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BRIEF COMMUNICATION

Influence of nitrogen supply and water stress on growth and nitrogen, phosphorus, potassium and calcium contents in pearl millet

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Abstract

Influence of supra-optimal concentrations of N on growth and accumulation of N, K, P and Ca in the shoots and roots in *Pennisetum glaucum* (L.) R.Br. under water stress was assessed in a pot experiment under glasshouse conditions. Thirty four-day-old plants of two lines, ICMV94133 and WCA-78, were subjected to 224, 336, or 448 mg(N) kg^{-1}(soil) and soil moisture 100 or 30 % of field capacity for 30 d. Increasing soil N supply decreased growth of both lines under water deficit. Nitrogen content in the shoots of both lines was not affected by supra-optimal levels of N or different watering regimes, but in contrast, the root N content was increased consistently in WCA-78 with increase in soil N content. Shoot P content increased considerably in WCA-78 at the two higher N contents, but it was significantly lower at drought stress than at well-watered treatment. In contrast, shoot or root P content in ICMV94133 did not differ under both watering regimes. Potassium content in the shoots of WCA-78 was considerably increased at the two higher N contents under drought conditions. Root K content was increased in WCA-78 at the highest N content under well-watered conditions, whereas the reverse was true in ICMV94133. Calcium content in the shoots of ICMV94133 was higher under drought stress compared with that at well-watered conditions, but such pattern was not observed in WCA-78. However, root Ca content increased in both lines with increase in N supply.

Additional key words: drought stress, nutrient content, *Pennisetum glaucum*.

Shortage of usable water is one of the major factors causing low productivity in arid and semi-arid regions. Pearl millet (*Pennisetum glaucum* (L.) R.Br.) is usually grown on low rainfall areas. However, its yield is greatly depressed under severe water deficit conditions (Bidinger *et al.* 1987, Ashraf *et al.* 1994, Van Oosterom *et al.* 1995).

Inorganic fertilization is known to alleviate drought stress effects on the crop growth (Marschner 1995, Payne *et al.* 1995, Raun and Johnson 1999). For instance, Halvorson and Reule (1994) found that wheat, maize and barley yield in dry lands increased with increase in N supply. In winter wheat it was found that grain yield increased at low doses of applied N under mild water deficit, whereas high doses of N proved to be detrimental under severe water stress (Nielsen and Halvorson 1991). In maize, Eghball and Maranville (1993) found non-significant interactions between N supply and water stress for root dry mass, root length, average root radius, root/shoot ratio, and N influx. In view of these reports it is clear that additional amounts of N do not always play a positive role in alleviating the adverse effects of drought on plant growth.

This study aimed to assess whether supra-optimal N levels could alleviate the adverse effects of severe water deficit on growth of pearl millet.

Seeds of two lines (ICMV-94133 and WCA-78) of pearl millet [*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 conducted in a naturally-lit glasshouse at 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

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1760 μmol m^{-2} s^{-1}, day/night relative humidity about 28/54 % and temperature 44/31 °C. In June 1999, seeds were sown in plastic pots (25 × 25.5 cm) which contained 8.0 kg sandy loam soil (pH = 7.76; electrical conductivity = 2.73 dS m^{-1}). After 34 d, nitrogen treatments [224, 336, or 448 mg(N) kg^{-1}(dry soil) in half strength Hoagland's nutrient solution without N] and water deficit treatment were started. Drought was imposed by maintaining the soil moisture at 30 % of field capacity whereas the well-watered pots were maintained at full field capacity. The moisture content was monitored daily by weighing and watering the pots. The experiment was arranged in a completely randomized design with three replicates with nine plants each, three N treatments and two water regimes.

Plants were harvested at 15 and 30 d after the start of N and water deficit treatments. After recording fresh mass of both shoots and roots they were oven-dried at 65 °C to constant dry mass.

