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Optimising productivity and profitability of *rabi* maize (*Zea mays*) through irrigation scheduling and integrated nutrient management in eastern Uttar Pradesh

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ABSTRACT

The cultivation of maize (*Zea mays* L.) during the winter (*rabi*) season is increasingly at risk due to insufficient moisture availability and is further hindered by suboptimal nutrition management practices. Hence, the present study was carried out during the winter (*rabi*) seasons of 2022–23 and 2023–24 at Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The experiment was laid out in a split-plot design (SPD) with four irrigation levels, viz. I_1, 1.0 IW/CPE throughout crop growth; I_2, 0.6 IW/CPE ratio during the vegetative phase (VP) *fb* 1.0 IW/CPE ratio during the reproductive phase (RP); I_3, 0.8 IW/CPE-VP *fb* 1.0 IW/CPE-RP and I_4, 1.0 IW/CPE-VP *fb* 1.2 IW/CPE-RP in the main plots and five INM practices, that were, N_1, 100% RDF; N_2, 75% RDF+15% RDN through poultry manure (PM) + biofertilisers; N_3, 75% RDF + 15% RDN-PM + 5% vermiwash; N_4, 75% RDF + 15% RDN-PM + 5% seaweed extract and N_5, 75% RDF + 15% RDN-PM + biofertilisers + 5% each of vermiwash and seaweed extract as tank mix in subplots. Results showed that treatment I_1 exhibited the highest kernel yield (9,028 kg/ha) registering 9% increases over I_2, with an additional net return of ₹17,667/ha. Among the INM practices, N_3 yielded kernel yield of 8,897 kg/ha which was 7.9% higher than N_1. The synergistic interaction I_1N_5 achieved the highest kernel yield (9,317 kg/ha) accompanied by an additional net return of ₹20,791/ha. These findings affirm the importance of maintaining consistent soil moisture and combining RDF with organic and biological nutrient sources to maximise *rabi* maize productivity and profitability.

Keywords: Economics, Integrated nutrient management, Irrigation scheduling, Poultry manure, Seaweed extract

Maize (*Zea mays* L.) is one of the most important cereal crops in India because of its wide use as a source of food, animal feed and industrial raw material. In India, maize ranks third after rice and wheat in terms of contributing to the economy and food security of the nation (Kumar *et al.* 2014). India stands among the top five global producers of maize with approximately 15 million maize growing farmers, that covers 12.09 mha and yields approximately 43.41 mt, averaging 3.59 t/ha (Agricultural Statistics at a Glance 2024–25). In India, *rabi* maize has emerged as a high-yielding winter crop, particularly in the states of Bihar, Uttar Pradesh and Karnataka, where favourable climatic conditions, such as optimal temperatures and longer sunshine hours, contribute to enhanced productivity. *Rabi* maize cultivation has emerged as a significant component of sustainable agricultural systems in India and several other maize-growing regions owing to its high yield potential, market demand and adaptability to diverse agro-climatic conditions in India. Moisture stress during important growth stages, such as tasselling and grain filling, can greatly reduce the number and weight of kernels (Singh *et al.* 2022).

Maize requires large quantities of nutrients, especially nitrogen, phosphorus and potassium, to grow quickly and build up a lot of biomass (Chandrawanshi *et al.* 2024). The overuse of chemical fertilisers can cause nutrient loss through leaching, volatilisation and runoff, creating environmental pollution (Rathwa and Bhanvadia 2023). Therefore, integrated nutrient management, has shown to improve soil health, nutrient availability and microbial activity (Ghosh *et al.* 2020). Furthermore, bio-stimulants like vermiwash and seaweed extracts enhance plant growth, nutrient uptake and stress tolerance due to the presence of phytohormones and bioactive compounds (Khan *et al.* 2009).

Despite the availability of improved agronomic practices, limited studies have addressed the combined optimisation of irrigation scheduling and INM practices for

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rabi maize in Eastern Uttar Pradesh. Since soil moisture directly influences nutrient uptake and crop productivity, understanding their interaction is crucial. Therefore, the present study was undertaken to evaluate the effect of irrigation levels and INM practices on yield and economics of *rabi* maize for developing a sustainable and resource-efficient production system.

MATERIALS AND METHODS

The present study was carried out during winter (*rabi*) seasons of 2022–23 and 2023–24 at Institute of Agricultural Sciences, Banaras Hindu University (25°18′N and 83°31′E; at an elevation of 75.7 m amsl), Varanasi. The soil of the experimental field was sandy clay loam (*typic Ustochrepts*) in texture, deep, flat, well-drained and moderately fertile, being low in organic carbon (0.43%), available nitrogen (210 kg/ha) and phosphorus (22.4 kg/ha) and medium in potassium (220 kg/ha). Post-harvest soil organic carbon was determined by the Walkley and Black (1934) method. Available nitrogen was estimated using the alkaline permanganate method (Subbiah and Asija 1956) with a Kjeldahl distillation unit. Available phosphorus was determined by the Olsen method (Olsen *et al.* 1954) using 0.5 N $NaHCO_3$ (*p*H 8.5) and measured spectrophotometrically at 760 nm. Available potassium was estimated using neutral NH_4OAc extraction (*p*H 7.0) and measured by flame photometer (Jackson 1973). Poultry manure, a nutrient-rich organic source, contains 2.5–3.5% N, 2.0–2.5% P_2O_5 and 1.5–2.0% K_2O with a low C-N ratio (10–15:1), ensuring rapid mineralisation and improved soil properties. Well-decomposed manure was used to avoid phytotoxicity. A liquid biostimulant, Sagarika seaweed extract (IFFCO), was applied to enhance crop growth and yield. Vermiwash, was applied as a diluted foliar spray to improve nutrient uptake and plant health. The weekly weather conditions during the two consecutive growing seasons are shown in Fig. 1 and 2.

