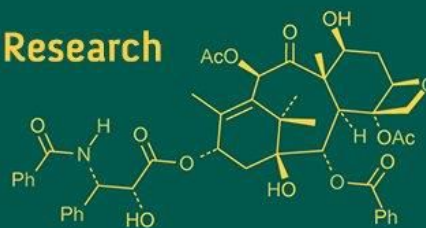


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Pragya Tiwari

a) Instructional-cum-Research Farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, Chhattisgarh, India
b) Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Dr. Dinesh Pandey

a) Instructional-cum-Research Farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, Chhattisgarh, India
b) Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Sunil Kumar

a) Instructional-cum-Research Farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, Chhattisgarh, India
b) Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

PK Keshry

a) Instructional-cum-Research Farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, Chhattisgarh, India
b) Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

NK Chaurse

a) Instructional-cum-Research Farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, Chhattisgarh, India
b) Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Corresponding Author:**Pragya Tiwari**

a) Instructional-cum-Research Farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, Chhattisgarh, India
b) Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Effect of irrigation methods and nutrient managements on growth of late sown wheat (*Triticum aestivum*)

Pragya Tiwari, Dinesh Pandey, Sunil Kumar, PK Keshry and NK Chaurse

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Abstract

The present experiment entitled “Effect of irrigation methods and nutrient managements on growth of late sown wheat (*Triticum aestivum*)” was conducted during *rabi* season in year 2023-24 at Instructional cum research farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, (C.G.). The experiment was laid out in Split Plot Design (SPD) with Irrigation methods (03): Main plot, Nutrient management (05): Sub plot treatments and three replications. The treatment consists of I₁ (Surface Irrigation (Check Basin) Dept of irrigation 6 cm (IW/CPE =1), I₂ (Sprinkler Irrigation (Dept of irrigation 3 cm)), I₃ (Surface + Sprinkler Irrigation (Dept of irrigation 3 cm)) at Main plot: Irrigation methods and N₁ (100% RDN (90:60:40 kg NPK/ha)), N₂ (100% RDN through (FYM enriched by Rock Phosphate + Microbial + Consortia + Jivamrit+ Decomposer)), N₃ (50% RDN through enriched FYM with microbial Consortia + 50% % RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer), N₄ (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia + 25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer), N₅ (Control (No NPK)) at Sub plot: Nutrient management. The results showed at Main plot: Irrigation methods, the I₃ (Surface + Sprinkler Irrigation (Dept of irrigation 3 cm)) performed the best in terms of ear length (cm), ear weight (g), number of ears plant⁻¹, physiological maturity, number of grains ear head⁻¹, 1000 grain weight (g), grain yield (q ha⁻¹), biomass yield (q ha⁻¹), harvest index, which was followed closely by the treatment I₂ (sprinkler irrigation) and the lowest was observed in the treatment I₁ (Surface Irrigation (Check Basin)). The results showed at Sub plot: Nutrient management, the N₄ (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia + 25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) performed the best in terms of plant population (no. m⁻²), plant height (cm), Number of tillers (no. m⁻²), plant canopy temperature at CRI, flowering, milking stage, plant canopy humidity at CRI, flowering, milking stage, number of active leaves plant⁻¹, dry matter accumulation (g day⁻¹ plant⁻¹), crop growth rate (CGR) (g day⁻¹ m⁻²), relative growth rate (RGR) (g g⁻¹ day⁻¹), water expanse (mm) and water expanse efficiency (kg cm), which was followed closely by the treatment N₁ (100% RDN) and N₂ (100% RDN through FYM enriched by Rock Phosphate + Microbial + Consortia + Jivamrit+ Decomposer) and the lowest was observed in the treatment N₅ (Control).

Keywords: Irrigation methods, nutrient management, surface irrigation, sprinkler irrigation, integrated irrigation, enriched FYM, microbial consortia, RDN

Introduction

Wheat is cultivated in at least 63 countries of the world. The leading countries in wheat cultivation are China, India, Russia, U.S.A and Canada (IWPS, 2022a) [10]. Total world production of wheat was 772 million tons on an area of 218 million hectares with a productivity of 2960 kg ha⁻¹ (IWPS, 2022b) [11]. Globally, rice demand is expected to increase by 25% from the year 2001 to 2025 to meet the requirement of increasing population (Rosegrant *et al.*, 2002) [24]. Globally, total rice area is about 164.62 M ha, production is 504.71 Mt with productivity of 3.1 t ha⁻¹ (Anonymous, 2021b) [2].

Wheat is the most important staple food in the world and is the second important cereal crop after rice in India. It is cultivated in 31.61 million ha area with an annual production of about 109.52 million tonnes and an average productivity of 2813 kg/ha (GOI, 2021c).

In India, increase in minimum support price of rice and its adaptability to various biotic and abiotic factors have made it a preferable crop for farmers especially those who fall under the category of marginal farmers. In Indian subcontinent, rice is grown with an area of 45.07 M ha and 122.27 Mt of production and 3964 kg ha⁻¹ productivity in the year 2020-21 (Anonymous, 2021c) [3].

The area under wheat cultivation in Chhattisgarh has increased further to 1.02 million hectares in 2021-22 from 0.84 million hectares in 2019-20. Wheat production in the state reached a record high of 4.76 million tonnes in 2021-22, up from 3.3 million tonnes in 2019-20 (Anonymous, 2022c) [3]. This shows a significant rise in wheat output. However, wheat productivity in Chhattisgarh remains below the national average. In 2021-22, wheat productivity in the state was around 23.7 quintals per hectare compared to the all-India average of 28.13 quintals per hectare (Anonymous, 2022d) [4].

Chhattisgarh, the central eastern state is also called as the "Rice bowl of India." The total estimated area of rice in Chhattisgarh is 3.70 million ha, production is 4.89 million tonnes and productivity is 2702 kg ha⁻¹ in 2021 (Anonymous, 2021d) [4]. Presently, there are indications of declining crop productivity and soil quality due to depletion in soil organic matter, over mining of nutrient reserves, low factor productivity and loss of nutrients. Moreover, both rice and wheat being exhaustive crops deplete soil fertility. Crop yield is directly proportional to energy input (Srivastava 1982) [27].

The rice-wheat cropping system plays a vital role in ensuring food security for millions of farmers in North India. However, the continuous cultivation of these crops in the same fields without adequate attention to soil health and fertility replenishment has made the system unsustainable over long periods of time. The over-exploitation of natural resources typically associated with this system leads to degradation in soil quality parameters (Prasad, 2007) [20]. Consequently, there has been a gradual decrease observed in the yields of both rice and wheat crops cultivated sequentially in the same fields. However, nutrient management, the managerial aspect of Integrated Plant Nutrition System (IPNS) is more vital in sustaining increased productivity (Yadav and Kumar 2009) [31]. The organic matter component in the INM strategy influences soil biological populations and processes.

2. Material and Method

The field experiment was conducted during rabi 2023-24 at Instructional cum research farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, (C.G.). The soil type was sandy loam. The experiment was laid out in a Split Plot Design (SPD) with Irrigation methods (03): Main plot, Nutrient management (05): Sub plot treatments and three replications. The CG 1029 wheat variety is a high-performing and stable wheat genotype, known for its superior grain yield across various environments. It demonstrates resilience to heat stress, with a heat susceptibility index of 0.48, significantly lower than that of HD 2932. Additionally, CG 1029 exhibits strong resistance to both brown and black rusts, ensuring better crop health. It has a high protein content of approximately 12% and excellent gluten quality, rated chapati making score 8 out of 10, making it ideal for bread and good chapati

production. The CG-1029 variety has a high yield, with an average productivity of 52.1 q/ha.

