-row spacing of 20 cm was achieved using *jesli* in each plot. *Jesli* is similar to an adjustable rake used for marking and is operated manually to ensure proper spacing between maize plants within the rows.

2.1 Methods of Measurement

2.1.1 Plant height (cm)

In the *kharif* maize, plant height measurements were taken at 30, 60 days after sowing (DAS), and at harvest. Initially, five randomly selected plants were chosen for the measurement of plant height, from ground level to the tip of the extended upper leaf in the case of juvenile plants. These plants were then tagged for subsequent parameter measurements. Plant height was measured after 60 DAS and at harvest from ground level to the last point of tassel of the plant.

2.1.2 Grain yield (kg/ha)

The harvested produce of each net plot was threshed separately using a thresher and cleaned. The grain yield was recorded in kg/net plot then after a seed sample was taken for further analysis. Subsequently, the grain yield was converted into hectare basis.

2.1.3 Straw yield (kg/ha)

After removing the border lines, the net plot was harvested, and the harvested produce was kept in the respective plot for sun drying for approximately 8-10 days. Subsequently, the total produce was weighed in kilograms. The plot-wise straw yield was obtained by deducting the grain yield (kg/plot) from the biological yield (kg/plot), and then it was converted into kg/ha.

3. RESULTS AND DISCUSSION

3.1 Effect of Nitrogen Management on Plant Height (cm) of Maize

Growth and development of any crop depend upon the progressive initiation of cell differentiation, organ primordia and expansion of component cells until characteristics of the plant is realized. Plant height (cm) of *kharif* maize increased progressively with advancement of age of crop up to harvest.

Application of various integrated nitrogen management treatments manifest significant influence on periodical plant height of maize recorded at 30, 60 DAS and at harvest during the years 2022, 2023 and on pooled analysis as furnished in Table 2

3.1.1 Plant height at 30 DAS

The results presented in Table 2 indicated that plant height recorded at 30 DAS was significantly affected due to various integrated nitrogen management treatments application. Among the various treatments, treatment T_1 (100% RDN through chemical fertilizer) recorded significantly higher plant height (86.61, 88.54 and 87.57 cm during the year 2022, 2023 and on pooled basis, respectively) than the remaining treatments excluding treatment T_4 (50% RDN through FYM + 50% RDN through chemical fertilizer) during the both individual years & pooled analysis and treatment T_3 (75% RDN through FYM + 25% RDN through chemical fertilizer) during the first year. However, the lowest plant height (72.74, 75.38 and 74.06 cm) was recorded under the treatment T_2 (100% RDN through FYM) in both individual years as well as in pooled analysis.

3.1.2 Plant height at 60 DAS

The data present in Table 2 showed that, at 60 DAS, plant height was significantly affected due to various integrated nitrogen management treatments. Among the various treatments, T_1 (100% RDN through chemical fertilizer) recorded significantly higher plant height (145.41, 149.28 and 147.35 cm during the year 2022, 2023 and on pooled basis, respectively) than rest of the treatments excluding T_4 (50% RDN through FYM + 50% RDN through chemical fertilizer) during both individual years and pooled analysis. While, treatment T_5 (50% RDN through FYM + 25% RDN through chemical fertilizer + Bio NPK consortium) and T_3 (75% RDN through FYM + 25% RDN through chemical fertilizer) were remained at par on individual year basis (2022 and 2023) with treatment T_1. Nevertheless, the lowest plant height (119.48 121.48 and 120.48 cm) was recorded under the treatment T_2 (100% RDN through FYM) in both individual years as well as in pooled result.

3.1.3 Plant height at harvest

The data in Table 2 revealed that, plant height at harvest affected significantly due to various nitrogen management treatments. Among the various integrated nitrogen management treatments, treatment T_1 (100% RDN through chemical fertilizer) recorded significantly higher plant height (195.35, 198.01 and 196.68 cm during the year 2022, 2023 and on pooled result, respectively) and remain at par with T_4 (50% RDN through FYM + 50% RDN through chemical fertilizer) in both year and pooled analysis. While, treatment T_5 (50% RDN through FYM + 25% RDN through chemical fertilizer + Bio NPK consortium) and T_3 (75% RDN through FYM + 25% RDN through chemical fertilizer) during individual years, remains at par with treatment T_1 only. However lowest plant height (155.20, 158.60 and 156.90) was recorded under the treatment T_2 (100% RDN through FYM) in both individual years as well as in pooled analysis.

