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Water and Potassium Management for Enhanced Maize (*Zea mays* L.) Productivity

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ABSTRACT

An experiment was conducted during 1992 and repeated in 1993 to evaluate growth and yield response of maize cv. Akbar to irrigation at different levels of available soil moisture deficit (ASMD) i.e. 75, 50 and 25% and potassium levels *viz.* 0, 100, 150 and 200 kg K_2O ha^{-1}. Irrigation at 25% ASMD with 200 kg K_2O ha^{-1} considerably increased LAI, DW $plant^{-1}$, crop growth rate, net assimilation rate as well as grain yield components of maize over other treatment combinations. Application of irrigation at 25 and 50% ASMD enhanced grain yield by 24.83 and 16.79%, respectively over irrigation at 75% ASMD. Addition of K_2O @ 200, 150 & 100 kg ha^{-1} increased grain yield by 24.18, 18.41 and 11.54%, respectively over control.

Key Words: Potassium management; Maize; Water; ASMD

INTRODUCTION

Maize is high yield potential crop and responds well to potassium fertilizer. Proper management of potassium nutrient is essential to realize maximum potential of the crop because it plays an important role in activating various enzymes (Tisdale *et al.*, 1990). Large amount of potassium is also needed for regulation of different physico-chemical processes in plants including water utilization by the plant. An adequate supply of potassium confers drought tolerance and frost resistance on plants (Corazzina *et al.*, 1991). It also enhances grain yield by increasing grain number, grain weight and 1000-grain weight (Roy & Kumar, 1990). Greater LAI depends on rapid leaf growth that requires K to maintain the osmotic potential of cells (Wynjones *et al.*, 1979). Similarly application of K increases DW $plant^{-1}$, CGR and NAR because K has been implicated in the rapid plant growth (Wallingford, 1980).

Availability/uptake of potassium to plants depends on the amount of water available to them because diffusion of nutrients towards roots depends upon sufficiently high soil moisture content, Besides water is essential for crop growth and productivity as it not only maintains the turgor pressure of the cells but also regulates various metabolic functions. Irrigation, thus, improves the efficiency of fertilizer utilization by the crop (Shimshi, 1969). There are several reports which indicate that maize grain yield ha^{-1} increases with a decrease in ASMD level. Water stress induces reduction in grain number due to either prevention of ovule fertilization or post fertilization cessation of development of some apical grains (Grant *et al.*, 1989) and in grain weight by shortening the duration of grain filling by causing premature desiccation of the endosperm and by limiting embryo volume.

Keeping the above information in view, present study was designed to determine the effect of various levels of potassium and available soil moisture deficit on growth and yield of maize.

MATERIALS AND METHODS

Site. The experiment was conducted under field conditions at the University of Agriculture, Faisalabad during 1992 and repeated in 1993. The experiment was laid out in split-plot design with three replications. ASMD levels for irrigation (irrigation at 75, 50 and 25% ASMD) were placed in main plots while potassium levels (0, 100, 150 and 200 kg ha^{-1}) were allocated to subplots. Subplot size measured 2.40m x 7.50m.

Crop husbandry. Maize variety Akbar was sown on a well-prepared seed bed in 60 cm spaced single rows with a single row hand drill. A basal dose of nitrogen and phosphorus @ 200 kg N + 100 kg P_2O_5 ha^{-1} was applied. All K in the respective plot & P along with half of N was side dressed at sowing. The remaining half of N was top dressed with first irrigation. Subsequent irrigations were applied when soil attained the specified available soil moisture deficit (ASMD) level in each treatment. Thinning was done at 2-4 leaf stage to maintain a plant to plant distance of 15 cm. All other agronomic practices were adopted according to the requirement of crop.

Observations recorded were LAI at the end of silking, DW $plant^{-1}$ at the end of silking, Ave. CGR, Ave. NAR, grains cob^{-1}, Grain weight cob^{-1}, 1000-grain weight, grain yield and harvest index. CGR and

NAR were determined by using the formulae of Beadle (1987). The data were statistically analysed by the methods described by Steel and Torrie (1984).

