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# PLANT TOLERANCE TO SOIL SALINITY IN THE CONCEPTION OF THE IAŞI SCHOOL OF SOIL SCIENCE

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***ABSTRACT*** *- The paper represents a synthesis of the research carried out by the Soil Science Department within the Agronomical University of Iasi concerning the tolerance of cultivated plants to soil salinity in non-irrigated agriculture. Salt tolerance was established by analysing the decrease in crop yield for each kind of plants, with the increase of soil salinity in layer roots. The experiments were conducted on 22 grass species and numerous hybrids, 28 grape cultivars and seven fruit-tree species. In each case, the following tolerance coefficients were established: 1. The sensitivity threshold for an excess of soluble salts,* $Cl^-$*,* $SO_4^{2-}$*, pH level; 2. The plant-drying threshold; 3. The tolerance interval; 4. The relative agronomical tolerance; 5. The yield decrease (in %) for a total salt increase unit (10 mg ss). Finally, the species were grouped in four categories depending on the coefficients of tolerance to soil salinity, as follows: a) tolerant; b) moderately tolerant; c) moderately sensitive and d) very sensitive (table 2 and 4).*

**Key Words:** salt tolerance indices, working method, cereals, technical plants, legumes and fodders species, fruit trees, vine stock tolerance to total salts content, $Cl^-$, $SO_4^{2-}$ and pH in soil

***REZUMAT - Toleranţa plantelor la salinitatea solului în concepţia şcolii ieşene de ştiinţa solului.*** *În lucrare se prezintă o sinteză a cercetărilor efectuate de Departamentul de Ştiinţa Solului din Universitatea Agronomică Iaşi cu privire la toleranţa plantelor cultivate neirigat la salinitatea solului. Cercetările s-au efectuat în perioada 1954-1986. Toleranţa a fost stabilită printr-o metodă originală, analizând descreşterea recoltei fiecărei specii de plante cultivate în condiţii naturale, în funcţie de creşterea salinităţii solului la nivelul stratului radicular. Au fost folosite în cercetare 22 specii de plante cultivare ierboase, numeroase soiuri sau hibrizi din aceeaşi specie, 28 portaltoi de viţă şi 7 specii de pomi fructiferi. La fiecare specie au fost precizaţi următorii coeficienţi ai toleranţei la salinitatea solului: 1) pragul de sensibilitate la excesul de săruri solubile (ctss), la* $Cl^-$*,* $SO_4^{2-}$ *şi la pH-ul alcalin; 2) pragul de uscare a*

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*plantelor; 3) intervalul de toleranță la salinitate; 4) toleranța agronomică relativă şi 5) şi 5) coeficientul de descreştere a recoltei (în procente) pe unitatea de săruri solubile (10 mg săruri solubile). În final, speciile au fost grupate în patru categorii în funcție de coeficienții de toleranță menționați: a) tolerante; b) moderat tolerante; c) moderat sensibile şi d) foarte sensibile. Salinitatea solului a fost măsurată prin conductivitate electrică şi exprimată sub forma conținut total de săruri solubile (ctss).*

**Cuvinte cheie:** indici de toleranță la salinitate, metoda de lucru, cereale, plante tehnice, leguminoase şi specii furajere, pomi, toleranța portaltoilor de vie la conținutul total de săruri, $Cl^-$, $SO_4^{2-}$ şi pH din sol

## INTRODUCTION

The plant tolerance to soil salinity preoccupied scientists in the first half of the XX century. Kearney and Schofield published the first list of their "resistance" to salinity in 1936, and Magistad and Christiansen elaborated the second one in 1944, and Richard in 1947. The Laboratory of Study on Soil Salinity from Riverside, California, 1954, elaborated the most complete list, which was subsequently reviewed and completed by other specialists (Horn, 1992; Torn, Peterson, 1962).

In Romania, N. Bucur et al. have initiated the first investigations during 1954-55, on the salted soils from Jijia-Bahlui Depression, which were continued until 1969, when the famous Professor Bucur died. Subsequently (1969-1990), other investigations were carried out by Al. Măianu et al.(1973), Albescu et al. (1965), Teşu et al. (1972-1986).

The Iaşi School of Soil Science has defined the tolerance to salinity of crops, grown under non-irrigated, as their feature of *immediate adaptability* to saline environment. The term *tolerance* is more proper than *resistance to salinity*, because it has a larger understanding sphere and presents terminological advantages.

