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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

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Abstract: Two field experiments were carried out at the Agricultural Experimental Station of National Research Centre, at Shalakan, Kalubia Governorate during the summer seasons of 2002 and 2003 to study the effect of foliar application of zinc, potassium or magnesium on growth, yield and yield components and some chemical constituents of mungbean plants grown under water stress conditions (missing one irrigation at vegetative, flowering and pod formation growth stages). The results revealed that missing one irrigation at any of the three studied stages significantly reduced all the tested growth parameters, yield and yield components as well as photosynthetic pigments content as compared with unstressed plants (control). However, subjecting mungbean plants to moisture stress at vegetative stage had the most negative effect on growth parameters. Meanwhile, stress at a pod formation stage produced the least yield and yield components' values. On the other hand, water stress had a stimulating effect on proline and crude protein contents. The present study also indicate that foliar application of Zn, K or Mg had a positive effect on growth parameters, yield and yield components but K application surpassed the two other nutrients.

Key wards: Mungbean · water stress · zinc · potassium · magnesium · growth · photosynthesis · proline · yield · crude protein · drought susceptibility index

INTRODUCTION

Mungbean (*Vigna radiata* L. Wilczek) is a new introduced summer pulse crop in Egypt with short growing season and high nutritive value grown principally for its protein rich edible seeds [1]. This crop can be used for both seed and forage production. It plays an important role not only in human diet, but also in improving the soil fertility by fixing atmospheric nitrogen into available form with the help of *Rhizobia* species present in the nodules of its roots [2].

Water deficit is frequently the primary limiting factor for crop production under arid and semi-arid conditions [3]. It affects nearly all the plant growth processes. However, the stress response depends upon the intensity, rate and duration of exposure and the stage of crop growth [4].

When considering a watering regime for a crop, it is wise to understand the sensitive growth stages for water stress and the water requirements of the crop in order to achieve maximum yield and maintaining adequate soil moisture conditions during moisture-sensitive stages of growth, so irrigation water may be saved if soil water could be depleted to a greater extent during certain growth stages without affecting yield.

Currently, foliar-applied nutrients have limited direct use for enhancement of stress resistance mechanisms in field crops. Nevertheless, the interactions between plant nutrient levels and stress repair mechanisms are now being studied [5].

Foliar application of potassium during vegetative growth is one of these precautions. Potassium is essential in maintenance of osmotic potential and water uptake and had a positive impact on stomatal closure which increases tolerance to water stress [6]. Moreover, it is involved in activating a wide range of enzyme systems which regulate photosynthesis, water use efficiency and movement, nitrogen uptake and protein building [7]. In this regard, Thalooth *et al.,* [8] found that potassium application improve the water content in the broad bean leaves and the plants showed more tolerance to drought stress.

Another possible approach to minimize drought-induced crop losses is the foliar application of magnesium which plays several physiological and biochemical roles (i.e) chlorophyll formation, activation of enzymes, synthesis of proteins, carbohydrate metabolism and

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energy transfer. Magnesium also acts as a catalyst in many oxidation, reduction reactions inside the plant tissues, as well as it may increase crop resistance to drought. In this concern Saad and El-Kholy [9] stated that foliar application with magnesium sulphate increase net assimilation rates, seed yield and crude protein content of plants.

On the other hand, foliar application of zinc greatly affect plant growth and crop production. In this regard, Krishna [10] reported significant positive effect of zinc treatment on dry matter, seed and straw yield of mungbean as well as crude protein % in the seeds. Kassab [11] indicated that foliar application of Zn, Mg, Mn and Fe significantly increased growth parameters, yield and its components of mungbean plants.

Therefore, this investigation was undertaken to evaluate the efficiency of foliar application of zinc, potassium or magnesium to the harmful effect of water stress on growth and yield of mungbean plants.

MATERIALS AND METHODS

Two field experiments were carried out at the Agricultural Experimental Station of the National Research Centre at Shalakan, kalubia Governorate during the two successive summer seasons of 2002 and 2003 to study the effect of foliar application of Zn, K or Mg on growth, yield and some chemical constituents of mungbean plants grown under water stress conditions. Soil chemical and mechanical characteristic are presented in Table 1.

A split-plot design with four replicates was applied. The main plots included the four irrigation treatments

- Unstressed (control treatment).
- Stressed by skipping one irrigation at vegetative growth stage.
- Stressed by skipping one irrigation at flowering growth stage.
- Stressed by skipping one irrigation at pod formation growth stage.

