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IMPACT OF SEED PRIMING AND COMPOST APPLICATION ON YIELD AND GROWTH ATTRIBUTES OF CLUSTER BEAN IN SALINITY STRESS

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Abstract

Guar bean is a commercial and export crop in Pakistan. The increase in the saline area due to arid climatic conditions in Pakistan is an excellent threat to guar bean production. Guar can tolerate salinity stress to some specific extent, but its production can be affected above it. Seed priming helps accept salinity stress in many crops, but limited studies have been conducted on its effect on cluster beans' productivity. Therefore, it is essential to evaluate new cultivars of cluster bean with seed priming before their recommendations to cultivate on saline lands. Thus, two years of field experiments (2018 and 2019) were conducted at the Research Farm of MNS-University, Multan, Pakistan, to evaluate the seed treatment (hydropriming and potassium nitrate) and soil treatment (compost) on four cultivars of guar bean (BR-2017, S-5885, S-6165, and S-6547). The treatments were applied in a Randomized Complete Block Design (RCBD) with the split-plot arrangement. The medicines (control, hydropriming, potassium nitrate, and compost) are in main plots, with their sub-plot variety. The seed of the guar bean was dipped in deionized water for hydropriming and in 2% potassium nitrate solution for potassium nitrate seed priming for two hours before sowing while compost (10 Mg ha^{-1}) was applied during the seedbed preparation. BR-2017, among other cultivars (S-6165 and S-6547), showed higher plant height, grains per pod, fodder yield, leaf area index, relative water contents, and transpiration rate. The BR-2017 showed 8.33, 94.9, and 69.5% higher grains per pod than S-5885, S-6165, and S-6547, respectively, with potassium nitrate application in crop growing season 2018. The peroxidase, super oxidase dismutase, catalase, potassium contents in the Leaf, potassium contents in the root, and sodium contents in the Leaf and root were higher in variety S-6165. The potassium nitrate seed application increased the grains per pod, pod length, fodder yield, leaf area index, peroxidase, catalase, potassium content in Leaf and root, and transpiration rate. The potassium nitrate priming showed higher potassium contents in the root by 6.8, 2.2, and 3.3% compared to control hydropriming and compost treatments in 2019. Thus, BR-2017 and S-6165 with potassium nitrate seed priming can help achieve the yield potential of the guar bean. However, long-term field studies on different climatic zones are recommended to revalidate the current findings.

Key words: BR-2017, Hydropriming, Compost, Seed treatment, Saline-environment.

Introduction

Pakistan is situated in the arid and semi-arid regions of the world, with a subtropical climate in most of its area (Fahad & Wang, 2020). The subtropical climate causes the buildup of salt in soils due to low rainfall and high temperature across the year (Corwin, 2022). The salt-affected area in Pakistan is 4.5 MHA (Syed *et al.*, 2021). The saline soil environment hinders the growth and yield of crops. The crop could not find an ideal environment to grow and produitseir potential gain. The increase in saline areas in Pakistan could potentially threaten food security. Agriculture is the primary livelihood of the country. Therefore, to ensure food security in Pakistan, it is essential to bring the sizeable salt-affected land into the agricultural production system to feed the country's ever-increasing population.

The cluster bean belongs to the Fabaceae family, a drought and salt-tolerant crop. The crop is also grown as fodder for livestock and human consumption (Naqvi *et al.*, 2019). India, Pakistan, and the USA are significant producers of cluster beans worldwide (Shockey, 2016). The crop's salt tolerance behaviour varies with the soil's salinity level and the variety's genetic makeup. Therefore, screening newly developed types of cluster beans is essential before they recommend to local farmers for cultivation in salt-affected areas.

The soil salinity adversely affects seed germination due to a reduction in water availability, changes in the mobilization of stored reservoirs, and structural organization of protein (Shahzad *et al.*, 2019). The crop production was severely affected due to disturbance in seed germination and vigour of the seedling. To improve seed germination and make it stronger for future stress, seed priming is one of the emerging techniques (Ibrahim, 2016). In seed priming, seeds are hydrated in a controlled environment and then dry for some time to start the germination process, but radical emergence does not occur. The priming empowers the seed with a defence mechanism to overcome future stress on plants. The priming also results in rapid and uniform seed germination. Seed priming is a less cost, easy, and low-risk technique to overcome salinity stress in agricultural soils (Johnson & Puthur, 2021). The different seed priming techniques are classified based on priming agents like hydropriming, halopriming, hormone priming, solid matrix, hardening, stratification, humification, and thermal shock. Hydropriming is the most common technique among the other methods. Jyotsna & Srivastava (1998) found higher protein, soluble sugars, and amino acids in pigeon peas with seed priming of KNO_3 during the germination stage under a saline environment. Seed priming in different studies was found helpful in the accumulation of osmolytes (Ruan *et al.*, 2002), production of protein, proline, glycine betaine, sugars, and polyol (Girija *et al.*, 2002), osmotic adjustment, and higher uptake of K^+ (Hasegawa *et al.*, 2000).

The organic amendments application in salt-affected areas can help lower salt stress. The compost application in the soil increases the structure and permeability of the earth, resulting in the leaching of soluble salts and reducing evaporation, lowering the accumulation of salts on the soil surface (Al-Omran *et al.*, 2019). Melero *et al*., (2007) found an increase in total carbon, available phosphorus, total nitrogen, enzymatic activities, and microbial biomass when compost was applied in the Mediterrane climate. Therefore, adding compost to the soil can help provide a favourable environment in saline conditions. A study on priming potassium nitrate and hydropriming to tackle the saline problem in cluster bean production is unavailable in Pakistan's arid climate. The central hypothesis of this study was that the hydropriming, potassium nitrate, and soil compost application could help reduce the salinity stress, and the potential growth and yield of cluster beans could be achieved in the saline soil. The main objective of the current study was the evaluation of seed priming (hydropriming and KNO_3) and soil treatment (compost) on the productivity of four cluster bean cultivars under saline soil.

Materials and Methods

Experimental site: The two-year study (2018 and 2019) was conducted at the Research Farm of Jalal Pur Pirwala, Muhammad Nawaz Shareef University, Multan, Pakistan, in 2018 and 2019 29°30.4122′ N, 71°13.1502′ E). The soil texture was loam with electrical conductivity of 8.01 dS m^{-1}, pH 8.30, available potassium 210, total nitrogen 0.20 g kg^{-1}, and organic matter 5.60 g kg^{-1} (Table 1). The area's climate was arid, with low rainfall and high temperature (Fig. 1).

Table 1. The properties of experiment site soil and compost used in the experiment.

Properties	Units	Soil	Compost
Texture		Loam	
Electrical conductivity	dSm^{-1}	8.01	3.70
pH		8.30	6.24
Available potassium	mg kg^{-1}	210	0.20
Available phosphorus	mg kg^{-1}	6.50	0.14
Total nitrogen	g kg^{-1}	0.20	1.23
Organic matter	g kg^{-1}	5.60	

Treatments: The seeds were soaked in a water bath containing distilled water for two hours. The 2% solution of KNO_3 was prepared for potassium nitrate priming. The seeds were soaked in KNO_3 solution for two hours. The roots of cluster beans cultivars S-6165, S-6547, BR-2017, and S-5885 were collected from Guar Research Station, Bahawalpur, Punjab, Pakistan. The compost was purchased from the local market. The compost was applied @ 10 Mg ha^{-1} (Baldi *et al*., 2018). The compost was used with a hand drill during land preparation on soil ridges.

