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Extraction of K^+, Ca^{2+}, Mg^{2+}, Na^+ in saline soil by mono or multi-germ sugar beet

Extracción de K^+, Ca^{2+}, Mg^{2+}, Na^+ en suelo salino por remolacha azucarera mono o poligermen

Extração de K^+, Ca^{2+}, Mg^{2+}, Na^+ em solo salino pela beterraba sacarina mono o poligérmen

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Abstract

Approximately 33 % of surface of irrigated valleys in Peruvian northern coast, has a bad drainage or salinity problem. Sugar beet has good yields in those soils (90 $t.ha^{-1}$). The objective of present work was to know if in those soils there is a relationship between soil K, Ca, Mg, Na, and its extraction by sugar beet, and if they contribute with crop salinity tolerance. Experiment was made in Chicama valley, with randomized complete block design, ten treatments: five multi-germ cultivars, five monogerm; six replications. In each plot five soil sub-samples were taken, mixed in the field making one sample per plot, and available K, Ca, Mg, Na analyzed. Sugar beet extractions of those elements were evaluated in buried dry bio mass (roots) and aerial (leaves + crowns). Sugar beet mono or multi-germ did not absorb more K, Ca, Mg, Na if their quantity augmented in soil; for that is not an efficient soil “reclamator”. K and Na contributed to sugar beet salt tolerance, Ca could give salt tolerance, Mg had any action in salt tolerance. In those soils where there are large amounts of $CaCO_3$, Ca was absorbed with low or high available Ca soil amounts. Na contributed to salt tolerance because it was “included”. Mono or multi-germ showed no differences “including” nutrients.

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Resumen

Aproximadamente el 33 % de la superficie de los valles áridos irrigados en la costa norte peruana, presenta problemas de salinidad o mal drenaje. La remolacha azucarera tiene buenos rendimientos en dichos suelos (90 $t.ha^{-1}$). El objetivo de este trabajo fue determinar si en dichos suelos hay una relación entre K, Ca, Mg, Na, y su absorción por la remolacha azucarera, y si contribuyen con la tolerancia a la salinidad. El experimento se instaló en el valle Chicama, diseño estadístico en bloques completos al azar, diez tratamientos: cinco cultivares poligermen, cinco monogermen; seis repeticiones. De cada una de las parcelas se tomaron cinco submuestras de suelo, se mezclaron en el campo, haciendo una muestra por parcela, donde se analizó K, Ca, Mg, Na disponibles. La cantidad de dichos elementos extraídos del suelo por el cultivo, se evaluó con la biomasa seca subterránea (raíces) y aérea (hojas + coronas). La remolacha (mono o poligermen) no absorbió más K, Ca, Mg, Na, si su cantidad aumentaba en el suelo; por lo que no es un eficiente "mejorador" del mismo. K y Na contribuyeron con la tolerancia a la salinidad, Ca pudo actuar dando tolerancia a la salinidad, Mg no tuvo ningún papel en la tolerancia. En dichos suelos donde hay altos contenidos de $CaCO_3$ se absorbió el Ca con contenidos disponibles bajos o altos. Na contribuyó a la tolerancia a la salinidad porque fue "incluido". Mono o poligermen no muestran diferencias "incluyendo" nutrientes.

