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Effect of Plant Regulators on Growth, Yield Attributes, Yield and Economics in Wheat under Restricted Irrigation

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ABSTRACT

The effect of plant regulators on growth, yield and yield attributes was studied for five plant regulators : thiourea @ 10 mM, salicylic acid @ 10 μM, gibberellic acid @ 25 ppm, potassium nitrate @ 15 g/l and NS (no spray i. e. control) at anthesis; 7 days after anthesis and 15 DAA under restricted irrigations. The restricted irrigations were I_1 i. e. one irrigation applied at 21 DAS and I_2 two irrigations i. e. first at 21 and 80 DAS in split-split plot design with three replications. The results revealed that gibberellic acid @ 25 ppm resulted in significantly higher plant height (106.9 cm) applied at 15 DAA under two irrigations. The other growth parameters like dry matter and number of tillers were found significantly higher (186.2 g and 99.0, respectively) when salicylic acid @ 10 μM was applied at 15 DAA under two irrigations. Salicylic acid @ 10 μM applied at 15 DAA resulted significantly in higher effective tillers (320.7/m^2), number of seeds per earhead (48.0), grain yield (5225 kg/ha) and harvest index (40.4%) under two irrigations. The highest gross returns (Rs. 106462/ha), net returns (Rs. 10,749/ha) and B : C (1.11) were recorded with salicylic acid applied at 15 DAA under two irrigations with lowest cost of cultivation (Rs. 95713/ha) comparable to control treatment i. e. no spray (Rs. 95711/ha). Two irrigations in wheat resulted in significantly higher gross returns (Rs. 106594/ha), net returns (Rs. 9708/ha) and highest B : C (1.10).

Key words : Economics, irrigation, plant regulators, salicylic acid, wheat

INTRODUCTION

Human population is increasing day by day and the production of the cereals is a major issue before the agricultural scientists all over the world in the changing climatic conditions. The global estimate for the production of wheat during 2016-17 was 752.0 million metric tonnes and in India estimated production was about 106.21 million tonnes during 2020 which is higher by 2.61 million tonnes as compared to wheat production during 2018-19 and is higher by 11.60 million tonnes than the average wheat production of 94.61 million tonnes (Anonymous, 2020). Production of cereals including wheat is dependent on the climatic changes which affect production of these crops. The total wheat production in India at national level was 97.44 million tonnes during 2016-17 (Ray, 2017) with average productivity of 3,075 kg/ha which was lower than the world average 3,257 kg/ha during 2013 (Economic Survey, 2016).

It is predicted that there will be an increase in the mean ambient temperature by 2.6 to 4.8 ^{0}C by the year 2081 to 2100 (IPCC, 2014) which will cause serious ramifications in global food security, and will result in 25-35% decline in the Middle East and 15-35% decline in Asia and Africa, respectively (Deryng *et al.*, 2014).

The increase in the night temperature during

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the reproductive phenophases it is very difficult for the plants to divert more photosynthates towards grain filling. The increase in temperature during March under Indian conditions leads to decrease in productivity per unit area. To overcome the effect of increased temperature and drought conditions, work is going on global basis on plant regulators remedies. Some of the most promising plant regulators are salicylic acid, thiourea, potassium nitrate and gibberellic acid.

Wassie *et al.* (2020) reported that alfalfa seedlings treated with 0.25 or 0.5 mM salicylic acid (SA) for five days prior to high stress treatment (three days) showed that exogenous SA pretreatment improved leaf morphology, plant height, biomass, chlorophyll content and photosynthetic efficiency under heat stress. SA is a naturally occurring derivative of the group of phenolic acid compounds distributed in many species of monocotyledonous and dicotyledonous plants, including rice, barley, crabgrass and soybean. The amount of SA in the leaves and reproductive organs of angiosperm plants is approximately 1 mg/g fresh weight. It regulates the physiological processes, such as photosynthesis, transpiration, nutrient uptake, chlorophyll synthesis and plant development. It also participates in the regulation of stomatal closure, nutrient uptake, protein synthesis and inhibition of ethylene biosynthesis in wheat seedlings and grape vine leaves. Ganj-Abadi *et al.* (2021) in mustard reported that foliar application of salicylic acid, increased seed and oil yields at the density of 40 plants/m^2 in L 14 genotype and in HW 118 at the densities of 50 and 60 plants/m^2.

