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Effect of Low Potassium Regimes on Some Salt- and Drought-Tolerant Lines of Pearl Millet

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With 2 Figures

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Summary

ASHRAF M., ZAFAR Z. U. & CHEEMA Z. A. 1994. Effect of low potassium regimes on some salt- and drought-tolerant lines of pearl millet. – Phyton (Horn, Austria) 34 (2): 219–227, 2 figures. – English with German summary.

The effect of K deficiency on three salt- and drought-tolerant lines of pearl millet (*Pennisetum glaucum* A. Br.), Kitui local, KAT/PM-2 and Selection II was studied in a pot experiment. Plants of these lines were treated with 235 (control), 117.5, 58.8, 29.4, and 14.7 mg L^{-1} K in Hoagland's nutrient solution. Of the three lines, Selection II was the highest, Kitui local the lowest and KAT/PM-2 intermediate in shoot and root mass. Analysis of tissue K showed that Selection II had high K^+ concentrations in the leaves and low concentrations in the roots compared with the other two lines. This relatively greater translocation of K^+ from roots to leaves could explain this line's vigorous growth under K-deficient regimes. By contrast, Kitui local was not able to efficiently translocate K^+ from roots to leaves, a factor which may account for its greater relative sensitivity to K-deficient conditions. The moderate growth performance of KAT/PM-2 could be related to its moderate uptake of K^+ in its leaves and roots.

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It is concluded that Selection II is the most K-efficient of the lines examined in this study and can be used for salt affected and drought-prone sandy soils naturally low in potassium.

Zusammenfassung

ASHRAF M., ZAFAR Z. U. & CHEEMA Z. A. 1994. Die Wirkung von niedrigen Kaliumgehalten auf einige Salz- und Trockenheit-tolerante Rassen der Perl-Hirse. – Phyton (Horn, Austria) 34 (2): 219–227, 2 Abbildungen. – Englisch mit deutscher Zusammenfassung.

In einem Topfversuch wurde der Einfluß von K-Mangel auf drei salz- und trockentolerante Rassen der Perl-Hirse *(Pennisetum glaucum* A. Br.), nämlich Kitui-local KAT/PM-2 und Selection II, untersucht. Die Pflanzen wurden mit 235 (Kontrolle), 117,5; 58,8; 29,4 und 14,7 mg L^{-1} K^{+} in Hoagland-Nährlösung behandelt. Von den drei Rassen besaß Selection II die höchste und Kitui-local die geringste oberirdische Pflanzen- und Wurzelmasse. KAT/PM-2 nahm eine Zwischenstellung ein. Die Analyse von K^{+} im Gewebe zeigte, daß im Verhältnis zu den beiden anderen Rassen Selection II hohe K^{+} Konzentration in den Blättern und geringe in den Wurzeln aufwies. Die relativ größere Verlagerung von K^{+} aus den Wurzeln in die Blätter könnte den kräftigeren Wuchs dieser Rasse unter K-Mangelbedingungen erklären. Im Gegensatz dazu war Kitui-local nicht in der Lage K^{+} von den Wurzeln in die Blätter effizient zu übertragen. Dies könnte ein Grund für die relativ größere Empfindlichkeit gegenüber K-Mangelbedingungen sein. Die mäßige Wachstumsleistung von KAT/PM-2 könnte auf die mäßigere K^{+} Aufnahme in den Blättern und Wurzeln zurückzuführen sein. Zusammenfassend kann gesagt werden, daß von den drei in dieser Studie untersuchten Rassen Selection II am besten K^{+} verwertet und für Salz belastete und zur Trockenheit neigende Sandböden, welche einen geringeren natürlichen K-Gehalt haben, verwendet werden kann.

Introduction

It is now well evident that salt affected soils, in particular saline-sodic or sodic soils, are deficient of most of the major nutrients including K (U. S. SALINITY LABORATORY STAFF 1954, CHAPMAN 1966, PONNAMPERUMA 1976, KUIPER 1984). It has also been noticed that sandy soils are usually deficient of these minerals (BARBER 1984, MARSCHNER 1986). Soils under continuous crop cultivation are also deficient in important minerals. Thus, the crops grown on such soils experience mineral deficiencies and those well adapted to such deficiencies produce considerable yield on soils of low mineral status.