Field experiment: The effect of hydropriming and KNO_3 priming seed treatments and compost application in soil was evaluated on the productivity of four cultivars (S-6165, S-6547, BR-2017, and S-5885) in the crop growing season of 2018 and 2019. The field was tiled up to 30 cm with a plough, and then ridges were prepared. The plots were demarcated, and treatments were applied in the RCBD-split plot arrangement. The priming and compost application in the main field while the cultivars are in the split plots. The sowing was done in April 2018. The potassium (50 kg ha^{-1}) and phosphorus (kg P_2O_5 ha^{-1}) were applied at the time of sowing while nitrogen kg N ha^{-1}) was used in two splits: half was at sowing and half with second irrigation. Three irrigations were applied to saturation at 30 days intervals. The crop was harvested when 75% pods got matured.

Data collection: The plant height was measured at maturity with a meter rod. The Leaf of three loose leaves was measured with a leaf area meter. The ten pods were detached from the plants, their length was measured with a meter rod, and grains per pod were counted. The transpiration rate, stomatal conductance, and photosynthetic rate were measured with an infra-Red Gas Analyzer from 10 am to 12:00 pm. The chlorophyll contents of expanded leaves were measured with a chlorophyll meter. The manual harvesting of each plot was done, and fodder yield was calculated per plot and then converted into Kg ha^{-1}. The fresh weight of leaf discs was measured, then Leaf was dipped in water for four hours then the turgid weight was measured. These leaves tissue was oven dried till a constant weight and relative water contents were measured using the following equation:

$$\text{Relavie water content} = \frac{(\text{Fresh weight} - \text{Dry weight}}{(\text{Turgid weight} - \text{Dry weight}}$$

Superoxidase dismutase was determined by the method of Giannopolitis & Ries (1977), Peroxidase by Chance & Maehly (1955), and catalase activity by methods of Chance & Maehly (1955). The Leaf was oven-dried and wet digestion was done using diacid (nitric acid and perchloric acid). The potassium and sodium contents were measured with a flame photometer.

Statistical analysis

The collected data on plant growth, physiology, and yield parameters were analyzed using software version 4.1.2 by the linear model (R_Core_Team, 202). The treatment and year effects were fixed, while the variety effect was variable. Tukey's multiple comparison test was us to compute the difference among the means. The "means" was used to perform the mean comparison test at $p<0.05$.

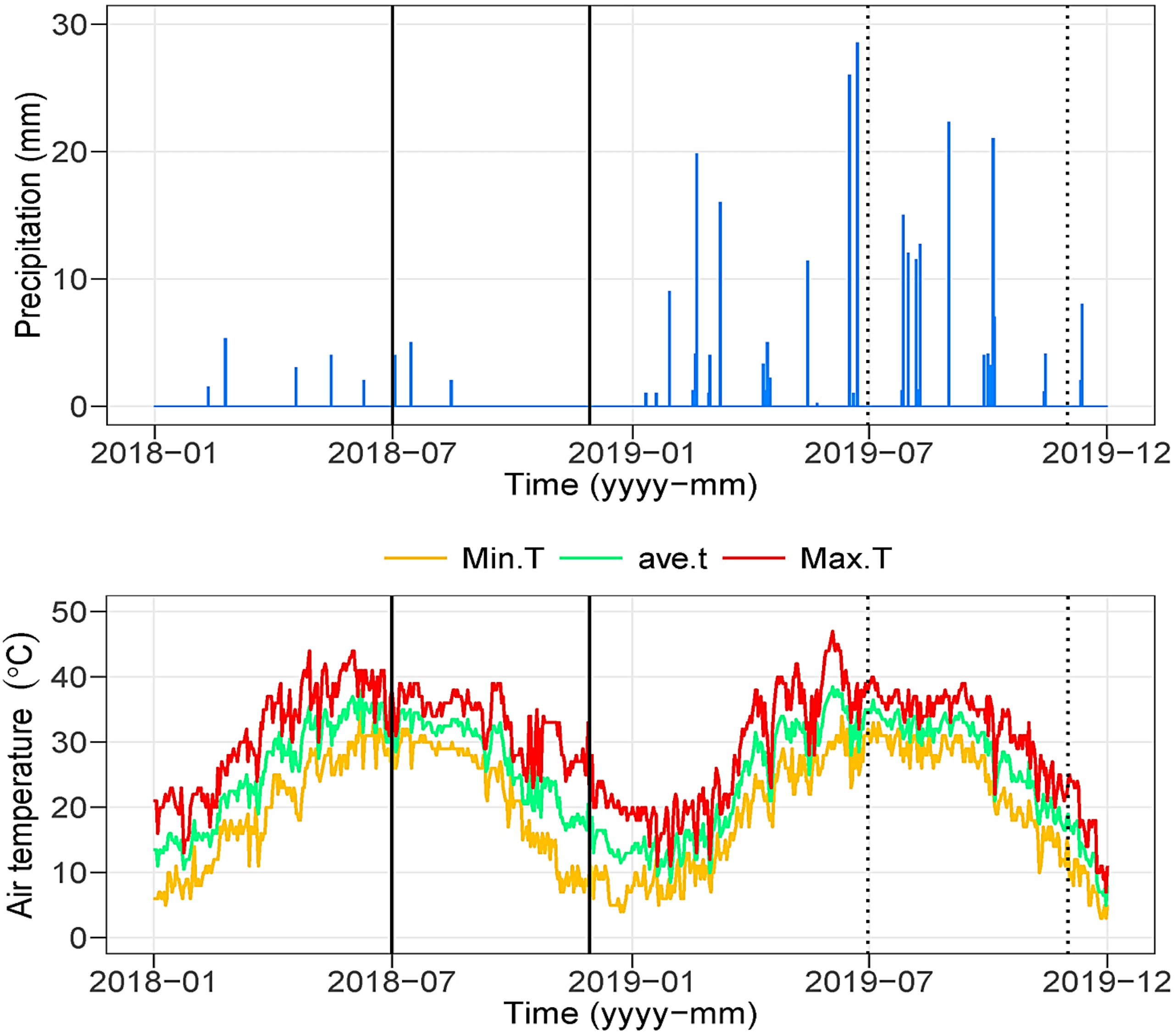

Fig. 1. The minimum, maximum, and average temperature, and rainfall in Jalalpur Pirwala during the years 2018 and 2019. The vertical lines show the crop sowing and harvesting timing.

Results

Plant height and leaf area index: The main effect of variety was significant in both crop growing seasons 2018 and 2019 on the plant height in both crop growing seasons 2018 and 2019, at $p<0.05$ (Table 2A). Overall, variety S-5885 showed higher plant height in all treatments (hydropriming, compost, and potassium nitrate) except control, where BR-2017 performed well during crop growing season 2018. Plant height was higher in all varieties where seed hydropriming treatment was used compared to other treatments (Control, compost, and potassium nitrate). The variety BR-2017 within control treatment during crop growing season 2018 showed a 2.40, 9.58, and 8.49% increase in plant height compared to varieties S-5885, S-6165, and S-6547, respectively (Table 3).

The main effect of treatment and variety significantly affected the leaf area index in both crops during the growing season at $p<0.05$ (Table 2A). The hydropriming treatment showed higher leaf area in the index than control, compost, and potassium nitrate in both crop growing seasons, 2018 and 2019. The variety BR-2017 showed a higher leaf area index than S-5885, S-6165, and S-6547 in both crop-growing seasons. The BR-2017 within potassium nitrate application during crop growing season 2018 showed 2.44, 10.53, and 10.53% higher leaf area index as compared to varieties S-5885, S-6165, and S-6547, respectively (Table 3)

Pods per plant and pod length: The main effect of treatment and variety was significant on the pods per plant in the crop growing season 2018 at $p<0.05$ (Table 2A). The main impact of type was also substantial in the crop growing season 2019 at $p<0.05$ (Table 2A). The variety BR-2017 showed higher pods per plant in all treatments (control, hydropriming, compost, and potassium nitrate) compared to varieties S-5885, S-6165, and S-6542. Potassium nitrate application showed higher pods per plant compared to control, hydropriming and compost during the crop growing season in 2018. The varieties BR-2017 with potassium nitrate application in crop growing season 2018 showed an increase in pods per plant by 0.53, 32.62, and 32.62% over S-5885, S-6165, and S-6542, respectively (Table 4).

