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SALINITY TOLERANCE COMPONENTS AND RESPONSE OF IRANIAN WHEAT CULTIVARS TO NaCl STRESS

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ABSTRACT

Introduction and target: Salinity stress is a major constraint inhibiting yield of crops throughout the world. Salinity tolerance in crops can be categorized to three main mechanism including osmotic tolerance, ion exclusion and tissue tolerance. method: In this experiment, we try to quantification of these traits to increase salinity tolerance in future wheat genotypes. Selected cultivars for this aim named: Akbari, Sistan, Arg, Ofogh as salinity tolerant and Kohdasht and Morvarid as local cultivated wheat and finally Falat and Roshan as old and successful cultivars in last decades. The seeds planted in pots with sandy medium and irrigated with saline (150 mM NaCl) and nonsaline Modified Hoagland solutions. The growth rate reduction after salt application was used for calculation of osmotic tolerance. Na+ exclusion mechanism was quantified by measuring of the concentration of Na+ in leaves which exposed by salinity. Combination of Na+ content in salt stressed plants and measuring of salt induced leaf senescence was used to estimate tissue tolerance. Findings: Results showed that Ofogh and Roshan cultivars were best excluders than others. The strategy of osmotic tolerance considered as the best mechanism for all of experimental cultivars, and there were a little difference among them. Tissue tolerance was less effective in predicted total salinity tolerance and the cultivars of Morvarid, KohDasht and Falat were the best cultivars in this trait. Conclusion: It appears that cultivars with two tolerance mechanism either osmotic tolerance with Na+ exclusion (such as Ofogh and Roshan) or tissue tolerance with osmotic tolerance (such as Morvarid and KohDasht) have higher total salinity tolerance.

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KEY WORDS

Stress salinity stress, wheat, ion exclusion, osmotic tolerance, tissue tolerance.

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INTRODUCTION

Salinity is a major environmental stress responsible for reduced crop yield in many of the agricultural lands in all over the world. It's estimated that salinity is affecting 45 million hectares of irrigated lands [1] and it is expected that over 800 million hectares will be affected by salinity problem due to unsuitable irrigation practice and irrigation with saline waters [2]. The severity of salinity problem in Iran is so extended and is predicted to become a larger problem in near future. Also it's estimated that 30% of irrigated farms in Iran is irrigated with saline waters [3] and potential of this areas is half because of salinity stress.

Crop growth is reduced by salinity via two main processes, which are related either to the osmotic stress of salt accumulation in the root media or which are salt accumulation in photosynthesis organs of plant and ion specific damages [4, 5, 6]. This also can caused disruption in absorption of some essential nutrient elements [7]. Sodium and chloride are the two main ions responsible for both osmotic and toxicity damages of salinity effects. Based on Munns and Tester [8] salinity effects caused two main phases in plant growth. The first phase observed immediately after salt application and related to osmotic effects of salinity stress. This phase takes in minutes to a few days; so it's not related to the accumulation of ions in plant organs. Roy et al., [9] argued that stomatal closure and inhibition of shoot elongation are the two best documented for effects of this phase. The second phase takes in several days to weeks and more reduction of growth occurred in this period which is due to ionic toxicity and disruption in photosynthesis. Some plants or genotypes can tolerate to the second effects of salinity by sodium exclusion and/or sodium compartmentation in vacuoles thereby reducing the toxic effects of cytosolic enzymes and processes.

Mechanisms of salinity tolerance can be different due to different effects of salinity. Munns and Tester [10] classified three main mechanisms of salinity tolerance in cereal: Osmotic tolerance, Sodium exclusion and Tissue

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tolerance or tolerance to the sodium in the tissue. In last decade the most experimental studies on salinity tolerance based on Na+ exclusion without considering of compartmentation of Na+ in particular cell types or organelles. Rajendran et al; [11] argued that consideration of tissue tolerance and recognizing of this component of salinity tolerance from Na+ exclusion is necessary to improve salinity tolerance in crops. It is so important that we understand difference of Na+ exclusion and tissue tolerance. Na+ exclusion, where Na+ transport processes in roots reduce the accumulation of toxic concentration of Na+ within leaves and tissue tolerance, where high salt concentration are found in leaves but are compartmentalize at the vacuoles and intracellular levels and shows less leaf senescence and necrosis. Also two main mechanisms of synthesis of compatible solutes and production of enzymes catalyzing detoxification of reactive oxygen species (ROS) attributed to tissue tolerance [12]. Some papers, reported success of tissue tolerance to improve salinity tolerance and some of them reported importance of Na+ exclusion in salinity tolerance. Also it is important that we know there are different and unknown genes are controlling of this mechanisms, so it is hard to combine them to improve salinity tolerance in crops. But it must be clear that determination of importance of mechanisms that controlling salinity tolerance within individual crop species will be showing us the way that we must go on. Unfortunately there is not enough evidence and data available to make sure which salinity tolerance mechanism would work best for certain crop. So we must find a way to quantifying of salinity tolerance components and determining of importance of each of them for each crop. This work is a study to find this challenge in Iranian wheat cultivars which introduced for saline areas with different climatic condition.

