ISSN 1023-1072

Pak. J. Agri., Agril. Engg., Vet. Sci., 2013, 29 (1): 31-43

SUNFLOWER HYBRIDS DIFFERENTIALLY ACCUMULATE POTASSIUM FOR GROWTH AND ACHENE YIELD

M. A. Chajjro[1], Zia-ul-hassan, I. Rajpar, A. N. Shah and K. A. Kubar

[1]Faculty of Crop Production, Sindh Agriculture University, Tandojam, Pakistan

ABSTRACT

Potassium (K) nutrition ensures optimum yield and quality of crops. This field study was conducted to evaluate the impacts of varying levels of K on the growth, yield and K accumulation of two sunflower (*Helianthus annuus* L.) hybrids. The experiment was conducted in a two factor split plot design with three replications. Sunflower hybrids (Hyson-33 and Hyson-39) were grown in main plots, accommodating five K doses 0 (control) 30, 60, 90 and 120 kg ha^{-1}) in sub-plots. The soil of the experimental area was a non-saline and alkaline sandy clay loam, low in organic matter but adequate in K. Though adequate K nutrition did not affect plant height across sunflower hybrids over control, it significantly enhanced growth, biomass production and achene yield of sunflower hybrids (22 to 67%). Across K application rates, sunflower hybrids significantly varied from each other. Hyson-39 had enhanced growth and yield traits than Hysun-33 (4% to 39%), but decreased K accumulation (15%). K accumulation was positively correlated with the growth and achene yield of sunflower hybrids, but these relationships were stronger in case of Hyson-39. The study concluded that adequate K nutrition (120 kg K ha^{-1}) enhanced the growth and achene yield of both sunflower hybrids even under adequate soil K condition.

Keywords: Achene yield, growth, potassium accumulation, sunflower hybrid.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is an important non-conventional oilseed crop of Pakistan. However, sunflower yield in Pakistan during last decade (1999-00 to 2008-09) remained highly stagnant ranging from 1.07 t ha^{-1} to 1.52 t ha^{-1} during 2007-08 (GoP, 2010). The growth and development of sunflower is adversely affected by a variety of abiotic stresses, including nutrient deficiency stress. Unfortunately, despite the recent reports of potassium (K) deficiency in many important benchmark soil series of Pakistan, the K status of Pakistani soils is mistakenly considered adequate (Zia-ul-Hassan *et al*., 2008). This misconception has played havoc with the sustainability of agriculture and profitable crop production in Pakistan. Hence, it is high time to test the significance of K in acquiring the maximum yield potential of various crops, including sunflower.Potassium is the most abundant cation in the cells of non-halophytic higher plants and is required in the amounts equal or even greater than the nitrogen (Epstein and Bloom, 2005). Apart from these important functions, K also plays a vital role in the transport of assimilates from leaves to the roots and also to the storage organs, like tubers and grains. The leaves and shoot and of K deficient plants retain most of the low molecular assimilates that decreases the efficiency of the conversion of sun energy into assimilates. Hence, the excessive electrons released from the chloroplasts lead to the formation of highly toxic oxygen radicals (Cakmak, 2005). Additionally, K activates more than 60 enzymes that control energy conversion, carbohydrate formation and translocation, N metabolism and other metabolic processes in plants (Epstein and Bloom, 2005). Potassium deficiency increases the activity of NADPH oxidase which generates the production of oxygen radicals (Cakmak, 2005). Sunflower requires an adequate supply of K ranging from 1.28% or in most cases 3.0 to 6.7% to offer optimum yields. Nonetheless, many research workers have generally considered K ‘deficient’ or ‘marginal’ for sunflower when it was lower than 2.5%. Accordingly, the ‘critical K concentration’ reported for sunflower ranges from 1.8 to 2.6 %. These K concentrations represent various plant parts of sunflower, sampled at

Corresponding author: zhnshah@gmail.com

various growth stages (Reuter and Robinson, 2008). Keeping in view the rapid mining of K from Pakistani soils, negligible K fertilization and high K requirement of sunflower, it is hypothesized that the modern high yielding and hybrid sunflower varieties may require an adequate supply of K to offer optimum yields. This field study was conducted to evaluate the response of two sunflower hybrids to varying levels of potassium for their growth and achene yield.

