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RESPONSE OF FIVE SUNFLOWER GENOTYPES (*Helianthus annuus* L.) TO DIFFERENT CONCENTRATIONS OF SODIUM CHLORIDE

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SUMMARY

Understanding mechanisms involved in the response of plants to environmental stress is a prequisite for chooising a suitable genotype for a given environment. Present study was carried out to identify morphological and physiological parameters that might be involved in adaptation of sunflower to salt conditions. Five sunflower genotypes (Oro 9, Mirasol, Flamme, Pinto and Ludo) were submitted, under greenhouse conditions, to four NaCl concentrations (0, 50, 75 and 100 mM). Results showed that increasing NaCl concentrations in the medium significantly reduced all morphological parameters of genotypes. Leaf area was more affected (-72% for Oro 9), followed by the plant height (-67% for Ludo). Root lenght and root volume were also affected. Sodium chloride depressed more root growth than shoot growth of all genotypes. Chlorophyll content declined drastically at 100 mM NaCl (-61,67%). Mirasol displayed the highest chlorophyll content. At the opposite, amino acids (AA) content of both leaves and roots of stressed plants increased as NaCl concentrations in the medium was increased. Oro 9 and Pinto accumulated less AA in their shoots whereas Ludo accumulated more. Under stress conditions, all genotypes accumulated soluble sugars in both shoots and roots. At 100 mM NaCl, Oro 9 showed the highest shoot soluble sugar content, whereas Mirasol alone showed the highest content in both shoots and roots. Proline was another solute that accumulates under stress conditions. Pinto displayed the lowest shoot proline content under saline conditions whereas Ludo had the highest. Proline content of root was also increased by NaCl. Flamme displayed the highest root proline content, whereas Oro 9 showed the lowest one. Root volume and shoot biomass were positively correlated ($r=0.63$) but total soluble sugars content and NaCl tolerance were negatively correlated ($r=-0.94$).

It was concluded that soluble sugars could be a suitable criteria for screening plants for higher saline constraints (100 mM NaCl) with root volume and soluble sugars could be used for screening for lower salt conditions.

Key words: **Sunflower, *Helianthus annuus* L., salt stress, morphological parameter, solutes**

INTRODUCTION

As in other species, physiological processes of sunflower involved in dry matter production are sensitive in many ways to environmental constraints. Their effects depend upon their target and on the species subjected to constraints (Blum, 1989). Therefore, effects of saline conditions during germination, growth and pollinization are often different and causes in many instances important damages to agricultural crops. Damages are more pronounced when salt increases in the medium. Severity of damages depends upon genotype, organ, growth rate, physiological stage of plant and soil type.

Many workers have investigated effects of saline conditions on several species. Hurkman *et al.* (1988) reported that overall effects of salinity resulted in reduction of growth rate depending on species and the concentration and the nature of salt. Slama (1986) reported that growth of planted crops on hydroponic medium containing 50 mM NaCl decreased by 40%. Salt effects are not always damaging, small amounts in the medium may stimulate growth (Cohan, 1975).

Salt tolerance is a complex character. It represents the capability of a plant to growth normally under high salt concentration. However, the degree of salt tolerance of a given species depends on its age. It is higher for a whole plant than for an organ, a tissue or a cell (Binet, 1978). It varies also depending on salt nature, salt concentration, physico-chemical characters of soil, climatic conditions and interaction among other stresses (temperature, drought, mineral stress, biotic stress, etc.) (Boucaud and Ungar, 1978; Monneveux *et al.*, 1990).

Tolerance in case of a low water potential is expressed by maintaining plant turgidity through osmotic adjustement (Yeo, 1983; Blum 1989). Capability of osmotic adjustement of a plant is related to its capabilty to accumulate solutes at the symplasmic level and in an active manner. Solutes ensure protection of membranes and enzymatic systems (Blum and Ebercon, 1976).

Among solutes involved in osmotic adjustment we find potassium, soluble sugars (Morgan, 1984), amino acids especially proline (Bellinger et Lahrer, 1989), linear alcohol such as sorbitol and inositol and cyclic alcohols such as mannitol and pinnitol. Accumulation of these compounds resulted either from an increase of their synthesis or a decrease of their degradation or both (Hubac and Da Silva, 1980; Oumbey and Muhal, 1983).

Mechanisms involved in adaptation of crop plants to saline conditions are numerous and complex. They include phenological, morphological, physiological and biochemical characters. These mechanisms interact at different levels of plant organization. In this situation a strategy to be developped should take into account the description of the overall behaviour in a given medium. Therefore, identifying and classifying different mechanisms involved in salt tolerance is a prerequisite for using them in a breeding program.