Plant population (no. m-2) at 30 DAS and at harvest

The number of plants per meter square was recorded from five randomly selected spots in each plots at 30 DAS and at harvest stage.

Plant height (cm) at 30, 60, 90 DAS and at harvest

Five plants of each experimental plot were selected randomly and tagged. Plant height of the tagged wheat plant was recorded with the help of meter scale from the base of the plant to the tip of upper most leaf of the plant before panicle emergence and up to the tip of panicle after heading, averaged and expressed in cm.

Number of tillers (no. m-2) at 30, 60, 90 DAS and at harvest

Number of tillers was recorded from each treatment at 30, 60, 90 DAT and at harvest. Five hills were randomly selected in each plot and then counted and recorded the numbers of tillers along each plant. Averaged and converted into in number of tillers/m²

Plant canopy temperature at CRI, Flowering, Milking stage

Canopy temperature is measured using a thermometer to capture the surface temperature of plant canopy at CRI, Flowering, Milking stage.

Plant canopy humidity at CRI, Flowering, Milking stage

Plant canopy humidity can be measured by recording the dry and wet bulb temperatures and using hygrometric tables to calculate the relative humidity at CRI, Flowering, Milking stage.

Number of active leaves plant-1 at 30 and 60 DAS

The number of active leaves per plant at 30 and 60 days after sowing (DAS) was measured by manual leaf counting. This involves physically counting the fully developed, healthy, and photosynthetically active leaves on each tagged plant to monitor growth and development stages.

Dry matter accumulation (g day-1 plant-1) at 30, 60, 90 DAS and at harvest

Dry matter accumulation was measured by uprooting plant sample from each plot. Plants were cut close to the ground portion to remove the root part to record dry matter accumulation at different crop growth stage. Samples were first dried in sun and then oven dried at 70°C ± 2°C till constant weight achieved. After drying, the samples were weighted for recording dry weight and expressed in gram plant.

Crop growth rate (CGR) (g day-1 m -2) at (30-60), (60-90) and (90-harvest): It represents dry weight gained by a unit area of crop in a unit time expressed as g m⁻² day⁻¹ (Hunt, 1978). The values of plant dry weight at 0-30, 30-60, 60-90 and 90 DAS- at harvest stage intervals were used for calculating the CGR.

Relative growth rate (RGR) (g g-1 day-1) at (30-60), (60-90) and (90-harvest): The relative growth rate (RGR) of a plant at a constant time (t) is defined as "the increase in

plant material per unit material present per unit time". The mean relative growth rate of the crop was calculated by using the following relationship (Evans, 1982).

- $W1$ and $W2$ = Total dry weight (g) of the plants at the time $t1$ and $t2$ respectively.

Water expanse (mm)

- Total water expanse was calculated by using following formula:
- WE = Water applied through drip + Re

Where,

- WE = water expanse (mm)
- Re = effective Rainfall (mm)

Water expanse efficiency (kg cm)

WUE ($\text{kg ha}^{-1}\text{mm}^{-1}$) was calculated as the ratio of seed yield to water expanse (used) (mm) for wheat crop for different treatments:

$$WUE (\text{kg ha}^{-1}\text{mm}^{-1}) = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Water expanse (mm)}}$$

3. Result

The data pertaining to plant population (no. m^{-2}), plant height (cm), Number of tillers (no. m^{-2}), plant canopy temperature at CRI, flowering, milking stage, plant canopy humidity at CRI, flowering, milking stage, number of active leaves plant-1, dry matter accumulation (g day^{-1} plant-1), crop growth rate (CGR) ($\text{g day}^{-1} m^{-2}$), relative growth rate (RGR) ($\text{g g}^{-1} \text{day}^{-1}$), water expanse (mm) and water expanse efficiency (kg cm) were influenced by effect of irrigation methods and Nutrient managements on productivity of late sown wheat has been recorded and presented in Table 1, Table 2, Table 3, Table 4, Table 5, Table 6. Table 7, Table 8, Table 9 and Table 10.

Plant population (no. m^{-2})

The data pertaining to plant population (no. m^{-2}) of wheat has been recorded at 30 DAS and at harvest and presented in Table 4.1.

Irrigation methods

Data presented in Table 4.1 showed that plant population (no. m^{-2}) has showed non-significant difference, among treatments of irrigation methods at 30 DAS and at harvest during both the year of experimentation.

Nutrient managements

Among different Nutrient managements Plant population (no. m^{-2}) found non-significant difference among Nutrient managements treatments at 30 DAS and at harvest during both the year of study.

Plant height (cm)

The data pertaining to plant height (cm) has influenced by effect of irrigation methods and Nutrient managements on late sown wheat has been recorded and presented in Table 4.2.

Irrigation methods

The highest plant height (cm) was recorded due to treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm) (27.11 cm), which was significantly superior over I2

(Sprinkler Irrigation (Depth of irrigation 3cm) (24.71 cm) treatment and I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm ($IW/CPE = 1$) (23.11 cm) on pooled mean at 30 DAS. The lower plant height (cm) was obtained in the treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm ($IW/CPE = 1$) (23.11 cm).

The highest plant height (cm) was recorded due to treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm) (72.95 cm), which was significantly superior over I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (68.05 cm) and treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm ($IW/CPE = 1$) (23.11 cm) on pooled mean at 60 DAS. The lower plant height (cm) was obtained in the treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm ($IW/CPE = 1$) (63.20 cm). At 90 DAS, the tallest plants (92.08 cm) were recorded under treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm), which was significantly superior over I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (87.22 cm) and treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm ($IW/CPE = 1$) (23.11 cm) on pooled mean at 90 DAS. The lower plant height (cm) was obtained in the treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm ($IW/CPE = 1$) (82.13 cm). The highest plant height (cm) was recorded due to treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm) (90.30 cm), which was significantly superior over I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (84.10 cm) and treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm ($IW/CPE = 1$) (23.11 cm) on pooled mean at harvest. The lower plant height (cm) was obtained in the treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm ($IW/CPE = 1$) (80.43 cm). The superior plant height under I3 treatment is attributed to efficient moisture availability from combined surface and sprinkler irrigation, promoting better growth. In contrast, I1's excessive depth may cause nutrient leaching, limiting height. Thus, I3 proved most effective in enhancing plant height at all growth stages, indicating its suitability for late sown wheat. Similar result was also found by Rao *et al.* (2020) and Karangiya *et al.* (2019)^[11, 21].

