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Effect of Salicylic Acid on Physiological Parameters and Yield in Chickpea (*cicer arietinum* l.) under Water Stress

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ABSTRACT

A field experiment was conducted at Agricultural College Farm, Bapatla during *rabi*, 2015-16 to study the effect of foliar application of salicylic acid (SA) on physiological parameters and yield in chickpea under water stress. The experiment was laid out in split plot design with three main treatments viz., no stress (M_0), stress from flowering stage (M_1) and stress from pod formation stage (M_2) and four sub treatments viz., no SA spray (S_0), SA spray @ 0.01 mM (S_1), SA spray @ 0.1 mM (S_2) and SA spray @ 1.0 mM (S_3) in three replications. Water deficit stress significantly reduced the physiological parameters (i.e. leaf area, total dry matter and total chlorophyll content) and yield in chickpea. Leaf area was reduced by 19.8, total dry matter was reduced by 33.1, total chlorophyll content was decreased by 18.7 and seed yield of chickpea was decreased by 22.8 per cent, respectively, with the plants that were stressed from flowering stage over control. Salicylic acid spray @ 0.1 mM at 35 DAS increased the leaf area by 18.9, total dry matter by 20.4, total chlorophyll by 10.5 and seed yield by 19.7 per cent, respectively, over unsprayed plants. Exogenous application of SA @ 0.1 mM at 35 DAS to the plants that were stressed from pod formation stage significantly increased the total dry matter, total chlorophyll and seed yield of chickpea than the plants that were stressed from flowering stage. Hence, it can be concluded from the study that, chickpea plants are more sensitive to water stress from flowering stage rather than pod formation stage, and SA spray @ 0.1 mM at 35 DAS to the plants that were stressed from pod formation stage helped in mitigating the adverse effects of water stress and improved the growth and yield of chickpea under water stress.

Key words: *Chickpea, Drought stress, Salicylic acid, Physiological parameters and Yield.*

Chickpea (*Cicer arietinum* L.) is a third most important legume crop grown all over the country during *rabi* season. In India, it is grown on an area of about 8.25 million hectares with an annual production of 7.33 million tonnes with an average yield of 899 kg ha^{-1}. Chickpea occupies 40% of total pulse growing area and 47% of the total pulse production in the country.

Chickpea is a self pollinated, annual, herbaceous food legume originated from South Eastern Turkey and subsequently spread to India and Europe (Singh and Auckland, 1975). It is generally grown in arid or semi-arid climates where soils are generally marginal in their physico-chemical characteristics. Drought is one of the main environmental factors limiting plant growth and yield and it is the most prevalent cause of crop yield loss due to an increase in temperature and a decrease in water availability respectively, that deviates from the optimal condition for plant life (Larcher,2003). In chickpea, flowering and pod formation stages are sensitive to drought stress and terminal drought reduce seed yield by 58-95% (Leport *et al*., 1999) compared with irrigated plants.

Salicylic acid (SA) (2-hydroxybenzoic acid) is an endogenous plant growth regulator that can play an important role in abiotic stress tolerance. It plays a key role in providing tolerance to the plants exposed to water stress (drought or flooding). It has the ability to induce a protective effect on plants under stress (Hayat *et al*., 2008). Evidences exist that externally applied SA can increase the plant tolerance to several abiotic stresses, including osmotic stress (Wang et al., 2010). Seed treatment of salicylic acid may increase yield of different crops due to reduction in stress induced inhibition of plant growth, enhanced photosynthetic rates, leaf area and plant dry matter production (Khan *et al*., 2003). Hence, the present study was taken up to study the effect of SA on physiological parameters and yield of chickpea under water stress.