Palabras clave: cationes, cultivares, Perú, salinidad, tolerancia a las sales

Resumo

Aproximadamente 33 % de superfície dos vales áridos irrigados na costa norte do Peru apresenta problemas de salinidade ou má drenagem. A beterraba sacarina tem bons rendimentos nesses solos (90 $t.ha^{-1}$). O objetivo deste estudo foi determinar se existe relação entre K, Ca, Mg, Na e sua absorção pela beterraba sacarina, e se eles contribuem para a tolerância à salinidade. O experimento foi instalado no vale Chicama, com o delineamento estatístico em blocos completos casualizados com dez tratamentos: cinco cultivares de poligermes, cinco monogermes; seis repetições. Para cada uma das parcelas se tomaram cinco sub-mostras do solo, fueiro misturadas o campo, faceando uma mostra por parcela donde foram analisados os K, Ca, Mg, Na disponíveis. A quantidade desses elementos extraídos do solo pela cultura foi avaliada com a biomassa seca subterrânea (raízes) e aérea (folhas + copas). A beterraba (mono o poli germe) não absorveu mais K, Ca, Mg, Na, se sua quantidade aumentou no solo; portanto, não é um "melhorador" eficiente dele. K, Na contribuiu para a tolerância à salinidade, Ca pode atuar para dar tolerância à salinidade e Mg não teve papel na tolerância ao sal. Nesses solos onde há altos teores de $CaCO_3$, o Ca foi absorvido com baixos ou altos teores disponíveis. Na contribuiu para a tolerância à salinidade porque foi "incluído". Mono o poli germe na mostra diferences "incluindo" nutrimentos.

Palavras-chave: cátions, cultivares, Peru, salinidade, tolerância à salinidade

Introduction

Salinity and poor drainage soils problems occurred and occur in 33 % of irrigated arid valleys on coast of Peru (Masson, 1973; MINAGRI, 2020). Most of these soils, potentially arable are in marginal areas, have a high to very high concentration of salts: more than 15 $dS.m^{-1}$ (MINAGRI, 2020; Alva *et al.*, 1976). Rehabilitation of these soils is a national need, but large investments are required for efficient drainage and reclamation works, which are limited by the scarce sources of good quality water (MINAGRI, 2020; Alva *et al.*, 1976). However, an economical solution in recovery of these soils could be the use of salinity tolerant plants, such as sugar beet (*Beta vulgaris* L. subsp. *vulgaris* var. *altissima* Döll) (Misra *et al.*, 2020; Tayyab *et al*., 2023). In Peru, research work has been done with sugar beet in saline soils in 1980, and it was shown that is a profitable crop which produces 90 $t.ha^{-1}$, develops in soils with high salinity (around 11.45 $dS.m^{-1}$) that do not allow any other crop economically (Reynoso *et al*., 2001); but there is no bibliographic evidence that the crop absorbs more nutrients from these soils, if they are more abundant in it.

The amount of K^+, Na^+, $-NH_2$ amino solutes in beet plant contribute to its high tolerance to frost (Reinsdorf *et al.*, 2013), as well as its "osmolality" (Loel and Hoffmann, 2015). Betaine in grape, contribute to tolerance to frost, as well as to salinity in the soil (Kandilli *et al.*, 2024), as in other crops (Kurepin *et al.*, 2015); betaine is synthesized and stored in beet (Loel and Hoffmann, 2015). The first mentioned authors affirm that betaine, as well as the stress produced by drought or salinity, induce the expression of genes (*wcor* 410, and *wcor* 413) responsible for response to low temperatures; and that tolerance to stress due to osmosis-tolerance (Kandilli *et al.*, 2024; Kurepin *et al.*, 2015) produced by dehydration due to salinity, drought, or cold, are associated with certain "osmolytes".

Tolerance to drought, frost, salinity in sugar beets is controlled by the same physiological processes, basically the ones mentioned in last paragraph (El-Sarag and Moselhy, 2013; Abbasi *et al.*, 2018). In other species, tolerance to salinity is given by exclusion of chloride and inclusion of sodium, there is accumulation in aerial part of sodium and potassium, implies a mechanism of vacuolar compartment of sodium, which prevents its toxicity in the cytoplasm, where it inhibits enzymatic reactions. Vacuolar compartment of sodium occurs in aerial parts, but not in roots. While potassium acts as an "osmoticum" (osmotic agent) (Hamrouni *et al.*, 2011). Ca contributes to drought tolerance, improving efficiency of mineral nutrition, sugar metabolism, and redox status (Hosseini *et al.*, 2019), and tolerance to salinity due to its protection to cellular compounds (Hamrouni *et al.*, 2011).

Objective of this work was to determine if in saline areas of irrigated arid valleys of northern Peruvian coast, the greater the amount of nutrients K, Ca, Mg, Na, in soil, their absorption by sugar beet increases, and whether these nutrients contribute to tolerance to salinity and if there are differences among mono or muti-germ sugar beet cultivars.

