Research Article

Comparison of Soil and Hydroponic Based Screening Process to Select Salt Tolerant Wheat Varieties

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Abstract | Increase in temperature, rainfall fluctuations and poor quality water under present climatic conditions has drastic effect on plant physiology and growth. The current research experiment was performed to screen salt tolerant wheat varieties grown in hydroponic and soil medium on the basis of plant photosynthetic rate, potassium (K^+) and sodium (Na^+) contents. Twenty wheat genotypes/varieties were grown in hydroponic culture, having different residual sodium carbonate (RSC), electrical conductivity (EC), and sodium adsorption ratio (SAR). A substantial decrease in plant photosynthetic rate, and potassium contents were noted in all varieties under salt stress. Varieties i.e. V07096 and V05082 showed higher rate of photosynthesis and potassium contents than V05003 and V07194. The salt-tolerant and salt-sensitive genotypes, V07096 and V05003, respectively were then grown in soil medium. Lower plant sodium contents in soil medium were also observed in V07096 variety under salt stress treatments than V05003. Salt tolerant variety also showed higher potassium contents and photosynthetic rate in salt stress soil medium. Thus plant Na^+, K^+ contents, and photosynthetic rate in soil and hydroponic medium can be used as standards to screen salt -tolerant varieties.

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Keywords | Hydroponic, Soil medium, Plant photosynthetic rate, Na^+ and K^+

Introduction

Irrigating the crops with saline-sodic water accumulates salt contents in soil, which decreases plant growth. Various environmental factors like drought, air pollution and climate change limit the crop production and quality all over the world (IPCC, 2014; Sadiq et al., 2019). Lack of better quality water for irrigation is an important factor that limits crop plant development in several underdeveloped countries. Ever-increasing demand for food security issue is forcing progressive farmers and private sectors to get more land area under crop cultivation. Internationally, almost fifty percent of food stuff necessities will be enhanced in 2050, owing to the growing community (Rengasamy, 2006). In the existing situation, good land area has previously in farming, and the predictable aim can be achieved both by extension in cultivated area, or increasing yield of the presently cultivated area. Globally, brackish water and soil salinity are the main problems that deteriorate the cultivated land. Developing crop genotypes/varieties that tolerate salinity is the best technique to handle this problem (Munns, 2005; Ma et al., 2012). Slow progress in developing wheat varieties/cultivars tolerant to salinity may be owing to complicatedness in screening massive number of genotypes on naturally salt affected soil. Similarly, due to different salt types, salt contents in soil and lack of understanding for the selection of traits that truly represents salinity tolerance. Furthermore, it is reported that most crops give different reactions against salinity-sodicity stresses on various developmental stages. As a result, plant showed tolerant response at one growth period may perhaps be sensitive on other growth phase (Ashraf et al., 2010). Therefore, in most plant genus the extent of salinity/ sodicity tolerance observed on one growth period can or cannot be experienced on other growth phase. At different developmental growth phases, wheat crop reaction to salinity stress is described to be erratic. Early plant growth phases showed higher response to salt stress than later/mature (Munns et al., 2006). Previously most of the experiments were conducted in hydroponic culture, pots, and field conditions to select salt-tolerant wheat varieties/ genotypes. Definitely, there are substantial variances between the crop plants grown in soil and hydroponic culture. For example, in soil culture studies, the cation exchange process affects nutrients uptake by changing the cation and anion exchange. Conversely, the crop plants have to overcome the osmotic stress of the solution in hydroponic culture. Therefore, it is essential to clarify the salt tolerant responses of wheat plants in soil and hydroponic mediums. However, several experiments have depicted the effect of salinity stresses on wheat plants at dissimilar growth phases. There is limited information in the literature about a comparison in the changes of physiology, vegetative growth, sodium and potassium ions accumulations in the same wheat variety/genotype grown-up under saline environments in hydroponic and soil medium. And secondly to study the relationship of plant photosynthetic and transpiration rate with plant Na^+ and K^+ accumulation in the two growth mediums.