The experiment was laid out in a split-plot design (SPD) with four main plot treatments and five subplot treatments replicated thrice. In the main plot, four irrigation levels were tested, viz. 1.0 IW/CPE (Irrigation water/Cumulative pan evaporation) throughout crop growth (I_1); 0.6 IW/CPE ratio during the vegetative phase (VP) *fb* 1.0 IW/CPE ratio during the reproductive phase (RP) (I_2); 0.8 IW/CPE during the vegetative phase *fb* 1.0 IW/CPE during the reproductive phase (I_3); and 1.0 IW/CPE during the vegetative phase *fb* 1.2 IW/CPE during the reproductive phase (I_4). The total water applied in the respective treatment was 2,880; 1,920; 2,400 and 3,360 m^3/ha. Further, five integrated nutrient management practices, i.e. 100% RDF (Recommended dose of fertilizers i.e. 120–60–60 kg NPK/ha) (N_1); 75% RDF + 15% RDN through poultry manure (3.25% and 3.65% N during the respective years) + consortia of biofertilizers (*Bacillus* spp., *Pseudomonas* spp.; through seed treatment @5 mL/kg of seed) (N_2); 75% RDF + 15% RDN through poultry manure + 5% vermiwash (2 sprays) (N_3); 75% RDF + 15% RDN through poultry manure + 5% seaweed extract (2 sprays) (N_4) and 75% RDF + 15% RDN through poultry manure + consortia biofertilisers + 5% each of vermiwash and seaweed extract both as tank mix (2 sprays) (N_5) were evaluated in subplot. Two sprays, one at vegetative stage @20 L in 400 L water and other at reproductive stage @25 L in 500 L water was applied for both vermiwash and seaweed extract. The crop cv. 'Hybrid maize-9544 (Bio-9544)' was sown on 28th and 24th November with seed rate 25 kg/ha for the two consecutive years at spacing of 50 cm × 20 cm. The irrigation water depth was maintained

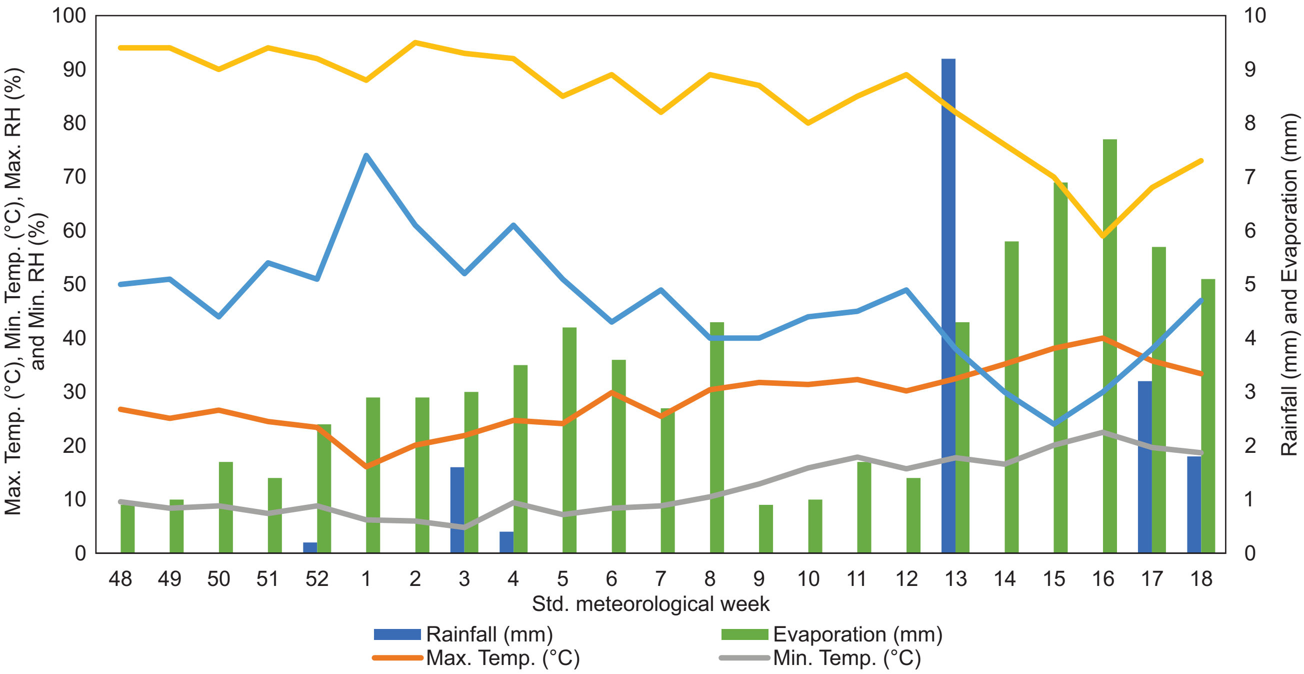

Fig. 1 Weekly weather conditions the crop season 2022–23.