MATERIALS AND METHODS

In order to evaluation and determination of salinity tolerance components in some Iranian wheat cultivars released by Seed & Plant Research Institute this experiment was conducted at randomized complete block design with 3 replications. Selected cultivars for this aim named: Akbari, Sistan, Arg, Ofogh as salinity tolerant and cultivar`s of Kohdasht and Morvarid as local cultivated wheat in experimental area (Gorgan), and finally Falat and Roshan as old and parents of many new varieties which was cultivated successfully in extended saline and nonsaline areas of Iran in last decades. The same size seeds planted in pots with sandy medium and irrigated with saline (150 mM NaCl) and nonsaline Modified Hoagland solutions. To keep the levels of free Ca++ constant with control condition, an additional 3.42 mM CaCl2 was added. Plants exposed to salinity condition when 4th leaf observed in individual pots. The leaf areas of 3 plants measured by portable leaf area meter in each pot, to determination of growth rate in control and salinity treatments. Also 3 plants were cut daily to measuring of leaf area and dry matters of leaves for one week; then this operation was continued with frequency of 2 days for 2 weeks. In the end of 3weeks after salt application, the 4th leaves of remained plants were cut and concentration of Na+ measured within 4th leaves samples and other parts of plant samples in all treatments. The leaf area meter calibrated base on the one safe leaf in control pot, to determination of leaf senescence in saline condition. The dry matter and leaf areas of died leaves measured during and end of the experiment in all pots.

The growth rate reduction of plants after salt application (for 1 week) was used for osmotic tolerance index. Cultivars which maintained similar growth rate under salinity condition when compared to plants in control were deemed as osmotic tolerant. To this purpose the mean of growth rate in salinity treatment divided to mean of growth rate in control. The cultivar that had lowest growth rate reduction in salinity condition, considered as best osmotic tolerant cultivar with osmotic tolerant index of 1 and others ordered based this one.

A cultivar's ability to exclude sodium was determined by measuring the concentration of Na+ in 4th leaf of plants which exposure by salinity for 3 weeks. Cultivars which accumulated low concentration of Na+ in their fourth leaves were assumed Na+ excluders. If we consider whole shoot Na+ it is not reality for Na+ excluder index, because some organs such as the sheath can be used for Na+ storage.

To determine tissue tolerance to sodium, we used combination of Na+ concentration and senescence in leaves. To this aim we considered that a cultivar which had low senescence and necrosis in leaves at salinity treatments rather than control and highest concentration of Na+ in shoot organs were deemed best tissue tolerant cultivar with tissue tolerance index of 1, while that with high leaf damages and lowest rate of Na+ concentration assumed as most sensitive cultivar and others arranged between them. Therefore tissue tolerance index can be calculated by: Tissue tolerance= ((Total shoot area-salt induced senescence)/Total shoot area) × 4th leaf Na+ concentration [13]. Salt induced senescence leaf area was calculated by: Total senescence leaf area in 150mM NaCl - Natural senescence leaf area in Control.

The osmotic tolerance index, Na+ excluder index and tissue tolerance index were combined to generate a total salinity tolerance index: Total Salinity Tolerance Index= (a× Osmotic Tolerance Index) + (b× Na+ Excluder Index) + (c× Tissue Tolerance Index). For determination of weight of each component (a;b;c) we used nlin method procedure in SAS software. Obtained equation was then applied for cultivars used in this experiment to calculate Total Salinity Tolerance Index. We also calculated total plant salinity tolerance by comparing the leaf areas and dry matter of plants in saline condition against those grown in nonsaline condition.

RESULTS AND DISCUSSION

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Sodium Exclusion Index

Na+ exclusion by roots ensures that sodium does not accumulate to toxic concentrations within leaves [14]. Leaf Na+ concentration is best measured in a defined leaf of a defined age if the plant was exposed to Na+ at around the time of the emergence of that leaf [15, 16]. By considering that a plant transpires 50 times more water than it retains in leaves [17], so excluding of sodium ions from the leaf blades is very important. A large proportion of Na+ that is delivered to the shoot remains in the shoot and only a small proportion of them recirculate to the root, so that the processes that controlling the net delivery of sodium ions into the root xylem is very important. This process involve a range of transporters and their controllers at both plasma membrane and tonoplast [18, 19, 21]. Based on Na+ content leaf blade in this experiment there are a significant variation in the Na+ content of studied wheat cultivars, ranging from the low sodium accumulators, Ofogh and Roshan, to the medium (Sistan, Arg and Akbari) and high Na+ accumulators (Falat, Morvarid, KohDasht). To develop a standardized Sodium exclusion index, the fourth leaf sodium concentration of the lowest accumulating cultivar was divided by the sodium concentration of the cultivar in question. So in Ofogh cultivar with lowest sodium accumulation, a value of 1 was obtained (as best excluder) and in Falat cultivar a value of 0.152 obtained as the worst among experimental cultivars. Theoretically, worst genotype would be value of 0 by using this method.