Materials and Methods

Hydroponic culture experiment

Seeds were sown in sand for germination. When seedling/plant growth reached 2-3 leaves, transferred into holes of thermoplastic sheets floating on 200 liters of size iron tubs. These tubs were lined with polyethylene sheets. Nutrients were added in the solution by following the standard method (Hoagland, 1950). Salt stress was given after seven days of seedling transplant. Electric pump was used to provide air in solution culture. Salinity levels in solution were developed according to (Abid, 2002; Majeed, 2015). A full extended second plant leaf from every one replicate was used to examine physiological parameters like transpiration (E) and photosynthetic rate (A). These physiological parameters were noted with moveable infrared gas analyzer (Abbasi et al., 2015). Each physiological parameter was recorded at noontime, while daylight intensity was full (Majeed et al., 2016; Kanwal et al., 2011). After one month, wheat plants were harvested from each treatment. Leaf juice extracted according to (Gorham et al., 1984) and analyzed for sodium (Na^+) and potassium (K^+) contents by using Jenway, PFP-7 Flame photometer.

Soil culture experiment

One salt- sensitive (V05003) and one salt-tolerant (V07096) wheat variety/cultivar were selected from first hydroponic culture experiment. Eight grains of each genotype/variety were grown in pots/lysimeters (75cm heigh×30 cm diameter) to compare the results of soil medium with hydroponic. Sandy clay loam soil used for filling of pots/lysimeters. The recommended rate of fertilizers, i.e. N (120), P (90) and K (60) kg ha^{-1} were added in soil of each pot/lysimeter. Water salinity levels like hydroponic experiment were prepared to irrigate the crop sown in pots/lysimeters. The ionic characteristics of the plant (K^+ and Na^+ contents) were determined with the use of flame photometer. Photosynthesis and transpiration rates of the plants measured with IRGA in both wheat genotypes/varieties (Abassi et al., 2015; Majeed, 2015).

Statistical design

Completely randomized design (CRD) was used with factorial arrangement. Data of all parameters were analyzed using the Statistics 8.1 software. Least significant difference (LSD) technique was used for comparison of treatments mean (Steel and Torrie, 1997).

Results and Discussion

Substantial variations were recorded in potassium and sodium ions in the plant leaf of salt sensitive and tolerant cultivars/varieties under treatments T_2 and

Table 1: *K^+ and Na^+ contents in normal and salt stress hydroponic culture.*

	K^+ Contents (mol m^{-3})			Na^+ Contents (mol m^{-3})		
Wheat Varieties/genotypes	T_1	T_2	T_3	T_1	T_2	T_3
Faisalabad-2008	172 ± 2.0	132 ± 3.0	112 ± 1.1	25 ± 0.5	60 ± 1.4	94 ± 3.3
Sahar2006	175 ± 2.5	129 ± 0.6	109 ± 1.4	26 ± 0.6	63 ± 1.4	103 ± 1.2
V07096	178 ± 1.5	139 ± 1.2	130 ± 1.5	24 ± 0.8	52 ± 1.4	76 ± 1.1
V07102	171 ± 1.5	126 ± 1.1	101 ± 1.1	25 ± 1.2	70 ± 1.4	121 ± 1.2
V04022	174 ± 1.4	123 ± 1.2	98 ± 1.2	26 ± 0.5	74 ± 0.8	127 ± 1.5
V08173	172 ± 1.5	122 ± 1.6	97 ± 1.6	26 ± 1.2	75 ± 0.5	130 ± 1.1
V07032	180 ± 2.0	121 ± 1.4	96 ± 1.4	31 ± 0.2	83 ± 1.2	136 ± 1.2
V07663	182 ± 2.0	124 ± 1.7	99 ± 1.7	30 ± 1.3	80 ± 1.4	133 ± 1.3
SARC 7	176 ± 0.8	142 ± 2.6	137 ± 0.8	24 ± 0.8	46 ± 1.7	64 ± 1.4
V06096	184 ± 2.0	126 ± 1.4	95 ± 1.7	29 ± 1.2	74 ± 0.5	127 ± 1.5
V08164	182 ± 1.4	127 ± 1.2	99 ± 1.8	31 ± 0.6	79 ± 1.2	133 ± 1.7
V08171	186 ± 2.0	121 ± 1.7	94 ± 1.2	30 ± 0.8	84 ± 1.1	140 ± 1.0
V03094	185 ± 1.7	125 ± 1.5	96 ± 2.5	28 ± 1.1	77 ± 1.4	132 ± 0.9
V05082	183 ± 1.7	137 ± 0.8	126 ± 1.2	25 ± 0.8	58 ± 1.7	81 ± 1.7
V08158	183 ± 2.3	147 ± 2.6	122 ± 2.6	32 ± 0.8	81 ± 2.4	136 ± 1.4
SARC 1	181 ± 2.0	145 ± 4.3	139 ± 0.8	27 ± 0.6	43 ± 1.4	62 ± 1.1
V07194	184 ± 2.6	116 ± 0.8	90 ± 0.8	31 ± 1.8	88 ± 0.8	143 ± 1.7
V05003	183 ± 1.7	115 ± 1.1	88 ± 0.8	32 ± 0.5	95 ± 0.6	155 ± 0.8
V07076	186 ± 2.6	118 ± 1.2	91 ± 0.5	30 ± 0.8	93 ± 0.8	147 ± 1.7
Pasban 90	179 ± 1.7	141 ± 1.7	135 ± 1.2	26 ± 0.5	49 ± 1.0	68 ± 1.5