MATERIAL AND METHODS

The experiment was conducted at Northern Block of Agricultural College Farm, Bapatla, on a sandy clay loam soil in *rabi*, 2016. It was laid out in a split plot design with three main treatments viz., no stress (M_0), stress from flowering stage (M_1) and stress from pod formation stage (M_2) and four sub treatments viz., No SA spray (S_0), SA spray @ 0.01 mM (S_1), SA spray @ 0.1 mM (S_2) and SA spray @ 1.0 mM (S_3) in three replications. The chickpea variety chosen for this study was JG-11. Nitrogen and phosphorus were applied @ 20 kg ha^{-1} in the form of urea and 50 kg ha^{-1} in the form of single super phosphate, respectively, before sowing of crop. For M_0 (i.e. no stress) treatment, irrigation was given as per the irrigation schedule. For

M_1 treatment, irrigation was withholded from flowering stage (i.e. from 30 DAS) to harvest, and for M_2 treatment, irrigation was not given from pod formation stage (i.e. from 40 DAS) to harvest. Foliar application of SA was done at 35 DAS.

The observations pertaining to leaf area, total chlorophyll content and total dry matter production were recorded at 60 DAS and at harvest, respectively. Seed yield and yield components were recorded at harvest. Total chlorophyll content in leaves was estimated calorimetrically by dimethyl sulphoxide (DMSO) method as described by Hiscox and Stam (1979) and it was calculated by the following formulae (Arnon, 1949).

$$\text{Total chlorophyll (mg g}^{-1}\text{)} = \frac{\text{D. 652 x 1000}}{34.5} \text{ X } \frac{\text{V}}{\text{1000 x W}}$$

Where,

D = Optical density
V = Final volume of DMSO
W = Fresh weight of sample taken

RESULTS AND DISCUSSION

Significant differences were observed between main treatments and sub treatments with respect to leaf area per plant at 60 DAS (Table 1). Among the main treatments, maximum leaf area was recorded by unstressed plants (M_0 - 487.83 cm^2) and minimum leaf area was recorded by the plants that were stressed from flowering stage (M_1- 391.2 cm^2). Plants that were stressed from flowering stage recorded 19.8 per cent reduction in leaf area over unstressed plants. Jaleel *et al.,* 2009 reported that water deficit stress mostly reduces leaf growth and in turn the leaf area in many species of plants. The reduction in leaf area under drought conditions was due to decreased cell division and expansion of cells that was reported by Pattangul and Madore (1999). Among the sub treatments, the plants which were sprayed with SA @ 0.1 mM at 35 DAS recorded the highest leaf area (S_2-495.93 cm^2) and the lowest leaf area was recorded by the plants with no salicylic acid spray (S_0 – 417.07 cm^2). Leaf area of the plants which were sprayed with SA @ 0.1 mM at 35 DAS was increased by 18.9 per cent over the plants that were not sprayed with salicylic acid (S_0). Hayat *et al*. (2005) reported maximum leaf area with SA treatment in wheat.

There was significant difference between main and sub treatments and their interactions pertaining to total chlorophyll content at 60 DAS (Table 1). Plants that were not subjected to water stress (control) recorded the highest total chlorophyll content (M_0 – 1.955 mg g^{-1}), whereas the lowest total chlorophyll content was recorded by the plants which were exposed to water stress from flowering stage (M_1 – 1.590 mg g^{-1}). Plants that were stressed from flowering and pod formation stages showed reduction in total chlorophyll content by 18.7 and 7.9 per cent, over control plants. Massacci *et al*. (2008) reported that the decrease in photosynthetic pigments were due to instability of protein complexes and destruction of chlorophyll by increased activity of chlorophyll degrading enzymes and chlorophyllase under stress condition in cotton. Among the sub treatments, the plants sprayed with SA @ 0.1 mM at 35 DAS recorded maximum total chlorophyll content (S_2 - 1.890 mg g^{-1}), whereas minimum total chlorophyll content was recorded by unsprayed plants (S_0 - 1.710 mg g^{-1}). Chickpea plants sprayed with SA @ 0.1 mM recorded 10.5 per cent increase in total chlorophyll content over unsprayed plants. Khan *et al*. (2003) reported that chlorophyll content was increased due to foliar application of SA in soybean leaves. Among the interactions, highest total chlorophyll content was recorded by the unstressed plants sprayed with SA @ 0.1 mM (M_0S_2 – 2.018 mg g^{-1}) and it was at par with unstressed plants sprayed with SA @ 0.01mM (M_0S_1 – 1.977 mg g^{-1}) and plants sprayed with SA @ 0.1 mM, which were stressed from pod formation stage (M_2S_2 – 1.882 mg g^{-1}), whereas the lowest total chlorophyll content was recorded by the unsprayed plants which were subjected to water stress from flowering stage (M_1S_0 – 1.471 mg g^{-1}). El-Tayeb (2005) reported that there is an increase in photosynthetic pigments under abiotic stress conditions by the foliar application of salicylic acid and it could be due to the fact that SA protects photosynthetic apparatus through increasing the ability of cell antioxidant defence system and new protein synthesis.

