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Effect of tillage methods, irrigation and nitrogen management in wheat crop under sub-tropical condition of Jammu and Kashmir

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ABSTRACT

A two-year study was conducted to assess the impact of tillage practices, irrigation methods, and nitrogen management on the growth and yield parameters of wheat in the sub-tropical region of Jammu. The study found that conventional tillage significantly outperformed zero tillage in terms of growth characteristics, with higher values recorded for plant height (96.30 cm vs. 95.4 cm), number of tillers (367.27 vs. 352.70), leaf area (2.95 vs. 1.9), and dry matter accumulation (913.77 g/m^2 vs. 908.48 g/m^2) at harvest. Among the irrigation treatments, the modified Penman-Monteith irrigation method (I_3) produced the highest growth parameters, including plant height (97.05 cm), tiller number (357.90), leaf area (3.07), and dry matter accumulation (925.55 g/m^2). Yield parameters were also superior under conventional tillage, which recorded the highest spike length (11.6 cm), grain yield (4287.18 kg/ha), and straw yield (6158.07 kg/ha), compared to zero tillage (10.35 cm, 3962.68 kg/ha, 5884.79 kg/ha, respectively). The I_3 irrigation method resulted in the highest spike length (11.75 cm), grain yield (4731.25 kg/ha), and straw yield (6209.64 kg/ha). Among nitrogen management practices, the Sensor-based Green Seeker (N_3) application led to the highest spike length (12.4 cm), grain yield (4872.92 kg/ha), and straw yield (6306.98 kg/ha). Based on these findings, it is concluded that the combination of conventional tillage, Penman-Monteith-based irrigation, and sensor-based Green Seeker nitrogen management is the optimal strategy for enhancing wheat growth and yield in the sub-tropical region of Jammu & Kashmir.

Keywords: *Irrigation management, Nitrogen management, Green seeker, Growth, Tillage, Wheat, Yield*

Introduction

Rice-wheat is a predominant cropping system of Indian Punjab which occupies about 68 per cent of the cultivated area of the state. Wheat (*Triticum aestivum*) is sown from the 4th week of October to the 1st week of December and raised through March-April hot periods when the evaporation rates are relatively more, requiring additional irrigation. There are reports indicating that 25-35 per cent of the wheat in India is sown late, which reduces wheat productivity [16]. The productivity of wheat depends upon the nutrient supplying capacity of the soil and fertilizers schedule there on. Among the major nutrients, high-yielding varieties of wheat have been found highly responsive to nitrogen fertilization [19]. This problem can be overcome by sowing of wheat immediately after rice harvest with a happy seeder in no-till field which saves time required for the preparation of seed bed. However, tillage practices strongly altered the physical properties of the topsoil and the productivity of crops [15], [10] and [8]. Nitrogen management also plays a pivotal role in wheat production, as nitrogen is a key nutrient influencing growth and yield. The subtropical environment of Jammu necessitates precise nitrogen application strategies to avoid nutrient losses and ensure efficient use of fertilizers [9]. The balanced dose of nitrogen inputs with crop requirements, while minimizing environmental impacts is crucial for achieving sustainable wheat production in this region. As grain development is a function of rate and duration of grain growth, determined by photosynthates supply and is affected by a number of environmental factors including water and nitrogen. Soil moisture is an important factor affecting plant growth, especially under restricted water supply [3]. Total evapotranspiration in a cropped field is largely contributed by soil surface evaporation [1]. Evaporation dominates moisture depletion from the root zone till the crop attains full vegetative cover. Water loss through evaporation, is not helpful in crop production. Therefore, the need has arisen to search for a suitable irrigation regime for growing wheat under different tillage, irrigation and nitrogen management systems to save the water as well as nitrogen.

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Thus, a field experiment was carried to study the interactive effects of tillage practices, irrigation and nitrogen management practices on yield and productivity of wheat.

MATERIALS AND METHODS

Experimental material, Site, Design and Soil

The experiment was conducted during *rabi* season of 2022-23 and 2023-24 at Agrometeorology Research Farm, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. Geographically, the experimental site was located at $32^0 39'33''$ North latitude and $74^0 48'45''$ East longitude. The area falls under Shivalik foothills of the North-Western Himalayas zone.

