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Mitigation of Drought Stress by Foliar Application of Salicylic Acid and Potassium Chloride in Cluster bean (*Cyamopsis tetragonoloba* L.)

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ABSTRACT

Background: Plant growth is often affected with hampered physiological and cellular functioning due to salinity and drought stress. To investigate the effectiveness of plant bioregulator (*i.e.* salicylic acid-SA) and potassium chloride (KCl) in mitigating abiotic stresses in cluster bean, a field experiment was conducted in rainy season from 2018 to 2020 at Agricultural Research Station, Fatehpur-Shekhawati (Sikar), Rajasthan.

Methods: The experiment was laid out in randomized block design with seven treatments and three replications. Total seven treatments consisted in experiment *viz.*,T_1: Control (no SA and KCl application); T_2: SA 100 ppm; T_3: SA 200 ppm; T_4: SA 300 ppm; T_5: KCl 0.5%; T_6: KCl 1.0%; T_7: KCl 1.5%.These foliar application of treatments were applied twice during season, first at flowering and second at pod formation stage.

Result: The results revealed that the foliar application of SA from 100 to 300 ppm and KCl from 0.5 to 1.5%, significantly improved all physiological, growth and yield parameters of cluster bean during the experimentation. In cluster bean, the maximum pooled leaf fresh, dry and turgid weight (2.37, 0.645 and 3.26 g) were recorded under the foliar application of salicylic acid@ 300 ppm, respectively. Similar results were also reported with higher relative leaf water content (65.98%), cell membrane stability (84.66%) and lowest transpiration rate (5.16 mg/g fw/m). Among the growth parameters the highest plant height (81.33 cm), number of branches per plant (12), number of clusters per plant (41), number of pods per cluster (5),number of pods per plant (194) and number of seeds per pod (7.67) were recorded with treatment foliar application of salicylic acid@ 300 ppm. Similarly, the yield parameters *viz.* test weight (34.84 g), grain yield (15.54 q ha^{-1}), stover yield (37.53 q ha^{-1}) and harvest index (31.33%) were also recorded higher with the application of salicylic acid @ 300 ppm in cluster bean, which were 1.46, 19.69, 17.50 and7.41% higher over control.

Key words: Cluster bean, Drought stress, Foliar spray, Potassium chloride, Salicylic acid.

INTRODUCTION

Drought stress is a global issue, limiting crop productivity and the recent climate change scenarios made it more serious and endanger food security (Seleiman *et al.,* 2021). Drought is also among the major constraints inûuencing crop productivity and ûnal yield including major cereals and legumes. The severe drought stress condition led to reduced plant growth with retard plants leading to poor dry matter accumulation (Fahad *et al.,* 2017). Hence, wise and conservative use of water is key for maintaining crop productivity sustainable. Agronomic techniques such as the use of plant growth regulators either through seed priming or foliar application are considered as *via*ble options to cope with abiotic stresses including drought stress for maintaining and increasing crop yield (Karlidag *et al.,* 2009; Islam *et al.,* 2023) *via* lowering abiotic stresses and improving physiological processes such as plant chlorophyll, cell membrane stability and leaf area index (Khan *et al.,* 2015). In this regard, salicylic acid (SA) can be helpful and work in a signaling pathway that improves the tolerance of crop plants to stresses for better crop performance and yield (Isfendiyarog˘lu, 2008). SA performs a vital role in improving physiological processes including regulation of stomata, photosynthetic rates and chlorophyll content under stress conditions (Arfan *et al.,* 2007). Additionally, it also lowers the negative effects of salt and other abiotic stresses as well (Khan *et al.*, 2015; Malaga *et al.,* 2020). Salicylic acid seed priming lowered theadverse effects of abiotic stresses *via* improving sugar and proline accumulation (Fahad and Bano, 2012). It was found that SA foliar application may increase plant pigments including chlorophyll a, band carotenoid content, proline content and leaf water traits leading to enhanced tolerance against

