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Potassium Driven Nutritional Enhancement in Sweet Corn under Water Deficit

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Abstract

Drought stress is a serious challenge for sweet corn in semi-arid and arid regions across the world. Potassium fertilization has been shown to be effective in mitigating the adverse effects of drought stress. However, the impact of potassium on nutritional quality of sweet corn has not been tested yet. Therefore this study investigated the role of potassium in alleviating the negative impacts of water scarcity and improving the nutritional quality of sweet corn. A pot experiment was conducted on two genotypes of sweet corn (SUGAR-75 and NSC901B) with three potassium levels (0, 500 ppm, and 700 ppm) recorded as control, K_1, and K_2, respectively under six different drought conditions to investigate the efficacy of potassium in improving the seed quality of sweet corn under drought stress. Drought stress considerably affected the yield quality of sweet corn in both genotypes, and when drought stress was sustained, these negative consequences were exacerbated. Furthermore, potassium supplementation reduced negative effects of drought and increases seed quality in sweet corn. Results of this experiment revealed that potassium fertilization can enhance the nutritional quality of sweet corn under normal as well as drought stress conditions.

Keywords: Potassium, Seed quality, Sweet corn, Water deficit.

Introduction

Plants are subjected to a variety of stresses during their growth and development in both natural and agricultural environments. Drought is one of the most serious environmental factors impacting plant productivity (Seleiman et al. 2021). Water content accounts for roughly 80-95% of the fresh biomass of the plant and is vital in several physiological activities, including metabolism plant growth and reproduction. (Brodersen et al. 2019). Water deficit arises when the amount of transpired water surpasses the volume of water received by the roots, which can be triggered by limited precipitation, low ground water levels, or soil with a poor water holding capacity (Lisar and Hamideh, 2016). According to the IPCC (2014) assessment, the decline in food yield and quality, mostly as a result of water scarcity, poses a severe danger to agriculture (IPCC, 2014; Zandalinas et al. 2018).

Globally, the productivity and nutritional value of main crops are negatively impacted by drought stress (Sabagh et al. 2019). In a field experiencing drought, yield losses normally range between 30% and 90% depending on the crop species (Hussain et al. 2019). Drought stress can impair the final quantitative and qualitative yield at any development stage (Prasad et al. 2017). According to Chen et al. (2014), drought stress that occurred during the period of growth and maturation had a significant impact not only on yield, but also on quality of tomato. Thus, maintaining nutritional quality in crops under drought stress may present an excellent prospect to supply sufficient food and nourishment to humans.

Potassium (K) is one of the most sought-after cationic minerals for growth and is strongly associated to yield and quality. Potassium (K) is among the most demanded cationic minerals for vegetative growth and is strongly linked to yield and quality (Kanai et al. 2011; Daoud et al. 2020). Potassium is involved in many metabolic and physiological processes such protein synthesis, enzyme activation, and plant photosynthesis (White and Karley, 2010). Application of potassium, fertilizer judiciously could increase both quantity and quality of the crop (Colpan et al. 2013).

Sweet corn (*Zea mays* convar. Saccharata var. rugosa) belongs to the Poaceae family. It is a sugar-rich maize type designed as a miracle crop. Sweet corn comprises 5-6% sugar, 10-11% starch, 3% water soluble carbohydrates and 70% water, in addition to moderate levels of protein, vitamin and minerals (Oktem and Oktem, 2005). The sweet corn kernel contains more protein and fat than other corn cultivars (Budak and Aydemir, 2018). Sweet corn is high in antioxidants such as carotenoids, lutein, and zeaxanthin (Ozata, 2019). Nowadays, improving the nutritional value and health benefits of food crops to minimize dietary inadequacies is becoming increasingly important. The aim of this research was to examine the impact of exogenously supplied potassium on the yield quality of sweet corn cultivars under water deficit.

Material and methods

A pot experiment was conducted for two consecutive years (2018-19) during the spring season at the anti-insect house of the Botany Department, Kurukshetra University, Kurukshetra, Haryana, India. This investigation was carried out by using two cultivars of sweet corn (SUGAR-75 and NSC901B). Sweet corn seeds were planted in the second week of March each year, and water treatments were administered following germination. The crop was maintained in 25 cm-diameter polythene bags that held 10 kg of soil. Completely randomized designs were used for the experimental analysis. The three-factor OP STAT developed by Sheoran et al. (1998) was used for statistical analysis.

Water scarcity was generated by withholding watering for varied stretches of time. a) Fully irrigated (FI): Daily watering after germination. c) Fully drought (FD): No watering after germination. b) Moderate early drought (MED): Weekly irrigation after germination. c) Severe early drought (SED): Irrigate every 14 days after germination. f) Moderate late drought (MED): Full irrigation till 50 days, then weekly irrigation. f) Severe late drought (SED): Irrigate continuously until 50 days, then after every 14 days.

