Effect of Spraying Salicylic Acid and Seeding Rates on Wheat Plants under Water Stress

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Abstract: An experiment has been done in a flowerpot for the study of seeding effect and on salicylic acid on the production of wheat under moisture tension by using the system of split bars once, and tri-repeated Random Complete Block Design (RCBD).So, the whole or main plots has included irrigation treatments irrigation (every 7, 14, and 21 days), whereas the has included the averages of seeding (60, 80) kg. ha^{-1}),and the sub-sub-plots has included sprinkle plants with ordinary water (comparison treatment),and with the salicylic acid by concentration of (0, 100 and 200) ppm. Results have indicated that; the plants which were irrigated every 7 and 14 days are high-level average (32.31and 36.61) .cm, the area of a flag –leaf is (31.87and34.20) cm^2, the seeds amount is (28..31 and 29.84) seed.$pike^{-1}$), the protein rate is 21.96and 23.91)% but plants –which where irrigated every 14 days –have surpassed move spikes (4.43 $spike.m^2$) and thetotal wheat is (6.40 ton. ha^{-1}), the treatment has given (60kg. ha^{-1}),the higher value of seeds weigh is (0.44gm. $plants^{-1}$).results of the study have showed the surpassing irrigation treatment and besides seeding treatment (12 day and 60kg. ha^{-1}) at the production features and their components with the exception of the dry weigh which hasn't indicated differences .Additionally, the study results have showed the surpassing concerns traction of salicylic acid (100 ppm)at the studied production features with the exception of the length of a spike (200) and recorded (5.50cm). Finally, the results were revealed possibility using salicylic acid during fertilization stage, and it helps to increase seed yield and oil percent.

1 INTRODUCTION

Water is one of the most determining environmental factors for the growth and production of crop plants in the arid and semi-arid regions of the world in which Iraq is located, which are the areas most affected by drought and associated climate changes [1]. Iraq is facing severe droughts as a result of high temperatures, as it suffers from multiple types of drought, including climatic, agricultural and dry water bodies [2]. Drought has negative effects on the growth of plants, which it reduces their vegetative and reproductive growth through inhibition of photosynthesis processes and disturbance of nitrogen metabolism in them and its role in increasing the production of reactive oxygen species, which works to destroy proteins and cell membranes [3].

The wheat (Triticum aestivum L.) is the most important food crop in the world and this importance is between the balance between carbohydrates and proteins in its grains. Despite the importance of this crop, its production in Iraq is low, so it comes in sixth place among the importing countries of this crop, the seeding rate, which expresses plant density, is the most important agricultural practice, which greatly affects the determination of the ideal environment for the growth of the crop by achieving a balance to compete with plants for each other and the amount of seeds is a determining factor for the wheat crop in the use of available genetic resources [4].

To determine the appropriate seeding rate, a major role is played, especially in the wheat crop, as it directly affects the yield and its components [5], it has become common in recent years to use plant hormones as one of the agricultural techniques used to increase the tolerance of plants to various stresses, including drought. These regulators control the response of plants to various stresses by controlling many physiological processes, because they work to reveal and widen the carrier vessels in the bark and wood, contribute to facilitating the flow of water and food, and control the division and distinction of cells for some plant tissues and the development of flowering and organelles such as plastids and the orientation of photosynthetic products [6]. As well as controlling the aging of leaves [7], and increasing the

size of green plastids and grana discs in them and in the accumulation of nutrients and then dragging them to certain places of the plant such as leaves to form chlorophyll and prevent its loss [8], and maintain the normal level of endogenous hormones [9] and leads to the treatment of plants exposed to environmental stresses with salicylic acid to increase the tolerance of plants to those stresses and improve the growth qualities and yield of the plant [10], [11].

This occurs as a result of many physiological activities of this plant hormone, including its inhibition of ethylene synthesis and control of the movement of stomata and its opposite to the effectiveness of abscisic acid and its ability to bind to amino acids and give the plant systemic acquired resistance (SAR) and its non-enzymatic antioxidant and it is important to synchronize the spraying of growth regulators with the growth stages of plants directly related to the components of the yield.

The aims are to investigate the effect of spraying agents and the treatment of plant seedlings at different water stress to improve the performance and yield of wheat plants and the ability of using this technique to increase the plant's tolerance to water stress conditions.

2 MATERIALS AND METHODS

2.1 The Location of the Experiment and the Procedures for its Implementation

An experiment was carried out in a pot in an arboretum of the Directorate of Agriculture in Diyala Governorate during the winter season 2023-2024 with the aim of studying the effect of seeding and spraying rates with salicylic acid on the productivity of wheat crop under drought and humidity conditions.

