The Andhra Agric. J 65 (4): 146-154, 2018

Effect of Seed Pre - Treatment and Foliar Application of Zinc on Growth and Yield of Mungbean (*Vigna radiata* L.) under Water Stress

B Srikanth, K Jayalalitha, Y Ashoka Rani and M Sree Rekha

Department of Crop Physiology, Agricultural College, Bapatla,A.P.

ABSTRACT

A field experiment was conducted during *rabi* season of 2017-18 at Agricultural College Farm, Bapatla to investigate the effect of seed pre - treatment and foliar application of zinc on growth and yield of mungbean under water stress. The experiment was laid out in split plot design with three replications consists of two main treatments and seven sub treatments. The results revealed that, mungbean plants subjected to water stress from flowering stage decreased the plant height and number of branches 5.0 and 14.7 per cent, respectively, compared to control (i.e. irrigated) plants. Number of pods plants^{-1}, 100 - seed weight and seed yield decreased by 23.0, 6.0 and 33.6 per cent, respectively, due to water stress from flowering stage. Among zinc treatments, foliar spray of zinc @ 500 ppm at 30 DAS significantly increased the plant height, number of branches and seed yield by 21.6, 20.9 and 55.2 per cent, respectively, over untreated control. In the present study, foliar spray of zinc @ 500 ppm at 30 DAS increased the yield and yield components of mungbean both under irrigated as well as water stress conditions. Under water stress conditions, zinc spray @ 500 ppm at 30 DAS increased the number of pods plants^{-1} and seed yield by 17.0 and 42.0 per cent, respectively, over unsprayed plants.

Key words: *Foliar application, Mungbean, water stress, seed treatment, Seed yield, Zinc.*

Mungbean (*Vigna radiata* L.) is an important pulse crop in arid and semi-arid regions, cultivated for edible green pods and dry seeds having high nutritive value. Its seed contains 24.2% protein, 1.3% fat and 60.4% carbohydrate. The average yield of mungbean is quite low which requires attention of the crop experts. Among the various factors influencing the growth and yield of mungbean, water stress is the one which occurs more frequently during the crop growth and thus leading to poor yields. The decrease in crop biomass production and yield was frequently observed in response to water deficit in mungbean (Miah and Carangal, 2001). Though, it is sensitive to water stress at all growth stages, it is more sensitive to drought at flowering and grain development stages (Zubair *et al*., 2002 and Thalooth *et al*., 2006).

Zinc is an essential micronutrient which is involved in many physiological functions such as auxin biosynthesis, activation of dehydrogenase enzymes and stabilization of ribosomal fractions (Aghatise and Tayo, 1994), protein and carbohydrate synthesis (Yadavi *et al*., 2014). It is essential for the biosynthesis of the carbonic anhydrase enzyme required for chlorophyll biosynthesis (Xi-Wen *et al*., 2011 and Rehman *et al*., 2012), and also as a key constituent of alcohol dehydrogenase and superoxide dismutase (Welch *et al*., 1982). Zinc application in maize improves photosynthetic rate, chlorophyll synthesis, nitrogen metabolism and resistance to both biotic and abiotic stresses (Ali *et al*., 2008; Mousavi, 2011 and Yosefi *et al*., 2011). The application of zinc under drought conditions would influence crop yield and quality. It plays a significant role in regulating stomatal opening and closing and ionic balance in crops and reduces the detrimental effects of drought (Moghadam *et al*., 2013 and Monjezi *et al*., 2013), and also has protective effects on oxidative damage caused by ROS in response to stresses (Akbari *et al*., 2013). The research work on foliar application of zinc on greengram was scanty. Hence the study was taken up to understand effect of foliar application of zinc on growth and yield of greengram.

MATERIAL AND METHODS

A field experiment was conducted during *rabi* season of 2017 at Agricultural College Farm, Bapatla. The average temperature during the crop period varied from 30.53 ^{0}C and 18.16 ^{0}C. The total amount of rainfall received during the crop growth period was 23.8 mm in four rainy days. Weekly mean relative humidity ranged from 90.29% to 81.43%. The experiment was laid out in split plot design with three replications keeping no stress i.e. control (M_0) and stress from flowering stage (i.e. from 30 DAS) up to harvest (M_1) as main plots and seven sub treatments viz., no zinc application (S_0), seed treatment with 0.05% $ZnSO_4$

