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Effect of Salts Stress on the Growth and Yield of Wheat (*Triticum aestivum* L.)

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Abstract

In order to study the effect of salts stress on the growth and yield of wheat (cv. Inqalab), a pot experiment was conducted in the wire-house of the Department of Soil Science, Sindh Agriculture University Tando Jam. The soil was artificially salinized to a range of salinity levels *i.e.* EC 2.16, 4.0, 6.0, 8.0 and 10.0 dS·m^{-1} with different salts ($MgCl_2$ + $CaCl_2$ + Na_2SO_4). The salinized soil used for the experiment was sandy clay in texture, alkaline in reaction (pH > 7.0) and moderate in organic matter (0.95%) content. The results showed that with increasing salinity there was an increase in the ECe, Na^+, Ca^{2+}, Mg^{2+} and Cl^- and decrease in the K^+, SAR and ESP values of the soil Increasing salinity, progressively decreased plant height, spike length, number of spikelets spike^{-1} 1000 grain weight and yield (straw and grain). Adverse effects of salts on plants were associated with the accumulation of less K^+ and more Na^+ and Cl^- in their flag leaf sap, grains and straw. This resulted in lower K^+:5Na^+ ratio in flag leaf sap, grains and straw of wheat plants. These results indicated that the effects of salts stress were greater at 10 than at 8, 6 and 4 EC dS·m^{-1}.

Keywords

Salinity, Tolerance, Effect, Yield, Wheat

1. Introduction

Wheat (*Triticum aestivum* L.) is an important cereal crop of the world. It is one of the staple foods for more than one third of the world population. Wheat played a vital role in the development of civilization. The king of cereals wheat is the principal source of food and is extensively grown, consumed and preferred in Pakistan. It contains approximately 60% - 80% protein, 2% - 2.5% glucose, 1.5% - 2% fat and 2% - 3% mineral matter [1]. However, these may vary in proportion from variety to variety and locality to locality. Wheat crop is cultivated in all provinces of Pakistan as a bumper winter crop. The average yield of wheat in Pakistan is about 23888 $kg \cdot ha^{-1}$ which is comparatively very low to the other wheat growing countries of the world. The factors behind the low yield include poor fertility status of soil, less and imbalance use of fertilizers, unawareness and utilization of modern technology by the farmers, environment and climatic condition of the area, deficiency of macro and micronutrients and availability of required irrigation water at proper time [2].

Besides the above factors, soil salinity is the major problem, which affects the yield of this important crop. It is commonly observed in arid and semi-arid regions of the world [3]. It is considered as a serious soil problem of Pakistan. About 6.3 m ha land is affected by salinity. Whereas in Sindh 2.3 m ha land is affected by different types of salts, mostly slats of chlorides and sulfates of sodium, calcium and magnesium [4]. The soil which contains inorganic salts, also supplies necessary nutrients to the plant but when the concentration of these salts reaches such a level that is harmful for plant growth [5].

Excess amount of salts in the soil affects plant from germination to harvesting [6]. It may affect the plants in two ways: a) by decreasing the rate of water entry in to plants, b) promoting the entry of toxic ions [7]. Generally, salinity problem increase with increasing salt concentration in irrigation water. Crop growth reduction due to salinity is generally related to the osmotic potential of the root-zone soil solution. This will lead to certain physiological changes and substantial reduction in crop production [8]. Plants in salt stress condition require a tight nutrition dose to maintain their normal physiology and to face the condition were they locate. In these circumstances they require a balanced nutrition of both macro and micronutrient elements to boost up their growth and development. Generally macronutrients N, P, K are supplied extensively but micronutrients are often ignored. However, their essentiality cannot be neglected for better crop yield especially under tough conditions.