MATERIALS AND METHODS

The field experiment was conducted in a two factor split plot design with three replications, by sowing two sunflower hybrids (Hysun-33 and Hysun-39) to main plots (4m × 6m= 24m^2), divided in five sub-plots receiving different K doses (0, 30, 60, 90 and 120 kg ha^{-1}). The sunflower hybrids were sown in rows spaced at 1.5 ft., having plants spaced at 1.0 ft. All the recommended cultural and management practices were followed during the whole crop life span, as per crop requirements. The requisite doses of K were maintained through soil application of potassium sulphate (50% K_2O). The crop also received the recommended doses of nitrogen (140 kg ha^{-1}) and phosphorus (70 kg ha^{-1}). The nitrogen was supplied as urea (46% N) while phosphorus (P) as diammonium phosphate, (DAP, 18% N and 46% P_2O_5). All the P and K, along with half dose of N, was supplied to the crop by broadcasting to the soil and then thoroughly mixed. The remaining half dose of N was given to the crop at first irrigation (two weeks after sowing). The soil analysis (Ryan *et al*., 2001) depicted that the experimental area was sandy clay loam in texture, free from salinity hazards (EC: 0.74 dS/m), alkaline in pH (7.9), low in organic matter (0.37%) and adequate in AB-DTPA-extractable potassium (167mg kg^{-1}). The crop was raised following the recommended production technology. At maturity (83 and 91 days after sowing for Hyson-33 and Hyson-39 respectively) five plants were harvested from each experimental unit to observe various growth and yield traits. After six weeks of sowing, five plants were harvested from each experimental unit for determining the K accumulation of sunflower hybrids following the standard method (Wolf, 1982). Plant K concentration was determined through Flame photometer (Jenway PFP). The obtained K concentration values were interpreted as categorized by Reuter and Robinson (2008). The collected data were subjected to requisite statistical analysis using Statistix ver. 8.1. The treatment means were separated by Tukey's honestly significant difference test at alpha 0.05. The relationships among various parameters were determined through correlation analysis using statistix ver. 8.1.

RESULTS

Plant height (cm)

The mean squares from analysis of variance (Table 1) revealed that all three sources of variance had no effect on the plant height of sunflower and were non-significant ($p > 0.05$). The data presented in Table 1 depict increase in plant height due to the application of K nutrition. Plant height of sunflower increased up to 22% at 120 kg K ha^{-1} as compared to control. A gradual increase was found in the average plant height of sunflower across genotypes with the increasing dose of K. However, this increase was statistically non-significant. Similarly, increase in the plant height of Hyson-33 and Hyson-39 was also noted up to 24% and 19% over their respective controls, respectively, but this increase was again statistically non-significant (Table 1).

Biomass yield (g)

The mean squares from analysis of variance (Table 2) illustrated that all three sources of variance, i.e. K rates (K), genotypes (G) and their interaction (K × G) significantly ($p < 0.001$) affected the biomass yield of sunflower. A gradual increase was found in the biomass yield of sunflower across genotypes with the increasing dose of K. The biomass yield increased from 267.3 g at 0 kg K ha^{-1} (control) to 364.9 g at 120 kg K ha^{-1}. Hence, biomass yield of sunflower hybrids increased up to 37% at 120 kg K ha^{-1} as compared to control, i.e. no K application (Table 2). The genotypic variation for K requirement also existed in sunflower hybrids to produce biomass yield. The biomass yield of Hyson-39 (320.2 g) was 4% more than Hyson-33 (307.9 g). In general, both the genotypes responded to K nutrition almost similarly. The biomass yield of Hyson-33 and Hyson-39 increased up to 36% and 37%, respectively, when K application rate increased from 0 to 120 kg ha^{-1} (Table 2).The significant interactive effect revealed that the sunflower hybrids behaved differently for biomass production at different K levels. The maximum biomass yield (373.6 g) was noted in case of Hyson-33, followed by Hyson-33 (356.2 g), when these hybrids received 120 kg K ha^{-1}. Similarly, minimum biomass yield was observed in case of Hyson-33 (261.6 g), followed by Hyson-39 (272.9), when these hybrids did not receive any K nutrition (Table 2).