Nutrient managements

At 30 days after sowing (DAS), the highest plant height (25.88 cm), based on pooled data of 2023-24 and 2023-24, was recorded under treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer). Which was significantly superior to both N1 (100% RDF (90:60:40 kg NPK/ha)) and N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer), which recorded plant heights of (25.62 cm) and (24.82 cm), respectively. The lowest plant height (24.05 cm) was observed in treatment N5 (Control (No NPK)). The highest plant height (70.52 cm) at 60 DAS, based on pooled mean data, was recorded under treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer). This treatment was significantly superior to both N1 (100% RDF (90:60:40 kg NPK/ha)) and N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer), which recorded plant heights of

(69.91 cm) and (67.56 cm), respectively. The lowest plant height (65.70 cm) was observed in treatment N5 (Control (No NPK)). At 90 DAS, a similar trend was observed. The maximum plant height (89.49 cm) was again recorded under treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer). This treatment was significantly superior to both N1 (100% RDF (90:60:40 kg NPK/ha)) and N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer), which recorded plant heights of (88.85 cm) and (86.95 cm), respectively. The lowest plant height (84.84 cm) was observed in treatment N5 (Control (No NPK)) in the pooled mean of 2023-24 and 2023-24. At harvest, the highest plant height (86.85 cm), based on pooled mean data, was recorded under treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer). This treatment was significantly superior to both N1 (100% RDF (90:60:40 kg NPK/ha)) and N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer), which recorded plant heights of (85.90 cm) and (85.34 cm), respectively. The lowest plant height (82.82 cm) was observed in treatment N5 (Control (No NPK)). Treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer). consistently produced the tallest plants due to the synergistic effect of integrated nutrient sources-chemical and enriched organic forms—enhancing nutrient availability and uptake. The presence of microbial consortia and bio-stimulants further promoted growth. Hence, N4 proved most effective in improving plant height, demonstrating the benefits of integrated Nutrient managements in late sown wheat. The results obtained in the present study are supported by the works of Teli *et al.*, (2018), Awaad and Deshesh (2019) and Patyal *et al.*, (2022) [15, 19, 28].

Number of tillers (no./m²)

The data pertaining to number of tillers (no./m²) is influenced by effect of irrigation methods and Nutrient managements on late sown wheat has been recorded and presented in Table 4.3.

Irrigation methods: The significantly highest number of tillers (no./m²) at 30 DAS was found in the treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm) (282.29 no./m²). Over the treatment I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (262.15 no./m² and I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) (227.41 no./m²). While the lowest number of tillers (no./m²) was observed in the treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) (227.41 no./m²) in the pooled mean of 2023-24 and 2023-24. At 60 DAS, treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm) (427.92 no./m²) again recorded the maximum number of tillers, which was followed by with the treatment I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (405.37 no./m²) and I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) (227.41 no./m²). The minimum number of tillers (380.15 no./m²) was noted in treatment I1 (Surface Irrigation (Check

Basin) Depth of irrigation 6cm (IW/CPE = 1) (380.15 no./m²) in the pooled mean of 2023-24 and 2023-24. At 90 DAS, the highest number of tillers (533.22 no./m²) was observed under treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm), which was followed by with the treatment I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (483.67 no./m²) and I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) (227.41 no./m²). While the lowest number of tillers (no./m²) was observed in the treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) (415.45 no./m²) in the pooled mean of 2023-24 and 2023-24. The highest number of tillers in I3 treatment is due to optimal water distribution from combined surface and sprinkler irrigation, ensuring better moisture availability for tiller development. In contrast, the lower number of tillers in I1 may be caused by excessive irrigation depth, leading to inefficient water use and restricted tillering. I3 proved most effective. The results obtained in the present study is in accordance with the results of Teli *et al.*, (2018), Gouda *et al.*, (2024) and Mishra *et al.*, (2024) [9, 15, 28].

Nutrient managements

At 30 days after sowing (DAS), the significantly highest number of tillers (266.11 no./m²), based on pooled mean data, was observed under treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) over other Nutrient managements treatments, but was at par with the treatment N1 (100% RDF (90:60:40 kg NPK/ha)) at (264.84 no./m²). While the lowest number of tillers (no./m²) was observed in the treatment N5 (Control (No NPK)) (244.55 no./m²). At 60 DAS, treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) continued to exhibit the highest number of tillers (412.40 no./m²), significantly outperforming N1 (100% RDF (90:60:40 kg NPK/ha)) (410.28 no./m²), which were at par. The lowest number of tillers (395.11 no./m²) was recorded in the control treatment N5 (Control (No NPK)) in the pooled mean of 2023-24 and 2023-24. At 90 DAS, treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) again recorded the highest number of tillers (494.24 no./m²), which was at par with treatment N1 (100% RDF (90:60:40 kg NPK/ha)) at (492.84 no./m²). The lowest number of tillers (456.25 no./m²) was observed in treatment N5 (Control (No NPK)) in the pooled mean of 2023-24 and 2023-24. Treatment N4 showed the highest number of tillers due to the balanced nutrient supply from both organic and chemical sources, promoting robust tillering. The use of microbial consortia and bio-stimulants likely enhanced nutrient uptake and plant growth. N1 also performed well, but N4's integrated approach provided a slight advantage in tiller production. The finding of present study is in accordance with those of Teli *et al.*, (2018) and Chaudhari & Zinzala (2024) [6, 28].

Plant canopy temperature (°C)

The data pertaining to plant canopy temperature (°C) is influenced by effect of irrigation methods and Nutrient

managements on productivity of late sown wheat has been recorded and presented in Table 4.4.

Irrigation methods

The canopy temperature (°C) at the CRI stage (18-20 days) did not show any significant difference across the various irrigation methods.

Nutrient managements

The canopy temperature (°C) at the CRI stage (18-20 days), flowering stage (50-60 days), and milking stage (90-100 days) did not show any significant difference across the various Nutrient managements treatments.

Plant canopy humidity (%)

The data pertaining to plant canopy humidity (%) is influenced by effect of irrigation methods and Nutrient managements on productivity of late sown wheat has been recorded and presented in Table 4.5.

Plant canopy humidity (%) was influenced by irrigation method (I3) and nutrient management (N5) treatment, but nonsignificant different were observed among irrigation method (I3) and nutrient management (N5) at the CRI, flowering and milking stage of late sown wheat during the study.

Number of active leaves per plant

Number of active leave recorded at different crop growth stage have been presented in table. 4.6.

Irrigation methods

At 30 days after sowing, significant highest number of active leaves per plant (12.71) was recorded under the treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm). Over the treatment treatment I2 (Sprinkler Irrigation (Depth of irrigation 3cm) with a measurement of (11.48). In contrast, the treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) displayed the lowest number of active leaves per plant, measuring just (10.74) in the pooled mean of 2023- 24 and 2023-24. At 60 days after sowing, significant highest number of active leaves per plant (20.48) was recorded under the treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm). This was followed by the treatment treatment I2 (Sprinkler Irrigation (Depth of irrigation 3cm) with the value of (18.54). In contrast, the treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) displayed the lowest number of active leaves per plant, value of (16.73) in the pooled mean of 2023-24 and 2023-24. Treatment I3, combining surface and sprinkler irrigation, promoted the highest number of active leaves due to efficient water distribution and better moisture retention, supporting optimal leaf growth. Treatment I1, with excessive irrigation depth, likely caused waterlogging or inefficient nutrient uptake, limiting leaf growth. Thus, I3 proved most effective treatment for increasing the number of active leaves per plant. Similar results were reported by Abdelraouf *et al.* (2013) [1].

