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Wheat Varietal Behavior in Hydroponic and Soil Culture Under Saline Conditions

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Abstract

The experiment was conducted to compare two systems (hydroponic and soil culture). Seven wheat varieties differing in salt tolerance were grown under saline conditions (100 mol m^{-3} NaCl) in these two systems. Ion contents (Na^+, K^+, Cl^-, Ca^{2+} and Mg^{2+}) in the fourth leaf were not correlated with ion contents in the flag leaf. There were few significant correlation coefficients between ion contents and grain weight per plant. Which suggests that ion contents in leaf sap may not be good indicators of salt tolerance in wheat. Linear correlation coefficients for grain yield, most of yield components and ion contents of seven wheat varieties between hydroponic and soil culture were non-significant. These results suggest that hydroponic culture system is independent from soil culture system.

Keywords: Wheat, salinity, hydroponic culture, soil culture

Introduction

Most studies of the effects of salinity on the physiology (Gorham *et al*., 1984) and yield of crop have been conducted using solution culture techniques (Ashraf and McNeilly, 1988) as they allow control over the amount and types of salt present and thereby facilitate comparative evaluations of speces and varieties. They also avoid potential confounding effects of salinity on soil structure. Hydroponic culture medium tend to be acid to facilitate availability and uptake of trace elements, especially iron, whereas most soils are more pH neutral and in many salt affected areas of the world, they are alkaline. Electrical Conductivity (EC) in solution culture is relatively constant, Whereas in soil it fluctuates temporally due to rain fall, temperature, irrigation and spatially due to variations in soil properties. Therefore if breeding and selection is to be done in solution culture there is a need to know that performance in this system correlates with the performance in soil culture. Very few studies have been conducted to investigate this. Storey (1995) reported that rates of net K^+, Na^+ and Cl^- uptake and transport of two genotypes of lime were substantially higher when grown in solution culture than when grown in sand culture. We have been unable to find any studies in the scientific literature comparing the ion uptake and yield of a range of contrasting wheat varieties under hydroponic and soil salinity.

Salt tolerant wheat varieties have lower Na^+ and Cl^- contents and higher K^+/Na^+ ratio than salt susceptible ones (Wyn-Jones, 1981; Sastry and Prakash, 1993). However in most studies ion contents have been measured in leaves formed early in development and hence often during vegetative growth. Although, most of the carbohydrate in the grain is derived from photosynthesis by the flag leaf (Thorne, 1982). Hence a second objective of the experiment was to study the correlation between ion contents in fourth and flag leaves, and between these ion contents and yield using varieties known to differ in salt tolerance.

Materials and Methods

The experiment tested seven wheat varieties grown in two systems (Hydroponics and soil culture). The varieties included two salt tolerant (SARC-111 and LU26S) and two salt sensitive (Blue sliver and Bhawalpur-73) from Pakistan; a salt tolerant Indian Landrace (Kharchia-65) and a selection (KRL1-4) with increased salt tolerance derived from it (supplied by Dr. S. Quarrie, Cambridge Laboratory, Norwich, UK.) and a Dutch variety (Alexandria) of unknown tolerance. The experiment was conducted in a glass-house and supplementary lighting was used. Average temperature during the growth period was 25.9°C (maximum 37.8°C and minimum 14°C). Seeds of the seven wheat varieties were germinated on capillary matting in growth-room set at 18°C.

Seedlings were transplanted at two leaf stage into each system in pots $21\times21\times23$ cm on 23-6-1994. Each pot contained sixteen plants in a 4×4 grid with plant-to-plant and row-to-row distances of 4 cm. There were three replicate pots of each variety in each system. A completely randomized design was used. In the hydroponic culture system, a modified Long Ashton Nutrient solution (Hewitt, 1966) was used in combination with Phostrogen (0̇.5 g L^{-1}, Phostrogen Ltd., Corwen, Clwyd, UK.) to supply macro and micro nutrients (Gorham *et al*., 1984). Salt stress was introduced in three increments over a period of 5 days, starting 6 days after transplanting. For the soil culture system (clay loam soil) was taken from a commercially cultivated fertile field that had been in a rotation of cereals and grass. It was sieved using 2 mm sieve to remove stones and placed in the pots. To create saline conditions two litres of 100 mol m^{-3} NaCl solution was applied twice a week to each pot.

