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AFFECTATIONS IN THE YIELD IN COMMON BEAN (*Phaseolus vulgaris* L.) VARIETIES CAUSED BY SALINITY

Afectaciones en el rendimiento de líneas de frijol común (*Phaseolus vulgaris* L.) provocado por salinidad

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ABSTRACT. The effect of soil salinity was studied in four varieties of common bean (*Phaseolus vulgaris* L.) from variables related to yield and its components. The varieties were planted simultaneously on two different soils, one saline and other non-saline and distributed in a design in random blocks with four replicates. At 60 days after sowing, the measurement of plant height and the number of folioles at the moment of the harvest was determined: the number of pods per plant, number of grains per pod, weight of 100 grains and yield. The salt inhibition index was also determined in the variables analyzed. The results showed that bean varieties evaluated showed significant affectations in growth and yield and components variables evaluated for the presence of salinity in the soil. The VAM-13 and VAM-14 varieties can be classified as tolerant and VAM-17 and VAM-43 varieties as susceptible considering inhibition rates shown for the indicators evaluated. The salt inhibition index used allows us classifying the lines according to salt tolerance level under field conditions can complement the studies performed to optimize the performance of this crop under conditions of salt stress.

Key words: inhibition, legumes, salinity, tolerance

RESUMEN. Se estudió el efecto de la salinidad del suelo en cuatro líneas de frijol común (*Phaseolus vulgaris* L.) a partir del rendimiento y sus componentes. Las líneas fueron sembradas de manera simultánea en dos suelos diferentes, uno afectado por sales y otro sin afectación, siguiendo un diseño en bloques al azar con cuatro réplicas. A los 60 días después de la siembra, se realizó la medición de la altura de la planta y el número de foliolos y en el momento de la cosecha se determinaron los indicadores del rendimiento: número de vainas por planta, número de granos por vaina, masa de 100 granos y rendimiento. Se determinó, además, el índice de inhibición por la salinidad, en las variables analizadas. Los resultados obtenidos mostraron que las líneas de frijol evaluadas presentaron afectaciones significativas en las variables del crecimiento y del rendimiento por la presencia de salinidad en el suelo. Las líneas VAM-13 y VAM-14 pueden ser clasificadas como tolerantes y las líneas VAM-17 y VAM-43 como susceptibles, teniendo en cuenta los índices de inhibición mostrados para los indicadores evaluados. El índice de inhibición por la salinidad utilizado, permitió clasificar las líneas de acuerdo a su nivel de tolerancia a la salinidad en condiciones de campo, lo que puede complementar los estudios que se realizan para incrementar el rendimiento de este cultivo bajo condiciones de estrés salino.

Palabras clave: inhibición, leguminosas, salinidad, tolerancia

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INTRODUCTION

Soil salinization can occur naturally in the arid and semi-arid zones of the planet, characterized by low rainfall and high evaporation rates (1). On the other hand, the use of irrigation water with high salt content, inappropriate cultivation practices, the excessive use of chemicals, among the fundamental ones, mark man as the main responsible for the salinization of many agricultural areas (1,2).

About 7 % of the arable lands in the world are affected by salts and for the next years its increase is estimated at more than 20 %, which is why salinity is considered one of the most important problems for agriculture at the international level (3).

Cuba has an agricultural area of around 7,08 million ha, presents about 1 million hectares affected by salinity and close to 1,5 million present potential problems of salinization (4) being the majority used in the production of important crops for human and animal food. To this, it can added the variations that are occurring in the factors of the climate during the last years, where the temperatures are getting higher and the droughts have been the most prolonged and intense, of the last 103 years, with direct incidence in the crops (5).

In the eastern region of the country, more than 65 % of the affected areas are concentrated, of which there are salinized plastic soils, which in total occupy 55 % of the soils of the region, with the provinces of Santiago and Granma being the most significant around of 380 thousand hectares, of them close to 28 and 11 %, strongly and very strongly salinized, respectively; however, 61 % are classified as moderately saline, which expresses the potential growth of this phenomenon in the coming years (5).