A split-split plot design was employed, with two tillage methods (main plots) *viz.*, T_1: Zero Tillage, T_2: Conventional Tillage, subplots constitute with four irrigation levels (I_0: No irrigation, I_1: Irrigation as per recommend, I_2: Based on deferential temp. C_a -C_p when value ≥ 0 to1 and I_3: Irrigation Scheduling based on Modified Penman monteith method, 1948) and under sub-subplots organize four nitrogen management levels (N_0: No nitrogen, N_1: Recommended dose of nutrients, N_2: Based on LCC<4 and N_3: Used sensor based green seeker), resulting in 96 treatment combinations. The experimental field had sandy clay loam soil, slightly alkaline pH (7.21), low organic carbon (4.54 g kg^{-1}) and available nitrogen (217.32 kg ha^{-1}), medium phosphorus (14.26 kg ha^{-1}) and potassium levels (151.38 kg ha^{-1}), with safe electrical conductivity (0.27 dSm^{-1}).

The wheat variety DBW-222 was sown with zero till seed cum fertilizer drill under zero tillage and normal seed cum fertilizer drill under conventional tillage by using 100 kg ha^{-1} seed rate. The application of fertilizers under N_0, no nitrogen, while P (50 kg ha^{-1}) and K (25 kg ha^{-1}) were applied as per the recommended dose. The recommended dose of nutrients for wheat under N_1 treatment. Whereas, N_2 treatment as a basal dose of NPK were applied as in case of N_1 and remaining dose of nitrogen as top dressing were fertilized on the basis of LCC value were ≤ 4, the nitrogen application was done according to their demand three dose of nitrogen were applied at 30, 58 and 85 days after sowing; when crop is at CRI, Jointing and flag leaf stage, respectively and total N applied 125 kg/ha. While under the treatment N_3 sensor-based green seeker treatment, the basal dose of NPK were applied as in case of N_1 and remaining dose of nitrogen as top dressing were fertilized on the basis of green seeker, when value of green seeker was ≤ 0.35 observed and compared with reference plot grown with additional 50 % more nitrogen (150 kg/ha) applied as compared to the recommended dose of N fertilizer, under this treatment (N_3) applied in three split doses on 35, 68 and 94 days after sowing, when crop is at tillering, jointing and spike emergence stage, respectively during 2022-23 and on 37, 74 and 99 days after sowing on the same growth stage in the previous year were applied split doses during 2023-24 and total 125 kg/ha were applied.

Green Seeker hand held optical sensor was used as a tool that provides precision measurement and data logging of the Normalized Difference Vegetative Index (NDVI) and a ratio of reflectance of red and near-infrared (NIR) radiation from the crop canopy. Green Seeker readings were taken at ten to fifteen days regularly from 25, 50 and 85 days after sowing. Green Seeker hand held optical sensor uses high-intensity light emitting diodes (LED's) that emit light at 660±10 nm (red) and 780±10 nm (NIR) as light source. Sensor is held 24"–48"(60–120 cm) above the crop when the trigger is pulled. The sensor displays the measured value in terms of an NDVI reading on its LCD display screen. NDVI readings can range from 0.00 to 0.99. Yield potential for a crop is identified using NDVI and an environmental factor. Normalized difference vegetation index measurements made by Green Seeker were computed by the following formula:

$$\mathbf{NDVI} = \frac{\mathrm{NIR}_{\mathbf{ref}} - \mathrm{Red}_{\mathbf{ref}}}{\mathrm{NIR}_{\mathbf{ref}} + \mathrm{Red}_{\mathbf{ref}}}$$

where,

NIR_{ref} or Red_{ref}: represent reflectance in the near-infrared and red bands.

