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Performance of Phytohormones under Distinct Levels of Drip Irrigation on Growth and Productivity of Wheat (*Triticum aestivum* L.)

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ABSTRACT

Background: Agronomic practices such as the precise water application with drip irrigation and strategic use of phytohormones are crucial for optimizing wheat growth and productivity. This study assesses the performance of different phytohormones under distinct levels of drip irrigation on wheat.

Methods: The research trail was conducted during rabi 2022-23, to evaluate the performance of distinct phytohormones (ABA, SA and GA) under varying levels of drip irrigation regimes on wheat (*Triticum asetivum* L.). The three drip irrigation levels were taken in main plots (1.0 ETc, 0.8 ETc, and 0.6 ETc) and three distinct phytohormone (ABA, SA, and GA) and water spray were taken as a subplot with three replications under split plot design.

Result: The experimental results revealed that, drip irrigation at 1.0 ETc recorded significantly highest growth attributes i.e. plant height (83.32 cm), number of tillers (343.8 no.) and dry matter accumulation (688.4 g m^{-2}) which was 8, 18, 5.6 % higher over drip irrigation level at 0.6 ETc and also foliar spray of salicylic acid recorded the highest plant height (84.77 cm), number of tillers (334.2 no.), dry matter accumulation (691.3 g m^{-2}) compared to foliar spray of water (control). ETc 1.0 with SA spray enhanced the Chlorophyl index by 1.21% and 14.8% over ETc 0.8 and 0.6, respectively. Drip irrigation at 0.8 ETc with SA increased grain yield by 8.1% and straw yield by 5.6% over drip irrigation at 0.6 ETc which were at par with drip irrigation at 1 ETc. Hence, application of 80% irrigation through drip with 150 ppm of salicylic acid foliar spray can be recommended to farmers.

Key words: Abscisic acid, Crop evapotranspiration, Dry matter accumulation, Gibberellic acid, Salicylic acid.

INTRODUCTION

Rice-wheat cropping system is dominant over south west Asia which accounts 10.3 M ha. The Indo-Gangetic plains dominate rice-wheat cultivation, accounting for 4.1 M ha of the major area covered in Punjab, Haryana, Uttarakhand and western Uttar Pradesh (Korav *et al*., 2024). Wheat is the world's major cereal crop known as 'king of cereals. After rice, wheat is the important staple food to India. The two third of the total food production of India is covered by wheat alone and it can be used to prepare *chapatti* and its straw is used for feeding the animals. Wheat is highly nutritious food crops in the human diet. It contains about 8-15% protein, 1-1.5% fat, 2-2.5% fiber and 62-71% carbohydrate and supplies 73% of the calories of the average diet protein (Chachaiya *et al*., 2017). After the intervention of green revolution, wheat yield increased in a number of different geographical locations. In anticipation of future food demands, it is imperative to enhance the yield potential of wheat, particularly under water-limited conditions, as agricultural lands face growing threats from drought stress worldwide. In current times, water scarcity has raisen as a major issue all over the world including the states of India (Pawar *et al*., 2015). Despite its agricultural significance, Punjab suffers from severe water constraint due to rapid urbanization, industrialization, population increase. The water scarcity in Punjab is multifaceted. On the one hand, groundwater resources are being exploited excessively for irrigation, owing principally to the high-water demand of agriculture, which is the state's economic backbone. Over the years, intensive agricultural techniques, especially the growth of water-intensive crops such as rice and wheat, have resulted in an alarming pace of water depletion. Addressing the water shortage in Punjab necessitates a comprehensive approach that includes legislative interventions, technical advances, community participation and awareness efforts. The equilibrium between water supply and demand necessitates a sustainable approach to agricultural water resource

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management. The groundwater table should not be declined when it's critical to change irrigation scheduling from excessive to restricted. This has made it urgently necessary to use more efficient irrigation practices and boost water usage efficiency for sustainable agriculture. Only efficient water management techniques and the application of micro-irrigation technology, including drip irrigation, can make this possible. Properly managed drip system has an efficiency about 90% compared to 40% in surface irrigation (Anu and Habeeburrahman, 2015; Narayanamoorthy *et al*., 2009). Several approaches made to apply irrigation water through drip system is only by crop evapotranspiration (ETc), pan evapotranspiration (PET), field capacity (FC) and critical crop growth stage based. When irrigation is applied at lower level of full crop evapotranspiration rate, plant faces a kind of waters stress leads to increase in generation of highly reactive molecules that damages the plant cell membrane by disrupting the various metabolic process.