While the four following foliar application treatments were distributed in the sub plots.

- Foliar application of distilled water (control)
- Foliar application of 300 ppm Zn-EDTA.
- Foliar application of 2.0% KNO_3.
- Foliar application of 50 ppm $MgSO_4$

Foliar application was carried out twice after 30 and 50 days from sowing. Area of each sub plot was 10.5 m^2 (3.5 m length and 3 m width). To avoid the effect of lateral movement of irrigation water, the plots were separated by borders of 1.5 m in width from all sides. Mungbean seeds (*Vigna radiata* L. Wilczek) cv. Kawmy - 1 were sown on 15 and 18 June in the first and second season, respectively in hills 15 cm apart at the two sides of the row.

Table 1: Soil mechanical and chemical analysis (average value of 2002 and 2003 seasons)

Properties	Values
Mechanical analysis	
Clay (%)	33.30
Silt (%)	59.40
Sand (%)	7.30
Soil texture	Clay loam
Chamical analysis	
pH	7.59
Ec (ds m^{-1})	0.27
K^+ (meq/L)	0.82
Mg^{++} (meq/L)	0.49
Zn^{++} (meq/L)	0.04
HCO_3^- (meq/L)	0.41
Ca^{++} (meq/L)	1.09
SO_4^- (meq/L)	0.57

Thinning was carried out 21 days after sowing to secure two plants per hill. NPK were added at the rate of 20 kg N/ fed as ammonium nitrate 33% N, 15 kg P_2O_5 /fed as calcium superphosphate 15.5% P_2O_5 (before sowing) and 24 kg K_2O /fed as potassium sulphate 48% K_2O. The other agronomic practice for growing mungbean was followed as recommended. Representative samples were collected from four replicates for each treatment after 75 days from sowing where plant height, leaf area, number of branches, leaves and pods as well as weight of stem, leaves and pods were determined. Proline concentration (µg g^{-1} fresh weight) was determined in the leaves according to the method described by Bates and Tear [12]. Photosynthetic pigments were determined as mg g^{-1} dry weight according to the formula described by Von Wettestein [13].

At harvest time twenty guard plants were chosen randomly from each plot to determine yield attributes ie. number of pods /plant, number of seeds /pod, pods dry weight and seed index. Whole plot was harvested for determination of seed, straw and biological yield /fed. Total nitrogen was determined in the dry seeds using the Kjeldahal method according to A.O.A.C., [14]. Crude protein % was calculated by multiplying the nitrogen % by the factor 6.25.

The Drought Susceptibility Index (S) was calculated for yield data under each stress and foliar application treatment using formula presented by Fischer and Maurer [15].

Table 2: Effect of foliar application with zinc, potassium or magnesium on growth parameter of mungbean plants grown under water stress conditions (Average values of 2002 and 2003 seasons)

Irrigation treatments	Foliar application	Plant height (cm)	Leaf area $(cm)^2$	Number of branches /plant	Number of leaves /plant	Number of pods /plant	Stem dry weight (g)	Leaves dry weight (g)	Pods dry weight (g)
Regular irrigation (control)	Control	67.50	834.35	2.75	16.75	22.25	16.26	14.46	12.40
	Zinc	68.75	888.00	3.00	18.00	25.00	17.60	15.54	13.58
	Potassium	68.25	835.81	3.75	16.75	24.25	16.26	14.46	13.18
	Magnesium	68.50	838.64	3.00	16.50	25.00	16.69	14.63	12.40
Skipping irrigation at vegitative growth stage	Control	55.00	598.37	2.50	12.00	20.25	11.65	10.36	10.59
	Zinc	57.75	608.25	3.00	12.50	21.50	12.33	10.79	11.37
	Potassium	58.25	641.13	2.75	13.25	23.75	12.86	11.44	12.55
	Magnesium	59.75	591.69	2.50	12.00	22.25	11.55	10.39	11.24
Skipping irrigation at flowering growth stage	Control	58.25	610.73	2.75	12.25	20.25	11.89	10.58	10.59
	Zinc	60.00	627.42	3.00	13.25	20.50	13.14	11.44	10.85
	Potassium	58.75	652.03	2.50	13.50	21.00	13.11	11.65	11.24
	Magnesium	59.25	612.99	2.75	12.50	20.50	11.65	10.58	10.81
Skipping irrigation at pod initiation growth stage	Control	63.00	642.91	2.75	13.25	19.50	12.86	11.44	9.95
	Zinc	64.75	653.40	3.00	13.75	20.00	13.71	11.87	10.21
	Potassium	62.50	677.04	2.75	14.50	20.00	14.08	12.52	10.34
	Magnesium	63.25	645.01	2.75	13.50	20.25	12.86	11.54	10.36
Irrigation mean	Control	68.25	849.20	3.13	17.00	24.13	16.70	14.77	12.89
	Vegitative	57.69	609.86	2.69	12.44	21.94	12.10	10.75	11.44
	Flowering	59.06	625.79	2.75	12.88	20.56	12.45	11.06	10.87
	Podding	63.38	654.59	2.81	13.75	19.94	13.38	11.84	10.21
Foliar application mean	Control	60.94	671.59	2.69	13.56	20.56	13.17	11.71	10.88
	Zinc	62.81	694.27	3.00	14.38	21.75	14.20	12.41	11.50
	Potassium	61.94	701.50	2.94	14.50	22.25	14.08	12.52	11.83
	Magnesium	62.69	672.08	2.75	13.63	22.00	13.19	11.79	11.20
LSD 5%	Irrigation	1.88	78.92	0.55	1.59	1.58	1.44	1.33	0.77
	Foliar	NS	40.76	0.49	0.76	1.49	0.74	0.59	0.64
	Irrig x Foliar	4.60	81.53	0.98	1.53	2.97	1.48	1.19	1.29