## WORKING METHOD

The method used by N. Bucur et al. was grounded on the knowledge of vegetative mass diminution, according to growth of soil salinity in the layer with maximum of roots. Certain salted plots from cultivated fields were chosen, some of them situated on slopes and others on river meadows, where a gradual passage was noticed from plant normal development on non-saline soil to another in the centre of salted plot, where plants developed little or died because of high soil salinity. On this passage, 3-8 areas were chosen, from which plants were harvested at maturity or earlier, thus registering the diminution of vegetative mass and increase in soil salinity in the arable layer. On the same field, soil was sampled from 10 to 10 cm until the depth of 40 or 80 cm, according to plant species. In certain species, the number of plants/ $m^2$ was noted, in order to point out the influence of salinity on plant germination and emergence after sowing. The harvest on 1 $m^2$ of salted soil was expressed as percentage, in comparison with the one obtained on non-saline soil, where plants had a normal development, equal to 100%. The harvest expression in percentage eliminates the development differences, which are due to different land management from one field to another. Plant and soil were sampled in the vegetation stage, which allowed the observation of the salinity damaging effect. The wooden species were submitted to 1-2 year-observation since planting, and only phenological observations and biometrical measurements were carried out.

In soil samples, the total content of soluble salts (ctss), $Cl^-$, $SO_4^{2-}$, and pH index for alkalinity were determined in laboratory. Soil salinity has been measured, by the electrical conductivity (EC), in water:soil solution at the ratio 1.5 and expressed on a dry soil basis as total salt content (ctss).

The above-mentioned determinations were used in many soil and plant samples, thus obtaining (by graphic representations) the necessary mean values for ctss, $Cl^-$, $SO_4^{2-}$ and pH at the base of root layer, by which help, other graphics were done, on which basis interpretations on tolerance to salinity were carried out.

The moment when plants begin to suffer because of high concentration in soluble salts from soil (yield begins its decrease) is *the lowest threshold of tolerance to salinity, the sensitivity threshold* or *tolerance threshold* of the cultivated plant on salted soil. The moment when plants die or develop hard, because of salt excess is *the highest threshold of tolerance to salinity* or the *drying threshold,* which gives an idea of the plant resistance to salinity. The interval between the above-mentioned limits represents *the interval of tolerance to salinity.* The three coefficients demonstrate that one should use the term of *tolerance to salinity* instead of *resistance*, because the first refers to an interval of tolerance and the second concerns only one figure of the salt content from soil (*Figure 1*).

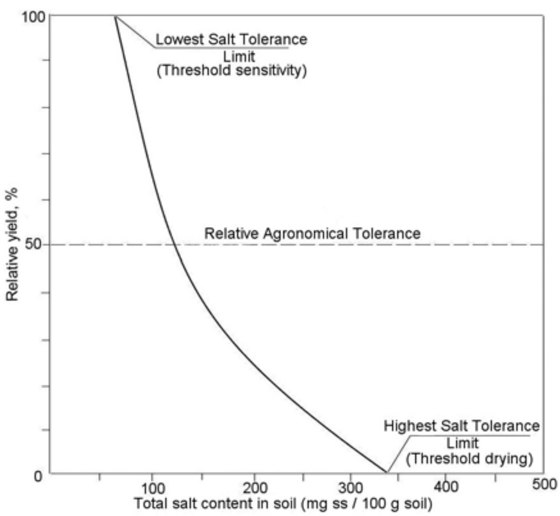


**Fig. 1 - Indices of salt tolerance (general view)**

The reproducibility of tolerance values was done by establishing mean coefficients according to systematic determinations on more salinized soils and then, grouping the values of tolerance for each plant species according to their geographical spreading and moisture of salted soils (wet salted soils from meadows or coasts and moist or dried salted soils on slope). Finally, the reproducibility of values was done by establishing an arithmetic average for each plant species and salted soil category.

The conclusion of investigations was that tolerance of a plant species to soil salinity, grown under non-irrigated, represents a *cumulative effect,* which main cause is the total content in soluble salts (ctss) from arable and subsoil layers. Moisture or dryness, alkalinity, nature of soluble salts and even the percentage of exchangeable sodium from adsorptive complex represent causes subordinated to salinity.

The determination of plants tolerance to salinity under field conditions leads to different conclusions from the ones obtained when experiments are carried out with solutions of different salts or in vegetation vessels with artificially or naturally salinized soil.

We found out that for non-irrigated agriculture, it is more advantageous to express soil salinity by the total content of soluble salts on a dry-soil basis (EC), and not by electrical conductivity of soil extract at saturation ($EC_e$), as most of American specialists recommend. Acording to our opinion, expressing salinity by $EC_e$ is necessary for irrigated soils. The influence of *soil solution salinity* on plant growth can be noticed by simultaneous determination of soil moisture and salinity at samples taken from non-salinized plots and from the field with different degrees of salinization (Bucur et al., 1957). Rhoades and Loveday (1990) consider that the estimate of tolerance according to the knowledge of soil solution salinity is preferred for soils with sandy texture. This advantage was because there were techniques allowing the simultaneous determination of soil moisture and salinity directly in the field.