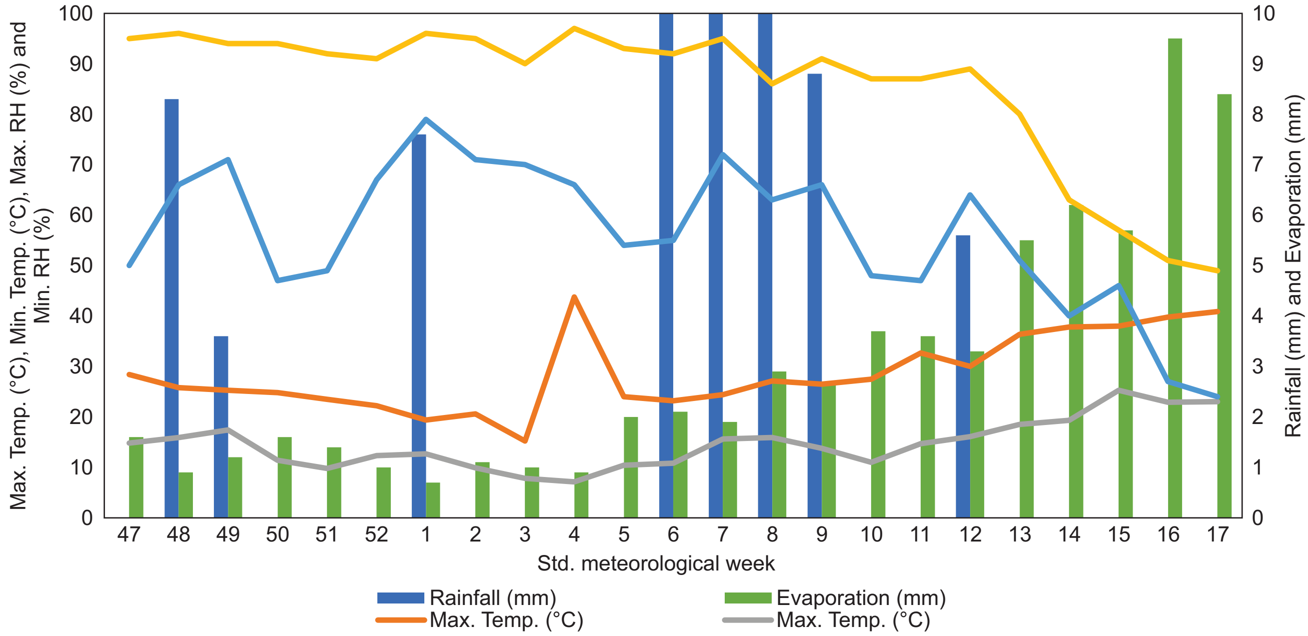

Fig. 2 Weekly weather conditions during the crop season 2023–24.

at 6 cm, when the cumulative pan evaporation value reached an appropriate level, irrigation was scheduled as per the treatment. Daily evaporation was noted from the US Weather Bureau Class. An Open Pan Evaporimeter was installed at the Meteorological Observatory of the Agricultural Research Farm, Banaras Hindu University, Varanasi. Cumulative pan evaporation was calculated based on precipitation since the previous irrigation deducted from daily evaporation. A water meter was used at the water source to measure the amount of irrigation water.

Observations on yield attributes and yield were recorded using standard procedures. Economics were calculated based on the minimum support price fixed by the government for maize during the growing season. Data pertaining to different parameters were subjected to analysis by adopting the proper method of analysis of variance and significance was tested by the F-test for split plot analysis using the SPSS software at $p<0.05$. Duncan's Multiple Range Test (DMRT) was used to compare the treatment means for the measured parameters (Duncan 1955).

RESULTS AND DISCUSSION

Pooled data revealed that irrigation levels and INM practices had a significant effect on the yield attributes of *rabi* maize. The application of 1.0 IW/CPE throughout crop growth (I_1) recorded the highest values for number of kernels/row (29.9), number of kernels/cob (449.9), cobs/plant (2.16), cob length (22.2 cm), cob girth (16.9 cm), cob weight (206.6 g) and kernel weight/cob (178.6 g), showing the importance of maintaining consistent soil moisture throughout the crop growing period (Table 1). However, this was at par with irrigation level of 1.0 IW/CPE (I_1) during VP *fb* 1.2 IW/CPE during RP (I_4). It was well recorded that maize responded well to irrigation level of 1.0 IW/CPE throughout crop growth (I_1), and the increased yield attributes such as number of kernels/cob, cob weight (g), kernels weight (g/cob), cobs/plant, length and girth of cob (cm) could be traced to the favourable soil water balance maintained in the rhizosphere (Khan *et al.* 2009). The soil-plant-water balance under 1.0 IW/CPE throughout crop growth (I_1) might have stimulated the increased activity of meristematic cells and cell elongation, resulting in a higher growth rate, which in turn promoted significant variations in yield attributes (Kang *et al.* 2000).

This was mainly due to the early vigorous growth of maize with the availability of the required quantity of water in the early stages. Congenial moisture availability under 1.0 IW/CPE throughout crop growth (I_1) enhanced nutrient uptake and led to higher values of yield attributes. Reduced irrigation levels, especially in 0.6 IW/CPE during the vegetative phase *fb* 1.0 IW/CPE during the reproductive phase (I_2) led to significantly lower values for these yield-attributing traits, mainly because of restricted cell elongation and poor reproductive development under moisture stress. This finding agrees with those of Gheith *et al.* (2022) and Chadak *et al.* (2025), who reported that water stress during the vegetative stages significantly reduced cob development and final yield. Moisture availability at critical stages, such as flowering and grain filling, is crucial for kernel set and cob growth (Uhart and Andrade 1995).

