AMELIORATION OF WATER STRESS BY POTASSIUM FERTILIZER IN CHICKPEA (*Cicer arietinum* L.)

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ABSTRACT

Drought stress is one of the major abiotic stresses in agriculture. The application of potassium mitigates the adverse effects of water stress which facilitate higher growth and yield of crop. The present study was carried out to investigate the effect of drought stress on dry weight partitioning, leaf area, leaf water potential, leaf osmotic potential, relative water content, photosynthesis, respiration and chlorophyll content in chickpea (*Cicer arietinum* L.) cv. H-208. The stressed condition was conducted by withholding irrigation at different sampling stages. Water stress resulted in marked decrease in chlorophyll content, stomatal conductance hence reduction in CO_2 fixation and induces reactive oxygen species formation in the genotype. Genotype of chickpea H-208 was investigated for the role of potassium on leaf area, water potential of leaf, leaf osmotic potential, relative water content, photosynthesis and respiration in alleviating water stress. Potassium was added to the soil as muriate of potash in different concentrations in addition to the existing potassium level. Water stress significantly decreased the dry weight of leaves, stem and leaf area. Potassium application significantly increased the dry weights and leaf area both under control and stressed conditions. Water potential, osmotic potential, relative water content of leaves (RWC), chlorophyll content and photosynthetic rate also decreased under stressed conditions. Application of potassium increased the relative water content of leaf, chlorophyll content and photosynthetic rate both under control and stressed conditions. Therefore, potassium in chickpea played a vital role in increasing water stress resistance and stabilizing yield.

Key words: chickpea, water stress, potassium, photosynthesis, respiration.

INTRODUCTION

Abiotic and biotic stresses negatively influence survival biomass production and crop yield (Dev 1995; Tomar 1998; Amtmann et al. 2004; Agrawal et al. 2006). Water deficit is frequently the primary limiting factor for crop production under arid and semi-arid conditions (Hussain et al. 2004). Water deficit results in a significant reduction in plant water potential, photosynthetic rates, respiration, and nitrogen-fixation (Farooq et al. 2009; Yarnia et al. 2011). Chickpea (*Cicer arietinum* L.), a member of fabaceae, is the world's third most important pulse crop and a major source of protein for millions of peoples in developing countries (Esfahani et al. 2010; Rahman et al. 2008). Chickpea cultivation not only provides a major protein source of our diet, it also has a capacity to improve the quality of nitrogen deficient soil by forming nitrogen fixing nodules in symbiotic association with specific rhizobial strains. Drought is also a significant yield limiting factor in chickpea production as the major chickpea growing areas are in the arid and semi-arid zones and about ninety percent of world's chickpea is grown under rain fed conditions (Kumar & Abbo 2001). Late season drought stress during flowering, pod formation and grain filling stages, is a major abiotic stress which reduces chickpea yield capacity (Molina et al. 2008; Sabaghpour et al. 2006). Therefore, studies are needed to increase the efficiency use of water available. It is important to elucidate the drought tolerance mechanism of these species in order to improve its agronomic performances (Subbarao et al. 1995). Status of mineral nutrients in plants plays a critical role in increasing plant resistance to drought stress (Marschner 1995).

The application of potassium mitigates the adverse effect of water stress which facilitates higher growth and yield levels of crop. Potassium is an important macronutrient for plants, it plays vital functions in metabolism, growth and stress adaptations (Krauss 2001), and only a very small amount

below 60 ppm becomes available to plants (Leigh & Jones 1984). Potassium influences the water use economy and crop growth through its effect on water utilization, economy, by root growth reflecting maintenance of turgor, transpiration and stomatal behaviour (Nelson 1978). The present investigation was thus undertaken to study the response of chickpea (Cicer *arietinum* L.) to potassium applications under water stress conditions.