The relative salt tolerance of wheat crop is 7.0 $dS \cdot m^{-1}$ and its yield decrease is 25% at 9.0 $dS \cdot m^{-1}$ [9]. The reduction in growth and yield varies between cultivars and salt concentrations of the medium [10]. The recently developed cultivars form a much diversed genetic base and may therefore possess a wider range of salts stress tolerance. Keeping in view the above facts, this study was planned to see the growth and yield response of Inqalab wheat variety to salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress.

2. Materials and Methods

In order to assess the effect of salts stress on the growth and yield of wheat variety Inqabab, a pot experiment was conducted in the wire-house of the Department of Soil Science, Sindh Agriculture University Tando Jam. The following methodology was adopted.

2.1. Experimental Design

Fertile soil (plough layer) was collected from the arable land of latif Experimental Farm of Sindh Agriculture University, Tando Jam. The soil was air dried ground and passed through 4 mm garden sieve. The air dried soil was placed in plastic containers with drainage holes in bottom. The 9 kg pots were arranged on wooden benches in RCBD with three replications.

2.2. Seed Sowing, Fertilizer and Irrigation

Seeds of wheat variety Inqalab were at 4 cm plant to plant distance. Few days after emergence, 7 seedlings were allowed to grow in each pot up to maturity. In order to reduce losses by evapotranspiration, the pots were regularly irrigated by normal irrigation water. The recommended does of NPK was applied in the form of NPK (10:23:15) and urea (46%N) to each pot. Nitrogen was applied at the rate 136 kg N ha^{-1} in the form of NPK and urea in three splits, first at the time of sowing, second at the 1^{st} irrigation and the remaining at the 2^{nd} irrigation. Phosphorus and K were applied at the rate 67 kg $P_2O_5^-$ ha^{-1} and 44 kg K_2O ha^{-1} in the form of NPK at the time of sowing.

2.3. Preparation of Saline Soil

Different saline soil treatments were prepared artificially by mixing different salts. The quantity of different salts ($MgCl_2$, $CaCl_2$ and Na_2SO_4) required for the preparation of saline soil treatments was calculated using the method described by Rowell [11]. The salinity levels developed for the experiment were:

T1 (control) 2.16 ($dS \cdot m^{-1}$) (Non-saline);
T2 ($MgCl_2 + CaCl_2 + Na_2SO_4$) 4.0 ($dS \cdot m^{-1}$) (Saline);
T3 ($MgCl_2 + CaCl_2 + Na_2SO_4$) 6.0 ($dS \cdot m^{-1}$) (Slightly saline);
T4 ($MgCl_2 + CaCl_2 + Na_2SO_4$) 8.0 ($dS \cdot m^{-1}$) (Moderately saline);
T5 ($MgCl_2 + CaCl_2 + Na_2SO_4$) 10 ($dS \cdot m^{-1}$) (Highly saline).

2.4. Agronomic Observations

Following agronomic observations were recorded:

- Plant height (cm),
- Spike length (cm),
- Number of spikelet's $spiket^{-1}$,
- Straw dry weight ($mg \cdot plant^{-1}$),
- Grain yield ($mg \cdot plant^{-1}$),
- 1000 grain weight (g).

2.5. Plant Analysis

2.5.1. Flag Leaf Sampling, Sap Extraction and Chemical Analysis

The flag leaf of three plants from each replication of all the treatments was detached, placed in Eppendorf tubes and stored in a freezer at −10˚C. The lamina of the flag leaves were removed and the sap was extracted and analyzed for Na^+, K^+ using the method of Gorham [12]. K^+/Na^+ ratio was also determined by using the values of K^+ and Na^+ (Table 1).

2.5.2. Preparation of Straw and Grain Samples for Chemical Analysis

Straw and grain samples from all the replications of each treatment were prepared for analysis of Na^+, K^+, Ca^{2+} and Mag^{2+}.

