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Investigating the Adjustment of Soil Drought Stress with Potassim in Different Levels of Potash Fertilizers (Case Study: Zinnia)

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Abstract

One of the important issues in sustainable agricultural management is the proper yeid of the agricultural products under environmental stress conditions. Naturally, in the dry country of Iran, lack of moisture is one of the main challenges of agriculture. Proper plant nutrition can moderate the effects of drought stress. To investigate the effects of drought stress on plant yield, *Zinnia* was used as a test plant. For this purpose, the growth of *Zinnia* plant in response to drought stress at different levels of potassium fertilization was investigated in a factorial experiment based on a randomized completely block design with two factors. The first factor: Three periods of irrigation including 2 days, 4 days, one week and the second factor: Four levels of potassium fertilizer including: 1) Use of potash fertilizer as base, 2) Use of potash fertilizer as base and during the growth period, 3) Use of potassium fertilizer as a base and during the growth period + 2 times foliar spraying, 4) Using potash fertilizer as base and during the growth period + 4 times foliar spraying. The cultivation medium was used in a 2:1 ratio of soil and manure in each pot. After the end of the growth period, the vegetative indicators include fresh and dry weight of aerial organs (shoot), plant height, number of lateral branches, number of flowers, flower weight, length of the longest branch were measured. The highest growth indices were: Fresh and dry shoot weight in treatment 4 and 2 days irrigation equal 2.36 and 0.33 g, respectively; plant height in treatment 4 and 2 days irrigation; the number of lateral branches in treatment 4 and 2 days irrigation equal 8; and the length of the longest branch in treatment 4 and 2 days irrigation equal 9 cm. The growth conditions in the fertilizer treatments were better than the control and this shows that potassium has increased the resistance of the plant to drought stress.

Keywords: Drought stress, Fertilization, Foliar Spraying, Nutrients, Nutrition.

INTRODUCTION

In sustainable agricultural management, maintaining production in the environmental stress condition is very important (Mohammadi Torkashvand *et al*., 2017). One of the ways to deal with environmental stress in the cultivation of agricultural products is proper nutrition (Majidi *et al*., 2019; Mohammadi Torkashvand *et al*., 2020). Considering the importance of flowers and ornamental plants, the nutritional management of plants in stressful conditions plays an important role in increasing the production of ornamental plants (Hamidpour *et al*., 2013). Zinnia plant is one of the most important cut flowers due to its diversity in shape and color (Yassin and Ismail, 1994) and high economic value (Carter and Grieve, 2010). Its combined cultivation with tomato prevents the growth of nematodes (Yassin and Ismail, 1994).

Water deficit in Iran has always been considered as a factor limiting the cultivation of agricultural crops (Majidi *et al*., 2019). Drought stress in different growth stages, especially the flowering and seeding stages, limits yield. The moisture deficit causes the plant to exhibit various morphological reactions such as leaf surface reduction, early fall, reduction of aerial parts, increase in root growth; and physiological and metabolic responses such as the closing of stomata, the accumulation of antioxidants and soluble substances, and the activity of specific genes (Tofighi Alikhani *et al*., 2021). Diagnosing the growth status of plants under different conditions of irrigation and drought stress can be a guide for the cultivation of resistant plants in dry or low-water areas (Hughes *et al*., 1989).

By reducing the water content of the plant, reducing the leaf water potential and losing turgorescence and closing the stomata, increasing photorespiration and consumption of carbohydrates produced through photosynthesis is one of the important environmental stresses that affect the cultivation of agricultural products. Despite this, the response of plants to drought stress is completely differentiates and depends on the intensity and duration of the stress, as well as the type and stage of plant growth (Ezzati Lotfabadi *et al*., 2022). The limitation of the country's water resources makes the necessity of saving water consumption, applying proper management and using advanced techniques in order to maintain soil moisture reserves, including effective measures to increase irrigation efficiency and thus improve the use of limited water resources (Mohammadi Torkashvand *et al*., 2015).