Nutrient managements

At 30 days after sowing, the highest number of active leaves per plant (12.09) was recorded in treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by

Rock Phosphate + Consortia + Jivamrit + decomposer). Which was at par with the treatment N1 (100% RDF (90:60:40 kg NPK/ha)) with a measurement of (11.83). In contrast, the treatment N5 (Control (No NPK)) displayed the lowest number of active leaves per plant, measuring just (11.25) in the pooled mean of 2023-24 and 2023-24. At 60 days after sowing, the highest number of active leaves per plant (19.43) was recorded in treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer). This was at par with the treatment treatment N1 (100% RDF (90:60:40 kg NPK/ha)) and N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer) with a measurement of (18.90) and (18.59) respectively. In contrast, the treatment N5 (Control (No NPK)) displayed the lowest number of active leaves per plant, measuring just (17.75) in the pooled mean of 2023-24 and 2023-24. Treatment N4, utilizing a combination of urea and enriched organic inputs, supported the highest number of active leaves due to improved nutrient availability and soil health through microbial consortia. This treatment enhanced leaf growth more effectively than N5 (control), which lacked nutrients. N1 also performed well, but N4's integrated nutrient approach provided a slight advantage. Similar results were also observed by Shaikh *et al.*, (2017) [25].

Dry matter accumulation (g/plant)

The data pertaining to dry matter accumulation (g/plant) is influenced by effect of irrigation methods and Nutrient managements on productivity of late sown wheat has been recorded and presented in Table 4.7.

Irrigation methods

The significant highest dry matter accumulation (g/plant) at 30 DAS was observed in treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm), over treatment, I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (0.74 g/plant). The significant lowest dry matter accumulation (g/plant) with the value of (0.72 g/plant) was noted in treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) in the pooled mean of 2023-24 and 2023-24. At 60 DAS, the highest dry matter accumulation (8.56 g/plant) was observed in treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm), over treatment, I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (7.98 g/plant). The significant lowest dry matter accumulation (g/plant) with the value of (7.34 g/plant) was observed under treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) in the pooled mean of 2023-24 and 2023-24. As per the data showed that the significant highest dry matter accumulation (g/plant) at 90 DAS with the value of (17.71 g/plant) was recorded under treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm), over treatment, I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (16.82 g/plant). The significant lowest dry matter accumulation (g/plant) with the value of (15.42 g/plant) was noted in treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) in the pooled mean of 2023-24 and 2023-24. Based on the data showed that the significant highest dry matter accumulation (g/plant) at harvest with the value of (17.51 g/plant) was noted in treatment I3 (Surface + Sprinkler Irrigation (Depth

of irrigation 3cm), over treatment, I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (16.84 g/plant). The lowest dry matter accumulation (g/plant) with the value of (15.90 g/plant) was noted in treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) in the pooled mean of 2023-24 and 2023-24. Treatment I3 showed the highest dry matter accumulation due to improved water efficiency and consistent moisture from combined surface and sprinkler irrigation, enhancing nutrient uptake and plant growth. In contrast, I1's higher water depth likely caused nutrient leaching or water stress. Thus, I3 was the most effective in maximizing dry matter accumulation in late sown wheat. Similar result was also reported by Laila *et al.* (2022), Yadav and Niwas (2022), Dhaker *et al.* (2022) and Singh *et al.* (2024) [7, 14, 17, 26, 30].

Nutrient managements

At 30 DAS, the significantly highest dry matter accumulation (0.75 g/plant) was recorded in treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) over other Nutrient managements, but was at par with the treatment treatment N1 (100% RDF (90:60:40 kg NPK/ha)) (0.75 g/plant). The significant lowest dry matter accumulation (g/plant) with the value of (0.73 g/plant) was noted in treatment N5 (Control (No NPK)) in the pooled mean of 2023-24 and 2023-24. As per the data showed that the significant highest dry matter accumulation (g/plant) at 60 DAS with the value of (8.18 g/plant) was noted in treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) over other Nutrient managements, but was at par with the treatment treatment N1 (100% RDF (90:60:40 kg NPK/ha)) (8.15 g/plant) and N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer) (7.93 g/plant). The significant lowest dry matter accumulation (g/plant) with the value of (7.71 g/plant) was noted in treatment N5 (Control (No NPK)) in the pooled mean of 2023-24 and 2023-24. Among the data showed that the significant highest dry matter accumulation (g/plant) at 90 DAS with the value of (17.03 g/plant) was noted in treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) over other Nutrient managements, but was at par with the treatment treatment N1 (100% RDF (90:60:40 kg NPK/ha)) (17.00 g/plant) and N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer) (16.67 g/plant). The significant lowest dry matter accumulation (g/plant) with the value of (16.16 g/plant) was noted in treatment N5 (Control (No NPK)) in the pooled mean of 2023-24 and 2023-24.

At harvest, the trend continued with the highest dry matter accumulation (17.10 g/plant) in treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) over other Nutrient managements, but was at par with the treatment treatment N1 (100% RDF (90:60:40 kg NPK/ha)) (17.75 g/plant) and N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit +

decomposer) (16.73 g/plant). The significant lowest dry matter accumulation (g/plant) with the value of (16.49 g/plant) was noted in treatment N5 (Control (No NPK)) in the pooled mean of 2023-24 and 2023-24. Treatment N4 consistently recorded the highest dry matter accumulation due to synergistic effects of integrated nutrient sources-chemical (urea) and enriched organics-enhancing nutrient availability, microbial activity, and plant metabolism. Its performance matched N1 and N2, indicating organic options can substitute synthetic fertilizers. N5, lacking nutrients, showed the lowest values, confirming the critical role of Nutrient managements. Also, similar results were reported by Moe *et al.*, (2019), Rao *et al.* (2020) and Patyal *et al.*, (2022) [13, 19, 21].

Crop Growth Rate (CGR) (g/day/m²)

The data pertaining to Crop Growth Rate (CGR) (g/day/m²) is influenced by effect of irrigation methods and Nutrient managements on productivity of late sown wheat has been recorded and presented in Table 4.8.

Irrigation methods

The data displayed in Table 4.8, regarding Crop Growth Rate (CGR) (g/day/m²) at 30-60 DAS, clearly shows that significant highest Crop Growth Rate (CGR) (g/day/m²) was observed in treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm) (0.260 g/day/m²). Over the treatment, I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (0.241 g/day/m²). Significant lowest Crop Growth Rate (CGR) (g/day/m²) was observed in treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) (0.221 g/day/m²) in the pooled mean of 2023-24 and 2023-24. At 60-90 DAS, the highest CGR (0.305 g/day/m²) was again observed in treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm) Over the Nutrient managements treatment, but was at par with the treatment, I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (0.241 g/day/m²). Significant lowest Crop Growth Rate (CGR) (g/day/m²) was observed in treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) (0.269 g/day/m²) in the pooled mean of 2023- 24 and 2023-24. Crop Growth Rate (CGR) (g/day/m²) from 90 DAS to harvest was influenced by Nutrient managements; however, the differences among the Nutrient managements treatments were found to be non-significant in the pooled mean of 2023-24 and 2023- 24. Irrigation methods significantly affected CGR, with I3 (Surface + Sprinkler) consistently showing the highest values due to optimized soil moisture and aeration. I2 followed closely, while I1 lagged due to over-saturation and reduced root activity. Post-90 DAS, nutrient influence became more pronounced, though statistical differences in CGR among treatments were non-significant. Similar study were also observed by Ronanki and Behera (2018) and Niwas *et al.* (2023) [17, 23].