Pertaining to total dry matter, significant differences were observed between main and sub treatments and their interactions (Table 1). Among the main treatments, higher total dry matter was recorded by unstressed plants (M_0 – 11.01 g $plant^{-1}$), whereas lower total dry matter was recorded by the plants that were stressed from flowering stage (M_1 – 7.37 g $plant^{-1}$), at harvest . Plants which were grown under stressed condition from flowering stage recorded 33.1 percent reduction when compared to the plants which were grown under no stress condition. Similar significant reduction was observed in morphological parameters like root length, shoot length, leaf area, fresh and dry weight of bhendi plants under drought stress conditions (Sanker *et al*., 2007). Among the sub treatments, plants which were sprayed with SA @ 0.1 mM at 35 DAS recorded higher total dry matter (S_2 - 10.29 g $plant^{-1}$), whereas the lower total dry matter was recorded by unsprayed plants (S_0 – 8.55 g $plant^{-1}$) at harvest. Salicylic acid spray @ 0.1 mM at 35 DAS recorded 20.4 percent increase in total dry matter over unsprayed plants. Singh and Usha (2003) demonstrated that SA enhanced plant dry mass and Rubisco carboxylase activity in wheat, which increased the photosynthetic rate, that might have stimulated plant total dry weight production. Among the interactions, maximum total dry matter was recorded with unstressed plants sprayed with SA @ 0.1 mM at 35 DAS (M_0S_2 - 11.91 g plant^{-1}) and it was at par with unstressed plants sprayed with SA @ 0.01mM at 35 DAS (M_0S_1 - 11.22 g plant^{-1}) and the plants sprayed with SA @ 0.1 mM which were stressed from pod formation stage (M_2S_2 - 10.50 g plant^{-1}) and superior over other treatments. Minimum total dry matter was recorded by the plants that were stressed from flowering stage with no salicylic acid spray (M_1S_0 – 6.39 g plant^{-1}). Khodary (2004) reported that fresh and dry weight of shoot and roots of stressed maize plants were enhanced by the application of SA, which was due to the induction of antioxidant reactions that protect the crop from damaging effect of drought stress and increased the photosynthesis.

