RESPONSE OF MAIZE HYBRIDS TO VARYING POTASSIUM APPLICATION IN PAKISTAN

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A field experiment was conducted in 2005 and 2006 to evaluate the growth, grain yield, N, P, K concentration in stalk, and quality parameters of three maize hybrids (Pioneer-30D55, Pioneer-3062 and Pioneer-3012) at different levels of potassium (0, 100, 150, 200, and 250 kg ha^{-1}). Pioneer-30D55 surpassed other two hybrids in growth rate, grain yield (6.01 t ha^{-1}), N (0.728%), P (0.078%), K (1.79%) concentration in stalk, crude starch (72.97%), protein (8.15%) and oil (4.46%) contents in grains. K application in all treatments significantly increased growth rate, grain yield, N, P, K concentration in stalk, and improved crude starch, protein and oil contents in grains over control. Maximum growth rate, grain yield (6.05 t ha^{-1}), N (0.751%), P (0.082%), K (1.86%) concentration in stalk, were recorded, when 200 kg K ha^{-1} was applied, and beyond this limit, tended to decline its growth rate, grain yield (6.02 t ha^{-1}), N (0.743%), P (0.071%) and K (1.76%) concentration in stalk when 250 kg K ha^{-1} was applied, but continued to increase crude starch (72.65%), protein (8.31%) and oil (4.53%) contents in grains. Interactive effects of maize hybrids and potash application levels on growth, yield and N, P, K concentration in stalk, crude starch, oil, and protein contents in grains were, however, non significant. It was concluded that Pioneer-30D55 performed best with 200 kg K ha^{-1} when previous soil K status was 124.5 ppm. However, grain quality parameters were the best at 250 kg K ha^{-1} application.
Keywords: Maize hybrids, K application, grain yield, N, P, K concentration and quality parameters

INTRODUCTION

Modern maize hybrids respond to potassium (K) application differently due to difference in its uptake, translocation, accumulation, growth and utilization (Minjian *et al.*, 2007). The K-efficient genotype is a complex one comprising a mixture of uptake and utilization efficiency mechanisms (Tsai and Huber *al.*, 1996). Differential exudation of organic compounds to facilitate release of non-exchangeable K is one of the mechanisms of differential K uptake efficiency (Damon and Rengel, 2008). Genotypes efficient in K uptake may have a larger surface area of contact between roots and soil and increased uptake at the root-soil interface to maintain a larger diffusive gradient towards roots (Nawaz *et al.,* 2006). Better translocation of K into different organs, greater capacity to maintain cytosolic K^+ concentration within optimal ranges and increased capacity to substitute Na^+ for K^+ are the main mechanisms underlying K utilization efficiency (Herbert *et al*., 2001).
Growth rate studies under different conditions of K limitation indicated that N, P and K concentration in stalk of crop plants facilitate the nutrients to move from roots to the reproductive structures (Alfoldi *et al*., 1994; Li *et al*., 2007; Tsai and Huber, 1996). The high concentration of K in silk further substantially improves crude starch (Koch and Mengel, 1977), protein (Davidescu, 1965), and oil (Usherwood, 1985) contents in grains, resulting in higher grain yield (Sharif *et al*., 1996; Roy and Kumar, 1990).
Efficient plant hybrids could have better fertilizer use efficiency (Epstein and Bloom, 2005) and hence may reduce input cost and conserve environment (Baligar *et al.,* 2001). These hybrids are characterized by high plasticity (Sparlangue *et al.,* 2007), higher grain yield, because of genetic yield improvement attributable, in part, to increase partitioning of dry matter to the ear (Echarte and Andrede*,* 2003). K fertilization improves yield which generally comes out because of increase in the kernel weight (Sharma *et al.,* 2005).
There is general consensus that the soils of Pakistan have large capacity to provide available K to crop under ordinary conditions most probably due to dominance of illite soil clay minerals (Ranjha *et al.*, 1990), but the increase in the intensity of cropping, substantial removal of straw from the field, excessive use of tube well water and introduction of high yielding hybrids in various cropping systems have resulted in considerable drain of soil K reserves and crops are becoming responsive to K fertilization (Malik *et al.*, 1989).
In Pakistan, K status of soils is rapidly decreasing at a distressing rate. The net K draining rate is even steeper 0.3 kg ha^{-1} year^{-1}. This may be due to the negligible (0.8 kg ha^{-1} year^{-1}) use of K in Pakistan as

compared to world average K use (15.1 kg ha^{-1} $year^{-1}$) (Ahmad and Rashid, 2003). Therefore, there was need to identify maize hybrids efficient in K up take, accumulation and utilization use, to offer the best opportunities for future breeding research towards low input, sustainable and environment friendly agriculture. The present study was aimed at exploiting the genetic variation among three maize hybrids for their appropriate K level.

