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Evaluation Effect of Salinity Stress and Potassium Sulfate on Seed yield, its Components and Qualitative Traits of Mung Bean (*Vigna radiate* L.)

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RESEARCH ARTICLE

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ABSTRACT

BACKGROUND: Among the abiotic stresses, soil salinity is a prevalent environmental issue that impacts more than 77 million hectares (5% of the cultivable land worldwide). Potassium plays a crucial role in plant growth under saline conditions, as it is involved in essential processes such as photosynthesis and osmo regulatory adaptations that help plants cope with water stress.
OBJECTIVES: To investigate the impact of salinity stress and potassium sulfate on crop production and qualitative traits of mung bean current research was done.
METHODS: This study was conducted according factorial experiment based on randomized completely block design with three replications. The study was carried out in pots located in Ahvaz during the 2014 cropping season. The investigated factors included potassium fertilizer at three levels (including 0, 100, 200 kg.ha^{-1}) from source of potassium sulfate and salinity stress from sodium chloride at 4 levels (including control, 2, 4, 6 ds.m^{-1}).
RESULT: The results indicated that both salinity stress treatment and potassium fertilizer had a significant impact on yield and yield components, biological yield, chlorophyll index and proline content. The highest seed yield (with an average of 15.4 grams per plant) was achieved in the 0 ds.m^{-1} (control), while the lowest yield (with an average of 9.8 grams per plant) was observed at the salinity level of 6 ds.m^{-1}. The treatment with 6 ds.m^{-1} salinity level exhibited the highest proline content (with an average of 7.76 mg.g^{-1} of leaf weight). Additionally, the application of potassium fertilizer led to a significant increase in both seed yield and biological yield. The highest seed yield was observed in the control treatment (without salinity stress) and with the consumption of 100 kg.ha^{-1} of potassium fertilizer (with an average of 15.29 grams per plant). On the other hand, the lowest seed yield was recorded in the treatment with 6 ds.m^{-1} salinity level and no application of potassium fertilizer (with an average of 6.86 grams per plant). According to the obtained results, under the salinity treatment of 4 ds.m^{-1}, the application of 100 kg.ha^{-1} of potassium fertilizer effectively prevented the reduction in Mung bean yield, which was not significantly different from the 200 kg.ha^{-1} fertilizer treatment.
CONCLUSION: The use of 100 kg.ha^{-1} of potassium fertilizer can be considered as an effective management strategy to mitigate the negative impact of salinity stress on mung bean yield.