This experiment was then carried out to identify and classify major morphological, and physiological characters that might be involved in the salt adaptation of five sunflower genotypes.

MATERIALS AND METHODS

Five sunflower genotypes (Oro 9, Mirasol, Flamme, Pinto and Ludo) were grown in a glasshouse. The main characters of the genotypes are listed in Table 1. After germination in petri-dish, seedlings were transplanted in a 7 l polyetylene pot filled with a mixture of a heavy soil and sand in 1/1 proportion. In order to facilitate drainage of nutrient solution, three holes were made at bottom of the pot which was filled with around 300 g of gravel before adding substrate. To avoid surface evaporation, the substrate was covered with a plastic film.

Table 1: Principal characters of the genotypes tested

Genotypes	Observations	Wild species background
Oro 9	Maroccan population	bred in dry conditions
Mirasol	Commercial F_1 hybrid	drought tolerant
Flamme	Commercial F_1 hybrid	drought tolerant
Pinto	Commercial F_1 hybrid	drought tolerant
Ludo	Commercial F_1 hybrid	drought tolerant

Soil salinization was obtained by irrigating pot with a complete nutrient solution free of NaCl (control) or containing 50 mM, 75 mM or 100 mM NaCl. Pots were maintained at field capacity by adding an amount of water equivalent to plant transpiration estimated by gravimetric mesurement. Experimental design was completely randomized, with three replicates.

Plants were harvested at seven pairs of leaves stage. The following measurement were done on shoots and roots.

Shoots

Leaf area of the biggest leaf was determined with and electronic planimeter Li3000 (LiCOR, Nebraska, USA); total leaf area was then calculated according to Pouzet and Buggart's method (1985); stem diameter was determined with scaled adjustable spanner; plant height was measured as the distance between the bottom of the stem and the end of the youngest leaf; fresh weight was determined immediately at harvest; harvested sub-samples were oven dried at 80°C until constant weight and then weighed to determine their dry weight.

Chlorophyll and amino acids contents. Methods described by Hayman (1975) and Kar (1975) were adapted for chlorophyll and amino acids measurements. An 0.2 g of leaf fresh weight were put in a test tube containing 10 ml of 80% ethanol. Tubes were immersed in water bath maintained at 80°C. When alcohol ebullition began, tubes were removed frequently and re-dipped in the bath to avoid alcohol evaporation. Ten minutes after being immersed in water bath, tubes were removed and let to cool at room temperature. An aliquot of 6 ml was used for chlorophyll determination by reading absorbancy of the sample at 649 nm (chl *a*) and 665 nm (chl *b*). A second aliquot of 0.5 ml was put in test tube for amino acids determination, 5 ml of 50% ethanol were added and vigourously mixed. Absorbancy of the solution was read at 570 nm. Leucine was used as standard for calculating total amino acids concentration.

Proline. Proline content was determined according to Bates and Waldren's method (1973). An 0.2 g of fresh leaves were homogenized with 10 ml of 3% sulfosalicylic acid solution during 30 s. Two ml of the homogenized sample were put in test tube containing 2 ml of 3% ninhydrine, orthophosphorique acide (6 M) and cold acetic acid. The mixture was heated in a water bath at 85°C for one hour. After cooling, 4 ml of toluene were added to separate the two phases. Absorbancy was determined with a spectrophotometer (Perkin Elmer 55-B) at 528 nm. Proline content was determined as of a pure proline (ref. Fluka 81710).

Total soluble sugars. The method of Lewichki as modified by Durnete (1960) and simplified with El Midaoui and Benbella (1996) was used. An 0.1 g of fresh leaf was put in a test tube containing 3 ml of 80% alcohol. The sample was heated at 80°C for 30 min. Tube were then coolted at room temperature. An aliquot of 2 ml was added to 4 ml of a reagent made of anthrone and sulfuric acid maintained at 0°C. Tubes were vigourously mixed before putting them in a water bath maintained at 92°C for 8 min. Tubes were remorved and let to cool for 30 min in ice. Absorbancy was red at 585 nm using the same apparatus as for proline. Total soluble sugars were determined using glucose (ref. Labosi G 305) as the standard.

Roots

Root volume (RV) was determined by the immersion technique as described by Musick *et al.* (1965). Root was measured from the top to the end of the longest root. Root dry weight was determined after oven drying roots at 80°C for 48^{h}.