MATERIALS AND METHODS

An experiment was conducted on a sandy clay loam soil at Government Agricultural Extension Farm, Model Town–A, Bahawalpur, Pakistan for two consecutive years, 2005 and 2006. As soil of the experimental area was quite uniform, a composite and representative soil sample to a depth of 30 cm was obtained with soil auger, prior to sowing of the crop. This sample was analyzed for its various physic-chemical properties by using methods as described by Moodie *et al.* (1959) and Homer and Pratt (1961). The soil was sandy clay loam, containing 65% sand, 15% silt, and 20% clay. Its chemical characteristics included saturation 36%age, pH 7.9, EC 1.3 dS m^{-1}, organic matter 0.83%, available N, P, K 0.043%, 1 ppm, and 124.5 ppm, respectively. The experiment was triplicated in a randomized complete block design in split plot arrangement.

The hybrids and K levels were randomized in the main and sub plots, respectively. The hybrids included in the experiment were H_1: Pioneer-3012, H_2: Pioneer-3062, and H_3: Pioneer-30D55. K was applied at the rate of K_0: 0, K_1: 100, K_2: 150, K_3: 200, and K_4: 250 kg ha^{-1}. A basal dose of 300 and 200 kg ha^{-1} of N, P was applied, respectively. N, P and K were added in the form of urea, diammonium phosphate and sulphate of K, respectively. All the P, K and half dose of N was side dressed at sowing, while remaining N was top dressed with first irrigation. All other agronomic operations except the ones under study were kept normal and uniform for all the treatments.

Crop growth rate (CGR) was calculated by the formulae given by Beadle (1987). CGR $= \frac{W_2 - W_1}{t_2 - t_1}\left(g\,m^{-2}\ day^{-1}\right)$, Where W_2=dry weight (DW) m^{-2} land area at second harvest, W_1=DW m^{-2} land area at first harvest, t_2= time corresponding to second harvest, t_1=time corresponding to first harvest. Seed yield was recorded on subplot basis and then converted into tones per hectare (t ha^{-1}).

Plant stem analysis for N, P and K was conducted at physiological maturity. For P and K determination the procedures used for physio-chemical analysis of all aforementioned plant parameters were described by Steckel and Flannery (1971). Crude starch contents in grains were determined by using the method given by Juliano (1991). N contents of maize grain samples, randomly selected from each sub-plot were determined by using micro-kjeldhal distillation method (Anonymous, 1980) and then the crude protein contents in grains were calculated by using the following formula. Crude protein = Nitrogen %age x 6.25. Crude oil contents in grains were determined by Soxhlet method described by Low (1990).

The data were analyzed by the "Mstat" statistical package on a computer (Freed and Eisensmith, 1986). When a significant "F" value was obtained for treatment effect, least significant differences (LSD) test at 0.05 P was applied to determine the significance of the treatment means (Steel *et al.*, 1997). The computer Hard Graphics was used to prepare the graphs.

RESULTS AND DISCUSSION

Periodic crop growth rate (CGR) of maize hybrids under different K levels is given in Fig. for both years. It was evident that Pioneer-30D55 has significantly higher CGR than Pioneer-3062 and Pioneer-3012. K application 100 to 250 kg ha^{-1} significantly increased CGR over control. The difference among the K levels was not pronounced and CGR was slow in the beginning in both years. However, 45 to 60 days after sowing the CGR increased in all K application treatments, and it reached to its maximum value, when 200 kg K ha^{-1} was applied and thereafter, it declined sharply in all the treatments and reached its maturity. Similar trends were described by Pettigrew (2008), Nawaz (2006) and Damon and Rengel (2008).