KEYWORDS: *Chloride, Chlorophyll, Proline, Pulse, Sodium.*

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1. BACKGROUND

Legumes, especially mung beans, are important sources of protein in most the countries especially the developing countries, because they are cheaper than animal protein. Also, legumes contain carbohydrates, some vitamins and essential minerals in the human diet and are used as soil fertilizers in crop rotations (Thalooth *et al*., 2006). Green mung bean with the scientific name (*Vigna radiate* L.) is a valuable legume rich in phosphorus, whose seeds contain about 24-25% protein, 56.7% carbohydrates and 1.3% fat (Majnoun Hosseini, 2008). Salinity is one of the important stresses limiting agricultural production. Salinity affects the growth and development of the plant by affecting most physiological and morphological activities (Baibordi *et al*., 2010). A lot of different solutes in irrigation water make the plant face salinity stress. When the plant is placed in a salty environment, the osmotic potential of the soil solution becomes negative and toxic ions such as sodium and chlorine accumulate. Salinity stress does not affect only one growth stage of the plant, but it is different according to the intensity of the stress, the type of stress, the level of resistance of the plant, different growth stages and the type of plant tissue and organ (developmental course) (Xiao-shan and Jian-guo, 2009). Salinity affects many processes involved in the growth and development of plants in addition to having a negative effect on yield and yield components. Salt stress is one of the important non-living stresses that have harmful effects on plant yield and product quality. One of the characteristics of a saline soil is the toxic levels of sodium chlorides and sulfates. The problem of soil salinity is increasing due to irrigation, improper drainage, the advance of the sea in coastal areas and the accumulation of salt in desert and semi-desert areas. Salinity is a limiting factor for plant growth because it causes nutritional limitations by reducing elements such as phosphorus, potassium, nitrate and calcium absorption, increasing the intracellular ion concentration and osmotic stress (Ahmadikhah, 2008). In a research, the effect of salinity stress on mung bean yield and yield components was investigated and it was reported that the decrease in seed yield was more pronounced under salinity stress conditions, and the number of seeds per pod and the 100 weight seeds were lower in salt stress conditions than the control treatment. Salinity stress had the greatest effect on vegetative growth, flowering and seed filling stages (Ahmed, 2009). Potassium is one of the essential nutrients and the most abundant cation absorbed in most plants, which plays an important role in their growth and development. Potassium is necessary for the activity of enzymes, maintaining cell turgorescence, increasing the process of photosynthesis, helping in the transfer of sugar and starch, helping in nitrogen absorption and for protein synthesis. In addition to plant metabolism, potassium improves product quality because potassium has a role in seed filling, seed weight, increasing disease resistance and in addition, it leads to an increase in plant resistance to stress (Sakinejad, 2003). This element mainly exists in three different forms in the soil, which includes usable, stabilized potassium and potassium found in soil minerals. Therefore, in order to supply potassium needed by the plant, soluble and exchangeable potassium should be provided by adding chemical fertilizers or by releasing stabilized potassium and weathering minerals containing potassium (such as mica and feldspar) (Tabatabaei, 2014). The appropriate amount of potassium sulfate fertilizer in the soil facilitates osmotic adjustment in the soil, as a result of which the osmotic pressure remains in the leaves and thus increases the plant's ability to cope with stress (Shirvanipour *et al*., 2014). In a research investigating the effect of potassium sulfate fertilizer on mung bean, it was reported that the yield of pod increased with increasing the amount of potassium sulfate fertilizer from 0 to 50 $kg.ha^{-1}$ under favorable irrigation conditions with a steep slope, which shows that the yield of pod increased to some extent with the increase of fertilizer. Potassium sulfate has increased and since then, with the increase of potassium sulfate fertilizer from 50 to 100 $kg.ha^{-1}$, the yield of pod has decreased rapidly (Ali *et al*., 2010). By investigating and studying different levels of potassium sulfate in mung bean plant, it was reported that the number of pods plant, seed and biological yield were significantly affected by potassium. The lowest number of pods and the number of seeds per pod were obtained from the treatment without potassium (control) (Abbas *et al*., 2011). Researchers reported that the use of potassium sulfate in mung bean is directly related to growth, biomass and yield. The results showed that the yield response to different levels of potassium (0, 100, 120 $kg.ha^{-1}$) is different. The lowest yield (700 $kg.ha^{-1}$) was obtained with no potassium application (control treatment) and the highest yield (1096 $kg.ha^{-1}$) was obtained with the application of 120 $kg.ha^{-1}$ potassium (Kumar *et al*., 2014). This research was conducted to assess the detrimental impact of salinity stress on mung bean cultivation in different regions of the province. The study aimed to comprehensively investigate the influence of varying potassium sulfate levels in combination with salinity stress on the plant's yield, yield components and important physiological characteristics. The researchers endeavored to explore potential solutions and strategies to ameliorate the adverse effects of salinity stress on mung bean crops. By understanding these intricate relationships, valuable insights could be gained to enhance resilience and productivity of mung bean cultivation under challenging environmental conditions.

2. OBJECTIVES

To investigate the impact of salinity stress and potassium sulfate on crop production and qualitative traits of mung bean current research was done.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

This study employed a factorial experiment using randomized complete block design (RCBD) with three replications. The research was conducted in

Ahvaz during the 2014 cropping season, using pots as experimental units. The main factors investigated were the application of potassium fertilizer at three different levels (0, 100 and 200 $kg.ha^{-1}$) sourced from potassium sulfate and the imposition of salinity stress using sodium chloride at four levels (control, 2, 4, and 6 ds.m-1). To conduct this experiment, utilized 72 plastic pots, each with a diameter of 28 cm and a height of 30 cm. The seeds were sown at a depth of 2 centimeters. The physicochemical properties of the pot soils are shown in table 1.