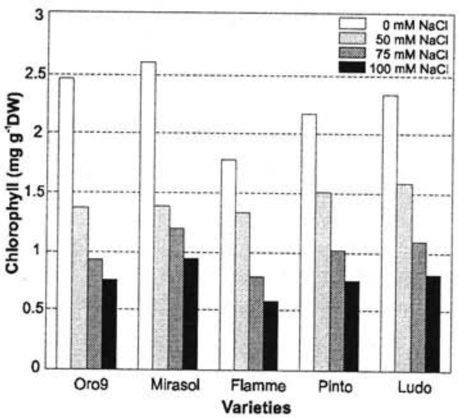


Figure 1: Chlorophyll content of leaves of five sunflower varieties submitted to different NaCl concentrations

RESULTS

I. Effect of NaCl on physiological parameters of shoots and roots

Chlorophyll content (Chl)

Chlorophyll content of leaves of the genotypes was shown in Figure 1. Increase in sodium chloride concentration reduced significanty chlorophyll content. The decrease was more pronounced for chl *b* than chl *a*. Percent reduction of total chlorophyll was 31.27%, 47% and 61.67% for 50, 75 and 100 mM NaCl, respectively. Mirasol was the only hybrid for which chl *a* and chl *b* content was less affected by NaCl.

Amino acids content (AA)

AA content of leaves under different NaCl concentration was shown in Figure 2a. All genotypes accumulated AA as NaCl concentration increased in the medium. Shoots tend to accumulate more AA than roots (+27%). AA content of leaves increased by 31.4%, 50% and 61.6% for 50, 75 and 100 mM NaCl, respectively. The lowest AA level was recorded in leaves of Ludo while Mirasol had the highest AA content at 100 mM NaCl. Moroccan variety Oro 9 and the hybrid Flamme displayed the lowest AA content at 100 mM NaCl. Roots of Oro 9, Mirasol and Flamme displayed lower AA content at 100 mM NaCl than those of Pinto and Ludo (Figure 2b).

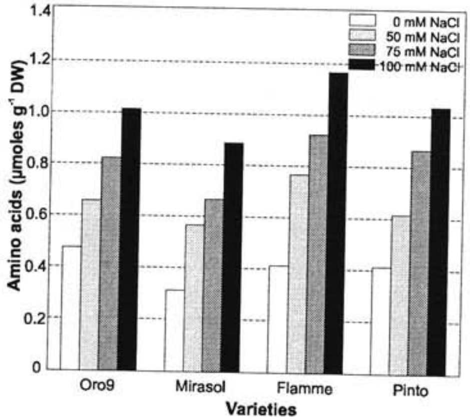


Figure 2a: Amino acids concentration of shoots of five sunflower genotypes submitted to different NaCl concentrations

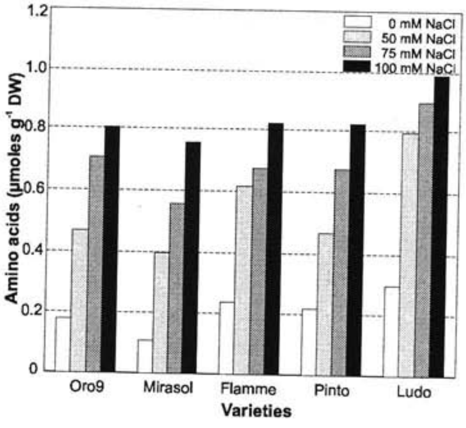


Figure 2b: Amino acids content of root of five sunflower genotypes submitted to different NaCl concentrations

Total soluble sugars (TSS)

Total soluble sugar content of shoots (Figure 3a) and roots (Figure 3b) varies among genotypes and increases significantly as NaCl concentration increases. Percent increase in leaves was 6%, 17% and 26% for 50, 75 and 100 mM NaCl, respectively. Oro 9 and Mirasol showed the highest TSS of leaves at 100 mM NaCl followed by Ludo, Flamme and Pinto.

