BIOLOGIA PLANTARUM 45 (1): 141-144, 2002

BRIEF COMMUNICATION

Effects of increased supply of potassium on growth and nutrient content in pearl millet under water stress

M. ASHRAF*, M. ASHFAQ* and M.Y. ASHRAF**

*Department of Botany, University of Agriculture, Faisalabad, Pakistan**
*Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan***

Abstract

Influence of increased K supply on growth and nutrient content in pearl millet (*Pennisetum glaucum*) under severe water stress was assessed in a pot experiment under glasshouse conditions. Nineteen-day-old plants of two lines, ICMV94133 and WCA-78 were subjected for 30 d to 235, 352.5, and 470 mg(K) kg^{-1}(soil) and two water regimes (100 and 30 % field capacity). Increasing soil K supply did not alleviate the adverse effect of water deficit on the growth of two lines of pearl millet. Accumulation of N and K in the shoots of both lines was higher under water deficit than that under well-watered conditions, but such effect was not observed for P or Ca.

Additional key words: drought stress, inorganic nutrients, *Pennisetum glaucum*.

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is a forage and grain crop of drylands of many countries. Although it is relatively drought resistant compared with most of the C_4 grasses, its growth and grain yield are markedly reduced under water deficit (Bidinger *et al.* 1987, Ashraf *et al.* 1994, Van Oosterom *et al.* 1995). The growth of the crop is also significantly inhibited by K deficiency (Ashraf *et al.* 1994) since K plays a vital role in osmoregulation, respiration, photosynthesis, protein synthesis, stomatal movement, *etc.* (Mengel and Pfluger 1972, Jacoby *et al.* 1973, Flowers and Läuchli 1983, Ashraf and Naz 1994, Quintero *et al.* 1998).

Potassium nutrition is positively associated with plant water relations inasmuch as this cation is known to be absorbed by plants both passively and actively and its concentration in the cytosol is very high compared with other essential cations (Mengel and Kirkby 1987, Marschner 1995). Jones *et al.* (1980) reported that K was the major cation contributing to osmotic adjustment in sorghum. Working with wheat, Morgan (1992) showed that the lines manifesting high osmotic adjustment had high accumulation of K in their tissues.

The positive interaction of K with drought resistance is attributable to its stimulating effect on water uptake by lowering osmotic potential of root cells and xylem sap as well as to the active role of K in stomatal movements (Marschner 1995). In a water-limited environment, wilting and low pressure potential in plants are typical symptoms of K deficiency. The lower tolerance of K deficient plants to drought can be primarily attributable to the role of K in stomatal regulation which is a major mechanism controlling the water balance in plants. This could also be due to the role of K as the major osmoticum in the vacuole, maintaining a high tissue water potential even under severe drought conditions (Marschner 1995). For instance, while studying the effect of K fertilization on water relations and growth of young sunflower plants under simulated drought conditions, Lindhauer (1985) found that despite increasing dry matter and leaf area, K fertilization caused the maintenance of high water content in the plant tissues even under severe water deficit conditions. Similarly, Abdel-Wahab and Abd-Alla (1995) have reported that harmful effects of water deficits on faba bean can be alleviated by increasing K supplementation.

The effects of K nutrition and drought stress on growth of pearl millet have been studied as isolated factors, but little information is available in the literature

Received 23 January 2001, *accepted* 16 February 2001.
Address for correspondence: Dr. M. Ashraf, 51-C Sheikh Colony, ABC Road, Faisalabad, Pakistan.
E-mail: ashrafm@fsd.paknet.com.pk

on their possible interactions. Thus the primary objective of the present study was to determine the effects of both K supply and water deficit on the growth of pearl millet. Whether K nutrition alleviates the adverse effect of drought on plant growth and whether soil water content affects uptake of K and other inorganic nutrients, were also determined.

