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EVALUATING SALINITY TOLERANCE THROUGH PHYSIOLOGICAL, BIOCHEMICAL AND AGRONOMICAL INDICATORS IN MEXICAN WHEAT VARIETIES, CULTIVATED UNDER FIELD CONDITIONS IN CUBA

Evaluación de la tolerancia de variedades mexicanas de trigo a la salinidad, a través de indicadores fisiológicos, bioquímicos y agronómicos, cultivadas en Cuba en condiciones de campo

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ABSTRACT. Salinity tolerance was evaluated through physiological, biochemical and agronomical indicators in six Mexican wheat varieties cultivated under field conditions in Cuba, in order to recommend those better responding to salinity stress-affected soils. The electric conductivity (CE_{es}) of salty soils employed in the study was 7,25 dS m^{-1}; a soil with an electric conductivity of CE 0,46 dS m^{-1} was used as control, both classified as Vertisols. To differentiate varietal tolerance degree to saline stress the following variables were evaluated: germination percentage, plant height, root length and dry matter accumulation; relative water content, transpiration, osmotic adjustment, saturated osmotic and water potentials, proline accumulation and agricultural yield. In all varieties, a significant decrease of the evaluated indicators was observed, germination and transpiration being the most affected variables. Due to salinity stress, osmotic and consequently water potentials diminished in every variable whereas osmotic adjustment took place. Proline content increased significantly under saline conditions. Yield showed significant differences among varieties, with values from 4,4 to 5,4 t ha^{-1}. Salinity tolerance evaluation allowed to classify Júpare C2001 as tolerant variety, Banámichi C2004 and Samayoa C2004 as moderately tolerant varieties, whereas Aconchi C89, Rafi C97 and Nácori C97 as susceptible varieties, recommending them in the same order where $CE_{es} \leq$ 7,25 dS m^{-1}.

RESUMEN. Se evaluó la tolerancia a la salinidad de seis variedades mexicanas de trigo, a través de indicadores fisiológicos, bioquímicos y agronómicos, con la finalidad de recomendar las de mejor respuesta para suelos afectados por el estrés salino. La conductividad eléctrica (CE_{es}) del suelo salino empleado en el estudio fue de 7,25 dS m^{-1}; como control se empleó un suelo con una CE de 0,46 dS m^{-1}, ambos son suelos agrupados como Vertisoles. Para diferenciar el grado de tolerancia varietal al estrés salino se evaluaron las variables porcentaje de germinación; altura de la planta; longitud de las raíces y acumulación de materia seca; contenido relativo de agua; transpiración; potenciales hídrico, osmótico saturado y ajuste osmótico; acumulación de prolina y rendimiento agrícola. En todas las variedades se observó una disminución significativa de los indicadores evaluados en el suelo salino, siendo la germinación y transpiración las variables más afectadas. Por efecto de la salinidad, el potencial osmótico y, en consecuencia el hídrico, disminuyeron significativamente en todas las variedades, teniendo lugar el ajuste osmótico. El contenido de prolina se incrementó significativamente en condiciones de estrés salino. El rendimiento agrícola presentó diferencias significativas entre variedades, con valores desde 4,4 a 5,4 t ha^{-1} en el suelo salino. La evaluación de la tolerancia a la salinidad permitió clasificar como tolerante la variedad Júpare C2001, moderadamente tolerantes las variedades Banámichi C2004 y Samayoa C2004 y susceptibles las variedades Aconchi C89, Rafi C97 y Nácori C97, recomendando tales variedades en el mismo orden cuando la CE_{es} sea igual o menor de 7,25 dS m^{-1}.

Key words: water regime, yield, salinity tolerance, wheat, varieties

Palabras clave: régimen hídrico, rendimiento, tolerancia a salinidad, trigo, variedades

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INTRODUCTION

Among the adverse conditions of agricultural systems in the world, soil salinity is one of the abiotic factors that influence the productivity of crop plants. Approximately 43 % of the land area used for cultivation in the world is affected by salinity, mostly exceeds the tolerance levels of traditional crop species. The percentage of soil salinity increases at an average annual rate of 0,5 %, mainly due to low rainfall, high evaporation surface, irrigation water of poor quality and traditional farming practices that favor increased concentration of salts in the soil (1). Currently, more than 953 million hectares of land affected by this stressful event in different regions of the world are recorded, being more aggravating the situation in regions of low pluvial rainfall (2).