T_1: Control; T_2: EC (Electrical Conductivity) 2.0 dS m^{-1}; SAR (Sodium Absorption Ratio) 15.0 (m mol $L^{-1})^{1/2}$ and RSC (Residual Sodium Carbonate) 2.25 m molc L^{-1} and T_3: EC (Electrical Conductivity) 4.0 dS m^{-1}; SAR (Sodium Absorption Ratio) 25.0 (m mol $L^{-1})^{1/2}$ and RSC (Residual Sodium Carbonate) 5.0 m molc L^{-1}.

T_3 in both hydroponic and soil medium compared to control treatment (T_1). Minimum sodium contents in plant leaf was recorded in SARC 1, Pasban-90, V07096 and V05082, while the highest in V05003 and V07194 cultivars in T_2 and T_3 salinity levels in hydroponic culture (Table 1). In T_2 and T_3 treatments, salt- tolerant wheat cultivars/genotypes had greater K^+ uptake as compared to salt- sensitive cultivar. Under saline sodic conditions the salt tolerant maize varieties/genotypes accumulated minimum Na^+ than salt sensitive (Abasi et al., 2015; Majeed et al., 2014). Similarly, in soil medium under treatments T_2 and T_3, the salt-tolerant V07096 cultivar accumulated less Na^+ than salt sensitive V05003 (Table 3). The results showed that response of sensitive and tolerant genotypes/varieties also differed significantly within a soil medium. Stunted growth and lower photosynthetic rate were observed in T_2 and T_3 treatments due to higher sodium contents of plant as compared to T_1 in both hydroponic (Table 2) and soil culture methods (Table 3). Higher sodium contents uptake in plant disturbed the leaf osmotic potential and causes the damage to plant cells (Hussain et al., 2011). Escalating accumulation of sodium ion in plant caused the reduction in potassium contents that caused in a decline of K^+: Na^+. Higher sodium concentration affects K^+ ion entry into plant cell (Saqib et al., 2006). Plant photosynthetic and transpiration rates decreased in treatments T_2 and T_3 due to higher

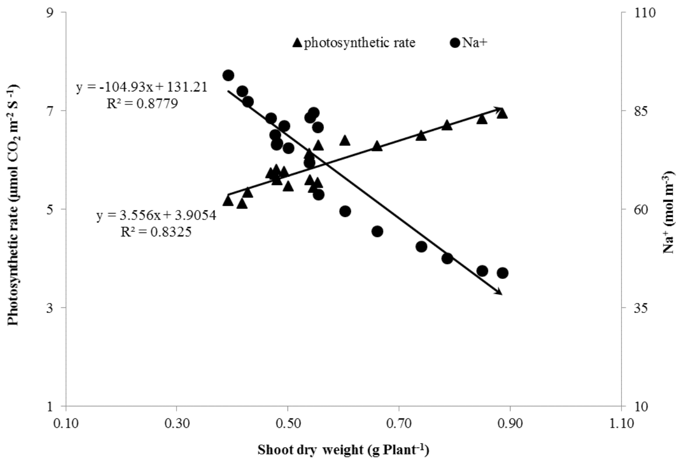

Figure 1: *Correlation of plant sodium content and photosynthetic rate with shoot dry weight.*