There was a significant correlation (r2=0.58) between concentration of Na+ in 4th leaf and conventional salt tolerance**[Figure-1]**. Poustini and Siosemardeh [18] also found a strong correlation between salt exclusion and salt tolerance in wheat cultivars. Roots must exclude most of the Na+ in the soil solution. To prevent salt building up with time in the shoot, roots should exclude 98% of the salt in the soil solution, allowing only 2% to be transport in the xylem to the shoots [22]. Difference between cereal genotypes with contrasting rates of Na+ uptake, when grown in 50 mM NaCl, range from 99% for Janz to 98% for other bread wheat [23]. In this experiment, cultivars of Falat and KohDasht with the lowest Na+ exclusion index (highest Na+ in leaf) had highest percent of salt induced injury in leaves**[Table-1]**.

Osmotic tolerance index

Distinguishing the osmotic phase of salinity stress from the ionic-effect phase requires daily measurements of the leaf growth, or spot measurements of the stomatal conductance [24]. The decreased rate of leaf growth after application of salt to root media is primarily due to the osmotic effect of the salt around the roots. An increase in soil solution in earlier growth period reduces the ability of the plant to take up water, and this leads to reductions in cell elongation and cell division, so slower leaf appearance and smaller final size.

To develop an osmotic tolerance index, the relative growth rate for the 7 days after salt application in salinity condition was divided by the relative growth rate of the plants in control condition for the same period. The best osmotic tolerance cultivar (Sistan) had the nearest RGR to the control condition, so for standardizing of osmotic tolerance index, the results divided to this one to generate an index value where the most osmotic tolerance cultivar (Sistan) had an index value of 1 and the most sensitive cultivar within experimental cultivars (Falat) had an index value of 0.743. By theoretically, the most sensitive genotype will have an index value of 0. Under 150 mM NaCl, there is a different reduction in leaf growth and thereby relative growth rate(RGR) for all of the experimental cultivars in the first 7 days after salt exposure **[figure-2]**. This initial reduction in growth rate can be mainly attributed to osmotic effect of salinity stress [25].

The osmotic stress of salt in the root media quickly reduces the growth rate. The rate at which new leaves are produced depends largely on the water potential of the soil solution, in the way as for a drought stressed plant [26]. Munns et al., [27] argued that in the osmotic phase there are chemical signals such as abscisic acid (ABA) coming from roots that reduce leaf growth. ABA has been considered the obvious candidate for this signal; however there is still no conclusive proof that ABA is the only signal from the roots [28]. In general, leaves were smaller and greener in saline condition than control in this experiment. Munns et al., [29] explained it due to lower cell division, small cells and increase in density of chloroplasts. Also, all of local cultivars (Morvarid, KohDash and Falat) had higher specific leaf weight (SLW) in saline condition than control, which means that their transpiration efficiency (carbon fixed per water lost) is high. Munns et al., [30] believed that it will can a future trait that is common in plants adapted to both dry and saline soil.

Two-phase growth response

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The effects of salts in root media and reduction of growth has two phases: The first phase of growth reduction is quickly apparent and due to the salt outside of the roots. In this time, the presence of salt in the soil solution reduces the ability of the plant to take up water and this leads to slower growth [31]. In this phase, the rate of the growth depends largely on the water potential of the soil solution and the salts taken up by the plant does not directly inhibit the growth of the new leaves, so it`s called water stress or osmotic phase. The second phase of the growth response results from the toxic effect of salt inside the plant. In this phase of salinity stress, which takes time to develop, salts accumulated in transpiring leaves. The cause of the leaf injury is due to the salt load exceeding the ability of the cells to compartmentalize salts in the vacuole [32].