The main effect of treatment and variety was found to be significant on pod length in both crop growing seasons, 2018 and 2019; however, the interaction effect treatment × variety was found effective in crop growing season 2018 at $p<0.05$ (Table 1). The variety and treatment effect was not consistent on pod length in the crop growing season in 2018. However, BR-2017 showed higher pod length in all treatments than other varieties (S-5885, S-6165, and S-6542). The BR-2017 with compost application during crop growing season 2019 showed a 1.74, 30.36, and 27.51% increase in pod length compared to S-5885, S-6165, and S-6542, respectively (Table 4).

Grains per pod and fodder yield: The main effect of treatment and variety was significant on grains per pod in both crop growing seasons, 2018 and 2019. However, the interaction effect treatment × variety was found to be substantial in the crop growing season 2018 at $p<0.05$ (Table 2A). The variety BR-2017 showed higher grains per pod in all treatments during crop growing seasons 2018 and 2019. The treatment effect on grains per pod was inconsistent during the crop-growing season in 2018. However, potassium nitrate application showed higher grains per pod compared to control, hydropriming, and potassium nitrate application in the crop growing season of 2019. The potassium nitrate in BR-2017, during crop growing season 2019, showed an increase in grains per pod by 200.23, 62.5, and 34.43% compared to control, hydropriming, and compost, respectively (Table 5).

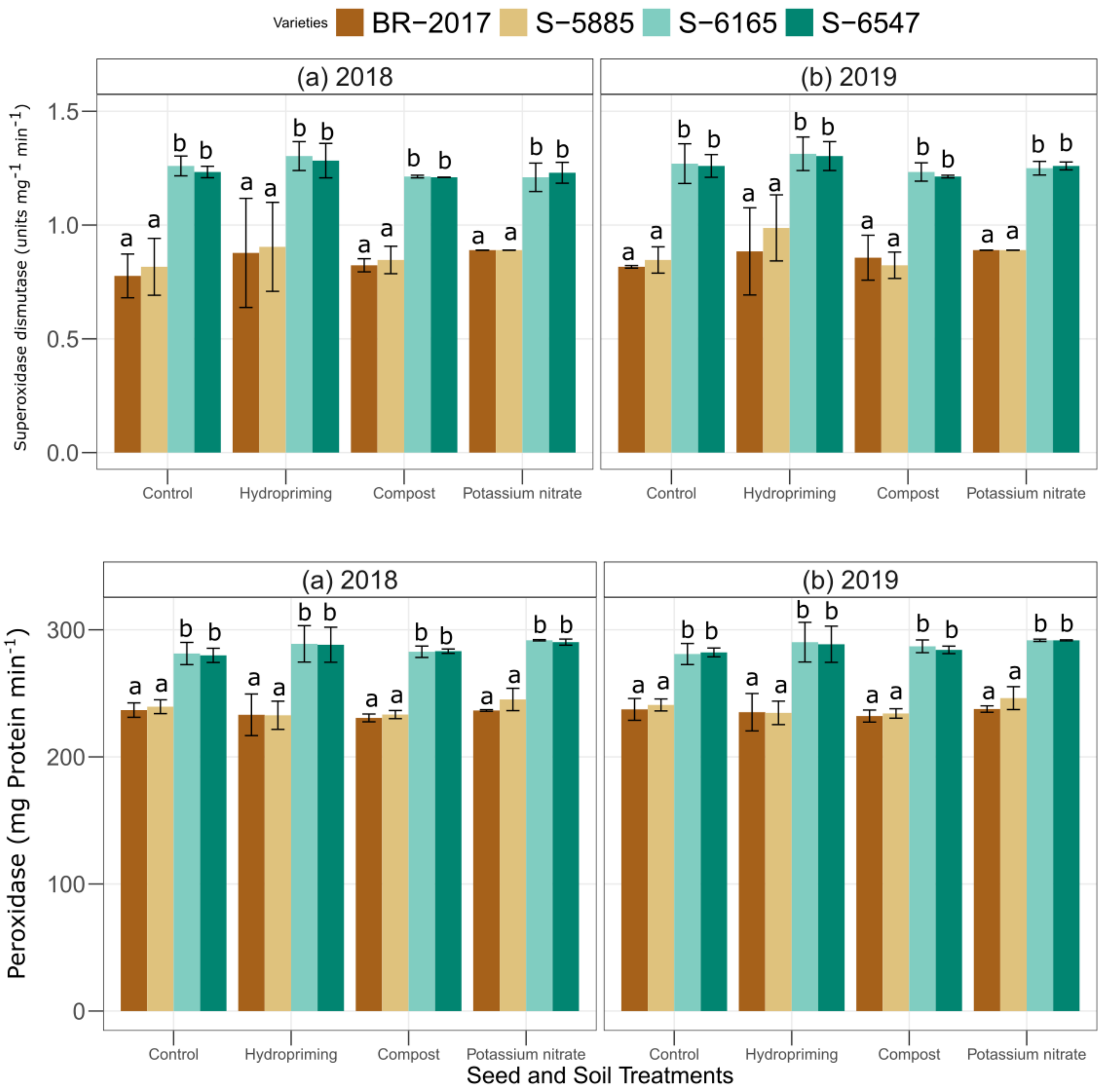

Fig. 2. Impact of seed (hydropriming and potassium nitrate) and soil (compost) on the superoxidase mutase and peroxidase antioxidants in guar bean cultivars during crop growing seasons 2018 and 2019. The error bar shows the standard deviation (n=3). The bar within treatments with the same letter (s) is statistically non-significant at $p<0.05$.