Seed of two lines (ICMV-94133 and WCA-78) of (*Pennisetum glaucum* (L.) R.Br.) were obtained from the Maize and Millet Research Station, Yousafwala, District Sahiwal, Pakistan. All seed samples were surface sterilized in 5 % sodium hypochlorite solution for 10 min before sowing. The experiment was carried out in a naturally-lit glasshouse at the Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan (latitude 31°30 N, longitude 73°10 E and altitude 213 m), where the average PAR measured at noon ranged from 929 to 1760 μmol m^{-2} s^{-1}, day/night relative humidity 28/54 % and temperature 44/31 °C. In June 1999, 15 seeds of each line were sown randomly about 5 mm deep in plastic pots (25 cm × 25.5 cm) which contained 8.0 kg sandy loam soil (pH = 7.76). After the emergence of seedlings the plants were thinned to nine in each pot. All the pots were irrigated for 34 d with normal canal irrigation water after which time treatments were begun. The K (K_2SO_4) concentrations used were 235, 352.5, or 470 mg kg^{-1} dry soil in half strength Hoagland's nutrient solution without K. These concentrations are supposed to be supra-optimal for most crop species (Epstein 1972, Mengel and Kirby 1987, Marschner 1995). At the same time drought was imposed by maintaining the moisture level equivalent to 30 % field capacity whereas the well-watered pots were maintained at full field capacity. The soil moisture content was monitored daily by weighing the pots. Thus there were two water regimes, *i.e.*, well-watered (field capacity) and water deficit (30 % field capacity) and three K treatments. The experiment was arranged in a completely randomized design with three replicates.

Plants were harvested at 15 and 30 d after the start of treatments. Three plants from each pot were harvested and washed well with distilled deionized water. After recording fresh mass of shoots they were oven-dried at 65 °C to constant dry mass.

Dried shoot samples (100 mg) were milled for the determination of the nutrients. They were determined by the methods described by Allen *et al.* (1986). Plant samples were digested in 2 cm^3 of sulphuric-peroxide digestion mixture until a clear and almost colourless solution was obtained. After digestion, the volume of the sample was made to 100 cm^3 with distilled deionized water. K and Ca were determined with a flame photometer *Jenway PFP7 (Gransmore Green,* Dunmow, UK). P was determined using a spectrophotometer *Hitachi U-2000* (Tokyo, Japan) and N by titration method following Allen *et al.* (1986).

Analysis of variance of data for all the parameters was computed using *COSTAT* computer package (*CoHort Software*, Berkeley, USA). The least significant differences between the mean values were calculated following Snedecor and Cochran (1980).

Imposition of water stress for a period of 30-d had a detrimental effect on shoot dry matter (Fig. 1). The shoot dry matter of ICMV-94133 decreased with increase in K supply under well-watered conditions, whereas in WCA-78 it remained almost unaffected either under well watered or water limiting conditions (Fig. 1). Plant height of both lines was significantly reduced due to water deficit but increased K supply did not show any significant effect on plant height (Fig. 1). Thus the increased supply of K to the medium of two pearl millet lines did not prove to be beneficial in alleviating the effect of drought on their growth. The reason could be the adaptation of this crop to low nutrient content usually encountered under water limiting conditions in dry lands (Bidinger *et al.* 1987, Ashraf and Naz 1994, Van Oosterom *et al.* 1995). Thus it is possible that the critical and adequate contents of K for this crop may be much lower than those for crops which are normally grown on well-watered fertile soils.

Shoot N concentration in both lines was significantly affected by water deficit but not by supra-optimal contents of K (Fig. 1). However, in WCA-78 shoot N increased consistently with increase in K supply under water stress (Fig. 1). Such a positive association of shoot N accumulation with external K supply has already been found in a drought resistant grass, *Dichanthium annulatum* (Ashraf and Naz 1994).

It has been reported that water deficit affects uptake of nutrients by the roots and shoots. It has also been reported that increasing supply of one cation in the growth medium can decrease the content of other cations in the plant. However, from the data for N accumulation, it is clear that the effect of increasing K content in the growth medium was non-significant on accumulation of N in shoots of both lines of pearl millet under both well-watered and water deficit conditions, although N accumulation in the shoots of both lines under water deficit conditions was higher as compared to that under well watered conditions. In WCA-78, N accumulation under water deficit conditions was considerably higher than that in ICMV-94133. In general, high N concentration in crop plants experiencing drought stress was ascribed to the fast accumulation of free amino acids that are not converted into proteins (Barnett and Naylor 1966). It is also possible that the slow growth rate of plants under water deficit stress prevents the dilution effect of nutrients within the cells or tissues.

There was no significant effect of K supply or water stress on P or Ca concentrations in shoots of both lines. Only in WCA-78 shoot P concentrations slightly increased with increasing K supply. The results are parallel to those of Ashraf and Naz (1994) for *D. annulatum* in which a positive relationship between P accumulation and external K supply was found.