Nutrient managements

The data presented in Table 4.8 regarding Crop Growth Rate (CGR) (g/day/m²) during the 30-60 DAS period clearly indicated that the significantly highest CGR was recorded in treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) (0.248 g/day/m²). Over the Nutrient managements treatment, but was at par with the treatment,

N1 (100% RDF (90:60:40 kg NPK/ha)) (0.247 g/day/m²) and N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer) (0.240 g/day/m²). Significant lowest Crop Growth Rate (CGR) (g/day/m²) was observed in treatment N5 (Control (No NPK)) (0.233 g/day/m²) in the pooled mean of 2023-24 and 2023-24. Crop Growth Rate (CGR) during the periods 60-90 DAS and 90 DAS to harvest was also influenced by Nutrient managements practices; however, the differences among the treatments were found to be non-significant in the pooled mean of 2023-24 and 2023-24. Nutrient managements significantly impacted CGR during 30-60 DAS, with N4 showing the highest rate due to the synergistic effect of organic and inorganic nutrient sources enhancing soil fertility and microbial activity. N1 and N2 followed closely. However, from 60 DAS onward, CGR differences among treatments became statistically non-significant. These outcomes are consistent with findings of Dhaker *et al.* (2022) and Singh *et al.* (2024) [7, 26].

Relative Growth Rate (CGR) (g/g/day)

The data pertaining to Relative Growth Rate (RGR) (g/g/day) is influenced by effect of irrigation methods and Nutrient managements on productivity of late sown wheat has been recorded and presented in Table 4.9.

Irrigation methods: The Relative Growth Rate (RGR) (g/g/day) during the 30-60 DAS period was significantly highest in treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm) (0.936 g/g/day) Over treatment I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (0.906 g/g/day). Significant lowest Relative Growth Rate (RGR) (g/g/day) was noted in treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) (0.870 g/g/day) in the pooled mean of 2023-24 and 2023-24. Similarly, during the 60-90 DAS period, the highest RGR was observed in treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm) (1.213 g/g/day), Over treatment I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (1.191 g/g/day). Significant lowest Relative Growth Rate (RGR) (g/g/day) was noted in treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) (1.153 g/g/day) in the pooled mean of 2023-24 and 2023-24. At the final growth interval of 90 DAS to harvest, treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm) maintained the significantly highest RGR (1.197 g/g/day), Over treatment I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (1.181 g/g/day). Significant lowest Relative Growth Rate (RGR) (g/g/day) was noted in treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) (1.157 g/g/day) in the pooled mean of 2023-24 and 2023-24. The RGR data indicates that the combination of Surface + Sprinkler Irrigation (I3) consistently resulted in the highest growth rate across all stages of wheat development. This suggests that I3 may optimize water distribution and enhance plant growth efficiency. In contrast, treatment I1, with the lowest irrigation depth and less efficient water use, recorded the lowest RGR at each stage, reflecting its limited ability to support optimal growth. Similar result was also found by Laila *et al.* (2022) and Dhaker *et al.* (2022) [7, 14].

Nutrient managements

The Relative Growth Rate (RGR) (g/g/day) during 30-60 DAS was significantly highest in treatment N4 (50% RDN

through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) (0.916 g/g/day), Overtreatment N1 (100% RDF (90:60:40 kg NPK/ha)) (0.914 g/g/day) and N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer) (0.902 g/g/day). Significant lowest Relative Growth Rate (RGR) (g/g/day) was noted in treatment N5 (Control (No NPK)) (0.890 g/g/day) in the pooled mean of 2023-24 and 2023-24. During the 60-90 DAS period, the highest RGR was observed in N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) (1.195 g/g/day), Overtreatment N1 (100% RDF (90:60:40 kg NPK/ha)) (1.195 g/g/day) and N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer) (1.186 g/g/day). Significant lowest Relative Growth Rate (RGR) (g/g/day) was noted in treatment N5 (Control (No NPK)) (1.173 g/g/day) in the pooled mean of 2023-24 and 2023-24. At 90 DAS to harvest, the highest RGR was again found in treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) (1.187 g/g/day), which was followed by the treatment N1 (100% RDF (90:60:40 kg NPK/ha)) (1.178 g/g/day) and N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer) (1.177 g/g/day). Significant lowest Relative Growth Rate (RGR) (g/g/day) was noted in treatment N5 (Control (No NPK)) (1.172 g/g/day) in the pooled mean of 2023-24 and 2023-24. The highest Relative Growth Rate (RGR) in treatment N4 can be attributed to the combined application of urea, enriched FYM, microbial consortia, Jivamrit, and rock phosphate, which enhanced nutrient availability and soil health. In contrast, the control treatment (N5) without nutrients showed the lowest RGR, emphasizing the importance of Nutrient managements. The results obtained in the present study are supported by the works of Rao *et al.* (2020) and Patyal *et al.*, (2022) [12, 21].

Water expanse (mm) and Water expanse efficiency (kg/ha-cm):

The data pertaining to water expanse (mm) and water expanse efficiency (kg/ha-cm) is influenced by effect of irrigation methods and Nutrient managements on productivity of late sown wheat has been recorded and presented in Table 4.10.

Water expanse (mm)

Irrigation methods: The data presented in Table 4.10 clearly shows that the highest water expanse (mm) was significantly observed in treatment I1 (Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1) (407.36 mm) Over the treatment I3 (Surface + Sprinkler Irrigation (Depth of irrigation 3cm) (355.54 mm). On the other hand, the significant lowest water expanse (mm) was recorded in treatment I2 (Sprinkler Irrigation (Depth of irrigation 3cm) (352.34 mm) in the pooled mean of 2023-24 and 2023-24. The higher water expanse in Surface Irrigation (Check Basin) (I1) can be attributed to the less controlled nature of water application, which results in significant losses through evaporation and runoff. The combination of Surface + Sprinkler Irrigation (I3) and Sprinkler Irrigation

(I2) reduces such losses by providing more precise and efficient water distribution. The results obtained in the present study is in accordance with the results of Waraich *et al.*, (2010), Narolia *et al.* (2016) and Gouda *et al.*, (2024) [9, 16, 29].

Nutrient managements

The data provided in Table 4.10 clearly shows that the highest water expanse (mm) was significantly observed in treatment N1 (100% RDF (90:60:40 kg NPK/ha)) (437.31 mm), Over treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) (356.40 mm) and N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer) (355.55 mm). On the other hand, the significant lowest water expanse (mm) was recorded in treatment N5 (Control (No NPK)) (354.26 mm) in the pooled mean of 2023-24 and 2023-24. The observed variation in water expanse across different Nutrient managements treatments can be attributed to the differing nutrient availability and soil health. Treatment N1 (100% RDF) showed the highest water expanse due to the full application of nutrients, leading to optimal plant growth and increased water uptake. Treatments N4 and N2, which used organic and microbial amendments, still supported good growth but with slightly lower water usage. Treatment N5 (Control) recorded the lowest water expanse, likely due to nutrient deficiency, resulting in reduced plant growth and lower water demand. The finding of present study is in accordance with those of

Patel (2014), Karangiya *et al.* (2019) and Niwas *et al.* (2023) [11, 17, 18].

Water expanse efficiency (kg/ha-cm)

Irrigation methods

Water expanse efficiency (kg/ha-cm) was influenced by Nutrient managements, but no significant differences were observed among the Nutrient managements treatments in the pooled mean of 2023-24 and 2023-24.