RESULTS AND DISCUSSION

Leaf area index (LAI). Both irrigation at different levels of ASMD and K_2O application had significant effect on LAI during both years (Table I). Maximum LAI of 6.21 and 6.51 were produced in 1992 and 1993, respectively by the crop irrigated at 50 and 25% ASMD. However, differences between 50 and 25% ASMD were non-significant in both years. Decrease in LAI in response to reduced water supply is attributed to a reduction in LA plant^{-1} (data not shown) primarily as a result of reduction in leaf width.

There was a progressive increase in LAI with each increase in K_2O level. In 1992, maize fertilized @ 200 kg K_2O ha^{-1} gave highest LAI (5.96) but was statistically equal to that fertilized @ 150 kg K_2O ha^{-1}. Similarly, in 1993 the difference between 150 and 200 kg K_2O ha^{-1} was non-significant but this year these two K_2O levels were statistically on a par with 100 kg K_2O ha^{-1}. Highest LAI was produced by the crop receiving 200 kg K_2O ha^{-1} as a result of rapid leaf growth which involves a requirement for K to maintain the osmotic potential of cells (18) (Wyn Jones *et al.*, 1979) Interactive effect of ASMD and K_2O levels on LAI was, however, non-significant in both years.

Dry weight plant^{-1}. There was significant increase in dry weight (DW) plant^{-1} with decrease in level of ASMD in both years. However, difference between 50 and 25% ASMD was non-significant. By contrast, lowest DW plant^{-1} was recorded at 75% ASMD. Low DW plant^{-1} at 75% ASMD was due to the reduced plant size as is evident from the decreased plant height, stem diameter (data not shown) and LAI. Reduced plant size results in a lower assimilation at the time of ear development, as production of dry matter depends upon size of the assimilatory surface (Paauw, 1949). Sufficient amount of irrigation has been found to increase DW plant^{-1} (Sridhar & Singh, 1989).

Although K_2O application significantly increased DW plant^{-1} over control, yet various K_2O levels did not significantly differ from one another in both years. Increase in DW plant^{-1} in response to K application is ascribed to greater plant height, stem diameter (data not shown) and LAI as a result of rapid plant growth in which K is involved (Wallingford, 1980). Interactive effect of irrigation at different ASMD and K_2O levels was non-significant in both years.

Crop growth rate. Crop irrigated at 25% ASMD significantly increased total seasonal crop growth rate (CGR) over that at 75% ASMD but was statistically equal to 50% ASMD. Slower growth at 75% ASMD is due to the reduced DW plant^{-1} as a result of decrease in plant height, stem diameter (data not shown) and LAI.

Addition of K_2O @ 200 kg ha^{-1} produced the maximum average CGR but was statistically on a par with all other K_2O levels. Greater CGR in response to enhanced K_2O levels is ascribed to promotive effect of K_2O on DW plant^{-1}, as K has been implicated in the rapid plant growth (Wallingford, 1980). By contrast, interactive effect of ASMD and K_2O levels on CGR was non-significant in both years.

Net assimilation rate. Net assimilation rate (NAR) increased with decrease in ASMD. Maximum NAR of 11.59 and 10.94 g m-2d^{-1} was recorded by irrigation at 25% ASMD in 1992 and 1993, respectively but difference between 50 and 25% ASMD was non-significant in both years. An increase in NAR in response to decreased ASMD may be due to enhanced DW plant^{-1} as net assimilation depends on size of the plant (Shaw & Laing, 1981).

All K_2O levels significantly increased NAR over control but differences among different K_2O levels were non-significant in both years. Enhancing effect of K application on NAR is due to the significant positive effect of K on DW plant^{-1} as NAR is directly proportional to size of the plant.