MATERIALS AND METHODS

The genotype of chickpea (Cicer *arietinum* L.) H-208, selected for the study, obtained from Chaudhary Charan Singh Haryana Agricultural University, Hisar. The crop was raised in earthen pots (30 cm in diameter× 30 cm in height) covered with polythene bags and filled with 5 kg of dune sand during rabi season, using complete randomized design (CRD). These pots were placed in the net house under natural conditions and sowing was carried out at field capacity of soil. Potassium was added to the soil after germination in the form of muriate of potash at 0, 60, 90 and 120 ppm potassium concentrations in addition to the existing level (50 ppm) of potassium in the soil medium. The water stress condition was created at 5.5 ± 0.5% of soil moisture content (SMC) by withholding irrigations at three sampling stages i.e. vegetative (40 Days after sowing), 50% flowering (85 DAS) and 50% pod formation (110 DAS) . The control plants were maintained at 12 ± 0.5% of SMC which was fifty per cent of soil saturation percentage (25%). Five pots of the stressed wilted plants were re-irrigated on the same day and sampled after two days to see the revival of stress. Each pot was supplied with equal quantity (200 ml) of nitrogen free nutrient solution (Wilson & Reisenauer 1963) at a regular interval of seven days. Two plants in each pot, replicated three times were sampled for various parameters under moisture stress and on revival along with control.

Fresh and dry weights of leaves, stem were taken at various sampling stages. Leaf water potential was measured with the help of pressure chamber (Model 3005, Soil Moisture Equipment Corporation,USA), Osmotic potential was determined by using Psychrometric technique (Model 5100-B Vapour Pressure Osmometer, USA) and Relative water content (RWC) was calculated as described by Weatherley (1950). The third fully expanded leaves from top were detached, weighed immediately to determine the fresh weight. The leaves were floated then on water surface in closed petridishes for 3 hours in diffused light at constant temperature of $25+\_1^0$ C, and weighed again (fully turgid). Finally the dry weight was taken after oven drying the leaves at 75^0 C. These three weights were then used to determine the RWC. The rate of photosynthesis and respiration were measured by monitoring changes in CO_2 concentration using Infra Red Gas Analyzer (IRGA ADC type, 225/2K, England). Photosynthesis was measured between 10.0 and 11.0 hr during day time.While respiration was measured between 9.00-10.0 hr during night. The plants enclosed in a Perspex chamber acc to height of the plant. The chamber was then connected to IRGA with the help of Teflon tubes. At the end the area of all the leaves was determined by leaf area meter.

Chlorophyll content of leaves was determined by the method of Arnon (1949). Three replicates for each parameter were taken and statistical analysis was done by using CRD factorial design.

RESULTS

A continuous increase in dry weights of leaves up to flowering stage was observed but decreased beyond that stage (Table 1). The dry weights of stem continued to increase with the age of the plants. Water stress significantly decreased the dry weights of leaves and stem during all the stages. Significant increase in dry weights in response to applied potassium under stress as well as under normal condition was observed. Maximum leaf area was recorded at flowering stage and then it showed sharp decline at pod formation stage. Leaf area significantly decreased under water deficit condition. Treatment with potassium brought a significant increase in leaf area in both control and stressed plants (Table 1).

Water potential of leaf decreased significantly under water stressed conditions. Potassium application also caused a decrease in water potential (Ψ_w) but to a lesser extent as compared to those in the

Table : 1. Interaction of drought and applied K on dry weight partitioning and leaf area of chickpea

Parameter	Stress Level	Vegetative Stage K (ppm)					Flowering Stage K (ppm)					50% pod formation k (ppm)				
		0	60	90	120	Mean	0	60	90	120	Mean	0	60	90	120	Mean
DW of leaf (g plant $^{-1}$)	Control	0.58	0.68	0.72	0.73	0.67	1.97	2.44	2.71	2.72	2.46	1.76	2.16	2.34	2.36	2.15
	Stress	0.44	0.51	0.53	0.54	0.50	1.50	1.81	1.93	1.94	1.79	0.86	1.21	1.27	1.29	1.15
	Revival	0.49	0.59	0.64	0.65	0.59	0.93	1.15	1.26	1.26	1.15	0.62	0.98	1.13	1.14	0.96
	Mean	0.50	0.59	0.63	0.64		1.46	1.81	1.96	1.97		1.08	1.45	1.58	1.59	
C.D. at 5% level		S=0.081, K=0.093, S×K=NS					S=0.016, K=0.018, S×K=0.031					S=0.015, K=0.017, S×K=0.029				
DW of stem (g plant^{-1})	Control	0.41	0.54	0.59	0.61	0.53	1.84	1.97	2.03	2.04	1.97	2.22	2.30	2.35	2.37	2.31
	Stress	0.26	0.35	0.37	0.38	0.34	1.30	1.39	1.43	1.44	1.39	1.79	1.85	1.89	1.90	1.85
	Revival	0.36	0.45	0.50	0.51	0.45	1.57	1.68	1.71	1.71	1.66	2.01	2.08	2.12	2.13	2.08
	Mean	0.34	0.44	0.48	0.50		1.57	1.68	1.72	1.73		2.00	2.07	2.12	2.13	
C.D. at 5% level		S=0.11, K=0.118, S×K=NS					S=0.15, K=0.17, S×K=0.29					S=0.19, K=0.22, S×K=NS				
Leaf area (cm^2)	Control	219	232	268	274	248	342	364	425	431	390	215	221	262	271	242
	Stress	118	129	143	146	134	241	254	274	279	262	107	113	134	138	123
	Revival	189	196	215	220	205	202	207	229	233	217	98	101	119	121	109
	Mean	175	185	208	213		261	275	309	314		140	145	171	176	
C.D. at 5% level		S=2.60, K=3.00, S×K=5.21					S=4.80, K=5.54, S×K=9.60					S=2.84, K=3.28, S×K=5.69				