There has been a cross talk in between the signaling process of phytohormones under recovery from the drought stress (Salvi *et al*., 2021). Naturally occurring chemical substances, phytohormones are made by plants and control their development, growth and reactions to external factors (Solaimalai *et al*., 2001). By indicating alterations in the expression or activity of genes, enzymes, or transporters involved in different biological processes, they provide a functional purpose. As per functions and chemical structure of phytohormones, it can be divided into a number of classes, including Ethylene, Abscisic acid (ABA), Cytokinins, gibberellins (GA), salicylic acid (SA) and brassinosteroids (Singh *et al*., 2024; The Plant Cell, 2010). Foliar spay of SA increases the antioxidant enzymatic activity to improve defense mechanism against drought and also improves the growth and development of wheat (Sathishkumar *et al*., 2020). The diterpenoid plant hormone, gibberellins (GAs) are widely used in contemporary agriculture and play a significant role in controlling a variety of plant developmental processes, including seed germination and blooming (Taiz and Zeiger, 2010). This study investigates the effectiveness of phytohormones *i.e.* SA, GA and ABA under different levels of drip irrigation regimes on wheat to mitigate the harmful effect of drought. For this reason, our hypothesis is that foliar spray of different level of phytohormones eliminate the determinant effect of drought by improving the defense mechanism and increase the growth and productivity of wheat under Trans-Gangetic plains.

MATERIALS AND METHODS

During *Rabi* 2022-2023, the research experiment was planned at LPU, Jalandhar, Punjab, using drip irrigation under sandy loam soil. Rainfall totalled 100.35 mm from November to April, the time of agricultural growth. The treatments consisted of 3 irrigation levels in main plot *viz.* drip irrigation (DI) at 1.0 ETc (I1), 0.8 ETc (I2) and 0.6 ETc (I3) and four sub plots *i.e.* phytohormone levels, they are, water spray (P1), Abscisic acid (ABA) -20 ppm (P2), Salicylic acid (SA) -150 ppm (P3), Gibberellic acid (GA3) -100 ppm (P4) with three replications. Recommended dose of fertilizers (150:80:40 Kg ha^{-1} NPK) is applied using urea, single super phosphate (SSP) and Muriate of potash (MOP) as their respective sources. Punjab Agricultural University package of practices was used for remaining crop management practices.

Initially, uniform establishment of wheat growth, three common irrigations were given at 3 to 4 days interval. The drip laterals (16 mm) and emitters (4 l hr^{-1} discharge) are laid in between the rows. The waterflow in the laterals were controlled by using Control valves. Based on crop evapotranspiration (ETc) data, drip irrigation was scheduled with 7 days interval and and ETc was calculated as per the following steps. Primarily, potential evapotranspiration (ETo, mm) was calculated by using Penman-Montieth method. (1)

$$ETo = Epan \times Kpan \quad ...(1)$$

Where,

Epan- Daily pan evaporation (mm).

Kpan- Pan coefficient (0.7).

The LPU Agro-Metrological Observatory's Class A open pan evaporimeter was used to gather the daily pan evaporation data. During crop growth, the average daily evaporation was 2.72. Using these parameters Further calculated ETc (Allen *et al*., 1998).

$$ETc = E_o \times K_c \quad ...(2)$$

Where,

K_c - Crop coefficient of wheat.

The crop coefficient (Kc) values are presented in Table 1. The wetted area concept was used to determine the drip irrigation application rate, total water applied and duration of irrigation (Sampathkumar *et al*., 2012).

Total water applied (mm) =

Crop evapotranspiration (mm) × Wetting area percantage (100% for closely space crops) ...(3)

Duration of irrigation (minutes) =

$$\frac{\text{Total water applied (mm)}}{\text{No. of emitters} \times \text{Emitter discharge (1 per hour)}} \times 60 \quad ...(4)$$

As per FAO, (2021), the effective rainfall was calculated by multiplying daily rainfall which exceeds 5 mm by 0.75 as per the measurements.

$$\text{Effective rainfall (mm)} = (\text{Rainfall} - 5) \times 0.75 \quad ...(5)$$

Total water delivered (mm) = Amount of irrigation water (mm) + Effective rainfall (mm) ...(6)

Statistical analysis

The analysis and interpretation of the data were followed using Fisher's method of analysis of variance, as reported by Gomez and Gomez (1984). The Least significant difference (LSD) at $p \leq 0.05$ and Statistix 10 used to calculate means of treatments. The software Origin was used to depict graphical representation of the data (Origin, 2024).