solution for 5 hrs before sowing (S_1), seed treatment with 0.075% $ZnSO_4$ solution for 5 hrs before sowing (S_2), foliar spray of 300 ppm $ZnSO_4$ at 30 DAS (S_3), foliar spray of 400 ppm $ZnSO_4$ at 30 DAS (S_4), foliar spray of 500 ppm $ZnSO_4$ at 30 DAS (S_5) and water spray at 30 DAS (S_6). The variety used in this study was LGG 460. Nitrogen and phosphorus fertilizers were applied as per the recommendation (20 kg N and 50 kg P_2O_5 ha^{-1}) before sowing of the crop. Experimental plots were protected from pest and diseases by spraying of chlorpyriphos @ 2.5 ml L^{-1} at the initial stage of the crop growth. Manual weeding was done at 15 days interval up to pod setting. Irrigation was given for control (M_0) as per the irrigation schedule up to harvest, and irrigation was withhold for M_1 treatment from flowering stage (i.e. from 30 DAS) up to harvest. Foliar spray of $ZnSO_4$ was done at flowering stage (i.e. at 30 DAS). The observation on plant height and number of branches were recorded at 15, 30, 45 and 60 DAS. The yield and yield components were recorded at harvest. The data was statistically analyzed by following analysis of variance (ANOVA) technique suggested by Panse and Sukhathme, (1978) for split plot design.

RESULTS AND DISCUSSION

During the crop growth period, the weekly mean maximum temperatures ranged from 29.94^{0}C to 31.90^{0}C and the weekly mean minimum temperatures ranged from 16.48^{0}C to 22.91^{0}C, while the average maximum and minimum temperature during the crop growth period were 30.53^{0}C and 18.16^{0}C, respectively. The weekly mean relative humidity ranged from 81.43 to 90.29 per cent with an average of 86.46 per cent. A total rainfall of 23.8 mm was received in four rainy days during first week of sowing. Later, there was no rainfall received, and the crop was exposed to water stress from flowering to maturity stage (i.e. treatment M_1). Control was maintained by providing irrigation as per the irrigation schedule (i.e. no stress). The soil moisture measured at different depths at the time of sowing was 26.23 and 26.36 per cent at 15-30 cm depth, and 24.24 and 24.28 per cent at 30-45 cm depth in M_0 and M_1 treatments, respectively. At 15 DAS, the soil moisture was 25.97 and 26.05 per cent at 15-30 cm depth, and 22.71 and 22.78 per cent at 30-45 cm depth in M_0 and M_1 treatments, respectively. At 30 DAS, the soil moisture was 25.39 and 24.46 per cent at 15-30 cm depth, and 22.05 and 21.69 per cent at 30-45 cm depth in M_0 and M_1 treatments, respectively. The soil moisture depleted from 24.46 to 20.39 per cent at 15-30 cm and 21.69 to 17.59 per cent at 30-45 cm depth from 30 to 45 DAS, and 20.39 to 17.28 per cent at 15-30 cm and 17.59 to 14.15 per cent at 30-45 cm depth from 45 to 60 DAS in the plots which received no irrigation from flowering stage (i.e. M_1 treatment).

Morphological Parameters

Plant Height (cm)

The data pertaining to the plant height as affected by water stress and zinc treatments were recorded at 15 days interval from 15 to 60 DAS were presented in Table 1. In all the treatments, there was a gradual increase in plant height from 15 to 60 DAS. At 15 and 30 DAS, significant differences were not noted among the main treatments and interactions, but the sub treatments significantly differed from 15 DAS onwards. Among the main treatments, significant differences were observed only after 30 DAS. At 45 and 60 DAS, the plants that were stressed from flowering stage recorded significantly lesser plant height (M_1 – 33.62 and 35.43 cm, respectively) compared to control i.e. no stress (M_0 – 35.51 and 37.30 cm, respectively). The plants that were stressed from flowering stage recorded 5.0 per cent reduction in plant height over control plants (i.e. no stress). Similar significant reduction in plant height due to drought stress was also recorded by Shahri *et al*. (2012). Increasing drought stress resulted in decrease in plant height, so the highest plant height was obtained with control. Drought stress lead to a reduction in water potential of stem cells to a lower level that is needed for cell elongation and consequently, shorter internodes and stem height. Amin *et al*. (2009) reported that reduction in plant growth under drought stress was due to the adverse effect of drought on the turgor pressure of cells resulting in a lower cell expansion rate and reduction in the metabolic activities of plant cells.