## RESULTS AND DISCUSSION

The damaging effect of salinity on plants was explained by the osmotic stress, diminution in allowable water for plants, an unbalanced nutrition with different species of ions, the toxic effect of $Na^+$, $Cl^-$ and $SO_4^{2-}$ excess from soil solution, phisiological and biochemical perturbations (Hasegana et al, 2000). Salinity affects seed germination, plant growth, and water and nutrient uptake. The investigations conducted by the scientists from Iaşi have studied plant tolerance to the excess of total soluble salts from soil (ctss), to $Cl^-$ and $SO_4^{2-}$ excess and to alkalinity.

The salinized soils from Jijia-Bahlui Depression, on which investigations were carried out, are salinized humic gley soils, transition soils and salipherous soils.

*Salinized humic gley soils* are found on the river meadows and are influenced by a ground water level close to soil surface, have a loam-clayey texture, and are wet or excessively wet, most of the year. Sometimes, they are found on alluvial colluviums or marls. They are included in the class of salsodisols (solonchaks and solonetz), having the salinity of surface layer until 3000 mg soluble salts/100 g soil.

*Transition soils* are salinized chernozems, and *salipherous soils* were formed on pre-salinized marls, are loam-clayey, and appear more as dry coast salted soils, rarely as dry plateau salted soils, usually weakly to strongly salinized. As spreading, salinized soils are found as plots on river meadows and slopes in cultivated fields (about 10% of field area), the eyes of salted soil could be located in summer as plagues inside the field, on which cultivated plants developed hard or vanished.

In comparison with salted soils on river meadows, those on slopes are poorer in chlorides, because of their partial leaching with the time.

The graphic representation of yield data (expressed as percentage) according to soil salinity (ctss) led to the conclusion that for each series of samples taken from one eye of salted soil, a curve could be obtained with one of the following shapes: concave, descending relatively right or convex (*Figure 2*). The concave curve is the most frequent, then follows the descending right curve; the convex one is accidental, probably determined by salinity secondary factors (moisture and NaS), which vary at the same series of samples and genetic factors.

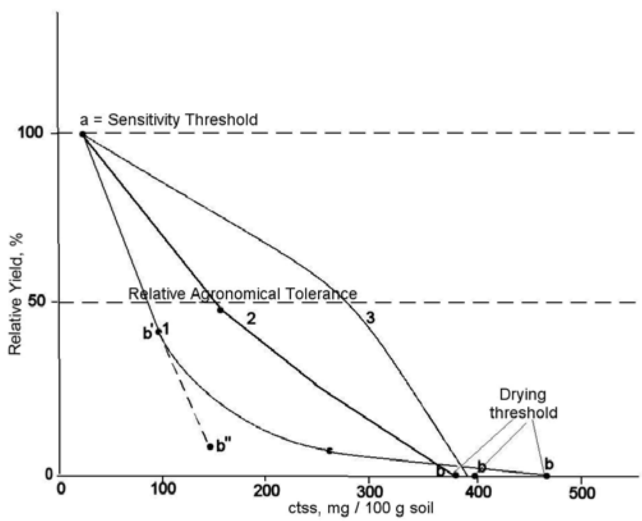


**Fig. 2. - Tolerance coefficients of plants grown on salinized soils (scheme).**
**1- concave curve;**
**2- descending relatively right curve;**
**3- convex curve**

For the determination of tolerance to salinity, there are three important moments in the way of a curve: 1. Sensitivity threshold; 2. Drying threshold and 3. Soil salinity at the moment when the yield value on salinized soil covers the production expenses. We agreed that the 50% of yield from the one obtained on non-salinized soil should be considered as covering totally the yield expenses, soil salinity in that moment being named “ the coefficient of relative agronomic tolerance to soil salinity” (*Figure 1*).

At concave curves (the most frequent ones), it is always found a segment beginning from the sensitivity threshold (point a, *Figure 2*) and ending in point b’, which indicates the significant yield diminution once with soil salinity increase. The a-b' segment may serve for calculating the fifth coefficient of tolerance, which indicates the measure at which yield diminishes per each unit (10 mg soluble salt) of soil salinity increase. The greater is the slope of *a-b'* segment and its continuation until *c,* the plant becomes more sensitive to soil salinity and yield diminishes more significantly. This index is called "yield decreasing coefficient on unit of soluble salts ctss (10 mg ss)".

The stress effect of salinity on plants is greater or lower, according to soil moisture, rainfall, adsorbed sodium percentage at adsorptive complex, fertilization, ratio between different species of nutritive ions from soil solution, thickness of non-salinized upper layer, and possibility that the excess of some ion species has a toxic effect on plants.

In the same species, the stress salinity effect depends on genetic nature of variety or hybrid (*Figure 3*).