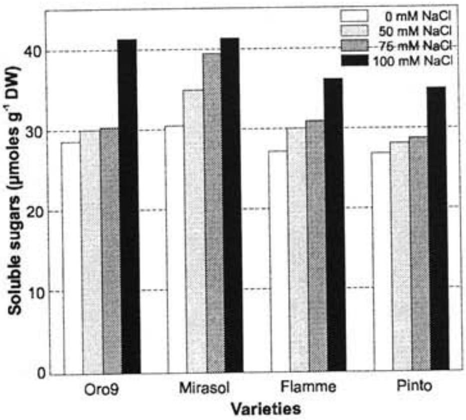


Figure 3a: Total soluble sugars of leaves of five sunflower genotypes submitted to different NaCl concentrations

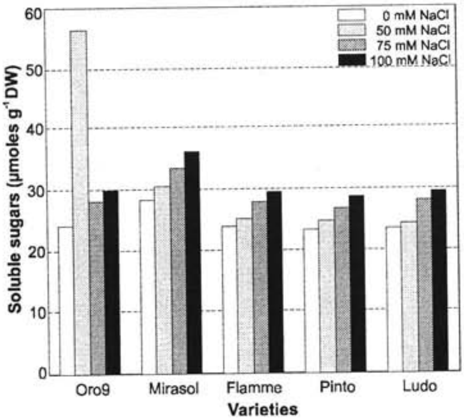


Figure 3b: Total soluble sugars of roots of five genotypes submitted to different NaCl concentrations

Accumulation of TSS in roots showed the same trend as leaves, but they accumulated less (-14%). Addition of 100 mM NaCl to nutrient culture increased root TSS concentration by 20% compared with the control. Roots of Mirasol had the highest TSS level at all NaCl concentrations. The lowest TSS content of roots was observed for Ludo. The other genotypes showed intermediate values.

Proline content (PR)

Leaves of control plants (NaCl-free) showed different proline contents. Ludo showed the highest value. Proline accumulation increased markedly as NaCl content of the nutrient solution increased (Figure 4a). Ludo showed the highest proline concentration of leaves. The lowest proline content under salt stress (50, 75 and 100 mM NaCl) was recorded by Flamme. The other genotypes showed intermediate concentrations.

Proline content of root (Figure 4b) of control plants and of plant receiving 50 mM NaCl was higher than that of leaves for the same treatments. In contrast, leaves accumulated more proline than roots when plants were irrigated with solutions containing 75 and 100 mM NaCl.

At 100 mM NaCl, three genotype groups can be distinguished. The first is constitued by Pinto alone whose proline content of roots is the highest. Mirasol, Flamme and Ludo formed the second group with intermediate proline content of roots. Finaly Oro 9 is the third group with the lowest proline content of roots.

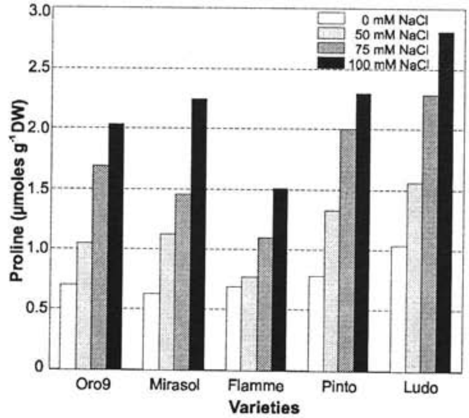


Figure 4a: Proline content of leaves of five sunflower genotypes submitted to different NaCl concentrations

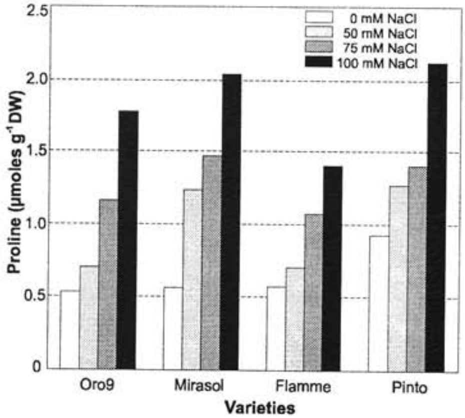


Figure 4b: Proline content of roots of five sunflower genotypes submitted to different NaCl concentrations

II. Effect of NaCl on morphological parameters

Statistical analysis showed a highly significant effect of genotype and NaCl on and their interactions with: leaf area, plant height, stem diameter and root length and volume. Sodium chloride reduced the size of these parameters. Percent reduction increased as NaCl concentration increased.