Among the nutrient management treatments, which combined 75% RDF with 15% RDN through poultry manure, consortia of biofertilisers, vermiwash and seaweed extract (N_5), recorded significantly superior yield attributes, including number of kernels/row (29.5), number of kernels/cob (453.5), cobs/plant (1.8), cob length (22.2 cm), cob girth (16.0 cm), cob weight (199.7 g) and kernel weight/cob (170.9 g) (Table 1). The improvement in these yield attributes

Table 1 Yield attributes of *rabi* maize under different irrigation levels and integrated nutrient management practices

Treatments	No. of kernels/row of cob	No. of kernels/ cobs	No. of cobs/ plant	Cob length (cm)	Cob girth (cm)	Cob weight (g)	Kernels weight (g/cob)	Kernel yield (kg/ha)	Stover yield (kg/ha)
Irrigation levels (I)									
I_1	29.9^{a}	449.9^{a}	2.16^{a}	22.2^{a}	16.9^{a}	206.6^{a}	178.6^{a}	9028^{a}	17688^{a}
I_2	27.9^{b}	425.4^{b}	1.42^{c}	19.1^{b}	13.8^{c}	178.1^{b}	148.6^{c}	8277^{c}	15782^{c}
I_3	29.0^{ab}	431.2^{ab}	1.50^{c}	19.7^{b}	14.5^{c}	183.3^{b}	153.9^{bc}	8387^{b}	16109^{b}
I_4	29.6^{ab}	447.3^{a}	1.81^{b}	21.7^{a}	15.7^{b}	195.8^{a}	166.4^{ab}	8938^{ab}	17588^{ab}
SEM±	0.22	3.4	0.02	0.24	0.09	1.45	2.08	98.3	157.5
Integrated nutrient management practices (N)									
N_1	28.5^{a}	422.5^{b}	1.64^{b}	20.1^{b}	15.0^{b}	185.2^{b}	155.7^{b}	8244^{b}	15990^{a}
N_2	29.0^{a}	432.4^{ab}	1.68^{ab}	20.2^{b}	14.9^{b}	187.2^{b}	158.2^{b}	8663^{b}	16805^{b}
N_3	29.2^{a}	438.4^{ab}	1.71^{ab}	20.3^{b}	15.1^{b}	189.5^{ab}	160.5^{ab}	8710^{b}	16896^{b}
N_4	29.3^{a}	445.4^{a}	1.77^{a}	20.6^{b}	15.2^{a}	193.1^{a}	164.1^{a}	8774^{a}	16988^{a}
N_5	29.5^{a}	453.5^{a}	1.80^{a}	22.2^{a}	16.0^{a}	199.7^{a}	170.9^{a}	8897^{a}	17280^{a}
SEM±	0.33	4.6	0.03	0.24	0.18	2.43	2.30	109	210
Interaction (I × N)									
I_1N_1	29.5^{ab}	437.3^{a-d}	1.97^{cd}	20.4^{def}	16.0^{bcde}	200.0^{b-e}	172.0^{b-d}	8533^{b-f}	16750^{b-f}
I_1N_2	29.8^{ab}	440.7^{a-d}	2.07^{bc}	21.84^{bcd}	16.8^{ab}	203.0^{a-d}	175.0^{a-c}	9057^{a-d}	17807^{ab}
I_1N_3	30.0^{a}	447.3^{a-d}	2.17^{ab}	21.94^{bcd}	16.9^{ab}	206.0^{a-c}	178.0^{ab}	9067^{a-d}	17828^{ab}
I_1N_4	30.0^{a}	456.2^{a-c}	2.31^{a}	22.37^{b}	17.0^{ab}	207.0^{a-c}	179.0^{ab}	9166^{a-c}	17859^{ab}
I_1N_5	30.0^{a}	467.8^{a}	2.27^{a}	24.47^{a}	17.4^{a}	217.0^{a}	189.0^{a}	9317^{a}	18198^{a}
I_2N_1	26.5^{c}	397.9^{e}	1.43^{i}	18.62^{f}	13.6^{i}	174.8^{g}	145.3^{f}	7869^{f}	15010^{g}
I_2N_2	27.6^{bc}	420.2^{de}	1.43^{i}	18.67^{f}	13.6^{i}	175.1^{g}	145.6^{f}	8262^{ef}	15752^{fg}
I_2N_3	28.0^{abc}	428.8^{b-e}	1.42^{i}	18.72^{f}	13.7^{i}	175.9^{fg}	146.5^{f}	8364^{d-f}	15946^{fg}
I_2N_4	28.3^{abc}	435.3^{b-d}	1.40^{i}	18.77^{f}	13.6^{i}	176.7^{fg}	147.2^{f}	8415^{d-f}	16042^{fg}
I_2N_5	28.8^{ab}	444.8^{a-d}	1.44^{i}	20.51^{cdef}	14.5^{fghi}	187.8^{d-g}	158.3^{d-f}	8477^{c-f}	16159^{e-g}
I_3N_1	28.6^{abc}	421.7^{de}	1.47^{hi}	18.93^{f}	13.9^{hi}	180.1^{fg}	150.6^{ef}	8045^{f}	15456^{fg}
I_3N_2	29.0^{ab}	426.2^{c-e}	1.44^{i}	19.12^{f}	14.1^{hi}	182.8^{fg}	153.3^{ef}	8404^{d-f}	16141^{e-g}
I_3N_3	28.8^{ab}	430.3^{b-d}	1.43^{i}	19.23^{f}	14.2^{ghi}	183.9^{e-g}	154.4^{ef}	8445^{c-f}	16220^{d-g}
I_3N_4	29.1^{ab}	435.9^{b-d}	1.53^{g-i}	19.73^{ef}	14.7^{fghi}	184.7^{e-g}	155.2^{ef}	8496^{c-f}	16318^{d-g}
I_3N_5	29.3^{ab}	441.5^{a-d}	1.63^{f-h}	21.55^{bcd}	15.5^{cdef}	185.0^{e-g}	155.9^{ef}	8545^{b-f}	16410^{c-g}
I_4N_1	29.1^{ab}	433.0^{b-d}	1.70^{e-g}	22.32^{bc}	16.3^{abcd}	186.0^{e-g}	155.0^{ef}	8530^{b-f}	16743^{b-f}
I_4N_2	29.5^{ab}	442.5^{a-d}	1.80^{d-f}	21.09^{bcde}	15.1^{efgh}	188.0^{d-g}	159.0^{d-f}	8927^{a-e}	17520^{a-e}
I_4N_3	29.8^{ab}	447.1^{a-d}	1.83^{de}	21.29^{bcde}	15.3^{defg}	192.0^{c-f}	163.0^{c-e}	8963^{a-e}	17591^{a-d}
I_4N_4	29.5^{ab}	454.0^{a-c}	1.84^{de}	21.39^{bcde}	15.4^{defg}	204.0^{a-c}	175.0^{a-c}	9019^{a-d}	17733^{a-c}
I_4N_5	29.8^{ab}	459.8^{ab}	1.86^{de}	22.19^{bcd}	16.5^{abc}	208.8^{ab}	180.1^{ab}	9251^{ab}	18354^{a}
SEM±	0.63	8.9	0.06	0.54	0.34	4.59	4.61	218	407