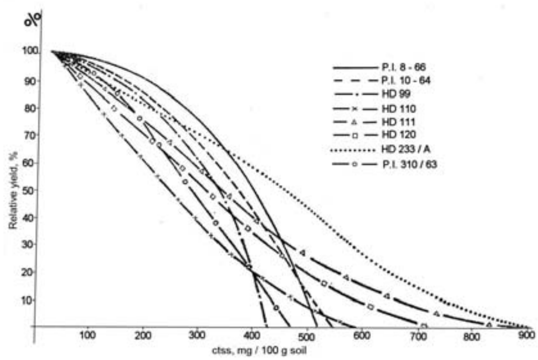


**Fig. 3. - Yield variation in an assortment of maize hybrids according to soil salinity in the rhisospheric layer**

The mean values of tolerance coefficients in main cultivated plants are presented in *Tables 1, 2 and 3*. Their size shows the differences between species as concerns the tolerance to salinity.

**a. In spiked cereals** (wheat, barley, two-row barley, oats and rye), the sensitivity threshold is between 22-88 mg soluble salts/100 g soil, the most sensitive species being rye and oats and the less sensitive ones – two-row barley, barley and winter wheat (*Table 1*).

The drying threshold has high values only in winter wheat, in the other species being lower. The tolerance coefficients were between 110-175 mg soluble salts/100 g soil in wheat and 80-100 mg soluble salts in the other spiked cereals.

In synthesis works (Sandu et al., 1986; Roades and Loveday, 1990; Horn, 1992; Prasad and Power, 1997, etc) the authors considered that the most tolerant field crop to soil salinity is rye, which sensitivity threshold is at 8 dS/m, and the most sensitive is bean, with sensitivity is at 1 dS/m. Our investigations have shown that in non-irrigated agriculture, barley was less indicated on salted soils because of its high sensitivity during germination. In an experiment with barley, wheat and rye, placed on a coast-salted soil with different salinity degrees, the lowest number of emerged plants was found in winter barley. In rye, the negative effect of salinity was average, and in winter wheat, only 24-99% of the number of plants found on non-salinized soil reached maturity (*Figure 4*).

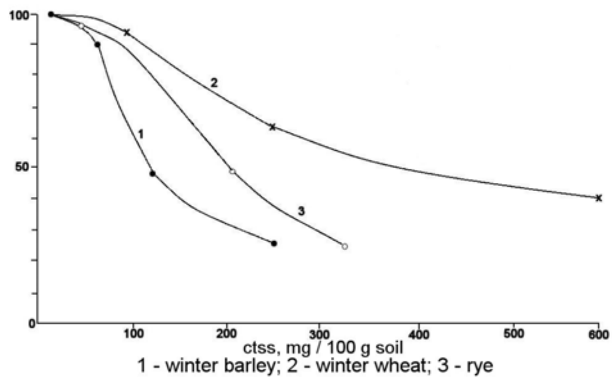


**Fig. 4. - Variation in the number of wheat, barley and rye/ $m^2$ according to soil salinity in the rhisospheric layer**

*Table 1* shows that an important yield decrease on unit of soluble salts (10 mg ss) was found in oats and rye (6.9-12.2%), followed by winter wheat (4.5-7.0%) and barley and two-row barley (1.35-1.72%).

**Table 1**

**Tolerance coefficients to soil salinity and slope of yield diminution on unit of soluble salts (10 mg soluble salts /100g soil) in grass species**

| Species and relief | Sensitivity threshold, mg ss/100g | Drying threshold, mg ss/100g | Agronomical tolerance 50%, mg ss/100 g | Slope of yield diminution/ 10 mg ss % |
|---|---|---|---|---|
| Winter wheat, river meadow | 38 | 200 | 110 | 7.0 |
| Winter wheat, slope | 50 | 616 | 140 | 5.6 |
| Winter barley, river meadow | 50 | 137 | 80 | 1.7 |
| Winter barley, slope | 67 | 146 | 104 | 1.35 |
| Two-row barley, slope | 88 | 117 | 105 | 1.72 |
| Oats, slope | 56 | 137 | 107 | 12.2 |
| Rye, river meadow | 22 | 107 | 80 | 8.5 |
| Rye, slope | 38 | 176 | 110 | 6.9 |
| Maize, river meadow | 32 | 205 | 130 | 5.1 |
| Maize, slope | 55 | 360 | 190 | 3.7 |
| Sorghum, river meadow | 78 | 383 | 175 | 5.1 |
| Sudan grass, river meadow | 20 | 246 | 90 | 7.1 |
| Sugar beet, river meadow | 75 | 600 | 360 | 1.8 |

