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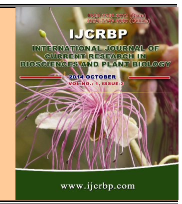

Original Research Article

Potassium to Alleviate the Adverse Effect of Water Deficit in Mungbean [*Vigna radiata* (L.) Wilczek]

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Abstract

Vigna radiata L. (Mungbean) is one of the most important pulse crops for protein supplement in a subtropical zone of the world, as it is the best alternative to meet the food needs of the large population of developing countries due to its nutritional superiority. The present study was carried out to ameliorate the water stress consequences on the water relation and yield attributes of Mungbean (*Vigna radiata* L.) *cv*. SML-668 by potassium application. The crop was raised in earthen pots under net house conditions (SMC 12.0±0.5%). Water stress (SMC 4.5±0.5%) was created by withholding irrigation at different sampling stages i.e. vegetative, 50% flowering and 50% pod formation. Effects of applied potassium (0, 1.54, 2.31, 3.08 mmol dm^{-3}) were investigated on water potential (Ψ_w), osmotic potential (Ψ_s), relative water content (RWC) and yield attributes. Water stress significantly decreased the water potential and osmotic potential. Decrease in water potential and osmotic potential caused higher decrease in RWC. Application of potassium increased the water potential and relative water content of leaf irrespective of soil moisture levels and lowers osmotic potential as compared to untreated plants. Osmotic potential during stress become more negative. Flowering stage proved most sensitive to water stress. Yield and its attributes increased in potassium treated plants. This study provides direct evidence of the beneficial physiological functions of potassium fertilization in mitigating the adverse effects of water stress.

Keywords

Potassium
Relative water content
Vigna radiata
Water potential
Water stress
Yield

Introduction

India is the largest producer of pulses, accounting for about 25 per cent of the global share (Chaturvedi, 2009). During 2009-10, 14.59 million tons of pulses were produced on 22.97 million hectare area in India. About 85-90% of the pulses are grown under rain fed conditions and only 10-

15% area under pulses is irrigated. Rain fed agriculture, which extends over 85 m ha in India covering wide variety of soils and crops often suffers from intermittent drought and water stress. Water stress plays a very important role in reducing the yield of crops (Jaleel et al., 2007).

Potassium has special role in rain fed agriculture as its optimum nutrition is associated with crop tolerance to water stress conditions, however its application in rain fed crops is meager. Potassium is reported to improve water relations as well as productivity of different crops under water stress conditions (Johnson, 1983; Islam et al., 2004). Among pulses, mungbean [*Vigna radiata* (L.) Wilczek] is a well-known crop in Asian countries. In India, mungbean occupies about 3 million ha, with a production of 1.42 million tons (Singh and Ahlawat, 2005).

Water stress is a widespread climatic event which frequently limits growth and yield of Mungbean (Miah and Carangal, 2001). Water stress affects water status in plants whereas, potassium helps in maintaining the water status of plants under water stress which in turn maintains various physiological processes and thereby increases the growth and yield. Since Mungbean is normally cultivated on relatively poor soil under rain fed conditions, it becomes imperative to study the effect of potassium on water relations and for yield and its attributes.

Materials and methods

The present study was carried out for two consecutive years (2011-12, 2012-13) during the month of April-June (summer seasons) under net house conditions at Botany Department, Kurukshetra University, Kurukshetra, India between latitude 29°-52' to 30°- 12' and longitude 76°-26' to 77°-04'. The climate of the district is of pronounced character i.e. very hot in summer and markedly cold in winter. It is as high as 45°C in summer and as low as 3°C in winter. The genotypes of Mungbean *cv.* SML-668 were selected for the study. The seeds were 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 5.0 kg of dune sand, using complete randomized design (CRD). The pots were placed in the net house under natural conditions and sowing was carried out at field capacity of soil (Fig. 1). Before sowing the seeds were surface sterilized with 80 % ethanol, washed with distilled water and then inoculated with *Rhizobium* sp. Ca 181. Thinning was carried out after five days of germination and two healthy and uniform plants per pot were retained.

Fig. 1: Experimental site at Botany Department, Kurukshetra University, Kurukshetra, India.