In a previous study, 24 local/exotic accessions of pearl millet (*Pennisetum glaucum* A. Br.) were screened for salt tolerance (ASHRAF & MCNEILLY 1992). Of these, Kitui local and KAT/PM-2 were found to be highly salt tolerant, whereas Selection II was an improved salt tolerant line being developed after two cycles of recurrent selection (ASHRAF & MCNEILLY 1992). In another study, drought tolerance of these salt tolerant lines was assessed. It was found that all of these salt tolerant lines were highly drought tolerant compared with many other lines examined (ASHRAF & NUSRAT unpublished data).

The role of potassium in plant metabolism is quite evident (MARSCHNER 1986, MENGEL & KIRKBY 1987). Potassium is associated with the synthesis of sugars, proteins and starch in plants. This element occurs in cells in large amount and plays important role in osmoregulation (SALISBURY & ROSS 1992). It was noted that K deficiency in rice increased soluble N (VAN EMBDEN 1966) and accumulation of soluble sugars, amides and amino acids (ISMUNADJI 1976, VAITHILINGAM & BASKARAN 1982). Due to potassium deficiency most cereal grains develop weak stalks, and their roots become susceptible to root-rotting organisms (BHANDAL & MALIK 1988).

Considerable variation in responses among cultivars to K deficiency was observed in snapbeans (SHEA & al. 1968), tomato (GERLOFF 1976), corn (BALIGAR & BARBER 1970), and in soybean (SALE & CAMPBELL 1986, 1987).

The principal aim of the present study was to investigate the responses of some lines of pearl millet possessing high degrees of salt tolerance and drought tolerance, to K deficiency. The selection of a cultivar which is better able to produce high yield in soils of low K status could be very economical.

Materials and Methods

Seed of the two lines of pearl millet, KAT/PM-2 and Kitui local, was obtained from Kenya through personal contact, whereas that of Selection II was raised at Multan (Pakistan). Selection II was originally bred for salinity tolerance and developed after two cycles of selection (ASHRAF & MCNEILLY 1992). All three lines were found to be drought tolerant in comparison with a large number of strains screened (ASHRAF & NUSRAT, unpublished data). All seed samples were surface sterilized in 5% sodium hypochlorite solution for 10 min. Twelve pre-germinated seeds were transplanted equidistant into 24 cm plastic pots containing 5.0 kg well washed and dry sand. The experiment was conducted in a wire-netting house under natural sunlight during summer and was arranged in a randomized block design with four blocks, each block containing three lines and five K-regimes. The five K concentrations were 235 (control - equivalent to that in Hoagland's nutrient solution), 117.5, 58.8, 29.4, and 14.7 mg L^{-1} and were prepared in Hoagland's solution by altering the concentration of only K to attain the required K-regimes. The full strength of Hoagland's nutrient solution was prepared following EPSTEIN (1972) using the following salts (concentrations in mM): 6.0 KNO_3, 4.0 $Ca(NO_3)_2.4H_2O$, 2.0 $NH_4H_2PO_4$, 1.0 $MgSO_4.7H_2O$, 0.05 KCl, 0.025 H_3BO_3, 0.002 $ZnSO_4.7H_2O$, 0.0015 $MnSO_4.2H_2O$, 0.0005 $CuSO_4.5H_2O$, 0.0005 H_2MoO_4, 0.005 FeEDTA. The deficiency of NO_3 due to the changing concentration of KNO_3 in the nutrient solution was compensated for by the addition of appropriate amount of $NaNO_3$. Varying K concentrations were applied at the beginning of the experiment and treatments continued for a period of 28 days. One litre of appropriate treatment solution was applied to each pot after every two days. Six plants from each pot were harvested after every two week interval, and the final harvest was taken 28 days after the start of the experiment. Roots were carefully removed from the sand , washed with deionized water and separated from the shoots. After recording the fresh weights of both shoots and roots, plant material was dried at 70° C for 5 days after which time dry weights of both shoots and roots were recorded.

Analysis of K^+: 100 mg of well-ground dry leaves, stems and roots was digested in 2 mL of concentrated HNO_3. K^+ concentrations in the digests were determined with a flame photometer (Jenway PFP7).

