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Research article

THE EFFECT OF POTASSIUM SULFATE FERTILIZER ON POTASSIUM ACCUMULATION IN LEAVES AND STOMATAL BEHAVIOR UNDER DEFICIT IRRIGATION AT FLOWERING STAGE IN COWPEAS

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ABSTRACT: In order to study the effect of potassium sulfate on potassium accumulation in leaves and stomatal behavior under deficit irrigation in cowpeas, a split plot experiment in randomized complete block design with three replications was carried out in Shahid Salemi field in Ahvaz at longitude 48°40´ east and latitude 31°20´ north and 22.5 m above the sea level in the summer of 2012. The experiment factors involved the main plot including three levels of deficit irrigation (irrigation at 70, 100 and 150 mm evaporation from class A evaporation pan) and the sub plot included four levels of potassium sulfate (0 kg/ha, 50 kg/ha, 100 kg/ha and 150 kg/ha). Each replication included 12 plots so the experiment included 36 experimental units. Stomatal conductance was measured at flowering stage by porometer. The results showed that the effect of deficit irrigation on stomatal conductance was significant and the highest conductance belonged to the treatment with irrigation at 70 mm evaporation. Moreover, the effect of different levels of potassium sulfate on stomatal conductance was significant and the highest stomatal conductance belonged to the treatment with 100 kg/ha potassium sulfate fertilizer.The interactive effects of different levels of deficit irrigation and potassium sulfate fertilizer on all the measured traits were significant. It could be said that among the applied treatments, irrigation at 70 mm evaporation and 100 kg/ha potassium sulfate fertilizer is the best treatment for cowpeas under Ahvaz weather conditions and is the most effective.
Key words: deficit irrigation, potassium sulfate fertilizer, cowpea, stomatal conductance, potassium rate in leaves, flowering

INTRODUCTION

Even though water is considered as one of the most abundant compounds and two-thirds of the Earth is covered by water, water deficit in large areas of the world has limited agricultural products [4]. Drought has major effects on the world agriculture and it might occur during the growth stage of plants and cause a lot of damage [13]. Drought and its consequent stress are among the most important and the most common environmental stresses which have limited agricultural products and have reduced the efficiency of semi-arid areas [7] [8] [14]. However, water scarcity by itself, does not decrease the yield potential to its lowest level and the time and duration of drought are associated with physiological processes [13]. The Economics and management of water resources require that maximum utilization be made of the volume of water. During deficit irrigation conditions, it is highly important to know plants responses and to determine the rate of sensitivity of different growth stages to deficit irrigation. Water is consumed by plants as transpiration and the factors which control or limit transpiration can be studied in two levels of environmental factors and internal factors in plants [2]. Due to population growth and increased demand for food and in order to supply food security, legumes are considered as the most important source of protein in human nutrition [1]. Another feature of legumes is that in agricultural ecosystems of the world and alternate with other crops and through symbiotic relationship with bacteria they contribute to atmospheric nitrogen fixation and provide much of the nitrogen which is required for crops after them. Each year, after these crops are harvested and their roots are rotted, large amounts of nitrogen are added to the soil which will enrich the soil particularly in areas of low agricultural outputs [5]. Cowpea is an important crop which grows widely in hot areas of Africa, Asia, and America and which is often cared for as a kind of crop with high adaptability to high temperatures and drought compared to other species [12].

Cowpea's adaptation to drought is associated with minimizing water losses through controlling the stomata pores [11].It has been proved that the cowpea is capable of maintaining high leaf water potential or relatively high leaf moisture content during water stress [15]. However, this strategy might lead to the decrease of CO2assimilation [10] and the decrease of growth and yield due to stomata closure. Therefore, it should be noted that with regard to the restriction of water and bean cultivation in Iran, the growth of plant and its yield are directly associated with plant water stress. Various bean cultivars have different growth characteristics and each one is suitable for one particular farming system.
This research was carried out as a split plot experiment in the form of randomized complete block design with three replications. The main objectives of the research are:
1. Investigating the effect of potassium sulfate fertilizer on growth components and yield of cowpea
2. Optimized interactive effects to obtain maximum yield
3. Investigating the effect of potassium on the rate of evaporation and transpiration
4. Determining the best time for irrigation

MATERIALS AND METHODS
Research Materials
Geographic Specifications of Experiment Location
This research was carried out in the summer of 2012 in the research field of Shahid Salemi in Ahvaz at longitude 48°40´ east and latitude 31°20´ north and 22.5 m above the sea level.
Physical and Chemical Characteristics of the Soil of Experiment Location

Table 1: Physical and chemical characteristics of the soil of experiment location

