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Effects of potassium rates and irrigation regimes on the yield of forage sorghum in arid regions

Khodadad Dahmardeh[1], Mohammad Reza Pahlavan Rad[1*], Mohammad Reza Naroui Rad[2], Mojtaba Hadizadeh[1]

[1]*Soil and Water Department, Sistan Agricultural and Natural Resources Research Center, AREEO, Zabol, Iran*

[2]*Seed and Plant Improvement Deptartment, Sistan Agricultural and Natural Resources Research Center, AREEO, Zabol, Iran*

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Abstract

To investigate effects of potassium application and irrigation regimes on the quantitative and qualitative yields of Forage Sorghum (Speed-feed cultivar) in dry regions, an experiment was conducted using a factorial design with three replications and three irrigation regimes (irrigation after depletion of 40, 60 and 80 percent of field capacity) and four potassium rates (0, 50, 100 and 150Kg ha^{-1}) in Sistan region, southern Iran. Stomatal resistance, water use efficiency, yields and plant height were measured in all treatments throughout growth season. The results showed, water stress had very significant effects on plant height, wet forage yield, dry forage yield, leaf stomata resistance and water use efficiency. Potassium fertilizer application on the dry and wet foliage yield, leaf stomata resistance and water use efficiency were high significant.

* **Corresponding Author:** M.R Pahlavan Rad ✉ pahlevan354@yahoo.com

Introduction

Due to importance of forage production in the studied region and it's suitable climatic condition for these plants group, doing different researches about their cultural requirements, such as nutrition and irrigation is completely necessary. Du *et al.*, (2010) observed that drought is a major factor limiting productivity in agriculture and have caused a collapse in food production by reducing uptake of water and nutrient. Drought is a significant limiting factor for agricultural productivity and generally inhibits plant growth through reduced water absorption and nutrient uptake (Marschner, 1995). Potassium is a valuable nutrient in decreasing the effects of water stress for the survival of crop plants. Ogunlela and Yusuf (1988) reported that potassium application increased growth and yield in grain sorghum. Quintero *et al.*, (1998), reported K fertilization is associated with increasing crop growth because of the positive effect of this nutrient in osmotic adjustment, stomata regulation, photosynthesis, and protein synthesis. Umar (2006) observed that K application increased yield under water stress condition in mustard, sorghum and groundnut. Roohbakhsh (2013) observed that potassium application reduced negative effects of water stress on growth and yield of forage sorghum. Hossein and Alva (2014) observed the biomass yield enhanced with an increase in NPK fertilizer rates and water stress decreased biomass yield in sorghum. Sharma and Kumari (1996) observed that plant height, dry matter production and grain yield improved with K application. Andersen *et al.*, (1992) observed increased leaf area and straw yield of K-sufficient compared with K deficient barley plants during drought stress.

Due to drought stresses in Sistan, Iran, the objectives of this experiment were to invest the effects of potassium on growth and the dry matter of forage sorghum.

Materials and methods

The experiment was carried out at Zahak agricultural research centre (30° 54' N, 61° 41' W; 483 m above sea level) in Sistan, during 2008 -2009. Soil and water analysis and climatic data are represented separately for each year in Tables 1-3. Table 3 indicates to arid climate.

Factorial design with three replications was assigned, main plot was irrigation regimes after depletion of 40, 60 and 80 percent of water plant usable and subplot was different potash fertilizer including 0, 50, 100 and 150kg/ha from potassium sulfate source. Irrigation time was determined based on TDR device. Irrigation rate was calculated with following formula.

$d\ (mm) = (FC - \theta_i)\ \rho_b \times D/100$

d: irrigation depth to reach moisture to FC(mm)

Fc: field capacity (%)

θ_i: weight soil moisture before irrigation(%)

ρ_b: apparent specific weight of soil($grcm^{-3}$)

D: maximum root depth (mm), usually between 50-60cm.

Forage yield was determined by harvesting of middle rows ($12m^{-2}$). Harvest was done in 10% of flowering stage by two times each year. Mean weight of forage was considered as annual yield. To determine dry forage yield, 1 Kg of each plot was cut, then dried by Oven (75C°) for 24 hours.

All cultivation operations such as hoeing, pest control and noting were done on time. Whole required phosphorous ($100Kgha^{-1}$) and one fifth of nitrogen were applied in 4 stages after planting. Also leaf stomata resistance and water use efficiency were determined. Analysis of variances and mean comparison were done by MSTAT-C software version 2.6.

Results and discussion

The means of soil physical and chemical properties of the experimental replications are shown in Table 1. The soil was Torrifluvent with a sandy loam texture, a pH higher than 8, and the organic carbon (O.C) was less than 0.5%.The amount of potassium was 100 and 110 $mgkg^{-1}$ in 2008 and 2009. Irrigation water provided from Hirmand river, had an EC of 2 $dS\ m^{-1}$ and a pH of 7 in 2008 (Table 2). Climatic data (Table 3) shows that study area is a very dry with rare precipitation.