RESULTS AND DISCUSSION

Response of drip irrigation regimes on growth and productivity of wheat

Distinct drip irrigation regimes and foliar spray of phytohormones show significant effect on wheat growth and yield parameters during 2022-23 (Table 2, Fig 1 and 2). The results revealed that, drip irrigation at 1.0 ETc recorded significantly maximum growth and development, yield attributes and yield of wheat as compared to other irrigation levels which is ETc 0.8 and 0.6. Drip irrigation at 1.0 ETc superior and recorded the highest plant height at maturity (83.32 cm) which was on par with drip irrigation at 0.8 ETc (79.82 cm) and drip irrigation at 0.6 ETc (77.14 cm) achieved lowest plant height. Depressed growth under deficit irrigation at 0.6 ETc is due to lower soil moisture availability and alternatively affection in plant various physiological process including cell elongation, cell expansion which directly influences plant height (Abdel-galil and Gawad, 2020; Damor *et al*., 2021). The number of tillers per m^2 was recorded significantly maximum in drip irrigation at 1.0 ETc (343.8 no.) as compared to drip irrigation at 0.8 ETc (321.1 no.) and 0.6 ETc (291.2 no.). The significantly highest dry matter accumulation was found in drip irrigation at 1.0 ETc (688.4 g m^{-2}) compared to drip irrigation at 0.8 ETc (676.7 g m^{-2}) and lowest was in drip irrigation at 0.6 ETc (651.7 g m^{-2}). This is due to the lower plant height and number of tillers m^{-2} were obtained with less quantity of irrigation and higher DM accumulation was due to the higher plant height and number of tillers m^{-2} obtained with high quantity of irrigation (Damor *et al*., 2021). The relative chlorophyll index (SPAD value) is an important parameter to indicate the leaf nitrogen content. It was also in decreasing trend in lower level of irrigation compared to higher irrigation level which was 20.6% lower as compared to higher irrigation level at 1.0 ETc. Higher chlorophyll content at high irrigation level can be the result of more moisture and nutrients being available continuously throughout the crop-growing season. The physiological attributes *i.e.* CGR and RGR which was 4.9%, 1.83% higher in drip irrigation level at 1.0 ETc compared to irrigation level at 0.6 ETc which was recorded 65.6% higher NAR compared to irrigation level at 1.0 ETc.

Table 1: Crop coefficient data followed during wheat growth period.

Crop growth period	Duration (days)	Crop coefficient (Kc)
Initial stage	20	0.30
Crop developmental stage	35	0.70
Reproductive stage	40	1.05
Late season stage	30	0.65

*source: FAO, (2021).

Table 2: Response of phytohormones and irrigation regimes through drip on growth and yield attributes of wheat during 2022-23.

Treatments	Plant height (cm)	Number of tillers/m^2	Chlorophyll index (SPAD)	Dry matter content (g/m^2)	Test weight (g)	Number of grains per spike
Irrigation level (I)						
I_1	83.32^{a}	343.8^{a}	40.28^{a}	688.4^{a}	40.64^{a}	350.6^{a}
I_2	79.82^{ab}	321.1^{b}	35.30^{b}	676.7^{b}	39.72^{b}	343.3^{b}
I_3	77.14^{b}	291.2^{c}	31.98^{c}	651.7^{c}	38.80^{c}	336.6^{c}
Phytohormones (P)						
P_1	74.92^{c}	309.8^{c}	33.76^{c}	650.8^{c}	38.33^{c}	327.7^{c}
P_2	77.39^{b}	307.0^{c}	34.40^{bc}	668.1^{b}	39.48^{b}	339.5^{c}
P_3	84.77^{a}	334.2^{a}	39.32^{a}	691.3^{a}	40.96^{a}	360.8^{a}
P_4	83.30^{a}	323.8^{b}	35.93^{b}	678.8^{b}	40.11^{b}	346.0^{b}
Interaction (I × P)						
I_1P_1	79.30^{cd}	333.4^{bc}	39.50^{ab}	664.8^{cd}	38.70^{def}	331.6^{def}
I_1P_2	80.93^{bc}	335.4^{bc}	40.13^{a}	682.2^{bc}	40.27^{bc}	341.6^{cde}
I_1P_3	87.37^{a}	363.3^{a}	41.27^{a}	706.4^{a}	42.10^{a}	372.3^{a}
I_1P_4	85.69^{a}	343.3^{b}	40.23^{a}	700.2^{ab}	41.50^{ab}	357.0^{b}
I_2P_1	73.03^{e}	309.7^{de}	31.67^{d}	650.0^{def}	38.20f	329.0^{defg}
I_2P_2	75.92^{de}	319.5^{cd}	32.10^{d}	660.3^{de}	39.63^{cde}	339.3^{def}
I_2P_3	85.70^{a}	329.9^{bc}	40.77^{a}	703.2^{a}	41.00^{abc}	362.0^{bc}
I_2P_4	84.63^{ab}	325.3^{c}	36.67^{bc}	693.2^{ab}	40.03^{cd}	343.0^{def}
I_3P_1	72.43^{e}	286.2^{f}	30.10^{d}	637.8^{f}	38.10^{f}	322.6^{fg}
I_3P_2	75.32^{e}	266.1^{g}	30.97^{d}	661.7^{de}	38.53^{ef}	337.6^{g}
I_3P_3	81.22^{bc}	309.5^{de}	35.93^{c}	664.3^{d}	39.77^{cde}	348.3^{cd}
I_3P_4	79.58^{cd}	302.8^{e}	30.90^{d}	643.2^{ef}	38.80^{def}	338.0^{efg}