Nutrient managements

The data provided in Table 4.10 clearly shows that the highest significant water expanse efficiency (kg/ha-cm) was observed in treatment N4 (50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer) (12.09 kg/ha-cm), Over treatment N2 (100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer) (11.71 kg/ha-cm). On the other hand, the significant lowest water expanse efficiency (kg/ha- cm) was recorded in treatment N1 (100% RDF (90:60:40 kg NPK/ha)) (10.12 kg/ha- cm) in the pooled mean of 2023-24 and 2023-24. Treatment N4 showed the highest water expanse efficiency (12.09 kg/ha-cm) due to organic amendments and microbial consortia improving nutrient and water uptake. N1, using synthetic fertilizers, had lower efficiency, indicating better results with integrated Nutrient managements. Similar results were also observed by Yadav and Niwas (2022) and Kumar *et al.* (2023) [12, 17, 30].

Table 1: Effect of Irrigation methods and Nutrient managements on plant population of late sown wheat at 30 DAS and at harvest.

Treatments	Plant population(no./m ²)					
	2022-23		2023-24		Pooled Mean	
	30 DAS	At harvest	30 DAS	At harvest	30 DAS	At harvest
Main plot - Irrigation methods (03)						
I1: Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1)	47.51	46.00	46.98	45.76	47.25	45.88
I2: Sprinkler Irrigation (Depth of irrigation 3cm)	46.59	45.51	46.06	44.27	46.33	43.39
I3: Surface + Sprinkler Irrigation (Depth of irrigation 3cm)	48.53	47.40	48.00	47.16	48.26	47.28
Sem (±)	0.18	0.14	0.18	0.14	0.18	0.14
CD (5%)	NS	NS	NS	NS	NS	NS
Sub plot - Nutrient managements (05)						
N1: 100% RDF (90:60:40 kg NPK/ha)	47.91	46.12	47.38	45.88	47.65	46.00
N2: 100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer	47.52	45.60	46.99	45.36	47.25	45.48
N3: 50% RDN through enriched FYM with microbial Consortia+50% % RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit +decomposer	47.36	45.41	46.83	45.17	47.10	45.29
N4: 50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	47.73	45.91	47.20	45.67	47.47	45.79
N5: Control (No NPK)	47.19	45.14	46.66	44.90	46.93	45.02
Sem (±)	0.14	0.12	0.14	0.12	0.14	0.12
CD (5%)	NS	NS	NS	NS	NS	NS
Interaction						
Sem (±)	0.25	0.21	0.25	0.21	0.25	0.21
CD (5%)	NS	NS	NS	NS	NS	NS

Table 2: Effect of Irrigation methods and Nutrient managements on plant height (cm) of late sown wheat at 30, 60,90 DAS & at harvest.

Treatments	Plant height (cm)											
	2022-23				2023-24				Pooled Mean			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Main plot - Irrigation methods (03)												
I1: Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1)	21.04	60.81	79.95	78.11	25.19	65.60	84.31	82.76	23.11	63.20	82.13	80.43
I2: Sprinkler Irrigation (Depth of irrigation 3cm)	22.54	65.82	84.87	82.56	26.88	70.28	89.56	85.64	24.71	68.05	87.22	84.10
I3: Surface + Sprinkler Irrigation (Depth of irrigation 3cm)	25.04	70.79	89.70	87.69	29.18	75.12	94.46	92.92	27.11	72.95	92.08	90.30
Sem ($\pm$)	0.39	1.10	0.63	0.83	0.37	1.02	0.59	0.65	0.37	1.06	0.60	0.73
CD (5%)	1.54	4.33	2.48	3.26	1.46	4.02	2.31	2.56	1.47	4.15	2.36	2.85
Sub plot - Nutrient managements (05)												
N1: 100% RDF (90:60:40 kg NPK/ha)	23.52	67.68	86.57	84.26	27.73	72.14	91.13	87.54	25.62	69.91	88.85	85.90
N2: 100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer	22.72	65.33	84.67	83.07	26.93	69.79	89.23	87.61	24.82	67.56	86.95	85.34
N3: 50% RDN through enriched FYM with microbial Consortia+50% % RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	22.41	64.44	83.31	81.60	26.62	68.90	87.87	86.04	24.52	66.67	85.59	83.82
N4: 50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	23.78	68.13	87.10	84.73	27.99	72.92	91.88	88.96	25.88	70.52	89.49	86.85
N5: Control (No NPK)	21.94	63.47	82.56	80.28	26.15	67.93	87.12	85.37	24.05	65.70	84.84	82.82
Sem ($\pm$)	0.35	0.91	0.89	0.65	0.33	0.92	0.91	0.79	0.33	0.90	0.89	0.66
CD (5%)	1.02	2.67	2.59	1.89	0.96	2.68	2.66	2.32	0.96	2.63	2.59	1.92
Interaction												
Sem ($\pm$)	0.61	1.58	1.54	1.12	0.57	1.59	1.58	1.38	0.57	1.56	1.54	1.14
CD (5%)	NS	NS	NS	NS	NS	NS	NS	4.02	NS	NS	NS	NS

Table 3: Effect of Irrigation methods and Nutrient managements on number of tillers (no./m²) of late sown wheat at 30, 60,90 DAS & at harvest.

Treatments	Number of tillers (no./m ²)								
	2022-23			2023-24			Pooled Mean		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Main plot - Irrigation methods (03)									
I1: Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1)	226.04	379.06	413.85	228.77	381.23	417.06	227.41	380.15	415.45
I2: Sprinkler Irrigation (Depth of irrigation 3cm)	261.69	403.92	481.24	262.61	406.82	486.10	262.15	405.37	483.67
I3: Surface + Sprinkler Irrigation (Depth of irrigation 3cm)	280.70	426.56	533.32	283.87	429.27	533.12	282.29	427.92	533.22
Sem ($\pm$)	2.12	2.87	4.45	3.04	2.66	2.24	1.55	2.46	2.52
CD (5%)	8.31	11.28	17.46	11.95	10.43	8.81	6.10	9.67	9.89
Sub plot - Nutrient managements (05)									
N1: 100% RDF (90:60:40 kg NPK/ha)	263.84	409.27	491.96	265.85	411.29	493.71	264.84	410.28	492.84
N2: 100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer	257.57	403.37	475.89	260.21	406.01	479.37	258.89	404.69	477.63
N3: 50% RDN through enriched FYM with microbial Consortia+50% % RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	250.14	399.06	464.50	253.90	400.76	468.07	252.02	399.91	466.29
N4: 50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	265.52	410.58	493.22	266.70	414.23	495.25	266.11	412.40	494.24
N5: Control (No NPK)	243.65	393.64	455.11	245.45	396.58	457.38	244.55	395.11	456.25
Sem ($\pm$)	2.11	3.08	2.55	1.96	1.80	2.52	1.60	1.98	1.29
CD (5%)	6.17	8.99	7.44	5.72	5.25	7.36	4.68	5.78	3.77
Interaction									
Sem ($\pm$)	3.66	5.34	4.42	3.40	3.11	4.37	2.77	3.43	2.24
CD (5%)	NS	NS	NS	NS	NS	12.74	8.10	NS	6.53

Table 4: Effect of irrigation methods and Nutrient managements on plant canopy temperature at CRI, Flowering, Milking stage of late sown wheat.