Macronutrients (K, Ca, N, and P) were determined by the methods of Allen *et al.* (1986). Ground dry samples of shoots and roots were digested in sulphuric-peroxide mixture and K was determined with a flame photometer *Jenway PFP7 (Gransmore Green,* Dunmow, UK), and Ca with an atomic absorption spectrometer *Analyst 100* (*Perkin Elmer,* Beaconsfield, Germany). 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).

Drought stress (soil moisture 30 % of field capacity) imposed for a period of 30 d to 34 d-old plants of two lines of pearl millet had a significant inhibitory effect ($P < 0.01$) on shoot dry matter (Fig. 1). ICMV94133 had almost uniform shoot dry matter at all N regimes under well-watered conditions, whereas WCA-78 had significantly greater ($P < 0.05$) shoot dry matter at 336 mg(N) kg^{-1}(soil) than at other N regimes. However, both the lines had a similar pattern of shoot dry matter reduction with further increasing N concentration of the soil. These results can be related to the findings of Nielsen and Halvorson (1991) who showed that high levels of N were inhibitory for winter wheat under severe water deficit conditions.

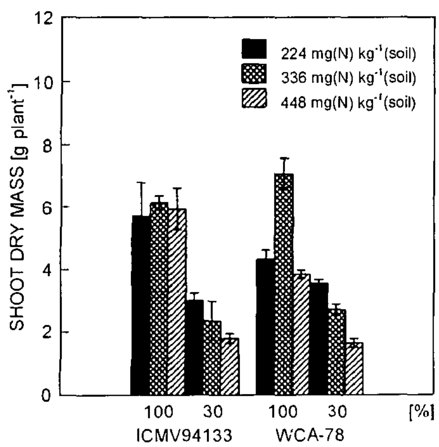

Fig. 1. Shoot dry mass of two lines of pearl millet when subjected for 30 d to varying levels of N under soil moisture 100 or 30 % of field capacity. Means ± SE, $n = 3$.

Shoot N concentration in both lines was not affected by supra-optimal levels of N or different watering regimes (Fig. 2). In contrast, in WCA-78 root N increased consistently with increase in N content in soil under both watering regimes, but the pattern of increase or decrease in root N in ICMV94133 was not consistent (Fig. 2). These results are not in agreement to what has been recently observed in wheat (Arora *et al.* 2001) in which some genotypes maintained higher leaf N content than the others under different N doses and water stress.

In WCA-78 shoot P concentration at drought stress was considerably lower than at well-watered treatment, and at the latter water regime, shoot P concentration increased considerably at the two higher N contents. A similar pattern in root P concentration was observed in WCA-78 under well-watered conditions. In contrast, shoot or root P concentrations in ICMV94133 did not differ under both watering regimes (Fig. 2). The results for P concentrations under well-watered conditions can be explained in view of Marschner (1995) that N and P may have synergistic effect since the critical deficiency level of N increases as the P content increases and vice versa.

Shoot K concentration in WCA-78 increased considerably at the two higher N levels under drought conditions (Fig. 2). Root K concentration was considerably higher in WCA-78 at the highest N level under well-watered conditions, whereas the reverse was true in ICMV94133 (Fig. 2). These results can be explained in view of Gartner (1969), and Yoshida and Yoneyama (1980) who found that the response of K uptake by a crop depends to a large extent on its supply of NO_3^--N. In addition, N and K are reported to have synergistic effect on the regulation of plant growth (Mengel and Kirkby 1987, Marschner 1995).

In ICMV94133 shoot Ca concentrations were higher under drought stress compared with those at well-watered conditions but such pattern was not observed in WCA-78 (Fig. 2). Root Ca concentrations increased with increase in external N supply in both lines. Although Ca is a phloem immobile element in plants, it plays a pivotal 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 process and the transpiration rate controls the upward translocation rate of Ca. But in contrast, under water limiting conditions where transpiration rate and pressure potential are usually low its concentration in both shoots and roots slightly increased in both pearl millet lines with increase in soil N supply.

Our study has revealed that supra-optimal levels of N were detrimental to the growth of pearl millet under severe water deficit conditions.