Following germination, various potassium solutions with varying concentrations (control=0 ppm, K_1=500 ppm, and K_2=700 ppm) were applied in form of muriate of potash in addition to the present level (52 ppm) in the soil. At the time of harvest samples for various parameters were obtained.

The Potassium ion content was measured as per Allen et al. (1976). Standard KCl solutions were made by combining KCl with DDW and increasing the final volume to 1 litre. Sample solutions were prepared and diluted to volume as needed. The flame photometer was standardized by running various concentrations of standards solutions and then a calibration curve was drawn. Readings from the flame emission photometer's digital display were taken. The Bradford (1976) method was employed to determine the total soluble protein content. Seeds were heated in a hot water bath for 2 to 5 minutes with 10 ml of 80% ethanol. It was homogenized in ethanol using a pestle and mortar after 5 minutes cooling at room temperature and then centrifuged at 5000g. The residue was then subjected to a second extraction using 5ml of 5% perchloric acid, followed by 10 minutes of centrifugation at 5000g. The supernatant was discarded, and the leftover material was further extracted using 5 ml of 1 N NaOH. After addition of 0.8 ml double-distilled water and 2.5 ml dye to 0.2 ml of the aforementioned extract absorbance was recorded at 595nm. A standard curve was prepared using bovine serum albumin for protein estimation. The starch content was calculated using the Hassid and Neufeld procedure (1964). The residue was mixed in 5ml of ice cold 26% perchloric acid and left overnight. The above was then centrifuged at 5000g for 15 minutes, and the residue was extracted using 26% perchloric acid. Then 0.2 g of anthrone reagent was added, with100 ml of concentrated H_2SO_4. To make the final volume 1 ml, took 0.2 ml of the extract that was previously formed and added distilled water to it. Anthrone reagent (4 ml) was then added, and the entire mixture was heated on a water bath for roughly 10 minutes. After cooling, the absorbance was measured at 620 nm. The standard curve was created applying graded doses of glucose. The amount of total soluble sugar was determined using the Hart and Fisher (1971) method. After extracting 100 mg of seeds in 10 ml of DDW, the mixture was centrifuged in a Remi centrifuge for 10 min. The supernatant was pooled out and the leftover residue was discarded. Double-distilled water was then used to increase the volume to 50 ml. A 3 ml sample of the extract was placed in a water bath at 100°C for 5 minutes. Following the placement of test tubes in a boiling water bath, 6 ml of the anthrone reagent was slowly added and absorbance was recorded in UV-Vis spectrophotometer at 600 nm.

Result

Potassium content of kernel

The total potassium content of kernels was found to be higher in genotype SUGAR-75 than the NSC901B genotype of sweet corn. Drought stress reduced the total potassium content of kernels. Maximum decrement of 26% was found under fully drought conditions in genotype SUGAR-75. The addition of potassium enhanced the total potassium content of sweet corn kernels in both genotypes. Exogenously administered 700ppm potassium (K_2) exhibited an increase of 16% in genotype SUGAR-75 under moderate early drought. The same potassium dose resulted in a maximum boost of 22% in genotype SUGAR-75 over test control of severe early drought.

Protein content of kernel

Drought stress reduced kernel protein content, with the greatest decrease of 46% in genotype NSC901B under fully drought treatment. In contrast to genotype NSC901B, genotype SUGAR-75 had kernels with greater overall protein content. Potassium application increased overall protein content in sweet corn kernels in both genotypes. Potassium concentration of 700 ppm (K_2) showed maximum increase of 15% in genotype SUGAR-75 in moderate droughts over test control of moderate early drought. The highest gain among severe droughts was found to be 22% in genotype SUGAR-75 over test control of severe early drought under the influence of 700 ppm (K_2) potassium concentration.

Starch content of kernel

In comparison to SUGAR-75, the total starch content of the kernels was somewhat higher in the NSC901B genotype. Both genotypes of sweet corn kernels had lower total starch contents after potassium application. The NSC901B genotype showed a maximum reduction of 19% in moderate early drought under the influence of 700 ppm potassium concentration. When compared to the test control of a severe early drought, genotype SUGAR-75 demonstrated a maximum decrease of 26% when700 ppm potassium concentration was supplied exogenously. Overall potassium decreased the starch content in both genotypes.

Total soluble sugar content of kernel

Genotype SUGAR-75 had a relatively greater total soluble sugar content concentration than NSC901B. Both genotypes of sweet corn kernels showed higher total sugar content after potassium application. The highest increase among moderate droughts was found to be 17% in genotype NSC901B compared to test controls of moderate late drought when 700 ppm (K_2) potassium concentration was applied. Among severe droughts, a maximum increase of 26% in genotype NSC901B over test control of severe early drought was reported when 700 ppm (K_2) of potassium was supplied.