| Species and relief | Sensitivity threshold, mg ss/100g | Drying threshold, mg ss/100g | Agronomical tolerance 50%, mg ss/100 g | Slope of yield diminution/ 10 mg ss % |
|---|---|---|---|---|
| Sugar beet, slope | 78 | 290 | 175 | 7.1 |
| Hemp, river meadow | 46 | 215 | 76 | 16.7 |
| Flax, river meadow<br>Flax, slope | 42<br>32 | 175<br>78 | 95<br>62 | 9.4<br>16.6 |
| *Carthamus t.*, river meadow | 38 | 310 | 82 | 11.3 |
| *Ricinus c.,* river meadow | 15 | 560 | 145 | 3.8 |
| Alfalfa, river meadow | 65 | 400 | 85 | 25.0 |
| Clover, slope | 21 | 74 | 60 | 12.8 |
| Soybean, river meadow | 38 | 243 | 110 | 7.0 |
| Beans, river meadow<br>Beans varieties, river meadow | 57<br>30 | 208<br>140 | 80<br>76 | 21.8<br>11.1 |
| Peas, river meadow | 55 | 245 | 90 | 15.0 |
| Melilot, river meadow | 15 | 248 | 60 | 11.1 |
| Horse bean, river meadow | 23 | 410 | 125 | 4.9 |
| *Festuca* and *Dactylis gl.* | 45 | 340 | 180 | 13.7 |

Barley and two-row barley have the lowest sensitivity and diminution coefficient on 10 mg of soluble salts, for the plants that did not die during germination. Having the highest ctss value at the drying threshold, wheat is indicated for salted soils capitalization. On coast-salted soils, its tolerance to salinity is higher than on river meadow soils. Maize has the coefficients of tolerance to salinity close as value to the ones of wheat. Its energy at emergence is great, but it stops developing if drought appears, when plants have only few leaves. A 20-30 cm thick non-salinized layer ensures normal yields in case of abundant rainfall. If non-salinized layer is thinner and drought appears, only maize stalks develop and plants do not fructify. Maize is less indicated than wheat for the capitalization of salinized soils.

Studying the tolerance in a few grasses and legumes grown in a vegetation house, Maniu and Albescu (1980) found that two-row barley was the most tolerant plant at adsorbed Na percentage, oats and Sudan grass are moderately tolerant, maize is sensitive and bean is very sensitive.

**b. Technical plants** have a few species with high tolerance to salinity (*Table 1*).

*a. Sunflower,* grown on salted soils with favourable moisture, germinates but penetrates hardly the crust formed at surface. The sensitivity degree is at 15-20 mg soluble salts, 2-3 mg Cl and 5-10 mg $SO_4$/100 g soil, and the drying one at 300 mg soluble salts, 23 mg Cl and 270 mg $SO_4$/100 g soil, the relative tolerance coefficient being at 120 mg soluble salts/100 g soil at river meadow salted soils and at 90 mg soluble salts at slope soils. The coefficient expressing the yield diminution on each 10 mg salinity has greater values on slope-salted soils than on river meadows.

Taking into account the sensitivity threshold and yield decrease (%) per each five salinized units (5 x 10 mg ctss), we have classified the cultivated plants in four tolerance groups: 1. Tolerant; 2. Moderately tolerant; 3. Moderately sensitive and 4. Very sensitive (*Table 2*). Sunflower belongs to the group of moderately tolerant species, next to wheat, oats, rye, etc. The specialty literature (Maas, 1986) frames it in the same group, according to $EC_e$.

*b) Sugar beet* is tolerant to salinity and prefers moisture. Therefore, soils from river meadows, with or without salinization processes, are good for this crop growing. Investigations from the Jijia-Bahlui Depression have shown that a content of 15-20 mg salts over 50-60 mg ss/100 g soil represents a stimulant for crop formation. Therefore, the sensitivity threshold of sugar beet must be at 70-75 mg ss/100 g soil. The salts exceeding these values diminished significantly the yield (*Figure 5*). The drying threshold was at higher ctss values on meadow-salted soils in comparison with coast ones, and yield diminution/10 mg ss increase proved that sugar beet was tolerant to salinity on relatively wet meadow soils (*Table 1*). Sugar beet was framed in the group of tolerant plants, according to $EC_e$ (*Table 2*).

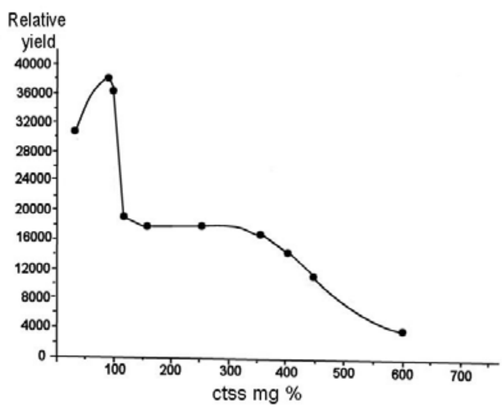


**Fig. 5. - Variation of sugar beet yield according to soil salinity**

The tolerance threshold at sulphates began at 50 mg $SO_4$/100 g soil. A negative correlation was found between the size of yield and sulphate content from soil (*Figure 6*). This correlation was not found in case of chloride, probably, because the salted soils from this geographic area were poor in chlorides and rich in sulphates. The size of yield was negatively correlated to soil alkaline response (*Figure 7*).