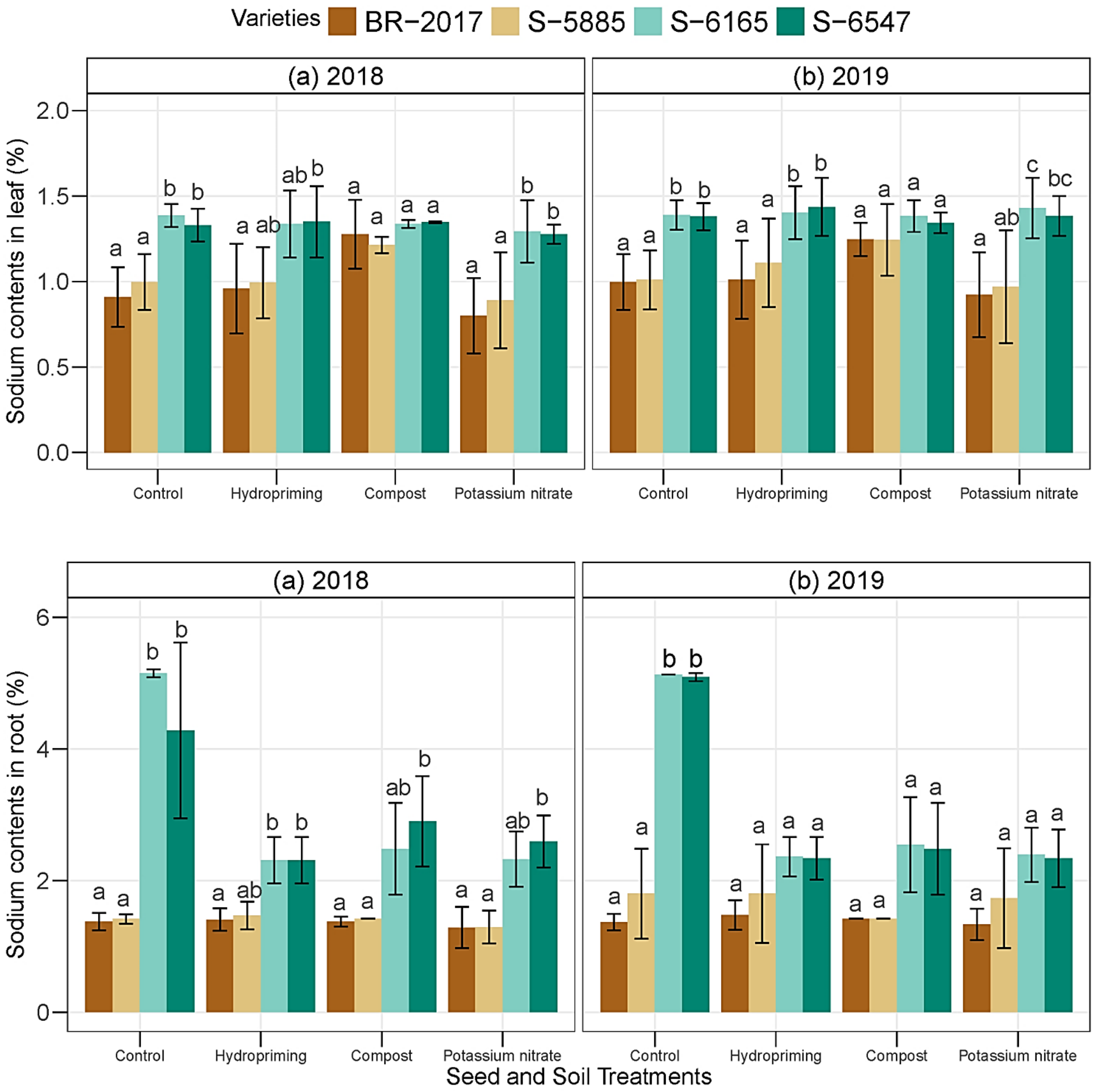

Fig. 3. Impact of seed (hydropriming and potassium nitrate) and soil (compost) on the sodium contents in Leaf and root of guar bean cultivars during crop growing seasons 2018 and 2019. The error bar shows the standard deviation (n=3). The bar within treatments with the same letter (s) is statistically non-significant at $p<0.05$.

The variety effect was significant on fodder yield in both crop growing seasons, 2018 and 2019 (Table 1). The BR-2017 showed higher food yield in all treatments except compost, where S-5885 showed a better response than BR-2017 during the crop-growing season of 2018. Potassium nitrate application in BR-2017 showed 2.58, 2.54, and 1.17% higher fodder yield than control, hydropriming, and compost during crop growing season 2018. The variety BR-2017 showed higher fodder yield than other varieties S-5885, S-6165, and S-6547 in all treatments (control, hydropriming, compost, and potassium nitrate) during the crop growing season 2019. The types BR-2017 with compost application during crop growing season 2019 showed 1.09, 19.64, and 19.66% higher fodder yield than S-5885, S-6165, and S-6547, respectively (Table 5).

Photosynthetic rate and chlorophyll contents: The main effect of variety was found to be significant on the photosynthetic rate in the crop growing season 2018, while in the crop growing season 2019, the main effect of treatment and variety was found to be significant at $p<0.05$ (Table 2A). The variety effect was inconsistent throughout the treatments during the crop-growing season in 2018. However, BR-2017 showed a higher photosynthetic rate during the crop-growing season in 2019 in all treatments. The BR-2017 within potassium nitrate treatment during the crop growing season 2019 showed 9.14, 48.87, and 43.23% higher photosynthetic rates over varieties S-5885, S-6165, and S-6547, respectively (Table 6).

Table 2A. P-values of the individual and interactive effect of treatments and variety on guar bean productivity.

	Plant height	Leaf Area index	Pod $plant^{-1}$	Pod length	Grains pod^{-1}	Fodder yield	Photosynthetic rate	Chlorophyll contents	Stomatal conductance
Treatment (T)	0.39	<0.01	0.04	0.81	<0.01	0.25	0.06	0.90	<0.01
Variety (V)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
T × V	1.00	0.32	0.95	0.99	<0.01	0.32	0.19	0.80	0.83
Treatment (T)	0.570	<0.01	0.210	0.010	0.000	0.060	0.000	0.290	0.010
Variety (V)	0.000	<0.01	0.000	0.000	0.000	0.000	0.000	0.000	0.000
T × V	1.000	0.970	0.170	0.920	0.880	0.120	1.000	0.090	0.940

Table 2B. P-values of the individual and interactive effect of treatments and variety on guar bean productivity.

	Transpiration rate	Relative water contents	Superoxidase mutase	Peroxidase	Catalase	Sodium contents in Leaf	Sodium contents in root	Potassium contents in Leaf	Potassium contents in root
Treatment (T)	0.00	0.00	0.17	0.10	0.17	0.03	0.00	0.11	0.33
Variety (V)	0.17	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
T × V	1.00	0.50	0.93	0.83	1.00	0.55	0.00	0.93	0.97
Treatment (T)	0.000	0.010	0.050	0.160	0.210	0.330	0.000	0.400	0.060
Variety (V)	0.180	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
T × V	0.940	0.740	0.910	0.850	0.780	0.690	0.000	0.920	0.770

Table 3. Impact of seed (hydropriming and potassium nitrate) and soil (compost) treatments on potassium contents in leaf and root of the cluster bean in crop growing seasons 2018 and 2019.

Variety	Plant height (cm)				Leaf area index			
	Control	Hydropriming	Compost	Potassium nitrate	Control	Hydropriming	Compost	Potassium nitrate
	Crop growing season 2018							
BR-2017	136.66 ± 5.85b	137.91 ± 4.94b	136.66 ± 1.57b	136.31 ± 6.32b	0.39 ± 0.07b	0.45 ± 0.03b	0.42 ± 0.01b	0.42 ± 0.07b
S-5885	133.46 ± 5.74ab	138.78 ± 4.56b	132.73 ± 3.29b	134.37 ± 7.45b	0.37 ± 0.06b	0.44 ± 0.03 ab	0.42 ± 0.01b	0.41 ± 0.06b
S-6165	124.71 ± 5.6a	126.94 ± 2.96a	123.67 ± 5.91a	126.85 ± 9.39a	0.22 ± 0.02a	0.35 ± 0.03a	0.32 ± 0.02a	0.38 ± 0.06a
S-6547	125.97 ± 5.69a	127.92 ± 1.68a	122.88 ± 4.9a	126.56 ± 7.72a	0.24 ± 0.03a	0.37 ± 0.03ab	0.32 ± 0.02a	0.38 ± 0.06a
	Crop growing season 2019							
BR-2017	133.82 ± 5.72a	136.96 ± 3.25b	136.62 ± 1.22b	136.58 ± 6.71b	0.32 ± 0.07a	0.41 ± 0.02b	0.39 ± 0.05b	0.41 ± 0.06a
S-5885	132.48 ± 6.04a	136.96 ± 4.58b	132.8 ± 3.21b	133.54 ± 7.13b	0.31 ± 0.06a	0.4 ± 0.04b	0.39 ± 0.05b	0.39 ± 0.07a

Table 4. Impact of seed (hydropriming and potassium nitrate) and soil (compost) treatments on potassium contents in pods plant^{-1} and pod length of cluster bean in crop growing season 2018 and 2019.