Number of leaves

The mean squares from analysis of variance (Table 3) illustrated that K rates (K) and genotypes (G) had highly significant ($p < 0.001$ and 0.01, respectively), while their interaction (K × G) had non-significant, effect on the number of leaves of sunflower hybrids. Number of leaves of sunflower hybrids increased significantly across genotypes, with the increasing dose of K. The number of leaves increased from 19.6 at 0 kg K ha^{-1} (control) to 28.6 at 120 kg K ha^{-1}. However, this was not statistically different with the number of leaves produced at 90 kg K ha^{-1} (27.4). Similarly, the number of leaves produced at 30 kg K ha^{-1} (23.4) was also statistically alike to that produced at 60 kg K ha^{-1} (24.4). Accordingly, the number of leaves of sunflower hybrids increased up to 46% at 120 kg K ha^{-1} as compared to control (Table 3). The genotypic variation for K requirement also existed in sunflower hybrids to produce number of leaves. The number of leaves of Hyson-39 (25.6) was 8% more than Hyson-33 (23.7). Hence, it is clear that both the sunflower hybrids responded to K nutrition in a similar manner. The number of leaves of Hyson-33 and Hyson-39 increased up to 51% and 43% over their respective controls, respectively, when K application rate increased from 0 to 120 kg K ha^{-1}. Hence, the data depicted that the number of leaves of Hyson-33 was more responsive to K nutrition than Hyson-39 (Table 3).The non-significant interactive effect highlighted that both the sunflower hybrids behaved similarly in producing the number of leaves at various K application rates (Table 3).

Stem diameter (mm)

The mean squares from analysis of variance (Table 4) illustrated that K rates (K) and genotypes (G) had highly significant ($p < 0.01$), while their interaction (K × G) had non-significant effect on the stem diameter of sunflower hybrids. Stem diameter of sunflower hybrids increased significantly across genotypes, with the increasing dose of K. The stem diameter increased from 15.4 mm at 0 kg K ha^{-1} (control) to 23.0 mm at 120 kg K ha^{-1}. However, this was not statistically different from the stem diameter at 90 kg K ha^{-1} (22.6 mm). Similarly, the stem diameter at 60 kg K ha^{-1} (20.1 mm) was significantly more from that produced at 30 kg K ha^{-1} (16.9 mm). Accordingly, the stem diameter of sunflower hybrids increased up to 49% at 120 kg K ha^{-1} as compared to control (Table 4). The genotypic variation for K requirement also existed in sunflower hybrids for their stem diameter. The stem diameter of Hyson-39 (20.9) was 14% more than Hyson-33 (18.3). Hence, it is clear that on an average basis Hyson-39 responded more to K nutrition for stem diameter as against Hyson-39. However, the stem diameter of Hyson-33 and Hyson-39 increased up to 54% and 45% over their respective controls, respectively, when K application rate increased from 0 to 120 kg K ha^{-1}. Hence, the data revealed that on individual basis Hyson-33 responded more vigorously to K nutrition than that of Hyson-39 (Table 4).The non-significant interactive effect depicted that there was no any difference between two sunflower hybrid genotypes under study and both responded alike for their stem diamter at various K application rates (Table 4).

Table 1. Plant height of sunflower hybrids under the influence of graded levels of potassium.

K (kg ha^{-1})	Plant height (cm)		
	Hyson-33	Hyson-39	K Mean
0	112.2	117.6	114.9
30	120.4	122.8	121.6
60	125.5	135.0	130.2
90	126.6	137.8	132.2
120	138.8	140.8	139.8
Genotype Mean	124.7	130.8	-
Analysis of variance and mean separation			
	Potassium rates (K)	Genotypes (G)	K × G

Mean Square	369.7 NS	77.09 NS	817.5 NS
$HSD_{0.05}$	-	-	-

NS: non-significant

Table 2. Biomass yield of sunflower hybrids under the influence of graded levels of potassium.