P accumulation was generally higher under water deficit than at well watered conditions.

Potassium concentration in the shoots of drought experiencing plants of both lines was significantly higher than that of the well-watered plants, although lines did not differ significantly (Fig. 1). Increase in shoot K content due to drought stress has also been observed in wheat cultivars (Sinha 1978). Potassium is one of the very mobile nutrients in plants. The uptake of water by cells and tissues is frequently the consequence of active K uptake (Läuchli and Pflüger 1978) since this element has been found indispensable for attaining optimum cell pressure potential.

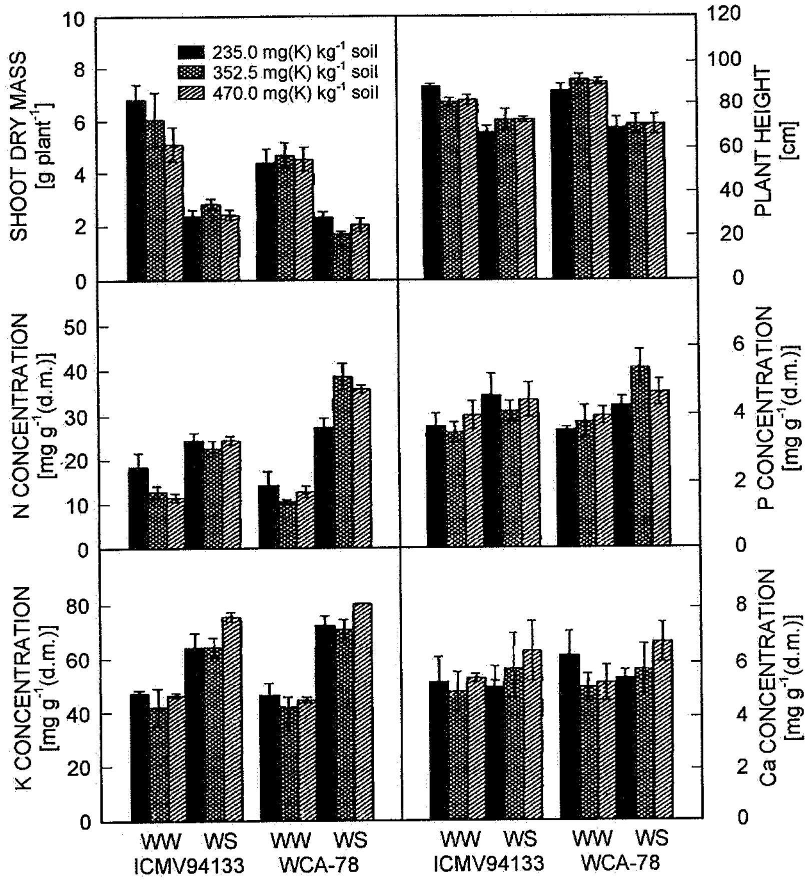

Fig. 1. Shoot dry mass, plant height, and concentrations of different nutrients in shoots of two lines of pearl millet when 19-d-old plants were subjected for 30 d to different K supply under well watered (WW) or water-stressed (WS) conditions.

Although Ca mobility in plants is low, it plays a vital role in many metabolic processes in addition to its important role in maintenance of membrane stability and permeability (Mengel and Kirkby 1987, Marschner 1995). However, in view of Loneragan and Snowball (1969) Ca uptake appears mainly to be a passive and its translocation is dependent on transpiration rate. Nevertheless, Ca concentration in both watering regimes remained unchanged (Fig. 1). There was a small increase in the shoot Ca concentration of both lines with increase in external K supply under water limiting conditions.

Our study has revealed that increased content of K was not beneficial for the growth of pearl millet under severe water deficit. N and K contents in the shoots of both lines were higher under water deficit than under well-watered conditions, but such effect was not observed for P or Ca.

References

Abdel-Wahab, A.M., Abd-Alla, M.H.: The role of potassium fertilizer in nodulation and nitrogen fixation of faba beans (*Vicia faba* L.) plants under drought stress. - Biol. Fertil. Soil **20**: 147-150, 1995.

Allen, S.E., Grimshaw, H.M., Rowland, A.P.: Chemical analysis. - In: Moore, P.D., Chapman, S.B. (ed.): Methods in Plant Ecology. 2nd Ed. Pp 285-344. Blackwell Scientific Publications, Oxford 1986.