Table 2: *Transpiration and photosynthetic rate in normal and salt stress hydroponic culture.*

	Transpiration rate (mmol H_2O m^{-2} S^{-1})			Photosynthetic rate (µmol CO_2 m^{-2} S^{-1})		
Wheat Varieties/genotypes	T_1	T_2	T_3	T_1	T_2	T_3
Faisalabad-2008	3.7± 0.13	2.3 ± 0.20	1.9 ± 0.08	9.6 ± 0.88	6.2 ± 0.78	3.3 ± 0.17
Sahar2006	3.8 ± 0.17	2.1 ± 0.17	1.8 ± 0.27	10.0 ± 0.58	5.7 ± 0.20	3.1 ± 0.18
V07096	3.9 ± 0.60	2.5 ± 0.18	2.2 ± 0.22	9.0 ± 0.52	6.6 ± 0.33	3.8 ± 0.17
V07102	4.0 ± 0.26	2.1 ± 0.18	1.6 ± 0.23	10.4 ± 0.33	5.1 ± 0.44	2.8 ± 0.17
V04022	4.1 ± 0.10	1.6 ± 0.24	1.5 ± 0.22	10.0 ± 0.58	4.3 ± 0.33	2.1 ± 0.20
V08173	3.9 ± 0.07	1.7 ± 0.14	1.1 ± 0.14	10.2 ± 0.69	4.6 ± 0.33	1.8 ± 0.06
V07032	4.2 ± 0.42	1.7 ± 0.30	1.1 ± 0.13	10.1 ± 0.69	4.6 ± 0.33	1.9 ± 0.03
V07663	3.8 ± 0.13	1.8 ± 0.24	1.2 ± 0.13	9.7 ± 0.63	5.0 ± 0.58	1.9 ± 0.10
SARC 7	3.8 ± 0.42	3.2 ± 0.18	2.9 ± 0.07	10.0 ± 0.58	6.3 ± 0.31	4.1 ± 0.17
V06096	3.6 ± 0.33	1.7 ± 0.24	1.3 ± 0.14	10.2 ± 0.51	5.0 ± 0.58	2.2 ± 0.21
V08164	3.8 ± 0.17	1.3 ± 0.25	1.1 ± 0.19	10.3 ± 0.33	5.0 ± 0.17	1.9 ± 0.15
V08171	3.6 ± 0.33	1.7 ± 0.23	1.3 ± 0.15	10.0 ± 0.58	4.3 ± 0.19	1.9 ± 0.07
V03094	3.8 ± 0.13	2.4 ± 0.23	1.7 ± 0.13	9.7 ± 0.41	5.2 ± 0.37	2.1 ± 0.20
V05082	3.8 ± 0.44	3.0 ± 0.20	2.4 ± 0.22	9.4 ± 0.29	5.9 ± 0.36	3.5 ± 0.29
V08158	3.9 ± 0.26	1.8 ± 0.22	1.3 ± 0.09	10.3 ± 0.40	5.0 ± 0.58	1.9 ± 0.07
SARC 1	3.6 ± 0.33	3.0 ± 0.10	2.6 ± 0.19	9.6 ± 0.33	6.7 ± 0.29	4.5 ± 0.29
V07194	4.2 ± 0.23	1.5 ± 0.15	1.0 ± 0.21	10.2 ± 0.51	4.3 ± 0.33	1.4 ± 0.09
V05003	4.1 ± 0.32	1.6 ± 0.34	0.7 ± 0.08	10.6 ± 0.33	3.6 ± 0.33	1.2 ± 0.06
V07076	4.1 ± 0.17	1.6 ± 0.19	0.8 ± 0.12	10.0 ± 0.58	4.0 ± 0.53	1.3 ± 0.09
Pasban 90	3.8 ± 0.44	2.7 ± 0.13	2.5 ± 0.19	10.1 ± 0.59	6.2 ± 0.57	3.8 ± 0.17

T_1: Control; T_2: EC (Electrical Conductivity) 2.0 dS m^{-1}; SAR (Sodium Absorption Ratio) 15.0 (m mol L^{-1})$^{1/2}$ and RSC (Residual Sodium Carbonate) 2.25 m molc L^{-1} and T_3: EC (Electrical Conductivity) 4.0 dS m^{-1}; SAR (Sodium Absorption Ratio) 25.0 (m mol L^{-1})$^{1/2}$ and RSC (Residual Sodium Carbonate) 5.0 m molc L^{-1}.