In the recovery policy and management of saline soils using species and varieties tolerant to stress it is of paramount importance, receiving special attention by different researchers in Cuba and abroad (3). Thus, several authors argue that increasing salinity tolerance in crop species is an important element in integrated farming systems in areas affected by this type of stress and, although this issue has been the subject of multiple investigations , particularly in the last 30 years, although not all expectations are met and will have to continue working on genetic improvement for this character or agro-biotechnology alternatives leading to remedy the problem on the soil or diminish their adverse effects on plant (4).

The polygenic nature of tolerance to salt stress was the main obstacle for genetic improvement (5). This situation imposes the need to evaluate the new variety tolerance of accurate and consistent forms throughout their life cycle (6), seeking congruence of tolerance among different phenophases and agricultural yields. It has been observed that many varieties show variability of response in terms of tolerance or susceptibility to salinity at different development stages, with some highly significant contribution in the final tolerance to salt stress (7). Thus, this research aimed to identify and assess tolerance to salinity in Mexican wheat varieties introduced and acclimatized in Cuba, which are being evaluated in saline soils of the eastern region, where some wheat varieties obtained nationally and other plant species such as rice, do not express their genetic potential productive because they can´t tolerate existing salinity in soils. Therefore, the study will allow the differential selection of high yielding varieties compared to salt stress and their recommendation to help increase biodiversity of species in fragile and degraded ecosystems, raising the utilization coefficient of these soils, where productions are not profitable as a global climate change consequence and use of susceptible varieties.

MATERIALS AND METHODS

In the research, six Mexican wheat varieties, which were provided by the International Maize and Wheat Improvement Center (CIMMyT) were used through the "Introduction and validation of wheat varieties project with tolerance to salinity and drought in Granma province, Cuba ". Such varieties are in the experimental stage for future expansion in the eastern region under national subprogram grain production, part of the National Food Production Program of Urban Agriculture in Cuba. The varieties were: Júpare C2001; Banámichi C2004; Samayoa C2004; Aconchi C89; Rafi C97; Nácori C97. All have similarity of origin (Mexico) and life cycle (120 days).

Experiment description

Characteristics of used soils

The experiment was conducted under field conditions, in order to assess tolerance to salinity of the six varieties. For it as a pilot area of "San Jose" farm was selected belonging to Genetics and Breeding Company "Manuel Fajardo" in Jiguaní municipality, Granma province, located at 20 ° 19' N the 76 ° 33' and W, on soils of a salinity range from weak to strongly saline (833-6656 ppm) (1,3 dS m^{-1} to 10,4 dS m^{-1}, classified as Vertic salic (VP saline) (8). This classification is correlated with group *Halic Haplustert*, pertaining to the classification developed by the Soil Taxonomy, which in turn, also correlates with the classification proposed by *World Reference Base* (9, 10).

The saline and non-saline soils are separated by a masterful irrigation channel whose flow comes from the dam "Cautillo". The effective distance of the fields was 38 m, which is the result of the separation between the border of each field to the channel (15 m), more their dimensions that are 8 m. The two fields were adjusted to a total area of 4900 m^2 (70 x 70 m). Both soils are master ones over 30 years of cultivation. Soil preparation in the two years of experimentation (2012 and 2013) was performed according to established standards in the Technical Instructions for the cultivation of wheat[A].

[A] INIFAT. *Instructivo Técnico del Trigo*. La Habana, Cuba, 2003, p. 23.

Plantings were made on October 10th, 2012 and October 14th, 2013 in each year of experimentation in rows and trickle, respectively, spaced 0,25 m, with a standard sowing 90 kg ha^{-1} seed .

Meteorological variables

The first year of experimentation (2012) in the study area, average minimum temperatures ranging between 22,5 and 27,9 °C (Figure 1A), with maximums between 29 and 33,4 °C were recorded between 15,4 and 24 °C. The average rainfall values were in the range of 600-800 mm annually. While the relative humidity showed values between 72 and 84 %, with the highest in the June to November months.

In 2013 an annual average temperature between 23,1 and 26,6 °C (Figure 1B), with maximum between 28,3 and 29,7 °C and minimum between 19,3 and 21 °C was recorded, while precipitation ranged from 570-720 mm annually.