Table 2: **Part A**. RV: root volume; RDW: root dry weight; RL: root length

Genotypes	RV (µl)			RDW			RL		
	T0	T1	T2	T0	T1	T2	T0	T1	T2
1	6.05	1.17	1.66	36.90	8.33	14.17	78.22	50.33	42.22
2	5.44	1.89	2.05	13.97	8.10	9.43	76.22	56.55	51.22
3	4.50	2.53	1.50	15.77	9.03	10.93	71.22	69.94	60.00
4	4.58	2.08	0.93	17.17	5.27	7.63	68.22	65.17	48.00
5	6.61	1.94	1.56	20.53	9.67	7.97	73.00	58.11	47.00
6	5.22	1.25	1.25	16.90	4.73	8.15	85.55	61.89	51.33
7	4.50	1.08	0.89	13.10	4.90	8.50	70.89	47.11	43.89
8	3.78	2.08	0.72	11.77	8.75	5.40	71.44	69.05	50.67
genotype		1%			1%			NS	
treatment		1%			1%			1%	
interaction		5%			1%			NS	

Table 2: **Part B.** ADW: aerial dry weight; PH: plant height, RDW/ADW

Genotypes	ADW			PH			RDW/ADW		
	T0	T1	T2	T0	T1	T2	T0	T1	T2
1	97.00	57.00	59.83	68.11	35.00	27.66	0.27	0.13	0.19
2	99.77	44.00	52.83	64.33	28.67	24.84	0.12	0.16	0.15
3	90.00	62.60	58.03	68.33	32.55	28.67	0.15	0.13	0.16
4	83.70	54.70	61.27	62.41	38.67	25.00	0.18	0.09	0.11
5	103.23	74.47	59.53	63.00	33.78	28.33	0.17	0.11	0.12
6	90.00	51.93	50.75	65.11	36.33	32.00	0.16	0.08	0.14
7	83.33	51.60	50.97	51.11	28. 00	24.67	0.14	0.09	0.14
8	71.67	43.60	35.07	60.11	34.72	25.00	0.14	0.16	0.13
genotype		1%			NS			1%	
treatment		1%			1%			1%	
interaction		NS			NS			5%	

Leaf area

Average percent reduction of leaf area induced by NaCl was 27%, 57% and 72% for 50, 75 and 100 mM NaCl, respectively (Figure 5). At 100 mM NaCl average reduction of leaf area of Ludo, Oro 9 and Flamme was 85%, 72% and 63% respectively. Plant grown in NaCl free solution showed very hight leaf area. Ludo and Pinto showed the highest leaf area whereas Oro 9 showed the lowest.

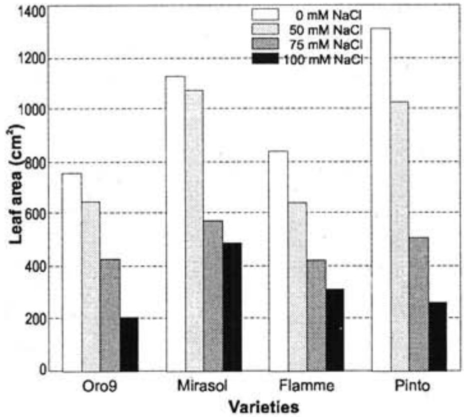


Figure 5: Total leaf area of plants of five sunflower genotypes submitted to different NaCl concentrations

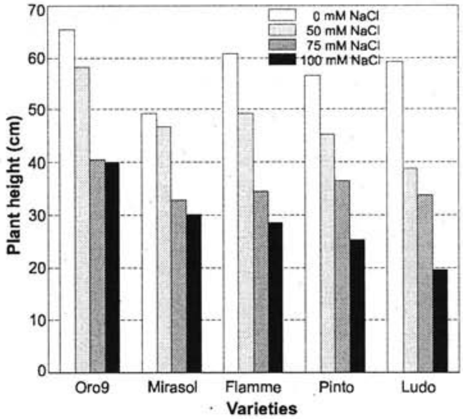


Figure 6: Plant height of five sunflower genotypes submitted to different NaCl concentrations

Plant height

Results showed that average plant height was reduced by 18%, 39% and 51% when they were submitted to 50, 75 and 100 mM NaCl, respectively (Figure 6).

Ludo and Pinto showed the lowest height under stress conditions. Oro 9 had the highest plant height for control and under saline conditions.

Stem diameter

Increasing NaCl concentration in the medium resulted in a decrease of stem diameter of all genotypes (Figure 7). Percent reduction was 12%, 21% and 34% for 50, 75 and 100 mM NaCl, respectively.

At 100 mM NaCl, reduction in stem diameter was more pronounced for Pinto (-45%). On the contrary, Oro 9 showed the lowest percent reduction (-13%) in stem diameter.

Root volume

Root volume of genotype was highly affected when plants were irrigated with salt water. Percent reduction at 7-8 pairs of leaves was 70%, 77% and 82% for 50, 75 and 100 mM NaCl, respectively (Figure 8).