2.6. Soil Analysis

The soil samples were collected before sowing from each treatment. Samples were prepared and analyzed for soil texture, pH, ECe ($dS{\cdot}m^{-1}$), O.M%, cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) and anions (CO_3^{2-}, HCO_3^- and Cl^-), Soil samples were also collected after harvest of the crop for the analysis of above properties with the exception of OM% and soil texture (Table 2).

2.7. Calculations

Sodium adsorption ratio (SAR), exchangeable sodium ratio (ESR) and exchangeable sodium percentage (ESP) were calculated using the following formula suggested by Rowell [11].

- Sodium Adsorption Ratio (SAR) $= (Na^+)/(Ca^2 + Mg^{2+})1/2$,
- Exchangeable Sodium Ratio (ESR) $= -0.013 + 0.05\ SAR$,
- Exchangeable Sodium Percentage (ESP) $= 100\ ESR/(1 + ESR)$.

2.8. Statistical Analysis

All plant data were analysed by performing ONEWAY-ANOVA using Minitab-12 statistical package. Standard Error for Different between Means (S.E.D) was calculated using the following formula: $SED = (2EMS/n)^1/2$Least Significant Different (LS.D.) = S.E.D × edf t value at 5% probability level.

3. Results and Discussion

3.1. Soil Properties

Physico-chemical properties of soil before sowing and after harvesting of wheat crop

Table 1. Plant analysis.

S. No.	Determinations	Method Used	Equipment used	References
1	Extraction of flag Leaf sap for Na^+ and K^+ analysis	Centrifuge method	Eppendorf Tubes	Gorham [13]
2	Preparation and Analysis of straw for Na^+ and K^+	Acid wet digestion	EEL-flame photometer	Rowell [11]
3	Preparation and Analysis of straw and grain samples for Cl^-	Dry ash method	Muffle Furnace	Methods Manuals Soils [14]

Table 2. Soil analysis.

S. No.	Determinations	Method adopted	Equipment used	References
1	Soil texture	Bouyoucos Hydrometer	Hydrometer	Kanwar and chopra [15]
2	ECe ($dS \cdot m^{-1}$)	1:2 soil water Extract	Digital EC Meter	Rowell [11]
3	pH	1:2 soil water Extract	Digital pH Meter	Rowell [11]
4	O.M. (%)	Walkley Black Method No.9 Titration with 0.5 N Ferrous Solution	Burette	Jackson [16]
5	Soluble Na^+ and K^+	Method No. 10 and 11	EEL-flame Photometer	Handbook-60 USSL [17]
6	Soluble Ca^{2+} and Mg^{2+}	Method No. 7 Titration with EDTA solution (soil and plant (samples)	Burette	Hand book-60 USSL [17]
7	CO_3^{2-} and HCO_3^-	Method No. 12 Titration with Standard H_2SO_4 Solution (soil and plant samples)	Burette	Hand book-60 USSL [17]
8	Cl^-	Method No. 13 Titration with Standard $AgNO_3$ Solution (soil and plant samples)	Burette	Hand book-60 USSL [17]

are summarized in Table 3 and Table 4. the chemical properties of soil before sowing and after harvesting of wheat crop showed ECe, pH soluble cations and anions, SAE and ESP values were typical of that an agricultural soils of Sindh. However, when the same soil was treated with different proportions of $MgCl_2$, $CaCl_2$ and Na_2SO_4 salts that showed an increase in ECe and very small decrease in SAR and ESP. The pH of treated soil was alkaline in reaction before sowing and it decreased slightly in all treatments after harvest of the crop. With increasing concentrations of salts there was rise in Na^+, Ca^{2+}, Mg^{2+} and Cl^- in all soil treatments. During the course of the experiment pH and soil salinity in almost all treatments (T2 = 5.91, T4 = 9.2 and T5 = 10.3 $dS \cdot m^{-1}$) decreased slightly possibly due to leaching and uptake of soluble salts by the plants.