Discussion

In this investigation drought stress decreased starch content, protein content and potassium content of kernels but the total soluble sugar content increased under water deficit condition in both cultivars. Cultivar SUGAR-75 showed significantly higher content of protein, total soluble sugar and potassium than genotype NSC901B under normal and stressed conditions. Our findings are in agreement with Du et al. (2019) where drought stress induced a decrease in starch content however soluble sugar and sucrose content were increased in soyabeans. Drought inhibits the synthesis of starch and proteins, which in turn prevents the accumulation of other seed contents (Asthir et al. 2012; Farooq et al. 2017). Mass flow and diffusion are the mechanisms by which plants acquire potassium from soil, and both of these processes are greatly influenced by the presence adequate water (Oliveira et al. 2010). Soil moisture scarcity can diminish soil potassium availability, so the plant uptake and transportation (Waraich et al. 2011).

Seed protein, sugar content and potassium content of seeds increased significantly under the influence of potassium in both the cultivars irrespective of conditions however, seed starch content decreased under the influence of potassium. Similar to our findings, Khayyat et al. (2007) also observed that application of potassium increased protein content, carbohydrate content and ascorbic acid in fruits and improved its chemical composition. Fawzy et al. (2007) on eggplant and Dkhil et al. (2011) on potato evaluated the positive influence of applied potassium on crop quality. Potassium supplementation also improved groundnut quality in terms of total protein contents of seeds (Imas and

Magen, 2008). Positive impact of soil applied potassium resulted in superior quality of the wheat straw and grain filling (Alderfasi and Refay, 2010). The foliar potassium application improved fruit marketable quality by improving its firmness, sugar content, ascorbic acid and beta-carotene (Lester et al. 2007).

Conclusion

The result indicates that water deficit reduced the kernel quality by negatively affected the protein, starch, sugar and potassium content of sweet corn seeds. Soil-applied potassium improved yield quality in drought-stressed plants by modulating the protein, starch, sugar, and potassium content. We conclude that the sugar-75 genotype of sweet corn paired with adequate potassium supply may be a promising technique for enhancing seed quality in drought conditions. However, more research on other crops is required to ensure its long-term sustainability.

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Table 01: The effect of water stress and applied potassium on kernel protein content (mg/g DW) and kernels starch content (mg/g DW) in sweet corn cultivars.

Treatment	Kernel Protein content			Kernel Starch content		
	SUGAR-75	NSC901B	Mean	SUGAR-75	NSC901B	Mean
FI	12.58 ± 0.058	10.93 ± 0.043	11.75	163.6 ± 0.782	169.7 ± 0.832	166.6
FI+K_1	13.20 ± 0.101	11.36 ± 0.097	12.28	155.4 ± 1.355	164.6 ± 1.429	160.1
FI+K_2	13.71 ± 0.143	11.69 ± 0.132	12.76	148.8 ± 1.916	157.8 ± 1.959	153.3
FD	7.296 ± 0.049	5.902 ± 0.037	6.599	106.3 ± 0.618	105.2 ± 0.583	105.7
FD+K_1	8.755 ± 0.083	6.669 ± 0.054	7.712	87.16 ± 0.106	89.42 ± 0.121	88.29
FD+K_2	9.192 ± 0.122	6.964 ± 0.104	8.078	83.97 ± 1.863	87.31 ± 1.908	85.64
MED	10.31 ± 0.202	8.416 ± 0.138	9.363	135.7 ± 2.710	144.2 ± 2.987	139.9
MED+K_1	11.54 ± 0.072	9.257 ± 0.067	10.39	119.4 ± 0.553	124.1 ± 0.645	121.7
MED+K_2	11.85 ± 0.129	9.510 ± 0.112	10.68	113.9 ± 0.828	116.8 ± 0.912	115.3
SED	8.302 ± 0.136	6.885 ± 0.121	7.593	112.8 ± 1.327	112.0 ± 1.316	112.4
SED+K_1	9.713 ± 0.074	7.711 ± 0.068	8.712	87.98 ± 1.761	91.84 ± 1.934	89.91
SED+K_2	10.12 ± 0.122	8.330 ± 0.094	9.225	83.47 ± 1.293	88.48 ± 1.302	85.97
MLD	10.81 ± 0.113	8.962 ± 0.110	9.886	142.3 ± 1.034	142.5 ± 1.031	142.4
MLD+K_1	11.67 ± 0.124	9.589 ± 0.105	10.62	129.4 ± 1.276	133.9 ± 1.324	131.6
MLD+K_2	11.99 ± 0.062	9.858 ± 0.054	10.92	120.9 ± 0.629	126.8 ± 0.782	123.8
SLD	8.554 ± 0.057	6.995± 0.037	7.774	117.7 ± 0.718	115.3 ± 0.689	116.5
SLD+K_1	9.837 ± 0.048	8.254 ± 0.028	9.045	98.86 ± 1.265	101.4 ± 1.327	100.1
SLD+K_2	10.35 ± 0.039	8.394 ± 0.031	9.372	89.45 ± 1.187	92.24 ± 1.287	90.84
Mean	10.54	8.633		116.5	120.1	
CD at 5%	Genotype(G)= 0.117			Genotype(G) = 1.573		
	Water treatment(WT)= 0.203			Water treatment(WT) = 2.725		
	G×WT= 0.288			G×WT = 3.854		
	Potassium(K)= 0.117			Potassium(K) = 1.573		
	G×K= N/A			G×K = N/A		
	WT×K= 0.288			WT×K = 3.854		
	G×WT×K= 0.407			G×WT×K = 5.450		