Based on the results of this experiment, the two-phase growth response observed within experimental cultivars in salt treated pots, but control plants show one phase of exponential growth over the experimental period **[Figure-3]**. This opinion it is shown in **figure-3**and **figure-4** between Sistan and Falat cultivars. These two genotypes had the same growth reduction for the first week after exposure of 150mM NaCl **[figure-4**: small scale of **fFigure-3**to show phase 1), however, leaf area reduction appeared before that immediately after salt application **[Figure-2]**. Based on calculation of relative growth rate, the genotype with the lower reduction in RGR relative to control (Sistan) considered as osmotic tolerance and Falat with higher reduction in RGR relative to control considered as sensitive **[Table-2]**. There is more difference in growth reduction after 3rd week of salt application between Sistan and Falat **[Figure-3]**so that Falat had lower dry production due to more Na+ accumulation in leaves **[Table-1]**. This growth reduction considered as salt toxicity phase or specific ion effect [33]. The two-phase growth response has been shown clearly for maize [34, 35] and wheat [36].

Tissue tolerance index

Tissue tolerance is a mechanism for salt tolerance species at the cellular level (on the tonoplast) involve keeping the salt out of the cytoplasm and sequestering it at high concentration within the vacuoles [37, 38]. This strategy allows plants to reduce or delay the toxic effects of high concentrations of ions on important and sensitive cytoplasmic processes. So that, the total leaf Na+ content of individual genotypes did not correlate with the percentage dead leaf, because of variation in the tissue tolerance [39]. The ratio of Na+ content to percentage dead leaf was calculated as an index of tolerance to Na+ (tissue tolerance) in the leaves. In order to determination of salt induced senescence it is necessary the measurement of natural leaf senescence in control plants, thereby enabling us to calculate the likely salt-induced senescent area. Rajendran et al.,[40] assumed accessions of wheat with low degree of salt-induced senescence and high salt concentrations have a higher tissue tolerance. We used their formula to calculate tissue tolerance index (Materials and Methods section).

Based on the results of this experiment KohDasht cultivar had the highest concentration of Na+ in leaves **[Table-1]** and highest amount of tissue tolerance **[Table-3]** In the Falat and Morvarid cultivars, also tissue tolerance was calculated higher than other cultivars. Based on **Table-3**, the Ofogh cultivar had lowest rate of tissue tolerance index, which released as salt tolerance by breeders. Of course the weight of tissue tolerance index (effectivity) is important in total salinity tolerance.

A higher Na+ content in salt stressed plants per percentage of total dead leaf also indicate a higher degree of tissue tolerance to Na+. There was a good correlation (r2=0.95) between them **[figure-5]**. This ratio ranged from 42.31 µmol Na+ per percentage of dead leaves in Roshan cultivar to 208.11 in Morvarid **[Table-3]**.

In saline condition the rate of the leaf death is crucial for the survival of the plant. The rate at which leaves die is the rate at which salts accumulate to toxic levels, so genotypes that have poor control of the rate at which salt arrives in leaves, or less effective at compartmentalization of that salt in cell vacuoles, have a greater rate of leaf senescence and necrosis [41]. Based on table1 Ofogh with lowest Na+ concentration had less salt induced injury and Falat and KohDasht cultivars with high Na+ in leaves had high leaves injury. On the other hand, Roshan had low Na+ in leaves but it produces high injury in leaf. The cause of the high injury in Roshan is probably due to the salt load exceeding the ability of the cells to compartmentalize salts in the vacuole (weak tissue tolerance: **Table-4**). In this condition, salts would rapidly build up in the cytoplasm and inhibit enzyme activity [42].
Total salinity tolerance index.

To generate a total salinity tolerance from the indices of Na+ exclusion, osmotic tolerance and tissue tolerance, we combined them together and calculated the weighting of each individual mechanism in total salinity tolerance by using of nlinmethod procedure in SAS software. Based on data, the weighting of osmotic tolerance was 0.528 and

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weight of Na+ exclusion and tissue tolerance was 0.259 and 0.171 respectively. These values applicable to the cultivars used in this experiment by this formula: Total plant salinity tolerance= (0.528 × osmotic tolerance index) + (0.259 × exclusion index) + (0.171 × tissue tolerance index + 0.0522 . The total plant salinity tolerance index calculated for each of the experimental cultivars by this formula and showed in **Table-4**. These data showed that Roshan and Ofogh had the best tolerance cultivars as they had better salt tolerance mechanisms of exclusion and osmotic tolerance **[Table-4]**. These cultivars had lowest values of tissue tolerance index, with little effectivity on total plant salinity tolerance (0.171). The Falat cultivar generate lowest value of total salinity tolerance index (0.648) with lowest indices of osmotic and Na+ exclusion **[Table-4]**. The mechanism of issue tolerance was high in Falat (0.970), but it has lowest effectivity in total salinity tolerance. A good correlation was found between the conventional salinity tolerance index, as measured by the reduction of leaf growth in saline condition relative to control, against calculated plant salinity tolerance index, as contributed to the mechanisms of the osmotic, exclusion and tissue tolerance **[figure-6]**.