Irrigation was applied to maintain requisite soil moisture as per the requirement of different irrigation treatments during the entire crop growing season. In control (I_0), there were no irrigation was applied expect the pre-sowing and the crop depended on the rainfall only. Whereas I_1 treatment the irrigation was applied as per POP of SKUAST-Jammu, in which under I_1 treatment three irrigations were applied at 22, 43 and 89 days after sowing when the crop is at CRI, tillering, flag leaf stage, respectively. While under the treatment (I_2) based on differential temperature C_a-C_p (Air minus canopy temperature) *i.e.*, canopy temperature is ≥0 and 1, the two irrigations were applied at 24 and 75 days after sowing, when the crop is at tillering and jointing stage in the year 2022-23 and data presented in appendix IV. Whereas, under the treatment (I_3) Irrigation scheduling based on the modified Penman Monteith method, the three irrigations were applied to the crop at 21, 47, and 89 days after sowing when the crop is at CRI, tillering stage, flag leaf stage, respectively based on the ET calculation with this formula and when cumulative ET exceeds from 25 after the pre-sowing irrigation, then only irrigation applied in this treatment with a measured quantity of water. Similarly, during 2nd year of *rabi* 2023-24 of trail only one irrigation was applied at 38 days and 44 days after sowing in the treatment (I_1) and (I_2) at tillering stage as per the demand of crop, while only two irrigation was given under treatment (I_3) at 49 and 129 days after sowing at tillering and milking stage to maintain optimum moisture conditions in the soil at different growth and development stages of the crop. The Modified Penman-Monteith Method calculation was done by adopting the formula as follows:

$$\mathbf{ET_0} = \frac{0.408\,\Delta\,(\mathrm{R_n} - G) + \gamma\,\frac{900}{\mathrm{T}_{+273}}\,\mathrm{U_2}\,(\theta_s - \theta_a)}{\Delta + \gamma\,(1 + 0.32\,\mathrm{U_2})}$$

where,

ET_0: Reference evapotranspiration (mm day^{-1})

R_n: Net radiation at the crop surface (MJ m^{-2} day^{-1})

G: Soil heat flux density (MJ m^{-2} day^{-1})

T: Mean daily air temperature at 2 m height (°C)

U_2: Wind speed at 2 m height (m s^{-1})

θ_s: Saturation vapour pressure (kPa)

θ_a: Actual vapour pressure (kPa)

θ_s - θ_a: Saturation vapour pressure deficit (kPa)

Δ: Slope vapour pressure curve (kPa $°C^{-1}$)

γ: Psychrometric constant (kPa$°C^{-1}$)

The information in the thesis was interpreted as mean values. To evaluate each observation statistically, the analysis of variance is employed. Using the F-test of significance, the findings were examined for the treatment mean based on the null hypothesis [5]. When appropriate, standard errors were calculated with a 5% threshold difference to separate treatment effects from chance effects [18].

RESULT AND DISCUSSION

Growth Parameters

The data in Table 1 demonstrated that different tillage methods had a significant impact on growth parameters *viz.* plant height, numbers of tillers/ m^2, leaf area at 120 days after sowing and dry matter accumulation in g/m^2 across both years of the study (2022-23 and 2023-24). Conventional tillage consistently resulted in taller plants compared to Zero tillage.

Growth parameters at harvest *viz.* plant height (93.61 cm), numbers of tillers/ m^2 (369.29), leaf area at 120 days after sowing (2.93), and dry matter accumulation in g/m^2 (910.85) under conventional tillage in first year was recorded which was significantly higher than zero tillage (92.66, 356.81, 1.87 and 906.69, respectively). This trend also recorded in 2^{nd} year of experimentation. Under different tillage methods significantly higher plant height of wheat crop was observed in both year with treatment (T_2) conventional tillage this was may be due to of conventional tillage practices generally involving multiple tillage operations before planting, which helps to aerate the soil and improve its structure enhance root penetration and improve nutrient availability. This process can enhance seedbed preparation, allowing for better root development compared to zero tillage systems, which leave soil undisturbed. As a result, crops grown under conventional tillage tend to exhibit taller growth due to these favorable conditions similar results were reported by [24]. Whereas, the significantly higher leaf area index, number of tillers and dry matter accumulation in both the years of *rabi* 2022-23 and 2023-24 experiment were registered with treatment (T_2) conventional tillage. This was due to positive correlation between tillage method and crop growth occurs due to favourable conditions which promote consistent and sustained growth that preserve soil aeration and reduce water evaporation better soil moisture availability and support active leaf growth better root development as well as maximum light interception which breakdown organic matter and makes nutrient essential for protein synthesis, cell division, photosynthesis which are key to faster growth and prevent water logging and overall biomass production [25]. Conventional tillage also improves soil water infiltration which prevent water logging and soil aeration that reduce compaction helps maintain soil structure, leading to more effective moisture retention and nutrient availability, thus fostering a greater leaf area for photosynthesis which leads in higher dry matter accumulation and crop growth rate similar results were also reported by [4]and [12].