Grain yield was significantly increased by K application in all hybrids. Pioneer-30D55 produced significantly higher grain yield (6.01 t ha^{-1}) as compared to Pioneer-3062 (5.81 t ha^{-1}) and Pioneer-3012 (5.59 t ha^{-1}). The differences between Pioneer-3062 and Pioner-3012 were also significant. Interactive effects of maize hybrids and K levels on grain yield were found to be non-significant. These results were in line with the findings of Pettigrew (2008), and Damon and Rengel (2008), who reported that different hybrids responded differently due to their different genetic potential.

K application increased grain yield in all treatments over control. The increase in yield up to 200 kg ha^{-1} was significant at each K level and significant reduction yield occurred at K level of 250 kg ha^{-1}. Interactive effects of maize hybrids and K levels on grain yield were, however, non significant. These results are in line with the findings of Sharif *et al.* (1996), Pettigrew (2008) and Roy and Kumar (1990). They reported that

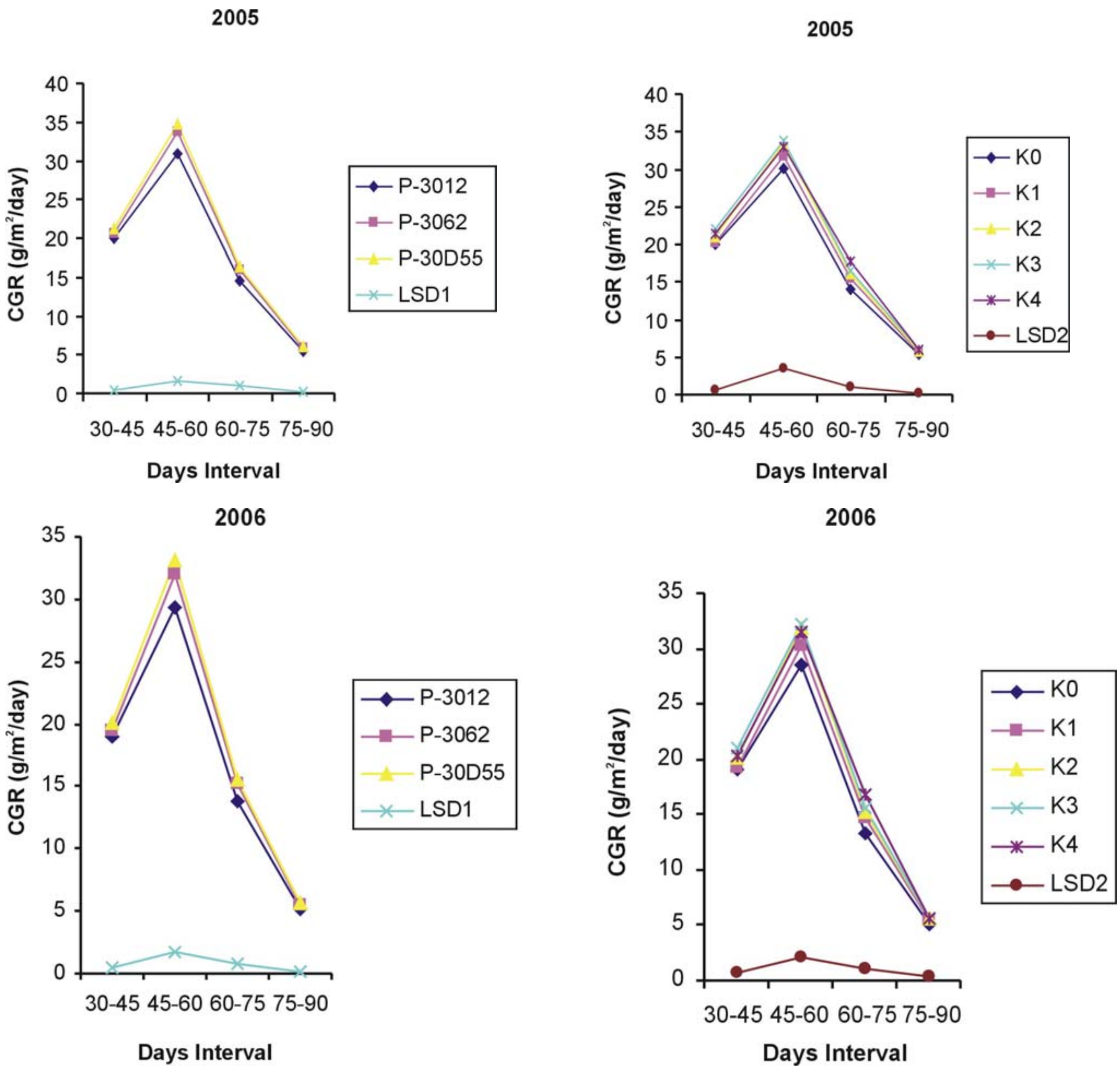

Fig. Effect of K levels on crop growth rate of maize hybrids

K application increased grain yield due to increase in prolificacy and grain weight.