Among the sub treatments, significant differences were observed at 15, 30, 45 and 60 DAS. At 15 DAS, pre – soaking of seeds with zinc @ 0.075% before sowing was recorded higher plant height (S_2 – 18.60 cm) compared to seed pre - treatment with zinc @ 0.05% (S_1 – 17.77 cm) and other zinc treatments. The treatment S_1 recorded significantly higher plant height than other treatments, but inferior to S_2. The remaining treatments were on par with each other, and lesser plant height was recorded by S_0 (i.e. no zinc application – 16.03 cm). At 30 DAS, pre - soaking of seeds with zinc @ 0.075% recorded significantly higher plant height (S_2 – 32.17 cm) compared to seed pre - treatment with zinc @ 0.05% (S_1 – 30.57 cm) and other treatments. The remaining treatments were on par with each other. At 45 and 60 DAS, the highest plant height was recorded by foliar application of zinc @ 500 ppm at 30 DAS (S_5 – 38.63 and 40.37 cm, respectively), followed by zinc spray @ 400 ppm at 30 DAS (S_4 – 36.27 and 38.03 cm, respectively) and seed pre - soaking with zinc @ 0.075% before sowing (S_2 – 35.20 and 36.97 cm, respectively), where as the lowest plant height was recorded by the treatment where zinc was not applied (S_0 – 31.40 and 33.20 cm, respectively). Foliar spray of water (S_6) recorded significantly higher plant height compared to control (S_0), but lesser plant height compared to other zinc treatments. In the present study, foliar spray of zinc @ 500 ppm exhibited superior performance in increasing the plant height by 21.6 per cent over control (i.e. no spray). These results are in agreement with the findings of Ali and Mahmoud (2013), who reported that the highest plant height was recorded with foliar spray of zinc @ of 500 ppm in mungbean. Zinc actively involved in auxin production which increases the cell size and number thus increases the plant height (Dashadi *et al*., 2013.)

Number of branches per plant

The data pertaining to the effect of water stress and zinc treatments on number of branches was recorded at 30, 45 and 60 DAS were presented in Table 2. In all the treatments, number of branches increased from 30 to 60 DAS. Significant differences were found among the main treatments, sub treatments and their interactions. At 45 and 60 DAS, significant difference was observed between main treatments. The plants that were subjected to water stress from flowering stage recorded less number of branches (M_1 – 8.31 and 9.92, respectively) compared to control (irrigated) plants (M_0 – 9.75 and 11.63). The decrease in number of branches in water stress treatment (M_1) is 17.3 and 14.7 per cent compared to control plants (M_0). Uddin *et al*. (2013) reported that, as the water stress increased, the number of branches and leaves plant^{-1} decreased, and this indicated that water stress had direct effect on initiation of branches and leaves. Ranawake *et al*. (2011) found that water stress affects the crop phenology, leaf area development and number of leaves of mungbean.

Among the sub treatments, significant differences were observed at 30, 45 and 60 DAS. At 30 DAS, seed pre - treatment with zinc @ 0.075% before sowing recorded significantly more number of branches per plant (S_2 – 5.97) compared to seed pre - treatment with zinc @ 0.05% (S_1 – 5.67). The remaining treatments except S_1, were at par with each other. The treatment S_1 is significantly superior over other treatments and inferior to S_2 in recording the number of branches per plant. At 45 and 60 DAS, foliar spray of zinc @ 500 ppm at 30 DAS recorded the highest number of branches per plant (S_5 – 9.94 and 11.85, respectively), followed by seed pre - treatment with zinc @ 0.075% before sowing (S_2 – 9.51 and 11.35, respectively) and zinc foliar spray @ 400 ppm at 30 DAS (S_4 – 9.30 and 11.09, respectively). The lowest number of branches per plant was recorded by untreated control (S_0 – 8.22 and 9.80, respectively). In the current study, the increase in number of branches per plant was 20.9 and 15.8 per cent with foliar spray of zinc @ 500 ppm at 30 DAS and seed pre - treatment with 0.075% zinc before sowing, respectively, over untreated plants. Thalooth *et al*. (2006) reported that, foliar application of 300 ppm Zn – EDTA at 30 and 50 DAS increased the plant height, number of branches per plant and stem dry weight per plant in mungbean. Such enhancement effect might be attributed to the stimulating effect of zinc on photosynthetic pigments and enzyme activity which in turn encourages vegetative growth of plants.

