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# Optimizing growth attributes of *Rabi* maize through irrigation levels and integrated nutrient management practices in Eastern Uttar Pradesh

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## Abstract
A field experiment was carried out during 2022–23 and 2023–24 at the Agricultural Research Farm, BHU, Varanasi, to evaluate suitable irrigation levels and integrated nutrient management (INM) strategies for *Rabi* maize. The study was conducted in a split-plot design with four irrigation levels in the main plots: 1.0 IW/CPE throughout crop growth ($I_1$), 0.6 IW/CPE during the vegetative phase (VP) followed by 1.0 IW/CPE during the reproductive phase (RP) ($I_2$), 0.8 IW/CPE during VP followed by 1.0 IW/CPE during RP ($I_3$), and 1.0 IW/CPE during VP followed by 1.2 IW/CPE during RP ($I_4$). Subplots consisted of five INM practices: 100% RDF ($N_1$); 75% RDF + 15% RDN through poultry manure + biofertilizers ($N_2$); 75% RDF + 15% RDN through poultry manure + 5% vermiwash ($N_3$); 75% RDF + 15% RDN through poultry manure + 5% seaweed extract ($N_4$); and 75% RDF + 15% RDN through poultry manure + biofertilizers + 5% each of vermiwash and seaweed extract as a tank mix ($N_5$). Results revealed that $I_1$ recorded the highest plant height, leaf area index, SPAD value and crop growth rate, though it was statistically similar to $I_4$. Among integrated nutrient management practices higher growth parameters was recorded under $N_5$ but at par with $N_4$. Overall, the study highlights that maintaining adequate soil moisture along with integrating chemical fertilizers, organic manures, and bio-stimulants can substantially enhance the growth of *Rabi* maize.

**Keywords:** Irrigation scheduling**,** Integrated nutrient management, *Rabi* maize, crop growth rate

## Introduction
Maize is one of the most important cereal crops in the India because its wide usage in industries. In India, corn is only third to rice and wheat in terms contributing to the economy and food security of the nation. The crop is grown all year round in irrigated parts of central and peninsular India, where the weather is favourable for maize cultivation with ample quantity of sun shine. *Rabi* maize cultivation has emerged as a significant component of sustainable agricultural systems in India and several other maize-growing regions due to its high yield potential, market demand, and adaptability to diverse agro-climatic conditions. To get the most out of *Rabi* maize, integrated nutrient management and scientific scheduling of irrigation are very important (Singh *et al*., 2023) [9]. Maize requires huge quantity of nutrients, especially nitrogen, phosphorus, and potassium, to grow quickly and build up a lot of biomasses. (Chandrawanshi *et al*., 2024) [1]. Over use of chemical fertilizer, which can cause nutrients to be lost through leaching, volatilization and runoff, which creates environmental pollution (Rathwa *et al*., 2023) [7]. So, site-specific nutrient management that uses both organic and inorganic sources is important for keeping the soil healthy and improving crop growth. Integrated nutrient management offers an economically viable and eco-friendly approach to optimize resource use, enhance system resilience and ensure sustainable *Rabi* maize production. On the other hand, managing irrigation water is also very important for growing *Rabi* corn. Unlike *Kharif* maize, which relies heavily on monsoon rainfall, *Rabi* maize is grown under cooler and drier conditions, making assured irrigation essential for optimal growth. Adequate and timely water supply, particularly during the germination, tasselling, silking and grain-filling stages, ensures proper nutrient uptake, kernel development, and grain quality. The timing of irrigation has a

direct effect on plant growth, nutrient absorption and yield development. Moisture stress during important growth stages, like tasselling and grain filling, can greatly reduce the number and weight of kernels (Singh *et al*., 2022) [9].

Although there are improved hybrids and agronomic advice available, not enough research has been done on how nutrient management methods and irrigation practices affect *Rabi* maize in many semi-arid and subtropical parts of India. Understanding this relationship is important because the ability of plants to take in nutrients is closely linked to the amount of water in the soil (Ghosh *et al*., 2020) [3]. Therefore, the present investigation was undertaken to study the effect of different integrated nutrient management practices and irrigation levels on performance of *Rabi* maize, with the objective of developing an integrated approach for sustainable and resource-efficient maize production.