Maize hybrids varied significantly from one another regarding N %age in stalk. Pioneer-30D55 produced significantly higher N %age in stalk and it was followed by Pioneer-3062 and Pioneer-3012 with significant variation between them. The results are in accordance with observations of Alfoldi *et al.* (1994), Li *et al.* (2007) and Tsai and Huber (1996). They also observed that maize hybrids differ in N %age in maize stalk due to their different genetic make up.

K application significantly affected N %age in maize stalk. All K levels resulted in higher N %age in maize stem over control. However, the differences between the levels of 100, 150, 200 and 250 kg ha^{-1} were not significant. The minimum N %age in maize stem was recorded in where no K was applied and maximum N %age was observed between maize hybrids at K level of 200 kg ha^{-1}. Interaction effects of maize hybrids and

K levels on N %age in maize stalk were non significant. These results are in harmony with the findings of Naeem (1998) and Herbert *et al*. (2001). They concluded that K application facilitated the up take of N from soil due to which N concentration in maize stalk was increased.

Pioneer-30D55 significantly accumulated more P concentration in maize stalk (0.078%) than Pioneer-3062 and Pioneer-3012. The results are quite in line with those of findings of Alfoldi *et al.* (1994), Li *et al.* (2007), Tsai and Huber (1996). They concluded that the higher up take of N probably have promoted effect on up take of P. K application increased P %age in maize stalk, probably due to more uptake of N, which promoted uptake of P. The application of K significantly affected the P %age in maize stalk and the highest P %age was noted at K level of 200 kg ha^{-1} and it was significantly higher than all other levels. The differences between K levels of 100,150, and 250 kg ha^{-1} was not significant. Interactive effects of maize hybrids and K levels on P %age accumulation in maize stalk was non significant.

K application significantly produced maximum P %age in stalk in K_3 (0.082%), where 200 kg ha^{-1} K was applied. Similarly, P %age in stalk recorded in K_4 (0.072%), K_2 (0.071%), and K_1 (0.070%) were statistically at par with each other, where 250, 150, and 100 kg ha^{-1} K was applied, while minimum P %age in stalk was found in K_0 (0.062%), where no K was applied. Interactive effects of maize hybrids and K levels on P %age in maize stalk were, however, non significant .The results are supported with the findings of the Alfoldi *et al.* (1994), Li *et al.* (2007) and Tsai and Huber (1996), who reported that K application promoted P up take by plants and consequently improved P concentration in stalk.

All maize hybrids varied significantly from one another regarding K %age in stalk (Table 1). Pioneer-30D55 significantly produced maximum K %age in stalk and minimum K %age was noted in Pioneer-3012. Minjian *et al.* (2007) and Nawaz *et al.* (2006) have also reported significant differences among the maize hybrids regarding K %age in stalk. They also attributed these differences due to differences in genetic make up of the hybrids.

K application significantly affected K %age in the stalk (Table 1). The application of the K at the rate of 200 kg ha^{-1} produced significantly high K %age in stalk than all other K levels. A significant reduction in stalk K contents was noted at K level of 250 Kg ha^{-1}. The K levels of 100 and 150 kg ha^{-1} produced statistically similar K contents in stalk. These results are in accordance with the findings of the Alfoldi *et al.* (1994), and Li *et al.* (2007), who reported that K application in soil also increased K %age in stalk.