Among the interactions, significant difference was observed at 45 and 60 DAS. At 60 DAS, foliar spray of zinc @ 500 ppm at 30 DAS to the irrigated plants recorded the maximum number of branches per plant (M_0S_5 – 12.56), whereas the minimum number of branches per plant was recorded by the plants that were subjected to water stress from flowering stage with no zinc treatment (M_1S_0 – 9.00). The plants that were subjected to water stress from flowering with zinc spray @ 500 ppm at 30 DAS recorded significantly more number of branches (M_1S_5 – 11.15) compared to irrigated plants with no zinc application (M_0S_0 – 10.60). Monjezi *et al*. (2013) found that, drought stress on wheat reduced the plant height and number of tillers, but with zinc application significantly increased the plant height and number of tillers. Hence, present results indicate that zinc spray can decrease the negative effects of drought stress on morphological parameters of mungbean.

Yield Attributes and Yield

Number of Pods per Plant

The data pertaining to yield and yield attributes as affected by water stress and zinc treatments at harvest were furnished in Table 3. The data presented in Table 3 showed that, water stress from flowering stage significantly decreased the yield and yield components of mungbean. Among the main treatments, the plants that were subjected to water stress from flowering stage significantly decreased the number of pods per plant (M_1 – 18.81) compared to control i.e. irrigated plants (M_0 – 24.44). Water stress decreased the number of pods per plant by 23.0 per cent over control plants. These results are in agreement with those obtained by Thalooth *et al*. (2006), who reported that subjecting mungbean plants to water stress at pod formation stage caused the highest reduction in number of pods per plant, pod dry weight, number of seeds per pod, test weight and seed yield, whereas stress at flowering came in the second order with respect to the above parameters.

Significant difference was noted among the sub treatments pertaining to number of pods per plant. Among the zinc treatments, foliar spray of zinc @ 500 ppm at 30 DAS recorded the highest number of pods per plant (S_5 – 24.06), followed by zinc foliar spray @ 400 ppm at 30 DAS (S_4 – 22.92) and seed pre - treatment with zinc @ 0.075% before sowing (S_2 – 22.55). The lowest number of pods per plant was recorded by untreated plants (S_0 – 19.29) followed by foliar spray of water (S_6 – 19.87). In the present study, foliar spray of zinc @ 500 and 400 ppm at 30 DAS and seed pre - treatment with zinc @ 0.075% before sowing increased the number of pods per plant by 24.7, 18.8 and 16.9 per cent over untreated plants. Rahman *et al*. (2015) also reported that, zinc application (3.0 kg ha^{-1}) recorded the highest plant height, number of branches per plant, number of pods per plant and number of seeds per pod in mungbean. This enhancement might be due to the crucial role of zinc in the synthesis of proteins and carbohydrate metabolism.

Significant difference was also noticed among the interactions. The highest number of pods per plant was recorded by irrigated plants that were sprayed with zinc @ 500 ppm at 30 DAS (M_0S_5 – 27.85), whereas the lowest number of pods per plant was obtained with water stressed plants from flowering with no zinc treatment (M_1S_0 – 17.34). Under water stress condition, foliar spray of zinc @ 500 ppm at 30 DAS recorded more number of pods per plant (M_1S_5 – 20.28) compared to the plants that were stressed from flowering with no zinc treatment (M_1S_0 – 17.34).In the current study, foliar spray of zinc @ 500 ppm at 30 DAS increased the number of pods per plant both under irrigated as well as water stress conditions.

Number of Seed per Pod

The statistical analysis of data (Table 3) revealed that, there was no significant difference between main treatments and interactions, but the sub treatments differed significantly pertaining to number of seeds per pod. Among the sub treatments, the maximum number of seeds per pod was recorded by foliar spray of zinc @ 500 ppm at 30 DAS (S_5 – 7.00), which was at par with other zinc treatments (i.e. S_4, S_2 and S_3) except S_1 treatment. The treatment S_1 is superior to control plants (untreated) and inferior to other zinc treatments. The minimum number of seeds per pod was obtained with untreated i.e. control plants (S_0 – 5.83) which was at par with foliar spray of water at 30 DAS (S_6 – 5.83). Foliar spray of zinc @ 500 ppm at 30 DAS increased the number of seeds per pod by 20.0 per cent, over untreated plants. Thalooth *et al*. (2006) reported that, foliar application of 300 ppm Zn – EDTA at 30 and 50 DAS had stimulatory effect on pods $plant^{-1}$, pods dry weight, number of seeds pod^{-1} and seed yield in mungbean. Ved *et al*. (2002) stated that foliar applied zinc enhances photosynthesis, early growth of plants, improves nitrogen fixation, grain protein and yield of mungbean.