Foliar application of osmotic solutes (potassium orthophosphate) could be an option to increase the thermal tolerance through osmotic adjustment in wheat leaf. Foliar application of potassium orthophosphate may delay high temperature or drought induced leaf senescence and thus improve grain yield of wheat. Foliar spray with thiourea has a great potential to mitigate the adverse effects of salinity and high temperature and as such recommended for field use in the areas, where moderate salinity or high temperature limits wheat production. The role of thiourea in abiotic stress tolerance is investigated less. Available reports show that it relieves the salinity induced seeds dormancy in *Allenrolfea occidentalis* (iodine bush) at lower concentration. External use of thiourea can increase the K uptake, net photosynthesis and chlorophyll content in drought stressed condition in plants. The present study was carried out to evaluate these effects on growth and yield.

MATERIALS AND METHODS

The study was carried at CCSHAU Regional Research Station, Kaul (Kaithal) during 2017-18 and 2018-19 to evaluate effects of plant regulators on growth and yield on wheat under the restricted irrigation. The variety under study was WH 1142 and the seed was procured from Directorate of Farms, CCSHAU, Hisar. There were five plant regulator treatments viz., thiourea @ 10 mM, salicylic acid @ 10 μM, gibberellic acid @ 25 ppm, potassium nitrate @ 15 g/l and NS (no spray i. e. control) at anthesis; 7 days after anthesis and 15 DAA under restricted irrigations. The restricted irrigations were I_1 i. e. one irrigation applied at 21 and I_2 two irrigations i. e. first at 21 and 80 DAS. The statistical design was split-split plot design where irrigation and time of spray was in main plot while the application of plant regulators in sub-plots. The soil of the experimental study was sandy loam and the available was 428.4 kg/ha (medium) N, 34.0 kg/ha (high) P and 351.5 kg/ha (high) K. The electrical conductivity of the soil was 0.35/dS and organic carbon was 0.42% (medium). The plant height was recorded on five plants tagged at 120 days after sowing per replication. For dry matter, the plants of 1 m length in a row at 120 days after sowing were cut and oven-dried at 80°C for 48 h. One-meter row length at 120 days after sowing was taken to count number of tillers. The biological and grain yield of the plots was converted into kg per hectare. The harvest index was calculated by dividing the grain yield by biological yield and multiplying with 100. The economics of irrigation and plant regulators were calculated.

RESULTS AND DISCUSSION

Frequency of irrigation in wheat significantly affected the growth parameters (Table 1). The mean plant height, dry matter and number of tillers were found significantly higher in I_2 (103.7 cm, 157.3 g/mrl and 86.7/mrl) where

Table 1. Effect of plant regulators on growth, yield attributes, biological grain and straw yield, and harvest index (Pooled data for 2017-18 and 2018-19)