$$S = (1 - YD / YP) / D$$

Whereas; S = Drought susceptibility index, YD = Yield of plants under drought stress condition, YP = Yield of plants without drought (under normal irrigation treatments), D = Drought intensity = 1 - (mean YD of all treatments /mean YP of all treatments).

The obtained results were subjected to statistical analysis of variance according to the method described by Snedecor and Cochran [16] and the combined analysis of the two seasons was calculated according to the method of Steel and Torrie [17].

RESULTS AND DISCUSSION

Effect on growth: The growth parameters as affected by irrigation treatment and foliar application of the different nutrients are presented in Table 2. However, all growth parameters i.e. plant height, number of branches, leaves and pods /plant, weight of stem, leaves and pods /plant as well as leaf area /plant were significantly reduced by skipping one irrigation at the different stages of growth as compared with the control plants. The magnitudes of reduction differed from character to another according to the growth stage. However, subjecting plants to water stress at vegetative stages of growth caused the highest reduction in all growth parameters except that of number and weight of pods /plant which reduced by stress at pod formation stage of growth. These results were in harmony with those obtained by Thomas *et al.,* [18]. The depressing effect of drought on plant growth was suggested to be attributed to the increase osmotic pressure in the root medium which tend to decrease synthesis of metabolites, reduce translocation of nutrient from the soil to the plant as well as decrease division and elongation of the cells [19]. Moreover, Maiti *et al.*, [20], added that water stress progressively declined net photosynthesis rate which is associated with a simultaneous decrease in leaf area, decrease starch content and increased free proline.

Regardless irrigation treatments, results in Table 2 reveal also that foliar application of Zn or K significantly increased all growth parameters. Differences among the effect of the foliar application were recorded. K was superior in the features of area, number and weight of leaves /plant as well as number and weight of pods /plant, while Zn surpass the features of plant height, number of branches /plant and stem dry weight /plant. On the other hand, application of Mg insignificantly increases all growth parameters as compared with control plants. These results coinside with those obtained by Basole *et al.*, [21], Gupta *et al.*, [22] and Kassab [11].