Means followed by the same letters (s) within a column do not differ significantly by DMRT ($p<0.05$). Treatment details are given under Materials and Methods.

can be attributed to the synergistic effect of integrated nutrient sources. The application of poultry manure likely enhanced soil organic matter and nutrient mineralisation, ensuring a sustained nutrient supply throughout the crop growth period. In addition, biofertilisers such as *Bacillus* and *Pseudomonas* may have improved nutrient solubilisation and uptake, particularly nitrogen and phosphorus. The foliar application of vermiwash and seaweed extract further contributed by supplying micronutrients and plant growth regulators, such as auxins and cytokinins, which are known to enhance cell division, cob development and grain filling. These combined effects might have resulted in improved source-sink relationship, leading to higher assimilate translocation towards reproductive structures and ultimately better yield attributes (Abid *et al.* 2020, Biswasi *et al.* 2020). Seaweed extracts and vermiwash enhance enzymatic activity, stimulate root proliferation and improve nutrient uptake (Sivasankari *et al.* 2006, Thirumaran *et al.* 2009). These substances stimulate several physiological processes in plants such as cell division, elongation and differentiation, which contribute to increase yield attributing characters. The positive effect of inoculation was due to the increase in available nutrients and synergistic effect of co-inoculation on plant growth, resulting in more yield attributes. Integrated nutrient supply strategies, especially those involving poultry manure and biofertilisers, have been shown to sustainably improve maize productivity and soil health (Mahato *et al.* 2020).

The interaction of irrigation and nutrient management significantly influenced both yield attributes and productivity of maize (Table 1). The treatment combination 1.0 IW/CPE throughout crop growth along with 75% RDF+15% RDN through poultry manure + consortia biofertilisers + 5% each of vermiwash and seaweed extract (I_1N_5) recorded the highest values of number of kernels/row (30), number of kernels/cob (467.8), cobs/plant (2.27), cob length (24.47 cm), cob girth (17.4 cm), cob weight (217.0 g) and kernel weight/cob (189.0 g) which ultimately resulted in higher kernel and stover yields. In contrast, 0.6 IW/CPE during the vegetative phase *fb* 1.0 IW/CPE during the reproductive phase + 100% RDF (I_2N_1), which relied solely on chemical fertilisers under moisture stress, consistently recorded the lowest performance. The superior performance of this treatment may be attributed to the synergistic effect of optimal soil moisture and integrated nutrient supply. Adequate irrigation throughout the crop growth period under 1.0 IW/CPE throughout crop growth (I_1) maintained favourable soil moisture conditions, which enhanced nutrient solubility, root activity and uptake efficiency, while also supporting physiological processes such as photosynthesis, assimilate partitioning and grain filling (Ning *et al.* 2024). Simultaneously, the combined application of inorganic fertilisers, organic manure, biofertilisers and bio stimulants ensured a balanced and sustained nutrient supply along with improved soil biological activity, thereby strengthening the source-sink relationship and resulting in higher productivity (Khan *et al.* 2009). Consequently, irrigation level 1.0 IW/CPE throughout crop growth (I_1) registered the highest kernel yield (9,028 kg/ha) and stover yield (17,688 kg/ha), affirming the role of adequate irrigation in assimilate partitioning and grain-filling (Table 1). In contrast, 0.6 IW/CPE during the vegetative phase *fb* 1.0 IW/CPE during the reproductive phase + 100% RDF (I_2N_1), consistently recorded the lowest performance in both yield attributes and yield, which may be due to moisture stress during early growth stages coupled with the absence of organic and biological nutrient sources. A similar trend was observed for total nutrient uptake, where nitrogen, phosphorus and potassium uptake were higher under 1.0 IW/CPE throughout crop growth (I_1) and 75% RDF+15% RDN through poultry manure + consortia biofertilisers + 5% each of vermiwash and seaweed extract (N_5) treatments (Fig. 3). The enhanced nutrient uptake under these treatments may be attributed to improved soil moisture availability, which facilitates nutrient solubility and transport to plant roots, along with the positive influence of integrated nutrient sources on soil microbial activity and nutrient mineralisation (Ghosh *et al.* 2020). Water availability also facilitates better nutrient uptake by improving root proliferation and mass flow of nutrients. Full irrigation ensures better translocation of photosynthates and reduces kernel abortion (Ning *et al.* 2024). Similar findings were reported by Shweta *et al.*

