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BIOMASS PARTITIONING AND POTASSIUM ACCUMULATION OF FIVE SORGHUM GENOTYPES UNDER DEFICIENT AND ADEQUATE POTASSIUM NUTRITION

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ABSTRACT

Potassium (K) has been reported to positively influence sorghum growth and productivity. This field study was conducted to evaluate the effect of K nutrition on the growth, biomass allocation and K accumulation of five sorghum genotypes. The experiment was launched in a two factor randomized complete block split plot design with three replicates. Five sorghum genotypes were grown at two levels of soil applied K_2O, i.e. 0 kg ha^{-1} (control) and 72 kg K_2O ha^{-1}. The crop also received recommended doses of nitrogen (120 kg ha^{-1}) and phosphorus (70 kg ha^{-1}). The results revealed that the two sources of variance highly significantly affected all the growth and yield parameters. Sorghum genotypes did not significantly differ for K accumulation. The interaction between two sources of variance significantly affected biomass allocation of shoot, root and total biomass only, but did not affect on leaf and flower (head) biomass, length of root and flower, number of leaves, shoot and root diameter and K concentration of plants. The genotype Sarokartuho had maximum root biomass, leaf biomass and number of leaves under both the levels of K. The genotype Red Janpur had maximum flower biomass, flower length and K concentration under both the K levels. The genotype Ghotki Turi produced maximum total biomass, shoot biomass, shoot length and shoot diameter under both K conditions, coupled with maximum number of leaves under deficient K condition. The genotype Rehmani had maximum root biomass under K deficiency stress, coupled with maximum root length under both the K regimes. The genotype Kundri had maximum root biomass under K deficiency stress, while maximum root diameter under both the K levels. The study concluded that the sorghum genotypes varied widely for their growth and biomass production, however, this variation was independent of their K accumulation. The sorghum genotype Ghotki Turi appeared to be a potential candidate to perform well both under low and high K input agriculture.

Keywords: sorghum, potassium, genotypic variation, K-use-efficiency

INTRODUCTION

Potassium (K) is an essential plant macro-nutrient. However, research on plant K requirements has not received due attention in many parts of the world. In mica

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dominated alluvial soils, most of the K is released by the mineral structure to support plant nutrition (Singh *et al*., 2007). However, this is considered insufficient for a longer period and it is necessary to quantify such contribution. Potassium (K) fertilizer is a very costly agricultural input in Pakistan (Zia-ul-hassan and Arshad, 2011) and farmers seldom involve K nutrition in their crop production programs (Nawaz *et al*., 2006). Nonetheless, different crops and their species have different K requirement which is very important to understand for cost effectiveness and for balancing K fertilization. Differences in K uptake and its utilization were reported for many crop species globally, such as cotton (Zia-ul-hassan *et al*., 2014), maize (Nawaz *et al*., 2006) and rice (Sabir *et al*., 2003).

The significance of adequate K nutrition for sustainable crop production and product quality are highlighted in many earlier studies (Valadabadi *et al*., 2009; Azam *et al*., 2010). Potassium nutrition with N and P was found improving sorghum growth and yield (Akram *et al.,* 2007; Azam *et al*., 2010), stem and total fresh biomass and quality of produce (Almodares *et al*., 2008). Further, K nutrition enhances grain growth rate by improving drought resistance of sorghum (Valadabadi *et al*., 2009). Valadabadi and Farahani (2010) observed that K nutrition significantly increased the root penetration of millet and sorghum plants under drought stress. An adequate supply of K increases grain and biological yield, chlorophyll content and leaf K and N while decreasing plant Na accumulation of sorghum (Asgharipour and Heidari, 2011). Saleem *et al.* (2011) recorded maximum grain and stalk yield when sorghum was fertilized with 120 kg K_2O ha^{-1}. However, Buah *et al*. (2012) did not observe significant interactions of fertilizer N, P, and K to affect any parameter of sorghum, which might be due to the difference in genotypes used in the two studies. K deficiency reportedly decreased plant height, number of leaves and root length of sorghum (Christin *et al*., 2009).

A number of studies reported the beneficial effects of adequate K nutrition in sorghum, whilst some studies did not find any significant influence. For instance, Buah *et al*. (2012) reported the beneficial effects of K nutrition in integration with N and P for economical sorghum production in Guinea savanna agro-ecology in Africa.