* Treatment details are given under materials and methods.

Due to higher growth parameters may have resulted in more photosynthesis and carbon assimilation allowing for the development of more yield components i.e. number of grains spike^{-1}, test weight and both grain and straw yield. Higher soil moisture availability in the root zone during the crop growth phase and increased water application were the primary factors in the significantly higher yield characteristics at higher irrigation levels. Maintaining greater leaf water potentials in the source was made possible by more soil moisture in the root zone. Number of spikes per m^2 also differed significantly with different drip irrigation levels of 1.0 ETc (350.6 no.), 0.8 ETc (343.3 no.) and 0.6 ETc (336.6 no.). These findings are correlated with Awaad and Deshesh (2019). By providing adequate water through irrigation level at 1.0 ETc, minimized the water stress and enables the plant to direct the resources into spike growth rather than stress tolerance. The test weight of wheat also differed significantly under different irrigation levels due to water stress because moisture deficit conditions reduce grain setting, shriveled and chaffy grain formation. Whereas, the continuous mobilization of nutrients from the stem dry matter and stored carbohydrates from the leaves caused the grains to accumulate a greater amount of starch, which led to a much higher test weight. The grain and straw yield of wheat also recorded significantly highest in drip irrigation at 1.0 ETc (57 q ha^{-1} grain yield and 65.2 q ha^{-1} straw yield) as compared to other irrigation levels. Because of the consistent and steady supply of water directly in the crop root zone and the complete utilization of it by crop, which

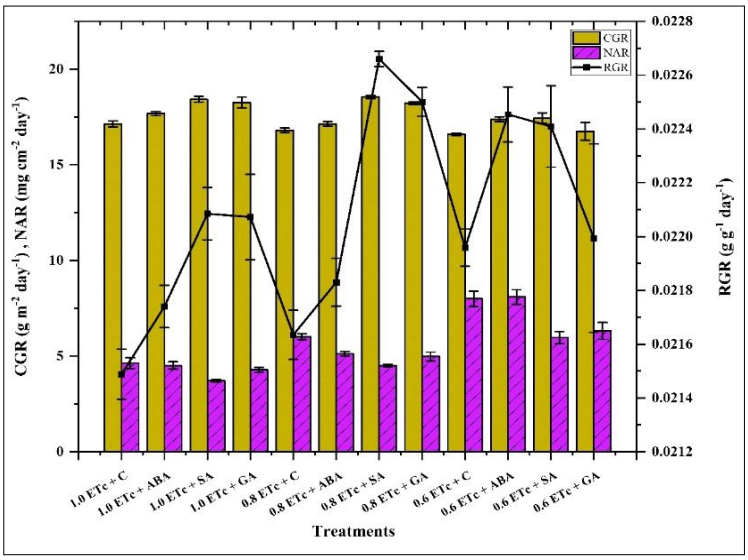

Fig 1: Response of phytohormones and irrigation regimes through drip on CGR (g m^{-2} day^{-1}), RGR (g g^{-1} day^{-1}) and NAR (mg cm^{-2} day^{-1}) of wheat during 2022-23.