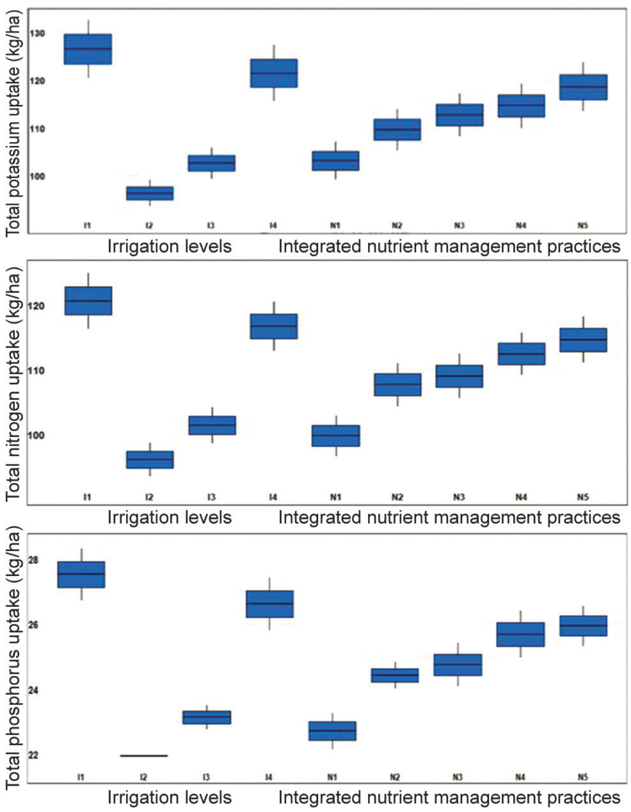

Fig. 3 Total nitrogen, phosphorous and potassium uptake (kg/ha) as influenced under different irrigation levels and integrated nutrient management practices (pooled data of 2 years).
Treatment details are given under Materials and Methods.

Table 2 Economics of *rabi* maize under different irrigation levels and integrated nutrient management practices

Treatments	Cost of cultivation (₹/ha)	Gross income (₹/ha)	Net return (₹/ha)	B:C
Irrigation levels (I)				
I_1	67,942	2,24,961[a]	1,57,020[a]	2.32[a]
I_2	66,034	2,05,387[c]	1,39,353[c]	2.12[c]
I_3	66,987	2,08,348[b]	1,41,360[b]	2.12[ab]
I_4	68,895	2,22,883[ab]	1,53,988[ab]	2.25[ab]
SEM±	-	3,286	2,255	0.04
Integrated nutrient management practices (N)				
N_1	58,247	2,05,112[b]	1,46,865[b]	2.52[a]
N_2	66,648	2,15,524[b]	1,48,703[b]	2.23[b]
N_3	68,900	2,16,702[ab]	1,47,802[ab]	2.14[b]
N_4	70,506	2,18,234[a]	1,47,728[a]	2.09[b]
N_5	73,022	2,21,402[a]	1,48,553[a]	2.03[b]
SEM±	-	4,285	2,938	0.04
Interaction (I × F)				
I_1N_1	58,724	2,12,683[a-c]	1,53,959[ab]	2.62[a]
I_1N_2	67,125	2,25,805[ab]	1,57,986[ab]	2.37[a-d]
I_1N_3	69,377	2,26,063[ab]	1,56,686[ab]	2.26[b-e]
I_1N_4	70,983	2,28,200[ab]	1,57,217[ab]	2.22[b-e]
I_1N_5	73,499	2,32,055[a]	1,59,250[a]	2.16[d-f]
I_2N_1	56,816	1,95,275[c]	1,38,459[b]	2.44[a-c]
I_2N_2	65,217	2,04,998 [a-c]	1,39,781[ab]	2.14[d-f]
I_2N_3	67,469	2,07,535 [a-c]	1,40,066[ab]	2.07[ef]
I_2N_4	69,075	2,08,803 [a-c]	1,39,728[ab]	2.02[ef]
I_2N_5	71,591	2,10,325 [a-c]	1,38,734[b]	1.94[f]
I_3N_1	57,770	1,99,865[bc]	1,42,095[ab]	2.46[ab]
I_3N_2	66,170	2,08,770 [a-c]	1,42,600[ab]	2.16[d-f]
I_3N_3	68,423	2,09,788 [a-c]	1,41,365[ab]	2.06[ef]
I_3N_4	70,029	2,11,060 [a-c]	1,41,031[ab]	2.01[ef]
I_3N_5	72,545	2,12,256 [a-c]	1,39,711[ab]	1.93[f]
I_4N_1	59,678	2,12,627[a-c]	1,52,949[ab]	2.57[a]
I_4N_2	68,078	2,22,525[a-c]	1,54,447[ab]	2.27[b-e]
I_4N_3	70,331	2,23,421[a-c]	1,53,090[ab]	2.18[c-f]
I_4N_4	71,937	2,24,872[a-c]	1,52,935[ab]	2.13[d-f]
I_4N_5	74,453	2,30,971[a]	1,56,518[ab]	2.1[d-f]
SEM±	-	8,340	5,719	0.09

Means followed by the same letters (s) within a column do not differ significantly by DMRT ($p<0.05$). Treatment details are given under Materials and Methods.