Salinity affects mainly the metabolism of the bean plant (*Phaseolus vulgaris* L.), reducing its growth and productivity due to the effect of reduced water potential, ionic toxicity and nutritional imbalance (1, 2, 6). The common bean is a species sensitive to salinity, since it reduces its yield by more than 50 % to an electrical conductivity of saturation of the soil extract (EC) ≥ a 2 dSm^{-1}, equivalent to 20 mM NaCl. Its tolerance to salinity is very limited and it is associated with a reduced rate of absorption and transport of Na^+ to the stem (7-9).

Although beans have been reported as a salinity sensitive species there are few scientific papers on the effect of salt stress in field conditions (10). Therefore, this research was aimed at evaluating the effect of soil salinity in common bean lines on growth, yield and component variables under field conditions, as well as selecting those with greater tolerance to salinity.

MATERIALS Y METHODS

The experiment, located in the Jiguaní municipality, Granma province at 20° 22'12'' North latitude and 76° 27'56" west longitude, it was developed simultaneously in two areas separated from each other by an approximate distance of 256 m. Their soils were classified within the Fluvisol grouping (11), which presented the chemical characteristics shown in Table 1.

In the first of them (non-saline soil), Fluvisol belonged to the differentiated Subtype and had a salt content of 614 ppm and average values of CE in the saturation extract of 0,96 dS m^{-1}, so it classified as not salinized (Table 1).

In the second area (saline soil), Fluvisol classified within the Differentiated subtype, Salinized genus, with an average total soluble salt content of 3 712 ppm and average values of electrical conductivity (CE) in the saturation extract of 5,8 dS m^{-1}, for which it classifies as salinized soil. Among the soluble salts of the affected soil, chlorine, sodium and sulphates stand out for their high concentrations (Table 1).

The chemical analysis of the soil was carried out in the Provincial Soils Laboratory of Granma province The extraction of the cations was carried out with a 1N NH_4Ac extract solution at pH 7. For the determination of Ca^{2+} and Mg^{2+}, the volumetric method with EDTA was used, while Na^+ and K^+ were determined by flame photometry. The results were expressed in cmol kg^{-1} (12).

The extraction of phosphorus and potassium was carried out with 0,1 N H_2SO_4 solution in relation to soil - solution 1:25 with stirring time of 3 min and determination by flame photometry. The anions $CO_3^{-,}$ HCO_3^-, Cl- and SO_4^{2-} were determined by the Unified Methods of the General Directorate of Soils and Fertilizers (13). The electrical conductivity (EC 25 °C) was determined by the Saturated Paste method, which was used to calculate the total soluble salts (SST) (12). The pH (H_2O) soil ratio: 1: 2.5 solution; by the potentiometric method. The organic matter was determined by the wet combustion method of Walkley-Black (12).

Four common bean lines were used (VAM-13, VAM-14, VAM-17 and VAM-43), whose characteristics and provenance are shown in Table 2. These lines were chosen for this research because they come from a breeding program for tolerance to salinity. The seeds were sown at a distance of 0,80 x 0,07 m. The agrotechnical work of the crop was carried out in accordance with what was recommended by the technology (14).

Table 1. Chemical characteristics of the two areas where the experiments were carried out (0-30 cm depth)

Soil	Soluble Cations and Anions (cmol$^{(+)}$ kg^{-1})								Other characteristics			
	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	C.E (dS m^{-1})	SST (ppm)	pH (H_2O)	M.O (%)
No saline	1,2	0,2	0,1	0,08	0,00	0,2	0,52	0,31	0,96	614	7	3
Saline	1,25	1,22	7,2	0,08	0,1	0,32	7,9	1,6	5,8	3712	8,3	3,3

Note: CE, electric conductivity; SST, total soluble salt; MO, organic matter

Table 2. Characteristics and origin of the bean lines used in the research

Lines	Origin	Characteristics and origin		
		Color	Flower color	Growth habit
VAM-13	Estación de Granos Velasco, Holguín, Cuba	Black	Purple	II-Determinate
VAM-14		Black	Purple	
VAM-17		Black	Purple	
VAM-43		White	White	

The experiments were established on an experimental design of randomized blocks with four replications in each variant in plots of 2,80 x 4,00 m (11,2 m^2). To define the design used, it was taken into account that the spatial variability of salinity showed a tendency to increase in the southeast-northwest direction for salinized soil and, north-south for non-salinized soil. For its determination, five samples were taken in each of the plots in a random manner to form a homogeneous sample that allowed assuring the previous criterion about the salinity present in the soils.