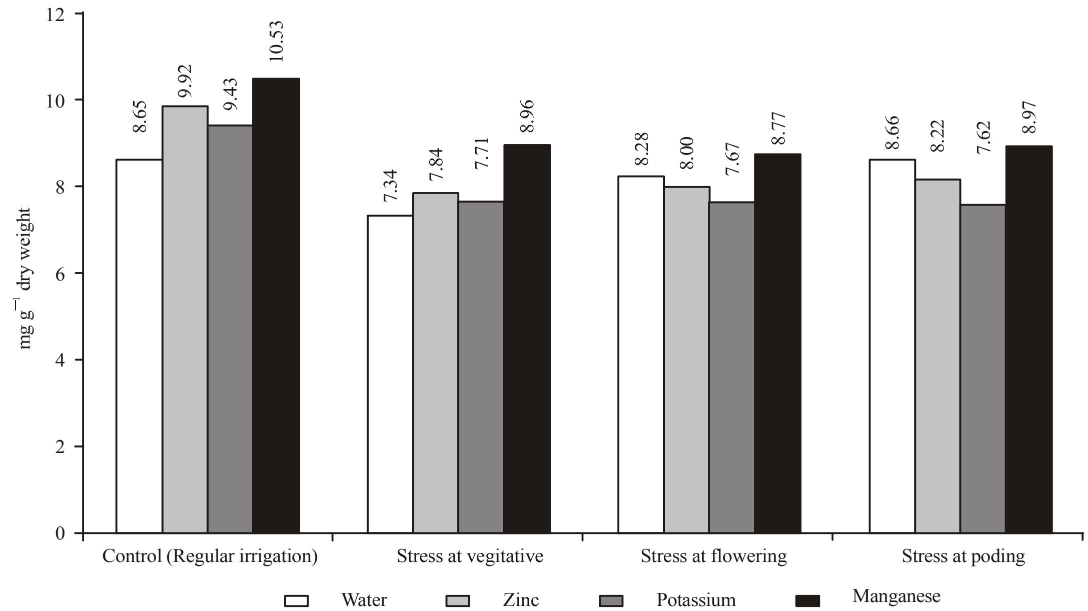

Fig. 1: Effect of foliar application of Zn, K and Mg on chl. a+b (mg g^{-1} dry weight) in the leaves of mungbean plants grown under water stress conditions. (LSD 5% NS)

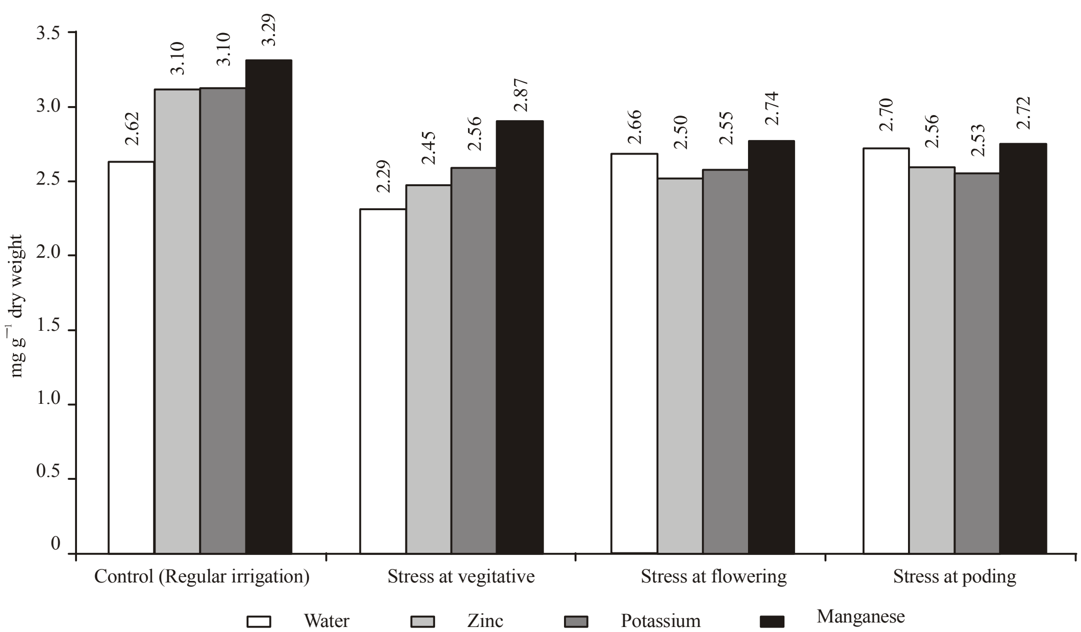

Fig. 2: Effect of foliar application of Zn, K and Mg on carotenoids content (mg g^{-1} dry weight) in the leaves of mungbean plants grown under water stress conditions. (LSD 5% NS)

It can be concluded also that the enhancement effect of spraying mungbean plants with Zn, K or Mg on growth parameters was very clear, hence treated plants resulted in taller, greater number and weight of leaves, branches, pods /plant. Such enhancement effect might be attributed to the favorable influence of these nutrient on metabolism and biological activity and its stimulating effect on photosynthetic pigments and enzyme activity which in turn encourage vegetative growth of plants [23].