100 Seed Weight

Significant difference was observed among the main treatments and sub treatments pertaining to 100 - seed weight of mungbean. Interaction was non significant. 100 - seed weight was decreased (Table 3) in water stress treatment (M_1 – 3.31 g) compared to control (M_0 – 3.52 g). The plants that were subjected to water stress from flowering recorded 6.0 per cent decrease in 100 - seed weight compared to control i.e. normal irrigated plants. The development of reproductive organs, which is under the control of photo - assimilate production and partitioning by the source tissues, is the most critical from flowering up to maturity stage. Therefore, increased drought at this stage has a pronounced effect on fruit development and yield (Uddin *et al*., 2013). Similar results were also reported by Moradi *et al*. (2008) in mungbean, and found that reproductive phase was more sensitive to water deficit. The early stage of pod development was characterized by active cell division in the young ovules and rapid pod expansion. The yield loss caused by drought stress was mainly due to an increased rate of floral abortion (Liu *et al*., 2003).

Among the sub treatments, foliar application of zinc @ 500 ppm at 30 DAS recorded the highest 100 - seed weight (S_5 – 3.48 g), and the lowest was recorded by untreated control (S_0 – 3.37 g). Foliar spray of zinc @ 400 ppm at 30 DAS (S_4 – 3.45 g) and seed pre - treatment with zinc @ 0.075% before sowing (S_2 – 3.44 g) came in the second order with respect to 100 - seed weight. Zinc foliar spray @ 500 ppm at 30 DAS increased the 100 - seed weight by 3.3 per cent, over untreated plants. Shahri *et al*. (2012) found that foliar application of zinc @ 1.0% two weeks before and two weeks after flowering increased the 100 - seed weight of sunflower compared to control (Zn_0).

Seed Yield

The data pertaining to the effect of water stress and zinc treatments on seed yield of mungbean were presented in Table 3. Significant differences were observed among the main, sub treatments and their interactions. Among the main treatments, water stress from flowering stage significantly decreased the seed yield of mungbean (M_1 – 1270.72 kg ha^{-1}) compared to control i.e. irrigated plants (M_0 – 1913.02 kg ha^{-1}). Water stress from flowering decreased the seed yield by 33.6 per cent over control plants. Thalooth *et al*. (2006) stated that irrigation is critical during flowering and pod filling stages in mungbean plants mainly because of higher leaf area index during these periods and consequently, greater demand for water. He reported that, subjecting mungbean plants to water stress at pod formation stage caused the highest reduction in number of pods per plant, pod dry weight,

Table 1. Effect of zinc on plant height (cm) of mungbean under water stress

TREATMENTS	15 DAS			30 DAS			45 DAS			60 DAS		
	M_0	M_1	Mean	M_0	M_1	Mean	M_0	M_1	Mean	M_0	M_1	Mean
S_0 : No Zinc application	16.07	16.00	16.03	27.87	27.80	27.83	32.20	30.60	31.40	33.93	32.47	33.20
S_1 : Seed treatment with Zinc @ 0.05% before sowing	17.67	17.87	17.67	30.53	30.60	30.57	34.67	33.13	33.90	36.60	34.93	35.77
S_2 : Seed treatment with Zinc @ 0.075% before sowing	18.60	18.60	18.50	32.27	32.07	32.17	36.13	34.27	35.20	37.87	36.07	36.97
S_3 : Foliar spray of Zinc @ 300 ppm at 30 DAS	15.87	16.27	16.00	27.60	27.73	27.67	34.93	33.20	34.07	36.73	35.00	35.87
S_4 : Foliar spray of Zinc @ 400 ppm at 30 DAS	16.13	16.20	16.10	27.93	27.93	27.93	37.40	35.13	36.27	39.13	36.93	38.03
S_5 : Foliar spray of Zinc @ 500 ppm at 30 DAS	16.07	16.20	16.03	28.00	27.73	27.87	40.20	37.07	38.63	41.93	38.80	40.37
S_6 : Foliar spray of water at 30 DAS	16.27	16.40	16.33	27.73	28.33	28.03	33.07	31.93	32.50	34.87	33.80	34.33
Mean	16.67	16.79		28.85	28.89		35.51	33.62		37.30	35.43	
	SEm±	CD	CV	SEm±	CD	CV (%)	SEm±	CD	CV	SEm±	CD	CV (%)
Main	0.15	NS	4.01	0.17	1.03	2.7	0.18	1.07	2.33	0.17	1.03	2.14
Sub	0.15	0.42	2.18	0.25	0.74	2.16	0.26	0.75	1.83	0.26	0.75	1.74
Interactions	0.21	NS		0.36	1.05		0.36	1.06		0.37	1.07	