Materials and methods

This experiment was carried out in an arid irrigated valley, in La Grama field (7°53'22" S; 79°17'53" W; 20 masl), in Casa Grande, on the north coast of Peru (Chicama Valley). Arid coast of Peru is classified as a hyper-arid region (UNESCO, 1977; Galán *et al.*, 2010), subtropical desert (Tosi, 1960) or subtropical desiccated desert (Guerrero *et al.*, 2019). Area under study has an annual rainfall generally less than 25 mm, average temperature of 20.5°C (between 15 and 25°C), relative humidity of 82.5 % (between 74 and 90 %), daily evaporation of 4.6 mm; this climate does not have major changes over time (SENAMHI, 2020). Soils belong to Entisols order according to the "Soil Taxonomy" classification (Luzio *et al.*, 1982), Fluvisols according to FAO (2016).

Experiment was done in a randomized complete block design with ten treatments: five cultivars of sugar beet, multi-germ (Maroc, Marina, Magna, Regina, Tribel), five mono-germ (Mono Hy6, Mono 3190, Mono HyD2, HH 30 Hybrid, Mono 4006); six replications for each cultivar, in accordance with the methodology published by Reynoso *et al.* (2001). Plots were 1.6 m wide (four rows), 20 m long (32 m²). Only the two central furrows (16 m²) were evaluated. Direct sowing was done, furrows irrigation was initially every three days until the establishment of the crop (20 days), then continuing with irrigation by gravity (furrows), every 10- or 15-days during development, and every 20 days until harvest, with a total of 5685 $m^3.ha^{-1}$ (568.5 mm). The sowing was on April 25, 1980, and it was harvested after 186 days when crop was ripe according to its sucrose content. No hormones or herbicides were applied (weeds were controlled manually), no ridging, and 180 kg $N.ha^{-1}$ were applied before the first month of age, phytosanitary controls were made when necessary with chemical products (Reynoso *et al.*, 2001). From each of the plots (60 in total), five soil sub-samples were taken at three depths (0-30, 30-60, and 60-90 cm), distributed (each four meters) along the entire furrow and mixed in the field, making one sample per depth and per plot. In these samples, saturation percentage, pH, electrical conductivity of the saturation extract (CEe), $CaCO_3$, organic matter (OM), total nitrogen (N*t*), available N (N*a*) (sum of the nitric nitrogen and of the ammonium nitrogen), available phosphorus (P*a*) with the modified Olsen method, available K, Ca, Mg, Na, were analyzed (Estefan *et al*., 2013) (table 1).

Table 1. Average results of 60 soil analysis of all experimental plots, in its average layer of 0 to 60 cm depth.

% Saturation	pH Paste	ECe dS.m^{-1}	CaCO3 %	OM %	Nt %	Na kg.ha^{-1}	Pa kg.ha^{-1}
50.5	7.9	11.45	4.77	3.07	0.17	81.9	83.6
SOLUBLE CATIONS in mg.100g^{-1}				AVAILABLE CATIONS in kg.ha^{-1}			
Ca^{2+}	Mg^{2+}	K^+	Na^+	Ca^{2+}	Mg^{2+}	K^+	Na^+
0.88	3.08	0.62	4.27	22,587	6,657	4,552	6,854

ECe: Electrical Conductivity of saturation extract, **OM**: Organic Material, **Nt**: Total-N, **Na**: Available-N (estimated), **Pa**: Available-P (Modified Olsen method).

In order to know the amount of K, Ca, Mg, Na extracted from the soil by sugar beet, fresh and dry underground (roots) and aerial (leaves + crowns) biomass was evaluated (Estefan *et al.*, 2013), the concentration of these elements were expressed in $kg.ha^{-1}$.

Regressions were carried out using the Excel computer program between the content of K^+, Ca^{2+}, Mg^{2+}, Na^+ in the plant (leaves + crowns, root, and total) and the content of those elements available in the soil; also soil Ca – plant K, plant Ca-K, plant Ca-Mg, in the layer average of 0-30, 30-60 cm depth, in the ten cultivars of sugar beet studied.