3.2. Effects of Salts Stress on Plant Growth and Yield

3.2.1. Plant Height (cm) at Flag Leaf Stage

The effect of salts stress on plant height is shown in Table 4 plant height recorded at flag leaf stage was significantly ($P < 0.05$ (decreased by increasing salinity. Plants grown in all salt treatments were significantly ($P < 0.05$) shorter than in the control soil treatment. Increasing salinity decreased the plant height. There was larger decrease in plant height at high salinity (EC 10 $dS \cdot m^{-1}$) levels.

3.2.2. Spike Length (cm)

The effect of salts stress on spike length is shown in Table 5 the plants grown in saline soil treatments had significantly ($P < 0.05$) shorter spikes than the plants grown in the control soil treatment. Increasing salinity significantly ($P < 0.05$) decreased the length of spikes. These decreases were greater at high salinity (EC 10 $dS \cdot m^{-1}$) level than at low (EC 6 $dS \cdot m^{-1}$) and medium (EC 8 $dS \cdot m^{-1}$) salinity levels.

Table 3. Physicochemical properties of soil before sowing.

S#	Name	Results
1	Carbonate	Absent in all samples
2	Soil organic Matter	0.95%
3	Soil Textural Class	Silty Clay Loam

Table 4. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on plant height (cm) recorded at flag stage.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	Plant height (cm)	Per cent Decrease over Control
Control (2.16)	Non-saline	52.53	-
4.00	Saline	46.10	12.45
6.00	Slightly saline	45.43	13.52
8.00	Moderately saline	43.20	17.61
10.00	Highly saline	41.97	20.11
S. E. D.		2.6798	
L. S. D.		1.2028***	

***Highly significant.

Table 5. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on spike length (cm).

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	Spike length (cm)	Per cent Decrease over Control
Control (2.16)	Non-saline	13.767	-
4.00	Saline	11.667	15.24
6.00	Slightly saline	11.533	16.23
8.00	Moderately saline	10.800	21.55
10.00	Highly saline	10.500	23.73
S. E. D.		0.3949	
L. S. D.		0.8798***	

***Highly significant.

3.2.3. Number of Spikelets Spike^{-1}

The effect of salts stress on number of spikelets spike^{-1} is shown in Table 6. The number of spikelets spike^{-1} was significantly ($P < 0.05$) decreased by increasing salinity level The Plants grown in saline soil treatments had significantly lower number of spikelets spike^{-1} than the plants grown in the control soil treatment. Increasing salinity had decreasing effect on the number of spikelets spike^{-1}. The larger decrease in number of spikelets spike^{-1} was recorde on the plants grown at high EC (EC 10 $dS \cdot m^{-1}$) than at low (EC 6 $dS \cdot m^{-1}$) and medium EC (EC 8 $dS \cdot m^{-1}$) levels.

3.2.4. Straw Yield ($Mg \cdot Plant^{-1}$)

The effect of salts on straw yield is shown in Table 7. Increasing salts stress significantly ($P < 0.05$) decreased the straw yield of wheat. The plants grown in saline soil treatments

Table 6. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) Stress on number of spikelets spike^{-1}.

Salinity Levels EC (dS·m^{-1})	Classification	Spikelets spike^{-1}	Percent Decrease over Control
Control (2.16)	Non-saline	10.533	-
4.00	Saline	9.633	8.54
6.00	Slightly saline	9.033	14.24
8.00	Moderately saline	8.733	17.09
10.00	Highly saline	8.367	20.56
S. E. D.		0.2118	
L. S. D.		0.4718***	

***Highly significant.

Table 7. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on straw yield (mg·plant^{-1}).