Ashraf, M., Naz, F.: Responses of some arid zone grasses to K deficiency. - Acta Physiol. Plant. **16**: 69-80, 1994.

Ashraf, M., Zafar, Z.U., Cheema, Z.A.: Effect of low potassium regimes on some salt- and drought-tolerant lines of pearl millet. - Phyton **34**: 219-227, 1994.

Bänziger, M., Edmeades, G.O., Lafitte, H.R.: Selection for drought tolerance increases maize yields across a range of nitrogen levels. - Crop Sci. **39**: 1035-1040, 1999.

Barnett, N.M., Naylor, A.W.: Amino acids and protein metabolism in Bermuda grass during water stress. - Plant Physiol. **41**: 1222-1226, 1966.

Bidinger, F.R., Mahalakshmi, V., Rao, G.D.P.: Assessment of drought resistance in pearl millet (*Pennisetum americanum* (L.) Leeke). II. Estimation of genotype response to stress. - Aust. J. agr. Res. **38**: 49-59, 1987.

Epstein, E.: Mineral Nutrition of Plants: Principles and Perspectives. - Wiley, New York 1972.

Evans, H.J., Sorger, G.J.: Role of mineral elements with emphasis on the univalent cations. - Annu. Rev. Plant Physiol. **17**: 47-77, 1966.

Flowers, T.J., Läuchli, A.: Sodium versus potassium: substitution and compartmentation. - In: Läuchli, A., Bieleski, R.I. (ed.): Encyclopedia of Plant Physiology. Vol. 15. Part B. Pp. 651-681. Springer-Verlag, Berlin - New York 1983.

Jacoby, B., Abas, S., Steinitz, B.: Rubidium and potassium absorption by bean-leaf slices compared to sodium absorption. - Physiol. Plant. **28**: 209-214, 1973.

Jones, M.M., Osmond, C.B., Turner, N.C.: Accumulation of solutes in leaves of sorghum and sunflower in response to water deficits. - Aust. J. Plant Physiol. **7**: 193-205, 1980.

Kirkby, E.A.: Nitrogen Nutrition of Plant. - The University of Leeds Press, Leeds 1970.

Läuchli, A., Pflüger, R.: Potassium transport through plant cell membranes and metabolic role of potassium in plants. - In: Potassium Research Review and Trends. Pp. 111-163. Potash Institute, Berne 1978.

Lindhauer, M.G.: Influence of potassium nutrition and growth of sunflower (*Helianthus annuus* L.). - Z. Pflanzenernähr. Bodenk. **148**: 654-669, 1985.

Loneragan, J.F., Snowball, K.: Calcium requirements of plants. - Aust. J. agr. Res. **20**: 465-478, 1969.

Marschner, H.: Mineral Nutrition of Higher Plants. 2nd Ed. Academic Press, London 1995.

Mengel, K., Kirkby, E.A.: Principles of Plant Nutrition. International Potash Institute, Berne 1987.

Mengel, K., Pflüger, R.: The release of potassium and sodium from young excised roots of *Zea mays* under various efflux conditions. - Plant Physiol. **49**: 16-19, 1972.

Morgan, J.M.: Osmotic components and properties associated with genotypic differences in osmoregulation in wheat. - Aust. J. Plant Physiol. **19**: 67-76, 1992.

Quintero, J.M., Fournier, J.M., Ramos, J., Benlloch, M.: K^+ status and ABA affect both exudation rate and hydraulic conductivity in sunflower roots. - Physiol. Plant. **102**: 279-284, 1998.

Sinha, S.K.: Influence of potassium on tolerance to stress. - In: Sekhon, G.S. (ed.): Potassium in Soils and Crops. Pp. 223-243. Potash Research Institute, New Delhi 1978.

Snedecor, G.W., Cochran, W.G.: Statistical Methods. 7th Ed. The Iowa State University Press, Ames 1980.

Van Oosterom, E.J., Mahalakshmi, V., Arya, G.K., Dave, H.R., Gothwal, B.D., Joshi, A.K., Joshi, P., Kapoor, R.L., Sagar, P., Saxena, M.B., Singhania, D.L., Vyas, K.L.: Effect of yield potential, drought escape and drought tolerance on yield of pearl millet (*Pennisetum glaucum*) in different stress environments. - Indian J. agr. Res. **65**: 629-635, 1995.