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# Potassium Deficiency-Stress Tolerance in Wheat Genotypes I: Sand Culture Study

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## ABSTRACT

Wheat genotypes were evaluated for growth responses, K uptake and utilization efficiency in micaceous sand as a K source for the wheat genotypes. Johnson's solution modified to contain either zero or 3 mM K was used as basal growth medium. Potassium level and variety interaction was significant for almost all the parameters studied. Substantial differences were observed among genotypes for accumulation of shoot dry weight (SDW); root dry weight (RDW), total biomass and relative reduction in shoot biomass due to K deficiency stress (KSF). KSF ranged between 5 to 42% indicating more than 8 -fold differences in relative reduction in SDW due to KSF among the genotypes due to deficient K supply. Significant differences were also observed for K utilization efficiency (KUE) in these genotypes. KUE was almost doubled in genotypes grown with no external K supply (except sand) compared to those grown with 3.0 mM supply. Potassium concentration and uptake in genotypes remained unchanged at deficient K supply but differed at adequate K level.

**Key Words:** Wheat; Potassium; Sand culture

## INTRODUCTION

Balanced use of nutrients is essential for successful harvesting of crops on sustainable basis. The use of fertilizer has been mainly confined to the application of nitrogen and phosphorus, while ignoring potassium. This has been due to the general consensus that soils of Pakistan contain sufficient amounts of K due to the dominance of illite in their clay fraction (Ranjha *et al*., 1990). However, crops still respond to K fertilization (Malik *et al*., 1989). Although total soil K is quite high but its release fails to meet the immediate potassium requirement of crops (Tisdale *et al*., 1984).

During the last 50 years major, efforts have been concentrated on changing the soil environment to suit the crop, rather than to breed/select varieties better adapted to nutrient stress environments. This has been due partly to the compartmental nature of much agricultural research and the changing soil environment. Further, the breeder of any crop plant has to take so many factors into account, e.g. yield, disease resistance, growth habit, agronomic adaptability, etc. (Vose, 1963).

Despite large standing awareness of intra-specific variation for traits governing nutrient use efficiency, the possibility of exploiting genetic differences for the absorption and utilization of mineral nutrients has received much attention during the recent past (Saric, 1987). This endeavor is now especially important due to the pressing need for increasing food production, which can be furnished by expanding crop production on marginal lands. A considerable progress has been made in recent years in improving plants to grow and produce effectively on nutrient deficient soils.

Remarkable genetic differences in K-uptake and utilization efficiency in field crop cultivars have been reported by several scientists (Glass *et al*., 1981; Siddiqui & Glass, 1981; Gill *et al*., 1997). Selection and use of germplasm with the ability to grow under low K condition will enhance productivity in K deficient soils.

Solution culture provide a control of nutrient concentrations and the opportunity for total root system recovery, but does not simulate complex situations of soil root interfaces and nutrient diffusion limitations. Soil, as a realistic medium provides K buffering capacity and diffusion limited features for nutrients, but establishing and maintaining specific levels of plant nutrients and recovering intact root systems are difficult. The objective of this study was to provide a growth medium to these genotypes for K deficiency stress tolerance screening that incorporates processes of K availability, some what K buffering comparable to those in soils, reproduces the physical and chemical root environment of soil and permits total root recovery.

## MATERIALS AND METHODS

Nine genotypes (Table I) were grown in 40 cm long PVC pipes with an inner diameter of 5.0 cm. These pipes were filled with thoroughly washed 310 g coarse sand (obtained from micaceous sand stone) having 16 ppm water extractable K. The bottom of pipe was closed with a nylon cloth in order to support the filled sand. After germination, seedling was thinned to two plants pipe$^{-1}$. These pipes were placed in holes of 4 mm thick black plastic sheet, which was placed on plastic tubs. Half strength Johnson solution (Jhonson *et al*., 1957) modified to contain either zero or three mM K was used as a basal growth medium. Plants grown under zero K were supposed to meet their K requirement from sand. The treatment solution was supplied from the bottom so that solution dips 5 cm bottom portion of the pipes. Additionally 50 mL of the treatment solution was applied from the top to each pipe everyday. The experimental layout was completely randomized block design and the treatments were quadruplicated. Plants were harvested six weeks after germination, separated into shoot and root and washed with distilled water. Shoot and root dry weights were recorded after oven drying at 70°C for 48 hours. These harvested plants were ground to 40 mesh and wet ashed in di-acid mixture of $HNO_3$ : $HClO_4$ (3:1). Potassium in the digested samples was measured on flame photometer. Potassium stress factor (KSF) for genotypes was calculated as $\{(SDW_{adeq} - SDW_{def\ K})/ (SDW_{adeq})\}*100$. Potassium utilization efficiency (KUE) in genotypes was calculated as (1/K conc. in shoot mg $g^{-1}$) x SDW g/plant (Siddiqui & Glass, 1981).