Results and discussion

Relationship of K in the plant and K in the soil

There was a tendency to increase K in plant when K in soil increased in the ten cultivars (table 2), although in six of them no significant statistical relationships were found (Marina, Magna, Regina, Tribel, Mono Hy6, Mono Hy2).

A significant relationship was found in Maroc cultivar, the higher the K in soil, concentration in crown + leaves increased (R^2 = *0.66*) and also in total plant (R^2 = *0.76*), being a not "strong" relationship, is not highly significant. Regression coefficient (0.0225) indicates little increase in extraction of K by plant as its quantity in soil increases. There was a significant response in Mono 3190 in total plant (R^2 = *0.77*). In this same cultivar there was a highly significant relationship (R^2 = 0.96**)** between K in soil and in root. In HH 30 Hybrid, the relationship between K of soil and leaves + crowns had R^2 = *0.80*. In Mono 4006, there was a significant relationship for K in soil and K in roots (R^2 = *0.81*). There was significant correlation in four of the ten cultivars, one mono-germ, three multi-germ, showing a little more tendency in multi than in mono-germ; which would explain the lack of research work on the increase in the absorption of K by beet, with its increase in the soil, despite being a very important nutritive element (Mahapatra *et al.*, 2020) and, for its tolerance to salinity (Hamrouni, *et al.*, 2011).

Although the tolerance to drought, salinity and frost of beet is controlled by the same physiological processes that involve K (Loel and Hoffmann, 2015) which acts as an "osmoticum" (Hamrouni *et al.*, 2011) an increase of its content in soil, due to increased salinity, or to any other reason, a little more K will be absorbed, but not much more, so the crop is not a more efficient soil "improver" of soils extremely rich in K, meaning in the best of cases an increase of 85.3 $kg.ha^{-1}$ of K in the plant by an increase of 1000 $kg.ha^{-1}$ in the soil (regression coefficient 0.0853 in Mono 3190), which indicates that its effect as an osmotic agent ("osmoticum") is manifested due to the great absorption of that nutrient (between 295 and 782 $kg.ha^{-1}$: "a" of the formulas of the regression lines), not requiring more, even if it is abundant in the soil. On the other hand, more K increases osmotic pressure of guard cells and for this its turgidity and stomata opens, photosynthesis increases (act as an "osmoticum") requiring a limited quantity of K.

The content in $kg.ha^{-1}$ of K was higher in root than in aerial part (leaves + crowns) in most cultivars, despite that concentration of K in root ranged between 1.75 and 2.05 %, and in leaves + crowns between 4.83 and 6.06 %; since roots weighed more than leaves + crowns (70 % of the total, roots, 30 % leaves + crowns, although for K the ratio is 60 - 40 %), except for Mono Hy6, Mono 4006 where the amounts were similar, and Mono HyD2 (Table 2) where it was higher in leaves + crowns. K concentration in aerial part, is inverse in non-saline and neutral soils, from 3.5 to 6 % (roots) and from 1.3 to 3.0 % (leaves + crowns) (Midwest Laboratories, 2020), having higher amounts in non-saline and calcareous soils in aerial part, ranging between 1.8 and 6.0 with an average of 4.2 % (Dursun *et al.*, 2017) being in the latter case closer to those of the present experiment, which suggests that the high concentrations of leaves + crowns is due to calcareous characteristics of soil; not improving its absorption, because there are not statistical relationship between quantity of Ca in soil and K in plant (only Mono HyD2, total plant, significant) neither between Ca and K in plant, but improving soil structure, water availability, and photosynthesis, promoting migration of K from roots to leaves.

It is not clear if there was "exclusion" of K as a mechanism of tolerance to salinity (it remains in root, and does not move towards aerial part), or "inclusion" (it moves towards aerial part), as a contribution to tolerance to salinity as stated by Hamrouni *et al.* (2011) for the vine, showing its "osmoticum" in aerial parts. It could be that "osmoticum" capacity of beets to tolerate salts is manifested in whole plant, roots or leaves + crowns.