Plant height

Analysis of variance showed that stress water ($p<0.01$) and potassium ($p<0.05$) had a significant effect on the plant height (Table 4).

Fig. 1 is shown interaction effect of different water and potassium levels on the plant height. Water stress decreased plant height but potassium application increased plant height in water stress condition (Fig. 1). Hossein and Alva (2014) saw that plant height decreased under water stress and NPK application increased plant height in forage sorghum.

Table 1. Physical and chemical soil characteristics of experimental site.

year	Depth (cm)	O.C%	pH	EC (dS m^{-1})	texture	K	P	Cu	B	Mn	Zn	Fe
						mg kg^{-1}						
2008	0-30	0.34	8.2	3	Sandy loam	100	11	0.58	1.07	4.86	0.26	2.84
2009	0-30	0.37	8.4	2.5	Sandy loam	110	6.5	1.05	1	3.2	1.57	3.5

Table 2. Some of chemical characteristics of water in 2008.

SAR	Na^+	HCO_3	$Ca^{++} + Mg^{++}$	Cl^-	pH	EC (dS m^{-1})
		meq L^{-1}				
2.67	11	5.1	34	8.5	7.3	2

Wet and dry forage yield

Table 4 shows that stress water and potassium had significant effect ($p<0.01$) on wet and dry forage sorghum. Fig. 2 and 3 shows that water stress decreased wet and dry forage yield but the application of 150 kgha^{-1} potassium increased forage sorghum yield significantly in normal condition (w1) and stress condition (w3) .

Table 3. Some of climatic data in spring and summer seasons of 2008 -2009.

Year	Temperature (°C)		%RH		Rain(mm)	Wind speed(km h^{-1})		Evaporation (mm month^{-1})	Sun(h)
	max	min	max	min		max	min		
2008	39.6	24.43	27.5	11	0.1	12.5	4.5	19.1	9.5
2009	43.5	16.9	57.3	7.7	3.38	18.3	0	17.8	10.5

Table 4. Combined variance analysis for wet and dry forage yield, leaf stomatal resistance and water use efficiency in forage sorghum under different Potassium rates and irrigation regimes in Sistan region.

S.O.V	df	Plant height	Wet forage yield	Dry forage yield	Leaf stomata resistance	Water use efficiency
year	1	0.009 ns	2.607 ns	39.16**	106.337**	0.003ns
Replication *year	4	167.022 ns	6.635 ns	10.517 ns	1.612 ns	0.011 ns
Moisture stress	2	5746.995**	1101.977**	236.863**	31.522**	0.602**
esters *year	2	264.118 ns	116.538**	57.838**	8.191**	0.048 ns
Fertilizer	3	1333.274*	200.973**	22.971**	79.788**	0.444**
Fertilizer *year	3	694.136 ns	4.623 ns	5.888 ns	3.623 ns	0.005ns
Fertilizer* esters	6	195.975 ns	23.967 ns	8.342 ns	7.309**	0.062ns
Fertilizer * esters *year	6	135.913 ns	11.291 ns	3.178 ns	7.605**	0.017ns
Error	44	335.028	21.027	4.670	1.414	0.051
Uniformity coefficient		16.65	14.33	19.11	20.28	14.97

** Significant at the 0.01 probability level.

*Significant at the 0.05 probability level.

NS, No significant.

Umar (2006) found that K application enhanced yield under stress condition in mustard, sorghum and groundnut. Roohbakhsh (2013) observed that potassium application reduced negative effects of water stress on growth and yield of forage sorghum. Hussein and Alva (2014) observer that biomass yield increased with an increase in NPK fertilizer rates.

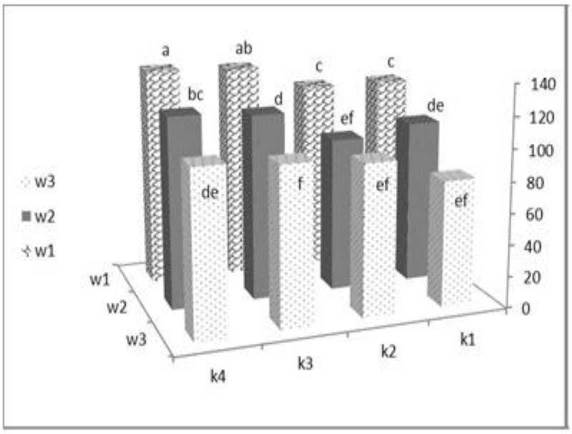

Fig. 1. Interaction effect between different levels of irrigation (W) and potassium (K) on the plant height (cm).

