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FOLIAR APPLICATION OF POTASSIUM AND GIBBERELLIC ACID (GA_3) TO ALLEVIATE DROUGHT STRESS IN WHEAT

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ABSTRACT

To investigate the ameliorative effect of foliar application of potassium and gibberellic acid on wheat to drought stress an experiment was conducted at the research field and laboratory of Crop Physiology and Ecology Department, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period of November 2018 to March 2019. The experiment was laid out in a split plot design with three replications. Four growing conditions viz. well water (WW), water deficit stress (WDS), foliar application of 2.23% K_2SO_4 under WDS and foliar application of 300 ppm GA_3 under WDS were set up as the main plot treatment and two wheat varieties (Kanchan and BARI Gom-30) were set up as sub plot treatment. Non-irrigated water stress significantly reduced different physiological traits, yield and yield attributes except proline content of flag leaf of wheat, whereas foliar application of potassium and GA_3 improved these traits under WDS. Foliar application of potassium improved biological yield (22.04% and 15.16%) and grain yield (3.19% and 2.59%) in Kanchan and BARI Gom-30, respectively, whereas foliar application of GA_3 improved biological yield (12.12% and 17.00%) and grain yield (1.47% and 1.18%) in Kanchan and BARI Gom-30, respectively under WDS. Though, foliar application of potassium and GA_3 ameliorated the adverse effect of drought on wheat but potassium was found more effective. Therefore, it may be concluded that additional foliar application of potassium along with recommended potassium could improve production of wheat under drought.

Key words: Drought tolerance, potassium, GA_3, physiology, yield, wheat

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second important cereal crop next to rice in Bangladesh (Barma *et al.* 2019). It is grown over an area of 0.33 million hectares with an annual production of about 1.03 million metric tons (BBS 2020). Still now, the average yield of the crop is comparatively low (3.09 t ha^{-1}) (BBS 2020) than other leading wheat growing countries of the world. Wheat production has been declined due to various abiotic stresses over the last two decades and drought is the most prominent one (Pramanik *et al.* 2021) which employs expressively adverse effects on production of wheat in northern and central part of the country (Abhinandan *et al.* 2018).

Drought or water deficit stress severely inhibits growth and productivity of wheat in comparison with other environmental stresses (Zhang *et al.* 2018). It simultaneously affects morphological, physiological, biochemical, and metabolic changes (Cochard *et al.* 2002); disturbs membrane stability, plant metabolism and photosynthesis machinery (Nardino *et al.* 2022) and finally reduce yield performance. In developing countries, the water shortages have reduced wheat yields from 50 to 90% of their irrigated potential (Cochard *et al.* 2002). Therefore, for sustaining wheat yield, a high priority should be given to minimize the detrimental effects of water stress on crop production by applying modern breeding techniques, increasing physical and chemical fertility and maintaining adequate and balanced supply of mineral nutrients and growth regulators.

Potassium enhances drought tolerance in plants through mitigating harmful effects on translocation, osmoregulation, photosynthesis, transpiration, maintaining water balance, stomatal opening and closing and synthesis of protein (Cakmak 2005 and Milford and Johnston 2007). Plant suffering from drought stress required more internal potassium and potassium plays a vital role in improving the plant resistance (Cakmak 2005). Low grain yield resulting from water deficit could be overcome by increasing potassium supply (Aowan *et al*. 2012). Recent studies have reported that exogenous gibberellins (GA_3) regulate the level of active gibberellins in the plant and may have the role in plant abiotic stress response (Tonkinson *et al.* 1997). Exogenous application of GA_3 was found to overcome the inhibitory effect of abiotic stress in maize, mustard and wheat (Tuna *et al.* 2008 and Yang 2013). Exogenous application of potassium and GA_3 may be one of the important practices in ameliorating drought stress of wheat. Thus, the present investigation was carried out to investigate the effect of foliar supplying of potassium and GA_3 on wheat to ameliorate drought stress.