Table 2. Regression equations and determination coefficients (R^2 values in brackets; n=6) of available elements in soil and its extraction by sugar beet.

Element	Cultivar	Root	Leaves+crowns	Total
K	Maroc	345.2+0.01X (0.57)	238.5+0.01X (0.66)	583.7+0.02X (0.76)
	Marina	318.5+0.03X (0.54)	212.1+0.00X (0.03)	530.6+0.03X (0.46)
	Magna	318.2+0.02X (0.58)	374.0-0.01X (0.64)	681.4+0.00X (0.04)
	Regina	268.6+0.04X 0.36)	155.9+0.02X (0.47)	424.4+0.05X (0.43)
	Tribel	366.0+0.01X (0.22)	475.3-0.02X (0.30)	782.5-0.00X (0.00)
	Mono Hy6	281.5+0.01X 0.26)	275.8+0.01X (0.45)	557.2+0.02X (0.48)
	Mono 3190	165.9+0.06X (0.96)	129.3+0.02X (0.28)	295.2+0.09X (0.77)
	Mono HyD2	321.6+0.01X (0.16)	342.3+0.02X (0.18)	664.0+0.03X (0.26)
	HH 30 Hybrid	328.4+0.01X (0.29)	173.4+0.01X (0.80)	501.8+0.02X (0.63)
	Mono 4006	274.1+0.02X (0.81)	299.4+0.01X (0.10)	573.6+0.03X (0.47)
Ca	Maroc	27.0+9E-05X (0.10)	31.8+0.00X (0.19)	58.8+0.00X (0.20)
	Marina	20.2+0.00X (0.24)	16.4+0.00X (0.48)	36.6+0.00X (0.44)
	Magna	18.4+0.00X (0.12)	1.94+0.00X (0.48)	15.9+0.00X (0.71)
	Regina	24.6+0.00X (0.15)	24.6+0.00X (0.27)	49.1+0.00X (0.42)
	Tribel	16.2+0.00X (0.46)	35.8+0.0X (0.18)	49.6+0.00X (0.24)
	Mono Hy6	2.0+0.00X (0.66)	42.3+0.00X (0.10)	44.3+0.00X (0.31)
	Mono 3190	6.7+0.00X (0.90)	22.5+0.00X (0.48)	29.2+0.00X (0.75)
	Mono HyD2	10.3+0.00X (0.68)	40.8+0.00X (0.27)	51.1+0.00X (0.42)
	HH 30 Hybrid	18.0+0.00X (0.10)	25.7+0.00X (0.21)	43.6+0.00X (0.17)
	Mono 4006	13.8+0.00X (0.15)	13.4+0.00X (0.43)	27.2+0.00X (0.39)
Mg	Maroc	72.0-0.00X (0.20)	52.7+0.00X (0.01)	124.7-0.00X (0.02)
	Marina	53.0+0.00X (0.05)	48.5-0.00X (0.08)	101.5-0.00X (0.01)
	Magna	86.4-0.00X (0.34)	40.9+0.00X (0.08)	127.0-0.00X (0.07)
	Regina	64.6-0.00X (0.05)	19.3+0.00X (0.29)	83.9+0.00X (0.07)
	Tribel	82.4-0.00X (0.23)	62.4+0.00X (0.01)	166.6-0.00X (0.06)
	Mono Hy6	24.2+0.00X (0.44)	33.3+0.00X (0.33)	57.5+0.01X (0.53)
	Mono 3190	59.9-0.00X (0.03)	43.8+0.00X (0.01)	103.6-0.00X (0.03)
	Mono HyD2	54.5+0.00X (0.01)	78.4-0.00X (0.03)	132.9-0.00X (0.00)
	HH 30 Hybrid	52.9+0.00X (0.06)	25.1+0.0X (0.10)	78.0+0.00X (0.15)
	Mono 4006	46.2+0.00X (0.08)	14.5+0.00X (0.36)	60.8+0.00X (0.31)
Na	Maroc	68.5+0.01X (0.20)	280.1+0.02X (0.35)	348.6+0.03X (0.48)
	Marina	49.0+0.01X (0.79)	223.4+0.01X (0.19)	272.4+0.02X (0.39)
	Magna	97.4+0.00X (0.06)	182.9+0.03X (0.94)	264.7+0.03X (0.93)
	Regina	194.0-0.01X (0.08)	279.5-0.00X (0.00)	473.6-0.01X (0.03)
	Tribel	58.0+0.01X (0.11)	526.4- 0.01X (0.15)	567.9+0.02X (0.00)
	Mono Hy6	59.5+0.00X (0.28)	257.5+0.02X (0.39)	316.9+0.02X (0.41)
	Mono 3190	233.5-0.02X (0.39)	371.5-0.02X (0.07)	605.1-0.04X (0.21)
	Mono HyD2	61.7+0.00X (0.32)	622.2-0.02X (0.19)	683.9-0.02X (0.14)
	HH 30 Hybrid	95.6-0.00X (0.01)	230.0+0.01X (0.11)	325.6+0.01X (0.07)
	Mono 4006	46.9+0.01X (0.70)	253.9+0.01X (0.52)	300.8+0.02X (0.70)