Table 2. Effect of zinc on number of branches of mungbean under water stress

TREATMENTS	30 DAS			45 DAS			60 DAS		
	M_0	M_1	Mean	M_0	M_1	Mean	M_0	M_1	Mean
S_0 : No Zinc application	5.00	4.87	4.93	8.89	7.54	8.22	10.60	9.00	9.80
S_1 : Seed treatment with Zinc @ 0.05% before sowing	5.60	5.73	5.67	9.77	8.19	8.98	11.65	9.77	10.71
S_2 : Seed treatment with Zinc @ 0.075% before sowing	5.93	6.00	5.97	10.20	8.82	9.51	12.17	10.52	11.35
S_3 : Foliar spray of Zinc @ 300 ppm at 30 DAS	5.27	5.00	5.13	9.48	7.95	8.72	11.32	9.49	10.40
S_4 : Foliar spray of Zinc @ 400 ppm at 30 DAS	5.00	4.93	4.97	10.04	8.56	9.30	11.97	10.21	11.09
S_5 : Foliar spray of Zinc @ 500 ppm at 30 DAS	4.80	5.00	4.90	10.53	9.34	9.94	12.56	11.15	11.85
S_6 : Foliar spray of water at 30 DAS	5.00	5.00	5.00	9.32	7.74	8.53	11.16	9.33	10.24
Mean	5.23	5.22		9.75	8.31		11.63	9.92	
	SEm±	CD	CV (%)	SEm±	CD	CV (%)	SEm±	CD	CV (%)
Main	0.1	NS	5.38	0.03	0.17	6.25	0.03	0.16	8.52
Sub	0.08	0.24	3.9	0.04	0.12	4.14	0.05	0.14	5.32
Interactions	0.12	NS		0.06	0.17		0.07	0.2	

Table 3. Effect of zinc on yield components and yield of mungbean under water stress

TREATMENTS	No.of pods plant-1			No.of seeds pod-1			100 seed weight			Seed yield (Kg ha-1)		
	M_0	M_1	Mean	M_0	M_1	Mean	M_0	M_1	Mean	M_0	M_1	Mean
S_0 : No Zinc application	21.24	17.34	19.29	6.00	5.67	5.83	3.48	3.26	3.37	1476.67	1069.69	1273.18
S_1 : Seed treatment with Zinc @ 0.05% before	23.92	18.75	21.33	6.33	6.00	6.17	3.51	3.30	3.40	1769.77	1237.91	1503.84
S_2 : Seed treatment with Zinc @ 0.075% before	25.63	19.47	22.55	7.00	6.33	6.67	3.54	3.33	3.44	2111.76	1366.91	1739.33
S_3 : Foliar spray of Zinc @ 300 ppm at 30 DAS	24.10	18.57	21.33	6.67	6.00	6.33	3.52	3.31	3.42	1881.25	1228.51	1554.88
S_4 : Foliar spray of Zinc @ 400 ppm at 30 DAS	26.51	19.33	22.92	7.00	6.33	6.67	3.55	3.35	3.45	2194.61	1363.02	1778.81
S_5 : Foliar spray of Zinc @ 500 ppm at 30 DAS	27.85	20.28	24.06	7.33	6.67	7.00	3.58	3.37	3.48	2435.67	1517.31	1976.49
S_6 : Foliar spray of water at 30 DAS	21.83	17.92	19.87	6.00	5.67	5.83	3.49	3.29	3.39	1521.40	1111.68	1316.54
Mean	24.44	18.81		6.62	6.10		3.52	3.31		1913.02	1270.72	
	SEm±	CD	CV (%)	SEm±	CD	CV (%)	SEm±	CD	CV (%)	SEm±	CD	CV (%)
Main	0.04	0.24	8.63	0.18	NS	12.8	0.006	0	8.25	49.41	300.63	14.22
Sub	0.07	0.2	7.48	0.26	0.8	10	0.005	0	6.34	59.71	174.27	9.19
Interactions	0.1	0.28		0.37	NS		0.007	NS		84.44	246.46	

number of seeds per pod, seed dry weight per plant and seed yield, whereas stress at flowering came in the second order with respect to above parameters, while early stress at vegetative stage has more detrimental effect on straw and biological yield.