Table 2

**Grouping plant species according to their relative tolerance to soil salinity**

| Group | Sensitivity | Scale of sensitivity 1) | Plant species |
|---|---|---|---|
| 1 | Tolerant | < 50 | Barley, two-row barley, sugar beet, castor-oil |
| 2 | Moderately tolerant | 50-100 | Winter wheat, oats, rye, sunflower, maize, Sudan grass, soybean, horse bean, *Carthamus t.*, fruit-trees, sorghum, *Festuca, Dactylis* |
| 3 | Moderately Sensitive | 100 -150 | Hemp, flax[2)], clover, oats, winter barley, two-row barley, hemp, melilot |
| 4 | Sensitive | >150 | Flax[3)] , beans, peas, hemp, alfalfa |

[1] yield diminution (%) to sensitivity threshold for each 50 mg ss/100g soil increase of soil salinity; [2] salinized, on river meadow; [3] salinized, on slope soil.

The diminution in sugar beet yield in case of ctss, $SO_4$, Cl excess and of alkaline pH has demonstrated that tolerance to salinity was a cumulative effect, without knowing the participation percentage of each factor in this process.

Beet should be grown on river meadow-salted soils with at most 360 mg ss/100 g soil at the level of root layer, which is the salinity proper to relative agronomic tolerance.

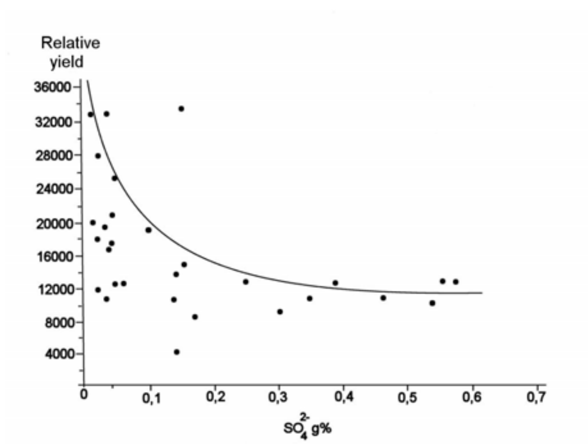


**Fig. 6. - Variation of sugar beet yield according to $SO_4^{2-}$ from soil in the layer with maximum quantity of roots**

*c) Hemp and flax* are species with low tolerance to soil salinity, their sensitivity threshold being at 42-46 mg ss, and the drying one at 78-215 mg ss/100 g soil. The coefficient of agronomical tolerance was between 62 and 95 mg ss, according to the situation of field on meadow or slope, and yield diminution/ ctss unit was between 9.4 and 21.7 % (*Table 1*). Alkalinity had a negative influence on plant development, the drying threshold being at pH 8.1 in case of hemp and at 7.8 in case of flax. Normal yields were obtained on salted soils that had at surface a non-salinized layer, thick of 20-30 cm, well loosened and fertilized with organic fertilizers, in order to diminish crust formation at surface.

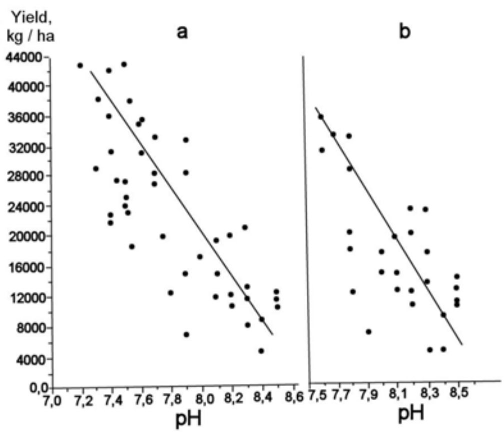


**Fig. 7. - Variation of sugar beet yield according to soil pH in the root layer: a - in salinized and non-salinized soils; b. in salinized soils**

*d) Carthamus tinctorius L.* and *Ricinus communis L.* are plants less cultivated in Moldavia. Salted soils from meadows were more favourable for these crops in comparison with the coast ones. According to tolerance coefficients from *Table 1*, caster-oil belongs to the group of salinity tolerant plants and saffron, to the moderately sensitive group (*Table 2*).

**c. Legumes and fodder species.** The mean coefficients of tolerance to soil salinity from Table 1 led to the conclusion that legumes had a low tolerance to salinity, cereals - an intermediary tolerance, and technical and fodder plants could be included in the group of tolerant or moderately tolerant to soluble salt excess from soil.

*a) Alfalfa,* after sowing in autumn on salted soils, emerges well if it has a proper seedbed, but in winter, it may die of cold on eyes of too wet salted soil. Its vegetation is good on moist or dry soils.

The process of nitrification is weak in salinized soils, and alfalfa has the advantage of enriching soil in organic nitrogen. A higher salt content than the one of chernozem has a stimulating effect on growth, and slightly alkaline pH meets the ecological requirements of the species.