MATERIALS AND METHODS

Location and duration: The experiment was conducted at the research field and laboratory of Department of Crop Physiology and Ecology, HSTU, Dinajpur, Bangladesh during November, 2018 to March, 2019. The experimental field is located at 25º39′ N latitude and 88º41′ E longitude with an elevation of 37.58 meters above the sea level and under the Agro-ecological zone Old Himalayan Piedmont Plain (AEZ-1).

Experimental design layout and treatments: The experiment was laid out in a split plot design and replicated thrice. The unit plot size was 2m × 1.5m having a plot to plot and block to block distance of 0.75m and 1m, respectively. Four growing conditions: i) well water (irrigation was given at crown root initiation, anthesis and grain filling stages), ii) water deficit stress (no irrigation), iii) foliar application of 2.23% K_2SO_4 under water deficit stress and iv) foliar application of 300 ppm GA_3 under water deficit stress were placed in main plots, whereas two wheat varieties (Kanchan and BARI Gom-30) were placed randomly in sub plots. Well water plots were irrigated three times but the water stress plots were not irrigated throughout the growing period to maintain water deficit stress condition and the crop was protected from rainfall by taking polythene shelter.

Sowing of seeds and intercultural operations: Seeds were sown on 23 November, 2018 at the rate of 120 kg ha^{-1} in rows of 20 cm apart. Slight irrigation was given after sowing to facilitate uniform germination. Recommended production technology of wheat was followed and necessary intercultural operations were done accordingly.

Preparation and application of potassium and GA_3: For 1% potassium fertilizer foliar application of 2.23% K_2SO_4 with 1% Tween 20 was sprayed. The GA_3 solution of 300 ppm concentrations was prepared by dissolving 300 mg of GA_3 in 10 ml methanol prior to dilution with distilled water. Then distilled water was added to make the volume 1 litre to get 300 ppm GA_3 solution. The foliar spraying was done at 40, 60 and 70 days after sowing with the help of a hand sprayer until all leaves were completed wetted.

Data collection on soil moisture content: Soil moisture content was calculated as dry weight basis from 15 cm depth soil using the formula; Soil moisture content (%) = {(Fresh weight of soil - Weight of oven fry soil) / Weight of oven dry soil} ×100

Data collection on physiological parameters

Relative water content (RWC) of flag leaf was measured at 16 days after anthesis according to Barrs and Weatherley (1962). Chlorophyll content of flag leaf was determined at 16 days after sowing according to Witham *et al.* (1986). A hand held infra-red thermometer was used to measure canopy temperature at 5 days after anthesis during noon period under bright sunlight and less wind. Canopy temperature depression (CTD) was calculated by calculating the difference between ambient air temperature and canopy temperature in degree centigrade. Proline content of flag leaf was determined at 16 days after sowing according to Bates *et al.* (1973).

Data collection on yield and yield contributing attributes: Plant height, spikes plant^{-1}, spikes m^{-2}, spike length, spikelets spake^{-1}, grains spike^{-1}, grains weight spike^{-1}, 500 grain weight, biological yield and grain yield were recorded manually from each of five sample plants from each replication at harvest.

Statistical analysis: For all investigated parameters, analysis of variance was performed by partitioning the total variance and the treatment means were compared using Tukey’s test with the help of STATA (Small STATA 12.0) software package.

RESULTS AND DISCUSSION

Soil moisture content at different days after sowing

The column graph compares the soil moisture content of well water and water stress plots at 80, 90 and 100 days after sowing of seed. It indicates that well water plots maintained higher soil moisture (18.66%, 15.33% and 11.55%) than that of water stressed plots (12.57%, 7.53% and 5.55%). The variation might be due to different irrigation supply and variation in rate of evapotranspiration and consumption of water by plants from soil at early and later crop growth stages. Other authors also recorded remarkable variation in moisture content of well water and water deficit stressed plots of wheat (Ali *et al.* 2018), maize (Ray *et al.* 2020 and Haque *et al.* 2021) and mung bean (Ahmed *et al.* 2021) that clarify our findings.