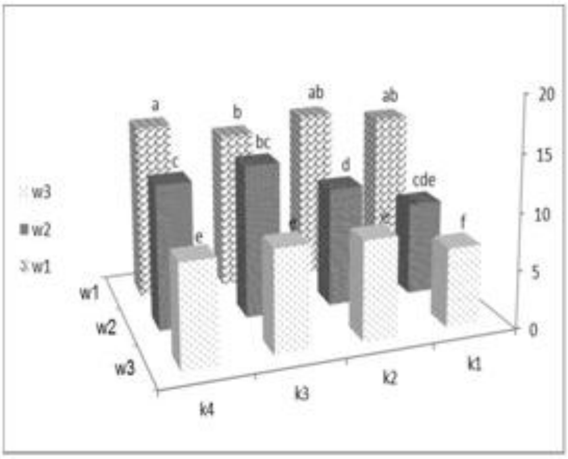

Fig. 2. Interaction effects between different levels of irrigation (w)and potassium (k) on the dry forage yield ton ha-1)

Leaf stomatal resistance and water use efficiency

Potassium ion has an important role in leaf water potential and thus cellular turgid potential in drought stress conditions. On the basis of combined and simple analysis of variances results (Table 4) moisture stress and potassium had a significant effect ($p<0.01$) on the leaf stomatal resistance and water use efficiency. Water stress decreased leaf stomatal resistance and increased water use efficiency (Fig. 4, 5). Mohammadian *et al.*, (2004) studied potassium application effects on the sugar beet in different irrigation periods. He suggested, although different potassium rate applications didn't have a significant effect on the water use efficiency in different irrigation periods, but this characteristic was affected by different levels of this fertilizer. Mohammadian *et al.*, (2004) suggested that potassium application can have positive effects on the yield and water use efficiency only in the stress less or justified stress conditions.

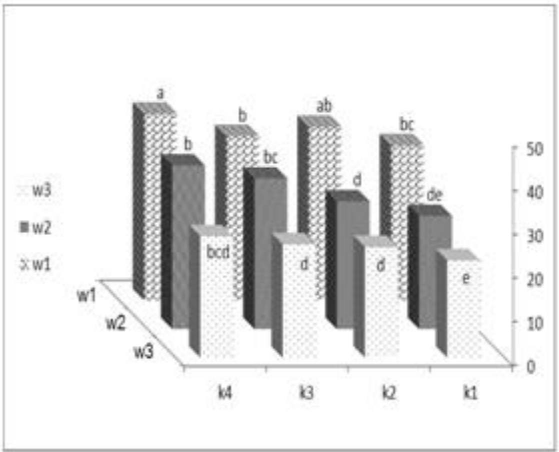

Fig. 3. Interaction effects between different levels of irrigation (w) and potassium (k) on the wet forage yield (ton ha-1).

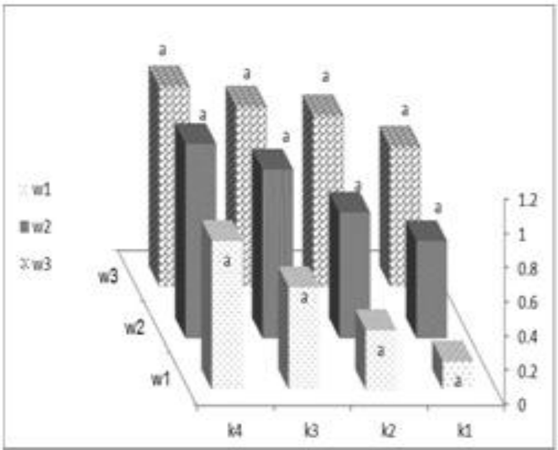

Fig. 4. Interaction effects between different levels of irrigation (w) and potassium (k) water use efficiency (kg m-3).

Results showed although potassium application didn't have significant effect on the average tiller number and leaf length, but its positive effects on these characteristics are undeniable.

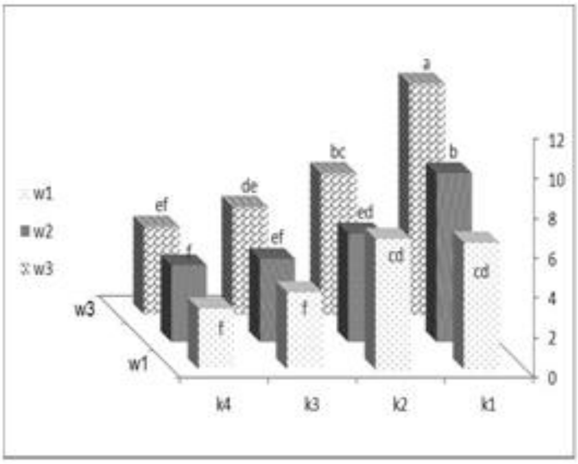

Fig. 5. Interaction effects between different levels of irrigation (w) and potassium (k) on stomatal resistance (sec cm^{-1}).

Conclusion

To achieve normal growth and crop production, forage sorghum like many other plants must receive enough water and potash fertilizer. Generally irrigation after soil moisture depletion and potash application about 150 Kg $ha^{-1}$are increased quantitative characteristics of sorghum.

Application of potash fertilizer can increase drought tolerance in sorghum through reduction damages derived from moisture stress on the plant, so can play an effective role in its yield.

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