2.2 Crop Management and Data Collection

Wheat grains of the Aba variety were planted in a pot of 2.5 kg. The experiment was applied by arranging the splinter panels and designing the whole randomized sectors with three replicates. The experiment included three factors, the main plots included three irrigation treatments (irrigation all 7, 14 and 21) days respectively, and the secondary factor seeding rates (60 and 80) $kg.ha^{-1}$ respectively and the sub-secondary factor spraying plants with tap water (comparison treatment), and salicylic at a concentration of (100 and 200) ppm respectively at the elongation stage. The seeds were planted on 25/11/2023 by 20 grains in the pot and an operation was performed Irrigation for all experimental units after the completion of planting until the completion of the emergence of seedlings, after which the irrigation treatments included in the experiment were initiated. The plant's requirements of nitrogen and phosphorus were added in the form of urea fertilizer (46% nitrogen) and phosphorus was added in the form of triple superphosphate 45% P_2O_5 and when the plants reached the stage of 100% flowering, the following characteristics were studied (plant height (cm), chlorophyll ($\mu g.cm^{-2}$) was estimated using the chlorophyll meter (Spad Plus Alrt 206-205), the area of the flag paper (m^2), the components and yield of the plant that included the number of spikes (m^2. $plant^{-1}$, spike length (cm), number of grains, $spike^{-1}$, grain weight (g. $plant^{-1}$), and grain yield ($ton.ha^{-1}$) and the weight of dry matter (g) and biological yield ($ton.ha^{-1}$). The data were analyzed following the method of analysis of variance according to the design used by the SPSS17 system, and the least significant difference test (L.S.D) at a significant level of 0.05 was used to compare the averages of the treatments (see Table 1).

Table 1: The chemical and physical properties of the soil.

The test	Unite	Value		
EC	D.S	2.45		
pH		7.3		
N	$mg.kg^{-1}$.soil	52		
P	$mg.kg^{-1}$.soil	12.12		
K	$mg.kg^{-1}$soil	176		
Ca	$mg.kg^{-1}$.soil	280		
Texture	$Gm.kg^{-1}$soil	Sand	Silt	Clay
		726 Mud	51	223
			Sandy Loam	

3 RESULTS AND DISCUSSION

3.1 Effect of Irrigation Treatments, Seeding Rates and Salicylic Acid on Growth Stages, Plant Height, Chlorophyll Content, Flag Leaf Area, Number of Grains, Grain Weight, Percentage of Protein

The results of Table 2 indicated the superiority of the plants that were irrigated every 7 and 14 days (in the characteristic of plant height and their value was (36.61 and 32.82), chlorophyll content 36.54 and 31.31 $\mu g.cm^{-2}$, the area of the flag leaf 34.20 and 31.87 cm^2 and the percentage of protein 23.91 and

21.36% with a non-significant difference between them. The plants irrigated every 7 days excelled in grain weight (0.59 gm.plant^{-1}) compared to all treatments.

The irrigation treatment, which provided appropriate amounts of moisture for the plant approaching its requirements, enabled it to form a large root system capable of absorbing water and nutrients with high efficiency, which reflected positively on a series of vital events directly or indirectly related to the accumulation of dry matter such as transpiration, gas exchange, respiration, photosynthesis, and others, increasing with it the number of stem buds below the soil surface [12] and increasing the growth rate of leaves and prolonging the duration of their effective stay.

Plants irrigated every 21 days gave the lowest values in plant height (22.56 cm), chlorophyll content (26.27 µg.cm^{-2}), flag leaf area (26.99 cm^2) and grain weight (0.18 gm. plant^{-1}). The reason for the decrease in growth stages may be attributed to the fact that the drought led to a reduction in the division and elongation of stem cells and their small size, which was reflected in the decrease in plant growth and negatively affected the process of carbon metabolism, transport and absorption of nutrients [13]. Their influence on other qualities is absent. As for the seeding rates, no significant differences appeared in the studied traits and the treatment exceeded 60 kg.ha^{-1} in the grain weight characteristic (0.44 gm.plant^{-1}). The reason is that the increase in plant density increases competition between plants for light, which prompted the stems to elongate to obtain the largest possible light needs [14]. Plants sprayed with salicylic acid at 100 ppm treatment outperformed all studied traits significantly except for protein (23.05%).