K (kg ha^{-1})	Biomass yield (g)		
	Hyson-33	Hyson-39	K Mean
0	261.6j	272.9i	267.3
30	282.0h	292.8g	287.4
60	304.9f	316.7e	310.8
90	334.7d	345.1c	339.9
120	356.2b	373.6a	364.9
Genotype Mean	307.9	320.2	-
Analysis of variance and mean separation			
	Potassium rates (K)	Genotypes (G)	K × G
Mean Square	9250.6***	1147.4***	12.49***
$HSD_{0.05}$	1.51	0.69	2.54

***: significant at alpha 0.001

Table 3. Number of leaves of sunflower hybrids under the influence of graded levels of potassium.

K (kg ha^{-1})	Number of leaves		
	Hyson-33	Hyson-39	K Mean
0	18.4	20.7	19.6C
30	22.6	24.1	23.4B
60	23.6	25.3	24.4B
90	26.4	28.4	27.4A
120	27.7	29.5	28.6A
Genotype Mean	23.7B	25.6A	-
Analysis of variance and mean separation			
	Potassium rates (K)	Genotypes (G)	K × G
Mean Square	76.04***	25.89**	0.15 NS
$HSD_{0.05}$	1.26	0.48	2.08

NS: non-significant, ** and ***: significant at alpha 0.01 and 0.001, respectively.

Table 4. Stem diameter of sunflower hybrids under the influence of graded levels of potassium.

K (kg ha^{-1})	Stem diameter (mm)		
	Hyson-33	Hyson-39	K Mean
0	13.9	16.9	15.4D
30	16.0	17.7	16.9C
60	18.7	21.5	20.1B
90	21.2	24.0	22.6A
120	21.4	24.5	23.0A
Genotype Mean	18.3B	20.9A	-
Analysis of variance and mean separation			
	Potassium rates (K)	Genotypes (G)	K × G
Mean Square	67.97**	47.27**	0.49 NS
$HSD_{0.05}$	1.08	0.73	1.82

NS: non-significant, **: Significant at alpha 0.01

Head diameter (mm)

The mean squares from analysis of variance (Table 5) illustrated that all three sources of variance, i.e. K rates (K), genotypes (G) and their interaction (K × G) significantly ($p < 0.05$ to 0.001) affected the head diameter of sunflower. Head diameter of sunflower across two hybrid genotypes increased gradually with the increasing dose of K. The head diameter increased from 50.6 mm with control to 61.9 mm with 120 kg K ha^{-1}. Hence, head diameter of sunflower hybrids increased up to 22% at 120 kg K ha^{-1} as compared to control (Table 5). The genotypic variation for K requirement was also noted between sunflower hybrids for head diameter. The head diameter of Hyson-39 (58.7 mm) was 5% more than Hyson-33 (55.8 mm). In general, both the genotypes responded to K nutrition almost similarly. The head diameter of Hyson-33 and Hyson-39 increased up to 26% and 19%, respectively, when K application rate increased from 0 to 120 kg K ha^{-1}. Hence, Hyson-33 had 7% more head diameter as against Hyson-39, based on its individual response to K nutrition (Table 5).The significant interactive effect revealed that the sunflower hybrids behaved differently for their head diameter at different K levels. Hyson-39 had maximum head diameter of 62.6 mm and 61.8 mm, at 120 and 90 kg K ha^{-1}, respectively. Similarly, minimum head diameter of 48.4 mm and 52.8 mm was noted in case of Hyson-33 and Hyson-39, when K nutrition was not supplied to both sunflower hybrids (Table 5).

Head length (cm)

The mean squares from analysis of variance (Table 6) illustrated that all three sources of variance, i.e. K rates (K), genotypes (G) and their interaction (K × G) significantly ($p < 0.01$) affected the head length of sunflower hybrids. Head length across sunflower hybrids increased gradually with the increasing dose of K. The head length increased from 17.1 cm at 0 kg K ha^{-1} to 51.6 cm at 120 kg K ha^{-1}. Hence, head length of sunflower hybrids increased up to 3-fold at 120 kg K ha^{-1} as compared to control (Table 6). The genotypic variation for K requirement was also existed between two sunflower hybrids for their head length. The head length of Hyson-39 (37.0 cm) was 39% more than that of Hyson-33 (26.7 cm). Hence, Hyson-39 responded K nutrition more vigorously than Hyson-33 to increase its head length. The head length of Hyson-33 and Hyson-39 increased up to 223% (3.2-fold) and 186% (2.9-fold), respectively, when K application rate increased from 0 to 120 kg K ha^{-1}. Hence, Hyson-33 had 37% more head length as against Hyson-39, based up on its individual response to K nutrition (Table 6).The significant interactive effect revealed that the sunflower hybrids behaved differently for their head length at different K levels. Hyson-39 had maximum head length of 57.0 cm followed by 45.4 cm, at 120 and 90 kg K ha^{-1}, respectively. Similarly, minimum head length of 14.3 cm and 18.8 cm was noted in case of Hyson-33, at K application rates of 0 and 30 kg K ha^{-1}, respectively (Table 6).