Variety	Pod plant^{-1}				Pod length (cm)			
	Control	Hydropriming	Compost	Potassium nitrate	Control	Hydropriming	Compost	Potassium nitrate
	Crop growing season 2018							
BR-2017	57.67 ± 2.89b	56.67 ± 12.58b	55.67 ± 0.58b	62.33 ± 6.35a	5.15 ± 1.16 a	5.62 ± 0.73a	5.51 ± 1.13a	5.61 ± 0.48b
S-5885	55.33 ± 5.03b	52.33 ± 10.21b	55.33 ± 0.58b	62.00 ± 6.08a	5.86 ± 1.62 a	5.52 ± 0.87a	5.35 ± 1.00a	5.66 ± 0.59b
S-6165	40.33 ± 5.51a	38.00 ± 11.53a	45.67 ± 4.04a	47.00 ± 6.93a	4.52 ± 0.2 a	4.59 ± 0.1a	4.42 ± 0.33a	4.83 ± 0.59a
S-6547	43.33 ± 3.51a	38.00 ± 11.53a	48.67 ± 2.08a	47.00 ± 6.93a	4.63 ± 0.14 a	4.62 ± 0.05a	4.63 ± 0.19a	4.90 ± 0.65a
	Crop growing season 2019							
BR-2017	54.00 ± 5.29b	54.67 ± 8.50b	53.33 ± 2.31b	62.00 ± 6.08b	5.16 ± 0.84a	5.86 ± 0.30b	5.84 ± 0.32b	5.72 ± 0.56a
S-5885	52.00 ± 6.08b	52.33 ± 9.29ab	51.67 ± 3.06b	61.00 ± 6.08b	4.93 ± 0.77a	5.82 ± 0.34b	5.71 ± 0.31b	5.61 ± 0.52a
S-6165	39.00 ± 3.61a	39.33 ± 4.04a	46.00 ± 1.00a	39.33 ± 3.79a	3.84 ± 1.18a	4.45 ± 0.13a	4.48 ± 0.30a	5.28 ± 1.18a
S-6547	41.00 ± 1.73a	42.67 ± 2.31ab	45.67 ± 3.21a	40.00 ± 4.36a	3.84 ± 1.33a	4.64 ± 0.13a	4.58 ± 0.40a	5.39 ± 1.36a

Values are mean ± standard deviation (n=3). Letter (s) indicate a significant difference ($p<0.05$) within treatment in each year

Table 5. Impact of seed (hydropriming and potassium nitrate) and soil (compost) treatments on grain pod-1 and food yield of the cluster bean in crop growing seasons 2018 and 2019.

Variety	Grains pod^{-1}				Fodder yield (kg ha^{-1})			
	Control	Hydropriming	Compost	Potassium nitrate	Control	Hydropriming	Compost	Potassium nitrate
	Crop growing season 2018							
BR-2017	6.67 ± 1.53a	9.00 ± 1.73b	9.67 ± 0.58a	13.67 ± 4.04b	290.1 ± 12.84b	290.20 ± 7.72b	294.12 ± 5.95b	297.59 ± 1.90b
S-5885	3.67 ± 1.53a	8.00 ± 3.46ab	9.67 ± 0.58a	13.67 ± 4.04b	282.8 ± 14.17b	290.89 ± 7.60b	297.16 ± 0.79b	291.5 ± 3.59b
S-6165	5.00 ± 0.01a	4.33 ± 0.58ab	9.00 ± 0.01a	04.67 ± 1.15a	254.1 ± 10.79a	257.3 ± 10.45a	248.57 ± 5.67a	260.73 ± 5.60a
S-6547	4.00 ± 1.73a	3.33 ± 1.15a	9.00 ± 0.01a	09.67 ± 0.58ab	259.66 ± 07.62a	257.36 ± 10.57a	249.62 ± 7.41a	260.59 ± 5.49a
	Crop growing season 2019							
BR-2017	4.33 ± 0.58b	8.00 ± 3.46b	9.67 ± 0.58c	13.00 ± 5.20c	283.94 ± 10.03b	288.97 ± 8.36b	297.06 ± 0.84b	285.50 ± 3.68b
S-5885	3.33 ± 0.58ab	7.33 ± 3.79b	8.33 ± 1.15b	12.00 ± 5.20bc	280.41 ± 14.12b	286.01 ± 3.04b	293.86 ± 5.250b	285.55 ± 3.69b
S-6165	2.00 ± 0.01a	5.33 ± 3.06a	5.00 ± 0.01a	6.67 ± 2.31a	247.01 ± 5.99a	247.82 ± 10.22a	248.30 ± 5.12a	261.04 ± 5.95a

Table 6. Impact of seed (hydropriming and potassium nitrate) and soil (compost) treatments on photosynthetic rate and chlorophyll of the cluster bean in crop growing season 2018 and 2019.

Variety	Photosynthetic rate (µ mol CO_2 m^{-2} s^{-1})				Chlorophyll contents (SPAD Value)			
	Control	Hydropriming	Compost	Potassium nitrate	Control	Hydropriming	Compost	Potassium nitrate
	Crop growing season 2018							
BR-2017	37.12 ± 15.06a	40.01 ± 12.45a	25.94 ± 5.52a	26.36 ± 2.19a	0.30 ± 0.10a	0.38 ± 0.16a	0.22 ± 0.01a	0.35 ± 0.10a
S-5885	25.60 ± 2.90a	39.14 ± 10.46a	28.98 ± 5.91a	31.00 ± 6.32a	0.34 ± 0.17a	0.44 ± 0.19a	0.25 ± 0.05a	0.36 ± 0.09a
S-6165	19.76 ± 2.84a	24.05 ± 1.38a	25.24 ± 1.71a	22.64 ± 0.85a	1.71 ± 0.11b	1.59 ± 0.04b	1.67 ± 0.22b	1.61 ± 0.27b
S-6547	20.30 ± 2.75a	24.69 ± 1.53a	25.27 ± 1.76a	23.59 ± 2.36a	1.59 ± 0.09b	1.58 ± 0.06b	1.67 ± 0.22b	1.59 ± 0.26b
	Crop growing season 2019							
BR-2017	26.31 ± 1.84b	30.58 ± 2.04b	31.4 ± 1.63 b	33.66 ± 4.61c	0.4 ± 0.13a	0.4 ± 0.16a	0.29 ± 0.12a	0.41 ± 0.02a
S-5885	25.60 ± 2.56 b	29.5 ± 1.50b	31.31 ± 1.53b	30.84 ± 4.20b	0.43 ± 0.2a	0.46 ± 0.18a	0.33 ± 0.10a	0.41 ± 0.02a
S-6165	17.81 ± 2.10a	21.11 ± 0.95a	22.68 ± 1.27a	22.61 ± 3.17a	1.63 ± 0.14b	1.61 ± 0.23b	1.92 ± 0.01b	1.64 ± 0.24b
S-6547	18.05 ± 2.01a	22.00 ± 0.45 a	22.82 ± 1.28a	23.50 ± 3.77a	1.64 ± 0.14b	1.51 ± 0.17b	1.92 ± 0.01b	1.59 ± 0.28b

Values are mean ± standard deviation (n=3). Letter (s) indicate a significant difference ($p<0.05$) within treatment in each year

Table 7. Impact of seed (hydropriming and potassium nitrate) and soil (compost) treatments on stomatal conductance in Leaf and transpiration rate of the cluster bean in crop growing season 2018 and 2019.