Table1. Some physical and chemical properties of experiment's soil

Depth of soil (cm)	Soil texture	Potassium (ppm)	Phosphorus (ppm)	Organic carbon (%)	pH	EC ($ds.m^{-1}$)	SP (%)
0-30	Clay loam	110.12	9.2	0.2	7.1	3.4	34.9

3.2. Farm Management

The required amount of fertilizer for each pot was calculated based on its area, with 0.5 grams of nitrogen and 0.8 grams of phosphorus per pot (equivalent to the consumption of 50 $kg.ha^{-1}$ of pure nitrogen and 80 $kg.ha^{-1}$ of pure phosphorus). The calculated amounts of potassium sulfate fertilizer were mixed with the soil and then poured into the pots. To prevent the accumulation of salts in the pots, three holes with a diameter of one centimeter were installed at the bottom of each pot as drainage outlets. After filling all the pots with the same amount of agricultural soil, five mung bean seeds were planted in five locations within each pot. Prior to planting, the seeds were soaked in water for 24 hours. The pots were then watered with normal water (without salt) for a period of two weeks after germination to establish the seedlings. Once the seedlings were fully established, three healthy plants were retained in each pot, and the excess seedlings were removed. The salinity treatment was initiated by irrigating the pots with water containing specific levels of electrical conductivity starting from the four-leaf stage of the plants.

3.3. Measured Traits

At the physiological ripening stage, various parameters were measured, including the number of pods per plant, the number of seeds per pod, the 100 seed weight, as well as seed and biological yield. The chlorophyll index (SPAD number) was determined using a SPAD meter (model SPAD-502) by measuring an average of 10 leaves at the time of flowering. The amount of proline accumulated in the plants was quantified using a spectrophotometer at a wavelength of 520 nm, following the standard curve established from different concentrations of proline at the 50% pod formation stage, and reported as $mg.g^{-1}$ leaf wet weight (Bates *et al.*, 1973).

3.4. Statistical Analysis

The data were subjected to variance analysis using the SAS statistical software (Ver.8) and Duncan's test was applied at the 5% of probability level to compare the means.

4. RESULT AND DISCUSSION

4.1. *Number of pods per plant*

The results showed that the number of pods per plant under the influence of salt stress and potassium fertilizer became significant at the 1% of probability level, but the interaction of factors on the number of pods per plant was not significant (Table 2). The highest number of pods per plant was related to the control treatment, which was not significantly different from the salinity level of 2 $ds.m^{-1}$, and the lowest number of pods per plant was related to the salinity treatment of 6 $ds.m^{-1}$ (Table 3). Under the conditions of salinity stress, The limitation of the absorption of nutrients by the root leads to a decrease in the production of photosynthetic materials and a decrease in its allocation to the reproductive organs. Therefore, the lack of resources during the flowering period causes the fall of the reproductive organs and fertile flowers, especially the young pods. Ahmed (2009) presented a similar report in a research on mung bean plant. According to the report of Liu *et al*. (2004), the decrease in the number of pods may be caused by the increase in abscisic acid hormone, because the excess of this hormone can cause the death of pollen grains, As a result, the number of pollinated flowers and the number of pods decrease. Since the applied stress, on the one hand, accelerates flowering and reduces the length of the flowering period, and on the other hand, causes less vegetative growth and, as a result, less production of photosynthetic substances, under these conditions, the plant ensures its survival by reducing the number of pods. In a research, Ahmed (2009) investigated the effect of salinity stress on mung bean yield and yield components and reported that the decrease in seed yield was more obvious under salinity stress conditions, and the number of pods per plant and the 100 seed weight under salinity stress conditions were less than the control treatment. Salinity stress had the greatest effect on vegetative growth, flowering and seed filling stages, which was consistent with the results of this research. Also, the highest number of pods per plant was allocated to the treatment of 200 $kg.ha^{-1}$ of potassium fertilizer and the lowest number of pods per plant was allocated to the treatment of no application of potassium fertilizer (control) (Table 3). By strengthening the photosynthesis system of the plant, potassium fertilizer increases the intensity of photosynthesis and more nutrients are transferred to the reproductive organs. As a result, a larger number of flowers are inoculated and turned into pods and finally the number of pods per plant increases. According to the reports of Shirvanipour *et al*. (2014), the effect of potash fertilizer on the number of pods per plant and the number of seeds per plant was significant, and the highest number of pods per plant was obtained from the treatment of using 100 $kg.ha^{-1}$ of potash and the lowest amount from not using potash fertilizer. As Abbas *et al*. (2011) reported in mung bean plant that the number of pods per plant and seed yield were significantly affected by potassium. The minimum number of pods and the number of seeds per pod were obtained from the treatment without potassium consumption (control treatment). Also, in their studies, they pointed out the vital role of potassium element in plant growth and sustainable crop production, which was consistent with the results of this research.