Head weight (g)

The mean squares from analysis of variance (Table 7) illustrated that all three sources of variance, i.e. K rates (K), genotypes (G) and their interaction (K × G) significantly ($p < 0.001$, < 0.001 and < 0.01, respectively) affected the head weight of sunflower. Head weight of sunflower across two hybrid genotypes increased gradually with the increasing dose of K. The head weight increased from 86.0 g at 0 kg K ha^{-1} to 143.7 g at 120 kg K ha^{-1}. Hence, head weight of sunflower hybrids increased up to 67% at 120 kg K ha^{-1} as compared to control (Table 7). The genotypic variation for K requirement was also noted between sunflower hybrids for their head weight. The head weight of Hyson-39 (112.4 g) was 6% more than Hyson-33 (106.5 g). In general, both the genotypes responded K nutrition almost similarly. The head weight of Hyson-33 and Hyson-39 increased up to 74% and 61%, respectively, when K application rate increased from 0 to 120 kg K ha^{-1}. Hence, Hyson-33 had 13% more head weight as against Hyson-39, based up on its individual response to K nutrition (Table 7). The significant interactive effect revealed that the sunflower hybrids behaved differently for their head weight at different K levels. Maximum head weight of 146.5 g was noted for Hyson-39, followed by 140.9 g in case of Hyson-33, at 120 kg K ha^{-1}, respectively. Similarly, minimum head weight of 80.9 g, followed by 89.2 g, was noted in case of Hyson-33, where no K was applied (Table 7).

Achene yield (g)

The mean squares from analysis of variance (Table 8) illustrated that all three sources of variance, i.e. K rates (K), genotypes (G) and their interaction (K × G) significantly ($p < 0.001$) affected the achene yield of sunflower. Achene yield of sunflower across two hybrid genotypes increased gradually with the increasing dose of K. The achene yield increased from 12.6 g at 0 kg K ha^{-1} to 30.6 g at 120 kg K ha^{-1}. Hence, achene yield of sunflower hybrids increased up to 143% (2.4-fold) at 120 kg K ha^{-1} as compared to control (Table 8). The genotypic variation for K requirement was also observed between two sunflower hybrids for their achene yield. The achene yield of Hyson-39 (24.8 g) was 27% more than that of Hyson-33 (19.5

g). Hence, Hyson-39 responded K nutrition more vigorously than Hyson-33 to produce more achene yield. The achene yield of Hyson-33 and Hyson-39 increased up to 150% (2.5-fold) and 136% (2.4-fold), respectively, when K application rate increased from 0 to 120 kg K ha^{-1}. Hence, Hyson-33 had 14% more achene yield as against Hyson-39, based up on its individual response to K nutrition (Table 8).The significant interactive effect highlighted that the sunflower hybrids behaved differently for their achene yield at different K levels. Hyson-39 had maximum achene yield of 35.2 g followed by 30.5 g, at 120 and 90 kg K ha^{-1}, respectively. Similarly, minimum achene yield of 10.4 g was noted for Hyson-33, followed by 14.9 g for Hyson-39, at 0 kg K ha^{-1}, respectively (Table 8).

Table 5. Head diameter of sunflower hybrids under the influence of graded levels of potassium.

K (kg ha^{-1})	Head diameter (mm)		
	Hyson-33	Hyson-39	K Mean
0	48.4g	52.8f	50.6
30	54.1ef	56.9de	55.5
60	55.9e	59.2cd	57.5
90	59.3bcd	61.8ab	60.6
120	61.2abc	62.6a	61.9
Genotype Mean	55.8	58.7	-
Analysis of variance and mean separation			
	Potassium rates (K)	Genotypes (G)	K × G
Mean Square	119.2**	61.8**	1.82*
$HSD_{0.05}$	1.31	1.12	2.2

* and **: Significant at alpha 0.05 and 0.01, respectively.