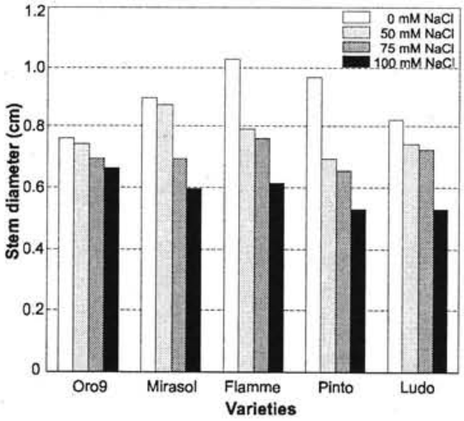


Figure 7: Stem diameter of five sunflower genotypes submitted to different NaCl concentrations

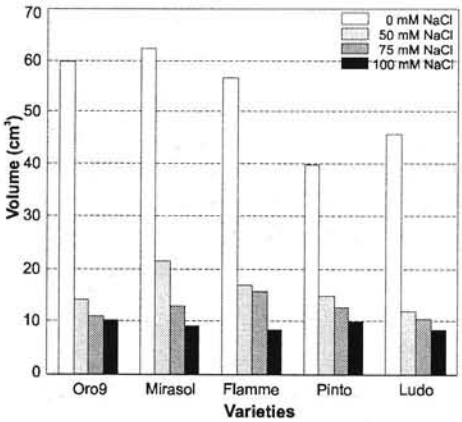


Figure 8: Root volume of five sunflower genotypes submitted to different NaCl concentrations

At 50 mM NaCl, the root volume of all genotypes was reduced by 62%. At 100 mM NaCl root volume reduction was 75% for Pinto and 85% for Mirasol. Under salt free conditions, the highest root volume was noticed for Mirasol (63 cm^3 10^{-3}) and Oro 9 (60 cm^3 10^{-3}), and the lowest for Pinto (40 cm^3 10^{-3}).

Root length

The length of the principal root of plants grown under saline conditions was reduced. Percent reduction was 15%, 26% and 36% when NaCl concentration in the medium was 50, 75 and 100 mM NaCl, respectively (Figure 9).

At 100 mM NaCl, Flamme showed the highest root lenght (30 cm) followed by Oro 9 (25 cm). Flamme had the highest root length when plants were irrigated with salt-free solution.

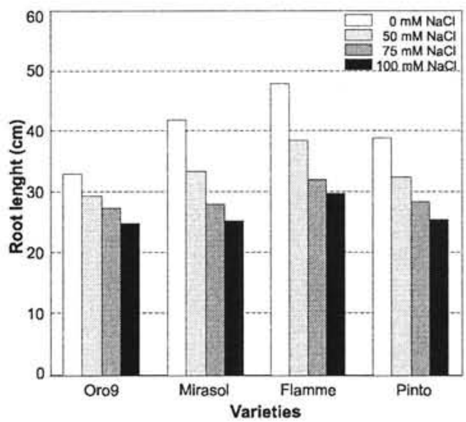
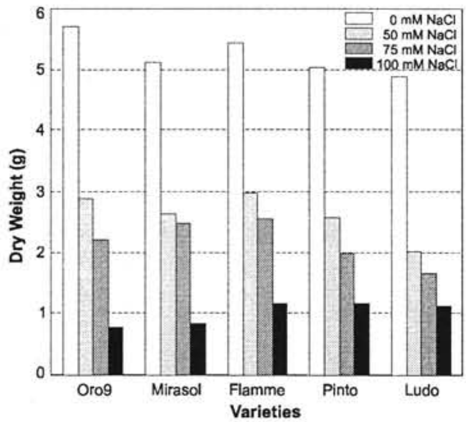


Figure 9: Root lenght of five sunflower genotypes submitted to different NaCl concentrations

Dry weight

Shoot and root dry weight were affected by NaCl. For the same NaCl concentration, shoot dry weight was more affected than root dry weight (Figure 10a). Percent reduction of shoot dry weight was 50%, 58% and 80% when plants were growth under 50, 75 and 100 mM NaCl, respectively. Oro 9 showed the highest shoot dry weight when irrigated with 100 mM NaCl solution. Under these conditions shoot dry weight was reduced by 86%.