CONCLUSION

Salinity has two main effects of osmotic and ionic on plants. Of course there are many different effects such as nutrient effect, morphologic effect, and physiologic effect in detail, so that there are many different mechanisms for tolerance plants to tolerate it. These mechanisms can be categorized into three main mechanisms of osmotic tolerance, ion exclusion and tissue tolerance. Based on the results, osmotic tolerance was a most effective component of total salinity tolerance with value of 0.528 , another mean, effectiveness of osmotic tolerance was more than half of total salinity tolerance. Roy et al., [43] believed that differences in osmotic tolerance may be due to differences in long–distance signaling via processes such as ROS waves, Ca2+ waves and or even electrical signals, or they may involve differences in the initial perception of the salt or differences in the response to the signals. The second mechanism that was effective is Na+ exclusion index with effectivity of 0.25 of total salinity tolerance. Plants can reduce toxicity effect of ions by reduction of toxic ions (mainly Na+) in the leaf blade. Gorham et al., [44] concluded that salt tolerance in bread wheat associated with low rates of transport of Na+ to shoots, with high selectivity for K+ over Na+. This character controlled by a locus (Kna1) on chromosome 4D [45]. Durum wheat is less salt tolerance than bread wheat due to absent of D chromosome. The 3rd mechanism that enhanced salinity tolerance is tissue tolerance. This mechanism can increase the ability of plants to tolerate the salts that they have failed to exclude from the shoot by accumulation of Na+ in the vacuoles, synthesis of compatible solutes and production of enzymes catalyzing detoxification of ROS [46]. The value of this component was 0.17 of total salinity tolerance among experimental wheat cultivars. At last, we can consider Ofogh as salt tolerance cultivar with good osmotic tolerance and Na+ exclusion mechanisms. We considered Morvarid and KohDasht as high tissue and osmotic tolerance cultivars. They had good predicted salt tolerance index notwithstanding low Na+ exclusion **[Table-4].** The Falat cultivar was sensitive to salinity among experimental cultivars. It had only good tissue tolerance and other salt tolerance components were lowest. It appears that cultivars with two tolerance mechanism either osmotic tolerance with Na+ exclusion (such as Ofogh and Roshan) or tissue tolerance with osmotic tolerance (such as Morvarid and KohDasht) have better estimated salinity tolerance than Falat cultivar which appear to use only one tolerance mechanism. Rajendran et al., [47] also concluded that two salinity tolerance mechanisms are better than one in Triticum monococcum species. To date, there is neither evidence that a particular plant is committed to only one strategy [48], nor that these mechanisms are mutually exclusive (49). It is clear that salinity tolerance is complex trait due to multigenic nature, and only little work was successful to release tolerant wheat cultivars by using traditional breeding methods [50]. It is therefore necessary to study the mechanisms of traits that are hypothesized to contribute to salinity tolerance and this experiment was an effort to this way.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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None declared.

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FIGURES AND TABLES

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Table:1. Calculation of Na+ exclusion index and percent of salt injury in leaves

Cultivar	Fourth leaf Na+ (mM Na+.g-1DM)	Na+ exclusion index	% of Salt induced injury
Akbari	12.319	0.529	23.78
Sistan	15.362	0.424	30.94
Arg	12.754	0.511	21.63
Ofogh	6.522	1	22.65
Roshan	7.391	0.882	28.87
Falat	42.899	0.152	36.52
Morvarid	38.406	0.170	29.85
KohDasht	42.029	0.155	33.68

Table:2. Calculation of osmotic tolerance index

Cultivar	RGR(nonsaline)=X	RGR(saline)=Y	Osmotic tolerance=Y/X	Osmotic tolerance index	Relative specific leaf weight
Akbari	0.31132	0.27330	0.876	0.965	0.893
Sistan	0.31356	0.28392	0.908	1	1.035
Arg	0.33777	0.26726	0.794	0.874	0.946
Ofogh	0.40181	0.29772	0.750	0.826	0.916
Roshan	0.35254	0.28486	0.806	0.888	1.133
Falat	0.35783	0.24038	0.675	0.743	1.198
Morvarid	0.34086	0.29747	0.872	0.960	1.234
KohDasht	0.35685	0.28891	0.812	0.894	1.174

Table:3. Calculation of tissue tolerance index for experimental Iranian cultivars

Cultivar	Total leaf area in 150mM NaCl	Total leaf area in control	Natural senescence leaf area in control	Salt induced senescence leaf area	Tissue tolerance	Tissue tolerance index	Na+ content / % dead leaves
Akbari	479.33	682.67	74.00	111.67	9.507	0.336	68.26
Sistan	390.00	555.33	73.67	118.33	10.407	0.368	79.63
Arg	489.00	718.33	66.00	105.67	9.942	0.351	74.78
Ofogh	394.67	554.33	52.67	85.67	5.036	0.178	49.11
Roshan	373.00	528.67	70.67	107.67	5.253	0.186	42.31
Falat	408.33	640.33	94.33	149.33	27.430	0.970	184.37
Morvarid	401.67	595.00	65.67	121.00	26.511	0.937	208.11
KohDasht	428.33	645.00	96.00	142.00	28.287	1	180.89

Table: 4. Total salinity tolerance index and components.