Potassium was added to the soil after germination in the form of muriate of potash (KCl) at concentration 0.00 (T_0), 1.54 (60 ppm {T_1}), 2.31 (90 ppm {T_2}) and 3.08 (120 ppm {T_3}) mmol, in addition to the existing level 1.32 mmol dm^{-3} (50 ppm) of potassium in the soil medium (Fig. 2). Water stress was created at 4.5±0.5% of soil moisture content (SMC) by withholding irrigations at three sampling stages i.e. vegetative (20 Days after sowing), 50% flowering (35 DAS) and 50% pod formation (47 DAS) (Fig. 3). The control plants were grown at 12±0.5% of SMC which was fifty per cent of soil saturation percentage (25%). The moisture levels of sand were maintained gravimetrically. Each pot was supplied with equal quantity (200 ml) of nitrogen free nutrient solution (Wilson and Reisenauer, 1963) at a regular interval of seven days.

Leaf water potential of third fully expanded leaf from the top was measured with the help of pressure chamber (Model 3005, Soil Moisture Equipment Corporation, USA). Osmotic potential of leaf was determined with Vapour Pressure Osmometer (Model 5100-B, Wescor, USA).

Relative water content (RWC) was calculated as described by Weatherley (1950). For the yield and its attributing characters, the data were recorded at the time of harvest in control and revived plants in which the stress was given at vegetative [RAS (V)], flowering [RAS (F)] and 50 percent pod formation [RAS (P)] stage.

Fig. 2: Effect of potassium concentration on growth of plants under control conditions [A= K (0 ppm), B= K (60 ppm), C= K (90 ppm), D= K (120 ppm)].

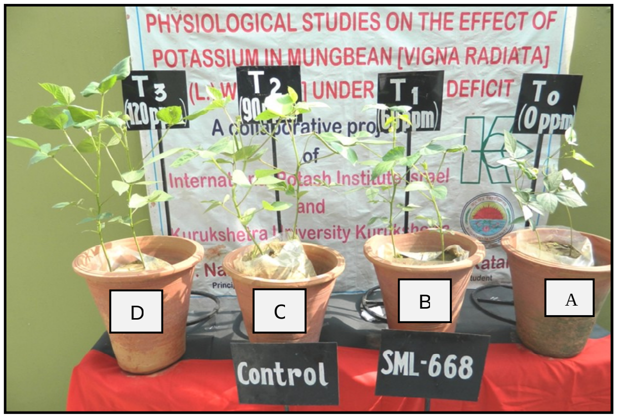
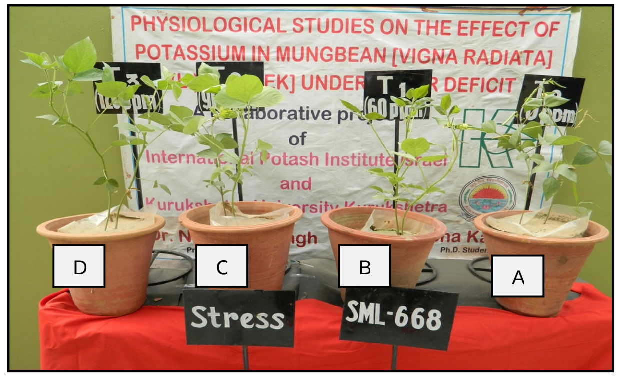


Fig. 3: Effect of potassium concentration on growth of plants under stress conditions [A= K (0 ppm), B= K (60 ppm), C= K (90 ppm), D= K (120 ppm)].



Statistical analysis

The data collected was analysed statistically by online Statistical Analysis (OPSTAT, CCS Haryana Agriculture University, Hisar). The significance of data obtained was judged from the critical difference at 5 % level of significance from three replicates.

Table 1. Interaction of water stress and applied potassium on water relations of Mungbean *cv.* SML-668.