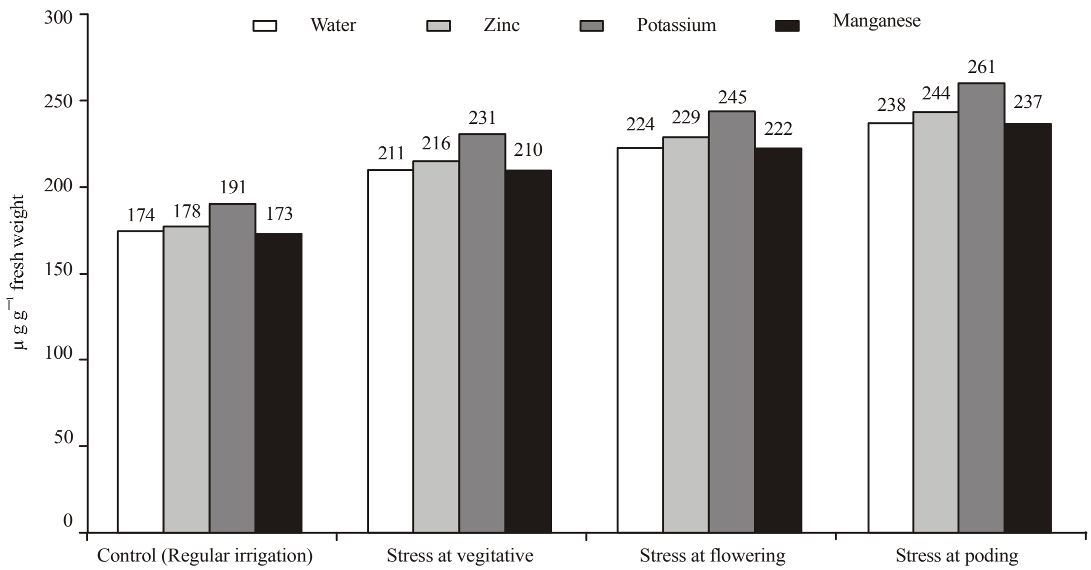

Fig. 3: Effect of foliar application of Zn, K and Mn on proline content μg g^{-1} fresh weight in the leaves of mungbean plants grown under water stress conditions. (LSD 5% 14.89)

The interaction between irrigation treatment and foliar application of the different nutrients significantly affected all the studied growth parameters. However, foliar application of Zn or K recorded the highest values for all growth parameters under normal irrigation treatment (control). On the other hand, skipping one irrigation at vegetative stage of growth x foliar application of distilled water treatment gave the lowest values for most growth parameters. Similar results were obtained by Thomas *et al.*, [18]. Such differences might be due to the variation existing among the role of plant nutrients on stress resistance and repair mechanisms [23].

Effect on photosynthetic pigments content: Data presented in Figs. 1 and 2 revealed that withholding one irrigation at any growth stage decreased the content of chl. a+b and carotenoids in the leaves of mungbean plants and this was true under the different foliar nutrients application. Similar results were obtained by Maiti *et al.*, [20]. Such decrease in chlorophyll content in the leaves of plants may be attributed to the high rate of chlorophyll degradation more than its biosynthesis under water stress conditions [24]. Furthermore, Schtz and Fangmeier [25], added that, water stress accelerate chlorophyll-a breakdown.

The same Figures also show that there was insignificant increase in photosynthetic pigments content (chl. a+b and carotenoids) under foliar application with Mg as compared with the other treatments. Such enhancing effect of Mg on chlorophyll accumulation could be attributed to the useful importance of magnesium for photosynthesis, net assimilation and transpiration rates [26]. On the other hand, the negative effect of foliar application of K on chlorophyll content may be attributed to the antagonism between K and Mg. In this respect Kabesh *et al.*, [27], observed that excess of K supply depress the uptake of Mg and this can induce Mg deficiency. The reduction in Mg content in plant leaves often causes inhibition of chlorophyll biosynthesis, since Mg is one of the main constituents of chlorophyll molecule. However, no clear effect was observed for zinc application. The previous results are in agreement with those obtained by Nobel [26].

Regarding the interaction effect between water stress and different types of foliar application on photosynthetic pigments content, the highest photosynthetic pigments was recorded in mungbean plants under regular irrigation treatment and foliar application of magnesium, while the least values was obtained by plants stressed at vegetative and treated with potassium. These results are in full agreement with those obtained by Kabesh *et al.*, [27] and Maiti *et al.*, [20].