Significant differences were observed between main and sub treatments and their interactions with respect to number of pods per plant (Table 2). Among the main treatments, the highest number of pods per plant was recorded with the plants which were subjected to no stress (M_0 – 49.5), whereas the lowest number of pods per plant were recorded by the plants that were stressed from flowering stage (M_1 - 33.3). The plants that were stressed from pod formation stage recorded significantly higher number of pods than the plants that were stressed from flowering stage, and lower than control plants. The plants that were stressed from flowering and pod formation stages recorded 32.7 and 11.7 percent reduction in number of pods per plant over unstressed plants. Siddique and Sedgley, 1986 reported that there was a reduction in pod number in chickpea under drought stress, which could be due to abortion of flowers and abiscission of pods. Among the sub treatments, the highest number of pods per plant was recorded by the plants that were sprayed with SA @ 0.1 mM at 35 DAS (S_2 - 50.8). The lowest number of pods per plant were recorded by unsprayed plants (S_0 – 36.1), which was statistically at par with SA spray @ 1.0 mM at 35 DAS (S_0 - 36.9). Plants sprayed with SA @ 0.1 and 0.01 mM increased the number of pods per plant by 40.7 and 24.1 per cent, over unsprayed plants. Keykha *et al*. (2014) reported that foliar application of SA increased the pod number in mung bean. Flowering is an important parameter that is directly related to yield and productivity of plants. Salicylic acid has been reported to induce flowering in a number of plants. Kumar *et al*. (1999) reported that the foliar application of salicylic acid to soybean also enhanced flowering and pod formation. Among the interactions, foliar application of SA @ 0.1 mM at 35 DAS to the unstressed plants recorded the highest number of pods per plant (M_0S_2 -61.5) and it was at par with unstressed plants sprayed with SA @ 0.01mM at 35 DAS (M_0S_1 – 52.8) and plants sprayed with SA @ 0.1 mM at 35 DAS, which were stressed from pod formation stage (M_2S_2 – 50.1), whereas the lowest number of pods per plant was recorded by the plants which were stressed from flowering stage with no SA spray (M_1S_0 – 27.6).

Significant difference was observed between main treatments only, sub treatments and interaction were non-significant. Maximum 100-seed weight (M_0- 17.0g) was recorded by the unstressed plants, and it was at par with the plants that were stressed from pod formation stage (M_2 - 16.7g), and minimum 100-seed weight was recorded by the plants that were stressed from flowering stage (M_1 - 16.1). Similar significant reduction in 100 seed weight was observed under drought stress in corn (Mamnouie *et al*., 2006).

Among the main treatments, the unstressed plants (control) recorded maximum seed yield (M_0 – 1447.5 kg ha^{-1}), whereas minimum seed yield was recorded by the plants that were stressed from flowering stage (M_1 – 1118.1 kg ha^{-1}). The plants that were stressed from flowering and pod formation stages recorded 22.8 and 8.9 per cent reduction in seed yield over unstressed plants (M_0). The reduction in seed yield under drought stress was due to the disruption in the absorption and translocation of nutrients, which decreases the supply of /photosynthesis assimilates (Moghadam *et al*., 2011).

Among the sub treatments, the highest seed yield was recorded by the plants that were sprayed with SA @ 0.1 mM at 35 DAS (S_2 – 1428.8 kg ha^{-1}) and the lowest seed yield was recorded by the unsprayed plants (S_0 – 1193.5 kg ha^{-1}) and it was at par with the seed yield recorded by the plants that were sprayed with SA @ 1.0 mM at 35 DAS (S_3 – 1224.1 kg ha^{-1}). The plants that were sprayed with SA @ 0.01 mM at 35 DAS recorded 1332.9 kg ha^{-1} seed yield which was significantly higher than S_0 and S_3 and lower than S_2. Seed yield of the plants sprayed with SA @ 0.1 mM at 35 DAS recorded 19.7 per cent increase over unsprayed plants. Dawood *et al*. (2012) observed that increase in seed yield and yield components of sunflower by salicylic acid was due to the effect on physiological and biochemical processes that were led to ameliorate the vegetative growth and active assimilate translocation from source to sink.

Among the interactions, maximum seed yield was recorded by the unstressed plants which were sprayed with SA @ 0.1 mM at 35 DAS (M_0S_2 -1590.9 kg ha^{-1}) and it was at par with unstressed plants sprayed with SA @ 0.01 mM at 35 DAS (M_0S_1 – 1487.6 kg ha^{-1}) and plants sprayed with SA @ 0.1 mM at 35 DAS,

Table 1: Effect of salicylic acid on leaf area, total chlorophyll content and total dry matter in chickpea under water stress