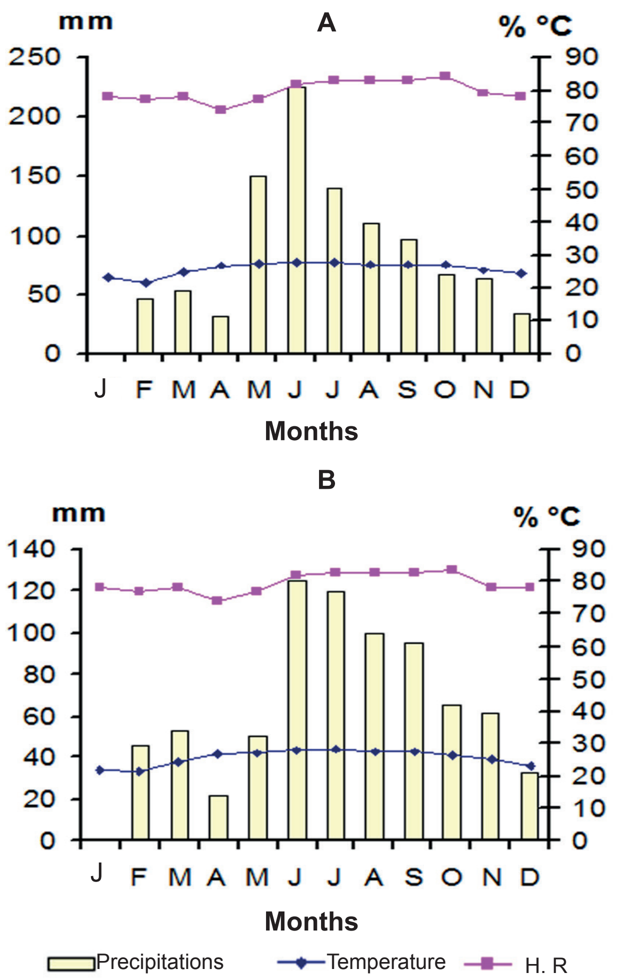


Figure 1 (a and b). Behavior of the main meteorological variables in the area where the experiment was set up in 2012 and 2013 respectively

Relative humidity showed values between 71 and 85 %, with the highest in the months of June to November. It was found that during the two years of study, the months of October, November and December showed some similarity in the behavior of the climatic variables. Meteorological data were obtained at the "Cautillo" agrometeorology station, which is located at a distance of 250 meters from the area where the experiment was developed.

Electric conductivity determining of soil samples

The salinity analysis of used soils was conducted using 50 samples in three transects within the study area, a distance among points of 1 m (11). Extraction of the samples was performed with a bit length of 1,20 m. Subsequently, samples were taken to the laboratory, shredded and placed in cardboard trays to be air-dried for 15 days. Then they were triturated, sieved through a mesh of 2,0 mm and they were deposited in glass jars, for later use in analysis once formed the saturated paste (11). The vacuum filtering technique was used to obtain the extract; in cases where this filtrate afforded extracts with high turbidity centrifugation technique was used (12).

Experimental design

Experimental design a randomized block factorial arrangement was established, forming four blocks oriented from north to south for existing spatial variability of electrical conductivity. The plot size was 16 m^2 (4m x 4m), spaced at 1,5m. The edge effect and neighboring variants in each plot sampling was taken into account, being the calculation surface of 12,25 m^2 (13).

Evaluated variables

The evaluated variables are quantified or processed in the existing mobile laboratory in the company of Genetics and Breeding.

Seed germination

Germination percentage (PG) in each variety was evaluated, based on the total seed set in the saline and non-saline soil and was expressed in relative value control, using the formula:

PG (%)=(GS/GC)*100 (3, 14)

where:

PG represents the germination percentage

GF and GC represent the percentages of seed germination in saline and non-saline soils, respectively, for each variety.

Seedling growth

After 15 days after germination, development variables seedling height (SH), root length (RL), both variables were expressed in centimeters (cm) and the accumulation of dry mass (DM) expressed in grams were evaluated (g). From these data rates salt stress tolerance (STI) were calculated by following formula:

$$STI\ (\%)=[(Yc*Ys)/(Yc)^2\ ]*100 \quad (3, 14)$$

where:

Yc represents the value of the indicator evaluated in non-saline soil.

Ys the indicator value assessed in saline soil.

The sample size for these evaluations was 12 seedlings per replication, which were taken at random on the surface calculation (2).

Relative water content

A sample taken at random at 10:00 am, in the middle of the foliage (leaves 3, 4, 5) 10 seedlings per treatment, to determine the fresh mass (FM) was used. Subsequently, the turgent mass (TM) was determined after keeping the samples in water for a time of 12 hours. Each fragment had a length of 1,5 cm. Later, the sample was taken to an oven (DK-83) for 72 hours, keeping the temperature constant at 80 ^{o}C for dry mass (DM). The relative water content (RWC) was determined according to the method of measurement by gravimetry (15).