## RESULTS AND DISCUSSION

The experiment was conducted in sand because it provides a well-aerated physical support and allows easy root recovery. Secondly, other essential nutrients and water can be supplied to plants by adding nutrient solution devoid of K. It was also desired to study plant responses to K in a medium that incorporated processes of K supply somewhat comparable to those in soil system and also allowing some reproducibility of the physical and chemical characteristics of natural root environment.

Nine wheat genotypes were evaluated for shoot and root growth characteristics and K uptake and utilization efficiency in micaceous sand as continuous K source for the wheat genotypes. Statistical analysis of data revealed a significant effect of K levels, genotypes and their interaction on SDW, RDW, R/S ratio, total biomass, K utilization efficiency, K concentration and K uptake (Table I & II). It is well documented that general plant health can be guessed on the basis of a number of growth parameters. Amongst different parameters, SDW is considered to be the most sensitive plant response parameter to nutrient deficiency and is given a pivotal place in screening experiments (Fageria *et al.*, 1988). It is, therefore, generally used as a selection criterion for evaluating genotype for nutrient efficiency at seedling stage. This study disclosed a considerable variation in SDW production among wheat genotypes at both K levels. Dirk produced more than 34% higher SDW compared to most other genotypes except Kohinoor-83 and Khyber-87, at low K level where sand was the only source of K. So, Dirk proved to be most K-efficient variety under these experimental conditions.

KSF reflects relative reduction in SDW of the genotypes due to K deficiency stress. It also indicates the responsiveness of the genotypes to adequate K supply. A higher positive value of KSF indicates higher response of a genotype to adequate K supply whereas, a negative or lower value shows no or little response to K supply. Wide variations for K stress factor was observed among genotypes and it ranged from 5 to 42%, indicating more than 8-fold difference among the genotypes in relative reduction in SDW due to deficient K supply (Table I). Dirk being the most efficient at deficient K supply showed high stress due to K deficiency because it is efficient but also responsive to K application.

All plants invest relatively more in their roots when grown under conditions of nutrient stress but the magnitude of response is species and nutrient dependent (Brouwer, 1983). Potassium deficiency is not known to affect root growth (Drew, 1975) but it has been recently reported that K significantly promoted adventitious rooting in dicots. Contrary to Drew's observation, RDW of wheat genotypes increased 22% with adequate K supply compared to deficient K level (Table I). However, differences among the genotypes for RDW were significantly only in deficient K treatment. Root/shoot ratio was significantly affected by K levels, genotypes and their interaction (Table I). It increased in genotypes grown with

**Table I. Shoot and root dry weight, potassium stress factor and root/shoot ratio of wheat genotypes grown at deficient and adequate K levels**

| VARIETIES | SDW (g 3plants$^{-1}$) | | KSF (%) | RDW (g 3plants$^{-1}$) | | Root/Shoot Ratio | |
|---|---|---|---|---|---|---|---|
| | Def. K | Adeq. K | | Def. K | Adeq. K | Def. K | Adeq. K |
| Khyber 79 | 2.19 ab | 2.40 c | 5 b | 1.51 bcd | 2.07 NS | 0.70 cd | 0.90 a |
| Punjab 81 | 1.86 bc | 2.70 c | 31 a | 1.44 bcd | 1.94 | 0.76 cd | 0.72 ab |
| Kohinoor 83 | 2.13 b | 2.35 c | 6 b | 2.00 ab | 1.63 | 0.96 bc | 0.70 ab |
| Rawal 87 | 1.58 c | 2.55 c | 38a | 1.88 abc | 2.19 | 1.22 ab | 0.87 ab |
| Yecora | 1.59 c | 2.67 c | 41 a | 1.29 cd | 1.65 | 0.79 cd | 0.62 bc |
| Zarghoon 79 | 1.71 c | 3.04 b | 42 a | 2.21 a | 2.20 | 1.29 a | 0.73 ab |
| Maxi Pak | 1.61 c | 2.46 c | 34 a | 1.57 a-d | 2.04 | 0.98 bc | 0.83 ab |
| Inqlab 91 | 1.60c | 2.48 c | 35 a | 1.10 d | 1.72 | 0.68 cd | 0.70 ab |
| Dirk | 2.50 a | 3.71 a | 33 a | 1.33 bcd | 1.99 | 0.53 d | 0.54 a |
| Mean | 1.86 B | 2.71 A | 29 | 1.59 B | 1.94 A | 0.92 A | 0.73 B |