Effect on proline content: From the data given in Fig. 3, it can be concluded that skipping irrigation at any growth stage significantly increased proline content in the leaves of mungbean plants as compared with the unstressed plants (control). It is worthy to note also that high proline content values were recorded in mungbean plants subjected to water stress at pod formation stage. The obtained results are in agreement with the findings of

Table 3: Effect of foliar application with zinc,potassium or magnesium on yield of mungbean plants grown under water stress conditions (Average values of 2002 and 2003 seasons)

Irrigation treatment	Foliar application	Number of pods /plant	Pods dry weight (g)	Number of Seeds /pod	Seed dry wt. g /plant	Seed index	Seed yield kg /fed.	Straw yield kg /fed.	Biological yield kg /fed.
Regular	Control	26.73	18.74	9.25	10.72	55.63	730.16	2199.67	2929.84
irrigation	Zinc	30.03	21.06	9.25	11.99	62.50	816.77	2535.75	3352.52
(control)	Potassium	29.79	20.89	9.50	11.84	60.63	806.25	2378.98	3185.23
	Magnesium	30.03	21.06	9.50	11.94	62.50	813.32	2450.18	3263.50
Skipping	Control	23.87	16.74	9.00	8.89	50.63	605.86	1648.46	2254.32
irrigation	Zinc	25.35	17.77	9.50	9.44	53.75	643.26	1723.34	2366.60
at vegitative	Potassium	28.40	19.92	9.25	10.71	59.38	729.26	1632.71	2361.98
growth stage	Magnesium	26.23	18.39	9.25	9.77	55.63	665.70	1711.86	2377.56
Skipping	Control	23.43	16.43	8.50	8.73	50.63	594.56	1791.15	2385.70
irrigation	Zinc	23.72	16.63	9.00	8.84	51.25	601.90	1888.42	2490.32
at flowering	Potassium	24.59	17.24	8.75	9.29	52.50	632.57	1780.58	2413.16
growth stage	Magnesium	23.72	16.63	8.50	8.84	51.25	601.90	1813.26	2415.16
Skipping	Control	21.56	15.12	8.25	8.03	48.75	547.19	1825.21	2372.40
irrigation at	Zinc	22.11	15.51	8.00	8.24	50.00	561.22	1991.76	2552.99
pod initiation	Potassium	22.33	15.66	8.50	8.44	50.00	575.14	2046.98	2578.57
growth stage	Magnesium	22.39	15.70	8.25	8.34	50.63	568.24	2005.48	2573.71
Irrigation	Control	29.14	20.44	9.38	11.62	60.31	791.62	2391.15	3182.77
mean	Vegitative	25.96	18.21	9.25	9.70	54.84	661.02	1679.09	2340.12
	Flowering	23.86	16.73	8.69	8.92	51.41	607.73	1818.35	2426.08
	Podding	22.10	15.50	8.25	8.26	49.84	562.95	1967.36	2519.42
Foliar	Control	23.90	16.76	8.75	9.09	51.41	619.44	1866.12	2485.57
application	Zinc	25.30	17.74	8.94	9.63	54.38	655.79	2034.82	2690.61
mean	Potassium	26.28	18.43	9.00	10.07	55.63	685.81	1959.81	2634.73
	Magnesium	25.59	17.95	8.88	9.72	55.00	662.29	1995.20	2657.48
LSD 5%	Irrigation	1.88	1.32	0.75	0.80	3.96	54.52	157.48	210.83
	Foliar	1.61	1.13	0.49	0.60	3.72	40.72	101.38	130.03
	Irrig x Foliar	3.22	2.26	0.98	1.20	7.44	81.43	202.76	260.06

Maiti *et al*., [20], who reported that proline accumulation is a mechanism for plants adaptation to abiotic stress conditions. Other roles for proline have been proposed, including stabilization of macromolecules, a sink for excess reductant and a store of carbon and nitrogen for use after relief of water deficit [28].

Figure 3 showed also that, foliar application of potassium significantly increased proline content, while no clear effect was observed for zinc or magnesium. Similar results were obtained by Nobel [26].

Regarding the effect of interaction between water stress and foliar treatments, data presented in Fig. 3 reveal also that the highest value of proline content (261 $\mu g\ g^{-1}$ fresh weight) was recorded by mungbean plants stressed at pod formation and treated with foliar potassium, whereas the lowest value (173 $\mu g\ g^{-1}$ fresh weight) was obtained by plant irrigated regularly (control) and treated with foliar application of magnesium. Basole *et al*., [21] came to the same conclusion. In this connection, Yang *et al*., [24], found that highly drought resistance plants reduce their water loss by increasing proline content.