To minitor salinity in the soil culture system three extra soil pots were prepared and watered in the same way as the experimental pots. Samples were taken regularly from these pots, usually before and one day after applying the saline water. Soil sample were air dried and the electrical conductivity (EC_e) was determined using the method of Talsma (1968) and Loveday *et al*. (1972). On occasion when the soil was found dry and EC_e was higher than 12 dS m^{-1}, one liter water per pot was applied to decrease the EC_e. The maximum EC_H recorded during the growth period was 18.3 dS m^{-1} and the average EC_e was 11.1 dS m^{-1}. The EC in the hydroponic culture was 10 dS m^{-1}.

The fully expended fourth and the flag leaves were sampled from two randomly selected plants per variety per pot. The leaves were rinsed quickly in distilled water and blotted dry with tissue paper. The samples were placed in Eppendorf tubes and stored in freezer set at -10°C. Cell sap was extracted by using the method of Gorham *et al*. (1984) and diluted with distilled water for the estimation of cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) using an atomic absorption spectrophotometer. Chlorides were measured with an ion selective electrode (Microprocessor lonalyzer/901).

The remaining plants (12 per pot) were harvested at maturity and main tiller height (cm), straw weight per plant (g), number of infertile and fertile spikelets per spike were recorded. Threshing was done by hand, number of grains per plant and grain weight per plant (g) were determined. Statistical analysis were performed by using the Minitab, SYSTAT statistical packages. Analyses of variance (ANOVA) were used to assess significant differences ($p < 0.05$) between means of the wheat varieties. Linear correlation coefficients were computed among ion contents, yield and yield components.

Results and Discussion

The results of the experiment provided clear evidence that the performance of the varieties was affected by the system under which plants were raised. In the analysis of variance the variety × system interaction was significant for grain weight per plant (Table 1).

Table 1: Effects of variety x growing system on grain weight per plant in hydroponics and soil culture under saline conditions.

Varieties	Grain weight per plant (g)	
	Hydroponic culture	Soil culture
SARC-III	0.107	1.25
KRL1 -4	0.163	1.12
Alexandria	0.033	0.46
LU26S	0.020	1.07
Bhawalpur-73	0.067	0.38
Kharchia -65	0.183	1.10
Blue Silver	0.067	1.33
LSD	0.25**	

** = $p < 0.01$.

Grain weight per plant was significantly positively correlated with number of grain per plant in both systems. Number of grain weight per plant was also positively correlated with number of fertile spikelets per spike in hydroponic culture, but not in soil culture. There was negative correlation found between grain weight per plant and straw dry weight per plant in soil culture. There were very few linear correlation coefficients between ion contents and grain weight per plant. Mg^{2+} content were found to be significantly correlated with grain weight per plant in flag leaf in both systems. Grain weight per plant was positively correlated with K^+ content and K^+/Na^+ ratio, and negatively correlated with Na^+ and Cl^- contents in the fourth leaf, but not in the flag leaf in soil culture. system. None of these linear correlation coefficients were significant in the flag leaf (except in the case of K^+ content) in hydroponic culture (Table 2).

There were very few significant correlation coefficients between ion contents in the fourth and flag leaves and non that were significant in both systems. Ion contents in the fourth leaf was correlated with ion contents in the flag leaf only in case of K^+/Na^+ ratio in soil culture and Na^+ in hydroponic culture (Table 3). Ion contents in the fourth leaf were not correlated with ion contents in the flag leaf. Although the flag leaf is the most important contributing source of carbohydrate in grains (Thorne, 1982). In addition, the linear correlation coefficients between ion contents and grain weight per plant were significant only in case of the data for the fourth leaf in solution culture. These results cause doubt on the use of leaf ion contents as an indicator of salt tolerance. Similar results for wheat have been reported by Ashraf and McNeilly (1988) and they proposed that whole plant performance can be useful for assessment of salt tolerance. In contrast Salam *et al*. (1992) reported highly significant negative correlation coefficients between Na^+, Cl^- and yield in wheat. They also reported high positive correlation coefficients between K^+/Na^+ ratio and yield. However, further experiments are required to establish the reasons why these apparently contrasting results have been found. Different research workers (Greenway and Munns, 1980; Kuiper *et al*., 1988; Weimberg and Shannon, 1988; Roy, 1991; Sastry and Prakash, 1993; Cramer *et al*., 1994) have suggested the use of different agronomic and physiological traits when screening crop plants for salt tolerance.