## Materials and Methods

### Experimental Site Description

The present investigation was conducted at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during *Rabi* seasons of 2022-23 and 2023-24. The geographical situation of the farm lies at 25°18′N latitude and 83°31′E longitude at an altitude of 75.7 meters above the mean sea level in the Northern Gangetic Alluvial plains.

### Experimental Design and Treatment Details

The experiment was laid out in split plot design combining four main plot treatments and five sub plot treatments with three replications. In main plot four irrigation scheduling were taken *viz.,* I1: Irrigation at 1.0 IW/CPE ratio (Throughout), I2: Irrigation at 0.6 IW/CPE ratio during vegetative phase *fb* 1.0 IW/CPE ratio during reproductive phase, I3: irrigation at 0.8 IW/CPE ratio during vegetative phase *fb* 1.0 IW/CPE ratio during reproductive phase and I4: irrigation at 1.0 IW/CPE ratio during vegetative phase *fb* 1.2 IW/CPE ratio during reproductive phase. Five sub plot treatments with nutrient management *viz.*, N1: 100% RDF, N2: 75% RDF+ 15% RDN through poultry manure + consortia of biofertilizers, N3: 75% RDF+ 15% RDN through poultry manure + 5% vermiwash (2-spray), N4: 75% RDF+ 15% RDN through poultry manure + sea weed extract (2-spray) and N5: 75% RDF+15% RDN through poultry manure + consortia biofertilizers + 5% vermiwash & sea weed extract both as tank mix (2-spray) taken in sub plot. RDF with 120,60,60 kg N, $P_2O_5$. $K_2O$. Block border effect, field border effects, plot border effect and irrigation channel effect are taken into account. The tube well water was used for irrigation. The Irrigation was scheduled at as per the treatments, when pan evaporation reached at appropriate level as per the treatment for $I_1$, $I_2$. $I_3$ and $I_4$ respectively, irrigation was applied. Irrigation water depth was maintained 6.0 cm for all treatments at every irrigation time. The daily evaporation was noted from the US Weather Bureau Class. A Open Pan Evaporimeter installed in the Meteorological Observatory of Agricultural Research Farm, BHU. Cumulative pan evaporation was calculated on the basis of daily evaporation minus the precipitation since the previous irrigation. A buffer channel of 0.25 m width between plots was carried out in order to prevent the seepage and overflow of water from the main and sub irrigation channel. Strong bunds were made around all the plot sides. The water meter was used at the water source to measure the amount of irrigation water.

The recommended dose of 120 kg N, 60 kg $P_2O_5$, 60 kg $K_2O$ was applied for *Rabi* maize crop in all the treatments through Urea, DAP and muraite of potash (MOP) respectively as per the treatments. Full dose of Phosphorus and potassium were applied at the time of sowing and Nitrogen were applied in two split doses as top-dressing half dose just after first irrigation and second dose after 2$^{nd}$ irrigation in optimum soil moisture condition and rest of the fertilizer are applied as per the treatment. 2-spray, one at 92 DAS and second at 122 DAS during the first year and 90 and 120 DAS in respect to the second year were applied. The rate of application during the first and second spray was 20 L sea weed extract per 400 L of water and 25 L sea weed extract per 500 L of water ha$^{-1}$, respectively. Consortium of biofertilizer is used for seed treatment *i.e.* NPK consortia Biofertilizer is a unique kind of bioformulation comprising nitrogen ($N_2$) fixing (Azotobacter chroococcum), P-solubilizing (Paenibacillus tylopili) and K-solubilizing (Bacillus decolorationis) bacteria. It has a longer shelf life (12–24 months) without loss of microbial populations and properties upon exposure to high temperature.

### Crop Details and Agronomic Practices

*Rabi* Maize variety Hybrid corn-9544 (Bio-9544) was used. Bio-9544 is a Medium-tall hybrid and medium duration (145-155 days) variety. It has the good content of carbohydrate protein iron and zinc with yield potential of 8.5-9.8 t ha$^{-1}$. Crop was sown with 50 cm row spacing and 20 cm plant to plant spacing.