For the evaluation of the growth indicators, ten plants selected at random by variety and by replicas were used, as well as three rows for each replica.

After 60 days, the height of the plant and the number of leaflets were measured, while at the time of harvest the yield components were determined: number of pods per plant, number of grains per pod, mass of 100 grains and estimated yield, for which all plants were taken from the calculation area of each of the plots.

In order to determine the lines of best behavior in terms of tolerance to salinity, the inhibition index by salinity was determined in the following variables analyzed: height of the plant, number of leaflets, yield and its components, taking into account the following equation (15):

$$I.I = (TC- TS / TC) * 100$$

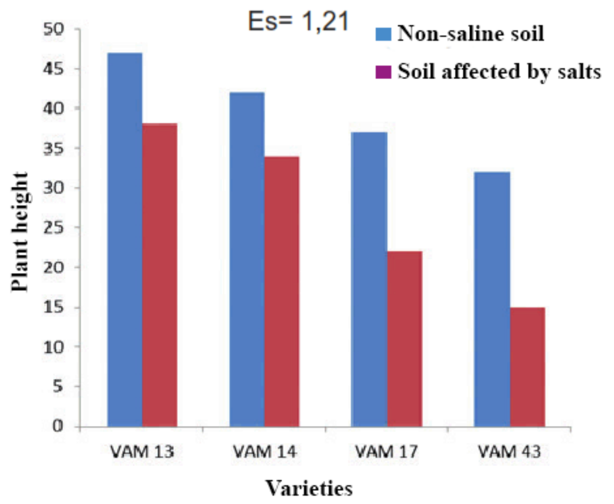
where: I.I is the inhibition index, TS is the saline treatment, TC the control treatment

The data obtained from the evaluated variables were analyzed by means of a double classification analysis of variance and for the multiple comparisons of means the Tukey test was used, with a level of significance of 95 %. The indices of inhibition of the indicators evaluated by salinity were analyzed by variance of simple classification and the multiple comparison of means was used Tukey Test, with a level of significance of 95 %. All the data was processed with the Statistic for Windows package, version 10 (16).

RESULTS AND DISCUSSION

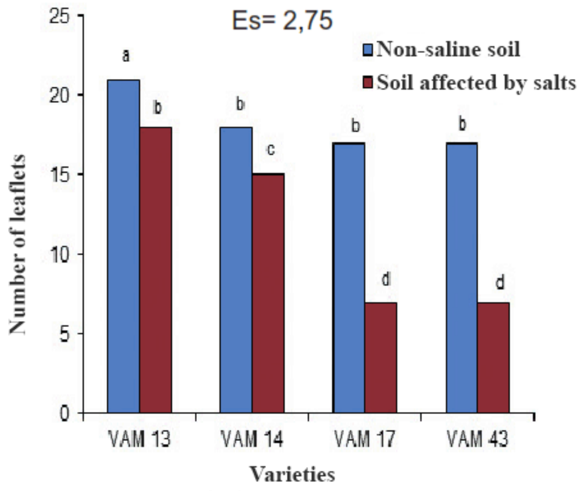
All the lines showed a significant decrease in the growth and development of the plant, as well as in the yield and its components in the salinized soil. The analysis of variance for the height of the plant showed significant differences both in the bean lines under normal conditions and in the presence of salinity (Figure 1). These cultivars showed different behavior in both conditions and a significant decrease in this indicator was observed under salinity conditions for the cultivars studied. It is interesting that the behavior of the varieties VAM-13 and VAM-14 can show the highest values of plant height, both under normal conditions and in the saline soil. Meanwhile, the VAM-43 variety presented the lowest values in both soil types (Figure 1).

