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Evaluation of Mung Bean (*Vigna Radiata*) Under Drought Stress by Foliar Application of Salicylic Acid

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ABSTRACT

Fabaceae family is of much importance in terms of soil health and fertility concerns. There is a need to evaluate the member of this family under changing climatic conditions. For that purpose, a field experiment was conducted at the experimental farm to evaluate the salicylic acid role in the mung bean (Vigna radiata) under different drought stress conditions. During the summer seasons, the experiments were done at the agronomic research area at Bahauddin Zakariya University, Multan. Soil has been tested for soil fertility and mineral contents before sowing. This work aims to investigate the drought stress mitigation by the foliar application of the salicylic acid at the three levels (0 ppm, 100 ppm and 200 ppm) to mung bean grown in the agronomic field under semiarid conditions. Foliar application of Salicylic acid (SA) was applied after 20, 40, and 60 days after sowing (DAS) intervals by using the knapsack sprayer. For the complete water requirements, a total of four irrigation were applied and for drought conditions skipping the irrigation at 45 to 60 days after sowing. Mung bean treated with the SA improved the morphological characteristics (fresh and dry weight of shoot and whole plant, number of sympodial and monopodial branches, and leaf area index) as compared to the untreated plants that exposed under drought conditions. Foliar application the SA to mung bean also increases the yield related attributes like (plant height, pod length, number. of ods, no. of seeds per pods. 100 grain weight) all these parameters were higher than the untreated plants that grown under drought conditions. Ultimately with enough amount of water and foliar application of salicylic acid to the mung man enhance the biomass and economic yield than the untreated plants under drought conditions. In conclusion, the cultivation of the mung bean under the normal water conditions was more effective and give a high yield with the foliar application of the SA at 200 ppm as compared to the drought conditions.

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INTRODUCTION

Mung beans belong to the leguminacae family and are known as green gram and golden gram. After the cereal crops the legumes are in the second position of their role in the fixation of the atmospheric nitrogen for better soil fertility (Anjum et al., 2006). In developing countries mung bean is named as the poor's meat crop (Tabasum et al., 2010). Legumes contains secondary metabolites, micro and macro nutrients that enhance its quality more than other cereals (White and Brown, 2010). It is grown in that area where annual rainfall occurs about less than 250 to 400 mm the World-wide (Thomas et al., 2004). The production of mung bean is highly popular and it also important for nitrogen fixing ability. It can perform a function in antimicrobial and anti-insecticidal activities (Sadia et al., 2016) soil enrichment, low input requirements, and inhibition of soil erosion (Roychoudhury et al., 2016). Mung bean is the main source of amino acid and antioxidants like aspartic acid, isoleucine, glutamic acid, isoflavonoids, and leucienephenlylalanine (Lambrides and Godwin, 2007). In the seed of mung bean, it contains protein, vitamin, moisture, and carbohydrates about 26%, 3%, 10%, and 51% respectively. For better soil fertility and food of livestock residues of mung bean are also used (Asaduzzaman et al., 2008).

There are many environmental factors (Drought, salinity, water logging, heat, and cold) that disturb the metabolism of plants and may reduce their growth, development and plant productivity ultimately causing plant death (Fathi and Bararitari, 2016). The production of mung bean is very sensitive to the drought because it effects on the leaf area index, turgor pressure and reduce the plant growth and cell enlargement (Keykha et al., 2014). The reproductive stage of the mung bean is highly sensitive to the drought as compared to the vegetative (Sangakkara et al., 2001) stage so, it reduces the no. of pods per plant and low grain yield. At the flowering stage, it causes a hostile effect on the plant. Drought stress at the vegetative stage reduces the leaf area size, root development, and dry matter accumulation. Foliar spray of the different chemicals like salicylic acid, kinetin (Gunes et al., 2007; Karlidag et al., 2009), and glycine betaine may raise the yield of many crops by reducing the growth inhibitors and encourage the plant development (Elwana and El- Hamahmyb, 2009).