Variety	Stomatal conductance (mmol H_2O m^{-2} s^{-1})				Transpiration rate (mmol H_2O m^{-2} s^{-1})			
	Control	Hydropriming	Compost	Potassium nitrate	Control	Hydropriming	Compost	Potassium nitrate
	Crop growing season 2018							
BR-2017	0.26 ± 0.06b	0.30 ± 0.03b	0.31 ± 0.05b	0.36 ± 0.10c	4.32 ± 0.51b	6.74 ± 1.67b	5.68 ± 0.01b	7.25 ± 1.10c
S-5885	0.24 ± 0.10b	0.33 ± 0.05b	0.25 ± 0.01ab	0.30 ± 0.08b	4.34 ± 0.48b	6.68 ± 1.69ab	5.68 ± 0.01b	7.08 ± 1.21b
S-6165	0.09 ± 0.05a	0.15 ± 0.02a	0.19 ± 0.05a	0.21 ± 0.09a	3.22 ± 0.06a	5.93 ± 2.09a	5.35 ± 0.12a	6.55 ± 1.15a
S-6547	0.10 ± 0.02a	0.17 ± 0.05a	0.20 ± 0.06a	0.22 ± 0.10a	3.31 ± 0.08a	5.93 ± 2.09a	5.35 ± 0.12a	6.57 ± 1.17a
	Crop growing season 2019							
BR-2017	0.24 ± 0.1b	0.30 ± 0.05b	0.28 ± 0.05b	0.33 ± 0.11b	3.56 ± 0.19a	06.2 ± 2.13b	5.68 ± 0.01b	6.99 ± 1.2b
S-5885	0.21 ± 0.10b	0.30 ± 0.06b	0.24 ± 0.020ab	0.3 ± 0.04b	3.51 ± 0.24a	6.12 ± 2.12ab	5.63 ± 0.08b	6.97 ± 1.17b
S-6165	0.08 ± 0.03a	0.12 ± 0.01a	0.18 ± 0.05a	0.18 ± 0.08a	3.72 ± 0.42a	5.34 ± 1.61a	4.69 ± 0.37a	5.74 ± 0.93a

The main effect of variety was significant on chlorophyll contents in crop growing seasons 2018 and 2019 at $p<0.05$ (Table 2A). The variety S-6165 showed higher chlorophyll contents in both crop-growing seasons, 2018 and 2019, compared to BR-2017, S-5885, and S-6547. The compost application in variety S-6165 showed higher chlorophyll contents by 17.79, 19.25, and 17.07% compared to the control, hydropriming, and potassium nitrate, respectively, during the crop growing season 2019 (Table 6).

Stomatal conductance and transpiration: The main effect of treatment and variety was significant on stomatal conductance in both crop-growing seasons, 2018 and 2019, at $p<0.05$ (Table 2A). The application of potassium nitrate increased the stomatal conductance in all varieties compared to control, hydropriming, and compost application in the crop growing season 2019. The potassium nitrate within BR-2017 during the crop growing season 2019 increased the stomatal conductance by 17.86, 10.00, and 3750% compared to control, hydropriming, and compost, respectively (Table 7).

The main effect of transpiration rate was found to be significant in both crop growing seasons, 2018 and 2019, at $p<0.05$ (Table 2B). The mixed effect of varieties was seen in the transpiration rate in both crop-growing seasons on the transpiration rate. The potassium nitrate application showed a higher transpiration rate in all sorts during crop growing seasons in 2018 and 2019. The potassium nitrate within BR-2017 during the crop growing season in 2019 increased the transpiration rate by 95.25, 12.74, and 23.06% compared to control, hydropriming, and compost application, respectively (Table 7).

Relative water contents and super oxidase dismutase: The main effect of treatment and variety was significant on relative water contents in both crop growing seasons, 2018 and 2019, at $p<0.05$ (Table 2B). The variety BR-2017 showed higher relative water contents in all treatments during crop growing seasons 2018 and 2019. The variety BR-2017 during the cotton growing season 2018 showed an increasing use in close water contents by 35.7, 21.84, and 15.00% compared to S-5885, S-6165, and S-6517, respectively. There were mixed treatment effects in both crop growing seasons, 2018 and 2019.

The main effect of variety was significant on the super oxidase dismutase in both crop growing seasons, 2018 and 2019, at $p<0.05$ (Table 2B). The mixed effect of treatments and variety were found on superoxidase mutase contents in both crop growing seasons, 2018 and 2019. The potassium nitrate within BR-2017 during the crop growing season 2018 showed an increase of superoxidase mutase by 14.10, 1.14, and 8.54% compared to control, hydropriming, and compost application, respectively.

Peroxidase and catalase: The main effect of variety was significant on peroxidase contents in both crop growing seasons, 2018 and 2019, at $p<0.05$ at $p<0.05$ (Table 2B). The effect of variety and treatment was inconsistent in both crop-growing seasons, 2018 and 2019. The potassium nitrate application within S-6547 during the crop growing season in 2018 increased the peroxidase contents by 3.72, 0.71, and 2.54% compared to control, hydropriming, and compost application, respectively (Fig. 2).

The main effect of variety was found to be significant on catalase contents in both crop growing seasons, 2018 and 2019, at $p<0.05$ at $p<0.05$ (Table 2B). The mixed effect of treatments and variety was found in both crop growing seasons, 2018 and 2019. The variety S-6165 with potassium nitrate application during the crop growing season in 2018 showed an increase in catalase contents by 45.50, 31.82, and 11.54% compared to BR-2017, S-5885, and S-6547, respectively (Fig. 2).

Sodium contents in leaf and root: The main effect of variety was significant on sodium contents in leaves in both crop-growing seasons, 2018 and 2019, at $p<0.05$ (Table 2B). The treatment and type of mixed effects were found on the sodium contents in leaves in both crop-growing seasons. The variety S-6165, with potassium nitrate application during the crop growing season 2019, showed an increase in sodium contents by 55.43, 47.42, and 3.62% compared to BR-2017, S-5885, and S-6457, respectively (Fig. 3).

The main effect of treatment and variety, the interaction effect of treatment × variety, was found to be significant on sodium contents in roots in both crops growing seasons 2018 and 2019 at $p<0.05$ (Table 2B). The higher sodium contents were found in S-6165 and S-6547 in control treatment during the crop growing season in 2018, while lower sodium contents were found in BR-2017 and S-5885, where potassium nitrate was applied (Fig. 3).

Potassium contents in leaf and root: The main effect of variety was found to be significant on potassium contents in Leaf in both crop growing seasons, 2018 and 2019 (Table 2B). The variety S-6165 showed high potassium contents in all treatments during the crop growing season in 2019 compared to control, hydropriming, and compost application. The S-6165 increased the potassium contents in the Leaf with the application of potassium nitrate by 11.24, 6.45, and 11.24 as compared to control, hydropriming, and compost application, respectively, during the crop growing season 2019 (Table 9).

The main effect of variety was found to be significant on potassium son 20contents in root both crop growing seasons 2018 and 2019 (Table 2B). The variety S-6165 showed higher potassium contents in roots in all treatments during both crop-growing seasons, 2018 and 2019. Higher potassium contents were found with potassium nitrate treatment compared to control, hydropriming, and compost application. The variety S-6165 showed an increase in potassium contents in the root by 85.11, 79.38, and 1.75% compared to BR-2017, S-5885, and S-6547, respectively, during the crop growing season 2019 (Table 9).

Table 8. Impact of seed (hydropriming and potassium nitrate) and soil (compost) treatments on relative water contents and catalase of cluster bean in crop growing season 2018 and 2019.