4.2. *Number of seed per pod*

The effect of salinity stress and potassium fertilizer on the number of seeds per pod was significant at the 1% of level, but the effect of treatments on the number of seeds per pod was not significant (Table 2). The control treatment had the highest number of seeds per pod (with an average of 10.68), which was not significantly different with the salinity level of 2 ds.m^{-1}. The lowest number of seeds belonged to the treatment of 6 ds.m^{-1} with an average of 7.65 (Table 3). In this research, factors such as salinity, increased osmotic pressure, and environmental factors decreased the number of seeds per pod. Ahmed (2009) reported that the number of seeds per pod and the 100 seed weight under salt stress conditions were lower than the control treatment. Salinity stress had the greatest effect on vegetative growth, flowering and seed filling stages, which was consistent with the results of this research. The mean comparison of the effect of potassium fertilizer on the number of seeds per pod showed that the highest number of seeds per pod was assigned to the treatment of 200 kg.ha^{-1} of potassium fertilizer and the lowest number was allocated to the treatment of no application of potassium fertilizer (control) (Table 3).

Table 2. Mean square of traits under salinity stress and potassium fertilizer

S.O.V	df	Number of pods per plant	Number of seed per pod	100-seed weight	Seed yield
Salinity stress (S)	3	6.58**	8.89**	3.03**	88.21**
Potassium fertilizer (P)	2	11.49**	10.2**	6.01**	23.79**
S × P	6	0.325^{ns}	0.058^{ns}	0.09^{ns}	10.81**
Error	24	0.549	0.153	0.22	0.49
CV (%)	-	7	4.2	7.08	4.67

^{ns}, * and **: Not–significant and significant at 0.05 and 0.01 probability levels, respectively.

Continue table 2.

S.O.V	df	Biological yield	Chlorophyll index	Proline
Salinity stress (S)	3	426.40**	6.25*	5.76**
Potassium fertilizer (P)	2	820.80**	14.46**	15.42**
S × P	6	136.3**	0.37^{ns}	0.11^{ns}
Error	24	14.30	1.43	0.56
CV (%)	-	10.91	2.15	13.03

^{ns}, * and **: Not–significant and significant at 0.05 and 0.01 probability levels, respectively.

Table 3. Mean comparison of traits under salinity stress and potassium fertilizer

Treatment	Number of pods per plant	Number of seed per pod	100-seed weight (g)	Chlorophyll index (Spad)	Proline ($mg.g^{-1}$ fresh weight)
Salinity stress					
0 (Control)	12.89 a*	10.68 a	8.54 a	57.40 a	3.8 bc
2 ($ds.m^{-1}$)	11.61 a	10.05 b	8.01 a	57.03 a	4.73 b
4 ($ds.m^{-1}$)	9.72 b	8.87 b	5.92 b	55.14 b	6.68 a
6 ($ds.m^{-1}$)	8.23 c	7.65 c	4.48 c	52.05 c	7.76 a
Potassium fertilizer					
0 (Control)	9.1 b	7.81 b	5 b	52 b	4.02 b
100 ($kg.ha^{-1}$)	11.03 a	10 a	7.21 a	57.07 a	6.08 a
200 ($kg.ha^{-1}$)	11.71 a	10.12 a	8.03 a	57.15 a	7.13 a

*Means by the same letters are not significantly different by Duncan's test at 0.05 probability level.

The reason for the high number of seeds per plant with the increase in fertilizer consumption can be attributed to the lack of resource limitations in these conditions. The presence of potassium in the plant prevents many seeds from aborting. Therefore, if there is no resource limitation, the reservoir limitation is also less, and these results were consistent with the findings of Kumar *et al*. (2014) who stated that the number of seeds per pod increases with the use of potassium fertilizer. Research results on mung bean plant showed that the number of pods per plant, the number of seeds per pod and the seed yield were significantly affected by potassium consumption, the minimum number of pods and the number of seeds per pod were obtained from the treatment without the potassium consumption (control treatment) (Abbas *et al*., 2011).