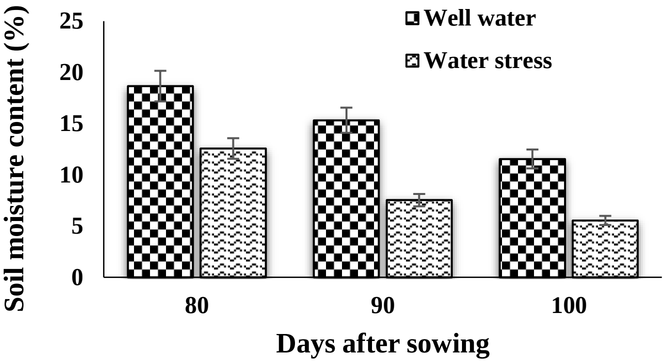

Figure 1. Soil moisture content (0-15 cm depth) at different days after sowing as influenced by water regimes.

Physiological traits

Relative water content, chlorophyll content and proline content of flag leaf and canopy temperature depression of wheat were significantly varied by the interaction effect of varieties and growing conditions (Table 1). The maximum water content of flag leaf (72.43%) was observed in BARI Gom-30 under WW, whereas minimum (61.66%) was observed in Kanchan under WDS. Water deficit stress reduced the water content of flag leaf in wheat at different magnitude (11.98% in Kanchan and 8.37% in BARI Gom-30). Water deficit stress reduced the chlorophyll content by 27.22% in Kanchan and 31.11% in BARI Gom-30. The well watered plots maintained comparatively cooler canopy than the water stressed plots. Water deficit stress reduced the cooling capacity of wheat canopy (21.52% in Kanchan and 24.64% in BARI Gom-30). Maximum proline content of flag leaf (1.92 µmole g^{-1} FW) was observed in Kanchan under WDS, whereas the minimum (1.37 µmole g^{-1} FW) was observed in BARI Gom-30 under WW. Water deficit stress increased the proline content of wheat varieties at different magnitude (38.13% in Kanchan and 36.50% in BARI Gom-30). Under WDS, improvement due to foliar application of potassium was observed by 11.03 and 8.33% in RWC of flag leaf, 31.65 and 22.82% in CC of flag leaf, 8.17 and 29.81% in CTD, whereas foliar application of GA_3 improved these traits by 3.28% and 7.98%, 2.80% and 19.21%, 5.86% and 29.13% in Kanchan and BARI Gom-30, respectively (Table 1). Under WDS, the proline content was reduced by foliar application of potassium and GA_3. Potassium reduced the proline content by 19.79 and 7.49%, while GA_3 reduced by 16.67% and 6.95% in Kanchan and BARI Gom-30, sequentially.

In present investigation, we found that physiological traits of wheat are negatively affected by WDS. Significant reduction in photosynthetic pigment due to WDS was observed by Farshadfar *et al.* (2014) that is parallel to our findings. Proline is well known to rise dramatically in higher crop plants in response to different abiotic stresses like drought (Nowsherwan *et al.* 2018) which is in agreement with the present findings. Meaningful reduction in relative leaf water and chlorophyll content and dramatic rose of proline in wheat leaf were also observed by Pramanik *et al.* (2021) that supports our present findings. Wheat plants maintained comparatively a hot canopy under WDS which might be due to low transpiration rate and reduced foliage as well as reduced canopy of plants under stress as plant shows diverse mechanisms to adapt unfavorable condition. Potassium plays a role as an enzyme stabilizing agent and has the ability to mediate osmotic adjustment (Sarwar *et al.* (2017). Physiological improvement was also observed due to foliar application of potassium (Mohammadi *et al.* 2013) and foliar application of gibberellic acid (Sarwar *et al.* 2017) that are supporting to our findings on physiological responses of wheat to potassium and GA_3.