Salinity levels EC (dS·m^{-1})	Classification	Straw yield (mg) spike^{-1}	Per cent Decrease over Control
Control (2.16)	Non-saline	1051.8	-
4.00	Saline	910.2	13.46
6.00	Slightly saline	861.5	18.10
8.00	Moderately saline	854.5	18.74
10.00	Highly saline	839.2	20.22
S. E. D.		59.4587	
L. S. D.		132.4741*	

*Non-significant.

produced significantly lower straw yield than in the control. Increasing salinity decreased the straw yield. The decrease in straw yield was greater at high EC (EC 10 dS·m^{-1}) than at low (EC 6 dS·m^{-1}) and medium EC (EC 8 dS·m^{-1}) levels.

3.2.5 Grain Yield (Mg·Plant^{-1})

The effect of salts stress on grain yield is shown in Table 8. The results revealed that grain yield (mg·plant^{-1}) decreased significantly ($P < 0.05$) with increasing salts concentration. The plants grown in salt treatments had significantly lower grain yield than in the control soil treatment. Increasing salinity also decreased grain yield per plant. Compared to the low (EC 6 dS·m^{-1}) and medium (EC 8 dS·m^{-1}) level, grain yield obtained from high salinity (EC 10 dS·m^{-1}) level remained significantly lower.

3.2.6. 1000 Grain Weight (g)

The effect of salts stress on 1000 grain weight is shown in Table 9. The results revealed that 1000 grain weight decreased significantly ($P < 0.05$) with the progressive increase in salts stress. The plants grown in saline soil treatments had significantly lighter grains than in the plants grown in the control soil treatment. The effect of increasing salinity on 1000-

Table 8. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on grain yield ($mg\cdot plant^{-1}$).

Salinity levels EC ($dS\cdot m^{-1}$)	Classification	Grain yield (mg) ($spike^{-1}$)	Percent Decrease over Control
Control (2.16)	Non-saline	480.40	-
4.00	Saline	355.83	25.94
6.00	Slightly saline	231.46	51.82
8.00	Moderately saline	219.31	54.25
10.00	Highly saline	162.31	66.52
S. E. D.		40.1995	
L. S. D.		89.5645***	

***Highly significant.

Table 9. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on 1000 grain weight (g).

Salinity levels EC ($dS\cdot m^{-1}$)	Classification	1000 grain Weight (g)	Percent Decrease over Control
Control (2.16)	Non-saline	357.10	-
4.00	Saline	228.10	36.16
6.00	Slightly saline	149.07	58.26
8.00	Moderately saline	130.60	63.43
10.00	Highly saline	108.57	69.60
S. E. D.		33.89	
L. S. D.		75.51***	

***Highly significant.

grain weight was decreasing. These grain were significantly lighter in weight at low (EC 6 $dS\cdot m^{-1}$), medium (EC 8 $dS\cdot m^{-1}$) and very high at high salinity (EC 10 $dS\cdot m^{-1}$) levels.

3.3. Plant Analysis

3.3.1. Na^+, K^+, and K^+/Na^+ Ratio in Flag Leaf Sap of Wheat

The effect of salts stress on Na^+, K^+, and K^+/Na^+ ratio in flag leaf sap of wheat is presented in Tables 10-12. The effect of increasing soil salinity was to increase Na^+ and decrease K^+ concentration in the flag leaf sap. This was resulted in lower K^+/Na^+ ratio. The increase in Na^+ and decrease in K^+ were more marked in the flag leaf sap of the plants grown in high salinity treatment than in the control and other sol treatments.

3.3.2. Na^+, K^+, Cl^- and K^+/ Na^+ Ratio in Grains of Wheat

The effect of salts mixture on ion concentration in the grains of wheat is shown in Tables 13-16. Salinity significantly increased Cl^- and Na^+ but decreased K^+ and K^+/ Na^+ ratio contents in the grains at all salinity levels. Plants grown at moderate and high salinity levels had significantly higher Cl^- and Na^+ but lower K^+/Na^+ ratio than the plants grown at the control and low salinity level.