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drought stress (Zafar *et al.,* 2021). Hence the use of SA is vital for alleviating osmotic stress as short term strategy under drought stress in many plant crops (Chaves *et al.,* 2011; Islam *et al.,* 2024), however further research is needed for clear understanding the mechanism in many crops including wheat (Khan *et al.,* 2015). Potassium (K) is among the essential macronutrients needed foroptimal growth and productivity and have central role in many enzymes activation as well as several important biological processes such as protein formation, stomatal movements, energy transformation including enhanced plant tolerance to abiotic stresses (Ul-Allah *et al.,* 2020). It has also key role against formation of reactive oxygen species (ROS) to combat the negative effect of drought stress and maintain crop yield (Aslam *et al.,* 2013). Due to the increased osmotic adjustment, K fertilization can mitigate ROS production under abiotic stresses (Sangakkara *et al.,* 2001). Potassium fertilization with optimal dose may not merely improve tolerance against drought stress but also can improve crop growth and productivity due to proper nutrition (Shah *et al.,* 2018). The stomatal regulation under optimal K application is considered important for enhanced photosynthetic rates (Marschner, 2012) as well as transport of photosynthates to sinks as well as to roots leading to increase dry matter production. The integrity and stability of cell membranes with the application of K under drought stress is important for mitigating drought stress conditions for better crop performance (Ul-Allah *et al.,* 2020; Islam *et al.,* 2024).

Cluster bean is an important legume cultivated mostly on marginal and sub marginal lands of arid and semi-arid regions. Overall, India produces around 80% of global cluster bean production. It is cultivated on more than 4 m ha in India, Rajasthan alone accounts for around 80% of the area and production. Owing to its demand in the international market, it has been introduced in the non-traditional growing areas like Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and Chhattisgarh (Bhatt *et al.,* 2016). There is big demand for Indian guar gum products, food additives, food thickener. Guar is a multipurpose legume crop cultivated mainly in the Kharif season in arid environments and is used as animal feed and fodder, green manure and for extraction of gum for various industrial uses (Baviskar *et al.,* 2010). It is from the endosperm that guar gum is derived, which is the prime marketable product of the plant. The spherical endosperm contains significant amount of galactomannan gum (19-43% of the whole seed), which forms a viscous gel in cold water (Chavan *et al.,* 2015).

Keeping in view the significance of SA and K for mitigating drought stress, the current study was undertaken to assess the impact of SA and K application on physiological and yield parameters of clusterbean and combat the negative inûuence of water stress *via* improving plant growth, leaf water deficit, retention and saturation capacity leading to enhance the productivity of clusterbean under field condition.

MATERIALS AND METHODS

The experiment was conducted in rainy season from 2018 to 2020 at Agricultural Research Station, Fatehpur-shekhawati, Sikar (latitude 27°56′10.37″ N, longitude 74°59′04.51″ E) located in Agro-Climatic Zone II-A of Rajasthan, Indiawhich is called as Transitional Plain of Inland Drainage. The climate of experimental site is tropical and characterized by hot dry summer, cold dry winter (minimum temperature of -5°C) and warm rainy seasons. Summers is very hot with high air temperature (up to 48°C in mid May), extends from mid March to mid June or up to receive of pre-monsoon rainfall. The strong winds (20-60 km h^{-1}) prevail during summer and most of rainfall is received from July to September. During the cropping seasons of experimental years the mean minimum temperature ranges from 13.3 to 25.8°C and maximum temperature varies from 32.9 to 36.8°C. In the starting year of experiment, total 211.2 mm rainfall occurs during July to October. The highest rains (307.2 mm) was received in cropping season 2019 by 20 rainy days and least rains (193.6 mm) was observed in the year 2020 having only 11 rainy days.

The soil of the experimental site was sandy loam in texture, moderately alkaline in reaction (pH 8.4) and had 0.21 to 0.23% organic carbon, nitrogen 190.7 to 205.0 kg ha^{-1}, phosphorus 17.4 to 19.3 kg ha^{-1} and potassium 112.7 to 130.5 kg ha^{-1}. The experiment was carried out in a randomized block design with three replications. Total seven treatments consisted in experiment *viz.*T_1: Control (no SA and KCl application); T_2: SA 100 ppm; T_3: SA 200 ppm; T_4: SA 300 ppm; T_5: KCl 0.5%; T_6: KCl 1.0%; T_7: KCl 1.5%. These foliar application of treatments were applied twice during season, first at flowering and second at pod formation stage. The experiment was started at the onset of monsoon in each year by sowing of clusterbean seeds, keeping all agronomic practices normal and uniform for all the treatments. Relative water content (RWC) was measured in the leaves harvested at one hour after sunlight in the field and calculated according to the formula:

$$\frac{\text{FW - DW}}{\text{TW - DW}} \times 100$$

Where,

TW= Turgid weight.