Yield and yield components

Different yield components and yield except spikes plant^{-1}, grain weight spike^{-1} and biological yield were significantly influenced by the interaction effect of varieties and growing conditions (Table 2 and 3). Detrimental effects of water deficit stress considerably reduced the yield and yield components of wheat but foliar application of potassium and GA_3 played significant role in compensating the negative effect of WDS and improving the yield traits. The tallest plant (99.69cm) was observed in Kanchan under WW condition, whereas the shortest plant (86.68cm) was observed in BARI Gom-30 under WDS. The longest spike (11.27cm) was observed in Kanchan which was statistically similar with that of BARI Gom-30 (11.10cm) under WW, whereas the minimum spike length (9.15cm) was observed in BARI Gom-30 under WDS. The maximum grains weight spike^{-1} of wheat (2.37g) was observed in BARI Gom-30 under WW, whereas the minimum (1.77g) was observed in Kanchan under WDS. The maximum biological yield of wheat (8.77 t ha^{-1}) was recorded from BARI Gom-30 under WW, whereas the minimum (6.85 t ha^{-1}) was recorded from Kanchan under WDS. BARI Gom-30 produced the maximum grain yield (4.48 t ha^{-1}) under WW but the minimum grain yield (4.07 tha^{-1}) was observed in Kanchan under WDS. Water deficit stress reduced the plant height (3.84% in Kanchan and 12.15% in BARI Gom-30), spikes number plant^{-1} (23.31% in Kanchan and 9.66% in BARI Gom-30), number of spikes m^{-2} (12.79% in Kanchan and 14.97% in BARI Gom-30), grains spike^{-1} (6.78% in Kanchan and 7.45% in BARI Gom-30), grain weight (18.81% in Kanchan and 10.55% in BARI Gom-30), 500 grain weight (4.45% in Kanchan and 1.37%) as compared to that of WW (Table 2 and 3). Under WDS, Kanchan constitutes 19.79% reduction in biological yield which is almost as similar as BARI Gom-30 which accounts for 19.49% reduction in biological yield. Kanchan made up 4.68% depletion and BARI Gom-30 accounts for 5.36% reduction in grain yield due to WDS. Foliar application of potassium amended the detrimental effect of WDS and recovered the loss by 1.94 and 1.38% in plant height, 14.04 and 9.26% in spikes plant^{-1}, 13.35 and 11.78% in spikes m^{-2}, 4.18 and 9.51% in spike length, 7.59 and 8.29% in spikelets spike^{-1}, 1.63 and 6.39% in grains spike^{-1}, 18.64 and 8.02% in grain weight spike^{-1}, 4.86 and 0.76% in 500 grain weight, 22.04 and 15.16% in biological yield and 3.19 and 1.18% in grain yield in Kanchan and BARI-Gom-30, respectively (Table 2 and 3). Foliar application of GA_3 compensated the loss of those traits by 3.94 and 9.33%, 11.32 and 6.89%, 2.60 and 3.25%, 0.56 and 6.99%, 3.79 and 4.80%, 0.76 and 6.30%, 3.75 and 0.36%, 12.12 and 17.00% 1.47 and 1.18% in Kanchan and BARI Gom-30, sequentially except grain weight spike^{-1} (Table 2 and 3). Foliar application of GA_3 improved the grain weight spike^{-1} by 4.52% in Kanchan but no improvement was found in BARI Gom-30 (Table 3).

Table 1. Interaction effect of varieties and growing conditions on different physiological traits of wheat