Table 4. Mean comparison of traits under interaction of salinity stress × potassium fertilizer

Treatment	Seed yield ($g.plant^{-1}$)	Biological yield ($g.plant^{-1}$)
Salinity stress × Potassium fertilizer		
0 (Control) × 0 (Control)	13 b*	34.80 b
0 (Control) × 100 ($kg.ha^{-1}$)	15.29 a	39.40 a
0 (Control) × 200 ($kg.ha^{-1}$)	15.78 a	39.78 a
2 ($ds.m^{-1}$) × 0 (Control)	12.10 b	33.65 b
2 ($ds.m^{-1}$) × 100 ($kg.ha^{-1}$)	14.96 a	38.54 a
2 ($ds.m^{-1}$) × 200 ($kg.ha^{-1}$)	15.45 a	39.8 a
4 ($ds.m^{-1}$) × 0 (Control)	9.40 cd	29.70 c
4 ($ds.m^{-1}$) × 100 ($kg.ha^{-1}$)	12.66 b	34.80 b
4 ($ds.m^{-1}$) × 200 ($kg.ha^{-1}$)	12.92 b	35.54 b
6 ($ds.m^{-1}$) × 0 (Control)	6.86 e	24.60 e
6 ($ds.m^{-1}$) × 100 ($kg.ha^{-1}$)	8.61 d	27.76 d
6 ($ds.m^{-1}$) × 200 ($kg.ha^{-1}$)	10 c	30.40 c

*Means by the same letters are not significantly different by Duncan's test at 0.05 probability level.

In a research by Asghar *et al*., (2006) by examining the effect of potassium sulfate (at three levels of 0, 150, 250 $kg.ha^{-1}$) on the yield of mung bean cultivars, they showed that the highest number of seeds per pod was obtained from the treatment of 250 $kg.ha^{-1}$ of potassium fertilizer which was consistent with results of this research.

4.3. *100 seed weight*

The effect of salinity stress and potassium fertilizer treatment on the weight of 100 seed weight was significant at the 1% of probability level, but the interaction of these treatments did not show a significant difference (Table 2). The highest and lowest 100 seed weight were assigned to the control treatment and the salt treatment of 6 $ds.m^{-1}$, respectively (Table 3). The significant decrease in the 100 seed weight with increasing salinity can be due to the reduction of photosynthetic materials in the seed filling stage, the decrease in growth intensity due to osmotic potential, or the decrease in the length of the seed filling period. As Ahmed (2009) reported that the 100 seed weight under salt stress was lower than the control treatment. Salinity stress had the greatest effect on vegetative growth, flowering and seed filling stages. Nabizadeh Marvdasht *et al*. (2002) stated another reason for the decrease in seed weight is the change in the path of photosynthetic materials and plant materials to deal with the effects of salinity stress. Mean comparison of the effect of potassium fertilizer on the 100 seed weight showed that the highest weight was assigned to the treatment of 200 $kg.ha^{-1}$ of potassium fertilizer and the lowest weight was allocated to the treatment of no application of potassium fertilizer (control) (Table 3).showed that the highest weight of 100 seed was assigned to the treatment of 200 $kg.ha^{-1}$ of potassium fertilizer and the lowest weight was allocated to the treatment of no application of potassium fertilizer (control) (Table 3). The lack of access to potassium in the soil, especially in the sensitive stages of Mung bean reproductive growth (including seeding), led to the production and transfer of less photosynthetic material and as a result, the weight of one hundred seeds was small at zero (control) level of potassium. Also, Shirvanipour *et al*. (2014) investigated different levels of potassium on mung bean yield and reported that the effect of potassium fertilizer on the number of seeds in a pod and the 1000 seed weight was significant. The highest amount of these traits was obtained from the treatment of 100 $kg.ha^{-1}$ of potash and the lowest from the non-application of potash fertilizer. On the other hand, it was reported that 100 seed weight was significantly affected by potassium consumption. The minimum number of pods, the number of seeds per pod and the 100 seed weight were obtained from the treatment without potassium consumption (control treatment) (Abbas *et al*., 2011), which was consistent with results of this research.