Transpiration (T)

It was determined at 10:30 am on the third, fourth and fifth leaves in its central portion, by the difference in fresh and dry mass, and it was expressed as a function of determined leaf area (LA) by MK, Delta–T Devices digital planimeter, Cambridge, UK (16). Leaves cutting was performed and weighed immediately that was the initial mass (IM). When passing 10 minutes (t), plant organ was weighed again, representing the final mass (FM). The transpiration (T) through this equation was calculated:

$$T= (IM–FM)/t*LA$$

Water potential

To determine the water potential, five random varietal seedling samples were taken in each treatment and measurements were performed with the pressure chamber Schollander (PWP-C04) (17).

Saturated osmotic potential

The potential of solutes in leaves was quantified holding the sample in saturated weight condition, frozen in N^2 liquid. Subsequently, it was thawed and sap sample was obtained; it was placed on a filter paper disc in the cell of a psychrometer (Wescor HR33T) to measure the concentration of solutes (18).

The solute potential was calculated according to:

$$\psi_s= -CRT$$

where:

C is the concentration of solutes expressed as molarity.

R is the gas constant 0,00831kg MPa mol^{-1} K^{-1}.

T is the absolute temperature:

Saturated osmotic adjustment

With the information obtained, osmotic adjustment (OA) was calculated as the difference between the saturated osmotic potential treatment plants control and saline ($\Delta\Psi_s$) (18).

Proline content

To determine proline content, samples of leaf and root tissues were collected at the rate of 0,50 g respectively, replicated four times, frozen in liquid nitrogen and homogenized with sulfosalicylic acid (3 %). The residue was removed by centrifugation at 13 000 rpm for 10 min. Then, 500,0 uL extract reacted with 500,0 mL of glacial acetic acid and 500,0 mL of ninhydrin at 100 °C for an hour. The reaction was stopped in ice bath. The chromophore-proline complex was extracted with 1,0 mL of toluene. Proline was quantified in a spectrophotometer (Hewlett Packard 8452) at 520 nm, using L-proline for the calibration curve.

Agricultural yield

The crop yield was obtained based on the mass of grains on the surface of each plot calculation of 12, 25 m^2, which was averaged and expressed in t ha^{-1}. The sample size in this case coincided with the total number of plots per variety (13).

Statistical analysis

In all physiological and biochemical evaluations, the mean and standard deviation were determined in the variables evaluated in both conditions (saline and non-saline soils) and differences were established by t test Student (19) for significance levels of 1 % in each variety. From these data rates salinity stress tolerance (STI) were calculated following the formula described above, to assess tolerance to stress during plant growth (14, 20).

For calculating agricultural yields, a similar procedure was followed. Subsequently, analysis of variance of simple classification based on a linear fixed effects model were made (21) and when there were differences between the index tolerance means and attributes of evaluated stress, these were compared by multiple comparison test Tukey for levels of significance of 5 and 1 % (22).

Stress intensity is calculated according to the formula

IS= 1-(YS/YC)*100

where:

YS and YC represent the average yield on saline and non-saline soils, respectively (20).

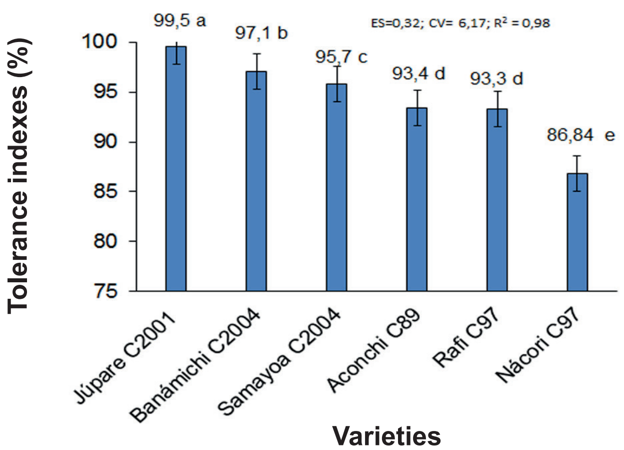
Once certain rates salinity tolerance for each variable, we proceeded to the classification of tolerant varieties, when the stress tolerance index (STI) was higher than 95 %; moderately tolerant when 95≥STI≥ 90 % and susceptible, when STI<90 % (23).

RESULTS AND DISCUSSION

Seed germination and growth in the early stages

Seed germination

In all varieties the germination rate of wheat seeds, growing under salt stress (EC=7,25 dS m^{-1}) was greater than 93 %, except in the variety Nácori C97. This response shows this process tolerance to salinity; however, differences among varieties, except between Aconchi C89 and C97 Rafi (Figure 2) were observed.