Salicylic acid has an effect on increasing the number and growth rates of cells due to the accumulation of metabolites in the developing peaks, an indicator of the increase in the effectiveness of DNA and RNA, the efficiency of carbon metabolism and the concentration of hormones such as auxins, kintien and gibberellins 9 and 16.

3.2 Effect of Irrigation Treatments, Seeding Rates and Salicylic Acid on Growth Parameters, Number of Spikes, Spike Length, Grain Yield, Dry Weight, Biological Yield Content

As for Table 3, the results show that the irrigation treatment is superior every 14 days in the characteristics of the yield and its components, as it significantly outperformed the number of spikes and reached a value of (4.43 spikes.m^{-2}), the length of the ears (5.94 cm), the yield of grains (6.40 tons.ha^{-1}) and the biological yield (23.29 tons.ha^{-1}).

The reason for this may be due to the irrigation treatment that provides the requirements of plants of moisture in converting the largest proportion of the formed seedlings into fertile seedlings through its role in increasing photosynthesis rates, and the high moisture deficiency leads to the failure to complete the grain contract or to abort it after holding it as a result of lack of processing with nutrients [15] while no significant difference appeared in the dry weight characteristic.

The reason is attributed to the increase in the vegetative total represented by the characteristics of plant height and the area of the flag leaf and its

Table 2: The effect of irrigation treatments, seeding rates and salicylic acid on some growth parameters.

Irrigation treatments (day)	Plant height (cm)	Chlorophyll (µg.cm^{-2})	Flag paper area (cm^2)	Number of grains (grain.spike^{-1})	Grain weight (gm.plant^{-1})	Protein %
7	32.82	31.31	31.87	28.31	0.59	21.96
14	36.61	36.54	34.20	29.84	0.52	23.91
21	22.56	26.27	26.99	21.32	0.18	19.16
L.S.D value p=0.05	5.98	2.02	1.53	6.05	0.12	1.91
Seeding rates kg. ha^{-1}						
60	31.75	33.23	32.52	28.81	0.44	22.40
80	29.58	29.52	29.52	24.18	0.42	20.95
L.S.D value P=0.05	3.19	2.49	3.30	3.39	0.18	2.79
Salicylic acid mg.L^{-1}						
0	27.03	28.72	26.86	22.75	0.25	20.05
100	33.50	33.39	34.17	29.51	0.83	23.05
200	31.48	32.00	32.03	27.21	0.21	21.92
L.S.D value P=0.05	3.77	1.80	2.39	4.08	0.13	2.30

competition for the root system on the products of photosynthesis of growing plants in conditions that provide moisture in addition to the lack of need for plant roots to expand to the soil layers may have contributed to their low dry weight.

As for the seeding rates, it appears from Table 3 that the sowing treatment (60 kg.ha^{-1}) is higher in the number of ears, and its value was (3.95 spike.m^{-2}), the length of the spike (5.71 cm), and the yield of grains (5.70 tons.he^{-1}) and significantly over the treatment of seeds (80 kg.ha^{-1}) respectively.

No significant differences were found in the dry weight and biological yield characteristic. The lower seeding rates increased the number of spikes and the length of the spike on the wheat plant in order to increase the number of branches due to the presence of sufficient distance [14].

The plants that were sprayed with salicylic acid at the time of treatment gave 100 ppm the highest values in the number of spikes and their value was (4.64 spikes.m^{-2}), the grain yield (6.10 tons.ha^{-1}) and the biological yield (21.95 tons.ha^{-1}) significantly respectively, and no significant differences were shown in the dry weight characteristic.

While the treatment exceeded 200 ppm in the length of the spike and significantly, as its value reached (5.50 cm), the reason may be that salicylic acid as a result of its role in the hormonal balance between cytokinin and auxins and increasing the level of cytokinin hormone metabolism within the plant and its contribution to increasing the proportion of the hormone florigen when the plant is exposed to drought stress and therefore it controls the emergence and differentiation and growth of flowers and thus in their number [16], [17]. Salicylic acid also contributes to inhibiting the metabolism of ethylene acid and maintains the water content of the leaves, raising the efficiency of water relations in the plant through its ability to conjugate with amino acids such as Glycine, Proline and Tryptophan, which works to regulate the osmotic leaves, withdraw water from neighboring cells, and maintain the fullness of cells when growing plants in drought conditions [18], [19].