Type of soil	Percentage of soil components (%)			Lime(%)	Organic materials (%)	Saturation Percentage (SP)	pH	Ec*10^	(cm) Soil depth
	Sand	Silt	Clay					mmoh/cm	
Clay silt loam	21	39	41	38	0.624	54.97	7.74	4.64	0-30
	18	40	42	39	0.702	57.94	7.76	6.56	30-60

Research methods
Experiment plan
The research was carried out as a split plot experiment in the form of randomized complete block design with three replications. The main treatment included three levels of deficit irrigation (irrigation at 70, 100 and 130 mm evaporation from class A evaporation pan) and the sub treatment included four levels of potassium sulfate (0 kg/ha, 50 kg/ha, 100 kg/ha and 150 kg/ha). Each replication included 12 plots so the experiment included 36 experimental units and each plot included 5 cultivation lines as long as 5 cm and 75 cm spaced from each other and the space between the seeds on the ridge was 20 cm. The distance between two sub plots was 2 m and the two main plots were spaced 2 m from each other by a ditcher.
Plan of Experiment

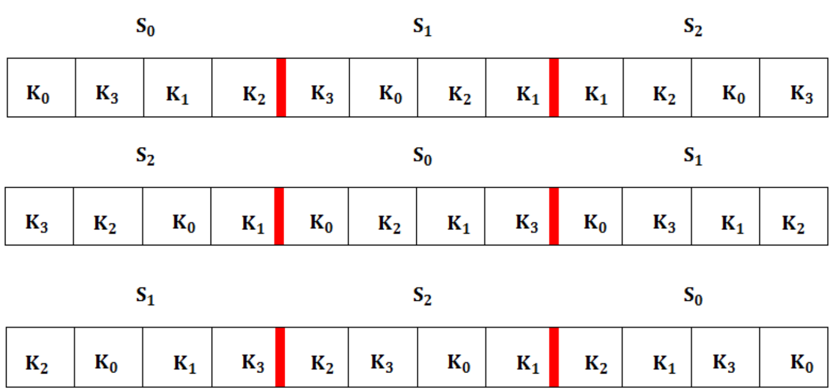

Figure 1: Experiment Map

Features of the Cultivar Used in the Experiment

The cultivar used in this experiment was Dezful local cowpea which was provided by Safi Abad Research Center in Dezful.

Farming Operations or Experiment Procedures

Pre-plant Operations

Land Preparation and Sowing Plan Implementation

Land preparation operations included preparing ground floor, brushing, plowing with moldboard plow at a depth of 30 cm, crushing the lumps, which were made through plowing, by disks and then leveling operation was with trowel before making furrows and for removing ups and downs made by plowing and disk and to level the land. Finally the ridge and furrow were made and plotting was done. After final leveling, the desired land was measured and marked. Replications and main plots were separated from each other by ditcher and planting rows were created using furrow opener.

Required Fertilizer

According to recommendations on optimum use of chemical fertilizers in order to provide the needed phosphorus for the plant, triple superphosphate fertilizer was used and the required nitrogen was prepared from urea resource during the interval between the first and the second disks by the average of 90 and 75 kg/ha respectively and then they were spread in the land as base fertilizer at the same time and then buried under the soil.

Planting Operations

Planting Seeds

Panting the cowpea seeds as one-way cultivation was done along the ridges in July. The seeds were planted manually. With regard to the experiment treatments, each plot included 5 planting lines as long as 5 m and 50 cm spaced from each other and the main plots were 2 m spaced from each other. The seeds on the rows were 20 cm spaced from each other and in each hole 3 seeds were planted at a depth of 3-4 cm.

Required Fertilizer

After planting the beans, potassium sulfate which was considered as sub treatment was added manually to the experimental filed according to the experiment map by making grooves on the rows by the rate of 0, 50, 100, 150 kg/ha.

Growing Operations

Irrigation

Irrigation was done based on full irrigation of the field until the fourth stage (establishment stage) and then irrigation treatments were applied according to the experiment plan.

Thinning Operations

Since during planting the seeds were planted 2-3 times as many as the required ones, in order to regulate density at 24-leaf stage thinning was done manually and the farm got the real density.

Dealing with the Weeds

During the growth stage the weeds were cut manually by workers.

Harvesting Operations

Plots were harvested manually by sickle as the pods were getting yellow. The final harvest area was considered to be 2 m^2.

Measured Traits and Method of Measurement

For sampling the behavior of stomata the leaf porometer was used and for measuring the rate of potassium in leaves, the flame photometer was used in Karun Dasht laboratory of soil, water, and plant in Khuzestan.

Statistical Analysis

Collected data was analyzed viavariance analysis of the data obtained by split plot experiment based on randomized complete block design by means of statistical software of Minitaband finally the means were compared through Duncan's test at probability levels of 5% and 1%. Excel 2007 software was used to draw diagrams and curves.