These results lead researchers to explore sorghum genotypes for their root penetration and consequent K requirements so as to identify sorghum genotypes that perform well under K deficient conditions. The present field study was planned to evaluate the comparative K requirement of five sorghum genotypes under deficient and adequate K nutrition conditions.

MATERIALS AND METHODS

The experiment was performed in 20 m^2 sub-plots. The sandy clay loam soil under study was alkaline in nature, non-saline, poor in organic matter content and deficient in AB-DTPA extractable K (107 mg kg^{-1}). A factorial randomized complete block split plot design with three replicates was followed in this study. Factor A comprised of five sorghum genotypes, while factor B comprised of two K_2O application rates. Sorghum genotypes were planted by applying 0 (control) and 72 kg K_2O ha^{-1} (as potassium sulphate (SOP) containing 50% K_2O). The space between the plants was 1.5 ft. while row spacing was 1.0 ft. A blanket dose of 120 kg N (as urea 46% N) and 70 kg P (as DAP 18% N and 46% P_2O_5) ha^{-1} was also given to the crop. Full dose of P and half N was broadcasted to the soil and thoroughly incorporated. The half dose of N fertilization was done at first irrigation. The plant traits, viz. biomass of leaf, flower, shoot, root and total, the length of shoot, root and flower, the number of leaves, the diameter of shoot and root and K concentration were recorded/determined from five randomly harvested plants per treatment at maturity. Leaf K accumulation was determined following the standard method (Zia-ul-hassan and Arshad, 2011). Necessary data analysis was performed using Statistix Ver. 8.1. Tukey's honestly significant difference ($HSD_{0.05}$) was employed to separate the treatment means.

RESULTS

Potassium nutrition (K) and sorghum genotypes (G) significantly affected all the growth and yield traits, however, no genotypic variation was found for K accumulation. The K × G interaction was found significantly affecting (P <0.05) the biomass of shoot, root and total biomass, while the treatment did not affect any other parameters of sorghum genotypes.

Biomass partitioning (g plant^{-1})

The data (Table 1) revealed that sorghum genotypes significantly responded to K fertilization for leaf biomass production per plant (26.9 g) as against at deficient K level (25.0 g). In addition to this differential response of sorghum genotypes at two K levels, all the sorghum genotypes exhibited wide genotypic variation to produce leaf biomass at each of the two K extremes. Moreover, across two K levels, sorghum genotypes Sarokartuho produced highest leaf biomass per plant (39.3 g), followed by Kundri (25.6 g), Ghotki Turi (23.4 g), Red Janpur (23.1 g) and Rehmani (25.6 g). Sorghum genotypes significantly (P <0.01) responded to 72 kg K_2O ha^{-1} K nutrition to produce flower biomass per plant (10.2 g) as against at 0 kg K_2O ha^{-1} (or control) K level (8.1 g) (Table 1). In addition to the significant response of sorghum genotypes at two K levels, all the sorghum genotypes exhibited wide genotypic variation to produce flower biomass at each of the two K levels. Moreover, across two K levels, sorghum genotypes Red Janpur produced maximum flower biomass per plant (12.3 g), followed by Sarokartuho (9.3 g), Ghotki Turi (9.1 g), Kundri (7.8 g) and Rehmani (7.2 g). Maximum shoot biomass was produced by Ghotki Turi, followed by Red Janpur at both the K levels. Across the two K levels, sorghum genotypes Ghotki Turi produced highest shoot biomass per plant (147.8 g), followed by Red Janpur (142.7 g), Sarokartuho (136.2 g), Kundri (123.3 g) and Rehmani (116.3 g). Maximum root biomass was produced by Rehmani and Kundri at deficient K level, and by Sarokartuho at both the K levels. Moreover, across two K levels, sorghum genotypes Sarokartuho produced highest root biomass per plant (21.9 g), followed by Rehmani (21.4 g), Kundri (21.2 g), Red Janpur (16.1 g) and Ghotki Turi (13.1 g). Maximum total biomass per plant was produced by Ghotki Turi, followed by Sarokartuho at both the K levels. Moreover, across two K levels, sorghum genotype Ghotki Turi out yielded its counterparts in producing total biomass per plant (316.7 g), followed by Sarokartuho (254.9 g), Red Janpur (228.2 g), Rehmani (200.0 g) and Kundri (184.9 g).