In addition to its importance in increasing cell divisions and numbers and in the accumulation of amino acids and preventing their oxidation when growing plants in drought conditions or at high temperatures, it raises the level of antioxidants and inhibits the concentrations of Reactive Oxygen Species (ROS) leading to the degradation of proteins and oxidation of enzymes leading to reduced metabolism and accumulation of dry matter [20], [21].

3.3 Bilateral Interactions

The results of Tables 4 and 5 showed a significant effect of the interaction treatments between irrigation treatments and seeding rates, we note the superiority of irrigation treatment and seeding treatment (14 days and 60 kg.ha^{-1}) in the characteristic of plant height and its value was (38.39 cm), chlorophyll content (37.23 µg.cm^{-2}), the area of the flag leaf (36.16 cm^2) and the number of grains per spike (31.75 grains.spike^{-1}) and significantly.

As for the interaction of irrigation treatment and salicylic acid concentration, the results show significantly higher irrigation treatment and salicylic acid concentration (14 days and 100 ppm) in plant

Table 3: The effect of irrigation treatments, seeding rates and salicylic acid on yield, its components and other characteristics.

Irrigation treatments (day)	Number of spikes (spike.m^{-2})	Spike length (cm)	Grain yield (ton.ha^{-1})	Dry weight (gm.m^{-2})	Biological yield (tons.ha^{-1})
7	4.13	5.75	5.38	0.12	21.28
14	4.43	5.94	6.40	0.13	23.29
21	2.38	4.65	4.30	0.10	16.59
L.S.D value P=0.05	0.86	0.76	1.32	0.08	3.55
Seeding rates kg. ha^{-1}					
60	3.95	5.71	5.70	0.12	20.91
80	3.34	5.18	5.01	0.11	19.86
L.S.D value P=0.05	0.44	0.70	0.46	0.05	1.33
Salicylic acid mg.L^{-1}					
0	2.18	5.39	4.40	0.12	18.09
100	4.64	5.45	6.10	0.12	21.95
200	4.12	5.50	5.58	0.12	21.13
L.S.D value P=0.05	0.71	0.68	0.52	0.03	2.58

height (40.33 cm) and chlorophyll content (39.49 μg.cm^{-2}). While the irrigation treatment and the concentration of salicylic acid (7 days and 100 ppm) in the area of the flag leaf (38.21 cm^2) and grain weight (1.00 gm. plant^{-1}) and significantly superior to the rest of the treatments and the interaction treatment between the irrigation treatments and the comparison treatment (21 days and 0 ppm) gave the lowest values in the characteristic of plant height (19.53 cm), chlorophyll content (25.22 μg.cm^{-2}), flag leaf area (24.90 cm^2), number of grains (17.85 grains.spike^{-1}) and grain weight per plant (0.18 g. plant^{-1}).

The interaction of seeding rates with salicylic acid concentration exceeds the treatment (60 kg.ha^{-1} and 100 ppm) in the characteristic of plant height and its value was (35.16 cm), chlorophyll content (35.12 μg.cm^{-2}), the area of the flag leaf (35.08 cm^2), the number of grains per spike (33.05 grains. spike^{-1}) and the grain weight of the plant (0.84 gm. plant^{-1}).

The lowest values in plant height, chlorophyll content, leaf area and grain count were recorded by the interaction between seeding rates and the comparison treatment (80 kg.ha^{-1} and 0 ppm). The lowest grain weight value at the time of treatment (80 kg.ha^{-1} and 200 ppm).

The results of Table 5 also indicated that the bilateral interaction treatment between irrigation treatments and seeding rates (14 days and 60 kg.ha^{-1}) in the number of spikes and its value was (4.62 spike.m^{-2}), the length of the spike (6.49 cm), the grain yield (7.04 tons.ha^{-1}) and the biological yield (23.81 tons.ha^{-1}) significantly over the rest of the treatments.

There were no significant differences in the dry weight characteristic. As for the interference of irrigation treatments with salicylic acid concentration, the interference treatment (14 days and 100 ppm) outperformed the rest of the treatments significantly in the number of spikes and amounted to (5.55 spikes.m^{-2}), spike length (6.04 cm), grain yield (7.60 tons.ha^{-1}) and biological yield (25.38 tons.ha^{-1}), while no significant differences appeared in the dry weight characteristic.

Table 4: The effect of bilateral interactions between irrigation treatments, seeding rates and salicylic acid on some growth indicators is illustrated.