DW = Dry Weight, S=Stress levels, K=Potassium concentration

Table : 2. Interaction of drought and applied K on leaf water relations of chickpea

		Vegetative Stage					Flowering Stage					50% pod formation				
Parameter	Stress level	K (ppm)					K (ppm)					K (ppm)				
		0	60	90	120	Mean	0	60	90	120	Mean	0	60	90	120	Mean
Water potential (-Mpa)	Control	0.517	0.563	0.586	0.591	0.564	0.595	0.642	0.681	0.685	0.650	0.733	0.827	0.840	0.845	0.811
	Stress	1.17	1.26	1.29	1.30	1.26	1.70	1.74	1.79	1.80	1.75	1.95	2.05	2.08	2.08	2.04
	Revival	0.708	0.776	0.814	0.821	0.779	1.04	1.10	1.15	1.16	1.11	1.28	1.38	1.39	1.40	1.36
	Mean	0.801	0.866	0.898	0.906		1.11	1.16	1.21	1.21		1.32	1.42	1.43	1.44	
C.D. at 5% level		S=0.11, K=0.13, S×K=0.10					S=0.14, K=0.17, S×K=NS					S=0.17, K=0.19, S×K=NS				
Osmotic potential (-Mpa)	Control	0.673	0.726	0.762	0.782	0.735	1.21	1.25	1.30	1.31	1.27	1.68	1.71	1.75	1.77	1.73
	Stress	1.49	1.53	1.58	1.59	1.55	2.42	2.45	2.49	2.50	2.46	2.83	2.86	2.88	2.90	2.87
	Revival	0.866	0.915	0.940	0.958	0.919	1.53	1.56	1.59	1.61	1.57	2.07	2.10	2.13	2.15	2.11
	Mean	1.01	1.05	1.09	1.11		1.72	1.75	1.79	1.80		2.19	2.22	2.26	2.27	
C.D. at 5% level		S=1.46, K=1.75, S×K=1.16					S=1.86, K=1.12, S×K=1.26					S=1.20, K=1.97, S×K=2.14				
RWC (%)	Control	72.6	73.4	76.4	78.0	75.1	65.8	66.4	68.9	69.6	67.6	56.2	56.8	58.4	59.9	57.8
	Stress	30.5	31.0	32.8	34.2	32.1	26.5	27.2	28.8	29.3	27.9	20.4	20.7	22.3	23.4	21.7
	Revival	70.2	70.8	73.2	74.6	72.2	62.3	63.8	66.2	67.5	64.9	51.3	52.0	53.6	54.5	52.8
	Mean	57.7	58.4	60.8	62.2		51.5	52.4	54.6	55.4		42.6	43.1	44.7	45.9	
C.D. at 5% level		S=0.28, K=0.33, S×K=0.80					S=0.38, K=0.44, S×K=NS					S=0.41, K=0.48, S×K=0.82				

Table : 3. Interaction of drought and applied K on rate of photosynthesis, respiration and chlorophyll content of leaves of chickpea