Potassium affects the quality of crops and the processing of produced products (Mohiti *et al*., 2014). There are more than 50 types of enzymes in plants that are either completely dependent on potassium or stimulated by it (Barker and Pilbeam, 2007; Bhandal and Malik, 1988). Cell enlargement is mainly due to the accumulation of potassium in the cells, which is necessary both to keep the pH of the cytoplasm and increasing the osmotic potential inside the vacuole (Barker and Pilbeam, 2015). In most plant species, potassium plays a major role in changes in turgorescence pressure inside stomatal cells (Bennett, 1993; Malakouti and Shahabi, 2014).

Water is one of the most essential vital needs of plants. Paying attention to agronomic factors is one of the ways to increase the resistance of plants to drought stress, and the role of nutritional factors, especially potassium nutrition, is very important in this regard. The direct effects of potassium in increasing water efficiency can be mentioned as reducing transpiration, increasing water uptake, or creating suitable internal conditions for the plant (Mohammadi Torkashvand *et al*., 2013; Malakouti and Shahabi, 2014). Indirect effects are due to the improvement of plant growth conditions and increase in yield (Mohammadi Torkashvand and Kaviani, 2014).

MATERIALS AND METHODS

Plant materials and growth medium

The experiment was carried out in Khorramabad city, located in Lorestan province, in the West of Iran. Zinnia plant seeds were obtained from Parmis Mahalat Institute. The seeds were planted on June 17 in a light bed of soil-manure and potassium sulfate chemical fertilizer. The soil was passed through a sieve to remove impurities, and one kilogram of soil-manure was poured into the pots with a weight ratio of 2:1. After 10 days passed and the seedlings reached the two-leaf stage (Fig. 1), the plants were transferred to pots (Fig. 2).

Fig. 1. Zinnia seedlings, 10 days after sowing seeds.

Fig. 2. Seeds planted in the main substrate on the first day.

Experimental design

In this research, a factorial experiment based on a randomized completely block design with two factors was designed and implemented (12 treatments in 3 replications and a total of 36 pots):

The first factor: Three irrigation periods including 2 days, 4 days, and one week;

The second factor: Four levels of potassium fertilizer including:

1.The use of potash fertilizer as a basis;

2.Use of potash fertilizer as base and during the growth;

3.The use of potash fertilizer in the form of base and during the growth + 2 times foliar spraying;

4.Use of potash fertilizer in the form of base and during the growth + 4 times foliar spraying.

After the completion of the growth period, the vegetative indicators include fresh and dry weight of aerial organs (shoot), plant height, number of lateral branches, number of flowers, flower weight, length of the longest branch were measured.

Measurement of food growth indices

After 50 days, plant growth traits such as fresh weight and dry weight of shoot, plant height, and number of lateral branches and length of the longest branch were investigated. Fresh and dry weights of the organs were measured with a digital scale, and the height of the plant and the length of the longest branch were measured in meters. To measure the dry weight, after collecting and bagging, the plants were kept at room temperature for 48 hours and dried.

Data analysis

The data from the experiment was analyzed by SPSS 18 software. LSD test was used to compare the averages and Excel software was used to draw graphs.

RESULTS AND DISCUSSION

The effect of fertilization treatments on growth indices

The results of data variance analysis showed (Table 1) that the effect of different treatments on fresh and dry weight of shoot, plant height, number of lateral branches and length of the longest branch was significant.

Table 1. The ANOVA of the data related to the effect of treatments on the growth indices of plants.

S.o.V	df	MS				
		Fresh weight of shoot	Dry weight of shoot	Height	Lateral branches	Longest branch
Fertilization (F)	2	47.8*	1.1**	14.6**	0.07*	12.3**
Irrigation (I)	3	62.7**	2.2*	23.2**	3.32**	42.4**
F × I	6	11.62**	0.37**	3.1**	0.11**	2.8**
Error		12.1	0.52	0.12	0.015	0.41
CV (%)	-	14.2	22.3	32.3	10.2	42.5

* and **: Significant at $P < 0.05$ and $P < 0.01$ based on the LSD test, respectively.

Table 2. The effect of treatments on the growth indices of plants.