Irrigation treatments (Day)	Seeding rates	Plant height (cm)	Chlorophyll (μg.cm^{-2})	Flag paper area (cm^2)	Number of grains (grain spike^{-1})	Grain weight (gm.plant^{-1})
7	60	33.09	32.57	33.49	29.78	0.60
	80	32.56	30.05	30.25	26.84	0.58
14	60	38.39	37.23	36.16	31.75	0.52
	80	34.83	35.84	32.25	27.93	0.52
21	60	23.76	29.88	27.93	24.88	0.20
	80	21.36	22.65	26.05	17.76	0.16
L.S.D value p=0.05		5.53	4.31	5.71	5.88	0.31
Salicylic acid mg.L^{-1}						
7	0	30.81	29.70	26.48	24.15	0.26
	100	34.80	32.89	35.04	31.25	1.29
	200	32.87	31.36	34.09	29.55	0.22
14	0	30.74	31.25	29.20	26.26	0.31
	100	40.33	39.49	38.21	31.50	1.00
	200	38.77	38.87	35.21	31.76	0.25
21	0	19.53	25.22	24.90	17.85	0.18
	100	25.37	27.80	29.26	25.80	0.19
	200	22.79	25.78	26.18	20.33	0.17
L.S.D value P=0.05		6.54	3.12	4.14	7.08	0.23
Salicylic acid	Seeding rates					
60	0	27.66	30.72	28.56	24.21	0.27
	100	35.16	35.12	35.08	33.05	0.84
	200	31.98	33.83	33.93	29.16	0.23
80	0	26.40	26.72	25.16	21.30	0.24
	100	31.39	31.65	33.25	25.97	0.82
	200	30.97	30.18	30.14	25.26	0.20
L.S.D value P=0.05		5.34	5.55	3.38	5.78	0.19

Table 5: The effect of bilateral interactions between irrigation treatments, seeding rates and salicylic acid on yield and its components.

Irrigation treatments (Day)	Seeding rates	Number of spikes (spike.m^{-2})	Spike length (cm)	Grain yield (ton.ha^{-1})	Dry weight (gm.m^{-2})	Biological yield (tons.ha^{-1})
7	60	4.45	5.93	5.67	0.12	21.99
	80	3.81	5.57	5.08	0.12	20.57
14	60	4.62	6.49	7.04	0.12	23.81
	80	4.25	5.39	5.76	0.13	22.77
21	60	2.78	4.71	4.41	0.11	16.94
	80	1.97	4.58	4.19	0.09	16.24
L.S.D value (P=0.05)		0.77	1.22	0.81	0.09	2.30
	Salicylic acid					
7	0	2.50	5.82	4.46	0.11	18.57
	100	5.40	5.49	6.01	0.13	22.88
	200	4.49	5.95	5.66	0.12	22.38
14	0	2.65	5.91	5.02	0.11	19.86
	100	5.55	6.04	7.60	0.15	25.38
	200	5.11	5.86	6.56	0.13	24.65
21	0	1.41	4.43	3.71	0.09	15.83
	100	2.98	4.82	4.67	0.12	17.58
	200	2.75	4.69	4.51	0.10	16.36
L.S.D value (p=0.05)		1.23	1.17	0.91	0.05	4.48
Salicylic acid	Seeding rates					
60	0	2.38	5.57	4.82	0.11	18.21
	100	5.11	5.74	6.50	0.13	22.62
	200	4.36	5.82	5.79	0.12	21.91
80	0	1.98	5.21	3.97	0.10	17.96
	100	4.17	5.16	5.70	0.12	21.27
	200	3.87	5.18	5.36	0.11	20.35
L.S.D value (P=0.05)		1.00	0.96	0.91	0.04	3.66

As for the interaction of the seeding treatments with the concentrations of salicylic acid, the results show that the treatment exceeds (60 kg.he^{-1} and 100 ppm) in the number of spikes (5.11 spike m^{-2}), grain yield (6.50 tons.ha^{-1}) and biological yield (22.62 tons.he^{-1}) and significantly. No significant differences were shown in the dry weight characteristic.

While the interaction treatment between seeding rates and salicylic acid concentration (60 kg.ha^{-1} and 200 ppm) showed superiority in the description of spike length (5.82 cm), and the lowest value was recorded in the number of spikes (1.98 spike.m^{-2}), grain yield (3.97 ton.ha^{-1}), dry weight (0.10 gm.m^{-2}) and biological yield (17.96 tons.ha^{-1}), the interaction treatment between seeding rates and the comparison treatment (80 kg.he^{-1} and 0 ppm) respectively.