Irrigation levels	Time of spray	Plant growth regulators	Growth parameters			Yield attributes			Yield		HI (%)
			PH (cm)	DM (g)	Tiller	ET/ m^2	SPEH	1000-GW (g)	BY (kg/ha)	GY (kg/ha)	
I_1	AA	TU @ 10 mM	91.8	116.5	76.7	288.7	43.0	34.3	12128	4628	38.2
		SA @ 10 µM	95.0	131.8	82.0	295.3	44.0	35.3	12105	4753	39.3
		GA @ 25 ppm	98.5	119.5	72.3	264.7	43.5	34.4	12077	4709	39.0
		PN @ 15 g/l	97.1	119.2	75.8	278.0	45.2	35.1	11814	4602	39.0
		Control	90.7	112.3	73.0	280.7	43.2	34.5	11846	4577	38.6
	7 DAA	TU @ 10 mM	94.3	146.0	78.8	296.0	43.8	34.3	12450	4902	39.4
		SA @ 10 µM	99.8	163.2	83.2	306.7	45.7	35.4	12483	5034	40.3
		GA @ 25 ppm	101.5	151.3	78.3	264.7	43.7	34.6	12550	5030	40.1
		PN @ 15 g/l	100.6	143.3	79.3	292.0	44.7	35.3	12139	4820	39.7
		Control	91.5	136.7	71.0	260.7	42.8	34.8	12141	4727	38.9
	15DAA	TU @ 10 mM	97.3	145.8	79.2	302.7	45.0	34.4	12704	5073	39.9
		SA @ 10 µM	101.1	165.8	85.0	307.3	47.3	35.4	12792	5138	40.2
		GA @ 25 ppm	101.8	157.0	81.7	290.7	44.3	34.6	12724	5059	39.8
		PN @ 15 g/l	101.8	146.8	83.7	296.0	44.7	35.5	12866	5194	40.4
		Control	94.3	141.8	75.0	262.7	43.0	34.4	12204	4901	40.2
I_2	AA	TU @ 10 mM	100.9	149.2	83.0	298.7	44.2	34.3	12655	5106	40.3
		SA @ 10 µM	103.5	164.7	91.5	316.0	46.0	35.6	12734	5139	40.4
		GA @ 25 ppm	104.1	141.2	85.2	281.3	45.3	34.8	12875	5132	39.9
		PN @ 15 g/l	102.0	132.8	83.8	288.0	45.7	35.6	12718	4973	39.1
		Control	101.2	146.7	79.2	302.0	43.3	35.2	12434	4920	39.6
	7 DAA	TU @ 10 mM	102.8	153.3	85.0	304.0	45.3	34.5	12752	5136	40.3
		SA @ 10 µM	104.2	176.0	90.3	328.0	46.5	35.7	12745	5173	40.6
		GA @ 25 ppm	105.7	162.5	87.5	288.7	45.0	34.8	12931	5148	39.8
		PN @ 15 g/l	104.3	153.5	85.2	292.7	45.7	35.8	12761	4992	39.1
		Control	101.3	154.2	82.5	308.7	44.0	35.5	12473	4909	39.4
	15DAA	TU @ 10 mM	104.7	158.2	87.3	309.3	46.0	34.5	12899	5155	40.0
		SA @ 10 µM	105.7	186.2	99.0	320.7	48.0	35.8	12945	5225	40.4
		GA @ 25 ppm	106.9	156.8	88.8	296.0	46.0	35.2	13015	5155	39.6
		PN @ 15 g/l	105.3	163.3	88.3	297.3	45.7	35.8	12841	5020	39.1
		Control	102.3	162.3	84.2	304.0	44.3	35.5	12604	4960	39.4

Factors	Irrigation (I)		Time of spray (S)			Plant regulators (PR)				
	I_1	I_2	S_1	S_2	S_3	TU	SA	GA	PN	Control
Mean PH	97.1	103.7	98.5	100.6	102.1	98.6	101.5	103.1	102.0	96.9
Mean DM	140.0	157.3	133.3	154.0	158.4	144.8	164.1	148.1	143.1	142.3
Mean tiller	78.3	86.7	80.3	82.1	85.2	81.7	88.5	82.3	82.7	77.4
Mean ET	285.8	303.7	289.3	295.3	299.6	299.9	312.3	281.0	294.0	286.4
Mean SPEH	44.3	45.4	44.3	44.7	45.4	44.6	46.3	44.6	45.3	44.4
Mean 1000GW	34.8	35.2	34.9	35.1	35.1	34.4	35.5	34.7	35.5	35.0
Mean BY	12335	12759	12339	12542	12760	12598	12634	12695	12523	12284
Mean GY	4876	5076	4854	4987	5088	5000	5077	5039	4933	4832
Mean HI	39.5	39.8	39.3	39.8	39.9	39.7	40.2	39.7	39.4	39.3
Statistics	I	S	I × S	PR	I × PR		S × PR		I × S × PR	
C. D. (PH)	0.4	0.5	0.7	0.6	0.9		1.1		NS	
C. D. (DM)	1.6	1.9	2.8	2.0	2.8		3.5		4.9	
C. D. (Tiller)	1.0	1.2	NS	1.0	1.4		1.7		2.3	
C. D. (ET)	2.5	3.1	NS	5.1	7.2		8.8		NS	
C. D. (SPEH)	0.3	0.4	NS	0.4	NS		0.8		NS	
C. D. (1000 GW)	0.1	0.1	NS	0.1	0.2		NS		NS	
C. D. (BY)	34	41	59	37	53		64		91	
C. D. (GY)	10	12	17	13	19		23		33	
C. D. (HI)	0.1	0.2	0.2	0.1	0.2		0.2		0.3	