	Leaf area (60 DAS)				Total chlorophyll (60 DAS)				Total dry matter (at harvest)			
TREATMENTS	M0	M1	M2	Mean	M0	M1	M2	Mean	M0	M1	M2	Mean
S0 : No spray	468.67	358.43	424.1	417.07	1.922	1.471	1.739	1.71	10.4	6.39	8.86	8.55
S1 : SA spray @ 0.01 mM	483.73	386.47	436.03	435.41	1.977	1.618	1.845	1.813	11.22	7.85	9.13	9.4
S2 : SA spray @ 0.1 mM	537.23	459.5	491.07	495.93	2.018	1.771	1.882	1.89	11.91	8.47	10.5	10.29
S3 : SA spray @ 1.0 mM	461.7	360.4	430.4	417.5	1.904	1.499	1.739	1.714	10.51	6.77	8.94	8.74
Mean	487.83	391.2	445.4		1.955	1.59	1.801		11.01	7.37	9.36	
	SEm±	CD	CV (%)		SEm±	CD	CV (%)		SEm±	CD	CV (%)	
Main	10.32	40.53	8.1		0.01	0.05	2.4		0.4	1.55	13	
Sub	18.82	54.93	12.79		0.02	0.04	2.5		0.09	0.27	7.04	
Interactions	29.16	NS			0.04	0.14			0.49	1.43		

Table 2: Effect of salicylic acid on number of pods per plant, test weight and seed yield in chickpea under water stress

TREATMENTS	Number of pods per plant				Test weight				Seed yield			
	M0	M1	M2	Mean	M0	M1	M2	Mean	M0	M1	M2	Mean
S0 : No spray	41.1	27.6	39.7	36.1	16.6	15.9	16.4	16.3	1327.2	1004	1249.4	1193.5
S1 : SA spray @ 0.01 mM	52.8	35.1	46.5	44.8	17.2	16.3	16.7	16.7	1487.6	1199	1312	1332.9
S2 : SA spray @ 0.1 mM	61.5	40.9	50.1	50.8	17.3	16.5	17.1	16.9	1590.9	1236.3	1459.2	1428.8
S3 : SA spray @ 1.0 mM	42.8	29.5	38.4	36.9	16.9	15.9	16.4	16.4	1385.3	1033	1254	1224.1
Mean	49.5	33.3	43.7		17	16.1	16.7		1447.5	1118.1	1318.7	
	SEm±	CD	CV (%)		SEm±	CD	CV (%)		SEm±	CD	CV (%)	
Main	1.07	4.21	8.8		0.14	0.54	7.09		35.65	124.78	9	
Sub	1.18	3.45	8.4		0.58	NS	9.38		17.07	49.83	6.1	
Interactions	3.87	11.61			0.84	NS			45.76	133.56		

which were stressed from pod formation stage (M_2S_2 – 1459.2 kg ha^{-1}), whereas minimum seed yield was recorded by the plants which were stressed from flowering stage with no SA spray (M_1S_0 – 1004.0 kg ha^{-1}). Hussain *et al*. (2008) reported that foliar application of SA improved the yield and yield traits in sunflower under drought stress, and it might be due to osmotic adjustment, maintenance of photosynthetic activity and assimilate partitioning to grain filling. In the present study, the increased seed yield due to salicylic acid @ 0.1 mM at 35 DAS could be due to more number of branches, higher dry matter accumulation and more number of pods per plant. Foliar application of salicylic acid @ 0.1mM at 35 DAS to the plants that were stressed from pod formation stage (M_2S_2) recorded higher seed yield (i.e. 1459.2 kg ha^{-1}), which was statistically at par with that of SA spray @ 0.1 mM at 35 DAS to the unstressed plants (i.e. 1590.9 kg ha^{-1}) and SA @ 0.01 mM at 35 DAS to the unstressed plants (1487.6 kg ha^{-1}).

CONCLUSION

From this study, it can be concluded that, chickpea plants are more sensitive to water stress from flowering stage rather than pod formation stage, and SA spray @ 0.1 mM at 35 DAS to the plants that were stressed from pod formation stage helped in mitigating the adverse effects of water stress and improved the growth and yield of chickpea under water stress.

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