These results are consistent with those obtained in other reports, which showed that salt affectations occur in the elongation of roots and hypocotyl length in common bean cultivars and indicate that the detrimental effect of salinity could be explained by the water deficit that occurs in growing foliar tissues, by decreasing cell turgor and changes in the permeability of membranes (10,17,18).



Means with the same letters are not statistically different when applying the Tukey test (p≤0,05)

Figure 1. Height of different bean lines grown in a saline and non-saline soil, evaluated 60 days after emergence



Means with equal letters are not statistically different when applying the Tukey Test (p≤0,05)

Figure 2. Number of leaflets of different bean lines grown in a saline and non-saline soil, evaluated 60 days after emergence

According to other authors, salinity affects bean growth due to the reduction of the water potential of the plant, to the creation of a nutritional imbalance, due to the high concentration of Na^+ and Cl^- ions that can interfere in mineral nutrition and cellular metabolism (1,2,17).

When evaluating the number of leaflets, the negative influence of salinity on the bean lines studied was observed when comparing this indicator for each variety in the saline and non-saline soils (Figure 2). For this indicator, the VAM 13 variety showed the best behavior in both conditions. The rest of the lines did not show significant differences in normal soil, but in saline soil conditions, where the VAM 17 and VAM 43 lines showed the lowest values, significantly lower than the rest of the lines in both types of soil.

The reduction of the development of the plants and the number of leaflets in highly salinized soils and therefore the decrease of the photosynthetically active area of the plant, can be attributed mainly to the negative effect of the mismatch that occurs in the osmotic potential in the aerial part, the which tends to decrease the intake of water and nutrients, in addition to causing toxicity in the body by the absorption of toxic ions (19-22).

Saline stress is one of the adverse environmental factors that influence aspects of the physiology of plants, which, in turn, limits the productivity of crops of economic interest. Salinity reduces the capacity of plants to absorb water, causing a reduction in the growth and number of leaflets (1,21).

When evaluating performance indicators and their components under conditions of a non-saline soil and the other affected by salts, it is shown that the components pods per plant and grains per plant, showed reductions in all the lines due to the presence of salts in the soil, when significant differences were found between treatments in normal and saline soils.

Under normal soil conditions, there were no differences between the lines for the pods indicator per plant, but when they were grown in the saline soil. The VAM 13 and VAM 14 lines showed the best results in these conditions, while VAM 17 and VAM 43 were the most affected.

For the grain-by-plant indicator, the VAM 13 and VAM 14 lines showed the best response under normal conditions and in saline conditions, likewise, the 100-grain mass did not show variations between bean lines in each type of soil, but did show variations significant differences between the non-saline and saline soils, which showed that this indicator is also affected when salts are present in the soil (Table 3).

Regarding yield in the field, significant differences were found between the lines sown in the two types of soil studied, with VAM 13, which showed the highest yield potential in both conditions, although its reduction was significant in the soil affected by salts. Meanwhile, variety VAM 43 was the lowest yield in both experimental conditions (Table 4).

Table 3. Amount of pods and grains per plant of different bean lines grown in a saline soil and in another non-saline one

Lines	Pods per plants		Grain per plants	
	Control	Saline	Control	Saline
VAM 13	12^{a}± 0,85	8^{b}± 0,57	54^{a}± 0,67	40^{c}± 1,35
VAM 14	11^{a}± 0,43	7^{b}± 0,80	52^{a}± 0,99	38^{c}± 0,95
VAM 17	10^{a}± 0,46	3^{c}± 0,97	49^{b}± 1,14	20^{d}± 0,55
VAM 43	9^{ab}± 0,99	5^{c}± 0,39	46^{b}±1,53	20^{d}± 0,78
ESx	0,11	0,17	0,31	0,57

Means with equal letters are not statistically different when applying the Tukey Test (p≤0,05)

Table 4. Mass of 100 grains and the yield of different bean lines grown in a saline soil and in another non-saline soil