Results

Decreasing K concentrations of the growth medium had a significant adverse effect on the fresh and dry mass of shoots and roots of all three lines of pearl millet examined in this study (Fig. 1 & Table 1). Selection II produced significantly greater ($p \leq 0.05$) shoot and root fresh biomass

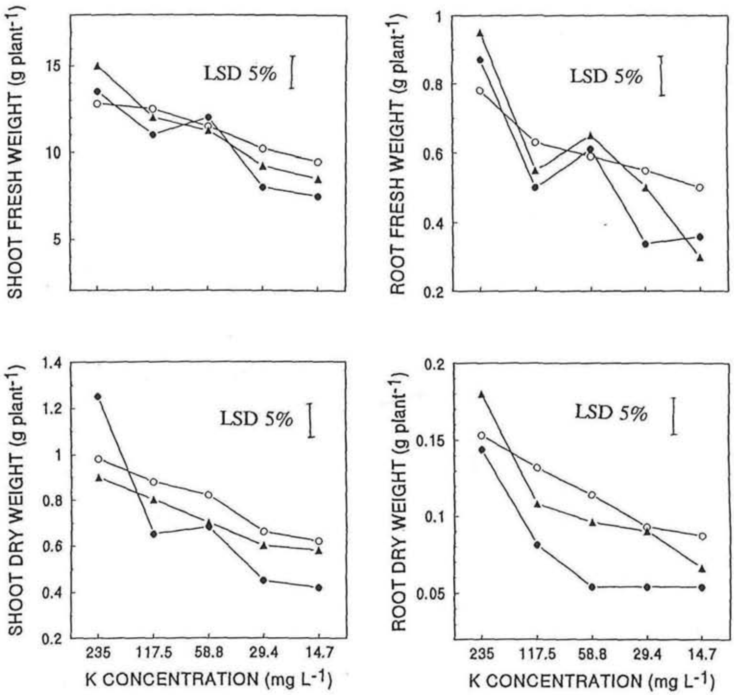

Fig. 1. Mean fresh and dry weights of shoots and roots (g $plant^{-1}$) of three lines of pearl millet when grown for four weeks in sand culture irrigated with Hoagland's nutrient solution containing varying concentrations of K. (Kitui local ●; Selection II ○; KAT/PM-2▲).

Table 1

Analysis of variance summaries (mean squares) of fresh and dry weights of shoots and roots of three pearl millet lines when grown for four weeks in sand culture irrigated with Hoagland's nutrient solution containing varying concentrations of K.

Source of variation	df	Shoot fresh weight	Shoot dry weight	Root fresh weight	Root dry weight
Blocks	3	1.26 NS	0.006 NS	0.006 NS	0.0001 NS
Concentrations (C)	4	19.21 ***	0.207 ***	0.116***	0.0046 ***
Lines (L)	2	16.53 ***	0.122 ***	0.081 ***	0.0038 ***
C × L	8	9.94 ***	0.074 ***	0.060 ***	0.0029 ***
Residual	42	1.16	0.008	0.005	0.0002

*** = significant at 0.001 level
NS = non-significant

than Kitui local at the two lowest K concentrations. Selection II was also superior to KAT/PM-2 in root fresh matter at 14.7 mg L^{-1} of K. Selection II had significantly greater ($p \leq 0.05$) shoot and root dry matters than those of Kitui local at all K concentrations. Conversely, shoot and root dry matters were not different from KAT/PM-2 except at 58.8 and 117.5 mg L^{-1} of K where Selection II had significantly greater shoot dry matter than KAT/PM-2.

Data for K^+ concentrations in different plant tissues (Fig. 2 & Table 2) show that K^+ concentrations in leaves, stems and roots decreased consistently with decreasing K concentration of the rooting medium. The leaf K^+ was significantly greater in Selection II compared with Kitui local at all K-regimes except the lowest K concentration. KAT/PM-2 was not statistically different from Selection II in leaf K^+. Kitui local was the lowest in leaf K^+ of all lines. The three lines did not differ significantly in stem K^+ concentrations. Root K^+ was significantly higher ($p \leq 0.05$) in Kitui local compared with Selection II and KAT/PM-2 at 58.8, 29.4, and 14.7 mg L^{-1} of K in the rooting medium, but the latter two did not differ significantly from each other.