Table 6. Head length of sunflower hybrids under the influence of graded levels of potassium.

K (kg ha^{-1})	Head length (cm)		
	Hyson-33	Hyson-39	K Mean
0	14.3h	19.9fg	17.1
30	18.8g	27.3de	23.1
60	23.5ef	35.6c	29.5
90	30.7d	45.4b	38.1
120	46.2b	57.0a	51.6
Genotype Mean	26.7	37.0	-
Analysis of variance and mean separation			
	Potassium rates (K)	Genotypes (G)	K × G
Mean Square	1091.48**	799.08**	17.77**
$HSD_{0.05}$	0.84	1.74	1.42

**: Significant at alpha 0.01.

Table 7. Head weight of sunflower hybrids under the influence of graded levels of potassium.

K (kg ha^{-1})	Head weight (g)		
	Hyson-33	Hyson-39	K Mean
0	80.9h	91.1g	86.0
30	89.2g	96.4f	92.8
60	97.9f	101.4e	99.7
90	123.5d	126.5c	125.0
120	140.9b	146.5a	143.7
Genotype Mean	106.5	112.4	-
Analysis of variance and mean separation			
	Potassium rates (K)	Genotypes (G)	K × G
Mean Square	3509.55***	262.73***	13.09**
$HSD_{0.05}$	1.52	0.36	2.37

** and ***: Significant at alpha 0.01 and 0.001, respectively.

Table 8. Achene yield of sunflower hybrids under the influence of graded levels of potassium.

K (kg ha^{-1})	Achene yield (g)		
	Hyson-33	Hyson-39	K Mean
0	10.4g	14.9f	12.6
30	15.6f	19.6e	17.6
60	20.5e	23.9d	22.2
90	25.3cd	30.5b	27.9
120	26.0c	35.2a	30.6
Genotype Mean	19.5	24.8	-
Analysis of variance and mean separation			
	Potassium rates (K)	Genotypes (G)	K × G
Mean Square	322.70***	208.72***	7.89***
$HSD_{0.05}$	0.89	0.38	1.50

***: Significant at alpha 0.01.

K accumulation (%)

The mean squares from analysis of variance (Table 9) illustrated that all three sources of variance, i.e. K rates (K), genotypes (G) and their interaction (K × G) significantly (p <0.001, <0.01 and <0.05, respectively) affected the K accumulation of sunflower. K accumulation of sunflower across two hybrid genotypes increased gradually with the increasing dose of K. The K concentration increased from 2.87% at 0 kg K ha^{-1} to 6.42% at 120 kg K ha^{-1}. Hence, K concentration of sunflower hybrids increased up to 124% (2.2-fold) at 120 kg K ha^{-1} as compared to control, i.e. no K application (Table 9). The genotypic variation for K requirement was also observed between two sunflower hybrids for their K concentration. The K concentration of Hyson-33 (4.79%) was 15% more than that of Hyson-39 (4.17%). Hence, Hyson-33 accumulated more K in response to K nutrition than Hyson-39. The K concentration of Hyson-33 and Hyson-39 increased up to 87% (1.9-fold) and 180% (2.8-fold), respectively, when K application rate increased from 0 to 120 kg K ha^{-1}. Hence, Hyson-39 accumulated 93% more K as compared to Hyson-33, based up on its individual response to K nutrition (Table 9).The significant interactive effect highlighted that the sunflower hybrids behaved differently for their K accumulation at different K levels. Hyson-33 accumulated maximum K (6.52%), followed by Hyson-33 (6.31), at 120 kg K ha^{-1}, respectively. Similarly, Hyson-39 accumulated minimum K, i.e. 2.25%, followed by 3.12%, at 0 and 30 kg K ha^{-1}, respectively (Table 9).

Table 9. Potassium accumulation of sunflower hybrids under the influence of graded levels of potassium.