Effect on yield and yield components: The data presented in Table 3 show that skipping one irrigation at any stage of growth significantly decreased yield and yield components of mungbean plants. However subjecting plants to water stress at pod formation stages of growth caused the highest reduction in number of pods /plant, pods dry weight, number of seeds /pod, seeds dry weight /plant, seed index and seed yield kg /fed. Stress at flowering came in the second order with respect to these features, while early stress at vegetative has more detrimental effect on straw and biological yield. These results are in full agreement with those obtained by Thomas *et al*., [18]. The expected depression as a result of water stress on yield and yield components of mungbean plants may be due to the reduction of growth criteria as indicated in Table 2. In this concern, De Costa *et al*., [29] stated that irrigation is critical during pod-filling and flowering stages in mungbean plants mainly because of the higher leaf area index during these periods and consequently, the greater demand for water. In addition, Dominique *et al.,* [30] stated that, early stress reduced vegetative biomass production and decreased the average internodes length without altering the efficiency of dry matter for producing and filling pods and seeds. They added that decreased pods weight was an effective indicator of water limitation during pod lengthening. It is clear also from the same table that mungbean plants appeared to be more sensitive to water stress during pod formation stage. Moreover, Kramer [31] reported that

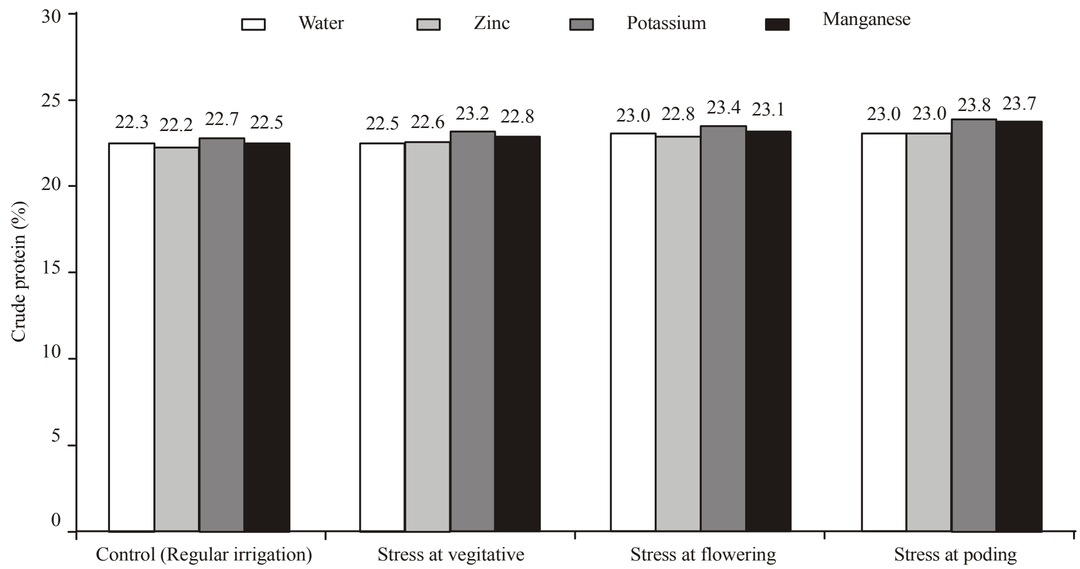

Fig. 4: Effect of foliar application of Zn, K and Mn on crude protein % in the seeds of mungbean plants grown under water stress conditions. (LSD 5% 0.89)

water stress resulted in a disturbance in photosynthesis, enzyme activity and protein synthesis which affect the metabolites transportation to the grains.

Irrespective to water stress, foliar application of Zn, K, or Mg significantly increased all the yield characters compared with control plants. Potassium foliar application had the greatest stimulatory effect on pods number /plant, pods dry weight, number of seeds /pod seeds dry weight /plant, seed index and seed yield kg /fed. On the other hand, zinc application was superior with respect to straw and biological yield /fed. The obtained result are in full agreement with the findings of Basole *et al.,* [21], Gupta *et al.,* [22] and Kassab [11]. These results suggested that foliar application of nutrient solutions partially alleviates the adverse effects of water stress on photosynthesis and photosynthesis-related parameters, yield and yield components through mitigating the nutrient demands of water-stressed plants. In this concern, Ved *et al*., [32] stated that foliar applied zinc enhances photosynthesis, early growth of plants, improves nitrogen fixation, grain protein and yields.