Table 1. Biomass partitioning of sorghum genotypes at deficient and adequate potassium levels

Genotype	**K nutrition (kg K_2O ha^{-1})**		**Genotype mean**
	0	**72**	
	Leaf biomass (g plant^{-1})		
Sarokartuho	38.3	40.3	39.3 a
Red Janpur	22.2	24.0	23.1 c
Ghotki Turi	22.5	24.3	23.4 c
Rehmani	17.4	19.2	18.3 d
Kundri	24.5	26.7	25.6 b
K level mean	25.0 b	26.9 a	-
SE: K: 0.4339, G: 0.6861; HSD 0.05: K: 0.9121, G: 2.0747; CV: 4.58%			
Flower biomass (g plant^{-1})			
Sarokartuho	8.2	10.3	9.3 b
Red Janpur	11.4	13.3	12.3 a
Ghotki Turi	8.1	10.2	9.1 b
Rehmani	6.1	8.3	7.2 c
Kundri	6.8	8.8	7.8 c
K level mean	8.1 b	10.2 a	-
SE: K: 0.3235, G: 0.5115; HSD 0.05: K: 0.6800, G: 1.5467; CV: 9.71%			
Shoot biomass (g plant^{-1})			
Sarokartuho	134.2 e	138.2 d	136.2
Red Janpur	141.8 c	143.6 c	142.7
Ghotki Turi	146.6 b	149.1 a	147.8
Rehmani	115.4 g	117.2 g	116.3
Kundri	123.7 f	123.0 f	123.3
K level mean	132.3	134.2	-
SE: K x G: 0.9267; HSD 0.05: K x G: 3.3214; CV: 0.85%			
Root biomass (g plant^{-1})			
Sarokartuho	20.2 b	23.6 a	21.9
Red Janpur	14.8 d	17.5 c	16.1
Ghotki Turi	12.5 d	13.7 d	13.1
Rehmani	21.2 b	21. 7 b	21.4
Kundri	20.5 b	21.9 b	21.2
K level mean	17.8	19.7	-
SE: K x G: 0.6544; HSD 0.05: K x G: 2.3453; CV: 4.28%			
Total biomass (g plant^{-1})			
Sarokartuho	253.5 c	256.3 c	254.9
Red Janpur	225.2 e	231.2 d	228.2
Ghotki Turi	314.0 b	319.3 a	316.7
Rehmani	198.9 f	201.1 f	200.0
Kundri	183.3 h	186.5 g	184.9
K level mean	235.0	238.9	-
SE: K x G: 0.8174; HSD 0.05: K x G: 2.9298; CV: 0.42%			

Table 2. Length of shoot, root and flower and number of leaves per plant of sorghum genotypes at deficient and adequate potassium levels

Genotype	K nutrition (kg K_2O ha^{-1})		Genotype mean
	0	72	
	Shoot length (cm)		
Sarokartuho	272.2	273.6	272.9 c
Red Janpur	226.6	228.5	227.5 e
Ghotki Turi	307.2	309.2	308.2 a
Rehmani	289.4	292.7	291.0 b
Kundri	262.1	265.7	263.9 d
K level mean	271.5 b	274.0 a	-
SE: K: 0.4742, G: 0.7498; HSD 0.05: K: 0.9968, G: 2.2673; CV: 0.48%			
	Root length (cm)		
Sarokartuho	27.3 e	29.6 d	28.5
Red Janpur	28.5 d	31.1 c	29.8
Ghotki Turi	27.5 e	32.6 b	30.0
Rehmani	31.6 c	34.1 a	32.9
Kundri	23.5 f	24.5 f	24.0
K level mean	27.7	30.4	-
SE: K x G: 3.5262; HSD 0.05: K x G: 0.9839; CV: 4.15%			
	Flower length (cm)		
Sarokartuho	15.0	17.1	16.0 a
Red Janpur	16.6	18.5	17.5 a
Ghotki Turi	16.2	17.9	17.0 a
Rehmani	12.0	13.8	12.9 b
Kundri	14.9	16.3	15.6 a
K level mean	14.9 b	16.7 a	-
SE: K: 0.4336, G: 0.6856; HSD 0.05: K: 0.9114, G: 2.0730; 7.5%			
	Number of leaves ($plant^{-1}$)		
Sarokartuho	9.6	11.8	10.7 a
Red Janpur	6.9	9.2	8.1 b
Ghotki Turi	9.5	11.3	10.4 a
Rehmani	7.9	9.7	8.8 b
Kundri	7.2	9.3	8.3 b
K level mean	8.2 b	10.3 a	-
SE: K: 0.4209, G: 0.6655; HSD 0.05: K: 0.8848, G: 2.0125; CV: 12.4%			