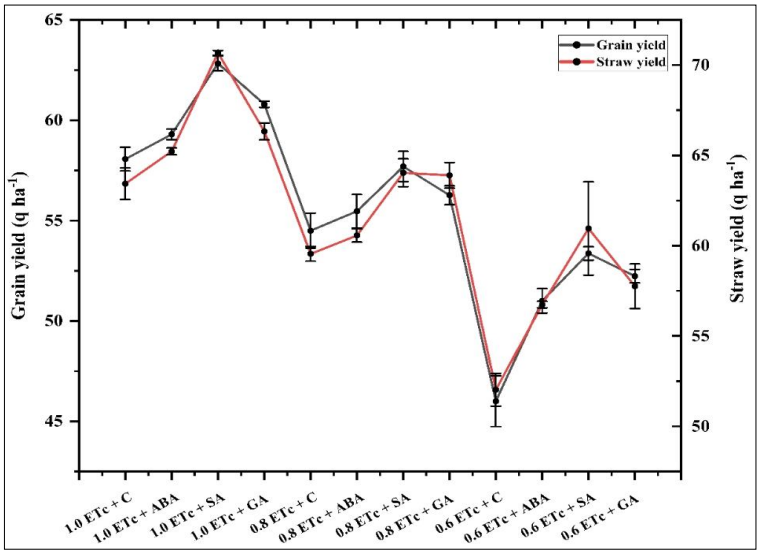

Fig 2: Response of phytohormones and irrigation regimes through drip on grain and straw yield of wheat during 2022-23.

led to a greater uptake of mineral nutrients over the growing season (Gadade *et al*., 2022).

This resulted in an increased rate of photosynthetic activity and increased the production of carbohydrate reserves. By better mobilizing of all carbohydrate reserves from stems and leaves to grains during the grain filling stage, a strong source to sink connection was also attained. As a result, the crop may have produced the highest possible economic yield. Improved grain yield may result from modest deficit watering, which may boost root growth, make it easier for grains to remobilize their store carbon and speed up grain filling (Bandyopadhyay *et al*., 2010). Reduced leaf growth, hampered photosynthetic mechanisms, early leaf senescence and modifications to the photosynthesis process all result in a drop in yield when there is a deficit in moisture.

Response of phytohormones on growth and productivity of wheat

Foliar spray of SA recorded the highest growth parameters and yield attributes over other phytohormones (Table 2, Fig 1 and 2). The highest plant height was recorded under salicylic acid (84.77 cm) as compared to gibberellic acid (83.30 cm), abscisic acid (77.39 cm) and control (74.92 cm). our findings are similar with Mevada *et al*. (2020). The number of tillers also effected by different levels of phytohormones. The highest number of tillers recorded in salicylic acid (334.2 no.) over other phytohormones and lowest number of tillers was recorded in control (309.8 no.). Similarly, the foliar application of SA recorded the highest DM accumulation (691.3 g m^{-2}) compared to gibberellic acid (678.8 g m^{-2}) which was at par with ABA (668.1 g m^{-2}) and lowest was found in control (650.8 g m^{-2}). The reason behind the enhancement of growth attributes is that, salicylic acid can improve the expression of genes that promote plant development, such as those encoding enzymes involved in cell elongation and division. This can cause plants to grow taller and produce more tillers (Li *et al*., 2022). Foliar spray of salicylic acid recorded the highest chlorophyll index (39.32) compared to other phytohormones and control (33.76). SA might protect chlorophyll molecules from oxidative damage by scavenging reactive oxygen species (ROS), maintaining a higher chlorophyll index and conserving chlorophyll content and also induce the genes involved in photosynthesis. CGR, RGR of wheat increases 7.59%, 3.2% in foliar spray of salicylic acid instead of water spray and 31% higher in control compared to salicylic acid and 31% higher NAR recorded in control in comparison to foliar spray of salicylic acid because SA may improve plant metabolism and resource allocation to growth processes by lowering stress levels, increasing the photosynthetic efficiency which raises CGR, RGR and NAR.