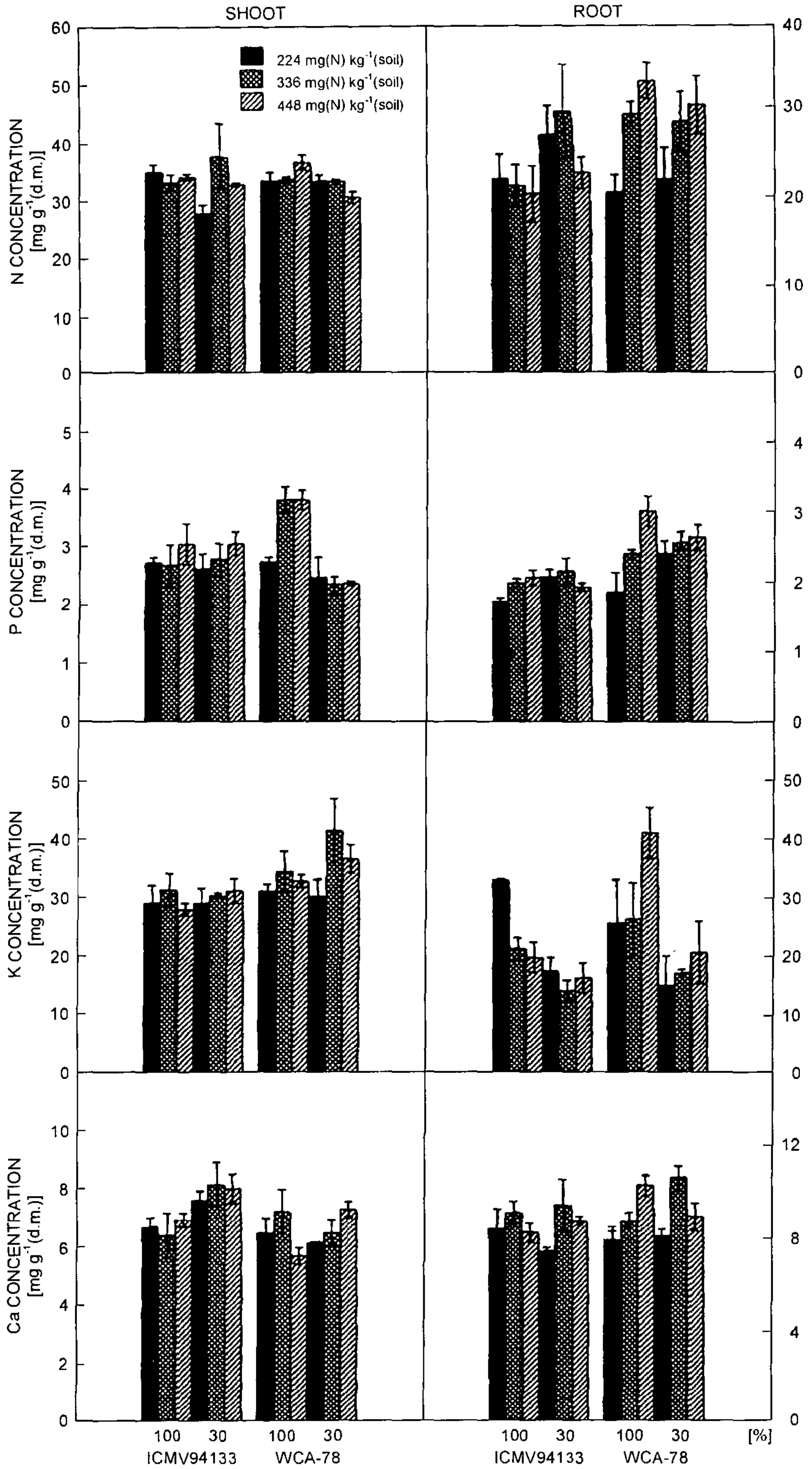

Fig. 2. Concentrations of different nutrients in shoots and roots of two lines of pearl millet subjected for 30 d to varying contents of N under soil moisture 100 or 30 % of field capacity. Means ± SE, $n = 3$.

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