RESULTS AND DISCUSSION

The Effect of Deficit Irrigation and Potassium Sulfate Fertilizer on the Mean of Stomatal Conductance and Potassium Rate in the Leaves of Cowpeas

The ANOVA results showed that the effect of deficit irrigation on the mean of stomatal conductance and potassium rate in leaves was significant at 5% probability level (Table 2). Moreover, the ANOVA results indicated that the effect of potassium sulfate on the mean of stomatal conductance and potassium rate in leaves was significant at 1% probability level (Table 2).

Table 2: The ANOVA table of stomatal conductance mean and potassium rate in Cowpea's leaves at different levels of deficit irrigation and potassium sulfate fertilizer

Mean squares		Degree of freedom	Sources of variation
Leaves potassium rate	Stomatal conductance		
0.00518	36547.21	2	replication
0.03306 *	14818.39 *	2	Deficit irrigation
0.00473	2119.81	4	Main plots error
0.00240 *	6761.08 *	3	Potassium sulfate
0.00308 **	5429.72 *	6	Deficit irrigation× potassium sulfate
0.00072	2018.36	18	Sub plot errors
15.98	7.79		Coefficient of variations (CV %)

ns, *, ** respectively represent non-significand difference and significant difference at probability levels of 5% and 1%.

The highest Stomatal conductance mean by the average of 749 belonged to the treatment with irrigation at 70 mm evaporation from class A evaporation pan. Moreover, the mean comparison of the simple effect of deficit irrigation on the mean of stomatal conductance and the rate of potassium in leaves showed that the highest rate of potassium in leaves by the average of 0.167 belonged to the treatment with irrigation at 100 mm evaporation from class A evaporation pan (Table 3). In addition, the mean comparison of the effect of different levels of potassium phosphate fertilizer on the mean of stomatal conductance and the rate of potassium in leaves showed that the highest rate of stomatal conductance by the average of 764 belonged to the treatment with 150 kg/ha potassium sulfate and the highest rate of potassium in leaves by the average of 0.158 belonged to the treatment with 150 kg/ha potassium sulfate (Table 3).
Liker (1999) stated that the reason of potassium intake increase under drought stress has been reported to be the active absorption mechanism of this ion, so that the plant, contrary to diffusion phenomenon, spends a lot of energy to increase potassium concentration in its roots and shoots in order to increase its own resistance to drought. The increase of potassium intake leads to a positive effect on photosynthesis, increase of leaf area index and growth, enhancement of ATP and NADPH syntheses, increase of a, b chlorophyll synthesis, increase of mobilization of nitrogenous materials to grains in cereals, further synthesis of protein and polymer compounds, regulation of stomata opening and closure, increase of the number of stomata, decrease of transpiration, and the most important thin during water stress, i.e. the increase of water absorption and provision of suitable internal conditions through regulating osmotic pressure and decreasing transpiration [3].

Table 3: Mean comparison of the effects of different levels of deficit irrigation and potassium phosphate fertilizer on the mean of stomata on the leaves, stomata under the leaves, stomatal resistance and the rate of potassium of cowpea leaves

Mean squares		treatments
Leaves potassium rate(g)	Stomatal conductance (m mol m-2S^{-1})	Irrigation levels
0.129 ab	794 a	Irrigation at 70 mm evaporation from class A evaporation pan
0.167 a	714 ab	Irrigation at 100 mm evaporation from class A evaporation pan
0.143 ab	600 b	Irrigation at 130 mm evaporation from class A evaporation pan
		Levels of potassium sulfate fertilizer
0.131 b	644 b	0 kg/ha
0.143 ab	677 b	50 kg/ha
0.153 a	725 ab	100 kg/ha
0.158 a	764 a	150 kg/ha

The means of the plots with similar letters are not significantly different from each other according to Duncan's multiple tests at 5% level.

It showed that the consumption of sufficient amount of potassium fertilizer, compared to lack of potassium, improved the moisture content and water relations of plant by reducing osmotic potential inokra, so that it led to stabilized rate of net photosynthesis, transpiration, and stomatal conductance under drought stress and stress free conditions.
Moreover, they stated that the use of enough potassium fertilizer in this plant while the water potential of plant is low leads to maintenance of net photosynthesis rate and increase of the ratio of net photosynthesis to transpiration. Studies have shown that under drought conditions the use of potassium fertilizer leads to the increase of leaf area within Ajax cultivar of potato [6].
The mean comparison of the interactive effects of different levels of deficit irrigation and potassium sulfate fertilizer on stomatal conductance and potassium rate in cowpea leaves showed that the highest mean of stomatal conductance by the average of 850 belonged to the treatment with irrigation at 70 mm evaporation from class A evaporation pan and 150 kg/ha potassium sulfate fertilizer and the highest rate of potassium in leaves by the average of 0191 belonged to the treatment with irrigation at 100 mm evaporation from class A evaporation pan and 150 kg/ha potassium sulfate (Table 4) (Figure-2).