Shoot, root and panicle length (cm)

The data (Table 2) elucidate that sorghum genotypes significantly responded to K fertilization to produce shoot length (274.0 cm) as against at deficient K level (271.5 cm) (Table 2). In addition to the response of sorghum genotypes at two K levels, all the sorghum genotypes exhibited wide genotypic variation to produce shoot length at each of the two K extremes (Table 2). Across two K levels, sorghum genotype Ghotki Turi produced highest shoot length (308.2 cm) followed by Rehmani (291.0 cm), Sarokartuho (272.9 cm), Kundri (263.9 cm) and Red Janpur (227.5 cm). Maximum root length was produced by Rehmani at both the K levels followed by Ghotki Turi at 72 kg K_2O ha^{-1} K level and Red Janpur at deficient K level. Sorghum genotypes significantly ($p < 0.01$) responded to 72 kg K_2O ha^{-1} K nutrition for their flower length (16.7 cm) as against at 0 kg K_2O ha^{-1} K level (14.9 cm) (Table 2). In addition to this response of sorghum genotypes at two K extremes, all the sorghum genotypes exhibited wide genotypic variation for flower length at each of the two K levels (Table 2). Across two K levels, though the flower length of four sorghum genotypes was statistically alike but significantly higher than Rehmani (12.9 cm).

Table 3. Diameter of shoot and root, and K concentration per plant of sorghum genotypes at deficient and adequate potassium levels

Genotype	**K nutrition (kg K_2O ha^{-1})**		**Genotype mean**
	0	**72**	
	Shoot diameter (mm)		
Sarokartuho	8.8	11.3	10.1 b
Red Janpur	8.1	10.3	9.2 b
Ghotki Turi	11.3	13.2	12.2 a
Rehmani	9.1	10.9	10.0 b
Kundri	8.7	11.7	10.2 b
K level mean	9.2 b	11.5 a	-
SE: K: 0.4399, G: 0.6955; HSD 0.05: K: 0.9247, G: 2.1032, CV: 11.6%			
	Root diameter (mm)		
Sarokartuho	10.2	12.8	11.5 c
Red Janpur	10.4	13.7	12.1 c
Ghotki Turi	11.8	13.8	12.8 b
Rehmani	9.1	11.3	10.2 c
Kundri	12.9	15.1	14.0 a
K level mean	10.9 b	13.3 a	-
SE: K: 0.4163, G: 0.6582; HSD 0.05: K: 0.8750, G: 1.9902, CV: 9.41%			
	K concentration (%)		
Sarokartuho	3.0	3.9	3.5
Red Janpur	3.1	4.0	3.5
Ghotki Turi	2.8	3.9	3.4
Rehmani	2.8	3.7	3.3
Kundri	2.9	3.9	3.4
K level mean	2.9 b	3.9 a	-
SE: K: 0.2383, G: 0.3768; HSD 0.05: K: 0.5009, G: 1.1393, CV: 19.2%			

Number of leaves (plant^{-1})

It is evident from the data (Table 2) that sorghum genotypes significantly ($p < 0.01$) responded to 72 kg K_2O ha^{-1} K nutrition to produce their photosynthetic apparatus (10.3 leaves plant^{-1}) as against at 0 kg K_2O ha^{-1} K level (8.2 leaves plant^{-1}). In addition to the response of sorghum genotypes at two K levels, all the sorghum genotypes exhibited wide genotypic variation in their number of leaves at each of the two K levels. Further, across K levels, two sorghum genotypes, viz. Sarokartuho and Ghotki Turi had statistically alike maximum leaves per plant (10.7 and 10.4, respectively) followed by the statistically similar leaves per plant produced by Rehmani (8.8), Kundri (8.3) and Red Janpur (8.1).

Shoot and root diameter (mm plant^{-1})

The data (Table 3) depict that sorghum genotypes significantly responded to K fertilization to produce shoot diameter (11.5 mm) as against at 0 kg K_2O ha^{-1} K level (9.2 mm). In addition to the response of sorghum genotypes at two K levels, all the sorghum genotypes exhibited wide genotypic variation for their shoot diameter at each of the two K levels. Moreover, sorghum genotypes had significantly ($p < 0.01$) different root diameter at K nutrition (13.3 mm) as against at 0 kg K_2O ha^{-1} K level (10.9 mm) (Table 3). In addition to this response of sorghum genotypes at two K levels, all the sorghum genotypes exhibited wide genotypic variation for their root diameter at each of the two K levels.