As for the interaction effect of water stress and foliar application treatment. Table 3 reveal that the highest values were recorded by the plants irrigated regularly (control) and sprayed with potassium. These results were parallel with those obtained by Basole *et al.,* [21] and Gupta *et al.,* [22], who observed a significant increase in yield under water stress condition in response to foliar K application. On the other hand, the lowest values were recorded by the plants stressed at pod formation and treated with distilled water. Similar results were obtained by Gupta *et al.,* [22] and Kassab [11].

Effect on crude protein % in the seeds: Data presented in Fig. 4 show that, subjecting mungbean plants to moisture stress at different stages of growth significantly increased the seed crude protein content. However, skipping one irrigation at pod formation stages recorded the highest crude protein % compared with the other treatments. These results are in agreement with those obtained by Kassab [11]. In this concern, Zhao *et al.,* [33] stated that water stress at grain filling stage can increase grain protein content.

Regardless irrigation treatment, foliar application of potassium significantly surpassed the other treatments with respect to crude protein percentage. Magnesium came in the second order, while no clear effect for zinc was observed. Similar results were obtained by Kassab [11] Such enhancement effect of potassium and magnesium might be attributed to the favorable influence of these nutrient on metabolism and biological activity and its stimulating effect on photosynthetic pigments and enzyme activity which in turn encourage vegetative growth and yield of plants and consequently protein content [23].

The interaction between moisture stress and foliar application significantly affect crude protein percentage. The highest value (23.8%) was recorded in plants stressed at pod formation and treated with potassium, while the

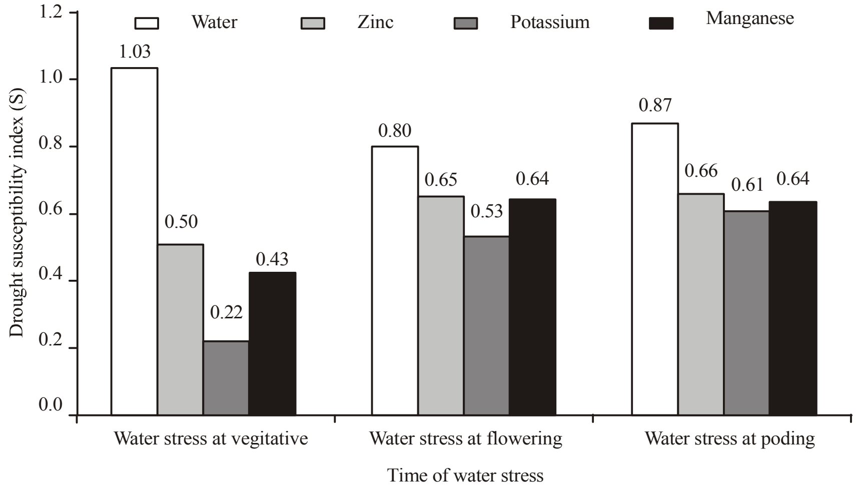

Fig. 5: Drought susceptibility index of mungbean plants as affected by moisture stress and some foliar nutrients application

least one (22.2) was recorded in unstressed plants and sprayed with Zn. Similar results were obtained by Gupta *et al.,* [22].

Effect on drought Susceptibility Index (S): Data presented in Fig. 5 show Drought Susceptibility Index (S) under each drought stress treatment. It is evident that subjecting mungbean plant to water stress at pod formation stage of growth has the most deleterious effect on its productivity. In other wards it means that mungbean plants are very susceptible to drought stress at this development stage of growth. On the other hand it can be noticed that mungbean plants are more tolerant to drought stress during vegetative stage of growth. Similar results were obtained by Tawfiles [34].

However, foliar application of Zn, K or Mg increased drought tolerance of mungbean plants according to Ceccarelli [35], who reported that low (S) value is an indication to drought tolerance.

It can be concluded that treatment mungbean plants grown under water stress conditions with K or Mg is solutions counteracted the deleterious effects of stress on the yield, especially the stress at early stages of growth and helped stressed plants to grow successfully under these adverse unfavorable conditions. Moreover, applying Zn is very effectively in case of using mungbean plants as forage. However this subject needs more and deeper study for achieving clearer conclusion.

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