Parameter	Stress level	Vegetative Stage K (ppm)					Flowering Stage K (ppm)					50% pod formation K (ppm)				
		0	60	90	120	Mean	0	60	90	120	Mean	0	60	90	120	Mean
Photosynthesis (mg CO_2	Control	16.96	17.97	30.35	21.53	19.20	38.12	41.16	47.44	49.55	44.06	9.44	10.01	11.51	11.98	10.73
fixed h^{-1} plant $^{-1}$)	Stress	4.41	4.85	5.73	5.95	5.23	9.63	10.78	13.00	13.67	11.77	2.33	2.56	3.06	3.23	2.79
	Revival	9.85	10.34	11.82	12.01	11.00	21.15	22.41	25.80	26.43	23.94	5.65	5.93	6.72	6.83	6.28
	Mean	10.40	11.05	12.63	13.16		22.96	24.78	28.74	29.88		5.80	6.16	7.09	7.34	
C.D. at 5% level		S=0.17, K=0.20, S×K=0.35					S=0.25, K=0.28, S×K=0.49					S=0.63, K=0.73, S×K=0.12				
Respiration (mg CO_2 evolved h^{-1} plant $^{-1}$)	Control	4.97	4.39	4.25	4.22	4.45	9.15	8.71	8.40	8.35	8.65	6.91	6.28	6.01	5.97	6.29
	Stress	8.68	8.20	8.00	7.95	8.20	4.33	3.91	3.74	3.71	3.92	2.21	2.51	2.01	1.99	2.18
	Revival	6.56	6.09	5.88	5.84	6.09	6.48	5.96	5.69	5.64	5.94	4.83	4.36	4.09	4.06	4.33
	Mean	6.73	6.22	6.04	6.00		6.65	6.19	5.94	5.90		4.75	4.28	4.03	4.00	
C.D. at 5% level		S=0.37, K=0.57, S×K=0.25					S=0.96, K=0.75, S×K=0.72					S=1.21, K=0.73, S×K=0.51				
Chlorophyll content (mg	Control	9.53	9.91	10.16	10.21	9.95	11.46	11.39	12.12	12.55	11.90	6.29	6.60	6.73	6.76	6.74
g^{-1})	Stress	4.96	5.10	5.26	5.29	5.15	6.29	6.64	6.77	6.78	6.62	2.88	3.20	3.33	3.34	3.18
	Revival	6.35	6.74	6.95	6.99	6.75	7.74	8.25	8.41	8.43	8.20	4.05	4.48	4.67	4.69	4.47
	Mean	6.94	7.24	7.45	7.49		8.49	8.92	9.10	9.12		4.40	4.76	4.91	4.93	
C.D. at 5% level		S=0.96, K=0.11, S×K=NS					S=0.14, K=0.16, S×K=0.24					S=0.40, K=0.46, S×K=0.79				

S=Stress levels, K=Potassium concentration

stressed treatment. Osmotic potential of leaf decreased with the advancement of stages of growth. Water stress resulted in a remarkable decrease in osmotic potential at all the stages (Table 2).

Application of potassium significantly decreased the osmotic potential but magnitude was much lower as compared to stress condition. Relative water content of leaf decreased progressively with the ageing of plants. Exposing the plants to water stress by withholding irrigations resulted in a significant decrease in RWC for the three growth stages. A significant increase in RWC of leaf with the increase in concentration of potassium was observed in both control and stressed conditions (Table 2).

The highest photosynthetic rate was observed at the flowering stage. Under water stress, photosynthetic rate significantly decreased. Potassium application significantly increased the rate of photosynthesis under stressed conditions. Water stress resulted in a sharp decline in the rate of respiration during flowering and pod formation stages. While at vegetative stage, it resulted in increased rate of respiration. Increased level of potassium has resulted in a progressive decreased in the rate of respiration at all the growth stages (Table 3).
Total chlorophyll content in leaves increased up to flowering stage. Water stress resulted in the significant reduction of total chlorophyll content but the magnitude of reduction was relatively higher at pod formation stage. Application of potassium resulted in a significant increase in the chlorophyll content under both control and water stressed conditions at all stage of growth.