The linear correlation coefficients for Na^+, K^+, Cl^- and Mg^{2+} contents of the seven wheat varieties between hydroponic and soil culture were found to be non significant except fourth leaf Ca^{2+} ($r = 0.874^*$) and flag leaf K^+/Na^+ ratio ($r = 0.933^{**}$). The linear correlation coefficients for grain weight per plant and most of yield components of the seven wheat varieties between hydroponic and soil culture were also found to be non significant, except straw weight per plant ($r = 0.829^*$) and number of infertile spikelets per spike ($r = 0.932^{**}$) (Table 4). Although linear correlation coefficients for straw weight per plant and number of infertile spikelets per spike were found significant and highly significant respectively, but they are not directly related to yield. However, it is concluded from the results that performance of genotypes in hydroponic culture is not correlated with the performance of genotypes in soil culture under saline conditions. Therefore, screening of genotypes for salt tolerance in hydroponic culture might be less useful.

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Table 2: Linear correlation coefficients between grain weight per plant and ion contents (mol m^{-3}), K^+/Na^+ ratio in the fourth and flag leaves and various yield components of seven wheat varieties grown under saline conditions in hydroponics and soil culture systems.

Traits	Grain weight per plant (g)			
	Hydroponic culture		Soil culture	
Ion contents	Fourth leaf	Flag leaf	Fourth leaf	Flag leaf
Na^+	-0.319^{NS}	-0.412^{NS}	-0.512*	-0.149^{NS}
K^+	0.230^{NS}	-0.032^{NS}	0.504*	0.444*
K^+/Na^+	0.229^{NS}	0.177^{NS}	0.502*	0.392^{NS}
Cl^-	-0.281^{NS}	0.104^{NS}	-0.717**	-0.075^{NS}
Ca^{2+}	-0.109^{NS}	0.093^{NS}	0.367^{NS}	0.503*
Mg^{2+}	0.365^{NS}	0.582*	0.039^{NS}	0.690*
Yield components	Hydroponic culture		Soil culture	
Main tiller height (cm)	0.737*		0.107^{NS}	
Straw weight per plant (g)	0.014^{NS}		-0.534*	
Infertile spikelets per spike	$-0.1\ 96^{NS}$		-0.252^{NS}	
Fertile spikelets per spike	0.564**		-0.249^{NS}	
Number of grains per plant	0.937**		0.626**	

NS = non-significant , * = significant, * = highly significant.

Table 3: Linear correlation coefficients between Na^+, K^+, Cl^-, Ca^{2+}, Mg^{2+} contents (mol m^{-3}) and K^+/Na^+ ratio in the fourth and flag leaves (data of seven wheat varieties from the soil and hydroponic culture systems) under saline conditions.

	Soil culture	Hydroponic culture
Fourth leaf	Flag leaf	Flag leaf
Na^+	0.421^{NS}	0.650**
K^+	0.131^{NS}	-0.258^{NS}
K^+/Na^+	0.204^{NS}	0.269^{NS}
Cl^-	0.524^{*}	0.416^{NS}
Ca^{2+}	0.154^{NS}	-0.198^{NS}
Mg^{2+}	0.106^{NS}	0.261^{NS}

NS = non-significant, * = significant, ** = highly significant.

Table 4: Linear correlation coefficients between the values of ion contents (mol m^{-3}), K^+/Na^+ ratio in the fourth and flag leaves and agronomic traits of seven wheat varieties recorded in hydroponic and soil culture systems.

Ion contents	Fourth leaf	Flag leaf	Agronomic traits	
Na^+	0.549^{NS}	0.753^{NS}	Grain weight per plant (g)	0.397^{NS}
K^+	0.365^{NS}	0.754^{NS}	Main tiller height (cm)	0.205^{NS}
K^+/Na^+	0.563^{NS}	0.933**	Straw weight per plant (g)	0.829*
Cl^-	0.650^{NS}	0.141^{NS}	Infertile spikelets per spike	0.932**
Ca^{2+}	0.874*	0.100^{NS}	Fertile spikelets per spike	0.447^{NS}
Mg^{2+}	0.654^{N5}	0.657^{NS}	Number of grains per plant	0.572^{NS}

NS = non-significant , significant, *" = highly significant.

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