Variety	Relative water contents (%)				Catalase (mg protein min^{-1})			
	Control	Hydropriming	Compost	Potassium nitrate	Control	Hydropriming	Compost	Potassium nitrate
	Crop growing season 2018							
BR-2017	47.49 ± 2.05c	44.98 ± 5.73a	35.58 ± 0.67a	44.69 ± 8.11a	0.13 ± 0.04a	0.18 ± 0.08a	0.16 ± 0.04a	0.20 ± 0.01a
S-5885	46.81 ± 2.21bc	42.13 ± 3.92a	35.34 ± 0.19a	43.15 ± 6.91a	0.14 ± 0.02a	0.18 ± 0.08a	0.18 ± 0.04ab	0.22 ± 0.03ab
S-6165	36.71 ± 7.30a	41.16 ± 4.26a	35.45 ± 0.36a	36.68 ± 1.37a	0.24 ± 0.11a	0.26 ± 0.11b	0.21 ± 0.01ab	0.29 ± 0.03b
S-6547	37.84 ± 7.47ab	41.06 ± 1.16a	35.55 ± 0.37a	38.86 ± 4.23a	0.24 ± 0.08a	0.27 ± 0.10b	0.23 ± 0.03b	0.26 ± 0.04ab
	Crop growing season 2019							
BR-2017	43.44 ± 2.82b	41.9 ± 3.03b	35.35 ± 0.22a	44.5 ± 8.21c	0.14 ± 0.02a	0.18 ± 0.08a	0.19 ± 0.03a	0.22 ± 0.03a
S-5885	41.63 ± 3.79ab	41.98 ± 2.69b	35.25 ± 0.12a	41.02 ± 4.75bc	0.14 ± 0.02a	0.24 ± 0.12ab	0.19 ± 0.02a	0.21 ± 0.01a
S-6165	35.70 ± 2.88a	36.15 ± 1.23a	33.6 ± 3.08a	36.98 ± 5.88ab	0.27 ± 0.07b	0.29 ± 0.12b	0.23 ± 0.03b	0.29 ± 0.05a
S-6547	35.20 ± 3.82a	38.65 ± 2.8ab	35.19 ± 0.31a	36.71 ± 5.77a	0.29 ± 0.07b	0.27 ± 0.12b	0.23 ± 0.02b	0.29 ± 0.04a

Values are mean ± standard deviation (n=3). Letter (s) indicate a significant difference ($p<0.05$) within treatment in each year

Table 9. Impact of seed (hydropriming and potassium nitrate) and soil (compost) treatments on potassium contents in the leaf and root of the cluster bean in crop growing season 2018 and 2019.

Variety	Potassium in leaf (%)				Potassium contents in root (%)			
	Control	Hydropriming	Compost	Potassium nitrate	Control	Hydropriming	Compost	Potassium nitrate
	Crop growing season 2018							
BR-2017	0.23 ± 0.03a	0.35 ± 0.12a	0.25 ± 0.05a	0.26 ± 0.14a	0.77 ± 0.07a	0.86 ± 0.10a	0.92 ± 0.20a	0.89 ± 0.23a
S-5885	0.25 ± 0.03a	0.36 ± 0.13a	0.26 ± 0.07a	0.35 ± 0.13a	0.82 ± 0.02a	0.89 ± 0.05a	0.93 ± 0.16a	0.94 ± 0.26a
S-6165	0.86 ± 0.12b	0.9 ± 0.09b	0.87 ± 0.12b	0.95 ± 0.04b	1.61 ± 0.12b	1.56 ± 0.11b	1.57 ± 0.11b	1.66 ± 0.13b
S-6547	0.87 ± 0.05b	0.86 ± 0.15b	0.8 ± 0.12b	0.94 ± 0.04b	1.56 ± 0.12b	1.52 ± 0.09b	1.55 ± 0.14b	1.66 ± 0.13b
	Crop growing season 2019							
BR-2017	0.30 ± 0.10a	0.36 ± 0.13a	0.26 ± 0.07a	0.30 ± 0.04a	0.88 ± 0.07a	0.92 ± 0.07a	0.91 ± 0.21a	0.94 ± 0.17a
S-5885	0.35 ± 0.11a	0.36 ± 0.13a	0.31 ± 0.13a	0.31 ± 0.03a	0.88 ± 0.07a	0.92 ± 0.07a	1.02 ± 0.21a	0.97 ± 0.22a
S-6165	0.89 ± 0.07b	0.93 ± 0.05b	0.89 ± 0.14b	0.99 ± 0.09b	1.68 ± 0.11b	1.5 ± 0.05b	1.69 ± 0.10b	1.74 ± 0.15b

Discussion

Salinity stress affects water availability, mobilization of seed reserves, and structural organization of protein, leading to diminishing seed germination and early growth attributes (Shahbaz *et al.*, 2019). Salt stress is one of the most harmful environmental stresses that reduce plants' growth and development (Shahbaz *et al.*, 2019). Although plants can cope with these conditions, this ability depends upon species or cultivar types (Shahbaz & Ashraf, 2013). In the present study, the imposition of salt stress caused a significant reduction in germination, growth, and phenological parameters of the selected cluster bean cultivars. Our findings agree with some previous studies in which salt-induced reduction in germination, growth and phenological attributes have been observed in different crops like wheat (Shahbaz *et al.*, 2013; Kausar & Shahbaz, 2013), rice (Shahbaz & Zia, 2011), various vegetables (Shahbaz *et al.*, 2012), eggplant (Abbas *et al.*, 2010), carrot (Bano *et al.*, 2012), cauliflower (Batool *et al.*, 2012), Solanum melongena (Shaheen *et al.*, 2012). The variation in germination, growth, and phenological attributes might be because of differences in the sensitivity range of different cluster bean genotypes, which depends on the growth stage of cluster bean genotypes. Plants were more sensitive to salt stress at germination than at a late stage.

Current findings revealed that KNO_3 salt priming and compost application improves the germination and growth attributes of cluster bean genotypes under saline conditions. Fuller *et al*., (2012) concluded that using priming techniques could enhance the germination of wheat seeds under saline conditions. These findings agree with Kubala *et al*., (2015), who found that seeds primed with an osmotic solution may improve germination performance through metabolic activation involving the synthesis of proteins, nucleic acids, and enzymes, and increasing water uptake, respiratory activity, and reserve mobilization (Shahbaz & Ashraf, 2013). Better seedling growth results in better plant development with expanded leaves, resulting in more photosynthesis and better productivity. The exogenous application of KNO_3 can produce substances that release NO. This molecule acts as a signaler in higher plants that regulate plant growth and development, defense against pathogens, and responses to abiotic stress (Sanz *et al.*, 2015). The addition of compost significantly improved the germination and growth attributes of the cluster bean genotypes. These results agree with Shahzad *et al*., (2019), who reported decreased growth attributes of maize grown under varying salinity levels. Application of organic amendments has been advocated for its known positive effects in salinity amelioration and improving the germination and growth attributes o improved availability of mineral nutrients to plants due to applied composted. Better growth under the saline stress by using compost might be the reason behind better leaf area and fewer days to pod formation. However, variability among cluster bean genotypes might be due to the genetic ability of each genotype under saline stress.

Gas exchange, photosynthesis, and water-related attributes substantially contribute to plant growth and development. These attributes are adversely affected in many crop plants due to root-applied saline stress (Shahbaz *et al.*, 2013). In our study, chlorophyll contents, photosynthetic rate, transpiration rate, stomatal conductance, and relative water contents decreased considerably in selected cluster bean genotypes under saline stress. Similar findings were observed by various researchers in many crops like wheat (Kanwal *et al.*, 2011), grasses (Akram *et al.*, 2007), rice (Naheed *et al.*, 2007), sunflower (Akram *et al.*, 2009; Shahbaz *et al.*, 2011), cotton (Shaheen *et al.*, 2012), etc. The photosynthetic rate decreased in cluster bean genotypes significantly, which can be associated with reduced utilization efficiency of light, photoinhibition of photosystem, and reduction in stomatal conductance with a subsequent decrease in CO_2 availability at the site of its fixation (Chedlia *et al.*, 2007). Loss in turgidity of guard cells may cause stomatal closure, which could be responsible for the low availability of CO_2 in mesophyll cells, ultimately leading to decreased photosynthetic efficiency. Improvement in water-related and photosynthetic attributes by nitrate salts priming might be due to its well-established role in stomata regulation by up-regulating photosynthetic genes (Chen *et al.*, 2002) and increased CO_2 exchange rate under optimal and saline conditions (Perveen *et al.*, 2010). The chlorophyll content is a crucial parameter often used to indicate the development of chloroplast and photosynthetic capacity (Anwar *et al.*, 2020). Results of increased chlorophyll contents and photosynthetic capacity attribute agree with previous studies, which reported that salt priming significantly improved the photosynthetic details under stressed conditions (Jiajin *et al.*, 2010; Rahimi, 2013; Siri *et al.*, 2013; Sharma *et al.*, 2014; Kwon *et al.*, 2019; Anwar *et al.*, 2020). However, in the present study, the application of compost was found to be an effective amendment for enhancing the photosynthetic rate of plants under saline soil conditions. Recently, Niamat *et al*., (2019) observed improved water relations of maize grown in varying salinity levels in terms of decreased electrolyte leakage and increased relative water contents under the application of compost.