(2025), who observed reduced maize productivity under water stress due to higher evapotranspiration losses during critical growth stages. Conversely, 0.6 IW/CPE ratio during the vegetative phase *fb* 1.0 IW/CPE ratio during the reproductive phase (I_2), which had water limitation during the vegetative phase, resulted in the lowest yields due to stunted early growth.

In the nutrient management modules, 75% RDF with 15% RDN through poultry manure, consortia of biofertilisers, vermiwash and seaweed extract (N_5) produced the highest kernel (8,897 kg/ha) and stover yield (17,280 kg/ha), indicating the effectiveness of integrating organic and inorganic nutrient sources for enhanced yield. Organic additives such as vermiwash and seaweed extract not only supply micronutrients but also act as biostimulants (Khan *et al.* 2009), improving grain filling and biomass production. Overall, integrated nutrient management enhances nutrient uptake (Fig. 3), promotes root growth, stimulates plant growth-promoting substances and provides protection against pathogens, all of which contribute to an increase in yield-attributing characteristics and ultimately the economic yield. Conjoint application of NPK along with FYM application increased maize grain yield by 6% over NPK application (Saini *et al.* 2019).

The treatment interaction of 1.0 IW/CPE throughout crop growth and 75% RDF with 15% RDN through poultry manure, consortia of biofertilisers, vermiwash and seaweed extract (I_1N_5) yielded the maximum kernel yield (9,317 kg/ha) and stover yield (18,197 kg/ha), showcasing the benefits of combining efficient irrigation with enriched nutrient sources. These results are consistent with those of Kumari *et al.* (2017), who reported the highest maize yield under well-watered conditions coupled with integrated nutrient management.

Economically, 1.0 IW/CPE maintained throughout crop growth (I_1) produced the highest gross income (₹2,24,961/ha) and net return (₹1,57,020/ha), with a B-C ratio of 2.32 (Table 2). This confirms that full irrigation not only enhances yield but also improves profitability, as supported by Zhao *et al.* (2021). Among the nutrient strategies application of 75% RDF + 15% RDN through poultry manure + consortia biofertilisers + 5% each of vermiwash and seaweed extract (N_5) was the most profitable in terms of gross (₹2,21,402/ha) and net return (₹1,48,553/ha). This is mainly because of the yield improvement in the integrated nutrient management practice. However, 100% RDF (N_1) recorded the highest B-C ratio (2.52) owing to lower input costs (Table 2). The combination of 1.0 IW/CPE throughout crop growth + 75% RDF + 15% RDN through poultry manure + consortia biofertilisers + 5% each of vermiwash and seaweed extract (I_1N_5) provided the maximum gross income (₹2,37,153/ha) and net return (₹1,59,250/ha). The highest B:C ratio (2.62) was observed under 1.0 IW/CPE throughout crop growth (I_1) and 100% RDF (N_1) owing to its lower cultivation cost. Similar trends of economic viability with integrated nutrient and water management were reported by Choudhary *et al.* (2018) for maize.

The experiment evaluated irrigation regimes and integrated nutrient management (INM) practices for *rabi* maize in eastern Uttar Pradesh. Irrigation at 1.0 IW/CPE throughout crop growth (I_1) recorded the highest kernel and stover yields and remained statistically comparable with 1.0 IW/CPE during vegetative phase *fb* 1.2 IW/CPE during reproductive phase (I_4). Among INM treatments, 75% RDF + poultry manure, biofertilisers, vermiwash and seaweed extract (N_5) produced superior yields and profitability over 100% RDF (N_1). The interaction effect was significant, with 1.0 IW/CPE throughout crop growth and 75% RDF+15% RDN through poultry manure + consortia biofertilisers + 5% each of vermiwash and seaweed extract (I_1N_5) achieving the maximum productivity. Overall, optimum irrigation scheduling combined with integrated nutrient and biostimulant application enhanced maize productivity and profitability.

REFERENCES

Abid M, Batool T, Siddique G, Ali S, Binyamin R, Shahid M J, Rizwan M, Alsahli A A and Alyemeni M N. 2020. Integrated nutrient management enhances soil quality and crop productivity in maize-based cropping system. *Sustainability* **12**(23): 10214. https://doi.org/10.3390/su122310214

Biswasi S K, Barik A K, Bastia D K, Dalei B, Nayak L and Ray M. 2020. Effect of integrated nutrient management on growth, productivity and economics of hybrid maize in Odisha state. *International Journal of Bio-resource and Stress Management* **11**(5): 465–71. https://doi.org/10.23910/1.2020.2072b

Chadak S, Sharma R P, Sankhyan N K, Kumar R, Sharotri A and Thakur I. 2025. Nutrient uptake and yield of maize as influenced by regular application of fertilisers and amendments in an acid Alfisol. *Himachal Journal of Agricultural Research* **51**(1): 99–104.

Chandrawanshi A, Bagri P K and Karade R. 2024. Effect of integrated nutrient management on growth and yield parameters of maize (*Zea mays* L.). *International Journal of Environment and Climate Change* **14**(3): 630–37. https://doi.org/:10.9734/IJECC/2024/v14i34071

Choudhary A K, Sharma R K and Yadav D S. 2018. Integrated nutrient and water management in maize. *Agricultural Reviews* **39**(3): 231–37.