Means with same letters do not differ significantly by Tukey, 1 %
SE: standard error
CV: coefficient of variation

Figure 2. Germination percentage of variety set seeds

The response of most varieties with high germination percentage, demonstrates the tolerance of the germination process to salinity, which is due to the morphological configuration of the seed (soft and permeable seed coat, which allows the entry of water and oxygen and output radicle) (3). In this regard, we have studied the physical process of epiblast imbibition in some varieties and species of plants, including wheat, as a necessary condition for germination; however sometimes still occurring imbibition no germination, due to the toxic effect of salt ions (24). Obtaining germination high rates of wheat at higher electrical conductivities to 7, 25 dS m^{-1} has great practical significance for the regionalization of varieties and their establishment in soils with similar or lower salinity values.

Growth variables

After 15 days after germination, significant differences among varieties for all three development evaluated indicators were found to yield the highest rates of tolerance in varieties as Júpare C2001 and C2004 Banámichi (Table I).

Table I. Tolerance indices of the variables plant height, root length and dry matter accumulation of varieties at 15 days after germination

Varieties	Tolerance indexes (%)		
	PH	RL	DM
Júpare C2001	99,02 a	99,11 a	95,16 a
Banámichi C2004	98,1 a	98,9 a	95,74 a
Samayoa C2004	96,35 b	95,16 b	91,27 b
Aconchi C89	91,19 c	91,71 c	91,31 b
Rafi C97	90,74 c	91,65 c	90,81 b
Nácori C97	88,93 d	91,46 c	94,88 a
SE	0,04	0,03	0,07
CV -	4,24	3,17	4,15

Means with same letters do not differ significantly by Tukey, 1%
PH: plant height; R L: length of the radicle; DM: dry matter
SE: standard error
CV: coefficient of variation respectively

Multiple investigations have been conducted on the evaluation of seedling growth under saline conditions in different grains, noting that the osmotic effect is manifested during this phenophase as a result of salt stress (6, 23). However, other researchers argue that in the phenophase wheat seedling is more evident ionic toxicity, mainly due to low specialization level of the root system (7).

All varieties showed high percentage of root length (over 90 %), although there were differences among them. High values of root length have been reported as an important indicator for the evaluation of tolerance to salinity in many plant species including wheat (23).

The Increase in root length promotes plant tolerance to salinity, because it allows more efficient exploration in environment where they develop (23); however, studies show that the capacity of water absorption is not dependent on the length, or the overall volume of the roots but their water potential, indicating that in the early stages of root development, at different depths, the water potential remains constant (7).

Another study shows that on variations in root water potential at different depths, being higher at greater depth (23), an aspect that needs to be assessed in the varieties that are studied in tolerance to salt stress. The rates of dry matter accumulation also showed significant differences among some of the varieties, settling two homogeneous response groups (Table I). The dry matter accumulation depends largely on water relations of the plant and the capacity to regulate this variable, through active accumulation of osmolytes and inorganic ions. Thus, varieties had tolerance indices greater than 90 %. A significant element was the high rate of dry matter accumulation Nácori C97 variety, the lowest values being those of GERM, PH and RL variables. The greater degree of tolerance, from germination to 15 days, Júpare C2001varieties presented and Banámichi C2004, followed by Samayoa C2004, Aconchi C89 and Rafi C97 while Nácori C97 classified as susceptible

Water regime

Relative water content and transpiration

The results of the variables of the water regime showed some similarity in the water economy in the varieties studied, as an adaptive response to salt stress. High values of CRA, even higher than perspiration mainly due to the ability of plants to maintain high volumes of water in leaves to prevent drying and cell damage by radiation, which generally occurs under water stress conditions (Table II). However, the CRA determinants and perspiration are water potential and hydraulic conductivity of the roots (7, 24).

Table II. Rates salt tolerance of varieties during tillering phenophase and active growth to change primordia (45DAG) in saline soil (EC=7,25 dS m^{-1}) compared to non-saline (EC=0,46 dS m^{-1})