Table 10. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on Na^+ (%) in flag leaf sap of wheat.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	Na^+ (%)	Per cent Decrease over Control
Control (2.16)	Non-saline	0.28333	-
4.00	Saline	0.34333	21.18
6.00	Slightly saline	0.41000	44.70
8.00	Moderately saline	0.45333	60.00
10.00	Highly saline	0.53667	89.41
S. E. D.			0.0313
L. S. D.			0.0697***

***Highly significant.

Table 11. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on K^+ (%) in flag leaf sap of wheat.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	K^+ (%)	Per cent Decrease over Control
Control (2.16)	Non-saline	0.7333	-
4.00	Saline	0.6500	11.36
6.00	Slightly saline	0.4733	35.46
8.00	Moderately saline	0.4133	43.64
10.00	Highly saline	0.3533	51.83
S. E. D.			0.1192
L. S. D.			0.2655*

*Non-significant.

Table 12. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on K^+/Na^+ in flag leaf sap of wheat.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	K^+/Na^+	Per cent Decrease over Control
Control (2.16)	Non-saline	2.6167	-
4.00	Saline	1.8700	28.54
6.00	Slightly saline	1.1667	55.42
8.00	Moderately saline	0.9300	64.46
10.00	Highly saline	0.6600	74.78
S. E. D.			0.3286
L. S. D.			0.7322**

**Significant.

3.3.3. Na^+, K^+, Cl^- and K^+/Na^+ Ratio in Wheat Straw

The effects of different salinity levels on ion concentrations in the straw are shown in the Tables 17-20. Salinity significantly ($P < 0.05$) increased the toxic ions (Na^+ and Cl^-) and decreased the concentration of K^+ and K^+/Na^+ ratio in the straw at all levels. At high salinity level plants accumulated more Na^+ and Cl^- but less K^+ and hence they ex habited lower K^+/Na^+ in their straw.

Table 13. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on Na^+ (%) in grain of wheat.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	Na^+ (%)	Per cent Increase over Control
Control (2.16)	Non-saline	0.3733	-
4.00	Saline	0.5033	34.82
6.00	Slightly saline	0.7033	88.40
8.00	Moderately saline	0.9033	141.97
10.00	Highly saline	1.1100	197.34
S. E. D.		0.0549	
L. S. D.		0.1223***	

***Highly significant.

Table 14. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on K^+ (%) in grains of wheat.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	K^+ (%)	Per cent Decrease over Control
Control (2.16)	Non-saline	0.35333	-
4.00	Saline	0.25667	27.36
6.00	Slightly saline	0.22000	37.74
8.00	Moderately saline	0.16333	35.78
10.00	Highly saline	0.11667	66.98
S. E. D.		0.0300	
L. S. D.		0.0668***	

***Highly significant.

Table 15. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on K^+/Na^+ in grains of wheat.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	K^+/Na^+	Per cent Decrease over Control
Control (2.16)	Non-saline	0.9440	-
4.00	Saline	0.5092	46.07
6.00	Slightly saline	0.3114	67.01
8.00	Moderately saline	0.1821	80.71
10.00	Highly saline	0.1038	89.01
S. E. D.		0.0489	
L. S. D.		0.1089***	

***Highly significant.

3.3.4. Ca^{2+} and Mg^{2+} Content in Grains and Wheat Straw

The effect of salts stress on Ca^{2+} and Mg^{2+} contents in grains and straw of wheat are shown in the Tables 21-24. The results indicated that with the increasing concentration of soluble salts in soil (Table 1, Table 2) the concentration of Ca^2 and Mg^{2+} increased both in grains and straw of wheat. Plants in high salinity treatments accumulated more Ca^{2+} and Mg^{2+} than in other soil treatments.

The soil used in this experiment was sandy clay with 37.5% clay and 0.95% organic matter. When this soil was treated with salts it showed properties typical to those of saline soils of Sindh (Ghafoor, 2004).