Wheat varieties	Growing conditions	RWC of flag leaf		CC of flag leaf		CTD		FLPC	
		%	% Change over WW	mg g^{-1} FW	% Change over WW	℃	% Change over WW	µmole g^{-1} FW	% Change over WW
Kanchan	WW	70.06abc	-	9.81a	-	23.70a	-	1.39ef	-
	WDS	61.66d	-11.98	7.14c	-27.22	18.60bc	-21.52	1.92a	+38.13
	WDS+Foliar K_2SO_4	68.46abc (+11.03%)	-2.28	9.40a (+31.65)	-4.08	20.12b (+8.17)	-15.11	1.54de (-19.79)	+10.79
	WDS+ Foliar GA_3	63.68cd (+3.28%)	-9.09	7.34c (+2.80)	-25.18	19.69b (+5.86)	-16.92	1.60cd (-16.67)	+17.17
BARI Gom-30	WW	72.43a	-	8.84ab	-	21.59ab	-	1.37f	-
	WDS	65.69bcd	-8.37	6.09c	-31.11	16.27c	-24.64	1.87ab	+36.50
	WDS+Foliar K_2SO_4	71.16ab (+8.33%)	-1.76	7.48bc (+22.82)	-15.38	21.12ab (+29.81)	-2.13	1.73bc (-7.49)	+26.28
	WDS+Foliar GA_3	70.93ab (+7.98%)	-2.07	7.26c (+19.21)	-17.87	21.01ab (+29.13)	-2.69	1.74bc (-6.95)	+27.00
Level of significance		*		*		*		*	
CV (%)		6.15		6.46		11.30		12.33	

In a column, values followed by the different letter(s) are significantly different from each other at P≤5% level by Tukey. *significantly different at 5% level of probability. CV= Coefficient of variation. WW=Well water. WDS=Water deficit stress. RWC=Relative water content. CC=Chlorophyll content. CTD= Canopy temperature depression. FLPC= Flag leaf proline content. Values in parenthesis indicate % improvement over WDS in respective variety.

Table 2. Interaction effect of varieties and growing conditions on yield components of wheat

Wheat varieties	Growing conditions	Plant height		Spikes $plant^{-1}$		Spikes m^{-2}		Spike length		Spikelets $spike^{-1}$	
		cm	% Change over WW	Number	% Change over WW	Number	% Change over WW	cm	% Change over WW	Number	% Change over WW
Kanchan	WW	99.69a	-	6.22	-	372.33a	-	11.27a	-	19.13a	-
	WDS	95.87ab	-3.84	4.77	-23.31	324.66ab	-12.79	10.77ab	-4.44	17.66bc	-7.63
	WDS+Foliar K_2SO_4	97.73ab (+1.94)	-1.97	5.44 (+14.04)	-12.54	368.00a (+13.35)	-1.15	11.22a (+4.18)	-0.44	19.00a (+7.59)	-0.68
	WDS+Foliar GA_3	99.65a (+3.94)	-0.04	5.31 (+11.32)	-14.63	332.00ab (+2.60)	-10.82	10.83ab (+0.56)	-3.90	18.33ab (+3.79)	-4.18
BARI Gom-30	WW	98.67ab	-	4.66	-	349.33ab	-	11.10a	-	16.68cd	-
	WDS	86.68c	-12.15	4.21	-9.66	297.00b	-14.97	9.15c	-17.57	15.20e	-8.87
	WDW+Foliar K_2SO_4	87.88c (+1.38)	-10.93	4.60 (+9.26)	-1.29	332.00ab (+11.78)	-4.95	10.02abc (+9.51)	-9.73	16.46d (+8.29)	-1.26
	WDS+Foliar GA_3	94.77b (+9.33)	-3.94	4.50 (+6.89)	-3.43	306.66ab (+3.25)	-12.20	9.79bc (+6.99)	-11.80	15.93de (+4.80)	-4.50
Level of significance		*		NS		*		**		*	
CV (%)		5.36		14.88		9.77		7.93		8.24	

In a column, values followed by the different letter(s) are significantly different from each other at P≤5% level by Tukey. *significantly different at 5% level of probability, **significantly different at 1% level of probability. NS=Not significant at 5% level of probability. CV= Coefficient of variation. WW=Well water. WDS=Water deficit stress. Values in parenthesis indicates % improvement over WDS in respective variety.