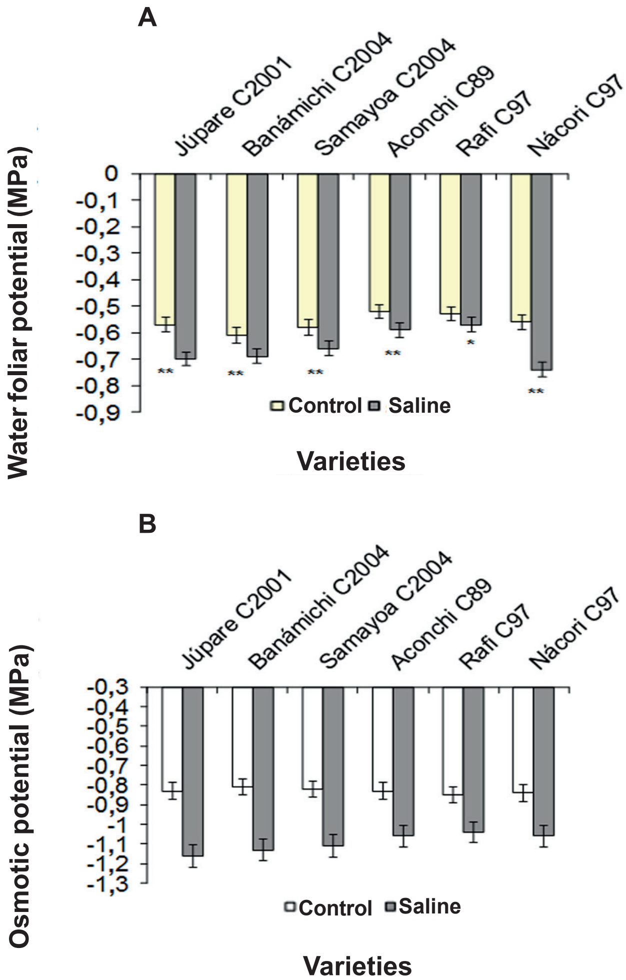
Varieties	Tolerance indexes (%)	
	CRA	T
Júpare C2001	95,02 a	87,2 b
Banámichi C2004	95,02 a	86,4 b
Samayoa C2004	96,35 a	86,1 b
Aconchi C89	91,19 b	83,1 c
Rafi C97	90,74 b	82,5 c
Nácori C97	88,93 c	97,4 a
SE	0,04	0,03
CV	4,24	3,17
R^2	0,99	0,98

Means with same letters do not differ significantly by Tukey, 1 %
SE: standard error
CV: coefficient of variation
R_2: unadjusted determination coefficient, respectively

The best response of these variables was found in varieties Júpare C2001, Benámichi C2004 and Nácori C97. At present, genetic improvement for water variables is a matter of special concern, since the efficient use of water (water economy) has high direct relationship to agricultural yields, although there are plants with higher ratio water-yield (23). Inefficient economy of water in plants grown in saline conditions occurs due to the emergence of a physiological drought state and it is more pronounced in species and varieties of poor or no osmotic adjustment (24).

Water and saturated osmotic potential

The water potential (Figure 3A) and saturated osmotic leaf (Figure 3B) showed significant differences among varieties in saline soil compared to the control.



a) Bars ** and * represent differences for 1 and 5 % respectively

b) There were always highly significant differences by t-student

Figure 3. Variation of water and osmotic potential in salinity conditions in the varieties in saline soil (EC=7,25 dS m^{-1}) compared to non-saline (CE=0,46 dS m^{-1})

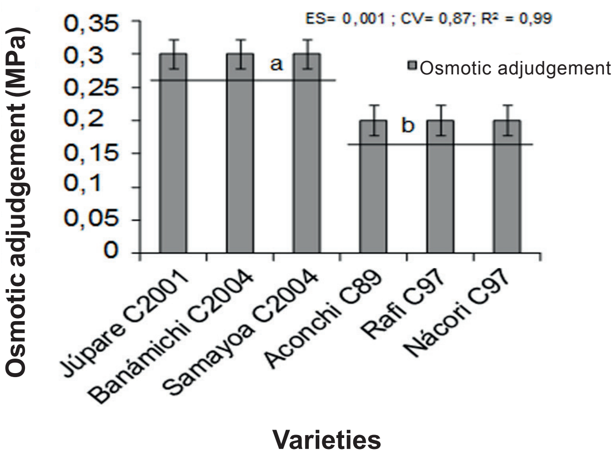
In all varieties the foliar water potential was less than -0,45 MPa and the saturated osmotic potential was below -1MPa; this result, when compared to some studies of potential soil, shows that in those with electrical conductivities extract over 3,5 dS m^{-1} saturation, the crop yield decreases considerably because of difficulties in processes taht determine the osmotic adjustment (24). Also it has been shown that soil vertisols EC 4 dS m^{-1}, classified as heavily saline, the water potential is combined with the coefficient of fractal expansion, reducing the absorbency of capillary water and significantly affecting the osmotic response of plants (25, 26).

Júpare C2001, C2004 Benámichi and Nácori C97 varieties showed more marked differences between control and stress, therefore, lower water potentials; however, the lower osmotic potential relative to the control was Júpare C2001, perhaps the enhanced accumulation of osmotically active compounds.

When the water potential of tissues decreases due to a salt stress, a reduction in osmotic potential can minimize the negative effects of salt when a potential gradient of water between the soil and roots is achieved, allowing the absorption of water (24, 27).