In stressed plants, the antioxidant defence system is one of the essential options for reactive oxygen species (ROS) regulation. According to Hasanuzzaman *et al*., (2019), some enzymatic antioxidants like the SOD, CAT and POD are essential for controlling ROS in plants under stress conditions. In this study, salinity increased enzymatic antioxidant activities. This is consistent with recent reports by Parvin *et al*., (2019), where salt toxicity augmented SOD activity and induced an extreme generation of ROS in plants. Nitrate salt priming significantly reduced SOD, CAT, and POD activities under salt stress with a preventive effect on protein downregulation (Ahmad *et al*., 2019). Similarly, it was noticed that salts priming techniques treatment prevents protein loss, decreases protease activity, and enhances catalase and peroxidase activities in wheat under H_2O_2-oxidative stress (Vaktabhai & Kumar, 2017; Ali *et al.*, 2021).

Table 10. Person's correlation among the cluster bean parameters.

	Superoxidase mutase	Peroxidase	Catalase	Transpiration rate	Photosynthetic rate	Sodium in leaf	Sodium in root	Potassium in leaf	Potassium in root
Superoxidase mutase	-								
Peroxidase	0.94****	-							
Catalase	0.71****	0.70****	-						
Transpiration rate	-0.05	-0.09	0.34***	-					
Photosynthetic rate	-0.67****	-0.65****	-0.46****	0.32**	-				
Sodium in leaf	0.71****	0.72****	0.61****	-0.18	-0.57****				
Sodium in root	0.64****	0.59****	0.39****	-0.46****	-0.58****	-0.51****			
Potassium in leaf	0.94****	0.97****	0.68****	-0.14	-0.63****	0.73****	-0.61****	-	
Potassium in root	0.89****	0.93****	0.63****	-0.22*	-0.64****	0.75****	0.65****	0.96****	

p<0.0001 '****'; p<0.001 '***', p<0.01 '**', p<0.05 '*'

The agronomic traits of cluster beans in this study were severely affected by salinity stress. This includes the number of branches, pods and seeds/plants, which were attributed to the inability of the plants to form new units and the early senescence of older components due to salt stress (Islam *et al.*, 2012). Taffouo *et al*., (2010) attributed the decrease in the number of pods and seeds/plants of cowpea to reductions in leaf chlorophyll concentrations. Reduced crop production at increasing salinity levels is a product of ionic imbalance that causes toxicity in plants (Ashraf, 2009). As reported previously, saline stress application significantly elongated the number of days to 50% flowering and pod development (Mannan *et al.*, 2013). Salinity stress delays early flowering and podding mainly due to its ability to deactivate the plants' defence system (antioxidants), which decreases yield and yield components (Shahbaz & Ashraf, 2013). More precisely, observed agronomical attributes, number of pods per plant, number of grains per pod, 1000-grain weight, and net grains weight were significantly enhanced by the application of compost as compared to its respective controls. Previously, substantial literature confirmed the happy relationship between organic material and increased growth and yield of maize, sunflower, wheat, rice, and holy basil (an aromatic crop) (Verma *et al.*, 2012; Shaaban *et al.*, 2013; Kamel *et al.*, 2016; Trivedi *et al.*, 2017; Niamat *et al.*, 2019). Increased growth and grain yield in the present experiment might be attributable to the improved availability of mineral nutrients to plants due to compost (Guo *et al.*, 2014). It has been established that varying levels and kinds of salts present affect the fresh and dry biomass of plants (Liu *et al.*, 2019). The compost increases the biological activities of soil, which are linked to the cycling of nutrients and eventually enhanced growth and yield parameters (Wang *et al.*, 2014; Abd El-Naby *et al.*, 2019). Moreover, compost application in the current study might have released organic acids that dissolved some of the $CaCO_3$ in the soil and replaced Na+ with Ca^{2+}. The positive correlation was observed between potassium contents in leaf and root, and superoxidase and catalase (Table 10).

In the present study, saline stress significantly increased leaf and root Na^+ and K^+ contents in all cluster bean genotypes. This increase in Leaf or root Na^+ contents had also been observed in earlier studies on different crops such as rice (Shahbaz & Zia, 2011), wheat (Perveen *et al.*, 2012), sunflower (Shahbaz *et al.*, 2011), cotton (Ashraf & Ahmad, 2000), etc. An increase in Leaf or root Na^+ may be due to a high concentration of sodium in the root-growing medium, causing its high uptake through sources (Munns & Tester, 2008). In our study, saline stress alters leaf or root K^+ contents. In contrast to our findings, Dar *et al.*, (2007) observed a decrease in shoot and root K^+ mungbean due to the imposition of salt stress. Shahbaz *et al.*, (2011) also observed a considerable reduction in leaf and root K^+ content in sunflowers. According to El-bassiouny & Bekheta (2005), Na^+ ion accumulation leads to reduced K^+ ion absorption in plants. Similarly, previous reports showed that priming with nitrate salts suppressed Na^+ uptake and stimulated K^+ proliferation in plant shoots (Shahbaz & Zia, 2011; Batool *et al.*, 2013). The beneficial effects of KNO_3 salt as a seed-priming agent include the controlled hydration of seeds, the essential roles of K^+ as an osmoregulator and its crucial role in metabolic processes (Nawaz *et al.,* 2017). KNO_3 is also an ideal source of two essential plant nutrients for metabolic processes during priming (Abd El Gayed & Knany, 2020). Moreover, under salinity stress, KNO_3 prevents salinity buildup in plant tissues because K^+ counteracts the harmful effects of Na^+ toxicity (Rabnawaz *et al.,* 2020). These results align with Li-ping *et al*., (2015), who found decreased Na^+-mediated stress in plants under applied cow dung and other ameliorants. It has previously been described that compost has an excessive concentration of Ca^{2+} that could modify the soil structure by developing cationic channels between clay particles and organic material (David & Dimitrios, 2002; Huang *et al.*, 2019). Previously, it was recommended that organic amendments such as farmyard manure be used as chelating agents for refining toxic salts, especially sodium (Na^+) and chloride (Cl^-) ions (Hanay *et al.,* 2004; Tejada *et al.,* 2006).

Conclusion

The seed priming improved the growth, physiology, and yield of the guar bean cultivars under saline conditions. The potassium nitrate seed application increased the grains per pod, pod length, fodder yield, leaf area index, peroxidase, catalase, potassium content in Leaf and root, and transpiration rate, especially in cultivars BR-2017 and S-6165. Thus, BR-2017 and S-6165 with potassium nitrate seed priming can be recommended based on current study results under saline soil conditions to achieve the maximum productivity of guar bean. The seed priming with KNO_3 and compost application may be successfully applied on cluster bean genotypes seeds to alleviate the adverse effects of salinity at the field level. Therefore, the organic and inorganic amendments significantly improved the growth, yield, physiological, and nutritional parameters of cluster bean genotypes grown under salt stress. The farmers with saline soils can cultivate cluster beans using potassium nitrate seed priming treatments and achieve a higher crop yield.

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