### Soil and Climate Parameters

The soil of the experimental field was sandy clay loam (typic *Ustochrepts*) in texture, deep, flat, well drained and moderately fertile being low in available nitrogen and phosphorus, and medium in available potassium. Organic carbon is slightly low. The *Rabi* season of experimental years, 2022-23 and 2023-24 received rainfall during the crop growth period, 16.4 mm in 2022-23 and 70.3 mm in 2023-24. During the crop growing period, the weekly mean maximum temperature varied from 16.1 to 40.0°C with an average of 28.05°C in 2022-23 and 15.2°C to 40.9°C with an average of 28.05°C in 2023-24. In 2022-23 the weekly mean minimum temperature was ranged from 4.8 to 22.5°C with an average of 13.65°C and in 2023-24, it was fluctuated from 7.1 to 25.3°C with an average of 16.2°C. The weekly mean maximum relative humidity during 2022-23 fluctuated from 59 to 95% with an average of 77%, whereas, in 2023-24, it varied from 49 to 97% with an average of 73%. The weekly mean minimum relative humidity during 2022-23 ranged from 24% to 74% with an average of 49%, whereas, in 2023-24, it varied from 24 to 79% with an average of 51.5%. The weekly mean evaporation fluctuated between 0.9 to 7.7 mm with an average of 4.3 mm in 2022-23 and in 2023-24; it ranged from 0.7 to 9.5 mm with a mean of 5.1 mm. The climatic conditions are deplicated in fig. 1 and 2.

### Data Collection and Observations

**Plant height (cm):** Five plants were selected randomly and tagged from each experimental plot for the measurement of plant height. Plant height of the *Rabi* maize was observed at 30, 60, 90 and 120 DAS at harvest with the help of meter scale from base of the plant to the tip of the plant before silk and tassel emergence and up-to the tip of kernel after silking and tasseling then average height was calculated and given in centimeter.

**Chlorophyll content (SPAD value):** Chlorophyll content (SPAD value) was recorded with non-destructive and quick estimation of extractable chlorophyll method by hand held SPAD (soil plant analysis development-502 meter) at 30, 60 and 90 DAS. For estimation of chlorophyll, the five top most fully developed leaves were taken from five randomly selected plants in net plot area then SPAD reading was observed, and averaged of all values to express in SPAD unit.

**Leaf area index (LAI):** Leaf area index (LAI)= Total leaf area ($cm^2$)/ Unit land area ($cm^2$), Land area plant$^{-1}$ = Row distance x plant distance.

**Crop growth rate (g m$^{-2}$ day$^{-1}$):** Crop growth rate (g m$^{-2}$ day$^{-1}$)= $W_2 - W_1$)/ ($t_2 - t_1$), where, $W_1$ = Total dry matter of crop plant at time interval $t_1$, $W_2$ = Total dry matter of crop plant at time interval $t_2$.

**Statistical Analysis**: The data generated from various observations during investigation period were tabulated and analyzed statistically for establishing the significance of difference between the treatments and to draw out a valid conclusion by adopting proper method of 'Analysis of Variance, F and t tests' described by Gomez and Gomez (1984) for split plot design at the level of significance of p=0.05.

## Results and Discussion

### Growth parameters

The data related to crop growth parameters *viz.*, plant height (cm), crop growth rate (gm$^{-2}$day$^{-1}$), leaf area index and chlorophyll content (SPAD value) were presented in Tables 4.1 and 4.2.Among irrigation levels 1 IW/CPE ratio recorded significantly higher plant height (221.5 and 222.8cm), crop growth rate (8.7 and 9.2 gm$^{-2}$day$^{-1}$), leaf area index (2.63 and 2.67) and chlorophyll content (26.3 and 28.6) respectively during both the year of study. A significant increase in growth parameters is due to the most favorable and adequate soil moisture conditions throughout the *Rabi* maize growth period. The availability of sufficient soil moisture supports essential metabolic processes in plants, helps maintain cell turgidity, and facilitates active cell division and elongation these findings are supported by Farre & Faci (2006) [2]. Regarding irrigation levels, the application of irrigation at 1.0 IW/CPE methods resulted in higher values for most of the growth parameters of *Rabi* maize compared to other irrigation levels similar results were observed by Kumar *et al*, (2017) [5] and Singh & Reddy, (2019).