Grains cob^{-1}. Irrigation at different levels of ASMD had significant effect on number of grains cob^{-1} in 1993 but non-significant in 1992. In 1993, maize crop irrigated at 50 and 25% ASMD produced significantly greater number of grains cob^{-1} than that irrigated at 75% ASMD but did not significantly differ from each other. Less number of grains cob^{-1} incase of 75% ASMD may be due to the enhanced water stress. Since water stress induces reduction in grain number due to either prevention of ovule fertilization (Grant *et al.*, 1989) or post fertilization cessation of development of some apical grains (Moss & Downey, 1971).

Effect of K on grains cob^{-1} was non-significant in 1992 but significant in 1993. In the latter year, all K_2O levels produced significantly greater number of grains cob^{-1} than that of control. Application of K_2O @ 200 kg K_2O ha^{-1} produced significantly more grains cob^{-1} than 100 kg K_2O ha^{-1} but was on a par with 150 K_2O kg ha^{-1}. Greater number of grains cob^{-1} in response to K application has also been previously reported by (Kolcar, 1975).

Interactive effect of irrigation at different ASMD and K_2O levels on number of grains cob^{-1} was also significant in 1993 but non-significant in 1992. In the former year, maximum grains cob^{-1} (514.67) was

Table I. Growth, yield and yield components of maize as affected by irrigation at varying ASMD level and potassium application

Treatments	LAI		DW plant^{-1}		CGR		NAR	
A. ASMD level (%)	1992	1993	1992	1993	1992	1993	1992	1993
I_1 75	4.85b	5.33b	176.99b	175.94b	18.77b	18.52b	9.98b	8.89b
I_2 50	6.21a	6.38a	203.23ab	204.74a	21.24a	21.35a	11.57a	10.89a
I_3 25	6.08a	6.51a	215.21a	217.32a	21.99a	21.77a	11.59a	10.94a
B. Potassium level ($kg\ K_2O\ ha^{-1}$)								
K_0 0	5.47c	5.91b	167.68b	179.32b	17.90b	17.71b	9.20b	8.31b
K_1 100	5.68bc	6.04ab	199.69a	201.26a	21.40a	20.98a	11.48a	10.63a
K_2 125	5.75ab	6.13a	203.58a	207.29a	21.33a	21.29a	11.50a	10.97a
K_3 200	5.96a	6.22a	222.94a	209.47a	22.14a	22.20a	12.00a	11.05a

Treatments	No. of grains cob^{-1}		Grain wt. cob^{-1} (g)		1000-grain weight (g)		Grain yield t ha^{-1}		Harvest index (%)	
A. ASMD level (%)	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
I_1 75	385.91^{NS}	457.70b	66.58c	67.19 c	197.37b	201.38^{NS}	6.71b	6.39c	40.10b	34.03^{NS}
I_2 50	426.13	494.78a	74.30b	72.90b	206.40ab	204.15	7.99a	7.35b	40.24b	36.43
I_3 25	421.50	500.20a	77.32a	77.90a	208.66a	204.97	8.07a	7.86a	41.23a	36.63
B. Potassium level ($kg\ K_2O\ ha^{-1}$)										
K_0 0	383.50^{NS}	439.08c	64.32b	65.39b	198.99b	200.83^{NS}	6.50d	6.39c	39.45b	35.03^{NS}
K_1 100	412.09	487.22b	74.09a	73.97a	204.83a	203.60	7.39c	7.26b	40.15ab	35.91
K_2 125	418.12	499.43ab	75.76a	75.42a	204.90a	204.68	8.06b	7.47ab	41.01a	35.84
K_3 200	431.01	511.17a	76.76a	75.61a	207.84a	204.88	8.39a	7.67a	41.50a	36.00

recorded in maize irrigated at 25% ASMD and fertilized @ 200 kg K_2O ha^{-1} (I_3K_3) which was on a par with I_3K_2, I_2K_3, I_3K_1, I_2K_1, I_2K_2 and I_1K_3. On the contrary, significantly minimum grains cob^{-1} (397.97) was produced by crop grown without K applications and irrigated at 75% ASMD (I_1K_0).