Discussion

From the results for biomass production, it is evident that Selection II was superior to Kitui local under varying K-deficient regimes. KAT/PM-2 was intermediate in growth performance. These results demonstrate that differential response among a small number of lines of pearl millet to K deficiency can be related to the early findings showing considerable variation in responses among cultivars to K deficiency in snapbeans (SHEA & al.

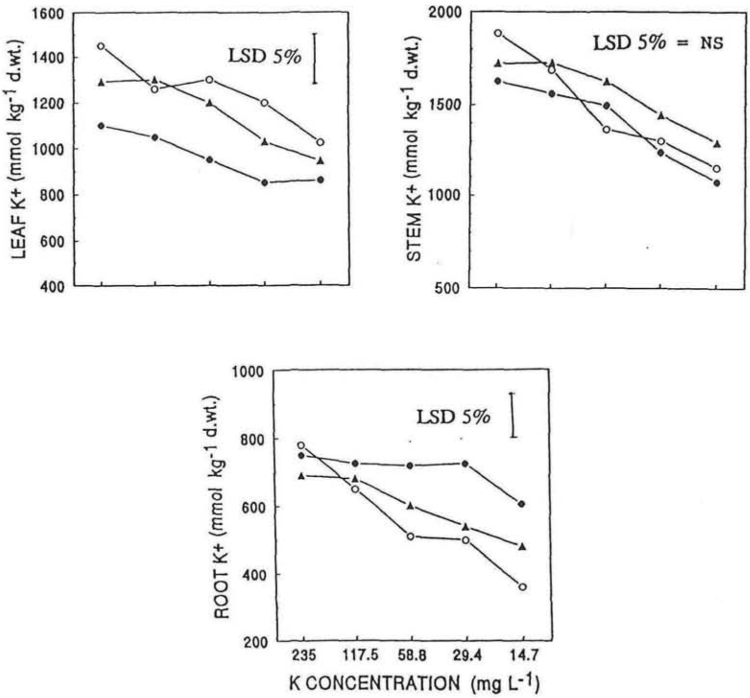

Fig. 2. K^+ concentrations in leaves, stems and roots of three lines of pearl millet when grown for four weeks in sand culture irrigated with Hoagland's nutrient solution containing varying concentrations of K. (Kitui local ●; Selection II ○; KAT/PM-2▲).

Table 2

Analysis of variance summaries (mean squares) of K^+ concentrations in leaves, stems and roots of three pearl millet lines when grown for four weeks in sand culture irrigated with Hoagland's nutrient solution containing varying concentrations of K.

Source of variation	df	Leaf K^+	Stem K^+	Root K^+
Blocks	3	18652.6 NS	31692.3 NS	6829.6 NS
Concentrations (C)	4	240638.7 ***	212814.7 ***	789127.7 ***
Lines (L)	2	219262.6 ***	39192.8 NS	723515.6 ***
C × L	8	92018.2 ***	36426.3 NS	34453.2 ***
Residual	42	20011.0	25764.5	5512.5

*** = significant at 0.001 level

NS = non-significant

1986), corn (Baligar & Barber 1970), and in soybean (Sale & Campbell 1986,1987). In addition to high shoot biomass production, Selection II maintained root growth under K-deficient regimes which would have improved its capacity for K acquisition under such conditions and contributed to its superior overall growth performance at low K concentrations of the growth medium. Similar results were observed in soybean cvs Braggs and Bossier (Sale & Campbell 1987).

A positive correlation was found between growth and K^+ uptake in leaves in all three lines. For instance the high biomass producing line Selection II was the highest in K^+ accumulation in the leaves under varying K-deficient regimes, whereas the low biomass producing line Kitui local had the lowest uptake of K^+ in the leaves of all lines. It is possible that high leaf K^+ content in Selection II contributed to its relatively vigorous growth under K-deficient conditions, since K^+ is one of the important major elements for plant growth (Marschner 1986, Salisbury & Ross 1992) and because it plays specifically important role in the synthesis of sugars, proteins and starch in plants (Mengel & Kirkby 1987).