Mean with different letter(s) differ significantly according to Duncan's Multiple Range Test (P=0.05) adequate compared to deficient K supply. Potassium concentration of shoot indicates the efficiency of plants to take up K from K deficient growth medium and uptake is the total amount of K that is actually taken up by plant in producing SDW at a particular stage of growth (Ashraf *et al*., 1997). Potassium concentration and uptake (Table II) differed due to K treatments. However, the differences among the genotypes were significant only in 3.0 mM K treatment. Wheat genotypes grown with 3.0 mM K had about 3-fold and 5-fold higher K concentration and uptake, respectively compared to those where sand was the only source of K. The highest K uptake at deficient K level was observed in Dirk while the lowest in Maxipak and Inqulab-91. As against generally reported positive correlation between root and shoot dry weight of the genotypes (Mian *et al*., 1993) and RDW and K uptake (Caradus, 1990) surprisingly no correlation between SDW and RDW (r = 0.187) and potassium uptake by shoot and RDW (r = 0.273) was observed in the experiment. This unexpected behavior of the genotypes is not understood. Although the diameter of the sand filled pipes was smaller (5 cm), both root and shoot did not show any adverse effect of restriction of the rooting volume (smaller pot size) as reported by Marschner (1995).

At the root-soil interface one important determinant of nutrient efficiency is the capacity for absorption of nutrient from soil solution. It varies extensively among and within crop species (Vose, 1963; Lauchli, 1976). Second component of efficiency is the effectiveness with which the absorbed nutrient is subsequently utilized by plant. Siddiqi and Glass (1981) expressed the efficiency in terms of yield per unit of tissue concentration rather than yield per unit content and referred it as utilization efficiency. Clarkson and Henson (1980) suggested that under conditions of nutrient scarcity, plant can either adjust its growth rate to make it compatible with nutrient supply or it can develop efficient internal nutrient economy, which may result from efficient redistribution within the plant and/or lowering requirement of that particular nutrient at functional sites. Differences in KUE among the genotypes were significant in both K treatments. With deficient K supply the highest KUE was observed in Dirk (Table II) whereas the lowest KUE was observed in Rawal-87 that had highest K concentration in shoot (Table II) while the lowest SDW at low K level. Potassium utilization efficiency was almost doubled in genotypes grown with no external K supply compared to those grown with 3.0 mM external K supply.

This study clearly showed that wheat genotypes differed considerably in terms of their growth response, K uptake and utilization efficiency under different K treatment. Dirk proved to be the most efficient and K responsive genotype amongst the nine wheat genotypes tested in this study. A significant positive correlation ($r = 0.68^*$, n = 9) between the shoot dry weight in this experiment and grain yield of the genotype grown in soil in the companion study (Mahmood, *et al*., 2001 this issue) suggested that sand can be used as a growth medium for initial screening of wheat genotypes against tolerance to K deficiency stress.

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**Table II. Potassium utilization efficiency, potassium concentration and its uptake in shoot of wheat genotypes grown at def. K and adeq. K levels**

| VARIETIES | KUE ($g^2$ SDW $mg^{-1}$ K) | | K Conc. ($mg\ g^{-1}$) | | K Uptake (mg) | |
|---|---|---|---|---|---|---|
| | Def. K | Adeq. K | Def. K | Adeq. K | Def. K | Adeq. K |
| Khyber 79 | 0.27 a | 0.07 b | 8.50 NS | 32.33 b | 18.71 NS | 78.25 b |
| Punjab 81 | 0.24 ab | 0.10 ab | 8.17 | 27.17 d | 15.12 | 73.22 b |
| Kohinoor 83 | 0.22 bc | 0.08 b | 10.00 | 29.67 bcd | 21.39 | 69.33 b |
| Rawal 87 | 0.16 d | 0.09 b | 10.67 | 29.17 bcd | 17.07 | 74.37 b |
| Yecora | 0.18 cd | 0.09 b | 9.17 | 29.50 bcd | 14.64 | 79.09 b |
| Zarghoon 79 | 0.19 cd | 0.09 b | 9.33 | 36.00 a | 16.09 | 109.50 a |
| Maxi Pak | 0.19 cd | 0.08 b | 8.67 | 29.33 cd | 13.84 | 71.80 b |
| Inqlab 91 | 0.19 cd | 0.08 b | 8.67 | 31.67 bc | 13.88 | 78.53 b |
| Dirk | 0.27 a | 0.13 a | 9.50 | 28.67 cde | 23.66 | 106.20 a |
| Mean | 0.21 A | 0.09 B | 9.19 A | 30.39 B | 17.15 B | 82.25 A |

Mean with different letter(s) differ significantly according to Duncan's Multiple Range Test (P=0.05)

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