Cultivar	Conventional salinity tolerance index (leaf area in salt/leaf area in control)	Na+ exclusion index	Osmotic tolerance index	Tissue tolerance index	Calculated total salinity tolerance index
Akbari	0.697	0.529	0.965	0.336	0.751
Sistan	0.703	0.424	1	0.368	0.748
Arg	0.681	0.511	0.874	0.351	0.701
Ofogh	0.710	1	0.826	0.178	0.767
Roshan	0.707	0.882	0.888	0.186	0.772
Falat	0.637	0.152	0.743	0.970	0.648
Morvarid	0.677	0.170	0.960	0.937	0.762
KohDasht	0.663	0.155	0.894	1	0.734

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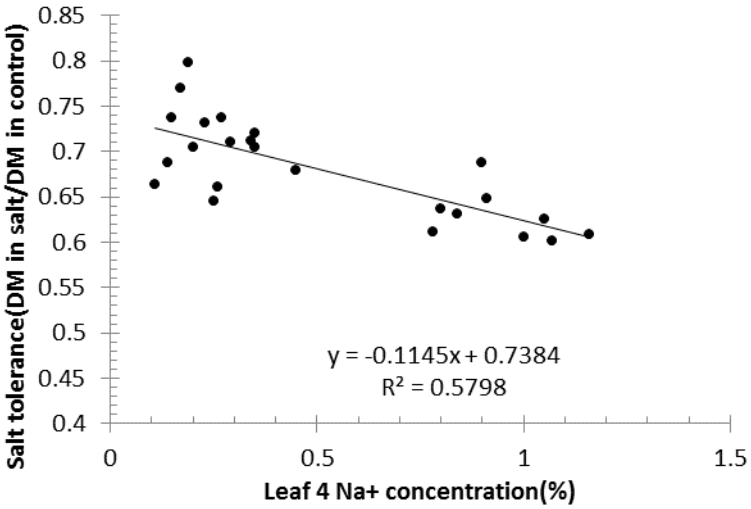

Fig:1. Relationship between salinity tolerance (% growth of control) and fourth leaf Na+ concentration were measured 21 days after 150mM NaCl was added.

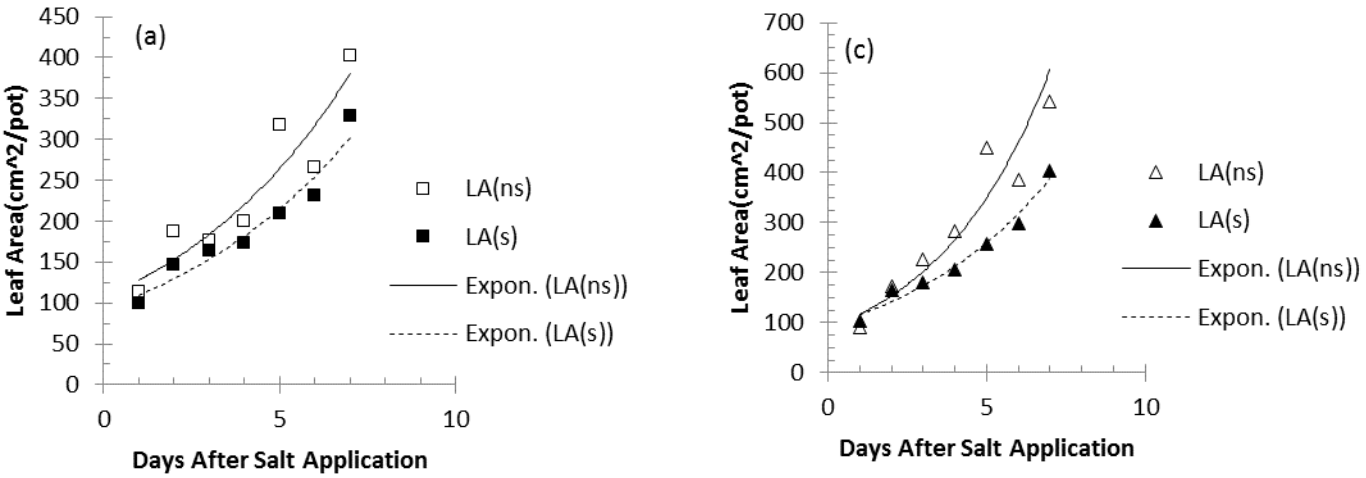

Fig:2. (a) Leaf growth response of Sistan cultivar (as osmotic tolerance) after addition of 0 (□) or 150mM NaCl (■). (b) Relative Growth Rate of Sistan cultivar after salt application (■) and in the control (□). (c) Leaf growth response of Falat cultivar (as osmotic sensitive) after salt application (▲) and in the control (△). (d) Relative Growth Rate of Falat cultivar. Each observation is the mean of 3 replications

ns : nonsaline ; s : saline ; RGR : Relative Growth Rate.