4.4. *Seed yield*

The results showed that the effect of salinity stress and potassium fertilizer and their interaction on yield was significant at the probability level of 1% (Table 2). The interaction of salinity stress and potassium fertilizer showed that the highest seed yield was obtained from the control treatment and 100kg.ha^{-1} of potassium fertilizer, and the lowest seed yield was obtained from the treatment of 6ds.m^{-1} and no application of potassium fertilizer (Table 4). It seems that the control treatment (no use of sodium chloride) and 100 kg.ha^{-1} of potassium fertilizer had the highest seed yield compared to other treatments due to the higher 1000 seed weight and the number of pods per plant. In this regard, Marschner (1995) showed that the imbalance between sodium and potassium ions causes a sharp decrease in seed yield, and this decrease in yield is due to the effect of potassium ions in activating enzymes and opening and closing stomatal cells. The increase of potassium ion in the aerial organs increases the plant's tolerance to salinity. The researchers reported that the use of potassium sulfate in mung bean plants is directly related to the growth, biomass and yield of crops. The results showed that the yield response to different levels of potassium (0, 100, 120 kg.ha^{-1}) is different. The lowest yield (700kg.ha^{-1}) was obtained with the application of no potassium (control treatment) and the highest yield (1096 kg.ha^{-1}) was obtained with the application of 120kg.ha^{-1} of potassium (Kumar *et al*., 2014). Also, Alavi Matin *et al*., (2015) in investigating the role of potassium in tolerance to salt stress reported that salt stress caused a decrease in seed yield by 68% compared to control. On the other hand, the application of different types of potassium under salinity conditions led to a reduction of the adverse effects of salinity on seed yield by 25% compared to the control. Under salinity stress conditions, potassium maintains photosynthesis by reducing the adverse effects of sodium accumulation, modulating the osmotic potential and relative water content, and increasing stomatal conductance as well as maintaining the chlorophyll content, thereby reducing the adverse effects of salinity stress on seed yield.

4.5. *Biological yield*

The results showed that the effect of salinity stress and potassium fertilizer and their interaction on biological yield was significant at the 1% of probability level (Table 2). The results of the interaction of salt stress and potassium fertilizer showed that the highest biological yield was obtained from the control treatment and 100 kg.ha^{-1} of potassium fertilizer, and the lowest biological yield was obtained from the treatment of 6 ds.m^{-1} and no application of potassium fertilizer (Table 4). Higher biological yield in favorable conditions, which indicates the potential for higher yield, can lead to higher yield in stressful conditions. In this regard, Alavi Matin *et al.* (2015) in the investigating the role of potassium in tolerance to salt stress reported that salt stress caused a decrease in biological yield by 51% compared to the control. On the other hand, the application of different types of potassium under salinity conditions led to a reduction of the adverse effects of salinity on biological yield by 27% compared to the control. By investigating and studying different levels of potassium sulfate in mung bean plant, it was reported that biological yield was significantly affected by potassium consumption. The minimum biological yield was obtained from the potassium deprivation treatment (control treatment) (Abbas *et al*., 2011). In this regard, Shirvanipour *et al*. (2014) investigated different levels of the potassium on mung bean yield and reported that the effect of potassium fertilizer on biological yield was significant. The highest amount of biological yield of 198.4 g.m^{-2} was obtained from the treatment of using 100 kg.ha^{-1} of potash, and the lowest amount equal to 117.1 g.m^{-2} was obtained from the treatment of not using potash fertilizer.