Treatments	Plant canopy temperature (°C)								
	CRI (18-20 Days)			Flowering (50 - 60 Days)			Milking stage (90-100 Days)		
	2022-23	2023-24	Pooled Mean	2022-23	2023-24	Pooled Mean	2022-23	2023-24	Pooled Mean
Main plot - Irrigation methods (03)									
I1: Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1)	30.39	30.14	28.76	29.26	31.38	30.32	29.26	31.38	30.32
I2: Sprinkler Irrigation (Depth of irrigation 3cm)	28.29	30.04	28.66	27.23	29.34	28.29	27.23	29.34	28.29
I3: Surface + Sprinkler Irrigation (Depth of irrigation 3cm)	29.69	30.34	28.81	27.36	29.55	28.46	27.36	29.55	28.46
Sem (±)	0.72	0.93	0.52	0.32	0.47	0.37	0.32	0.47	0.37
CD (5%)	NS	NS	NS	1.26	NS	1.44	1.26	NS	1.44
Sub plot - Nutrient managements (05)									
N1: 100% RDF (90:60:40 kg NPK/ha)	29.78	30.20	28.82	28.69	30.80	29.75	28.69	30.80	29.75
N2: 100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer	28.98	29.76	28.38	27.62	29.74	28.68	27.62	29.74	28.68
N3: 50% RDN through enriched FYM with microbial Consortia+50% % RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	29.43	30.70	29.06	27.92	30.00	28.96	27.92	30.00	28.96
N4: 50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	29.60	29.91	28.59	28.21	0.29	29.25	28.21	30.29	29.25
N5: Control (No NPK)	29.50	30.30	28.88	27.31	29.62	28.46	27.31	29.62	28.46
Sem (±)	0.63	0.89	0.56	0.82	0.72	0.58	0.82	0.72	0.58
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
Sem (±)	1.10	1.54	0.98	1.42	1.25	1.00	1.42	1.25	1.00
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5: Effect of irrigation methods and Nutrient managements on plant canopy humidity at CRI, Flowering, Milking stage of late sown wheat.

Treatments	Plant canopy humidity (%)								
	CRI			Flowering			Milking stage		
	2022-23	2023-24	Pooled Mean	2022-23	2023-24	Pooled Mean	2022-23	2023-24	Pooled Mean
Main plot - Irrigation methods (03)									
I1: Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1)	82.09	84.95	83.52	80.74	83.09	81.92	84.98	87.51	86.24
I2: Sprinkler Irrigation (Depth of irrigation 3cm)	81.92	84.89	83.40	80.76	83.11	81.93	84.99	87.64	86.32
I3: Surface + Sprinkler Irrigation (Depth of irrigation 3cm)	82.27	87.10	84.69	80.46	82.68	81.57	85.26	87.54	86.40
Sem (±)	0.92	0.69	0.49	1.00	1.72	1.25	0.94	1.58	1.09
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub plot - Nutrient managements (05)									
N1: 100% RDF (90:60:40 kg NPK/ha)	82.46	85.02	83.74	80.82	83.16	81.99	84.99	87.79	86.39
N2: 100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer	82.31	84.87	83.59	80.85	83.19	82.02	85.00	87.80	86.40
N3: 50% RDN through enriched FYM with microbial Consortia+50% % RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	81.62	86.08	83.85	80.36	82.78	81.57	85.10	87.75	86.42
N4: 50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	82.34	86.09	84.22	80.62	82.78	81.70	85.14	86.98	86.06
N5: Control (No NPK)	81.74	86.18	83.96	80.63	82.87	81.75	85.15	87.51	86.33
Sem (±)	1.01	1.09	0.77	1.56	1.56	1.27	1.24	1.53	1.04
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
Sem (±)	1.75	1.89	1.33	2.70	2.71	2.20	2.15	2.66	1.79
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 6: Effect of irrigation methods and Nutrient managements on number of active leaves per plant at successive stages of late sown wheat.

Treatments	Number of active leaves per plant					
	2022-23		2023-24		Pooled Mean	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
Main plot - Irrigation methods (03)						
I1: Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE= 1)	8.41	14.10	13.07	19.37	10.74	16.73
I2: Sprinkler Irrigation (Depth of irrigation 3cm)	9.15	15.90	13.81	21.17	11.48	18.54
I3: Surface + Sprinkler Irrigation (Depth of irrigation 3cm)	10.46	17.98	14.97	22.98	12.71	20.48
Sem ($\pm$)	0.14	0.27	0.13	0.30	0.12	0.28
CD (5%)	0.56	1.05	0.52	1.18	0.47	1.10
Sub plot - Nutrient managements (05)						
N1: 100% RDF (90:60:40 kg NPK/ha)	9.53	16.48	14.14	21.31	11.83	18.90
N2: 100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer	9.35	15.96	13.88	21.23	11.62	18.59
N3: 50% RDN through enriched FYM with microbial Consortia+50% % RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	9.17	15.62	13.70	20.89	11.44	18.26
N4: 50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	9.65	16.79	14.52	22.06	12.09	19.43
N5: Control (No NPK)	8.98	15.11	13.51	20.38	11.25	17.75
Sem ($\pm$)	0.17	0.36	0.16	0.36	0.14	0.35
CD (5%)	NS	1.04	0.46	1.06	0.42	1.03
Interaction						
Sem ($\pm$)	0.30	0.62	0.27	0.63	0.25	0.61
CD (5%)	NS	NS	NS	NS	NS	NS

Table 7: Effect of Irrigation methods and Nutrient managements on dry matter accumulation (g/plant) at successive stages of late sown wheat.

Treatments	Dry matter accumulation (g/plant)											
	2022-23				2023-24				Pooled Mean			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Main plot - Irrigation methods (03)												
I1: Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1)	0.69	7.03	13.01	13.44	0.74	7.65	17.83	18.36	0.72	7.34	15.42	15.90
I2: Sprinkler Irrigation (Depth of irrigation 3cm)	0.71	7.65	14.37	14.38	0.76	8.31	19.27	19.31	0.74	7.98	16.82	16.84
I3: Surface + Sprinkler Irrigation (Depth of irrigation 3cm)	0.74	8.25	15.27	15.10	0.79	8.87	20.16	19.92	0.77	8.56	17.71	17.51
Sem ($\pm$)	0.005	0.08	0.18	0.05	0.005	0.09	0.20	0.05	0.005	0.08	0.19	0.04
CD (5%)	0.021	0.31	0.71	0.21	0.021	0.35	0.80	0.19	0.019	0.31	0.75	0.17
Sub plot - Nutrient managements (05)												
N1: 100% RDF (90:60:40 kg NPK/ha)	0.72	7.83	14.58	14.28	0.77	8.47	19.43	19.22	0.75	8.15	17.00	16.75
N2: 100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer	0.71	7.62	14.23	14.27	0.76	8.25	19.10	19.18	0.74	7.93	16.67	16.73
N3: 50% RDN through enriched FYM with microbial Consortia+50% % RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	0.70	7.50	13.95	14.24	0.76	8.13	18.84	19.15	0.73	7.82	16.40	16.69
N4: 50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	0.73	7.86	14.60	14.67	0.78	8.49	19.46	19.53	0.75	8.18	17.03	17.10
N5: Control (No NPK)	0.69	7.40	13.72	14.06	0.76	8.03	18.61	18.92	0.73	7.71	16.16	16.49
Sem ($\pm$)	0.004	0.12	0.18	0.12	0.005	0.10	0.20	0.09	0.004	0.11	0.19	0.10
CD (5%)	0.012	0.35	0.53	0.36	0.014	0.30	0.59	0.27	0.012	0.32	0.56	0.29
Interaction												
Sem ($\pm$)	0.01	0.21	0.32	0.21	0.01	0.18	0.35	0.16	0.01	0.19	0.33	0.17
CD (5%)	NS	NS	NS	0.62	NS	NS	NS	0.47	NS	NS	NS	0.51

Table 8: Effect of Irrigation methods and Nutrient managements on Crop Growth Rate (CGR) (g/day/m²) at 30-60, 60-90 and 90 DAS- At harvest interval of late sown wheat.