Salicyclic acid is a phenolic compound (C7H6O3) and considered as hormone that works as antioxidant, growth regulator and defense mechanism against many biotic and abiotic stresses (Yalpani et al., 1994; Szalai et al., 2000; Keykha et al., 2014). Scientists introduced that the application of the salicylic acid in the form of foliar spray regulates the plant growth (He et al., 2005; Khan et al., 2014) regulating the stomatal opening, ions, and nitrogen uptake. It regulates the enzymes and proteins activities and enhances the development (Sakhabutdinova et al., 2003; Khan et al., 2012) of other growth hormones (auxin, cytosine), cell division, and cell enlargement. Foliar application of the SA enhances the photosynthetic process and photosynthetic activity increases the sap flow in the leaf lamella (Khan et al., 2010) that rise the conservation of water content in the plant leaf to grow, reducing the drought conditions by losing the transpiration rate. If the rate of the salicylic acid is in low concentration, then it increases the antioxidant capacity of the plant and if its concentration is high then it effects on the plants cell to grow (Hara et al., 2012). It is one of the chemicals that enhance the seed per pods, no. pods per plant and seed weight per plant.

This study was conducted with the aim that Salicylic acid foliar application helps the plants to increase their growth under drought conditions. It will help the plant to increase its yield under water-deficit circumstances.

MATERIAL and METHODS

Experimental location

The experiment was conducted during the summer seasons at the Agronomic Research Area, at Bahauddin Zakariya University, Multan, Pakistan in 2018. According to the environment the atmosphere of the experimental location was semi-arid in nature.

Soil analysis:

The soil was analyzed for its fertility and other soil related parameters and soil samples were collected by using agar at a depth of 30 cm.

Different soil analyses were given in the below table (A) that is following.

Table A. Soil analysis

Measurements	Units
Sand	28.1%
pH	8.2
Phosphorous	6.30 ppm
Silt	51.3%
Total soluble salt	0.92%
Clay	18.9%
Saturation	37.00%
EC	3.42 dSm^{-1}
Potassium	127 ppm
Organic substance	0.83%
Texture class	Silt clay loam
Nitrogen	0.043%

The experiment was conducted in the RCBD (Randomized complete block design) with the factorial arrangement. With the three replicates, the size of the experimental plot was about 3m × 5m.

Table B. Components of experiment

Factor A (Drought conditions)	
D0	No drought
D1	Drought condition
Factor B (Salicylic acid treatment)	
T1	No treatment of SA
T2	100 ppm foliar spray of SA
T3	200 ppm foliar spray of SA

Soil preparation and crop husbandry

For the soil preparation, firstly round irrigation was applied. For proper soil moisture and better seedbed preparation two cultivations with the tractors' mounted cultivars were done to make the soil in workable conditions. The seed rate for the sowing was about 20 kg/ha. With the help of human driven drill manually the sowing was done on the 15th of March 2018. Seeds of NM-98 was used in this study that has been collected from the department of agronomy, Bahhaudin Zakariya University, Multan, Pakistan. Row to row and plant to land the distance was maintained 30 cm and 10 cm respectively. 20 kg nitrogen was applied in the split form, first at the basal stage and second at the flowering phase. 60 kg of phosphorous was applied at the basal stage. By using the knapsack sprayer foliar application of the salicylic acid was applied at the rate of 0.00 ppm, 100 ppm, and 200 ppm after the 20, 40, and 60 days of sowing. For the water requirements total of four irrigations were applied after thinning and weeding the harvesting of the crop was done on 15th June 2018.

Parameters

Standard methods have been applied to evaluate different parameters. Plant height has been observed by using meter using. For that purpose, randomly five plants have been selected. By using the standard methods, we analyzed the different parameters that were (The whole plant fresh and dry weight, plant height, leaf fresh and dry weight, shoot fresh and dry weight, number of sympodial and monopodial branches, no. of seeds per plant, 100 grain weight, pods length, no. of pods, biological and grain yield, harvest index, and leaf area index).

Statistical analysis

Data collected was analyzed statistically using Fisher's Analysis of Variance (ANOVA) technique. The least significant difference (LSD) test at $P \leq 0.05$ was applied to compare the treatment mean values (Steel et al. 1997) using Statistical Package Statistix 8.1 (Tallahassee Florida, USA)

RESULTS

Plant height (cm)

According to the statistical data plant height of the mung bean crop with the salicylic acid application, drought conditions and interaction with them had a highly significant effect on it (Table 1). At 200 ppm foliar spray of the SA there was a maximum plant height (54.35 cm) as compared to 100 ppm and the minimum plant height that was about (47.00 cm) was recorded at control treatment (no treatment of SA).