The above result might be due to N play a major role in photosynthate formation and partitioning to stems that might have favorable impacts on plant height of maize. The higher plant height in T_1 at all the stages might be due to chemical fertilizer release more available form of nitrogen immediately, facilitating rapid uptake and optimum use of nitrogen during the critical growth stages of the maize, thus promoting greater growth during all the stages of maize. Treatment T_4 showed similar height with treatment T_1, might be due to application of organic and inorganic source of nitrogen, continuous full fill nitrogen demand of the plant. While the sole FYM treatment showed lowest yield might be due to FYM typically releases nitrogen more slowly compared to chemical fertilizers. The slower nutrient release might not meet the rapid nutrient demands during the initial growth phase of plants, leading to shorter plants as compare to remaining treatment at all the stages. Similar results also reported by Makinde & Ayoola (2010) and Augustine and Kalyanasundaram (2021) in maize.

3.2 Effect of Nitrogen Management on Yield (kg/ha) of Maize

3.2.1 Grain Yield (kg/ha)

The data in relation to the results on grain yield (kg/ha) as influenced by different integrated nitrogen management treatments during the years 2022 and 2023 as well as in pooled results are presented in Table 3.

A perusal of data summarized in Table 3 clearly revealed 100% RDN through inorganic fertilizer increase grain yield by 28.85% than the 100% RDN through FYM. Among the different treatments application 100% RDN through inorganic fertilizer (T_1) to the *kharif* maize, recorded significantly higher grain yield (4170, 4252 and 4211 kg/ha) during the year 2022, 2023 as well as in pooled results, respectively and it was remained statistically at par with T_4 (50% RDN through FYM + 50% RDN through chemical fertilizer) and T_5 (50% RDN through FYM + 25% RDN through chemical fertilizer + Bio NPK consortium) in both the years and in pooled analysis. However, during both the individual years, treatment T_3 (75% RDN through FYM + 25% RDN through chemical fertilizer) showed at par grain yield with T_1. In reveres the lowest grain yield (3214, 3321 and 3268 kg/ha) was recorded in 100% RDN through FYM (T_2) in year 2022, 2023 and in pooled result.

Table 2. Plant height of maize as influenced by various nitrogen management treatments at 30, 60 DAS and at harvest

\Treatments		Plant height (cm) at 30 DAS			Plant height (cm) at 60 DAS			Plant height (cm) at harvest		
		2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	100% RDN through chemical fertilizer	86.61	88.54	87.57	145.41	149.28	147.35	195.35	198.01	196.68
T_2	100% RDN through FYM	72.74	75.38	74.06	119.48	121.48	120.48	155.20	158.60	156.90
T_3	75% RDN through FYM + 25% RDN through chemical fertilizer	77.05	78.84	77.94	130.64	132.75	131.70	172.80	175.50	174.15
T_4	50% RDN through FYM + 50% RDN through chemical fertilizer	81.04	83.64	82.34	142.82	144.30	143.56	186.98	187.88	187.43
T_5	50% RDN through FYM + 25% RDN through chemical fertilizer + Bio NPK consortium	74.19	76.47	75.33	133.45	134.51	133.98	178.43	180.45	179.44
S. Em. ±		3.10	3.03	2.17	5.42	5.65	3.92	8.01	7.33	5.43
C. D. (*P* = .05)		9.56	9.33	6.33	16.70	17.42	11.43	24.69	22.59	15.85
Interaction (Y × T)		-	-	NS	-	-	NS	-	-	NS
C. V. (%)		7.92	7.52	7.72	8.07	8.28	8.18	9.02	8.14	8.58

Table 3. Grain and straw yield of maize as influenced by various nitrogen management treatments

Treatments		Grain yield (kg/ha)			Straw yield (kg/ha)		
		2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	100% RDN through chemical fertilizer	4170	4252	4211	5899	6006	5952
T_2	100% RDN through FYM	3214	3321	3268	4778	4775	4776
T_3	75% RDN through FYM + 25% RDN through chemical fertilizer	3631	3676	3653	5173	5250	5212
T_4	50% RDN through FYM + 50% RDN through chemical fertilizer	4105	4158	4131	5834	5910	5872
T_5	50% RDN through FYM + 25% RDN through chemical fertilizer + Bio NPK consortium	3798	3819	3808	5384	5431	5407
S. Em. ±		213	197	145	255	275	188
C. D. (P = .05)		657	607	424	787	848	548
Interaction (Y × T)		-	-	NS	-	-	NS
C. V. (%)		11.28	10.25	10.77	9.43	10.05	9.75