The cell membrane stability (MS) was determined by the method of Sullivan (1972) with using formula:

$$MS = \frac{1-T_1/T_2}{1-C_1/C_2} \times 100$$

The transpiration rate was estimated by quick weighing method (Srivastava and Kumar, 1993). Transpiration rate (TR) was calculated by the formula:

$TR = T_0 - T_1 \times 1000/T_0 \times 10$ measured in mg H_2o fr. wt. min^{-1},

Where,

T_0 = Fresh weight of leaves at given point of time.

T_1 = Fresh weight of leaves after 10 minutes of first reading.

The critical differences were calculated to assess the significance of treatment mean, whenever the F test was found significant at 5% level. All these estimates were computed by the standard statistical procedure (Gomez and Gomez, 1976).

RESULTS AND DISCUSSION

Leaf water parameters

The leaf water parameters of clusterbean were significantly influenced by the foliar application of SA and KCl (Table 1 and 2). From the pooled data of three years, relative leaf water content, cell membrane stability and transpiration rate were influenced significantly by the foliar application of SA and KCl (Table 1). The significantly higher relative leaf water content (65.98%), cell membrane stability (84.66%) and transpiration rate (5.16 mg/g fw/m) was recorded with treatment T_4 followed by treatment T_3 (65.96%, 83.99% and 5.34 mg/g fw/m, respectively). Similarly, it is observed that at 60 DAS the leaf fresh weight (2.37 g), leaf dry weight (0.645 g) and leaf turgid weight (3.26 g) were recorded with the foliar application of SA @ 300 ppm (T_4) followed by treatment SA @ 200 ppm (T3) and KCl 1.5% (2.33, 0.628 and 3.17 g and 2.11, 0.568 and 2.77 g, respectively) (Table 2). Potassium increases the plant's drought resistance through its functions in stomatal

Table 1: Effect of salicylic acid and potassium chloride application on leaf water parameters of cluster bean.

Treatments	Relative leaf water content (%)				Cell membrane stability (%)				Transpiration rate (mg/g fw/m)			
	2018	2019	2020	Pooled	2018	2019	2020	Pooled	2018	2019	2020	Pooled
Control	63.59	66.89	65.77	65.42	74.89	75.61	75.82	75.44	7.89	8.26	8.13	8.09
SA 100 ppm	64.47	66.96	66.13	65.85	76.23	76.58	75.97	76.26	6.69	6.83	6.57	6.70
SA 200ppm	64.61	66.97	66.29	65.96	82.51	84.26	83.99	83.59	5.38	5.36	5.29	5.34
SA 300 ppm	64.66	66.92	66.36	65.98	83.87	85.28	84.66	84.6	5.19	5.16	5.13	5.16
KCl 0.5%	63.66	66.9	65.8	65.45	75.23	76.1	75.94	75.76	7.13	7.66	7.49	7.43
KCl 1.0%	63.87	66.91	65.89	65.56	76.11	77.02	76.23	76.45	6.19	6.43	6.27	6.30
KCl 1.5%	63.91	66.91	65.89	65.57	76.43	77.76	76.23	76.81	6.19	6.41	6.25	6.28
CD (0.05)	0.151	0.157	0.155	-	0.340	0.342	0.339	-	0.183	0.187	0.185	-
SE(m±)	0.049	0.051	0.05	-	0.011	0.011	0.01	-	0.059	0.06	0.060	-

Table 2: Effect of salicylic acid and potassium chloride application on leaf water parameters of cluster bean.

Treatments	Leaf fresh wt. (g)				Leaf dry wt. (g)				Leaf turgid wt. (g)			
	2018	2019	2020	Pooled	2018	2019	2020	Pooled	2018	2019	2020	Pooled
Control	1.35	1.40	1.36	1.37	0.385	0.38	0.377	0.381	1.86	1.91	1.90	1.89
SA 100 ppm	1.72	1.80	1.77	1.76	0.486	0.487	0.472	0.482	2.47	2.45	2.38	2.43
SA 200ppm	2.29	2.34	2.36	2.33	0.619	0.632	0.633	0.628	3.13	3.18	3.21	3.17
SA 300 ppm	2.35	2.39	2.38	2.37	0.647	0.646	0.641	0.645	3.29	3.25	3.24	3.26
KCl 0.5%	1.63	1.64	1.66	1.64	0.433	0.449	0.441	0.441	2.33	2.32	2.28	2.31
KCl 1.0%	1.67	1.71	1.69	1.69	0.459	0.461	0.464	0.461	2.34	2.24	2.3	2.29
KCl 1.5%	2.14	2.12	2.06	2.11	0.574	0.572	0.557	0.568	2.68	2.88	2.76	2.77
CD (0.05)	0.034	0.033	0.029	-	0.009	0.008	0.008	-	0.039	0.04	0.041	-
SE(m±)	0.011	0.011	0.01	-	0.003	0.003	0.003	-	0.013	0.013	0.014	-

Table 3: Effect of salicylic acid and potassium chloride application on growth parameters of cluster bean.