Furthermore, maximum plant height (52.90 cm) was observed where not any drought stress was applied. The interaction of the treatments between SA application at the 200 ppm and under the zero drought (Table 1) condition gives maximum lant height (58.01 cm) followed by the 100 ppm under no drought condition (51.22 cm) as compared to the drought stress (44.54 cm) and where not any SA application was applied.

Number of sympodial branches

A maximum number of sympodial branches (9.16) was observed at 200 ppm whereas the lowest number of branches (7.37) was observed under drought stress as the interaction with the treatments (Table 1) means maximum branches (10.11) was recorded where not any drought stress and 200 ppm SA given. While the minimum number of sympodial branches (6.82) was estimated at control treatment with the drought stress.

Number of monopodial branches

Highest number of monopodial branches (8.58) was observed at the 200 ppm Salicylic acid foliar spray followed by the 100 ppm (7.76). The lowest number of branches (6.80) was observed during the drought stress. Under the normal water condition maximum no. of monopodial branches (8.34) was recorded as compared to water stress (Table 1).

Pod length (cm)

The maximum pod length (8.65) of the mung bean was observed at 200 ppm of SA spray and a minimum length of the pod (7.60) was recorded under the drought stress conditions. The highest value was recorded (9.19) at the 100 ppm and in (Table 1) the absence of drought stress. On the other hand, the lowest length (6.87) of the pods was observed without not any SA spray but drought stress was applied.

Number of seeds per pods

At the 200 ppm there was the highest number of seed per pods (10.38) was observed and a minimum (8.60) was observed under control conditions. Without of water (Table 1) stress and under normal conditions highest number (10.22) of seed per pods was recorded.

Number of pods per plant

The maximum number (27.72) of pods per plant at the 200 ppm which was followed by 100 ppm (24.12) and the lowest value (21.07) was recorded where drought stress was applied.

On the other hand, at the 200 ppm and under no drought condition (Table 1) the maximum number of pods per plant was (31.32) followed by the (28.04) as compared to the drought stress (18.06) where not any SA was used.

Biological yield (kg/ha)

Foliar application of the salicylic acid at the 200 ppm shows the highest biological yield (3603.8 kg/ha) and the lowest value about (2504.0 kg/ha) showed where not any application applies. Similarly, the maximum yield was observed (3120.4 kg/ha) was observed under control conditions as compared to drought stress. The interaction of both factors gives the (Table 1) significant result that reported maximum yield (3871.0 kg/ha) at the 200 ppm under normal conditions. While, on the other hand, the minimum yield was observed (2364.7 kg/ha) under stress conditions.

100 grain weight

Statistical observed that maximum grain weight (6.38) was recorded at 200 ppm SA spray however, minimum grain yield (5.16) was recorded without application of the SA spray. Under normal conditions, the highest value was measured (6.22) as compared to the non-irrigated area.

Economic yield (kg/ha)

The highest yield (1252.4) at 200 ppm of SA was analyzed while a minimum (847.4) was noted (Table 1) where not any SA was used. The maximum result (1154.2) was observed under normal conditions than the drought stress.

Leaf area index

At 200 ppm maximum leaf area index (2.86) was obtained while (Table 1) minimum index (2.09) was observed under no application of the SA. Under the well-irrigated condition maximum leaf area (2.86) was observed as compared to drought stress.

Harvest index

Harvest index at the 100 ppm was maximum (36.56) as compared to the 200 ppm where the harvest index was (34.74). Under normal conditions (Table 1) maximum value was (37.69) than drought stress.

Shoot fresh weight (g)

(22.79) is the maximum value at the 200 ppm of the SA spray. under stress condition minimum shoot fresh weight was (16.68) as compared to enough (Table 1) water then the maximum value was (21.61) recorded. Interaction of the 200 ppm SA spray and under normal water conditions maximum shoot fresh weight (25.26) followed by the 100 ppm under no water stress (21.33) as compared to control (18.24) where salicylic acid was not applied.

Shoot dry weight (g)

The highest dry weight (7.18) of the shoot was observed at 200 ppm of foliar spray of salicylic acid and the lowest weight (4.84) at the 100 ppm without application of SA minimum dry weight (3.74) was measured. Similarly, under (Table 1) drought stress maximum values (5.92) were recorded and the interactive effect of 200 ppm the values was (8.14) followed by 100 ppm SA through the foliar spray under not any water stress.