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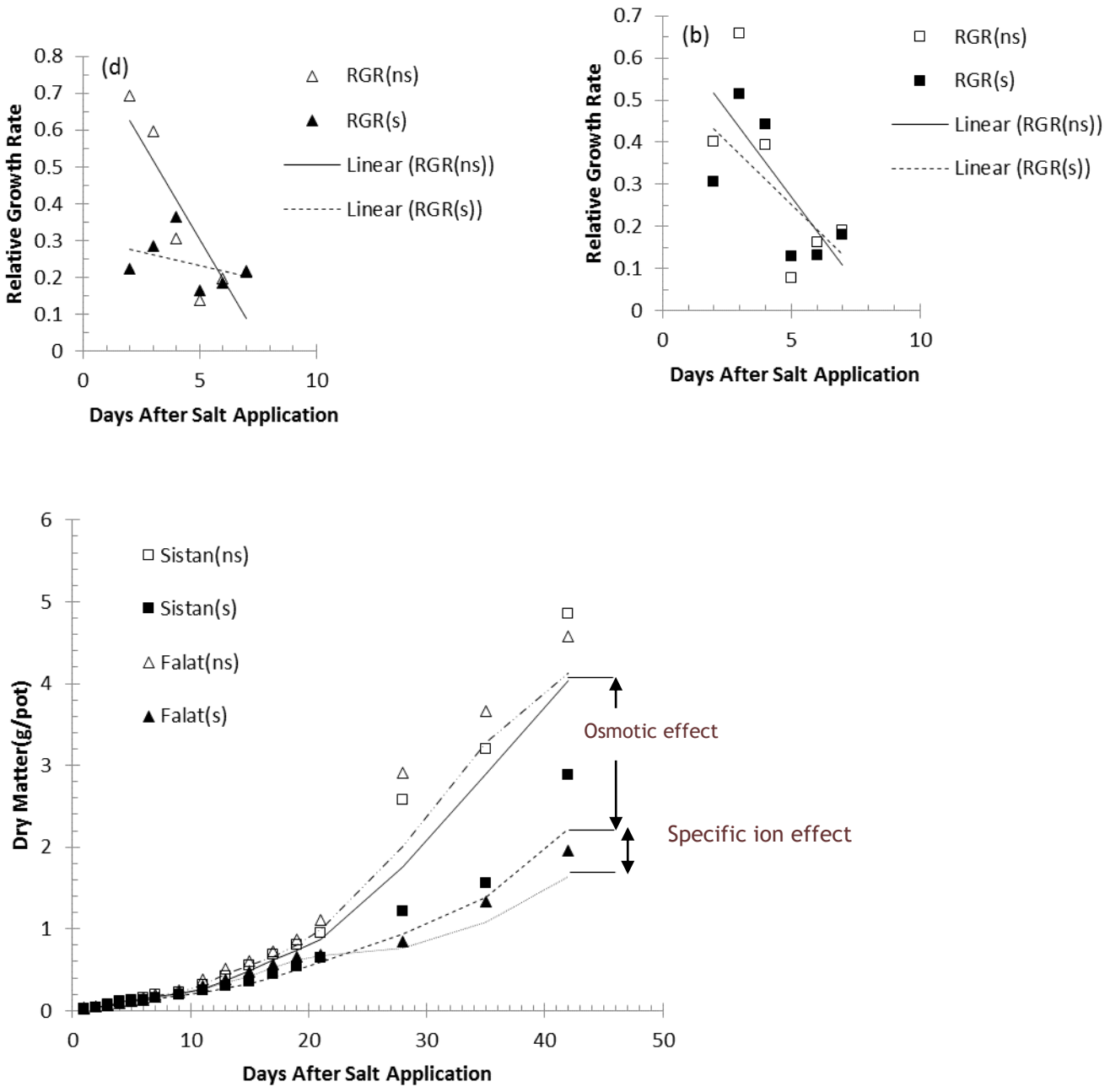

Fig:3. Response of two cultivars of wheat grown in control Hoagland solution (open symbols) and in 150 mM NaCl added to Hoagland solution (closed symbols). Squares denote the salt tolerant cultivar of Sistan and triangles the salt sensitive of Falat. Trendlines are (from above): control of Falat, control of Sistan, salt stressed of Sistan and salt stressed of Falat based on moving average in excel software. (ns: nonsaline and s: saline condition).