FI= Fully irrigation, FD =Fully Drought, MED = Moderate early drought, SED= Severe early drought, MLD= Moderate latedrought, SLD= Severe late drought K_1= 500ppm (potassium treatment), K_2 = 700ppm (potassium treatment)

Table 02: The effect of water stress and applied potassium on kernel sugar content (mg/g DW) and kernel potassium content (mg/g DW) in sweet corn cultivars.

Treatment	Kernel Sugar content			Kernel Potassium content		
	SUGAR-75	NSC901B	Mean	SUGAR-75	NSC901B	Mean
FI	58.21 ± 0.420	54.64 ± 0.413	56.42	3.098 ± 0.020	2.756 ± 0.019	2.927
FI+K_1	62.27 ± 0.727	57.33 ± 0.621	59.81	3.244 ± 0.035	2.832 ± 0.028	3.038
FI+K_2	64.60 ± 1.028	58.96 ± 1.002	61.78	3.337 ± 0.050	2.942 ± 0.037	3.139
FD	73.33 ± 0.428	66.61 ± 0.328	69.97	2.286 ± 0.027	2.145 ± 0.023	2.215
FD+K_1	82.12 ± 0.594	75.93 ± 0.431	79.02	2.720 ± 0.058	2.445 ± 0.043	2.582
FD+K_2	84.32 ± 1.021	77.98 ± 1.001	81.15	2.834 ± 0.070	2.552 ± 0.067	2.693
MED	65.18 ± 1.454	62.79 ± 1.254	63.98	2.688 ± 0.014	2.447 ± 0.011	2.567
MED+K_1	71.04 ± 0.297	67.18 ± 0.217	69.11	3.010 ± 0.039	2.667 ± 0.031	2.838
MED+K_2	73.65 ± 0.413	69.69 ± 0.402	71.67	3.118 ± 0.058	2.765 ± 0.038	2.941
SED	68.09 ± 0.729	64.97 ± 0.698	66.53	2.472 ± 0.019	2.282 ± 0.015	2.377
SED+K_1	78.98 ± 1.035	77.96 ± 1.021	78.47	2.916 ± 0.021	2.601 ± 0.019	2.758
SED+K_2	82.38 ± 0.456	81.86 ± 0.423	82.12	3.015 ± 0.028	2.692 ± 0.024	2.853
MLD	63.43 ± 0.378	58.42 ± 0.327	60.92	2.626 ± 0.010	2.391 ± 0.009	2.508
MLD+K_1	69.43 ± 0.687	66.59 ± 0.533	68.01	2.888 ± 0.076	2.679 ± 0.067	2.783
MLD+K_2	72.31 ± 0.543	68.35 ± 0.439	70.33	2.993 ± 0.092	2.750 ± 0.081	2.871
SLD	66.34 ± 0.432	63.33 ± 0.412	64.83	2.379 ± 0.043	2.255 ± 0.038	2.317
SLD+K_1	75.62 ± 0.513	74.72 ± 0.505	75.17	2.735 ± 0.037	2.503 ± 0.028	2.619
SLD+K_2	78.28 ± 0.476	77.89 ± 0.378	78.08	2.854 ± 0.058	2.638 ± 0.049	2.746
Mean	71.69	68.06		2.845	2.574	
CD at 5%	Genotype(G)= 0.117			Genotype(G) = 1.573		
	Water treatment(WT)= 0.203			Water treatment(WT) = 2.725		
	G×WT= 0.288			G×WT = 3.854		
	Potassium(K)= 0.117			Potassium(K) = 1.573		
	G×K= N/A			G×K = N/A		
	WT×K= 0.288			WT×K = 3.854		
	G×WT×K= 0.407			G×WT×K = 5.450		
	FI= Fully irrigation, FD =Fully Drought, MED = Moderate early drought, SED= Severe early drought, MLD= Moderate late drought, SLD= Severe late drought K_1= 500ppm (potassium treatment) , K_2 = 700ppm (potassium treatment)					