Leaf dry weight (g)

Application of the salicylic acid at 200 ppm gives the maximum (20.90) leaf dry weight of mung bean. The plant that grows under drought stress produces a minimum (16.68) dry weight as compared to normal conditions. Maximum leaf dry weight (22.36) was measured at the interactive effect of 200 ppm SA and with not any water stress (Table 1).

Table 1. Results for different morphological parameters

	Plant Height (Cm)			No. of Sympodial Branches			No. of Monopodial Branches		
Treatment	Control	Drought	Means	Control	Drought	Means	Control	Drought	Means
T1	49.47 d	44.54 f	47.00 C	7.88 d	6.82 f	7.35 C	7.39	6.17	6.38 C
T2	51.22 b	46.37 e	48.79 B	8.37 b	7.07 e	7.72 B	8.78	6.74	7.76 B
T3	58.01 a	50.69 c	54.35 A	10.11 a	8.22 c	9.16 A	9,29	7.88	8.58 A
Means	52.90A	47.20B		8.79 A	7.370 B		8.34 A	6.80 B	
	Pod Length (Cm)			No. of Seed per Pod			No. of Pod per Plant		
T1	7.47 d	6.87 e	7.17 C	9.56	7.63	8.60 C	27.20 c	18.06 f	23.05 C
T2	8.55 b	7.82 c	8.19 B	10.48	9.32	9.90 B	28.04 b	21.04 e	24.12 B
T3	9.19 a	8.11 c	8.65 A	10.63	10.12	10.38 A	31.32 a	24.12 d	27.72 A
Means	8.40 A	7.60 B		10.22A	9.02 B		28.85 A	21.07 B	
	Biological Yield			100 Grain Weight			Economical Yield (Kg/ha)		
T1	2643.3 e	2364.7 f	2504.0 C	5.70	4.62	5.16 C	926.0	768.9	847.4 C
T2	2847.0 c	2743.7 d	2795.3 B	6.24	5.52	5.88 B	1189.4	860.4	1024.9 B
T3	3871.0 a	3336.7 b	3603.8 A	6.74	6.02	6.38 A	1347.3	1157.6	1252.4 A
Means	3120.4 A	2815.0 B		6.22 A	5.38 B		1154.2 A	928.9 B	
	Leaf Area Index			Harvest Index			Shoot Fresh Weight (g)		
T1	2.60	1.5	2.09 C	36.49	33.09	34.79 B	18.24 d	12.30 f	15.27 C
T2	2.93	2.02	2.48 B	41.77	31.35	36.56 A	21.33 b	17.42 e	19.37 B
T3	3.04	2.67	2.86 A	34.80	34.69	34.74 B	25.26 a	20.31 c	22.79 A
Means	2.86 A	2.09 B		37.69 A	33.04 B		21.61 A	16.68 B	
	Shoot Dry Weight (g)			Leaf Dry Weight (g)			Leaf Fresh Weight (g)		
T1	4.23 d	3.26 e	3.74 C	16.4 d	14.33 f	15.37 C	4.30 d	2.66 f	3.49 C
T2	5.40 c	4.28 d	4.84 B	18.49 c	16.29 e	17.39 B	6.30 b	4.15 e	5.24 B
T3	8.14 a	6.21 b	7.18 A	22.36 a	19.44 b	20.90 A	7.18 a	5.27 c	6.22 A
Means	5.92 A	4.59 B		19.08 A	16.68 B		5.94 A	4.02 B	
	Whole Plant Dry Weight (g)			Whole Plant Fresh Weight(g)					
T1	15.74 d	13.45 f	14.59 C	37.04 d	31.50 e	34.27 C			
T2	16.44 c	15.10 e	15.77 B	40.26 c	37.33 d	38.80 B			
T3	19.53 a	17.34 b	18.43 A	46.36 a	41.46 b	43.91 A			
Means	17.23 A	15.30 B		41.22 A	36.76 B				

Values are means of 3 replicates ± S.D. These different lettering shows significant variation among the treatment means at $P \leq 0.05$.

Leaf fresh weight (g)

At 200 ppm application of SA more leaf fresh weight (6.22) calculated of mung bean. Mung beans grow (Table 1) under drought stress gave minimum weight (4.02) as compared to normal. At the interactive effect of 200 ppm and normal maximum (7.18) leaf fresh weight was observed.