Table 16. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on Cl^- (meq 100 g^{-1}) in grains of wheat.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	Cl^- (meq 100 g^{-1})	Per cent Increase over Control
Control (2.16)	Non-saline	50.00	-
4.00	Saline	81.67	63.36
6.00	Slightly saline	92.33	84.66
8.00	Moderately saline	102.33	104.66
10.00	Highly saline	115.67	131.34
S. E. D.		**13.9044**	
L. S. D.		**30.9790*****	

***Highly significant.

Table 17. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on Na^+ (%) in wheat straw.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	Na^+ (%)	Per cent Increase over Control
Control (2.16)	Non-saline	0.4900	-
4.00	Saline	0.6733	37.40
6.00	Slightly saline	0.7700	57.14
8.00	Moderately saline	1.1333	131.28
10.00	Highly saline	1.3833	182.30
S. E. D.		**0.0848**	
L. S. D.		**0.1891*****	

***Highly significant.

Table 18. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on K^+ (%) in wheat straw.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	K^+ (%)	Per cent Decrease over Control
Control (2.16)	Non-saline	1.7000	-
4.00	Saline	1.2333	8.14
6.00	Slightly saline	1.1467	20.46
8.00	Moderately saline	1.0700	29.46
10.00	Highly saline	0.9267	32.53
S. E. D.		**0.0870**	
L. S. D.		**0.1951*****	

***Highly significant.

The results obtained in this experiment showed that salinity had adverse effects on almost all growth and yield parameters. The effects of high salinity on soot height (Table 3), spike length (Table 4), number of spilelets spike^{-1} (Table 5), straw yield (Table 6), grain yield (Table 7) and 1000 grain weight (Table 8) were greater than low and medium salinity. The plants grown at high salinity level were 20.56% smaller in height, produced 23.73% smaller spikes, showed 20.56% fewer spikelets. High salinity

Table 19. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on K^+/Na^+ in wheat straw.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	K^+/Na^+	Per cent Decrease over Control
Control (2.16)	Non-saline	3.0874	-
4.00	Saline	2.1039	31.86
6.00	Slightly saline	1.5828	48.73
8.00	Moderately saline	0.9622	68.83
10.00	Highly saline	0.7410	76.00
S. E. D.		**0.3435**	
L. S. D.		**0.7653*****	

***Highly significant.

Table 20. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on Cl^- (meq 100 g^{-1}) in wheat straw.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	Cl^- (meq 100 g^{-1})	Per cent Increase over Control
Control (2.16)	Non-saline	75.00	-
4.00	Saline	91.33	21.77
6.00	Slightly saline	113.00	50.66
8.00	Moderately saline	125.67	67.56
10.00	Highly saline	131.00	74.66
S. E. D.		**7.8951**	
L. S. D.		**17.5903*****	

***Highly significant.

Table 21. Effect of salts ($MgCl_2 + CaCl_2 + Na_2SO_4$) stress on Ca^{2+} (%) in grains of wheat.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	Ca^{2+} (%)	Per cent Increase over Control
Control (2.16)	Non-saline	0.8333	-
4.00	Saline	1.0733	28.80
6.00	Slightly saline	1.1100	33.21
8.00	Moderately saline	1.1433	37.20
10.00	Highly saline	1.1833	42.00
S. E. D.		**0.0816**	
L. S. D.		**0.1818***	

*Non-significant.

decreased straw yield by 20.22%, grain yield by 66.52% other workers [18] [19] [20] [21] have also pointed out that the yield of wheat crop decreased significantly with increasing salinity levels. The decrease in grain yield under highly saline soil treatments was due to the fewer tillers, lighter grains. It has also been reported by others workers

Table 22. Effect of salts ($MgCl_2$ + $CaCl_2$ + Na_2SO_4) stress on Mg^{2+} (%) in grains of wheat.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	Mg^{2+} (%)	Per cent Increase over Control
Control (2.16)	Non-saline	1.2867	-
4.00	Saline	1.4267	10.88
6.00	Slightly saline	1.5600	21.24
8.00	Moderately saline	1.6667	29.53
10.00	Highly saline	1.8167	41.19
S. E. D.		**0.0423**	
L. S. D.		**0.0944*****	