Root K^+ was the lowest in Selection II and highest in Kitui local while the reverse was true for leaf K^+. It is clear that the roots of Selection II translocated a relatively large quantity of K^+ to the leaves compared with the other lines. By contrast, Kitui local retained the highest amount of K^+ in the roots but translocated relatively low amount into the leaves. A parallel situation has been observed in some salt tolerant species/lines whose leaves accumulated high levels of K^+, whereas their roots contained low amounts of K^+ compared with those of salt sensitive species/lines when subject to saline conditions (Greenway & Munns 1980). High concentrations of Na^+ in the rooting medium of plants have been reported to have an antagonistic effect on K^+ uptake (Lauchli & Epstein 1970, Jacoby & Ratner 1974, Greenway & Munns 1980).

The greater adaptability of Selection II to K deficiency compared with the other two lines may be due to the fact that this line was selected at very high selection pressure of salinity and using a very low concentration of K in the nutrient medium. Only 0.5 strength of Rorison nutrient solution (Hewitt 1966) was used which contained only 39 mg L^{-1} of K.

The considerable adaptation of Selection II to K deficiency is of potential value, for this line could be exploited for use in salt affected and drought-prone areas where K deficiency is prevalent.

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Recensiones

FRAHM Jan-Peter & FREY Wolfgang 1992. Moosflora. Mit 108 Abbildungen von J. DÖRING. 3., überarbeitete Auflage. – Uni-Taschenbücher 1250. - Kl. 8°, 528 Seiten; brosch. – Verlag Eugen Ulmer Stuttgart. – DM 39,80. – ISBN 3-8252-1250-5.

Der Nachfolgeband nach der beinahe legendären „Moosflora von Südwestdeutschland“ von Karl BERTSCH liegt nun schon in der dritten Auflage vor. Es sind nun die Moose der östlichen Bundesländer mitberücksichtigt, außerdem wurden Ergänzungen aufgenommen, Schlüssel verbessert und die Nomenklatur auf den neuen Stand gebracht. Diese Moosflora für Deutschland (für Horn-, Leber- und Laubmoose) ist nach Meinung der Autoren (im Vorwort) mit Ausnahme der Hochalpen auch für die angrenzenden Teile Mitteleuropas brauchbar. Der Aufbau des Werkes mit den bis zu den Arten führenden Bestimmungsschlüsseln und den Beschreibungen, denen Standorts- und Verbreitungsangaben folgen, ist inzwischen wohl so bekannt, daß darauf nicht näher eingegngen werden muß. Der Umfang hat sich seit der ersten Auflage [besprochen in Phyton 24 (2): 272] nicht geändert, außer daß ein fünf Seiten umfassender Anhang hinzugekommen ist, der notwendig gewordene Ergänzungen zu ca. 35 Arten enthält.

H. TEPPNER

SPETA Franz 1994. Leben und Werk von Ferdinand Schur [auf dem Umschlag: Ferd. Schur]. – In: Stapfia (Linz) 32, zugleich Kataloge des OÖ Landesmuseums, Neue Folge 75. – Lex. 8°, II + 334 Seiten, zahlreiche Abbildungen; kart. – Oberösterreichisches Landesmuseum, A-4010 Linz. – ATS 250.– + Porto. – ISBN 3-900746-68-0.

Der Band ist das Ergebnis jahrzehntelangen Interesses an Ferdinand SCHUR (geb. 1799 in Königsberg, gest. 1878 in Bielitz, Slowakei) und ist sichtlich mit Begeisterung und Emotion zusammengestellt. Neben den Lebensumständen und der wissenschaftlichen Tätigkeit vor dem Hintergrund seiner Zeit und seiner Fachkollegen gilt der Band, da SCHUR 1845–1854 in Siebenbürgen lebte und sein Hauptwerk dieses Gebiet betrifft, auch der Erforschung der Flora Siebenbürgens.

Im ersten Abschnitt (p. 9–109) wird das Leben SCHURS aufgrund von Briefen und anderen Originaldokumenten beleuchtet, wobei trotz einer Anzahl bereits exi-