Irrigation management played a key role in plant growth, with Irrigation treatment (I_3) resulting in attaining the highest growth parameters at harvest *viz.* plant heigh (94.62 cm), numbers of tillers/ m^2 (358.52), leaf area at 120 days after sowing (3.01) and dry matter accumulation in g/m^2 (923.09) under conventional tillage first year and same trend is followed in second year of study. The irrigation management treatments had a significant influence on growth parameters of the wheat crop were recorded. Treatment (I_3) irrigation scheduling based on modified Penman Monteith method recorded significantly higher plant height, no. of tillers, dry matter accumulation, leaf area index and crop growth rate over other irrigation management practices in both the years of experiment the reason for increase in plant height was due to application of irrigation at all critical growth stages lead sufficient availability of nutrients as well as the crop being exposed no moisture stress [21]. Also, the increase in plant height, dry matter accumulation and crop growth rate is linked to cell expansion and relies on cell water potential. The rise in plant height, dry matter accumulation and crop growth rate at higher levels of moisture regimes may be attributed to the consistent and adequate moisture supply to the plant, which promotes robust root establishment and supports various metabolic processes [22, 2]. This increase can be attributed to the sufficient availability of moisture, which enhanced nutrient absorption and resulted in fully turgid leaves, a higher number of green leaves with larger sizes, ultimately leading to a higher leaf area index These results closely align with the findings of [17].

Nitrogen management played a significant role in promoting plant growth, with nitrogen treatment (N_3) resulting in the growth parameters during *rabi* seasons both (2022-23 and 2023-24). Among the different nitrogen management practices significant variation in growth parameters of wheat crop were recorded. Nitrogen management had a significant influence the growth parameters. The better plant height, numbers of tillers/ m^2, leaf area at 120 days after sowing and dry matter accumulation in g/m^2 was observed under nitrogen level (N_3) that is sensor-based green seeker. This might be due to the utilization of sensor-based nitrogen management, application of on nitrogen with the use green seeker exhibited significantly higher plant heights, no. of tillers, dry matter accumulation and leaf area index compared to those managed with traditional nitrogen applications. This might be due to greater availability of nutrients from applied nitrogen fertilizer and supply of soil nitrogen over time and space to match the requirements of crops by applying the right amount of nitrogen at right time which help to maintain canopy temperature. The results are inconformity with [26] and [23].

The interaction effects between tillage, irrigation and nitrogen management on plant height of wheat crop found to be non-significant across all growth stages in both years. Specifically, there were no significant differences in plant height when analysing the interactions between Tillage × Irrigation, Irrigation × Nitrogen, Tillage × Nitrogen, or the three-way interaction Tillage × Irrigation × Nitrogen.

Yield Attribute and Yield

The data in Table 2, demonstrated that different tillage methods had a significant impact on spike length, grain yield and straw yield in both years of the study (2022-23 and 2023-24). Conventional tillage consistently resulted in significantly highest spike length (cm), grain yield and straw yield compared to Zero tillage.

In first year, among different tillage operations conventional tillage recorded significantly highest values of (11.0 cm) spike length, (4199.37 kg/ha) grain yield and (6115.13 kg/ha) straw yield as compared to zero tillage (9.9 cm, 3931.25, 5766.14 kg/ha, respectively). Similarly in the second year, conventional tillage recorded a significantly highest value of (12.2 cm) as compared to zero tillage (10.8 cm). This positive correlation between tillage method and crop growth rate occurs due to well decomposed organic matter better aeration, and crop residues decomposed in the soil which promotes moisture. This practice protects the soil from evaporation and reduces surface runoff, leading to better water availability for crops throughout the growing season. Also, enhances the biological activity in the soil, aiding in the natural decomposition of organic matter [6]. This process increases the availability of essential nutrients for crops, this increase is pivotal as effective tillers are directly associated with the plant's ability to produce seeds, ultimately increasing overall grain yield. [20] and [7] also observed better yield attributes in conventional tillage due to moderation of soil temperature.