Relationship of Ca in the plant and Ca in the soil

As in K, there was a tendency to increase Ca in plant, when Ca increased in soil (Table 2). In six of the ten cultivars no significant statistical relationships were found (Maroc, Marina, Regina, Tribel, HH 30 Hybrid, and Mono 4006). Regression coefficients had lower slopes than in the case of the previous element, meaning in the best case (Magna) an increase of 27 $kg.ha^{-1}$ of Ca in plant by an increase of 1000 $kg.ha^{-1}$ in soil. A significant relationship was found in Magna where there was an increase in Ca in total plant when Ca increased in soil (R^2 = *0.71*). A significant relationship in Mono Hy6 where increasing Ca in soil, Ca in roots increased (R^2 = *0.66*). A significant relationship in Mono 3190, an increase in Ca in total plant when Ca increased in soil (R^2 = *0.75*), and a highly significant relationship in roots, when Ca increased in soil (R^2 = 0.90). In Mono HyD2 there was a significant relationship between the increase in Ca in roots with the increase in soil (R^2 = *0.68*). Lower extraction of Ca from soil varied only between 16 and 59 $kg.ha^{-1}$, much less than that extracted by Hamrouni *et al.* (2011) found that the accumulation of Ca is not modified by saline stress, coinciding with the present experiment, where its content varied very little with its increase in soil, that is, with salinity, which would demonstrate that this crop is not a more efficient "improver" of them, than in saline soils with lower calcium content. Likewise, in soils of the Peruvian coast, where there are high contents of $CaCO_3$, this nutrient is absorbed with low contents of available Ca or with high, in relatively low quantities, so that they will not be presented deficits of this element, which is very important for the crop (Hosseini *et al.*, 2019).

There was more Ca in aerial part than in root, except in Marina, Regina, and HH 30 Hybrid (Table 2), where contents were similar in root and aerial part. Ca is clearly "included"; however, scientific literature does not include Ca as an ion that can act to give crops tolerance to salinity "including" it (Hadi and Karimi, 2012) although it may be less absorbed if a lot of Na is absorbed by the plant in saline soils (Haouala *et al.*, 2007) or vice versa (Artyszak *et al.*, 2014). In this case, its effect of providing tolerance to salinity would not be due to its "osmoticum", or to its vacuolar compartment, but to its protection of cell compounds (Hamrouni *et al.*, 2011), or to its effect on cell membranes or in transport and selectivity of ions, or in the improvement of ion exchange (Hadi and Karimi, 2012); or by the mechanisms that act giving resistance to the plant to drought (Hosseini *et al.*, 2019); those who would work in the aerial or underground part.