The seed yield of mungbean among the sub treatments ranged from 1273.18 to 1976.49 kg ha^{-1}. Foliar spray of zinc @ 500 ppm at 30 DAS recorded the highest seed yield (S_5 – 1976.49 kg ha^{-1}), and the lowest seed yield was recorded by untreated control (S_0 – 1273.18 kg ha^{-1}). Foliar spray of zinc @ 400 ppm at 30 DAS (S_4 – 1778.81 kg ha^{-1}) was at par with seed pre - treatment with zinc @ 0.075% before sowing (S_2 – 1739.33 kg ha^{-1}), which came in the second order with respect to seed yield of mungbean. Foliar spray of water at 30 DAS (S_6 – 1316.54 kg ha^{-1}) was also at par with untreated control. Zinc foliar spray @ 500 ppm at 30 DAS increased the seed yield by 55.2; 400 ppm zinc spray at 30 DAS by 39.7 and seed pre – treatment with zinc @ 0.075% before sowing by 36.6 per cent over untreated plants. In the present study, increasing zinc concentration caused increase in seed yield of mungbean. Ved *et al*. (2002) stated that, foliar applied zinc enhances photosynthesis, early growth of plants, improves nitrogen fixation, grain protein and yield in mungbean. Significant positive effect of zinc treatment was found on dry matter, seed and straw yield of mungbean as well as crude protein % in the seeds (Krishna, 1995).

As for the interaction effect of water stress and zinc treatments, Table 3 revealed that the highest seed yield was recorded by the plants irrigated regularly (control) and sprayed with zinc @ 500 ppm at 30 DAS (M_0S_5 – 2435.67 kg ha^{-1}), whereas the lowest seed yield was recorded by the plants that were stressed from flowering stage with no zinc application (M_1S_0 – 1069.69 kg ha^{-1}). In the present study, foliar spray of zinc @ 500 ppm at 30 DAS to the plants that were subjected to water stress from flowering stage (M_1S_5 – 1517.31 kg ha^{-1}) recorded the seed yield which is at par with irrigated plants with no zinc application (M_0S_0 – 1476.67 kg ha^{-1}).

CONCLUSION

Thus it can be concluded that foliar spray of zinc @ 500 ppm at 30 DAS increased the seed yield of mungbean both under irrigated as well as water stress conditions.

LITERATURE CITED

Aghatise V O and Tayo T O 1994 Response of mungbean to zinc application in nigeria. *Indian Journal of Agriculture Sciences*. 64 (9): 597-603.

Akbari G A, Amirinejad M, Bagizadeh A, Allahdadi I and Shahbazi M 2013 Effect of Zn and Fe foliar application on yield, yield components and some physiological traits of cumin (*Cuminum cyminum*) in dry farming. *International Journal of Agronomy and Plant Production*. 4(12): 3231-3237.

Ali E A and Mahmoud A M 2013 Effect of foliar spray by different salicylic acid and zinc concentrations on seed yield and yield components of mungbean in sandy soil. *Asian Journal of Crop Science*. 5(1). 33-40.

Ali S, Riaz K A, Mairaz G, Arif M, Fida M and Bibi S 2008 Assessment of different crop nutrient management practices for yield improvement. *Australian Journal of Crop Sciences*. 2: 150-157.

Amin B, Maghleghah G, Mahmood H M R and Hossein M 2009 Evaluation of interaction effect of drought stress with ascorbate and salicylic acid on some physiological and biochemical parameters in Okra (*Hibiscus esculentus* L.). *Research Journal of Biological Sciences.* 4: 380-387.

Dashadi M, Hossein A, Radjabi R and Babainejad T 2013 Investigation of effect of different rates of Phosphorus and Zinc fertilizers on two cultivars of Lentil (Gachsaran and Flip92-12L) in irrigation complement condition. *International Journal of Agriculture and Crop Science*. 5: 1-5.

Krishna S 1995 Effect of sulphur and zinc application on yield, S and Zn uptake and protein content of mung (green gram). *Legume Research*. 18: 89-92.