Spike length, grain and straw yield among different irrigation methods wheat crop irrigated based modified penman monteith Method (I_3) recorded significant maximum spike length of (11.4 cm), grain and straw yield (4706.25 and 6128.84 kg/ha, respectively) as compared to the all-other methods of irrigation. Whereas, the lowest number of spike length (8.4 cm), grain yield (2793.45 kg/ha) and straw yield (5612.67 kg/ha) was recorded in control (I_0). Similar trend was recorded in the second year, during *rabi* 2023-24. Treatment (I_3) irrigation scheduling based on modified Penman Monteith method recorded significantly higher spike length, grain yield and straw yield over other irrigation management practices in both the years of *rabi* 2022-23 and 2023-24 experiment this was due to of as this method focus on maintaining optimal soil conditions also plays a vital role in promoting higher yields. By avoiding both over-irrigation and under-irrigation, the modified Penman Monteith method minimizes waterlogging and drought stress, creating a conducive environment for crop growth. This balance ensures that spikes are not only longer but also produce more grains. Moreover, optimal soil moisture levels enhance straw yield, contributing to the overall biological yield of the crop similar results where, also reported by [11] and [13].

While among different nitrogen management, the nitrogen fertilizer applied based on Sensor based Green Seeker (N_3) recorded significantly highest spike length of (12.1cm), grain and straw yield (4847.91 and 6199.17 kg/ha, respectively.) as compared to all treatment of nitrogen fertilizer. Whereas, the lowest number of spike length (7.1 cm) was recorded in control (N_0). Similar trend was recorded in the second year, where sensor-based (green seeker) (N_3) recorded significantly highest value of (12.7 cm) as compared to the rest of the treatments. However, lowest number of spike length, grain and straw yield was recorded in control (N_0) respectively, this was due to the sensor utilizes the NDVI to measure the reflectance of plant biomass, allowing for precise nitrogen recommendations based on the crop's actual needs. This precise application leads to better synchronization between nitrogen availability and crop demand, reducing nitrogen losses and increasing the effective uptake by the plants. As a result, crops achieve better physiological conditions, which enhances their growth, particularly in metrics such as effective tillers and grains per spike. Also, by ensuring that nitrogen is applied at the optimal time and in the correct amounts, crops experience less nutrient stress throughout their growth stages. This optimal management results in robust plant development, characterized by longer spikes and increased grain numbers and ultimately, this leads to increased grain yield, straw yield, and overall biological yield as crops are not deprived of essential nutrients at critical growth phases [14].

The interaction effects between tillage, irrigation, and nitrogen management on the spike length of wheat crop were found to be non-significant across all growth stages in both years. Specifically, there were no significant differences in spike length analysing the interactions between Tillage × Irrigation, Irrigation × Nitrogen, Tillage × Nitrogen, or the three-way interaction Tillage × Irrigation × Nitrogen.

CONCLUSION

On the basis of the study, the conventional tillage recorded significantly higher growth parameter, yield attributes and yield which was followed by zero tillage. Among irrigation management practices I_3 (irrigation scheduling based on modified Penman Monteith method) recorded significantly higher growth parameter yield attributes and yield followed by treatment I_2(based on deferential temperature) and treatment I_0 – control (No irrigation) recorded the lowest growth parameter yield attributes and yield. Between different nitrogen management practices treatment N_3- Sensor-based (green seeker) recorded significantly higher growth parameter yield attributes and yield which was followed N_2- Based on LCC> 4 while control treatment (No nitrogen) recorded the lowest growth yield attributes and yield.

Despite conventional tillage showing better short-term yield results, zero tillage systems could be promoted in regions facing soil erosion or water scarcity, provided that more research into appropriate crop management techniques under zero tillage is undertaken. As water availability becomes an increasing concern globally, efficient irrigation management systems such as I_3 could play a crucial role in ensuring higher crop yields with minimal water usage. The adoption of I_3-based irrigation systems could lead to more sustainable agricultural practices, particularly in arid and semi-arid regions. Precision nitrogen management using tools like the green seeker sensor could significantly reduce the risk of nitrogen overuse and leaching, contributing to both increased crop productivity and environmental sustainability. As the global focus shifts toward reducing agricultural pollution, technologies like sensor-based nitrogen management could become a standard practice for efficient nutrient use.

Compliance with Ethical Standards

Conflict of interest: The authors declare that they have no conflict of interest.