Osmotic adjustment

All varieties osmotic adjustment made and formed, according to results of multiple comparison of means, only two homogeneous groups of response to salt stress, but all greater values than 0,15 MPa pressure (Figure 4).



Bars with the same letter do not differ significantly by Tukey, 1 %
SE: standard error
CV: coefficient of variation
R_2: unadjusted determination coefficient, respectively

Figure 4. Saturated osmotic adjustment in varieties on saline soil (EC_{es}=7,25 dS m^{-1}) compared to the control (EC_{es}=0,46dS m^{-1})

Wheat is a species that can make the osmotic adjustment; however, it has high genetic variation for this character, something that has limited the production stability when varieties are established in soils with different EC_{es} (1, 27). There are studies that indicate that osmotic adjustment is positively related to performance under saline and water stress in this cereal, thus improving grain yield under stress. Besides extracting more water from the soil, wheat genotypes with high osmotic adjustment can produce high root biomass, density and length and have increased perspiration (1, 23).

Varieties which tolerate certain levels of salinity, when subjected to salt conditions after germination, make rapid osmotic adjustment generally based on organic compounds (proline, glycine betaine and total soluble proteins) and thus reduce the osmotic potential and, therefore cellular water potential. Parallel modify the hydraulic conductivity of the roots and their membranes, to prevent the entry of toxic ions; therefore, the initial growth slows. Once achieved homeostasis, it can restore growth (23). Macroscopic changes observed in saline conditions, such as leaf area reduction and the air part/root ratio, among others, also reflect the magnitude of the adjustment required to restore the water balance.

Proline content

Proline content, assessed at 15 days after germination and early flowering significant differences among treatments and varieties, in addition to a significant increase in more than half of the indicator values during flowering, It results important because it has been shown that in response to salt stress one of the best indicators for the selection of varieties with tolerance, is the content of proline. In varieties Nácori C97 and C2001 Júpare the largest increases in proline in both organs in saline medium were presented (Table III).

In the control treatment, proline content values were similar, except in Aconchi C89 (in roots) and Júpare C2001 varieties. This result is a trait of tolerance in these varieties. The fact, the proline content has been obtained an increase in all varieties in the saline treatment, is an important sign of tolerance to stress conditions, which were exposed (25, 26), as it has been shown that proline participates in multiple tolerance events in plants under stress, acting as a mediator of osmotic adjustment; also it has been studied its function as protein stabilizer and membranes (3); as inducer of genes related osmotic adjustment (5); as carbon and nitrogen source, easily available in cellular rehydration; as a source of reducing equivalents (proline catabolism), to support oxidative phosphorylation and ATP generation, during recovery from stress. It also helps to control acidification of the cytosol and can maintain the NADH/NAD + a ratio to values compatible with the metabolism, helping cells to overcome oxidative stress (capture of reactive oxygen species) (26).

Obtaining plants with greater storage capacity of organic compounds with protective function (proline, glycine betaine and other compounds of the quaternary ammonium), as in the present study, in the case of proline, it has resulted in phenotypes with increased tolerance to salinity (24, 27). Hence the importance of monitoring available germplasm under field conditions, through physiological and biochemical variables for the identification of genetic variation and selection, as well as the recommendation of tolerant varieties (23).

Agricultural yield

Varieties studied showed significant differences in performance in saline soil, compared to control and therefore in their stress indices evaluated. In all varieties decreased the average yield was 0,9 t ha^{-1}, but in Bernámichi C2004 and Aconchi C89 the average decrease was greater than 1,1 t ha^{-1} and the lower intensity of salt stress was obtained in Nácori C97 (Table IV).

In other cereal species such as barley and rye, as in some wheat cultivars, which are assessed as tolerant to salinity, its performance decreases slowly, so that the stress intensity values are not significant (intensity light, between 8 and 14 %) (1). At the other extreme are species that have a high sensitivity to salt stress, in which performance decreases very quickly, showing high levels of stress intensity (15-20 %) (5).

Evaluating the overall average tolerance

When analyzing the overall average tolerance of varieties, it was observed that all concentrated their values between 80 and 100 % of their tolerance rates, something that demonstrates the physiological, biochemical and agronomic response of plants to achieve adaptation and productivity in stress conditions (Figure 5).

The greatest response obtained was in Júpare C2001; perhaps this result is a function of the soil and climatic conditions (soil with average salinity and controlled deficit irrigation regime), in which was acclimated in the final stages of breeding. This is an important plant breeding and in recent years the varietal monitoring aspect has been given special attention because of the polygenic nature of tolerance to salt stress and their high degree of connection with the natural conditions where these varieties were obtained.