Similarly, in yield attributes *i.e.* the number of grains also increased in salicylic acid (360.8 no) compared to gibberellic acid (346.0 no.) and abscisic acid (339.5 no.) which was on par with water spray (327.7). The TW and yield also differed significantly under foliar spray of different phytohormones compared to water spray. The foliar spray of salicylic acid recorded highest test weight (40.96 g), grain yield (59.6 q ha^{-1}) and straw yield (65.6 q ha^{-1}) as compared to other phytohormones and control. This is due to more accumulation of photo-synthates stored in sink (grains) and significantly increase the grain yield of wheat (Monga and Kumar, 2022). Salicylic acid can improve the absorption and assimilation of important nutrients such as nitrogen, phosphorus and potassium. Improved nutritional status and boosts overall plant health and vigor, resulting in higher biomass output, including straw yield.

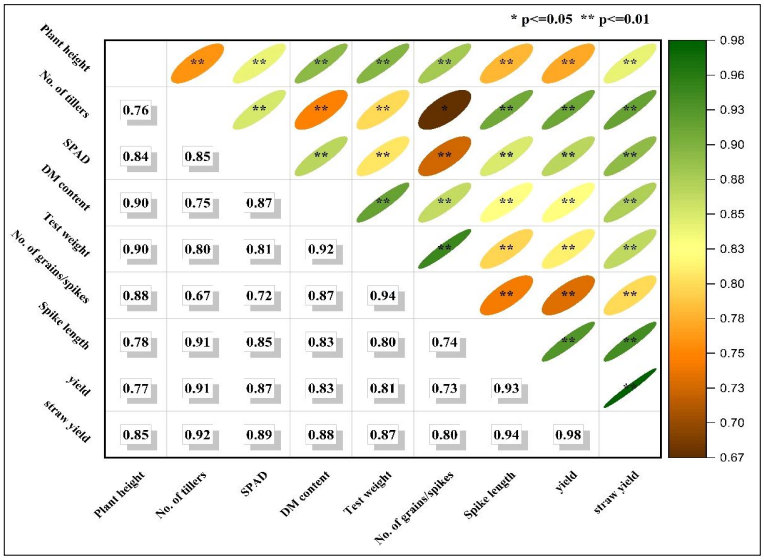

Fig 3: Relationship between phytohormones and irrigation regimes through drip on growth and yield attributes with grain and straw yield of wheat during 2022-23.

Interaction effect of irrigation regimes and phytohormones on growth and productivity of wheat

The irrigation regimes and phytohormones interaction were significantly effect on growth and yield attributes of wheat (Table 2, Fig 1 and 2). The treatment combination of salicylic acid with drip irrigation recorded the highest growth attributes compared to other treatment combination and also recorded the highest growth attributes in drip irrigation levels at 0.6 ETc as compared to other phytohormones in irrigation level at 0.6 ETc. The similar result was obtained in yield attributes, grain and straw yield. The hypothesis of our result is that salicylic acid is functioned as a signaling molecule in plants, activating defense responses under drought conditions. Plants may have been better prepared to deal with the stress caused by reduced water supply when salicylic acid had been applied (Yang *et al*., 2023). Overall, applying a salicylic acid foliar spray at an irrigation level of 0.6 ETc probably increases plant growth and yield by reducing stress, boosting photosynthetic efficiency, optimizing water and nutrient use efficiency, enabling osmotic adjustment and adjusting hormone balance in plants that are experiencing water stress.

Relationship between growth and yield parameters with grain yield of wheat

Influence of phytohormones and drip irrigation levels showed significant correlation with crop growth and development, yield attributes and productivity wheat during 2022-23 (Fig 3). Growth parameters like, plant height (0.77 and 0.85) no. of tillers (0.91 and 0.92), SPAD (0.87 and 0.89), dry matter content (0.83 and 0.88) and yield attributes like test weight (0.81 and 0.87), no. of grains per spike (0.73 and 0.80), spike length (0.93 and 0.94) of wheat was found to show significant positive correlation ($p<0.01$ and $p<0.05$) for grain and straw yield of wheat, respectively.

CONCLUSION

Application of drip irrigation at 1.0 ETc was out performed and achieved statistically maximum growth parameters, yield parameters, grain and straw yield. Among the phytohormones and water spray tested, salicylic acid statistically outperformer over rest of the phytohormones. The interaction effect of drip irrigation at 0.8 ETc with SA noticed significantly maximum growth and development, yield attributes and productivity of wheat over rest of the treatment combinations which is also, on par with drip irrigation level at 1.0 ETc. with ABA 20 ppm and water spray. Hence, application of 80% irrigation through drip with 150 ppm of salicylic acid foliar spray can be recommended for moisture stress condition.

Conflict of interest

All authors declared that there is no conflict of interest.

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