Treatment No.	Fertilization	Fresh weight of shoot (g)	Dry weight of shoot (g)	Height (cm)	Lateral branches	Longest branch (cm)
1	Base use of K fertilizer	0.55 c	0.27 b	24.5 c	5.22 c	3.44 c
2	Base and installment use of K fertilizer	1.04 b	0.29 b	23.8 c	5.77 c	6.88 ab
3	Base and installment use of K fertilizer plus 2 foliar spraying	1.60 ab	0.43 a	30.3 b	6.00 b	7.88 a
4	Base and installment use of K fertilizer plus 4 foliar spraying	1.80 a	0.29 b	34.7 a	7.11 a	7.27 a
	Irrigation period					
1	2 days	1.79 a	0.31 b	30.6 a	6.91 a	7.91 a
2	4 days	1.34 b	0.32 b	28.8 ab	6.16 ab	6.58 b
3	One week	0.59 c	0.50 a	26.4 b	5.02 b	4.66 c

*In each column, means with similar letter(s) are not significantly different ($P < 0.05$) using the LSD test.

The results of table 2 showed that the highest weight of shoot was related to treatment 4. The fresh weight of aerial organs in this treatment was significantly more than other treatments. The lowest weight of shoot was obtained in the control treatment. Shoot weight in treatments 2, 3 and 4 increased compared to the control. The results of table 2 showed that the highest amount of dry weight of aerial organs was in treatment 1. The fresh weight of shoot in this treatment was significantly more than other treatments. The lowest dry weight of shoot was obtained in treatment 3. Treatments 2, 3 and 4 had a decrease of dry weight of shoot in compared to the control. Potassium is not present in the structure of proteins, fats and carbohydrates, but it directs various biochemical processes in the assimilation of structural materials in the plant (Barker and Pilbeam, 2007; Ajili Lahiji *et al*., 2018).

The height of the plant in this treatment was significantly higher than other treatments. The lowest plant height was obtained in treatment 2. Treatment 2 decreased height in compared to the control and treatments 3 and 4 increased it in compared to the control. The results (Table 2) showed that the highest number of lateral branches was related to treatment 4. The number of lateral branches in this treatment was significantly more than other treatments. The least number of lateral branches was obtained in treatment of control; reatments 2, 3 and 4 increased compared to the control. The results (Table 2) showed that the length of the longest branch was related to treatment 3. The length of the longest branch in this treatment was significantly more than other treatments. The lowest length of the longest branch was obtained in control treatment; treatments 2, 3 and 4 increased compared to the control.

Fawzy *et al.* (2007) tested the effect of different levels of N (100, 150, 200 and 250 kg/ha) and K (250, 300 and 350 kg/ha) on tobacco plants. The results showed that nitrogen, at the level of 250 kg per hectare, increased the height, number and length of leaves, leaf width and nicotine percentage. The combined use of foliar spraying and soil nutrition caused a significant increase in plant growth indices, including plant length, number of branches per plant, number of leaves per plant, plant fresh weight and fruit weight (El-Naggar, 2009).

The effect of irrigation on growth indices

The results of data variance analysis (Table 1) showed that the effect of different irrigations on fresh and dry weight of shoot, plant height, number of lateral branches and length of the longest branch was significant. The results (Table 2) showed that the highest amount of fresh weight of shoot was in two days irrigation and the lowest in irrigation for one week, the highest amount of dry weight of aerial organs in irrigation for one week and the lowest in irrigation two days, the maximum height of the plant, the number of lateral branches and the length of the longest branch in two days irrigation and the lowest in one week irrigation.

The interaction effect of treatments and irrigation on growth indices

The interaction effect of fertilizer treatments and irrigation period can be seen in table 3. According to the results, plant growth indices in fertilizer treatments were more than the control treatment, and in the interaction effects, it can be seen that the growth status in treatment 4, even in the irrigation cycle of one week, which was the longest irrigation cycle, the growth of the plant is similar to the control treatment with the irrigation cycle of two days. This shows that available potassium to the plant during growth has increased the resistance of the plant.

In the fresh weight of shoot, treatment 4, i.e. fertiliztion of potassium as base and during the plant growth with foliar spraying 4 times, caused a significant increase in the fresh shoot weight in compared to the control, so that the fresh weight of shoot increased 3.3 times than in the control, but there is no significant difference between treatments 3 and 4. This increase is due to the divided consumption of potassium and the provision of potassium needed in two stages of plant growth, as well as providing the plant's need for potassium during growth in the form of foliar spraying. Drought stress can be moderated by the correct consumption of nutrients (Malakouti and Shahabi, 2014; Mohammadi Torkashvand *et al*., 2015).