Table III. Proline content in roots and leaves of studied plants varieties in saline soil and control

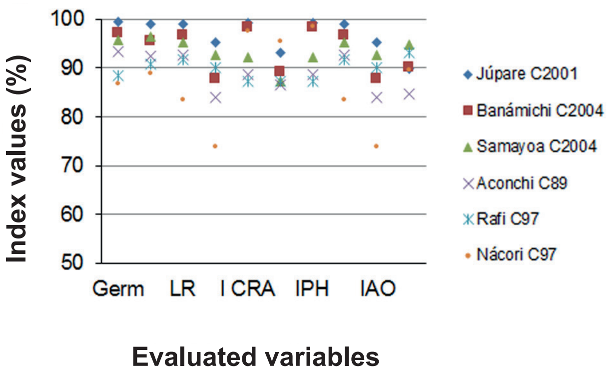
Variety	Proline (mg g^{-1} mf) (roots)		Proline (mg g^{-1} mf) (leaves)	
	Control	Saline	Control	Saline
Júpare C2001	1,43	13,88**a	6,11	38,91**a
Banámichi C2004	1,26	12,14**b	5,34	35,79**b
Samayoa C2004	1,88	12,11**b	4,24	24,24**d
Aconchi C89	3,68	12,19**b	4,26	24,49**d
Rafi C97	1,89	12,10**b	5,47	31,72**c
Nácori C97	1,56	14,18**a	5,16	39,17**a

** Represents significant differences to 1% by the Student t-test in the ranks
In the middle columns with different superscript letters are there significant differences by Tukey for 1%

Table IV. Agricultural yield and stress indicators in varieties in saline soil (EC= 7,25 dS m^{-1}) compared to the control (EC= 0,46 dS m^{-1})

Varieties	Yield (t ha^{-1})		Stress indicator	
	No saline soil	Saline soil	STI	IS
Júpare C2001	6,1	5,4**	88,52 b	11,48 b
Banámichi C2004	6,3	5,2**	82,54 c	17,46 d
Samayoa C2004	5,7	4,8**	84,21 d	15,79 c
Aconchi C89	6,2	4,4**	70,97 e	29,03 e
Rafi C97	6,1	5,4**	88,52 b	11,48 b
Nácori C97	6	5,4**	90 a	10 a

** Represents significant differences to 1% by the Student t-test in the ranks
In the middle columns with different superscript letters are there significant differences by Tukey for 1%
STI and IS represent stress tolerance index and intensity of stress, respectively



Classification of varieties according to their tolerance indices (Munns y James, 2006)

Varieties	IMG	classification
Júpare C2001	96,85	tolerant
Banámichi C2004	93,74	moderately tolerant
Samayoa C2004	93,48	moderately tolerant
Aconchi C89	88,82	susceptible
Rafi C97	89,73	susceptible
Nácori C97	87,19	susceptible

Figure 5. Indices tolerance of variables in varieties, the overall average rate (IMG) and the classification of varieties in their degree of tolerance (tolerant, moderately tolerant and susceptible)

It has been shown that immediately after germination of the seeds, place various mechanisms to ensure survival, adaptation and productivity, as the active accumulation of ions, the synthesis of osmotically active compounds and the synthesis of stress signal hormones such as acid abscisic, being, the osmotic adjustment one of the mechanisms more explained and in turn, complex (24). Stability studies yield, after making breeding programs for tolerance to salt stress and drought have as validation test the osmotic adjustment capacity and degree of relationship to agricultural yields (24).

In several assessment work of salinity tolerance in wheat, it has been shown that the crop yield decreases markedly with increasing salinity levels from 6 dS m^{-1}, affecting their physiology and productivity (5, 27), an element that has considerable genetic variability (28), so it is important germplasm evaluation under field conditions, where the largest genotype-environment interaction have given their polygenic character (29, 30). With the evaluation of tolerance through physiological, biochemical and agronomic indicators under field conditions, has succeeded in identifying genetic variability (31), propose possible parent in breeding programs, recommend and regionalize, tolerant genotypes to saline soils, in which impacted climate change are added(32, 33), which favors the entry of other stressors such as drought and heat stress (34, 35).

CONCLUSIONS

- Salinity variations led in most physiological variables evaluated in six varieties, being more significant the effects on germination, transpiration and osmotic adjustment. Regarding the latter, the proline content as osmotically active compound, increased highly significantly in response to salinity stress.
- Variability was observed in response to salinity in the six varieties, through the assessment of the overall average tolerance among all the indicators evaluated, showing greater tolerance Júpare C2001 variety, while Banámichi C2004 and Samayoa C2004 were classified as moderately tolerant and Aconchi C89, Rafi C97, Nácori C97as susceptible.

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