I_1–One irrigation at 21 DAS, I_2–Two irrigations (1st at 21 DAS, 2^{nd} at 80 DAS), AA–At anthesis; 7 DAA–7 Days after anthesis; 15 DAA–15 Days after anthesis; TU–Thiourea; SA–Salicylic acid; GA–Gibberellic acid; PN–Potassium nitrate and Control-No spray. PH–Plant height, ET–Effective tillers/m^2; SPEH–Seeds per earhead; 1000-GW–1000 g weight (g) and CD–Critical difference at 5%.

two irrigations were applied (first at 21 and second at 80 DAS) as compared to only one irrigation I_1 (97.1 cm, 140.0 g/mrl and 78.3 mrl) applied at 21 days after sowing.

Plant regulators sprayed 15 days after anthesis resulted in significantly taller plants (102.1 cm), higher dry matter accumulation (158.4 g/mrl) and maximum number of tillers (85.2/ mrl) in plot where plant regulators were sprayed at 15 DAA over rest of the other time of spray. Among different plant regulators, application of gibberellic acid @ 25 ppm gave significantly taller plants (103.1 cm) over other plant regulators. Also among different plant regulators, application of salicylic acid @ 10 μM gave significantly higher dry matter (164.1 g/mrl) over all other treatments. Similarly, in different plant regulators, application of salicylic acid @ 10 μM gave significantly maximum tillers (88.5/mrl) over all other treatments.

Plant height was highest under spray of gibberellic acid @ 25 ppm applied at 15 DAA under irrigation regime I_2. The increase in height was due the effect of gibberellic acid as it enhanced the intermodal length at cellular level. The irrigation affected the plant height as water was important for various metabolic reactions helping in cell division, higher turgidity in the cells and favourable environment for plant growth. Gibberellic acid resulted in the production of thin elongated shoots due to its promoting effect on net orientation of the microtubule array that was perpendicular to the long axis of the cells. Gibberellic acid functioned mainly by promoting the longitudinal growth, the induction of hydrolytic enzymes in germinating seeds, the induction of bolting in long-day plants, and the promotion of fruit setting and development (Rademacher, 2018). Salicylic acid improved the other growth parameters like dry matter and tillers in the present study. It regulated the physiological processes, such as photosynthesis, transpiration, nutrient uptake, chlorophyll synthesis and plant development. It also helped in sufficient nutrient uptake, protein synthesis and inhibition of ethylene biosynthesis in wheat seedlings. Shemi *et al.* (2021) reported in maize that application of salicylic acid led to improvement in the dry matter of the plant. Khan *et al.* (2020) reported in chickpea that inoculation of PGPR and PGR treatment effectively ameliorated the adverse effects of moisture stress and the shoot and root fresh weight (81%) and dry weights (77%) which enhanced significantly in the treated plants.

The yield attributes like effective tillers, number of seeds per earhead and 1000-grain weight were maximum under salicylic acid treatment applied at 15 DAA. This might be due to role of salicylic acid in regulation of physiological processes like photosynthesis and amelioration of abiotic stress at the time of maturity. The results are in confirmation with the results of Pirasteh-Anosheh *et al.* (2021) who pointed in wheat that exogenously SA application not only led to higher grain yield of barley and wheat but also significantly improved their salt tolerance. Alam *et al.* (2020) pointed out that salicylic acid had the oxygen, carbon and hydrogen at particular ratio, which played a specific role in the production of fruits and flowers imparting higher yield.

Frequency of irrigation influenced the yield attributes like effective tillers, seeds per earhead and 1000-grain weight. The effective tillers were highest in two irrigation regimes i. e. (303.7/mrl). The same irrigation regime also improved the number of seeds per earhead (45.4) and 1000 g weight (35.2 g). The biological yield (12759 kg/ha), grain yield (5076 kg/ha) and harvest index (39.8%) were also significantly higher in I_2 (two irrigations at 21 and 80 DAS) as compared to only one irrigation I_1.