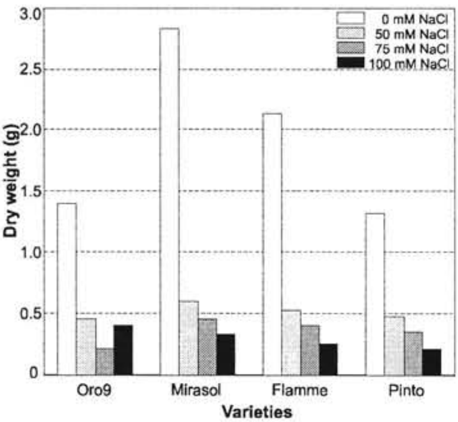


Figure 10a: Shoot dry weight of five sunflower genotypes submitted to different NaCl concentrations

Figure 10b: Root dry weight of five sunflower genotypes submitted to different NaCl concentrations

Increasing NaCl concentration in the medium reduced average root dry weight by 72%, 80% and 87% for 50, 75 and 10mM NaCl, respectively (Figure 10b). Oro 9 lost 90% of its root dry weight compared with control.

Root dry weight/shoot dry weight

The ratio was high for plant grown in free NaCl solution (control). It decreased as the solution was progressively enriched by NaCl. At 100 mM NaCl, Mirasol showed the highest ratio, followed by Flamme and Ludo. The other two genotypes showed the lowest ratio.

DISCUSSION AND CONCLUSION

Adding different amounts of NaCl to nutrient solution resulted in a significant decrease of all morphological parameters. Percent reduction was high for all genotypes when submitted to 100 mM NaCl. Effects were more pronounced for total leaf area (Oro 9, -72%) and plant height (Ludo, -67%). Root volume and length were also affected by NaCl. El Midaoui *et al.* (1997) found the same result for sunflower, Huck *et al.* (1970) for coton and Wendel and Davis (1973) for sugar beet. Reduction of all morphological parameters resulted in a loss in biological yield. Total biomass yield reduction by NaCl had been attributed to effects of salt on water and mineral absorption (Iescke, 1991). Plants then reduced their transpiration through a stomata closure which in turn hindered CO_2 diffusion and fixation and then yield (Raissac, 1992). The linkage between high levels of NaCl and nutritional disorders were also reported for barley (Greenway and Munns, 1980; Tourraine and Ammar, 1985).

Sodium chloride depressed more root growth than shoot growth for all five genotypes. These results are in disagreement with those of Mukhiya *et al.* (1987) and Taleisnik (1987) for wheat. They found a pronounced effect of NaCl on shoot growth under saline conditions.

Positive correlations were found between root volume and shoot biomass (r=0.63) and root volume and root biomass (r=0.67). Mirasol and Oro 9 showed the highest root volume. Negative correlation was found between total soluble sugars and NaCl tolerance (r=-0.94). These results suggested that the more the genotype is tolerant the lesser it accumulates soluble sugars. This agrees with the finding of Rather (1984), and suggests that osmotic adjustement is an important mechanism of adaptation to excess salt in the medium. Proline accumulation under salt stress conditions was also reported by several authors (Hanson *et al.*, 1977; Katz and Tal, 1980). However, its accumulation is unlikely to be involved in osmotic adjustement. Therefore, increase in proline concentration under stress conditions might be considered as a consequece of metabolic disorder. Wyne Jones *et al.* (1984) considered proline content as a poor criteria for screening genotypes for stress tolerance.

Analysis of interactions between genotypes and NaCl levels showed that genotypes responded differently to NaCl concentrations. This result rendered necessary to chose specific criteria for each case. In accordance with this, foliar total soluble sugars is suggested as a better criteria for screening genotypes under 100 mM NaCl.

However, if we want to screen for lower level salt stress (50 mM NaCl), both root volume and root total soluble sugars are more suitable parameters. Under these conditions, genotype with high root volume and total soluble sugars is considered as the most tolerant.

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REACCION DE CINCO GENOTIPOS DE GIRASOL (*Helianthus annuus* L.) A DIVERSAS CONCENTRACIONES DE CLORURO SODIO