3.4 Triple Interactions

The results of Table 6 showed a significant effect of triple overlap between irrigation treatments, seeding rates and growth regulator in some yield characteristics. The interaction treatment between irrigation treatments, seeding rates and salicylic acid concentration (14 days and 60 kg.ha^{-1} and 100 ppm) in the number of spikes (5.93 cm^2), spike length (6.65 cm), number of grains per spike (34.66 grains.spike^{-1}), grain yield (8.29 tons.ha^{-1}), biological yield (26.10 tons.ha^{-1}) and protein percentage (26.60%) significantly compared to the interaction treatment between irrigation treatments, seeding rates and comparison treatment (7 days, 60 kg.ha^{-1} and 0 ppm).

The interaction treatment between irrigation treatments, seeding rates and salicylic acid concentration (7 days and 60 kg.ha^{-1} and 100 ppm) outperformed in the number of spikes (5.86 cm^2) and in the grain weight (1.30 gm. plant^{-1}) and significantly over the rest of the treatments.

The lowest values in the number of spikes (1.66 cm^2), spike length (4.36 cm), number of grains (15.43 grains.spike^{-1}), grain yield (3.45 tons.ha^{-1}), biological yield (15.16 tons.ha^{-1}) and protein percentage (17.50%) were recorded by the interaction treatment

Table 6: The effect of triple interaction between irrigation treatments, seeding rates and growth regulator on some traits.

Irrigation treatment (Day)	Seeding rates	Salicylic acid	Number of spikes (cm^2)	Spike length (cm)	Number of grains ($grain.spike^{-1}$)	Grain weight ($gm.plant^{-1}$)	Grain yield ($ton.he^{-1}$)	Biological yield ($tons.ha^{-1}$)	Protein %
7	60	0	2.83	5.88	25.20	0.28	4.77	18.77	20.76
		100	5.86	5.65	32.50	1.30	6.26	24.10	23.70
		200	4.66	6.27	31.66	0.23	5.99	23.10	22.33
	80	0	2.16	5.76	23.10	0.25	4.14	18.38	20.66
		100	4.93	5.33	30.00	0.28	5.77	21.66	22.83
		200	4.33	5.63	27.43	0.21	5.33	21.66	21.48
14	60	0	2.66	6.33	27.16	0.32	5.72	19.38	21.96
		100	5.93	6.65	34.66	1.00	8.29	26.10	26.60
		200	5.26	6.48	33.43	0.26	7.09	25.96	25.50
	80	0	2.63	5.50	25.36	0.31	4.32	20.33	20.73
		100	5.16	5.43	28.33	0.99	6.92	24.66	24.66
		200	4.96	5.25	30.10	0.24	6.03	23.33	23.89
21	60	0	1.66	4.50	20.26	0.20	3.98	16.50	19.43
		100	3.53	4.93	32.00	0.21	4.94	17.50	21.33
		200	3.16	4.72	22.40	0.20	4.30	16.05	20.00
	80	0	1.66	4.36	15.43	0.16	3.45	15.16	17.50
		100	2.43	4.71	19.60	0.18	4.41	17.50	19.10
		200	2.33	4.66	18.26	0.15	4.71	16.05	18.33
L.S.D value P=0.05			1.74	1.66	10.01	0.33	1.29	6.34	5.64

between irrigation treatments, seeding rates and comparison treatment (21 days and 80 kg.ha-1 and 0 ppm) respectively, and the interaction treatment (21 days, 80 kg.he-1 and 200 ppm) recorded the lowest value in grain weight and was (0.15 g.plant-1).

The significant overlap between irrigation treatments and seeding rates and growth regulator for a particular trait is evidence of the response of that trait to the three variables in a homogeneous manner, while the non-significant interaction indicates a difference in the response of the trait to those variables.

4 CONCLUSIONS

The results of this study highlight the effectiveness of using salicylic acid and optimal seeding rates to improve wheat growth and yield under water stress conditions. Irrigation every 14 days combined with a seeding rate of 60 $kg.ha^{-1}$ and foliar application of salicylic acid at 100 ppm showed the most positive impact on growth traits, grain yield, and protein content. This combination significantly improved plant height, chlorophyll content, spike number, and overall productivity. Salicylic acid proved beneficial in enhancing the plant's tolerance to drought by promoting physiological activities and improving water-use efficiency. Additionally, lower seeding density reduced competition among plants, contributing to better yield components. The application of salicylic acid at 100 ppm during the elongation stage, along with moderate seeding rates and scheduled irrigation, can be an effective strategy to enhance wheat performance under limited water availability.

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