Higher grain yield which evidently due to the cumulative effect of improvement in growth and yield attributes such as plant height, cob length, cob girth and number of grains/cob. The grain yield was recorded higher with application of 100% RDN trough chemical fertilizer due to the higher availability and immediate and efficient uptake of nitrogen which might have produced and converted more photosynthates into numerous metabolites like amino acids, vitamins and growth promoting substance throughout the crop growth; it led to the increased plant height, cob length, number of grains per cob resulting in higher grain yield. Additional reason for the treatments' positive impacts might be that they quickly provided nutrients from inorganic sources to the crop. These treatments might have enhanced appropriate biomass production and improvements in yield parameters, resulting towards higher grain yield. Treatments combining inorganic and organic fertilizers (T_4 and T_5) and the 75% FYM with 25% chemical fertilizer blend (T_3) also produced higher yields, indicating that a mix of quick-release and slow-release nitrogen sources can effectively support crop productivity by maintaining a steady nutrient supply. However, the treatment using only FYM (T_2) resulted in the lowest yields, which could be due to the slower rate of nitrogen release from organic sources, potentially failing to meet the crop's peak demand for nitrogen. These findings are also agreement with finding of Sarwar *et al*. (2012) and Augustine and Kalyanasundaram (2021) in maize crop.

3.2.2 Straw Yield (kg/ha)

Straw yield (kg/ha) directly represents the total biological yield (biomass) of the plant for excluding economic yield. In Indian condition straw is very useful for fuel, feed livestock, mulch and composting. Nutritional value of maize straw is also a good and is a very good organic source.

A perusal of data summarized in Table 3 clearly indicated that in 100% RDN through inorganic fertilizer increase 24.62% straw yield than the 100% RDN through FYM. Among the different treatments, application of 100% RDN through inorganic fertilizer (T_1) to the *kharif* maize, recorded significantly higher straw yield (5899, 6006 and 5952 kg/ha) during the year 2022, 2023 as well as in pooled results and it was remained statistically at par with T_4 (50% RDN through FYM + 50% RDN through chemical fertilizer) and T_5 (50% RDN through FYM + 25% RDN through chemical fertilizer + Bio NPK consortium) during both the years and in pooled analysis. However, in both the individual years (T_3) 75% RDN through FYM + 25% RDN through chemical fertilizer showed at par straw yield with treatment T_1. In contrast the lowest straw yield (4778, 4775 and 4776 kg/ha) was recorded in 100% RDN through FYM (T_2) in year 2022, 2023 and in pooled result.

The significantly higher straw yield recorded with 100% nitrogen application through inorganic fertilizer was might be attributed to the crop benefiting from optimal nutrition. This higher nutrient availability could enhance photosynthesis, facilitate greater carbohydrate translocation to vegetative plant parts and lead to an accumulation of dry matter, thus fostering more vigorous vegetative and reproductive growth reflected in higher straw yields of maize. Another probable reason could be the increased growth and yield attributes, such as plant height, plant dry matter, cumulative growth rate (CGR) and relative growth rate (RGR) from early growth stages to harvest, which in turn result in higher straw yields. Similarly, the combination of organic and inorganic treatments (T_4 and T_5) provides a balance of immediate and sustained nitrogen release, effectively supporting plant growth throughout the season. In contrast, the treatment with only FYM (T_2), which resulted in the lowest straw yields, suggests that the slower release of nutrients from organic sources may not sufficiently meet the rapid growth demands of maize for optimal biomass production. Similar results were observed by Makinde and Ayoola (2010) and Kaur and Rani (2022) in maize crops.

4. CONCLUSION

Among the nitrogen management treatments, application 100% RDN through inorganic fertilizer (T_1) gave the highest plant height, grain yield and straw yield, closely followed by a 50% RDN from FYM + 50% from chemical fertilizer in *kharif* maize. Maize, being nutrient-intensive, responds well to both chemical and organic inputs. Implementing INM practices can reduce costs, enhance soil fertility, and ensure sustainable maize production, helping to meet future food demands while minimizing environmental impact.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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