DISCUSSION

Dry weight of leaves reached their maximum at 120 ppm of potassium concentration at flowering stage in control as well as in stress, followed by reduction in the dry weight of leaves at pod formation stage (Table 1). This reduction was due to severe leaf abscission and senescence during pod formation stage. Dry weight of stem continued to increase as secondary branches continued to emerge on the stem both in control and stressed plants. Water stress significantly reduced the dry weight of different plant organs. On revival, the recovery in dry weight was partial in different plant parts. There was reduction in the dry weight of leaves at flowering and pod formation stage during revival which can occur due to enhanced abscission under water stress (Table 1). Such deleterious effects of water stress have long been recognized Huck et al. (1986). These observations confirm those of Matthias and Smith (1997); Bai and Li (2003) and Gorai et al. (2010). Water stress lowers the cell turgor and causes slower cell expansion. Consequently growth and development of a plant decreased that leads to a lower plant dry weight (Plaut et al. 2000). Treatment with K increased the dry weight of leaves and stem. In general, the per cent increase in dry weight of leaves under the influence of potassium (120 ppm) was 25.2, 14.9, 23.5 and for stem the increase was 24.2, 16.2, 30.1 under control and water deficit, respectively. Stimulating effect of potassium on dry matter accumulation was reported by Sharma et al. (1992), Cadisch et al. (1993) and Umar et al. (1993). The increase in rate of photosynthesis, leaf area and decrease in rate of respiration under the influence of potassium may be due to the increase in dry weight of different plant parts. Significant decrease in leaf area under water stress was observed which was mainly due to the decrease in RWC (Table1). Leaf area decreased continuously with an increase in soil moisture stress as observed by Umar et al. (1993). Potassium brought a significant expansion of leaf area under control (24.7%) as well as stress conditions (14.1%) at flowering stage.

Water potential, osmotic potential and relative water content (RWC) of leaves decreased significantly under water stress conditions (Table 2). Gorai et al. (2010) reported that the RWC decreased significantly as water stress intensified. A similar behaviour was observed in *Phaseolus vulgaris* (Martinez et al. 2007) and *Medicago truncatula* (Nunes et al. 2008). Under water stress, values of osmotic potential (Ψ_w) was relatively lower than the control values at all sampling stages. The values of osmotic potential and RWC of leaf increased upon re-watering the plants but remained lower than the control. Maribona et al. (1992) reported that osmotic potential of the plants tends to decrease under water stress, is accompanied by a change in RWC indicating a higher or lower osmo regulation depending upon the magnitude of the decrease. Decreased leaf water potential ($\Psi_{w)}$ under stress may

be due to decreased absorption and translocation of water as a result of loss of gradient in Ψ_w between the soil and roots which is the guiding principle for water movement and decline in transpiration pull. Under stress condition, the decreased in osmotic potential was mainly due to the accumulation of solutes like proline, soluble carbohydrates and potassium. The change in Ψ_w under water deficit may reflect change in osmotic potential and can be used in screening for osmotic adjustment. Moreover, the osmotic adjustment enables plants to deplete the soil water to a lower soil Ψ_w and thus facilitate a greater exploration of available soil moisture by roots. Khan et al. (1999) observed in wheat the drought tolerant genotypes maintained turgor by decreasing osmotic potential in a condition of lower leaf water potential due to stress. They also concluded that sucrose and K^+ were the major factors affecting osmotic potential. Perhaps the high level of potassium contributed for the maintenance of turgor and thus improved the growth processes of the plant, which were affected due to water stress. The study on the trend of RWC changes showed that with increase in plant age, a decrease was observed in RWC under the irrigation regimes in different sampling stages (Table 2). Palomo et al. (1999) and Ardestani and Rad (2012) also reported that the increase in RWC at the beginning of the season and a decrease at later stages. Potassium application has increased the RWC under favourable moisture conditions and under drought stress conditions (Table 2). This suggests that potassium has a positive role in turgidity maintenance and continual cell growth (Egilla et al. 2005; Fusheng 2006). The high drought stress intensity increases the potassium requirement of plants for improving the water status and maintaining photosynthesis (Umar 2006). RWC of leaves and was enhanced with the increase in concentration of potassium. Umar et al. (1993) reported that potassium enhanced the RWC of leaves and was coupled with reduction in water loss. The enhanced RWC helped the plants to perform various physiological processes like photosynthesis, enzymes activity and biochemical metabolism to continue more efficiently even under low soil moisture condition.