Relationship of Mg in the plant and Mg in the soil

Contrary to K and Ca, Mg did not increase in plant when Mg increased in soil, and no significant statistical correlations were found in all cultivars (Table 2). There was a slight tendency to increase only in Mono Hy6, Mono 4006. As with K and Ca, in soils with excessive levels of Mg, there is no efficiency as a crop "improver". There was not relationship between Ca and Mg in plant (only Regina total significant, leaves + crowns highly significant; Tribel leaves + crowns significant) ratifying the relative low quantities of Ca absorbed even if there are high contents of $CaCO_3$. Mg extraction from soil varied between 57 and 166 $kg.ha^{-1}$, greater than that of Ca, but less than that of K.

It was observed that the amount of Mg in the aerial part was similar to that of the root, except in Marina, Regina, HH 30 Hybrid, where the quantity was higher in the root than in the leaves + crowns. Mg is not included or excluded, which indicates that it has no role in tolerance to salts that sugar beet has, or to frost, since it is an element that is not mentioned in the scientific literature for this purpose (Reinsdorf *et al.*, 2013), nor probably with drought resistance (El-Sarag *et al.*, 2013; Abbasi *et al.*, 2018).

Relationship of Na in the plant and Na in the soil

There was a tendency to increase Na in plant when Na in soil increased in Maroc, Marina, Magna, Mono Hy6, HH 30 Hybrid, Mono 4006, with slopes similar to those of K (Table 2) ratifying the importance of soil $CaCO_3$ improving soil structure and promoting K and Na absorption. There was no such trend in the rest of cultivars, where it was maintained or decreased. Significant statistical correlations were found only in Marina where the higher Na in soil, the higher in root (R^2 = *0.79*), in Magna highly significant, when Na in soil increased also did it in total plant (R^2 = 0.93) and in leaves+ crowns (R^2 = 0.94), and Mono 4006 the greater Na in soil, significantly more Na in total plant (R^2 = *0.70*), and a greater amount of Na in soil significantly more Na in roots (R^2 = *0.70*).

Extraction of Na by crop is very high, between 264 and 683 $kg.ha^{-1}$, less than that of K, showing much greater variation than K, with amounts greater than Mg, similar to those of K. There was no increase of Na in plant with increase of Na in soil, indicating that sugar beet did not act as an efficient "improver" of that nutrient, as what happens with K, Ca, Mg. For greater tolerance to saline soils, which often have Na in abundance, beet does not need to absorb this element any more, indicating that although Na contributes to resistance to salinity, drought, frost (El-Sarag *et al.*, 2013; Abbasi *et al.*, 2018), its content in plant is independent of whether there is more or less Na in soil.

Na content was higher in aerial part (leaves + crowns) than in root in all cultivars (Table 2), despite the fact that roots weighed considerably more than leaves + crowns (70 % of total roots, 30 % leaves plus crowns). Its concentration was much higher in crowns + leaves, where it ranged between 5.77 and 7.80 % than in roots (between 0.45 and 0.70 %). There is more absorption in the aerial part, having "inclusion" of this element as a mechanism of tolerance to salinity of soil, that is, it does not remain in root, but moves to aerial part, as stated by Hamrouni *et al.* (2011) for the vine. This confirms that Na is important for tolerance to salinity, drought, and frost (Reinsdorf *et al.*, 2013; El-Sarag *et al.*, 2013; Abbasi *et al.*, 2018).

Conclusions

Sugar beet, mono or multi-germ, in soils with levels greater than 5000, 25000, 7000, 8000 $kg.ha^{-1}$ of K, Ca, Mg, Na, did not absorb more these elements if their quantity increased in soil, so it was not a more efficient "improver" of soil, than in saline soils with lower contents of those elements. K did not show more absorption in aerial part, did not move to it ("inclusion") nor did it stay in the root ("exclusion") as a mechanism of tolerance to salinity. Ca was "included" although scientific literature does not include Ca as an ion that can act to give tolerance to salinity "including" itself. Mg was neither included nor excluded, indicating that it has no role in salt tolerance of beets. Na showed more absorption in aerial part, there being no "exclusion", it did not remain in root, but moved to aerial part ("inclusion"), as a mechanism of tolerance to soil salinity. Mono or multi-germ are not different in "inclusion" properties of beet.

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