Lines	Mass 100 grains (g)		Yield (t ha^{-1})	
	Control	Saline	Control	Saline
VAM 13	25^{a}±0,32	17^{b}±0,72	1,60^{a}±0,02	1,40^{b}±0,08
VAM 14	24^{a}±0,99	16,6^{b}±0,71	1,44^{b}±0,04	1,18^{d}±0,05
VAM 17	22^{a}±1,21	16,3^{b}±1,52	1,25^{c}±0,08	0,88^{e}±0,05
VAM 43	22^{a}±1,06	17^{b}±0,87	1,10^{d}±0,06	0,76^{e}±0,04
ESx	0,21	0,84	0,11	0,08

Means with the same letters are not statistically different when applying the Tukey test (p≤0,05)

The calculation of the inhibition index by salinity on the indicators evaluated in the four bean lines studied, allowed defining the lines of best behavior. The VAM 13 and VAM 14 lines had the lowest values of inhibition of the evaluated indicators, while VAM 17 and VAM 43 were the most susceptible, showing values of inhibition significantly higher than the rest of the bean lines studied (Table 5).

The affectations that manifest in conditions of salinity in the yield of crops and their components are the result of a series of chemical, physiological and biochemical damages and in turn a series of metabolic, enzymatic and hormonal responses that they experience since the plants begin their germinative process, until the end of its biological cycle (18,23,24).

On the effect of salinity on the yield and its components, numerous investigations have been developed in different crops and the results coincide in that such affectations in the plants cultivated under stress conditions, are due to the biochemical variations of the physiological processes and important, the concentration and relation of endogenous hormones that stimulate and inhibit growth and development that are reflected in agricultural performance (25-28).

In saline soils, the predominance of chloride salts and sodium sulphate produces an osmotic effect due to the high content of salts; however, other types of damage such as the specific toxicity produced by the over accumulation of toxic ions is also present (18). On the other hand, they begin to observe interferences in the metabolism and damages that, as a consequence, take place in organelles and membranes, alterations in the functionality of the membrane, inhibition of photosynthesis, repercussion in transport mechanisms and selectivity and derivation of part of the metabolic energy of the plant, all of which may have induced a decrease in growth, development and yield and its components in the lines studied (29,30).

In several salinity tolerance assessment works, it was concluded that the agricultural yield decreases significantly with the increase in saline levels and it depends to a large extent on the degree of tolerance of the variety and the species, therefore its evaluation under conditions field is important, as well as its complementation with studies of water relations in the vegetative stage (31-33).

Table 5. Index of inhibition of plant height, pods by plants, grains per plant, weight of 100 seeds and yield of different bean lines grown in a saline soil and in another non-saline one

Lines	Inhibition Index					
	Plant height	Number of leaflets	Pods plants^{-1}	Grains plant^{-1}	Weight 100 seeds	Yield (t ha^{-1})
VAM 13	20^{c} ±0,45	14^{c} ±0,27	33,3^{c} ±0,61	25,9^{c} ±0,41	27,2^{c}±0,54	12,5^{c}±0,36
VAM 14	16^{d} ±0,22	16,6^{b}±0,59	36,3^{c} ±0,7	26,9^{c} ±0,13	33^{a} ±0,87	18,05^{b}±0,2
VAM 17	43,6^{b}±0,52	58,2^{a}±0,38	70^{a} ±0,85	59,1^{a} ±0,82	31,7^{b}±0,13	29,6^{a}±0,58
VAM 43	53,6^{a}±0,65	58,2^{a}±0,61	44,4^{b} ±0,65	56,52^{b} ±0,79	28,5^{c}±0,56	30,9^{a}±0,9

Means with equal letters are not statistically different when applying the Tukey Test (p≤0,05)

CONCLUSIONS

The bean lines evaluated had significant effects on the growth and yield indicators and their components evaluated for the presence of salinity in the soil. The VAM 13 and VAM 14 lines showed the best response to salt stress due to having the lowest values of inhibition in the evaluated indicators. These results allow complementing the studies that are carried out in order to increase the survival of this crop under conditions of salt stress.

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