4.6. *Chlorophyll index*

The effect of salinity stress and potassium fertilizer on chlorophyll index was significant at the 1% of probability level, but the effect of these treatments on chlorophyll index was not significant (Table 2). The highest chlorophyll index was assigned to the control treatment and the lowest chlorophyll index was assigned to the 6 ds.m^{-1} treatment (Table 3). Also decreased under the influence of salinity stress. At salinity levels of 0 and 2 ds.m^{-1}, no significant difference was observed in terms of chlorophyll index. In this research, the decrease in chlorophyll concentration is due to the inhibitory effects of the accumulation of different salt ions in the biosynthesis of different parts of chlorophyll. Kaya *et al*. (2006) reported that due to salinity, the amount of chlorophyll decreases. One of the causes of this decrease can be the loosening of the connection of chlorophyll with chloroplast proteins, which depends on the amount of ions. Under the influence of salinity, the amount of Na^+ and CL^- ions increases and reaches the toxic level in severe salinity. Subsequently, the absorption of nutrients such as potassium, calcium and magnesium is reduced, which can be another reason for the reduction of chlorophyll. This reduction can cause the inefficiency of the leaves in carrying out photosynthesis and ultimately reduce the growth and yield of the plant. Jamali *et al*. (2007) reported based on their research that chlorophyll formation stops under severe salinity stress conditions. The decrease in the amount of chlorophyll has various reasons, one of which can be related to the deterioration of the membrane. The highest chlorophyll index was assigned to the treatment of 200 kg.ha^{-1} of potassium fertilizer and the lowest chlorophyll index was assigned to the treatment of no application of potassium fertilizer (control) (Table 3). It seems that the higher chlorophyll index in fertilizer treatments is due to the fact that potassium activates many enzymes, which are necessary for the synthesis of chlorophyll and the formation of carbohydrates. Studies by Ganjipour (2007) confirmed these results. Abbas *et al*., (2011) by investigating and studying different levels of potassium sulfate in mung bean plant, reported that the chlorophyll index and seed yield were significantly increased by potassium consumption, which was consistent with the results of this research.

4.7. *Proline*

The results of this research showed that the effect of salinity stress and potassium fertilizer on the amount of proline was significant, but the interaction of factors had no significant effect on the amount of proline (Table 2). The highest amount of proline was assigned to the salt treatment of 6 ds.m^{-1} and the lowest amount of proline was assigned to the control treatment (Table 3). In salty environments, the amount of amino acids such as proline increases to regulate the osmosis of the internal environment, and the amount of these substances in some plants is 10-20% of the dry weight of the plant (Bandurska and Stroinski, 2003). Accumulation of free proline is a common response to stress in higher plants. Proline affects the solubility of different proteins and enzymes and prevents them from changing their nature (Vendruscolo *et al*., 2007). In plant cells, proline acts as a substance to maintain the osmotic balance between cytoplasm and vacuole. The increase of proline during stress may be the result of the breakdown of proteins and also the reduction of their use due to the reduction of plant growth. Other researchers also reported the accumulation of proline under stress conditions (Nayyar and Walia, 2003). Mean comparison of the effect of potassium fertilizer on the amount of proline showed that the highest amount of proline was assigned to the treatment of 200 kg.ha^{-1} of potassium fertilizer and the lowest was allocated to the treatment of no application of potassium fertilizer (control).. It seems that in this research, the consumption of potassium sulfate reduces the osmotic stress caused by salinity by increasing the amount of potassium absorption, increasing the protein content, preserving the leaf chlorophyll and, as a result, more effective photosynthesis, and also by increasing the concentration of proline in the leaves of the plant improved the resistance of mung bean plant against salt stress (Asghar *et al*., 2006). Also, as Jamali *et al*. (2012) stated the use of potassium sulfate increased proline content under stress conditions, which was consistent with the results of this research.

5. CONCLUSION

The findings of this research indicate that as salinity stress increased, there was a gradual decrease in the measured parameters, with the most significant impact observed between the 4 ds.m^{-1} and 6 ds.m^{-1} salinity levels. As the salt concentration in the soil increased, the water potential of the soil became negative, posing challenges for the plant to absorb water effectively. This situation led to the plant experiencing drought stress, despite the presence of water in the soil. The negative effects of salinity on the plant's water uptake and subsequent drought-like conditions resulted in reduced yield and growth of the plant. As the salt concentration in the soil increased, it adversely affected the development rate of the leaf surface. This was due to the lack of sufficient potential for cell swelling, which impeded proper leaf growth. Moreover, in high salt concentrations, chlorine and sodium ions caused toxicity to the plant, negatively impacting its photosynthetic activities. In salinity conditions of 4 ds.m^{-1}, the application of 100 kg.ha^{-1} of potassium fertilizer effectively prevented yield reduction, and this result was not significantly different from the treatment using 200 kg.ha^{-1} of the same fertilizer. However, as the salinity level increased from 4 to 6 ds.m^{-1}, the treatment with 200 kg.ha^{-1} of potassium fertilizer produced a better yield. This suggests that higher salinity levels necessitate a higher rate of potassium consumption to achieve improved crop yield under such stressful conditions.

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FOOTNOTES

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