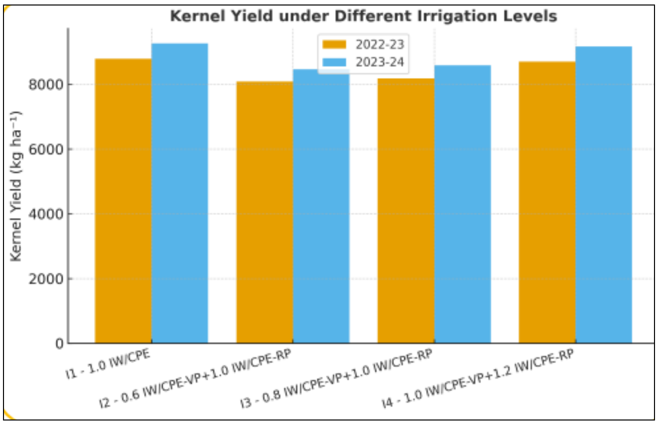
Among nutrient management application of 75% RDF+15% RDN through poultry manure + consortia biofertilizers + 5% each of vermiwash & sea weed extract both as tank mix, shown superiority in plant height (220.4 and 221.6 cm), crop growth rate (7.3 and 7.6 gm$^{-2}$day$^{-1}$), leaf area index (2.49 and 2.55) and chlorophyll content (25.6 and 27.8) respectively during both the year of study. The combined application of organic and inorganic fertilizers along with bio-inoculants improved the physical condition of the soil, ensured a slow and sustained release of nutrients, and enhanced microbial activity. These factors collectively contributed to prolonged nutrient availability in the soil, which in turn supported the *Rabi* maize in achieving greater plant height, higher leaf area index, crop growth rate, leaf area index and chlorophyll content throughout the experimental period. When 100% of the nutrients are supplied to *Rabi* maize through inorganic sources such as urea, DAP, and MOP, the nutrients become rapidly available to the crop but are not retained in the soil for an extended period. This result in reduced long-term benefits to the crop, leading to lower plant height, leaf area index, and chlorophyll content under the 100% RDF treatment. These findings are also supported by the studies of Valadabadi *et al.* (2010) [11], and Sharma *et al.* (2020) [8], Meena *et al.* (2022) [6]. These outcomes align with the findings of Irfan *et al.* (2014) [4] and Tossou *et al.* (2020) [10].

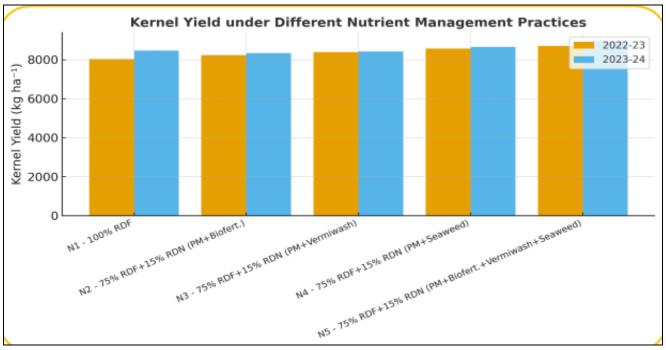
**Table 1:** Plant height (cm) and Crop growth rate (gm$^{-2}$day$^{-1}$) of *Rabi* maize as influenced by irrigation levels and nutrient management at harvest.

| Treatments | Plant height(cm) | | Crop growth rate (gm$^{-2}$day$^{-1}$) | |
|---|---|---|---|---|
| | 2022-23 | 2023-24 | 2022-23 | 2023-24 |
| **Irrigation Levels** | | | | |
| $I_1$ - 1.0 IW/CPE | 221.5 | 222.8 | 8.7 | 9.2 |
| $I_2$ - 0.6 IW/CPE-VP+ 1.0 IW/CPE-RP | 204.7 | 205.8 | 4.5 | 4.6 |
| $I_3$ - 0.8 IW/CPE-VP+ 1.0 IW/CPE-RP | 207.1 | 208.2 | 5.7 | 5.9 |
| $I_4$ - 1.0 IW/CPE-VP+ 1.2 IW/CPE-RP | 220.9 | 222.1 | 7.6 | 8.0 |
| S.Em ± | 4.05 | 3.85 | 0.09 | 0.12 |
| LSD (p=0.05) | 14.01 | 13.34 | 0.31 | 0.41 |
| **Nutrient Management** | | | | |
| $N_1$ - 100% RDF (120-60-60 kg N P K ha$^{-1}$) | 207.7 | 208 | 5.9 | 6.2 |
| $N_2$- 75% RDF+ 15% RDN through poultry manure + consortia of biofertilizers | 208.0 | 209.2 | 6.1 | 6.4 |
| $N_3$ - 75% RDF+ 15% RDN through poultry manure + 5% vermiwash (2-spray) | 212.1 | 213.3 | 6.7 | 7.0 |
| $N_4$ - 75% RDF+ 15% RDN through poultry manure + sea weed extract (2-spray) | 219.5 | 220.7 | 7.1 | 7.4 |
| $N_5$-75% RDF+15% RDN through poultry manure + consortia biofertilizers + 5% vermiwash & sea weed extract both as tank mix (2-spray) | 220.4 | 221.6 | 7.3 | 7.6 |
| S.Em ± | 3.74 | 3.61 | 0.13 | 0.09 |
| LSD (p=0.05) | 10.78 | 10.40 | 0.38 | 0.25 |