The graphic representations on the yield variation according to ctss, Cl and $SO_4$ from soil, in the rhisospheric layer, concluded that the sensitivity threshold was at 65-70 mg ss, 4-5 mg Cl and 38-40 mg $SO_4$/100 g soil, the drying one was at 400 mg ss, 20 mg Cl and, respectively, 320 mg $SO_4$/100 g soil. The coefficient of relative agronomical tolerance was at 85 mg ss, 5-7 mg Cl and 55-60 mg $SO_4$/100 g soil. The last coefficients demonstrated that alfalfa was sensitive to salinity (*Table 1, Figure 8*). Moist or dry salted soils could be cultivated with alfalfa during vegetation, at which the values for ctss, Cl and $SO_4$, at the depth of 0-40 cm, were below the ones for the relative agronomical tolerance.

The authors that interpret tolerance according to $EC_e$ considered that alfalfa was found in the group of moderately sensitive plants to salinity. We included it in the group of the sensitive plants, because it has a great sensitivity after emergence. The next year, it becomes more tolerant, and, therefore, could be considered a moderately sensitive plant.

*b. Clover* is more sensitive than alfalfa to soil salinity, and vegetal mass yield in the forest-steppe area is lower than alfalfa's. The tolerance coefficients (*Table 1*) demonstrate that it is a moderately sensitive species to soil salinity and prefers a neuter pH.

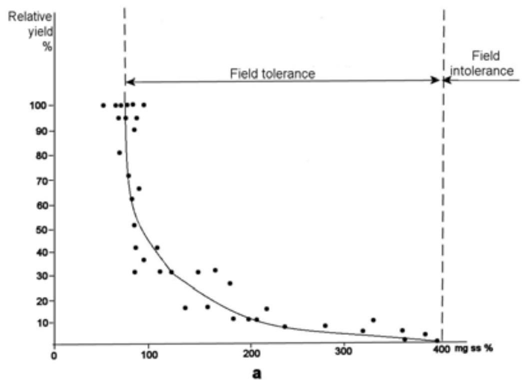


**Fig. 8a. - Variation of green mass alfalfa in relation to soil salinity.**

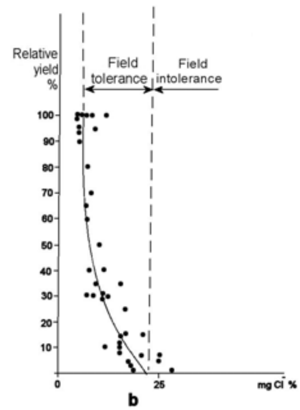


**Fig. 8b. - Variation of green mass yield according to $Cl^-$ content from soil**

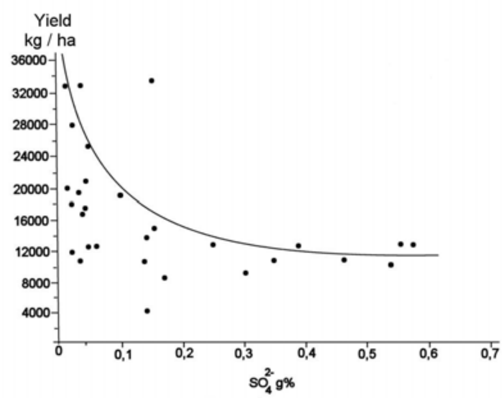


**Fig. 8c. - Variation of green mass alfalfa in relation to the content of $SO_4^{2-}$ from soil in the root layer'**

c. *Soybean* is moderately tolerant to soil salinity. It is less indicated than alfalfa for salted soils capitalization. It is the same case for *vetch* and *bean,* the latest being the most sensitive cultivated species to soil salinity. In exchange, *horse bean* is moderately tolerant. *Sorghum* and *Sudan grass* are moderately tolerant, and *Festuca pr.* and *Dactylis gl.* are within the same category.

**d. The tolerance to salinity of fruit-tree species** was estimated according to the growth in thickness of fruit-tree trunk, according to shoot number and length and the vegetative growth. Instead of sensitivity degree, we have used leaf-wilting degree. Observations and measurements have shown that the wilting degree was at about 100 mg ss, 2-3 mg Cl and, respectively, 25-30 mg $SO_4$/100 g soil, and the drying threshold was within 200-800 mg ss, 11-40 mg Cl and 86-340 mg $SO_4$/100 g soil.

Salinity was measured until the depth of 50 cm (*Table 3*).

The assessment of tolerance was done according to the wilting threshold and the diminution in trunk growth/ each 10 mg ss/100 g soil of salinity increase. We have established the following sequence of fruit-tree species to soil salinity: quince tree> pear tree> plum tree > apricot tree> sweet cherry tree >sour cherry tree. Data are available for slope soils with sulphate salts.