Treatments	Crop Growth Rate (CGR)(g/day/m ²)								
	2022-23			2023-24			Pooled Mean		
	30-60 DAS	60-90 DAS	90 DAS - At harvest	30-60 DAS	60-90 DAS	90 DAS - At harvest	30-60 DAS	60-90 DAS	90 DAS - At harvest
Main plot - Irrigation methods (03)									

I1: Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1)	0.211	0.199	0.0143	0.230	0.339	0.018	0.221	0.269	0.016
I2: Sprinkler Irrigation (Depth of irrigation 3cm)	0.231	0.224	0.00002	0.251	0.365	0.001	0.241	0.295	0.001
I3: Surface + Sprinkler Irrigation (Depth of irrigation 3cm)	0.250	0.234	0.006	0.269	0.376	0.008	0.260	0.305	0.007
Sem ($\pm$)	0.003	0.005	0.006	0.003	0.004	0.007	0.003	0.004	0.006
CD (5%)	0.010	0.018	NS	0.012	0.017	NS	0.010	0.016	NS
Sub plot - Nutrient managements (05)									
N1: 100% RDF (90:60:40 kg NPK/ha)	0.237	0.225	0.010	0.257	0.365	0.007	0.247	0.295	0.008
N2: 100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer	0.230	0.221	0.001	0.249	0.362	0.003	0.240	0.291	0.002
N3: 50% RDN through enriched FYM with microbial Consortia+50% % RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	0.227	0.215	0.010	0.246	0.357	0.010	0.236	0.286	0.010
N4: 50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	0.238	0.225	0.002	0.257	0.365	0.002	0.248	0.295	0.002
N5: Control (No NPK)	0.223	0.211	0.011	0.242	0.353	0.010	0.233	0.282	0.011
Sem ($\pm$)	0.004	0.006	0.007	0.003	0.007	0.007	0.004	0.006	0.007
CD (5%)	NS	NS	NS	0.010	NS	NS	0.011	NS	NS
Interaction									
Sem ($\pm$)	0.007	0.010	0.012	0.006	0.012	0.012	0.006	0.011	0.011
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 9: Effect of Irrigation methods and Nutrient managements of on Relative Growth Rate (RGR) (g/g/day) at 30-60, 60-90 and 90 DAS- At harvest interval of late sown wheat.

Treatments	Relative Growth Rate (RGR) (g/g/day)								
	2022-23			2023-24			Pooled Mean		
	30-60 DAS	60-90 DAS	90-At harvest	30-60 DAS	60-90 DAS	90-At harvest	30-60 DAS	60-90 DAS	90-At harvest
Main plot - Irrigation methods (03)									
I1: Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1)	0.852	1.085	1.091	0.887	1.221	1.222	0.870	1.153	1.157
I2: Sprinkler Irrigation (Depth of irrigation 3cm)	0.888	1.128	1.119	0.923	1.254	1.243	0.906	1.191	1.181
I3: Surface + Sprinkler Irrigation (Depth of irrigation 3cm)	0.920	1.153	1.139	0.951	1.273	1.256	0.936	1.213	1.197
Sem ($\pm$)	0.005	0.006	0.002	0.005	0.005	0.001	0.005	0.005	0.001
CD (5%)	0.018	0.022	0.007	0.019	0.018	0.004	0.018	0.019	0.004
Sub plot - Nutrient managements (05)									
N1: 100% RDF (90:60:40 kg NPK/ha)	0.897	1.133	1.116	0.931	1.257	1.241	0.914	1.195	1.178
N2: 100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer	0.886	1.123	1.115	0.919	1.250	1.240	0.902	1.186	1.177
N3: 50% RDN through enriched FYM with microbial Consortia+50% % RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	0.879	1.114	1.115	0.913	1.244	1.239	0.896	1.179	1.177
N4: 50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	0.899	1.133	1.127	0.932	1.257	1.247	0.916	1.195	1.187
N5: Control (No NPK)	0.873	1.107	1.109	0.907	1.239	1.234	0.890	1.173	1.172
Sem ($\pm$)	0.007	0.006	0.004	0.005	0.005	0.002	0.006	0.005	0.003
CD (5%)	0.020	0.016	0.011	0.016	0.013	0.006	0.017	0.015	0.008
Interaction									
Sem ($\pm$)	0.012	0.010	0.006	0.009	0.008	0.003	0.010	0.009	0.005
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 10: Effect of Irrigation methods and Nutrient managements on water expanse (mm) and Water expanse efficiency (kg/ha-cm) of late sown wheat.

Treatments	Water expanse (mm)			Water expanse efficiency (kg/ha- cm)		
	2022-23	2023-24	Pooled Mean	2022-23	2023-24	Pooled Mean
Main plot - Irrigation methods (03)						
I1: Surface Irrigation (Check Basin) Depth of irrigation 6cm (IW/CPE = 1)	406.68	408.03	407.36	11.01	11.34	11.17
I2: Sprinkler Irrigation (Depth of irrigation 3cm)	351.38	353.29	352.34	11.21	11.58	11.39
I3: Surface + Sprinkler Irrigation (Depth of irrigation 3cm)	354.52	356.55	355.54	10.63	10.99	10.81
Sem ($\pm$)	1.74	2.07	0.51	0.16	0.15	0.15
CD (5%)	6.83	8.14	1.99	NS	NS	NS
Sub plot - Nutrient managements (05)						
N1: 100% RDF (90:60:40 kg NPK/ha)	436.38	438.24	437.31	9.98	10.27	10.12

N2: 100% RDN through FYM enriched by Rock Phosphate + Microbial Consortia + Jivamrit + decomposer	354.69	356.42	355.55	11.54	11.87	11.71
N3: 50% RDN through enriched FYM with microbial Consortia+50% % RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	354.36	356.05	355.20	10.74	11.07	10.91
N4: 50% RDN through Urea + 25% RDN through enriched FYM with microbial Consortia+25% RDN through FYM enriched by Rock Phosphate + Consortia + Jivamrit + decomposer	355.61	357.19	356.40	11.85	12.32	12.09
N5: Control (No NPK)	353.27	355.24	354.26	10.64	10.97	10.81
Sem (±)	1.57	1.69	1.17	0.28	0.28	0.28
CD (5%)	4.58	4.93	3.41	0.82	0.81	0.81
Interaction						
Sem (±)	2.72	2.93	2.03	0.48	0.48	0.48
CD (5%)	7.93	8.54	5.91	1.41	1.40	1.40

4. Conclusion

The study clearly established that both irrigation methods and nutrient management practices have a significant impact on the growth and productivity of late sown wheat. The combined irrigation approach (I3: Surface + Sprinkler at 3 cm depth) consistently resulted in superior growth parameters, including greater ear length, ear weight, number of ears per plant, grain weight, grain yield, and biomass yield. Among the nutrient management treatments, N4 (50% RDN through Urea + 50% through enriched FYM and consortia) proved most effective, followed by N1 (100% RDF) and N2 (100% organic). In contrast, the control treatments (I1 and N5) yielded the lowest performance across all parameters. These results underscore the importance of integrated irrigation and nutrient strategies in improving the performance of late sown wheat under the specific agro-climatic conditions of Bilaspur, Chhattisgarh.

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