K (kg ha^{-1})	K accumulation (%)

	Hyson-33	Hyson-39	K Mean
0	3.48fg	2.25h	2.87
30	3.83efg	3.12g	3.47
60	4.43de	4.21ef	4.32
90	5.71bc	4.96cd	5.33
120	6.52a	6.31ab	6.42
Genotype Mean	4.79	4.17	-
Analysis of variance and mean separation			
	Potassium rates (K)	Genotypes (G)	K × G
Mean Square	12.19***	2.90**	0.27*
$HSD_{0.05}$	0.43	0.21	0.75

*, ** and ***: Significant at alpha 0.05, 0.01 and 0.001, respectively.

Table 10. Correlation among various traits of sunflower hybrids under the influence of graded levels of potassium.

Trait of sunflower	Hyson-33		Hyson-39	
	K accumulation	Achene yield	K accumulation	Achene yield
Biomass yield	0.988**	0.975**	0.996***	0.998***
Number of leaves	0.936*	0.980**	0.968**	0.991***
Stem diameter	0.945*	0.911*	0.956*	0.968**
Head diameter	0.932*	0.983**	0.955*	0.967**
Head length	0.975**	0.881*	0.997***	0.996***
Head weight	0.998***	0.928*	0.955*	0.966**
Achene yield	0.938*	-	0.998***	-

*, ** and ***: Significant at alpha 0.05, 0.01 and 0.001, respectively.

Relationship among K accumulation, achene yield and growth traits of sunflower hybrids

The correlation analysis of K accumulation and achene yield with growth traits of two sunflower hybrids is given in Table 10. It is crystal clear that in case of Hyson-33, K concentration was significantly correlated with number of leaves, stem diameter, head diameter and achene yield. However, these relationships were little meager ($p < 0.05$). Interestingly, K concentration highly significantly influenced biomass yield, head length ($p < 0.01$) and head weight ($p < 0.001$). In case of Hyson-39, K concentration was weakly correlated ($p < 0.05$) with stem diameter, head diameter and head weight. Nonetheless, the relationship of K concentration was highly significant with number of leaves ($p < 0.05$), biomass yield, head length and achene yield. Similarly, the achene yield of two sunflower hybrids was weakly correlated ($p < 0.05$) in case of Hyson-33 with stem diameter, head length, head weight. Nonetheless, it was highly significantly ($p < 0.01$) correlated with biomass yield, number of leaves and head diameter. In case of Hyson 39, the achene yield was highly significantly correlated with the stem diameter, head diameter and head weight ($p < 0.01$). Moreover, achene yield of Hyson-39 was even more strongly correlated ($p < 0.001$) with biomass yield, number of leaves and head length.

DISCUSSION

The present study witnessed the significance of adequate K nutrition in enhanced growth, biomass production and achene yield of sunflower hybrids (Table 2 to 9). Earlier research workers also categorized K as one of the major plant nutrients determining crop yield and quality (Cakmak, 2005; Epstein and Bloom, 2005). Potassium deficiency reduces both the number of leaves and their area (Pettigrew, 2008). It has been reported that K nutrition of sunflower (100 kg K ha^{-1}) reduces cost of production, enhances seed oil and protein concentration, and increases yield and profit. Increased K content of plants increases seed oil concentration and decreases seed protein concentration. Adequate K nutrition also increases both oil and protein yields per unit area by improving yield components and enhanced seed yield (Amanullah, 2010). Gerendas *et al*. (2008) reported that achene yield of sunflower increased due to adequate K supply.Bakht *et al*. (2006) also reported significant effect of adequate K nutrition on the growth and yield of ten sunflower hybrids. Similar, results were also reported by Asadi (2010). The results of present study further revealed that genotypic variation existed between two sunflower hybrids for their possible exploitation for low and high input sustainable agriculture. A number of research studies highlighted the differences in K relations among crop genotypes and their species in Pakistan and else where maize (Nawaz *et al*., 2006; Zia-ul-hassan *et al*., 2011). Increasing K application rates increased the accumulation of K by sunflower hybrids. Hyson-33 accumulated more (4.79) K than Hyson-39 (4.17) (Table 9). Reuter and Robinson (2008) emphasized that sunflower requires an adequate supply of K to offer optimum yield. K content is considered 'deficient' or 'marginal' for sunflower when it was lower than 2.5 g kg^{-1}, the 'critical K concentration' ranged from 1.8 to 2.6 g kg^{-1}, while the 'adequate' K concentrations for sunflower ranged from 3.0 to 6.7 g kg^{-1}. Nonetheless, lower range of 1.28 to 2.70 g kg^{-1} is also found in the literature. These K concentrations represent various plant parts of sunflower, sampled at various growth stages (Reuter and Robinson, 2008). The correlation analysis of K accumulation with achene yield with growth traits of two sunflower hybrids (Table 10) revealed that enhanced K accumulation by sunflower genotypes increased their growth traits and consequently achene yield. Zia-ul-hassan *et al*. (2011) reported that K relations of plant genotypes significantly affect their biomass production. It is also interesting to note that despite adequate K status of soil under study, sunflower genotypes accumulated increased K with the increasing rate of K and hence the growth traits and consequently the yield of sunflower hybrids were increased. These results again endorsed the previous findings that K requirements of plant may be equal or even more than that of N (Epstein and Bloom, 2005).