Water stress resulted in the significant reduction of total chlorophyll content of the leaves. Likewise, Maiti et al. (2000) and Thalooth et al. (2006) revealed that withholding irrigation at any growth stage decreased the content of chlorophyll, 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 (Yang et al. 2001). Furthermore, Schtz and Fangmeier (2001) added that water stress accelerates chlorophyll-a breakdown. Photosynthetic rate increased up to flowering and then declined (Table 3). The decrease in rate of photosynthesis of leaves after flowering in legumes seems to be a common phenomenon (Luthra et al. 1983). Under water deficit condition the net photosynthetic rate was drastically reduced. Both stomatal and non-stomatal factors can contribute to this decrease (Kuhad & Sheoran, 1982). Reduction in photosynthesis may also be due to decreased Ψ_w and RWC under water stress which led to loss of leaf turgor and ultimately decreased stomatal conductance of leaves. Our experiment of results further indicates that reduction in photosynthesis seems to be due to a decrease in chlorophyll content under water stress (Table 3). Sharkey (1990) suggested that the photosynthetic machinery can tolerate high levels of leaf water deficit and that the inhibition of CO_2 fixation typically observed in water-stressed leaves is almost exclusively due to reduced CO_2 supply resulting from stomatal closure. Severe drought stress also inhibits the photosynthesis of plants by causing changes in chlorophyll content, affecting chlorophyll components and damaging the photosynthetic apparatus (IturbeOrmaetxe et al. 1998). The rate of photosynthesis was enhanced with supply of potassium in control (23.3 %) and water stress conditions (26.3 %). It helps in maintaining the rate of photosynthesis by improving RWC and Ψ_w of leaf through osmotic adjustment under water stress. It was reported that accumulation of K^+ in guard cells provides the necessary amount of solute, for developing Ψw gradient required for water movement into guard cells for stomatal opening and gas exchange necessary for photosynthesis (Jensen & Tophoj 1985). Potassium takes part in many essential processes in plants (Marschner 1995) and enhances photosynthetic rates, plant growth and yield under stress conditions (Egila et al. 2001; Sharma et al. 1996; Tiwari et al. 1998; Umar & Moinuddin 2002). The application of potassium fertilizer mitigates the adverse effects of drought on plant growth (Andersen et al. 1992; Sangakkara et al. 2001). When plants are grown under low K supply, drought stress induced reactive oxygen species production which can be additionally enhanced, at least due to K^+ deficiency-induced disturbances in stomatal opening, water relations, and photosynthesis (Marshner 1995). The more K^+ requirement of plants under different abiotic stresses appears to be related to the inhibitory role of K^+ against reactive oxygen species, production during

photosynthesis and NADPH oxidase (Cakmak 2005). In addition, under drought conditions, chloroplasts lose high amount of K^+ to further reduce photosynthesis (Sen Gupta & Berkowitz 1987) and induce further reactive oxygen species (ROS) formation. Alleviation of detrimental effects of drought stress, especially on photosynthesis, by sufficient K^+ supply has been also shown in legumes by (Sangakkara et al. 2000).

The rate of respiration was declined at pod formation stage (Table 3). The rates of dark respiration are known to be the highest in young actively growing plant parts and it declined as soon as these plant parts mature (Ryle et al. 1979). Water stress suppressed the rate of respiration, however, a slight upsurge in respiration under water stress was recorded at vegetative stage due to hydrolysis of reserved food materials and enhanced activity of respiratory enzymes. Similarly extensive measurements made by a number of workers have shown that water stress affects the rate of dark respiration, but considerable respiration occurs even when no net photosynthesis is detectable (Huda 1987). Dabas & Sheoran (1984) demonstrated that during early phase of growth, desiccation caused a slight increase in activity of the enzymes of the respiratory metabolism. The rate of respiration decreased with increased concentration of potassium. It may be attributed to improve water status in plants. Similar types of results were reported by (Sharma et al. l992) in *Brassica*. However, Jensen and Tophoj (l985) reported an increase in the rate of respiration with potassium application in barley.

CONCLUSION

Water stress resulted in significant reduction in leaf area and dry weight partitioning of different plant parts. The growth parameters were partially recovered on re-watering the plants. Application of potassium increased all the growth parameters studied. Water potential, osmotic potential and relative water content of leaves decreased significantly under water deficit. Potassium treatment improves the relative water content of leaves irrespective of soil moisture condition. Potassium improved the water status of the plant through osmotic adjustment. Photosynthetic rate and respiratory rate also significantly decreased under water deficit. Increased concentration of potassium brought a consecutive improvement in rate of photosynthesis under stress and normal conditions. Therefore, it is concluded that potassium helps in maintaining the water status of plants under water stress which in turn maintains various physiological processes and thereby increase the growth and yield.

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