Liu F, Andersen M N and Jensen C R 2003 Loss of pod set caused by drought stress is associated with water status and ABA content of reproductive structures in soybean. *Functional Plant Biology*. 30:271-280.

Miah M Z I and Carangal V R 2001 Yield of 10 mungbean cultivars evaluated in intensive rice based cropping system. *International Rice Research. Newsletter*. 6(4): 27.

Moghadam H R T, Zahedi H and Ashkiani A 2013 Effect of zinc foliar application on auxin and gibberellin hormones and catalase and superoxide dismutase enzyme activity of corn (*Zea mays* L.) under water stress. *Maydica Electronic Publication*. 58: 218-223.

Monjezi F, Vazin F and Hassanzadehdelouei M 2013 Effects of iron and zinc spray on yield and yield components of wheat (*Triticum aestivum* L.) in drought stress. *Cercetãri Agronomice în Moldova*. 1 (153): 23-32.

Moradi A, Ahmadi A and Zadeh A H 2008 The effects of different timings and severity of drought stress on gas exchange parameters of mungbean. *Desert*. 13(1): 59-66.

Mousavi S R 2011 Zinc in crop production and interaction with phosphorus. *Australian Journal of Basic Applied Sciences*. 5: 1503-1509.

Rahman M M, Adan, M J, Chowdhury M S N, Ali M S and Mahabub T S 2015 Effects of phosphorus and zinc on the growth and yield of mungbean (BARI mug 6). *International Journal of Scientific and Research Publications*. 5 (2): 1-4.

Ranawake A L, Dahanayaka N, Amarasingha U G S, Rodrigo W D R J and Rodrigo U T D 2011 Effect of water stress on growth and yield of mung bean (*Vigna radiata* L.) *Tropical Agricultural Research and Extension* 14(4): 11-20.

Rehman H, Aziz T, Farooq M, Wakeel A and Rengel Z 2012 Zn nutrition in rice production systems. *Plant Soil*. 361: 203-226.

Shahri Z B, Zamani G R and Sayyari-Zahan M H 2012 Effect of drought stress and zinc sulfat on the yield and some physiological characteristics of sunflower (*Helianthus. annuus* L.). *Advances in Environmental Biology*. 6 (2): 518-525.

Thalooth A T, Tawfik M M and Mohamed H M 2006 A comparative study on the effect of foliar application of zinc, potassium and magnesium on growth, yield and some chemical constituents of mungbean plants grown under water stress conditions. *World Journal of Agricultural Sciences*. 2 (1): 37-46.

Uddin S, Parvin S and Awal M A 2013 Morpho-physiological aspects of mungbean (*vigna radiata* L.) in response to water stress. *International Journal of Agricultural Science*. 3(2): 137-148.

Ved R, Misra S K and Upadhyay R M 2002 Effects of sulphur, zinc and biofertilizers on the quality characteristics of mungbean. *Indian Journal of Pulses Research*. 2: 139-141.

Welch R W, Webb M J and Loneragan J F 1982 Zinc in membrane function and its role in phosphorus toxicity. *Plant Nutrition, proceeding of the 9th International Plant Nutrition Colloquium,* Warwick University, U.K., PP. 710-715.

Xi-Wen Y, Xiao-Hong L, Xin-Chun T, William G J and Yu-Xian C 2011 Foliar zinc fertilization improves the zinc nutritional value of wheat (*Triticum aestivum* L.) grain. *African Journal of Biotechnology*. 10: 14778-14785.

Yadavi A, Aboueshaghi R S, Dehnavi M M and Balouchi H 2014 Effect of micronutrients foliar application on grain qualitative characteristics and some physiological traits of bean (*Phaseolus vulgaris* L.) under drought stress. *Indian Journal of Fundamental and Applied Life Sciences*. 4 (4): 124-131.

Yosefi K, Galavi M, Ramrodi M and Mousavi S R 2011 Effect of bio-phosphate and chemical phosphorus fertilizer accompanied with micronutrient foliar application on growth, yield and yield components of maize (single cross 704). *Australian Journal of Crop Sciences*. 5: 175-180.

Zubair M, Haqqani A M and Malik M R 2001 Strategies to enhance mungbean production in Pakistan: plausible approaches. *Agridigest*. XXI(5): 19-20.

Received on 21.06.2018 and Revised on 28.08.2018