**Table 3**

**Coefficients of tolerance to soil salinity and slope of yield diminution in fruit-tree species cultivated on slope-salted soils**

| Plant | Optimum limits of development (100 %) mg ss/100g | Wilting threshold mg ss/100g | Drying threshold, mg ss/100g | Diminution in trunk diameter / 10 mg ss/100g increasing, % |
|---|---|---|---|---|
| Quince tree | 36 - 80 | 120 | 800 | 0.72 |
| Pear tree | 21 - 70 | 120 | 400 | 1.72 |
| Plum tree | 32 - 70 | 110 | 300 | 2.63 |
| Apple tree | 30 - 65 | 105 | 325 | 2.38 |
| Apricot tree | 34 - 60 | 98 | 260 | 2.98 |
| Sweet cherry tree | 30 - 55 | 92 | 240 | 3.38 |
| Sour cherry tree | 30 - 50 | 88 | 200 | 4.46 |

**e. Tolerance to salinity of vinestock.** The experiments were conducted on vinestocks rooted and planted on slope-salted soil (salted marl); the estimate of vinestock development was done at the end of the first year after planting by biometrical measures (thickness and length) on shoots. Determinations have shown that the sensitivity threshold appeared at 35-60 mg ss, 13-24 mg $SO_4$ and, respectively, 0.0-1.0 mg Cl/100 g soil, according to vinestock.

A number of 28 vinestock varieties were experienced, and three groups of tolerance were established according to drying threshold: 1. slowly tolerant (sensitive) varieties, with drying threshold below 300 mg ss/100 g soil; 2. moderatly tolerant (moderately sensitive) varieties, with drying threshold below

400 mg ss/100 g soil and 3. highly tolerant varieties, with drying threshold over 400 mg ss/100 g soil (*Tab 4*). Vinestocks Berlandieri x Riparia 153-11, Chasselas x Berlandieri x Riparia 153-11, Chasselas x Berlandieri 41 B, Aramon x Rupestris Ganzin no 1, no 2 and no 9 and Vitis Solonis belong to the third category.

**Table 4**

**Grouping vinestocks according to drying threshold and slope of shoot diminution in thickness (%) to the increase of soil salinity**

| Group | Sensitivity | Interval of tolerance to ctss, $Cl^-$ and $SO_4^{2-}$ | Vinestock |
|---|---|---|---|
| I | Sensitive | < 300mg ctss<br>< 120mg $SO_4^{2-}$<br>< 10mg $Cl^-$ | Riparia Grande Glabre; Cordifolia x Riparia; Riparia x Rupestris 101-14; Berlandieri x Riparia Kober 5BB (S2); Riparia x Rupestris 3306; Rupestris Du Lot; Mourvedre x Rupestris 1202; Berlandieri x Riparia Teleki 8B SA; Solonis x Riparia 1616 |
| II | Moderately sensitive | 300 - 400mg ctss<br>120 - 150mg $SO_4^{2-}$<br>10 - 15mg $Cl^-$ | Rupestris Berlandieri Riechter 41; Riparia x Rupestris 3309; Berlandieri x Riparia 420A; Riparia Gloire de Montpelier |
| III | Tolerant | > 400mg ctss<br>>150mg $SO_4^{2-}$<br>> 15mg $Cl^-$ | Berlandieri x Riparia 153-11; Chasselas x Berlandieri 41B; Aramon x Rupestris Ganzin no 1, no 2 and no 9; Vitis Solonis |
| General sensitivity to ctss, $Cl^-$ and $SO_4^{2-}$: 35-60mg ctss; 13 – 21mg $SO_4^{2-}$ and 0.0 - 1.0 mg $Cl^-$/100g soil | | | |

In Tămâioasă Românească vine variety, the tolerance interval was between 75-172 mg ss/100 g soil, and the relative tolerance was at 115 mg ss.

Vine is moderately sensitive to salinity. The higher tolerance of certain vinestocks is caused by their characteristic feature to absorb through roots at lower measure the ions of Cl (and, possibly, of $SO_4$) from salinized soil. The vinestocks sensitive to soil salinity accumulate a chloride excess in leaves, which disturbs the biosynthesis processes, diminishes the starch content and growth of shoots, the number of grapes/vinestock, the number of grapes/bunch of grapes and sugar content accumulated in grapes and increases the organic acid content from grapes (Walker, 1994).

## CONCLUSIONS

In 1957, the Iaşi School of Soil Science has studied for the first time in Romania, the plant tolerance to soil salinity, according to the total content of soluble salts (ctss), to $Cl^-$ and $SO_4^{2-}$ content and pH.

The following coefficients for assessing the tolerance to salinity were established: a. sensitivity threshold; b. drying threshold; c. interval of tolerance; d.

relative agronomical tolerance and e. yield decrease per unit of soluble salts with which soil salinity increased.

The tolerance to soil salinity was investigated in 22 grass species, 7 fruit-tree species and 28 winestocks.

According to the tolerance to ctss, $Cl^-$, $SO_4^{2-}$ and pH, the species of cultivated plants have been grouped in four categories: 1. tolerant; 2. moderately tolerant; 3. moderately sensitive and 4. Sensitive (*Table 2 and 4*).

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