CONCLUSION

Potassium nutrition enhanced the growth and achene yield of both sunflower hybrids. Hyson-33 responded K nutrition more strongly, with comparatively lower K accumulation, as compared to Hyson-39. A dose of 120 kg K ha^{-1} was found to be the best dose in enhancing most of the growth and yield traits of sunflower hybrids.

REFERENCES

Amanullah. 2010. Effects of macronutrients on seed quality and profitability analysis of sunflower production in northwest Pakistan. Selected paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Orlando, FL, February 6-9.

Asadi, S. 2010. Influence of different K fertilizer sources on sunflower production. 19th World Congress of Soil Science, Science and Research campus, Tehran, Iran. pp. 16-18.

Bakht. J., S. Ahmed, M. Tariq, H. Akber, M. Shafi. 2006. Performance of various hybrids of sunflower in Peshawar Valley. J. Agric. Bio., 1: 25-29.

Cakmak, I. 2005. The role of potassium in alleviating detrimental effects of abiotic stresses in plants. J. Plant Nutr. Soil Sci., 168: 521-530.

Epstein, E. and A. Bloom. 2005. Mineral Nutrition of Plants: Principles and Perspectives. 2^{nd} ed. Sinauer Associates, Sunderland, MA, USA.

Gerendás, J., J. Abbadi and B. Sattelmacher. 2008.Potassium efficiency of safflower (Carthamustinctorius L.) and sunflower (Helianthus annuus L.). J. Plant. Nutr., 171: 431–439.

GoP. 2010. Agricultural Statistics of Pakistan 2008-2009. 42^{nd} ed. Government of Pakistan, Ministry of Food and Agriculture (Economic Wing), Islamabad.pp. 273 + xi.

Nawaz, I., Zia-ul-hassan, A. M. Ranjha and M. Arshad. 2006. Exploiting genotypic variation among fifteen maize genotypes of Pakistan for potassium uptake and use efficiency in solution culture. Pak. J. Bot., 38: 1689-1696.

Pettigrew, WT. 2008. Potassium influences on yield and quality production for maize, wheat, soybean and cotton. J. Physiol. Plan., 133: 667-681.

Reuter, D. J. and J. B. Robinson. 2008. Plant analysis: An Interpretation Manual. 2nd Indian ed. SBS Publishers & Distributors Pvt. Ltd., New Delhi, India, pp. 572 + xii.

Ryan, J., G. Estefan and A. Rashid. 2001. Soil and Plant Analysis Laboratory Manual. 2nd ed. pp. 172. ICARDA, Aleppo, Syria.

Wolf, B. 1982. A comprehensive system of leaf analysis and its use for diagnosing crop nutrient status. Commun. Soil Sci. Plan., 13: 1035-1059.

Zia-ul-hassan and M. Arshad. 2011. Relationship among root characteristics and differential potassium uptake and use efficiency of selected cotton genotypes under potassium deficiency stress. Pak. J. Bot., 34: 1831-1835.

Zia-ul-hassan, K. S. Memon, M. Memon and M. Arshad. 2008. Quantifying the effect of temperature on ammonium bicarbonate diethylenetriaminepenta-acetic acid extractable potassium and developing a novel correction factor to express the data. Commun. Soil Sci. Plan., 39: 3047-3056.

(Received November 02, 2012; Accepted May 24, 2013)