K concentration (%)

Sorghum genotypes accumulated 35% more K under 72 kg K_2O ha^{-1} supply as against its 0 kg K_2O ha^{-1} level (Table 3). However, it was quite astonishing to note that all the sorghum genotypes had statistically similar K accumulation across two K levels, ranging from 3.4 to 3.5%.

DISCUSSION

Wide genotypic variation existed among sorghum genotypes for their different traits as a result of the influence of potassium application rates, genotypic variation and the interaction of these two sources of variance (Table 1 to 3). However, interestingly this difference in biomass accumulation was independent of K accumulation by sorghum genotypes and was mainly derived by the 72 kg K_2O ha^{-1} K nutrition of sorghum. Nonetheless, the positive effects of K application on all plant traits of sorghum genotypes highlight the significance of 0 kg K_2O ha^{-1} K nutrition for sorghum productivity. The results endorse the significance of adequate K nutrition for sustainable crop production and product quality as highlighted in many earlier studies (Valadabadi *et al*., 2009; Azam *et al*., 2010; Asgharipour and Heidari, 2011; Buah *et al*., 2012; Zia-ul-hassan *et al*., 2014).

These results further depict the narrow variation among sorghum genotypes under study for their K accumulation from rhizosphere. Pholsen *et al.* (2001) did not find significant effect of K nutrition at various stages of sorghum growth on its dry biomass production, i.e. leaf, stem, flower, seed head, total, coupled with leaf area, seed yield and 1000-seed weight.

In a solution culture study, fifteen maize genotypes, grown under adequate and deficient K nutrition, varied substantially for their biomass accumulation, allocation, and uptake and use-efficiency of K. The higher biomass producing genotypes were those which acquired increased root-shoot ratio with higher K uptake (Nawaz *et al*., 2006). In a more recent study Zia-ul-hassan and Arshad, (2011) endorsed these results for 15 K-deficient genotypes of cotton in a hydroponics study.

Akram *et al*. (2007) highlighted that the integration of 80 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1}, along with of 120 kg N ha^{-1} was better than single use of nitrogen and phosphorus for improved and economical production of sorghum. However, Almodares *et al.* (2008) pointed out that the application of 50 kg potassium sulfate, integrated with 180 kg urea ha^{-1} increased stem and total fresh biomass, total sugar, carbohydrate and juice of sorghum genotypes at physiological maturity. Likewise, Christin *et al.* (2009) found reduced height, leaf number and root length of sorghum and sunflower plants under K deficient condition. Valadabadi *et al*. (2009) observed that K fertilizer enhanced growth rate of sorghum grains. Potassium nutrition helped sorghum plants to tolerate drought stress. Similarly, the results of research conducted by Azam *et al*. (2010) also advocated the balanced fertilization of sorghum involving adequate K nutrition with nitrogen and phosphorus to claim maximum grain fodder yield of sorghum.

Valadabadi and Farahani (2010) observed that K nutrition significantly increased the root penetration of millet and sorghum plants under drought stress. Asgharipour and Heidari (2011) also reported that the adequate K nutrition enhanced grain and biological yield of sorghum as against control treatment while increasing leaf K and N and decreasing leaf Na accumulation. Moreover, adequate K nutrition also conferred drought stress tolerance by enhancing the chlorophyll content of sorghum plants, singly and in interaction with optimum irrigation. Moreover, in combination with P, K nutrition also enhanced agronomic N-use-efficiency in sorghum. Saleem *et al.* (2011) recorded maximum grain and stalk yield when sorghum received 120 kg K_2O ha^{-1}. However, Buah *et al*. (2012) did not observe significant interactions of fertilizer N, P, and K to affect any parameter of sorghum, might be due to the difference in genotypes used in two studies.

CONCLUSION

The study concluded that sorghum genotypes varied widely for their growth and biomass production, however, this variation was independent of their potassium accumulation. Hence, a wide range of sorghum genotypes may be involved to exploit their variation for K accumulation in quest of identifying K-use-efficient sorghum genotypes.

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