Plant regulators sprayed 15 days after anthesis resulted in significantly higher effective tillers (299.6/mrl), seeds per earhead (45.4), maximum 1000-grain weight (35.1 g) in plots where plant regulators were sprayed at 15 DAA over rest of the other time of spray. Time of spray of plant regulators influenced the biological yield and grain yield. Significantly higher biological yield (12760 kg/ha), grain yield (5088 kg/ha) and harvest index (39.9%) were recorded in plots where plant regulators were sprayed at 15 DAA (299.6/mrl) over rest of the other time of spray.

Irrigation regimes also influenced the economics of wheat cultivation. It was evident from the data presented in Table 3 that maximum gross returns (Rs. 106594/ha), net returns (Rs. 9708/ha) and benefit : cost ratio (1 : 10) were estimated from irrigation regime I_2 where two irrigations were applied (first at 21 and second at 80 DAS).

Among different plant regulators, application of salicylic acid @ 10 μM gave significantly higher effective tillers (312.3/mrl), number of seeds per earhead (46.3) and 1000-grain weight (35.5 g) over all other plant regulator treatments. Application of salicylic acid @ 10 μM resulted in significantly higher grain yield (5077 kg/ha) and harvest index (40.2%) over all other treatments.

The irrigation regime I_2 with application of gibberellic acid @ 25 ppm resulted in taller plants (106.9 cm). Further, irrigation regime I_2 with application of salicylic acid @ 10 μM significantly resulted in dry matter (186.2 g/mrl), tillers (99.0/mrl), effective tillers (320.7/mrl), seeds per earhead (48.0 g), 1000-grain weight (35.8 g), grain yield (52.25 kg/ha) and harvest index (40.6%) under two irrigations regime over other interaction combinations. The time and spray and irrigation frequency might be correlated with each other as in case of gibberellic acid when applied at 15 days after anthesis, at first (21 DAS) and second irrigation (80 DAS) favoured the plant to cope up with the drought condition and higher temperature during March month.

The interaction effects of irrigation regime I_2 along with spray of plant regulators at 15 DAA found useful in wheat to improve growth parameters, yield attributes and yield significantly. Application of gibberellic acid @ 25 ppm at 15 days after anthesis resulted in significantly higher values of growth parameters, yield attributes and yield as compared to other interaction combination. The interaction among irrigation, time of spray and plant regulators significantly affected the growth and yield in wheat.

The highest gross returns (Rs. 106462/ha), net returns (Rs. 10,749/ha) and benefit : cost ratio (1 : 11) were recorded with salicylic acid applied at 15 days after anthesis under two irrigations (Tables 2 and 3) with lowest total cost (Rs. 95713/ha) comparable to control treatment i. e. no spray (Rs. 95711/ha). Two irrigations in wheat at 21 and 80 days after sowing resulted in significantly higher gross returns (Rs. 106594/ha), net returns (Rs. 9708/ha) and highest benefit : cost ratio (1.10). Thus, salicylic acid @ 10 μM enhanced the growth, yield and yield attributes with highest monetary returns.

Use of salicylic acid at 15 DAA under two irrigations resulted in higher grain yield which in turn led to higher net returns with higher B : C. The total cost incurred on the application of salicylic acid was quite low i. e. (Rs. 95713/ha) which was comparable with control (no spray) i. e. Rs. 95711/ha.

Table 2. Costs incurred on plant regulators

S. No.	Particulars	Packing size (g)	Price/ unit (Rs.)	Per g price (Rs.)	Qty. used (g)	Water used/ given liter	Qty. used/ liter (g)	Water used/ acre	Qty. used/ acre (g)	Cost/ acre (Rs.)	Cost incurred/ ha (Rs.)
1.	TU	250	683	2.73	12.1800	16	0.76125	300.00	228.375	623.92	1559.80
2.	SA	500	700	1.40	0.0221	16	0.00138	300.00	0.414	0.58	1.45
3.	GA	10	1200	120.00	0.1250	5	0.02500	300.00	7.500	900.00	2250.00
4.	PN	500	418	0.84	30.000	2	15.00000	300.00	4500.000	3762.00	9405.00

TU : Thiourea @ 10 mM, SA : Salicylic acid @ 10 μM, GA : Gibberellic acid @ 25 ppm and PN : Potassium nitrate @ 15 g/l.