**Table 2:** Crop growth rate (gm$^{-2}$day$^{-1}$) and SPAD value of *Rabi* maize as influenced by irrigation levels and nutrient management at harvest.

| Treatments | Crop growth rate (gm$^{-2}$day$^{-1}$) | | | | SPAD value | | | |
|---|---|---|---|---|---|---|---|---|
| | 60- 90DAS | | 90-At Harvest | | 60 DAS | | 90DAS | |
| | 2022-23 | 2023-24 | 2022-23 | 2023-24 | 2022-23 | 2023-24 | 2022-23 | 2023-24 |
| **Irrigation Levels** | | | | | | | | |
| $I_1$ - 1.0 IW/CPE | 18.0 | 18.8 | 8.7 | 9.2 | 46.3 | 47.3 | 26.3 | 28.6 |
| $I_2$ - 0.6 IW/CPE-VP+ 1.0 IW/CPE-RP | 15.0 | 15.4 | 4.5 | 4.6 | 35.5 | 39.1 | 22.0 | 24.1 |
| $I_3$ - 0.8 IW/CPE-VP+ 1.0 IW/CPE-RP | 16.2 | 16.7 | 5.7 | 5.9 | 40.0 | 41.8 | 22.3 | 24.4 |
| $I_4$ - 1.0 IW/CPE-VP+ 1.2 IW/CPE-RP | 17.6 | 18.3 | 7.6 | 8.0 | 44.3 | 45.6 | 25.9 | 28.1 |
| S.Em ± | 0.34 | 0.18 | 0.09 | 0.12 | 1.00 | 1.41 | 0.38 | 0.40 |
| LSD (p=0.05) | 1.19 | 0.63 | 0.31 | 0.41 | 2.87 | 4.06 | 1.31 | 1.39 |
| **Nutrient Management** | | | | | | | | |
| $N_1$ - 100% RDF (120-60-60 kg N P K ha$^{-1}$) | 16.0 | 16.6 | 5.9 | 6.2 | 38.1 | 39.4 | 22.7 | 24.8 |
| $N_2$- 75% RDF+ 15% RDN through poultry manure + consortia of biofertilizers | 16.2 | 16.8 | 6.1 | 6.4 | 40.2 | 41.6 | 23.3 | 25.5 |
| $N_3$ - 75% RDF+ 15% RDN through poultry manure + 5% vermiwash (2-spray) | 16.8 | 17.4 | 6.7 | 7.0 | 45.5 | 46.9 | 23.8 | 26.0 |
| $N_4$ - 75% RDF+ 15% RDN through poultry manure + sea weed extract (2-spray) | 17.2 | 17.8 | 7.1 | 7.4 | 49.1 | 50.4 | 25.2 | 27.4 |
| $N_5$-75% RDF+15% RDN through poultry manure + consortia biofertilizers + 5% vermiwash & sea weed extract both as tank mix (2-spray) | 17.4 | 18.0 | 7.3 | 7.6 | 0.51 | 0.87 | 25.6 | 27.8 |
| S.Em ± | 0.33 | 0.08 | 0.13 | 0.09 | 1.77 | 3.02 | 0.38 | 0.43 |
| LSD (p=0.05) | 0.95 | 0.23 | 0.38 | 0.25 | 38.1 | 39.4 | 1.08 | 1.23 |




## Conclusion

The study reveals that irrigation at 1.0 IW/CPE, combined with nutrient management through 75% RDF + 15% RDN from poultry manure, consortia biofertilizers, and foliar application of 5% vermiwash and 5% seaweed extract as a tank mix, significantly enhances the growth and yield of *Rabi* maize under the agro-climatic conditions of Varanasi.

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