SML-668		Relative Water Content(RWC)%			Osmotic Potential (-MPa)			Water Potential (-MPa)		
Sampling Stages	K (ppm)	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean
Vegetative Stage	0	84.18±5.19	73.36±6.13	78.7	0.72±0.10	1.02±0.11	0.87	0.41±0.04	0.73±0.05	0.57
	60	87.20±4.17	75.42±5.05	81.3	0.67±0.13	1.11±0.14	0.89	0.38±0.05	0.70±0.07	0.54
	90	89.50±3.80	79.78±4.81	84.6	0.62±0.16	1.24±0.18	0.93	0.32±0.03	0.62±0.04	0.47
	120	90.18±6.10	81.28±5.14	85.7	0.60±0.12	1.27±0.10	0.93	0.30±0.02	0.61±0.05	0.45
	Mean	87.76	77.46		0.652	1.16		0.35	0.66	
Flowering stage	0	77.86±5.17	67.71±3.68	72.7	1.43±0.09	1.57±0.11	1.50	0.67±0.09	0.98±0.12	0.82
	60	79.58±5.31	69.93±5.55	74.7	1.40±0.09	1.66±0.06	1.53	0.64±0.10	0.96±0.13	0.80
	90	82.46±7.07	72.72±5.37	77.5	1.35±0.08	1.82±0.10	1.58	0.58±0.10	0.87±0.12	0.72
	120	83.30±4.33	74.91±4.40	79.1	1.28±0.12	1.86±0.07	1.57	0.57±0.10	0.85±0.11	0.71
	Mean	80.8	71.3		1.36	1.72		0.61	0.91	
Pod formation stage	0	68.92±4.34	60.80±3.20	64.8	0.87±0.10	1.01±0.13	0.94	1.05±0.09	1.43±0.13	1.24
	60	71.61±5.78	61.50±6.19	66.5	0.81±0.09	1.10±0.13	0.95	1.02±0.10	1.41±0.14	1.21
	90	75.82±4.18	64.20±4.25	70.0	0.76±0.11	1.21±0.15	0.98	0.96±0.13	1.31±0.16	1.13
	120	76.58±3.75	65.40±3.52	70.9	0.70±0.11	1.25±0.12	0.97	0.94±0.10	1.30±0.13	1.12
	Mean	73.2	62.9		0.78	1.14		0.99	1.36	
C.D. at 5% level	A= 2.87, S= 2.34, K=3.32, A×S= N/A, A×K=N/A, S×K=N/A, A×S×K= N/A; A= 0.068, S= 0.056, K=N/A, A×S= N/A, A×K=N/A, S×K=0.112, A×S×K= N/A; A= 0.059, S= 0.049, K=0.069, A×S=N/A, A×K=N/A, S×K=N/A, A×S×K= N/A; A= Stages; S =Stress levels; K = Potassium Conc.									

Values represent mean, ±: Standard deviation.

Results

Relative water content of leaf decreased progressively with the ageing of plants. The highest value of relative water content was observed at vegetative stage followed by flowering and then pod formation stage.

Exposing the plants to water stress by withholding irrigations resulted in a significant decrease in RWC for all 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 1). This indicates that mungbean benefited from the potassium application. 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 (more -ve). Application of potassium significantly increased the osmotic potential under controlled conditions while it decreased under stressed conditions. Highest value of osmotic potential was observed at vegetative stage. Water potential of leaf decreased significantly under water stressed conditions (more –ve). In potassium treated plants, the water potential of leaf increased irrespective of soil moisture levels (less –ve). Highest values of water potential were observed at vegetative stage and the least at pod formation stage (more –ve) (Table 1).

The water stress resulted in significant reduction of number of pods and application of potassium was effective in alleviating the effect of water stress on number of pods. Control plants maintain the highest values for number of pods plant^{-1} (Table 2).

Table 2. Interaction of water stress and applied potassium on yield and its attributes of Mungbean *cv.* SML-668.