Crude starch contents in grains significantly differed in maize hybrids. Pioneer-30D55 gave the highest crude starch contents in grains, which was statistically at par with Pioneer-3062 (72.15%). Similarly the differences between Pioneer-3062 (72.15%) and Pioneer-3012 (70.83%) were not significant. These results are in agreement with those of Asghar (1999), and Minjian (2007). K levels application significantly influenced crude starch contents in grains. Maximum crude starch contents in grains were recorded when K was applied at the rate of 250 kg K ha^{-1} and it was statistically at par with when K levels of 200 kg K ha^{-1} was applied. Minimum grain starch contents were found in control. Interactive effects of maize hybrids and K levels on grain starch contents were not significant. Similar trends were observed by Davidescu (1965), Koch and Mengel (1977), and Tisdale *et al.* (1997). They concluded that K along with N promoted nitrogenous compounds to form starch for translocation to grains from straw and roots.

Crude protein contents in grains significantly differed in maize hybrids. Pioneer-30D55 yielded significantly higher crude protein contents in grains than Pioneer-3062 and Pioneer-3012. These results are in accordance with those of Asghar (1999), and Minjian *et al*. (2007). They attributed the differences due to difference in genetic make up of the hybrid. K application levels significantly influenced grain protein contents. K application at the rate of 250 kg ha^{-1} produced significantly higher crude protein contents in grains but it was statistically similar to 200 and 250 kg K ha^{-1}. Interactive effects of maize hybrids and K levels on crude protein contents in grains were not significant. Davidescu (1965), and Petttigrew (2008), have also reported that K application increased crude protein contents in grains.

Significant differences were observed among maize hybrids for crude oil contents in grains. Pioneer-30D55 produced significantly higher crude oil contents in grains, than Pioneer-3012 but statistically similar to Pioneer-3062. Asghar (1999) and Minjian *et al*. (2007) have also reported significant differences among maize hybrids for crude oil contents in grains. The maize hybrids varied significantly from maize hybrids regarding crude oil contents in grains. The application of K significantly improved the crude oil contents in grains. The application of K at the rate of 200 kg ha^{-1} produced statistically similar crude oil contents from 150 to 250 Kg K ha^{-1}. The maximum and minimum crude oil contents in grains were noted in control and 250 Kg K ha^{-1}, respectively. Interactive effects of maize hybrids and K levels on crude oil contents in grains

Table 1. Production potential and chemical composition of maize hybrids as influenced by potassium application (Mean of two years)

Treatments	Grain Yield (t ha^{-1})	N Conc. in stalk (%)	P Conc. in stalk (%)	K Conc. in stalk (%)	Crude starch contents in grains (%)	Crude protein contents in grains (%)	Crude oil contents in grains (%)
Hybrid							
Pioneer 3012	5.59 c	0.686 c	0.066 c	1.62 c	70.83 b	8.09 c	4.26 b
Pioneer 3062	5.81 b	0.704 b	0.070 b	1.72 b	72.15 ab	8.12 b	4.39 a
Pioneer 30D55	6.01 a	0.728 a	0.078 a	1.79 a	72.97 a	8.15 a	4.46 a
LSD=0.05	0.192*	0.009*	0.002*	0.07*	1.6787*	0.021*	0.1129*
K levels (kg ha^{-1})							
K0=0	5.45 e	0.675 c	0.062 c	1.64 cd	70.46 d	7.87 c	4.22 d
K1=100	5.65 d	0.698 b	0.069 b	1.72 bc	71.85 c	8.00 bc	4.29 cd
K2=150	5.85 c	0.700 b	0.070b	1.73 b	72.36 b	8.12 ab	4.36 bc
K3=200	6.05 a	0.751 a	0.082 a	1.86 a	72.59 a	8.24 a	4.46 ab
K4=250	6.02 b	0.743 a	0.071 b	1.76 b	72.65a	8.31 a	4.53 a
LSD=0.05	0.270*	0.021*	0.005*	0.09*	0.065*	0.1999*	0.1253*
Interaction (H x K) N.S							
CV=%	5.37	6.65	5.25	6.78	8.42	3.68	4.28

Means followed by different letters in a column are significantly different at 0.05P.
* = Significant
N.S = Non Significant

were not significant. These results are in line with the findings of Davidescu (1965), and Usherwood (1985).
Pioneer-30D55 surpassed other two hybrids (Pioneer-3062 and Pioneer-3012) in grain yield, N, P, and K %age in stalk and quality parameters (crude starch, protein and oil contents in grains). It gave the highest grain yield at 200 kg K ha^{-1} application, with previous soil K status of 124.5 ppm. However, grain quality parameters were the highest at 250 kg K ha^{-1} application.

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