Treatments	Plant height (cm)				No. of branches/plant				No. of clusters/plant			
	2018	2019	2020	Pooled	2018	2019	2020	Pooled	2018	2019	2020	Pooled
Control	66	75	71	70.67	6	8	7	7	29	34	31	31.33
SA 100 ppm	70	78	76	74.67	7	10	7	8	32	39	35	35.33
SA 200 ppm	77	82	81	80	10	13	11	11.33	38	43	38	39.67
SA 300 ppm	79	83	82	81.33	13	14	12	13	40	44	39	41
KCl 0.5%	66	76	72	71.33	6	9	7	7.33	30	36	31	32.33
KCl 1.0%	68	77	74	73	7	10	8	8.33	31	37	31	33
KCl 1.5%	68	78	74	73.33	7	11	8	8.67	32	37	32	33.67
CD (0.05)	0.243	0.247	0.245	-	0.17	0.174	0.172	-	1.29	1.32	1.31	-
SE(m±)	0.076	0.079	0.077	-	0.055	0.056	0.056	-	0.41	0.42	0.42	-

Table 4: Effect of salicylic acid and potassium chloride application on yield parameters of cluster bean.

Treatments	No. of pods/cluster				No. of pods/ plant				No. of seeds/ pod				Test weight (g)			
	2018	2019	2020	Pooled	2018	2019	2020	Pooled	2018	2019	2020	Pooled	2018	2019	2020	Pooled
Control	3	3	4	3.33	93	131	115	113	6	7	5	6	34.29	34.37	34.33	34.33
SA 100 ppm	3	4	5	4	129	163	149	147	7	7	6	6.67	34.39	34.49	34.46	34.45
SA 200ppm	4	5	6	5	166	196	181	181	8	8	7	7.67	34.61	34.79	34.65	34.68
SA 300 ppm	4	5	6	5	187	213	194	198	7	8	7	7.33	34.76	35.02	34.73	34.84
KCl 0.5%	2	3	4	3	99	139	117	118	5	7	5	5.67	34.33	34.48	34.34	34.38
KCl 1.0%	3	4	4	3.67	109	162	126	132	5	7	5	5.67	34.39	34.61	34.37	34.46
KCl 1.5%	3	4	5	4	115	176	130	140	5	7	5	5.67	34.4	34.73	34.37	34.5
CD (0.05)	0.213	0.266	0.269	-	2.132	2.613	2.334	-	0.721	0.752	0.713	-	0.03	0.031	0.03	-
SE(m±)	0.081	0.085	0.281	-	0.779	0.839	0.809	-	0.199	0.241	0.19	-	0.01	0.01	0.009	-

regulation (Marschner, 2012). Khan *et al.,* 2003 observed that foliar application of SA enhanced the stomatal conductance and transpiration rate in soybean and Altaf *et al.,* 2023 found similar trends in maize under limited water conditions. In another study on wheat, it was observed that foliar application of SA increased the stomatal conductance under drought stress (Waseem *et al.,* 2006). Majeed *et al.* (2016) reported that foliar application SA and K improved in transpiration rate and stomatal conductance in moongbean. K and SA application with optimal dose may not merely improve tolerance against drought stress but also can improve crop growth and productivity due to proper nutrition (Shah *et al.,* 2018). The stomatal regulation under optimal K application is considered important for enhanced photosynthetic rates (Marschner, 2012) as well as transport of photosynthate to sinks as well as to roots leading to increase dry matter production.

Growth parameters

The effect the foliar application of different levels of SA and KCl on growth parameters of cluster bean are also found significant Table 3. At harvesting of crop, tallest plant (81.33 cm) and number of branches plant^{-1} (12.0) and number of clusters plant^{-1} (41.0) were recorded with the treatment T_4 and which received SA @300 ppm followed by the treatment T_3 (80.0 cm, 12 and 39.67 g, respectively) in cluster bean. In cluster bean, increased in plant height, number of branches per plant and number of clusters per plant in response to SA and KCl application may occurs mainly due to decrease drought stress by improved stomatal regulation and increase plant water uptake ability that leads to improve plant growth and metabolic processes by the dilution of toxic ions (Yadav *et al.,* 2020). Drought stress induces proline accumulation in plants which contribute to the reduction of deleterious effects of stress factors and ultimately enhanced plant growth (Hayat *et al.,* 2012; Islam *et al.,* 2023).