DA&FW. 2025. *Agricultural Statistics at a Glance 2024–25.* Economics, Statistics and Evaluation Division, Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India.

Duncan D B. 1955. Multiple range and multiple F tests. *Biometrics* **11**: 1–42.

Gheith E M S, El-Badry O Z, Lamlom S F, Ali H M, Siddiqui M H, Ghareeb R Y, El-Sheikh M H, Jebril J, Abdelsalam N R and Kandil E E. 2022. Maize (*Zea mays* L.) productivity and nitrogen use efficiency in response to nitrogen application levels and time. *Frontiers in Plant Science* **13**: 941343. https://doi.org/10.3389/fpls.2022.941343

Ghosh D, Brahmachari K, Brestic M, Ondrisik P, Hossain A, Skalicky M, Sarkar S, Moulick D, Dinda N K, Das A and Pramanick B. 2020. Integrated weed and nutrient management improve yield, nutrient uptake and economics of maize in the rice-maize cropping system of Eastern India. *Agronomy* **10**(12): 1906. https://doi.org/10.3390/agronomy10121906

Jackson M L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd, New Delhi.

Kang S, Shi W and Zhang J. 2000. An improved water-use efficiency for maize grown under regulated deficit irrigation. *Field Crops Research* **67**: 207–14.

Khan W, Rayirath U P, Subramanian S, Jithesh M N, Rayorath P, Hodges D M, Critchley A T, Craigie J S, Norrie J and Prithiviraj B. 2009. Seaweed extracts as biostimulants of plant growth and development. *Journal of Plant Growth Regulation* **28**(4): 386–99. https://doi.org/10.1007/s00344-009-9103-x

Kumar R, Srinivas K, Boiroju N K and Gedam P C. 2014. Production performance of maize in India: Approaching an inflection point. *International Journal of Agricultural and Statistical Sciences* **10**(1): 241–48.

Kumari K, Dass A, Sudhishri S, Kaur R and Rani A. 2017. Yield components, yield and nutrient uptake pattern in maize (*Zea mays*) under varying irrigation and nitrogen levels. *Indian Journal of Agronomy* **62**(1): 104–07. https://doi.org/10.59797/ija.v62i1.4265

Mahato M, Biswas S and Dutta D. 2020. Effect of integrated nutrient management on growth, yield and economics of hybrid maize (*Zea mays* L.). *Current Journal of Applied Science and Technology* **39**(3): 78–86. https://doi.org/10.9734/CJAST/2020/v39i330517

Ning D, Chen H, Qin A, Gao Y, Zhang J, Duan A, Wang X and Liu Z. 2024. Optimising irrigation and N fertigation regimes achieved high yield and water productivity and low N leaching in a maize field in the North China Plain. *Agricultural Water Management* **301**: 108945. https://doi.org/10.1016/j.agwat.2024.108945

Olsen S K, Cole S V, Watanbe F S and Dcan L A. 1954. *Estimation of Available Phosphorus in Soil by Extraction with Sodium Bicarbonate*, USDA Circular No. 939. United States Department of Agriculture, Washington DC.

Rathwa M K and Bhanvadia A S. 2023. Impact of irrigation scheduling and nitrogen management through drip irrigation system on nutrient content and uptake of *rabi* maize (*Zea mays* L.). *International Journal of Plant and Soil Science* **35**(23): 345–55.

Saini S P, Singh P and Brar B S. 2019. Nutrient management productivity and nutrient-use efficiency in floodplain soils under maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping. *The Indian Journal of Agricultural Sciences* **89**(10): 1589–93. https://doi.org/10.56093/ijas.v89i10.94583

Singh D, Kumar M, Birla D, Gajanand and Shrivastava S. 2022. Effect of irrigation methods, nutrient management and intercropping system on grain yield, maize equivalent yield, protein content and economics of maize *(Zea mays* L.). *International Journal of Plant and Soil Science* **34**(23): 1248–53. https://doi.org/10.9734/IJPSS/2022/v34i232539

Sivasankari S, Venkatesalu V, Anantharaj M and Chandrasekaran M. 2006. Effect of seaweed extracts on the growth and biochemical constituents of *Vigna sinensis*. *Bioresource Technology* **97**(14): 1745–51. https://doi.org/10.9734/IJPSS/2023/v35i234249

Shweta, Kumar A, Kumari A, Neelam, Sehwag M, Malik K and Munjal R. 2025. Irrigation scheduling and superabsorbent polymers for enhancing productivity and improving plant water dynamics of *kharif* baby corn (*Zea mays*). *The Indian Journal of Agricultural Sciences* **95**(6): 630–36. https://doi.org/10.56093/ijas.v95i7.148206

Subbiah B V and Asija G L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science* **25**(8): 259–60.

Thirumaran G, Arumugam M, Arumugam R and Anantharaman P. 2009. Effect of seaweed liquid fertiliser on growth and pigment concentration of *Cyamopsis tetrogonolaba* (L.) Taub. *American-Eurasian Journal of Agronomy* **2**(2): 50–56.

Uhart S A and Andrade F H. 1995. Nitrogen deficiency in maize: I. Effects on crop growth, development, dry matter partitioning and kernel set. *Crop Science* **35**(5): 1376–83.

Walkley A and Black I A. 1934. An examination of the Degtijareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29–38.

Zhao Y, Li F and Jiang R. 2021. Irrigation schedule optimisation based on the combination of an economic irrigation quota and the AquaCrop model. *Irrigation and Drainage* **70**(4): 773–85. https://doi.org/10.1002/ird.2577