In the treatments in which potassium foliar spraying (treatment 4) and irrigation were done for two days, the amount of growth indices increased significantly. Potassium is an important substance in cell expansion and the growth of different parts of plants is the result of potassium concentration in cells and vacuoles (Marschner, 1995; Mohammadi Torkashvand *et al*., 2017). In greenhouse experiments, it was reported that the amount of growth decreased due to potassium deficiency, and a noticeable decrease in height, branch length, linear growth, and stem diameter could be seen in the plant. This effect can be related to the reduction of assimilation (Idrisi, 2018).

Table 3. The interaction effect of treatments (fertilization × irrigation period) on he growth indices of plants.

Fertilization	Irrigation period	Fresh weight of shoot (g)	Dry weight of shoot (g)	Height (cm)	Lateral branches	Longest branch (cm)
Base use of K fertilizer	2 days	1.17 cd	0.24 cd	30.6 bc	7.00 abc	6.00 c
	4 days	0.42 e	0.51 a	18.3 d	5.33 cd	4.33 c
	One week	0.09 f	0.06 e	22.33 cd	3.33 d	4.33 c
Base and installment use of K fertilizer	2 days	1.30 c	0.43 b	25.3 c	5.33 cd	7.66 ab
	4 days	1.06 d	0.14 d	20.3 d	6.01 b	7.02 b
	One week	0.76 de	0.03 e	26.0 c	6.02 bc	7.01 b
Base and installment use of K fertilizer plus 2 foliar spraying	2 days	2.32 a	0.28 cd	34.33 b	7.33 ab	9.00 a
	4 days	2.08 ab	0.45 b	31.33 bc	6.66 bc	9.00 a
	One week	0.42 c	0.09 e	28.33 bc	4.00 d	5.66 b
Base and installment use of K fertilizer plus 4 foliar spraying	2 days	2.36 a	0.33 c	32.33 bc	8.00 ab	9.00 a
	4 days	1.82 ab	0.17 d	43.00 a	6.66 bc	6.00 bc
	One week	1.23 c	0.14 d	27.00 c	66.00 bc	7.00 b

*In each column, means with similar letter(s) are not significantly different ($P < 0.05$) using the LSD test.

Potassium is the most abundant ion in the cell and plays an important role in osmotic control, besides it is involved in glycolysis and protein synthesis and activates cytoplasmic enzymes. Studies have shown that mineral salts such as potassium chloride, potassium nitrate and ammonium nitrate are involved in the osmotic balance of flowers (Halvey, 1976).

Bani Jamali and Shafiei (2003) investigated the effect of different levels of nitrogen and potassium on the quantitative and qualitative characteristics of gladiolus. The treatments included nitrogen at five levels of 0, 75, 150, 225 and 300 kg/ha from the source of ammonium nitrate and potassium (potassium oxide) at four levels of 0, 100, 200 and 300 kg/ha from the source of potassium sulfate. The best quantitative and qualitative characteristics of flowers, including the number of florets in an inflorescence, stem diameter and length of flower cluster and life after harvest were obtained from treatments of 200-300 kg/ha of potassium and 75 kg/ha of nitrogen. Bonari *et al*. (1992) stated that the occurrence of water limitation and the creation of drought stress causes a decrease in leaf activity and then a decrease in plant yield. The reasons for the decrease in yield at this stage are the decrease in the length of the seed filling period and the premature aging of the leaves. Kumar (1998) also reported that drought stress in millet causes a decrease in grain yield, the number of grains per cluster, and the weight of 1000 grains.

In general, the results showed that potassium, by controlling the effects of stress and improving plant nutrition, caused better plant growth and growth indices including fresh and dry weight of shoot, plant height, number of lateral branches, and length of the longest branch of the plant. It is suggested to use potassium fertilizer in combination with other fertilizers, especially magnesium and calcium fertilizers, both in foliar spraying and soil fertilization.

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