Table 3. Economics of plant regulators

Treatments	Gross returns (Rs./ha)	Total costs (Rs./ha)	Net returns (Rs./ha)	B : C ratio
Irrigation (Main plot) (I)				
I_1 : First irrigation at 21 DAS	102469	95710	6759	1.07
I_2 : First at 21 and 2nd at 80 DAS	106594	96887	9708	1.10
Plant growth regulators (sub-plot) (PR)				
PR_1 : Thiourea @ 10 mM	105020	97666	7354	1.08
PR_2 : Salicylic acid @ 10 μM	106462	95713	10749	1.11
PR_3 : Gibberellic acid @ 25 ppm	105842	98533	7309	1.07
PR_4 : Potassium nitrate @ 15 g/l	103733	107562	-3829	0.96
NS : No spray (control)	101626	95711	5915	1.06

CONCLUSION

Application of salicylic acid @ 10 µM applied at 15 days after anthesis in wheat under two irrigations regimes enhanced the growth, yield and yield attributes with highest monetary returns under two irrigations.

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REFERENCES

Alam, M., Hayat, K., Ullah, I., Sajid, M., Ahmad, M., Basit, A. and Hussain, Z. (2020). Improving okra (*Abelmoschus esculentus* L.) growth and yield by mitigating drought through exogenous application of salicylic acid. *Fres. Environ. Bull.* **29** : 529-535.

Anonymous (2020). India's 2019-20 food grain production to hit a record high of 291.95 million tonnes. Retrieved May, 07, 2020, from Economic Times. *https://economictimes.indiatimes.com/news/economy/agriculture/indias-2019-20-foodgrain-production-to-hit-a-record-high-of-291-95-million-tons-estimates-second-advance-estimate-of-govt/articleshow/74192668.cms.*

Deryng, D., Conway, D., Ramankutty, N., Price, J. and Warren, R. (2014). Global crop yield response to extreme heat stress under multiple climate change futures. *Environmental Res. Letters* **9** : 034011.

Economic Survey (2016). Agriculture : More from less. Chapter 4. Volume **1** : 68-83. *http://indiabudget.nic.in/budget2016-17/vol1_survey.asp.*

Ganj-Abadi, F., Rad, A. H. S., Sani, B. and Mozafari, H. (2021). Grain yield and qualitative of rapeseed genotypes change in response to exogenous application of salicylic acid and planting density. *Gesunde Pflanzen* **73** : 1-10.

Khan, Naeem, Asghari, M. D., Bano and Ali Babar (2020). Impacts of plant growth promoters and plant growth regulators on rainfed agriculture. *PloS One* **15** : e0231426.

Pirasteh-Anosheh, H., Ranjbar, G., Hasanuzzaman, M., Khanna, K., Bhardwaj, R. and Ahmad, P. (2021). Salicylic acid-nediated regulation of morpho-physiological and yield attributes of wheat and barley plants in deferring salinity stress. *J. Plant Growth Regulation* **40** : 1-13.

Rademacher, W. (2018). Chemical regulators of gibberellin status and their application in plant production. *Annual Plant Reviews* online **49** : 359-403.

Ray, R. K. (2017). India foodgrain output up 8.7% at a record 273.38 MT in 2016-17. *http://www.hindustantimes.com/business-news/india-foodgrain-output-up-8-7-at-a-record-273-38-mt-in2016-17/story-LzejleKlZ9Axjh3ppDQ5SJ.html.*

Shemi, Ramadan, Rui, Wang, El-Sayed, M. S., Gheith, Hafiz, Athar, Hussain, Saddam, Hussain, Muhammad, Irfan, Linna, Cholidah, Kangping, Zhang, Sai Zhang and Longchang, Wang (2021). Effects of salicylic acid, zinc and glycine betaine on morpho-physiological growth and yield of maize under drought stress. *Scientific Reports* **11** : 1-14.

Wassie, M., Zhang, W., Zhang, Q., Ji, K., Cao, L. and Chen, L. (2020). Exogenous salicylic acid ameliorates heat stress-induced damages and improves growth and photosynthetic efficiency in alfalfa (*Medicago sativa* L.). *Ecotoxicology and Environmental Safety* **191** : 110206.