Table 4: the mean comparison of the interactive effects of different levels of deficit irrigation and potassium sulphate fertilizer on stomatal mean and potassium rate of cowpea leaves

Mean squares		plot	
Leaves potassium rate (g)	Stomatal conductance (mmol $m^{-2}s^{-1}$)	Potassium sulfate levels	Irrigation levels
0.119 c	732 bc	0 kg/ha	Irrigation at 70 mm evaporation from class A evaporation pan
0.133 bc	774 b	50 kg/ha	
0.128 c	819 a	100 kg/ha	
0.136 bc	850 a	150 kg/ha	
0.133 bc	686 c	0 kg/ha	Irrigation at 100 mm evaporation from class A evaporation pan A
0.155 ab	697 c	50 kg/ha	
0.187 a	708 bc	100 kg/ha	
0.191 a	765 b	150 kg/ha	
0.142 b	513 e	0 kg/ha	Irrigation at 130 mm evaporation from class A evaporation pan A
0.140 b	562 de	50 kg/ha	
0.143 b	648 cd	100 kg/ha	
0.146 b	676 cd	150 kg/ha	

The means of the plots with similar letters are not significantly different from each other according to Duncan's multiple tests at 5% level.

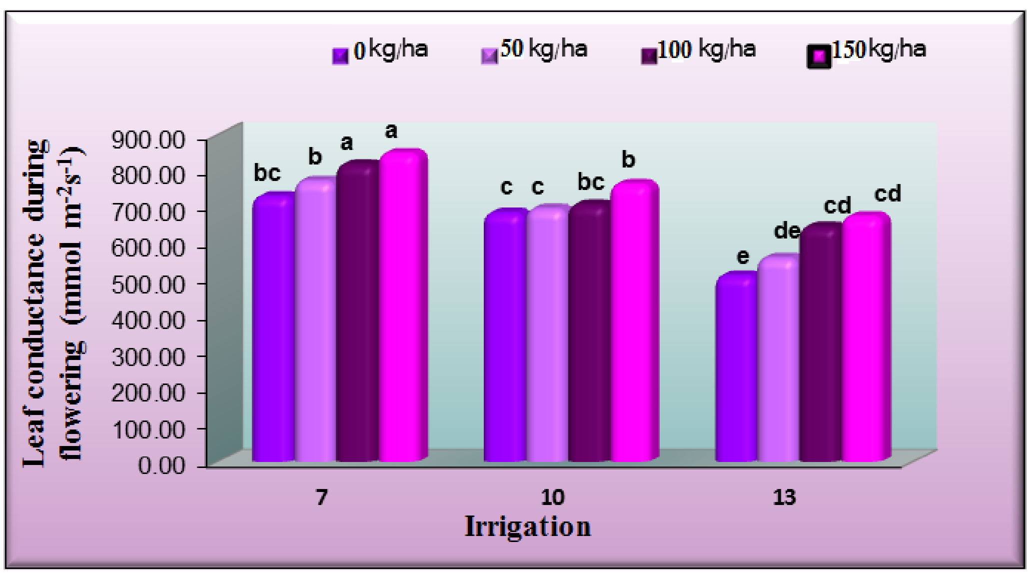

Figure-2: The mean comparison of interactive effects of different levels of deficit irrigation and potassium sulfate fertilizer on the mean of stomatal conductance during cowpea flowering time

The results of the reserch conducted by Saki Nejad (2003) showed that during its early growth stages when enogh water is available to it, the plant had liitel stomatal resistance, but by practicing more serious stress and during growth stages of V2 and V3 stmatal resistance increased singnificantly and this stomatal resistance in lower surface of the leaf was more than in upper sarface of it [3].

Ania and Herzog [9] reported that throgh the passage of drought stess time in cowpeas, the rate of photosynthesis, transpiration, and stomatal conducance decreased and CO_2 concentration under stomatal chamber increased. They stated that this matter might be due to leaflets aging; in addition, the decrase of assimilation rate was mailly due to the closure of stomata and some limitatoions wre seen as well due to non-stomatal regulation. Over time, the drought stress in cowpea, photosynthetic rate, transpiration, stomatal conductance decreased versus CO_2 concentration on stomatal chamber increases. Also assimilatory reduction in the rate was primarily due to stomatal closure, however, some limitations due to non-stomatal regulation was also observed [9].

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