SML-668		K (ppm)				
Parameter	**Stress level**	**0**	**60**	**90**	**120**	**Mean**
No. of Pods Plant^{-1}	Control	15.04±0.12	16.05±0.14	18.07±0.12	19.00±0.10	17.0
	RAS (V)	14.08±0.11	15.09±0.12	18.02±0.14	18.07±0.13	16.3
	RAS (F)	7.07±0.14	8.01±0.09	10.02±0.11	10.03±0.12	8.78
	RAS(P.F)	8.09±0.15	9.04±0.14	11.07±0.11	11.09±0.09	9.82
	Mean	14.7	12.0	14.2	14.5	
C.D. at 5% level	A= 0.073, S= 0.060, K=0.084, A×S= 0.103, A×K=0.146, S×K=0.119, A×S×K= 0.207					
No. of Seeds Pod^{-1}	Control	53.06±0.07	55.04±0.16	59.07±0.10	60.06±0.10	56.8
	RAS (V)	51.08±0.10	54.01±0.19	58.09±0.10	60.00±0.10	55.7
	RAS (F)	37.00±0.12	38.09±0.15	42.08±0.17	43.04±0.17	40.0
	RAS(P.F)	39.08±0.14	41.05±0.14	45.07±0.13	46.02±0.16	42.8
	Mean	45.0	47.0	51.0	52.2	
C.D. at 5% level	A= 0.077, S= 0.063, K=0.089, A×S= 0.108, A×K=0.153, S×K=0.125, A×S×K= 0.217					
Seed Weight Plant^{-1}(g)	Control	3.31±0.12	3.62±0.17	4.30±0.17	4.44±0.12	3.92
	RAS (V)	3.05±0.12	3.39±0.13	4.07±0.14	4.23±0.12	3.69
	RAS (F)	1.53±0.13	1.81±0.11	2.28±0.11	2.37±0.10	1.99
	RAS(P.F)	1.75±0.10	1.97±0.15	2.49±0.20	2.58±0.10	2.20
	Mean	2.41	2.69	3.28	3.40	
C.D. at 5% level	A= 0.082, S= 0.067, K=0.095, A×S= 0.116, A×K=N/A, S×K=N/A, A×S×K= N/A					
100×seed Weight (g)	Control	4.48±0.18	4.81±0.17	5.22±0.12	5.30±0.12	4.95
	RAS (V)	4.22±0.11	4.47±0.11	4.91±0.13	5.01±0.11	4.65
	RAS (F)	3.71±0.10	4.01±0.15	4.46±0.20	4.54±0.18	4.18
	RAS(P.F)	3.54±0.13	3.79±0.10	4.22±0.06	4.33±0.14	3.97
	Mean	3.98	4.27	4.70	4.79	
C.D. at 5% level	A= 0.085, S= 0.069, K=0.098, A×S= 0.120, A×K=N/A, S×K=N/A, A×S×K= N/A					
Pod weight plant^{-1}	Control	4.33±0.10	4.69±0.10	5.36±0.05	5.47±0.11	4.96
	RAS (V)	4.14±0.06	4.51±0.11	5.25±0.09	5.38±0.12	4.82
	RAS (F)	2.19±0.09	2.44±0.07	3.01±0.09	3.08±0.11	2.68
	RAS(P.F)	2.50±0.09	2.76±0.10	3.40±0.10	3.46±0.09	3.03
	Mean	3.29	3.60	4.25	4.34	
C.D. at 5% level	A= 0.058, S= 0.047, K=0.066, A×S= 0.081, A×K=N/A, S×K=N/A, A×S×K= N/A					

Values represent mean, ±: Standard deviation A= Stages; S =Stress levels; K = Potassium Conc.
RAS (V) =Revived after stress at vegetative stage; RAS (F) =Revived after stress at flowering stage; RAS (P) =Revived after stress at pod formation stage.

Flowering stage [RAS (F)] proved to be the most sensitive to water stress in reducing the number of pods, followed by pod formation [RAS (P)]. Vegetative stage [RAS (V)] seemed to be less sensitive to water stress for number of pods. With increasing potassium concentration considerable increase was observed in number of pods plant^{-1}. Potassium treated plants showed better results than untreated plants. Significant reduction in number of seeds per plant was observed during water stress conditions. Flowering stage proved to be most deleterious in reducing the number of seeds, whereas the reduction was least observed under [RAS (V)] stage. Potassium treated plants shows better than the untreated ones (Table 2).

Seed weight plant^{-1} were least affected when stress was given at vegetative stage. The reduction in seed weight per plant was maximum at flowering stage [RAS (F)]; followed by pod formation [RAS (P)] stage. Potassium application leads to increase in seed weight plant^{-1}. Water stress resulted in significant reduction of test weight (100-seed weight). Maximum reduction in test weight was observed when stress was created at pod formation stage. Treatment with potassium was effective in alleviating the deleterious effect of water stress on above parameter. The weight of 100-seeds was least affected when stress was given at vegetative stage (Table 2).