***Highly significant.

Table 23. Effect of salts ($MgCl_2$ + $CaCl_2$ + Na_2SO_4) stress on Ca^{2+} (%) in wheat straw.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	Ca^{2+} (%)	Per cent Increase over Control
Control (2.16)	Non-saline	0.9733	-
4.00	Saline	1.1067	13.71
6.00	Slightly saline	1.1600	19.18
8.00	Moderately saline	1.2400	27.40
10.00	Highly saline	1.2933	32.88
S. E. D.		**0.1194**	
L. S. D.		**NS**	

Table 24. Effect of salts ($MgCl_2$ + $CaCl_2$ + Na_2SO_4) stress on Mg^{2+} (%) in wheat straw.

Salinity levels EC ($dS \cdot m^{-1}$)	Classification	Mg^{2+} (%)	Per cent Increase over Control
Control (2.16)	Non-saline	1.2933	-
4.00	Saline	1.9667	52.07
6.00	Slightly saline	2.3300	80.16
8.00	Moderately saline	2.5200	94.85
10.00	Highly saline	2.9100	125.00
S. E. D.		**0.3521**	
L. S. D.		**0.7846***	

*Non-significant.

[20] that decreased tillering is the main cause for lower crop yield in salt-affected soils of arid and semi arid regions.

The greater effects of salinity on plants were associated with larger effects on ions (**Tables 9-23**). As was expected, the effects of salinity on plants was to increase Na^+, Cl^-, Ca^{2+} and Mg^{2+} and decrease K^+ and K^+/Na^+ ratio compared to control plants. The increase in Na^+, Cl^-, Ca^{2+} and Mg^{2+} contents may be attributed to the increase amount of sodium, calcium and magnesium in soil solution due to the addition of salts ($MgCl_2$ + $CaCl_2$ + Na_2S0_4) when soils were prepared. Similar effects of salinity on wheat plants for ions content have been reported by many workers [22] [23] [24] [25] [26].

4. Conclusions

A pot experiment was conducted in the wire-house of the department of Soil Science, Sindh Agriculture University Tando Jam to see the effects of salts stress on the growth and yield of wheat (Cv. Inqalab).

The soil used in the experiment was clay loam in texture, alkaline in reaction (pH > 7.0), moderate in organic matter (0.95%). The soil was artificially salinized to different salinity levels *i.e.* ECe 2.16, 4.0, 6.0, 8.0 and 10.0 $dS \cdot m^{-1}$ with different salts ($MgCl_2$ + $CaCl_2$ + Na_2SO_4). The plant data were subjected to statistical analysis.

Following key points have been observed during this study.

1) Increasing salinity increased the ECe, Na^+ Ca^{2+}, Mg^{2+} and Cl^- content and decreased the K^+, SAR and ESP values in the soil.

2) Increasing salinity significantly decreased plant height, spike length, number of spikelets $Spike^{-1}$, 1000 grain weight, and straw and grain yields $plant^{-1}$. Increasing salinity significantly increased Na^+ concentration but decreased K^+ concentration and K^+/Na^+ ratio in the flag leaf sap.

3) Increasing salinity increased Na^+, Ca^{2+}, Mg^{2+} and Cl^- content while decreased K^+ and K^+/Na^+ ratio in straw and grains.

4) Effect of salts ($MgCl_2$ + $CaCl_2$ + Na_2SO_4) stress on almost all parameters was significant.

It was concluded from the present study that salts stress ($MgCl_2$ + $CaCl_2$ + Na_2SO_4) adversely affects the growth and yield of cultivar Inqalab. Due to the osmotic and ionic toxicity effects, its yield immediately decreased as salinity level increased.

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