Table 3. Interaction effect of varieties and growing conditions on yield components and yield of wheat

Wheat varieties	Growing conditions	Grains spike^{-1}		Grain weight spike^{-1}		500 grain weight		Biological yield		Grain yield	
		Number	% Change over WW	g	% Change over WW	g	% Change over WW	(t ha^{-1})	% Change over WW	(t ha^{-1})	% Change over WW
Kanchan	WW	39.40b	-	2.18	-	25.10a	-	8.54	-	4.27abc	-
	WS	36.73c	-6.78	1.77	-18.81	23.48c	-4.45	6.85	-19.79	4.07c	-4.68
	WW+Foliar K_2SO_4	37.33c (+1.63)	-4.24	2.10 (+18.64)	-3.21	24.62b (+4.86)	-1.91	8.36 (+22.04)	-2.11	4.20bc (+3.19)	-1.64
	WS+Foliar GA_3	37.01c (+0.76)	-6.04	1.85 (+4.52)	-14.68	24.36b (+3.75)	-2.95	7.68 (+12.12)	-9.95	4.13bc (+1.47)	-3.28
BARI Gom-30	WW	46.15a	-	2.37	-	22.60d	-	8.77	-	4.48a	-
	WS	42.71b	-7.45	2.12	-10.55	22.28d	-1.37	7.06	-19.49	4.24abc	-5.36
	WW+Foliar K_2SO_4	45.44a (+6.39)	-1.52	2.29 (+8.02)	-3.38	22.45d (+0.76)	-0.66	8.13 (+15.16)	-7.26	4.35ab (+2.59)	-2.90
	WS+Foliar GA_3	45.40a (+6.30)	-1.63	2.12	-10.13	22.36d (+0.36)	-1.06	8.26 (+17.00)	-5.82	4.29abc (+1.18)	-4.24
Level of significance		**		NS		**		NS		**	
CV (%)		9.45		9.98		4.69		10.64		3.36	

In a column, values followed by the different letter(s) are significantly different from each other at P≤5% level by Tukey. **significantly different at 1% level of probability. NS=Not significant at 5% level of probability. CV= Coefficient of variation. WW=Well water. WDS=Water deficit stress. Values in parenthesis indicates % improvement over WDS in respective variety.

Spikes plant^{-1}, spikes m^{-2}, spike length, grains spike^{-1}, grain weight spike^{-1} and 500 grain weight in wheat may have considered being most important yield contributing components that are positively correlated with final grain yield. In our present study, WDS dramatically declined all these yield components. These results are in accordance with the results of Pramanik *et al.* (2021) who found WDS significantly reduced spikes plant^{-1}, spike length, grains spike^{-1}, grains weight spike^{-1} and finally biological yield plant^{-1} and grain yield plant^{-1}. Plant height was decreased under water deficit condition which might be due to decreased in cell expansion as well as reduced cell division. Water deficit stress significantly reduced spike length results in a smaller number of spikelets spike^{-1} and grains per spike^{-1} which ultimately reduced grain yield (Anjum *et al.* 2011). Yield reduction in wheat due to water deficit stress was also found by Daryanto *et al.* (2017) and Pramanik *et al.* (2021). Zhang *et al.* (2018) also observed 25.00% and 27.50% reduction in wheat biomass and grain yield, respectively due to drought. These findings are very much consistent to our present findings. Our research findings reveal that foliar application of potassium and GA_3 significantly increased the physiological and yield attributes of wheat than that of water deficit stress. It might be due to improved physiological processes that eventually increases plant growth and development leading to increase in yield and yield components (Ibraheim and Mohsen 2015). Improvement of yield attributes under water deficit stress condition by foliar application of potassium and GA_3 was also reported by Mohammadi *et al.* (2013), Arabshahi *et al.* (2017), Rahman *et al.* (2014) and Mehri (2015) that support the results of the present study.

CONCLUSION

From the overall results of the present study, it may be concluded that foliar application of potassium and GA_3 had ameliorative effect on physiology, yield attributes and final yield of wheat under water deficit stress condition and potassium was more effective as compared to GA_3. Therefore, additional foliar application of potassium along with recommended potassium could improve wheat productivity under drought condition.

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