Table 3: *Plant K^+, Na^+, photosynthetic and transpiration rates in normal and salt stress under soil medium.*

Treatments	K^+ Contents (mol m^{-3})		Na^+ Contents (mol m^{-3})		Photosynthetic rate (µmol CO_2 m^{-2} S^{-1})		Transpiration rate (mmol H_2O m^{-2} S^{-1})	
	Cultivars/Varieties		Cultivars/Varieties		Cultivars/Varieties		Cultivars/Varieties	
	V07096	V05003	V07096	V05003	V07096	V05003	V07096	V05003
T_1	394 ± 3.08	371 ± 1.71	46 ± 1.44	52 ± 2.5	8.31 ± 0.16	7.19 ± 0.03	1.72 ± 0.01	1.65 ± 0.02
T_2	303 ± 1.48	241 ± 2.96	90 ± 1.43	117 ± 2.51	4.18 ± 0.04	3.45 ± 0.03	1.15 ± 0.02	1.06 ± 0.05
T_3	204 ± 2.26	156 ± 2.95	123 ± 1.44	160 ± 1.45	3.25 ± 0.06	2.61 ± 0.04	1.05 ± 0.04	0.89 ± 0.01

T_1: Control; T_2: EC (Electrical Conductivity) 2.0 dS m^{-1}; SAR (Sodium Absorption Ratio) 15.0 (m mol L^{-1})$^{1/2}$ and RSC (Residual Sodium Carbonate) 2.25 m molc L^{-1} and T_3: EC (Electrical Conductivity) 4.0 dS m^{-1}; SAR (Sodium Absorption Ratio) 25.0 (m mol L^{-1})$^{1/2}$ and RSC (Residual Sodium Carbonate) 5.0 m molc L^{-1}.

accumulation of sodium than T_1 under soil and hydroponic medium. Negative correlation observed between plant sodium contents and photosynthetic rate (Figure 1). Sodium ion toxicity caused damage to cell membrane, reduction in potassium uptake, plant development and photosynthetic rate (Abbasi et al., 2015; Majeed et al., 2016). Decrease in rate of photosynthesis activity of plants against salt stress takes place due to stomata closing (Shahbaz et al., 2011). Salt tolerant variety/genotype V07096 showed higher plant growth by sustaining superior photosynthetic activity and transpiration rate in salt stress treatments due to lower sodium uptake in contrast to V05003 variety/genotype. Salt -tolerant maize genotypes sustained superior photosynthetic activity and transpiration rate in contrast to salt-sensitive against salinity (Abbasi et al., 2015; Majeed et al., 2016). Salinity development in soil causes inadequate accessibility to nutrient present in soil medium and a smaller amount of water absorption through plant roots for photosynthetic activity and metabolic process that results in lower rate of transpiration, photosynthesis and affects cells division (Munns et al., 2005; Ashraf et al., 2008).

Conclusions and Recommendations

Salt-tolerant varieties/genotypes showed greater salt tolerance response both in hydroponic and soil medium as compared to salt-sensitive variety. Negative correlation observed between the plant photosynthetic rate and Na^+ uptake. Plant sodium, potassium, and photosynthetic rate can be used as standards to determine genotypic differences among different varieties against salt tolerance both in hydroponic and soil medium.

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Novelty Statement

Plant sodium, potassium contents, and photosynthetic rate can be used as screening criteria to determine genotypic differences against salt tolerance both in hydroponic and soil medium.

Author's Contribution

Abdul Majeed: Planned the study, conducted the ep-eriments and wrote the manuscript.
Muhammad Anwar-ul-Haq: Helped in writing the manuscript.
Abid Niaz: Analyzed the plant samples.
Abid Mahmood: Helped in reviewingthe literature to write methodolgy.
Naeem Ahmad: Helped in statistical analysis.
Hafiz Muhammad Walyat Ali Khan: Edited and proofread the article.

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