RESUMEN

La comprension de mecanismos incluidos en las reacciones de plantas al estres del medio ambiente es la condicion previa para la eleccion de genotipo conveniente para cierta area. Esta investigacion fue hecha para identificar los parametros morfologicos y fisiologicos que podrian ser incluidos en la adaptacion del girasol a las condiciones de salinidad. Cinco genotipos de girasol (Oro 9, Mirasol, Flamme, Pinto y Ludo) eran expuestos a la influencia de cuatro concentraciones de NaCl (0, 50, 75 y 100 mM) en las condiciones de invernadero. Los resultados han mostrado que las concentraciones de NaCl en el medio redujeron considerablemente todos los parametros morfologicos de los genotipos investigados. La superficie de hoja fue a lo mas afectada (-72% para Oro 9), pues la altura de plantas (-67% para Ludo). El largo y volumen de raiz fueron tambien afectados. El cloruro sodio influia sobre el crecimiento de raiz mas que sobre el crecimiento de vastago, en todos genotipos. El contenido de clorofila se redujo drasticamente en la concentracion de 100 mM NaCl (-61,67%). Mirasol ha retenido el mas grande contenido de clorofila. Al contrario, el contenido de aminoacidos en las hojas y raices de plantas expuestas a las concentraciones de NaCl elevadas en el medio era mas grande. Oro 9 y Pinto acumularon menos de aminoacidos en vastago, Ludo lo hizo mas. En las condiciones del estres, todos genotipos acumularon azucares solubles en vastagos asi como en raices. En la concentracion de 100 mM NaCl, Oro 9 tenia el mas grande contenido de azucares solubles en el vastago, mientras Mirasol tenia los mas grandes contenidos en el vastago asi como en las raices. Prolina es aun una substancia soluble que se acumulo en las condiciones del estres. En las condiciones de salinidad, Pinto tenia el mas bajo contenido de prolina en el vastago, y Ludo tenia el mas grande contenido. NaCl aumentaba tambien el contenido de prolina en raices. Flamme tenia el mas grande contenido en raices, Oro 9 - el mas bajo contenido. El volumen de raiz y la biomasa de vastago eran en la correlacion positiva ($r=0,63$), pero el contenido total de azucares solubles y la tolerancia para NaCl eran en la correlacion negativa ($r=-0,94$).

Concluimos que los azucares solubles puedan ser un criterio oportuno para la eleccion de plantas propicias para las condiciones de salinidad elevada (100 mM NaCl), mientras el volumen de raiz y los azucares solubles puedan ser utilizados para la eleccion de plantas propicias para las condiciones de salinidad reducida.

RÉACTION DE CINQ GÉNOTYPES DE TOURNESOL (*Helianthus annuus* L.) À DIFFÉRENTES CONCENTRATIONS DE CHLORURE DE SODIUM

RÉSUMÉ

Comprendre les mécanismes engagés dans la réaction des plantes au stress environnemental est une condition préalable au choix d'un génotype approprié à un milieu donné. Cette étude a été faite dans le but d'identifier les paramètres morphologiques et physiologiques qui pourraient être impliqués dans l'adaptation du tournesol à un milieu salin. Cinq génotypes de tournesol Oro 9, Mirasol, Flamme, Pinto et Ludo) ont été soumis à l'influence de quatre concentrations de NaCl (0, 50, 75 et 100 mM) dans des conditions de serre. Les résultats ont démontré que les concentrations augmentées de NaCl dans le médium ont réduit de manière importante tous les paramètres morphologiques des génotypes. C'est la surface de la feuille qui a été la plus touchée (-72% pour Oro 9), puis la hauteur de la plante (-67% pour Ludo). La longueur et le volume de la racine ont aussi été affectés. Le chlorure de sodium a eu plus d'effet sur le développement de la racine que sur celui de la pousse dans tous les génotypes. Le contenu en chlorophylle a radicalement diminué au taux de concentration de 100 mM NaCl (-61.67%). C'est le Mirasol qui a gardé le plus grand contenu de chlorophylle. Au contraire, le contenu d'acides aminés (AA) dans les feuilles et la racine de la plante exposée a augmenté avec l'augmentation de concentrations de NaCl dans le médium. L'Oro 9 et le Pinto ont accumulé moins d'acides aminés dans la pousse, le Ludo, plus. Dans des conditions de stress, tous les génotypes ont accumulé des sucres solubles et dans les pousses et dans la racine. À une concentration de 100 mM NaCl, l'Oro 9 contenait le plus de sucre soluble dans la pousse, alors que le Mirasol en contenait le plus dans la pousse et dans la racine. La proline est une substance soluble de plus qui s'est accumulée dans des conditions de stress. C'est le Pinto qui contenait le moins de proline dans la pousse dans des conditions salines et le Ludo le plus. Le NaCl a de plus augmenté le contenu de proline dans la racine. Le Flamme contenait le plus de proline dans la racine, l'Oro 9 le moins. Le volume de la racine et la biomasse de la pousse étaient en corrélation positive (r=0.63), mais le contenu total de sucres solubles et la tolérance au NaCl étaient en corellation négative (r=-0.94).

Il a été conclu que les sucres solubles pourraient constituer un bon critère pour le choix des plantes appropriées à des conditions de salinité plus grandes (100 mM NaCl) alors que le volume de la racine et la solubilité des sucres pourraient être considérés dans le choix des plantes appropriées à des conditions de salinité inférieure.