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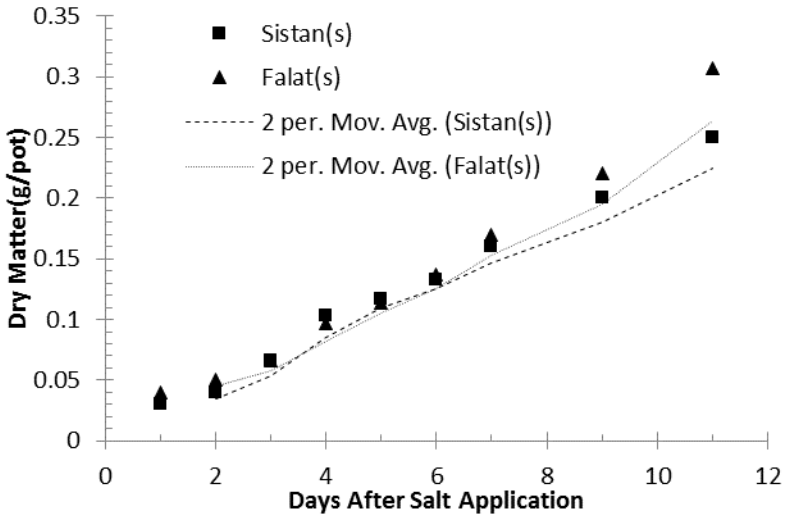

Fig:4. Response of two cultivars of wheat (Sistan ■ and Falat ▲) grown in 150 mM NaCl to clear differences of genotypes in osmotic tolerance. Trendlines are (from above): salt stressed of Falat and salt stressed of Sistan based on moving average in excel software (s: saline condition).

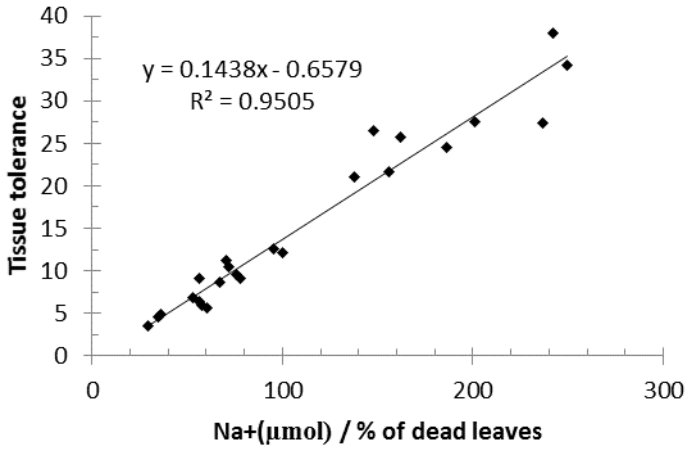

Fig:5. Relationship between leaves Na+ content per % of dead leaf and tissue tolerance of wheat cultivars

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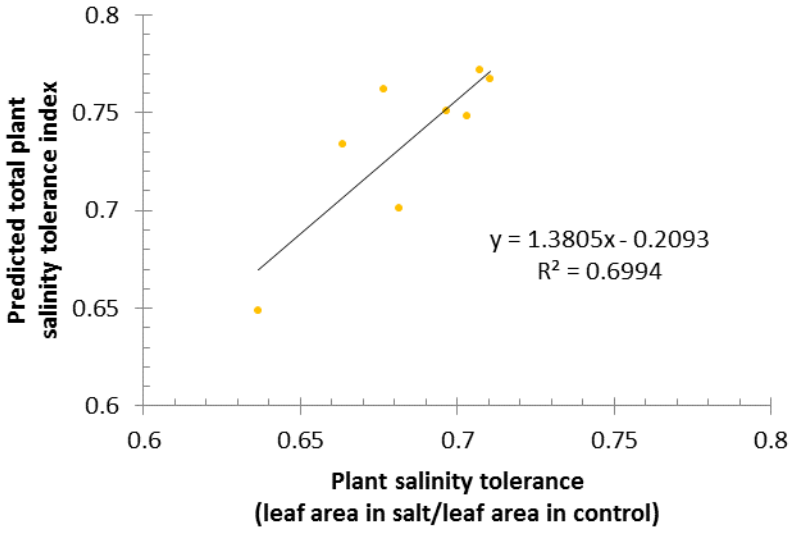

Fig: 6. Plot of conventional salinity tolerance index against the calculated total salinity tolerance index [Table-4].