Yield attributes and yield

Foliar application of SA and KCl affected significantly the yield attributes Table 4 and 5 and it has been observed that application of SA and K application has significantly increased number of pods per cluster, number of pods per plant, number seeds per pod and test weight that ultimately improve yield and performance of plant. Analysed data in Table 4 indicate that the highest value of number of pods per cluster, number of pods per plant, number seeds per pod and test weight (g) in clusterbean were recorded 5, 198, 7.33 and 34.84, respectively with treatment which received SA @300 ppm followed by the treatment T_3 (5, 198, 7.33 and 34.84, respectively) in cluster bean. Data presented in table 5 also indicate that the grain yield ha^{-1} (15.54 q), stover yield ha^{-1}(37.53 q) and harvest index (31.33%) were recorded with the foliar application of SA @ 300 ppm (T_4) followed by treatment SA @ 200 ppm (T3) and KCl 1.5% (15.24q, 37.0q and 31.01%, respectively) while lowest amount was recorded in control treatment.

Table 5: Effect of salicylic acid and potassium chloride application on yield and harvest index of cluster bean.

Treatments	Grain yield/ ha (q)				Stover yield/ ha (q)				Harvest index (%)			
	2018	2019	2020	Pooled	2018	2019	2020	Pooled	2018	2019	2020	Pooled
Control	12.33	13.26	11.86	12.48	29.46	32.33	31.09	30.96	28.79	29.08	29.15	29.01
SA 100 ppm	12.79	15.58	12.37	13.58	32.81	37.05	34.43	34.76	28.97	29.6	29.69	29.42
SA 200 ppm	14.39	17.75	13.58	15.24	36.77	37.22	37.01	37	30.57	31.72	30.73	31.01
SA 300 ppm	14.61	18.22	13.79	15.54	36.89	38.6	37.11	37.53	30.93	32.06	30.99	31.33
KCl 0.5%	12.34	13.88	11.86	12.69	29.66	32.56	31.29	31.17	28.8	29.08	29.16	29.01
KCl 1.0%	12.37	13.95	11.87	12.73	29.87	33.57	31.4	31.61	28.82	29.36	29.26	29.15
KCl 1.5%	12.42	14.03	11.93	12.79	29.99	33.88	31.52	31.8	28.89	29.29	29.33	29.17
CD (0.05)	0.651	0.652	0.649	-	0.86	0.87	0.86	-	0.177	0.201	0.167	-
SE(m±)	0.203	0.209	0.203	-	0.276	0.282	0.276	-	0.059	0.064	0.06	-

The increased in yield and yield parameters could be due to synergetic inûuence on the meristematic activity leads to enhance cell growth and elongation of leaves as well as roots, thus increased photosynthates and dry matter production. The increase in photosynthesis reaction resulted in increased crop yield (Ashraf *et al.,* 2012; Hanif *et al.,* 2024). In the present study, the foliar SA with KCl improved cluster bean yield under drought stress, however sole use of KCl fetch less increase in yield than use of SA (Sayyari *et al.,* 2013). The underlying mechanisms of SA in reducing the drought effects mediated osmolytes accumulation and enhance plant pigment content for maintaining osmotic homeostasis and regulating plant nutrient uptake as well as other vital plant growth pathways (Khan *et al.,* 2015). Substantial yield losses have been observed in different crops due to reduced supply of water even for a short period of time (Pinheiro *et al.,* 2005). The limited water present in the root zone might be utilized more efficiently under drought-stressed led to maintaining plant growth even under stress conditions. Higher soil moisture conservation was noted by some plants under water stress conditions due to greater accumulation of osmolyte content (Munsif *et al.,* 2022; Islam *et al.,* 2024).

CONCLUSION

Abiotic stresses specially drought is mitigated by foliar spray of salicylic acid and KCl at critical growth stages of cluster bean crop. The increasing counteractive effect of salicylic acid and KCl to drought stress was observed with longer dry spell period. SA and KCl use in cluster bean crop improved physiological parameters *i.e.* RLWC, CMS and TR and leaf weight and also growth and yield attributes.SA proved more effective as compared to KCl. Thus, SA and KCl @ 300 ppm and 1.5%, respectively can be recommended, after the large scale field testing and standardization of their economic spray schedules, for improving the cluster bean crop performance under marginal rainfall conditions.

Conflict of interest

All authors declared that there is no conflict of interest.

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