Crop growth rate

Periodic data regarding to (CGR) crop growth rate showed that the application of SA had a significant effect on the producing the maximum CGR as compared to control (Figure 1). Data reported that crop growth rate of mung bean increase from the 30 to 70 days of sowing. Maximum growth rate was reported at the 200 ppm as compared to other treatments as well as where drought was applied. The minimum crop growth rate was analyzed where drought stress was applied, and no SA foliar spray was given.

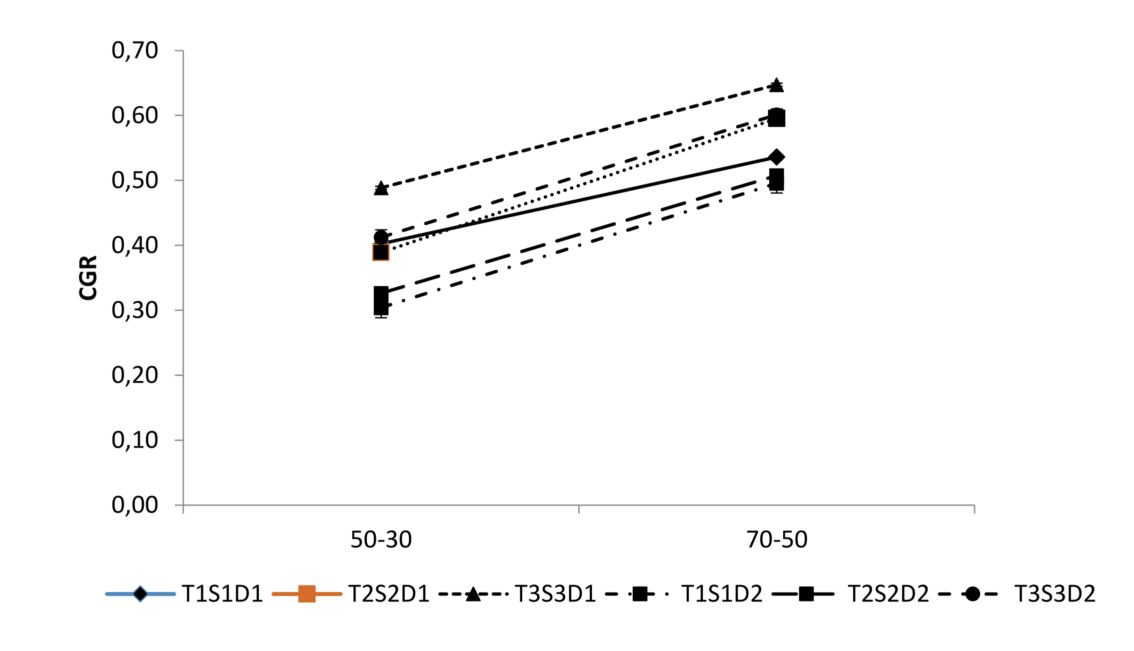

Figure 1. Result of foliar use of salicylic acid on crop growth rate of mung bean plant

Whole plant dry weight (g)

Maximum plant dry weight (18.43) measured at 200 ppm SA foliar spray. Minimum (15.30) reported where drought stress applied. Interaction of both 200 ppm and (Table 1) normal condition gave the highest (19.53) plant dry weight.

Whole plant fresh weight (g)

Whole plant fresh weight at the 200 ppm gave maximum (43.91) values. At the drought stress, there was a minimum value (36.76) of the (Table 1) whole plant fresh weight measured. Combine interaction of the 200 ppm and normal condition give (46.36) the highest values.