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Author's contribution

A.A. (Asif Ali) conducted the experiment and analyzed the data; M.S. (Mahender Singh) conceptualized the research and guided throughout the experiment; R. B., V. M. A., S. M. D. and S. K. helped in main manuscript writing and forming tables; S. N. K., R. S. B. and V. K. helped in data curation.

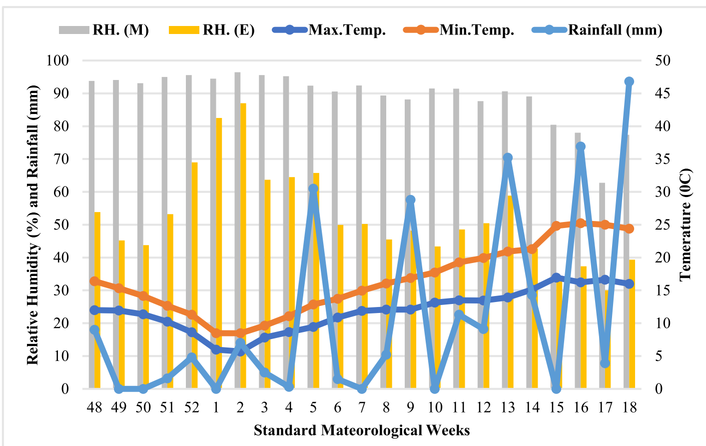

Figure 1. Graphical representation of average weekly meteorological data recorded for wheat during crop growing period of rabi 2022-23 and 23-24

Table 1: Effect of different treatments on plant height and no. of tillers of wheat during Rabi 2022-23 (Y_1) and 2023-24 (Y_2)

Treatments	Plant Height (cm)		Pooled Mean	No. of tillers/m²		Pooled Mean
	Y_1	Y_2		Y_1	Y_2	
Tillage methods						
T_1	92.66	98.14	95.40	356.81	348.6	352.71
T_2	93.61	99.00	96.31	369.29	365.26	367.28
SEm **(±)**	0.15	0.25	0.20	0.54	2.81	1.68
CD at (5%)	0.48	0.77	0.63	2.03	2.45	2.24
Irrigation management						
I_0	91.59	97.68	94.64	327.17	321.41	324.29
I_1	92.78	98.22	95.50	348.27	345.04	346.66
I_2	93.55	98.89	96.22	358.52	352.7	355.61
I_3	94.62	99.48	97.05	357.19	358.62	357.91
SEm **(±)**	0.20	0.16	0.18	1.52	5.3	3.41
CD at (5%)	0.63	0.52	0.58	5.72	19.88	12.80
Nitrogen management						
N_0	73.32	90.98	82.15	329.98	342.54	336.26
N_1	99.43	100.92	100.18	362.89	343.85	353.37
N_2	99.69	101.04	100.37	365.89	357.79	361.84
N_3	100.11	101.35	100.73	369.98	361.94	365.96
SEm **(±)**	0.23	0.07	0.15	2.68	2.51	2.60
CD at (5%)	0.77	0.22	0.50	10.05	9.44	9.75
All interaction*	**NS**	**NS**		**NS**	**NS**	

T_1-Zero tillage; **T_2** - Conventional tillage; **I_0**-Control no irrigation, **I_1**- Irrigation as per recommended, **I_2**- Based on differential temp, **I_3**- irrigation scheduling based on penman monteith method; **N_0**-Control (No nitrogen), **N_1**- Recommended dose as per POP, **N_2**- Based on LCC, **N_3**- Sensor Based (Green Seeker); **DOS**: 26th November in 2022 & 2023; ***All interaction =** T× I, I×N, T×N and T×I×N

Table 2: Effect of different treatments on leaf area index and dry matter accumulation of wheat during Rabi 2022-23 (Y_1) and 2023-24 (Y_2)