Grain weight cob^{-1}. Irrigation at various ASMD levels had similar significant effect on grain weight cob^{-1} in both years. Each decrease in ASMD level significantly increased grain weight cob^{-1} over the preceding level. Greater grain weight cob^{-1} at lower ASMD levels is ascribed to more grains cob^{-1} and heavier grain as water stress decreases grains weight cob^{-1} (Nesmith & Ritchie, 1992).

Although application of K_2O significantly increased grain weight cob^{-1} over control in both years, yet differences among various K_2O levels were statistically non-significant, K increase grain weight cob^{-1} by increasing number of grains cob^{-1} and grain weight.

Interactive effect of irrigation at various ASMD and K_2O levels on grain weight cob^{-1} was non-significant in both years.

1000-grain weight. There was significant differences in 1000-grain weight among ASMD levels in 1992 but non-significant in 1993. In 1992, maize crop irrigated at 25% ASMD produced significantly heavier grains than that irrigated at 75% ASMD but was statistically equal to that irrigated at 50% ASMD. The latter two ASMD levels were statistically on a par with each other. Reduction in grain weight increases with increasing water stress that shortens the duration of grain filling by causing premature desiccation of the endosperm and by limiting embryo volume (Westigate, 1994).

Application of K significantly increased 1000-grain weight over control in 1992 but not in 1993. In the former year all K_2O levels gave significantly higher 1000-grain weight than that in control but differences among them were non-significant. Greater 1000-grain weight at high K levels was also found by Kolcar (1975). By contrast, differences among the treatment combination were non-significant in both years.

Grain yield. There was significant increase in grain yield ha^{-1} with a decrease in ASMD level in both years. In 1992, although maize crop irrigated at 50 and 25% ASMD gave significantly higher grain yield ha^{-1} than that irrigated at 75% ASMD, yet the former two ASMD levels were statistically equal to each other. By contrast, in 1993 there was significant increase in grain yield ha^{-1} with each decrease in ASMD. Irrigation at 25% ASMD produced significant maximum grain yield of 7.86 t ha^{-1} against the significant minimum of 6.39 t ha^{-1} at 75% ASMD. Overall crop irrigated at 25 and 50% ASMD gave 21.53 and 17.10% greater grain yield than that at 75% ASMD. Greater grain yield at lower ASMD is associated with higher number of grains cob^{-1}, 1000-grain weight and subsequent more grain weight cob^{-1}. Sridhar and Singh also reported similar increase in grain yield ha-1 with a decrease in ASMD. 1989.

Application of K significantly increased grain yield ha^{-1} over control in both years. In 1992, maize crop fertilized @ 200 kg k2O ha^{-1} produced greatest grain yield (8.39 t ha^{-1}) followed by 150 and 100 kg ha^{-1} which produced 8.06 and 7.39 t grains ha^{-1}, respectively and significantly differed from each other. In 1993, although there was a progressive increase in grain yield ha^{-1} with each increase in K_2O level, yet difference between 200 and 150 kg K_2O ha^{-1} or between 150 and 100 kg K_2O ha^{-1} was non-significant. On the average, application of 200, 150 and 100 kg K_2O ha^{-1} increased grain yield by 24.50, 20.31 and 13.64%, respectively, over control because of increased 1000-grain weight and grain weight cob^{-1}. Greater test weight may be attributed to higher CGR and NAR as well as greater DW $plant^{-1}$. An increase in grain yield with the application of K has also been reported by Roy and Kumar (1990).

Harvest index. Irrigation at different ASMD levels had significant effect on harvest index (HI) in 1992 but non-significant in 1993. In the former year, irrigation at 25% ASMD gave significantly higher HI than that at 50 and 75% ASMD. Increase in HI as result of lower ASMD may be due to enhanced physiological ability of the plant to divert more dry matter for grain development. Application of K_2O @ > 150 kg ha^{-1} significantly increased HI over control in 1992 but not in 1993. Effect of treatment combinations on HI was non-significant in both years.

CONCLUSION

Maize cv. Akbar should be irrigated at 25–50% ASMD and fertilized @ 200 kg K_2O ha^{-1} to maximize its grain yield per unit area under the agro-ecological conditions at Faisalabad.

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