DISCUSSION and CONCLUSION

Drought stress is one of the important environmental factors that effects the plant growth and development. Even a short duration of drought creates a huge loss of yield of various crops. Water stresses reduce the plant height which effect the plant growth due to hormonal imbalance that take place on cell wall extensibility (Zhao et al., 2006). In this study at 200 ppm foliar application of SA produces maximum plant growth, height, no. of seeds per pods, leaf area and sympodial and monopodial branches. But all these parameters reduce under drought stress which showed that deficient of water severely effects on crop yield. Reduction of plant height under water stress occurred due to dehydration of the protoplasm, loss of turgidity, and low water potential that ultimately effect on the cell division and cell elongation (Hussain et al., 2008). The ABA accumulation under drought stimulates growth at water deficit due to the suppression of ethylene production (Yamaguchi and Sharp, 2010). Sympodial and monopodial branches define the plant height, plant yield, and straw yield. If the plant height is maximum, then it discloses the maximum sympodial and monopodial branches that enhance the yield productivity. Plant growth duration under different climate condition is badly effected by drought stress (Shao et al., 2016) and scarcity of water create a major problem for crop yield. If one plant has maximum sympodial and monopodial branches, then a number of pods significantly enhance which exposes the maximum grain yield of mung bean. For the positive enhancement in plant height, 100 grain weight, number of branches, number of pods per plant and economic yield there is a need for foliar spray of salicylic acid in many crops of the mung bean (Ali and Mahmoud, 2013). Analyzed data showed significant effect of the sympodial and monopodial branches under drought stress and different SA concentrations. Interaction between factors also showed a significant behavior. According to Sadia et al., (2016) study, Irrigation missing at the flowering stage, affected less the growth and yield as compared with irrigation missing at both flowering and pod formation stages. Pods length, a number of pods per plant, and number of seed per pods showed the significantly effect on the drought stress and at different levels of foliar spray of salicylic acid. It is reported that mung bean needs the optimum irrigation the required time and demand for its better reproductive stage and yield and crop production (Malik et al., 2011). The number of seeds per pods and number of pods per plant expresses the all over grain yield of the mung bean. Pods length, number of pods per plant and number of seeds per pod are enhanced by the sufficient application of the irrigation, nutrients amount, and salicylic acid application. In the black gram the rate of a grain production increase by the salicylic acid application (Jayakumar et al., 2008). The productivity of mung bean demonstrated by the number of pods per plant and number of seed per pods. Biological yield is extremely affected when the drought occurs at the flowering stage and pod filling setting in many leguminous crop (Liu et al., 2003). Biological yield showed the significant behavior at various levels of SA and interaction between these factors exposed significant behavior. The interaction between drought and salicylic acid in the 100-grain weight and economic yield showed the non-significant although both showed the positively significant effect as individual treatment. Both green house and under field conditions the use of salicylic acid enhanced the yield of faba bean (El- Hendawy et al., 2010). Leaf area index is important for the measurement of the photosynthetic activities. A higher leaf area means that there is high chance of photosynthetic action. Maximum sun light absorbs by the leaf area, higher the PSI and PSII higher rate of foods production, and ultimately give high quality yield. Roychoudhury et al., (2016) states that, seed priming with SA at the pre-sowing stage holds a great promise as a traditional method of agriculture in growing commercially important plants like V. radiata. It is considered that plant get tolerance against water stress by the enhancement of salicylic acid, and it work as antioxidant (Sreenivasulu et al., 2000). Harvest index and leaf area index, both factors showed the non-significant effect but there were highly significant effects of leaf area index of mung bean at different levels and at drought stress. Shoot fresh and dry weight of mung bean plant expressed the positively affects at the different levels of SA and drought treatment. There was also significantly relation under both factors. High growth and development of plant under drought stress supposed to be due to application of SA that reduce the activity of reactive oxygen species in the plants and speed up the antioxidant activity (Daneshmand et al., 2010). Leaf fresh and dry weight both showed the highly positive significant relationship at different levels of salicylic acid and drought stress. Under both factors there was also a significant effect between leaf fresh and dry weight. The enhancement of vegetative growth, yield, 100 grain weight, number of pods per pant and plant height is due to NPK content and by the foliar spray of salicylic acid (Ali et al., 2013). Crop growth rate highly significant at the SA foliar spray and drought stress. Maximum crop growth rate of mung bean observed at the application of salicylic acid and at the well water application as compared to other treatment as well as drought application. Minimum crop growth rate observed where drought was given and not any salicylic applied. Maximum green pods and pods related yield attributes values gained by foliar spray of salicylic acid in pea plants. Whole plant fresh and dry weight showed significantly effect on the SA foliar spray also under drought condition. Under both factors the whole plant fresh and dry weight of mung bean expressed highly significant behavior. Spraying of salicylic acid at 150 ppm in the snap bean improve the number of branches, quality of grains, fresh and dry weight, pod yield, total weight, pods setting and number of pods (Kmal et al., 2006).

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Conflict of Interest Statement

The authors have declared that there is no competing interest.

Authors' Contributions

All authors have equally contributed.

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