Treatments	Leaf area index at 120 DAS		Pooled Mean	Dry matter accumulation (g/m²)		Pooled Mean
	Y_1	Y_2		Y_1	Y_2	
Tillage methods						
T_1	1.87	1.93	1.90	906.69	910.27	908.48
T_2	2.93	2.98	2.96	910.85	916.69	913.77
SEm **(±)**	0.11	0.06	0.09	1.05	1.45	1.25
CD at (5%)	0.25	0.43	0.34	3.97	5.44	4.71
Irrigation management						
I_0	1.74	1.99	1.87	816.25	818.11	817.18
I_1	1.92	2.04	1.98	909.16	911.63	910.40
I_2	2.46	2.43	2.45	913.58	916.15	914.87
I_3	3.01	3.13	3.07	923.09	928.01	925.55
SEm **(±)**	0.04	0.02	0.03	2.02	0.82	1.42
CD at (5%)	0.10	0.15	0.13	7.59	3.11	5.35
Nitrogen management						
N_0	1.98	2.01	2.00	789.37	797.97	793.67
N_1	2.33	2.33	2.33	910.11	918.31	914.21
N_2	2.87	2.93	2.90	918.79	922.57	920.68
N_3	3.01	3.12	3.07	924.81	930.06	927.44
SEm **(±)**	0.02	0.03	0.03	14.48	6.64	10.56
CD at (5%)	0.13	0.11	0.12	54.33	24.92	39.63
All interaction*	**NS**	**NS**		**NS**	**NS**	

T_1-Zero tillage; **T_2** - Conventional tillage; **I_0**-Control no irrigation, **I_1**- Irrigation as per recommended, **I_2**- Based on differential temp, **I_3**- irrigation scheduling based on penman monteith method; **N_0**-Control (No nitrogen), **N_1**- Recommended dose as per POP, **N_2**- Based on LCC, **N_3**- Sensor Based (Green Seeker); **DOS**: 26th November in 2022 & 2023; ***All interaction =** T× I, I×N, T×N and T×I×N

Table 3: Effect of different treatments on yield attribute and yield (kg/ha) of wheat during Rabi 2022-23 (Y1) and 2023-24 (Y2)

Treatments	Spike length(cm)		Pooled Mean	Grain yield (kg/ha)		Pooled Mean	Straw yield (kg/ha)		Pooled Mean
	Y_1	Y_1		Y1	Y2		Y1	Y2	
Tillage methods									
T_1	9.9	10.8	10.35	3931.25	3994.12	3962.69	5766.14	6003.44	5884.79
T_2	11.0	12.2	11.60	4199.37	4375.00	4287.19	6115.13	6201.01	6158.07
SEm **(±)**	0.47	0.22	0.35	74.10	52.86	63.48	78.78	17.80	48.29
CD at (5%)	1.42	0.67	1.05	277.89	198.24	238.07	295.44	68.77	182.11
Irrigation management									
I_0	8.4	10.2	9.30	2793.45	2811.45	2802.45	5612.67	5801.34	5707.01
I_1	10.8	11.8	11.30	4471.25	4581.25	4526.25	5990.42	6134.58	6062.50
I_2	11.2	11.9	11.55	4526.04	4663.54	4594.79	6028.66	6184.34	6106.50
I_3	11.4	12.1	11.75	4706.25	4756.25	4731.25	6128.84	6290.44	6209.64
SEm **(±)**	0.49	0.47	0.48	40.14	28.21	34.18	25.45	27.09	26.27
CD at (5%)	1.87	1.79	1.83	150.55	105.79	128.17	95.44	101.59	98.52
Nitrogen management									
N_0	7.1	9.1	8.10	2931.25	3081.25	3006.25	5306.24	5467.05	5386.65
N_1	11.1	11.8	11.45	4605.95	4648.95	4627.45	6106.63	6219.37	6163.00
N_2	11.6	12.4	12.00	4734.37	4771.87	4753.12	6149.29	6308.33	6228.81
N_3	12.1	12.7	12.40	4847.91	4897.93	4872.92	6199.17	6414.8	6306.99
SEm **(±)**	0.51	0.49	0.50	74.19	121.42	97.81	28.11	33.00	30.56
CD at (5%)	1.55	1.47	1.51	278.23	455.33	366.78	105.44	123.75	114.60
All interaction*	**NS**	**NS**		**NS**	**NS**		**NS**	**NS**	

T_1-Zero tillage; **T_2** - Conventional tillage; **I_0**-Control no irrigation, **I_1**- Irrigation as per recommended, **I_2**- Based on differential temp, **I_3**- irrigation scheduling based on penman monteith method; **N_0**-Control (No nitrogen), **N_1**- Recommended dose as per POP, **N_2**- Based on LCC, **N_3**- Sensor Based (Green Seeker); **DOS**: 26th November in 2022 & 2023; ***All interaction =** T× I, I×N, T×N and T×I×N

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