Pod weight was significantly reduced under water stressed conditions. It was observed that the above parameter of yield was least affected when stress was given at vegetative stage. The reduction in pod weight was maximum at flowering stage (Table 2). The application of potassium improves the pod weight.

Discussion

Water potential, osmotic potential and relative water content of leaves decreased significantly under water stress conditions. Decreased leaf water potential (Ψ_w) under stress may be due to decreased absorption and translocation of water as a result of loss of gradient in water potential between the soil and roots which is the guiding principle for water movement. Drought stress lowers the soil water potential resulting in reduction of plant growth (Munns, 2002). Under stress condition, the decreased in osmotic potential was mainly due to the accumulation of solutes like proline and soluble carbohydrates. 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 were relatively lower than the control values at all sampling stages. 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 osmoregulation depending upon the magnitude of the decrease. 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 that sucrose and potassium ion 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.

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. This suggests that potassium has a positive role in turgidity maintenance and continual cell growth (Egilla et al., 2005; Fusheng, 2006). RWC of leaves 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.

Relative water content is the indicators of degree of drought stress. RWC of leaves is higher in the initial stages of leaf development and declines as the dry matter accumulates and leaf matures. Obviously, stressed plants have lower RWC than non-stressed plants. In studies performed on four cultivars of bread wheat, RWC reduced to 43 percent (from 88% to 45%) by moisture stress (Siddique et al., 2000). Therefore, osmotic regulation will help in cell development and plant growth in water stress. High relative water content is a resistant mechanism to more osmotic regulation or less elasticity of tissue cell wall. The decrease in relative water content resulted in closure of stomata that will minimize the photosynthetic rate. Overall decrease in water relations, due to water stress was also observed by Mohammadkhani and Heidari (2008) in maize, Moaveni (2011) and Farshadfar et al. (2011) in wheat. Shamsi (2010) reported that with an increase in the intensity of droughty stress on wheat cultivars, there was a decrease in relative water content.

Potassium increases the crop yield by significant improvements in yield components (Zulkarnain et al., 2009) and through its diverse roles in plant metabolic processes (Pervez et al., 2006). Karim et al. (2000) resulted that water stress reduced grain yield by reducing productive tillers per plant, textile spikelet per plant, number of grains per plant and individual grain weight. Potassium application had the greatest stimulatory effect on yield and its attributes (Thalooth et al., 2006; Kassab, 2005). Higher potassium concentration in plant tissues plays a vital role for increasing water stress resistance and crop yield stabilization (Umar, 2006). Potassium fertilization ameliorates the negative effects of water deficit on crop yield and its physiological traits, which are ultimately improved (Fanaei et al., 2009). Gunasekara et al. (2003) observed that the mean biological yield was decreased by 17.9 and 32.1% and the mean seed yield was decreased by 18.5 and 38.7% under moderate and high water stresses during reproductive growth. Seed yield of *Brassica napus, B. juncea and B. rapa* was decreased due to drought stress (Jenson, 1996). Water stress not only reduced plant growth and grain yield, but also affected plant physiological properties.

Jianweil et al. (2007) observed that rapeseed grain yield was significantly affected by potassium application. Drought adversely affected yield and physiological properties in contrast with increasing potassium consumption, negative effect of water stress on grain yield and physiological properties modified and consequently improved. Potassium increases the crop yield by significant improvements in yield components (Zulkarnain et al., 2009) and through its diverse roles in plant metabolic processes. Elevated doses of potassium stimulate plant growth, and enhance their yield (Celik et al., 2010).

Conclusion

Water potential, osmotic potential and relative water content of leaves decreased significantly under water deficit. Potassium treatment improved the relative water content of leaves irrespective of soil moisture conditions. Potassium improved the water status of the plant through osmotic adjustment. Water stress adversely affected the yield and its attributes. Potassium leads to a considerable increase in yield and its attributes.

Therefore, potassium in mungbean played a vital role in increasing water stress resistance and stabilizing yield. Increased concentration of potassium brought a consecutive improvement in water relations and yields both under stress and normal conditions. Therefore, it is concluded that potassium helps in maintaining the water status of the plants under water stress which in turn maintains various physiological processes and thereby increase the growth and yield.

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