JOURNAL OF THE Selva Andina Biosphere
Official Journal of the Selva Andina Research Society.

Research Article

ISSN 2308-3867 (print edition)
JSAB
ISSN 2308-3859 (online edition)

Influencia de la salinidad sobre el desarrollo de seis especies forrajeras en dos técnicas de implementación, cuenca baja del Río Lauca

Salinity influence in the development of six forage species with two implementation techniques in lower basin of the Lauca River

Paco-Pérez Víctor*, Choque-Marca Willy

Data of the Article

Faculty of Agricultural and Natural Sciences FANS.
Technical University of Oruro TUO.
Av. Dehene between Román Koslowky and León H. Loza (Ciudadela Universitaria).
Tel. + 591-52 61645-52 62735.
Fax. (591-2) 52 61645.
Oruro, Plurinational State of Bolivia.
www.fcan.uto.edu.bo

***Contact address:**
Faculty of Agricultural and Natural Sciences FCAN.
Technical University of Oruro UTO.
Av. Dehene between Román Koslowky and León H. Loza (Ciudadela Universitaria).
Tel. + 591-52 61645-52 62735.
Fax. (591-2) 52 61645.
Oruro, Plurinational State of Bolivia.
Mobile: +591-73720194

Víctor Paco-Pérez
E-mail: vicpaco@hotmail.es

Palabras clave:

Forraje,
salino sódico,
estrés,
siembra,
trasplante.

J. Selva Andina Biosph.
2020; 8(2):110-127.

ID of article: 095/JSAB/2020

Record from the article.

Received June, 2020.
Returned August, 2020.
Accepted September, 2020.
Available online November 2020

Editado por:
Selva Andina
Research Society

Resumen

La acumulación de sales solubles en la zona de raíces de las plantas, limita en gran medida la producción de forrajes en muchas partes del mundo. El objetivo del presente estudio fue evaluar la influencia de la salinidad sobre el desarrollo de las especies forrajeras entre las técnicas de siembra y trasplante. La investigación se realizó a 204 km de la ciudad de Oruro, Bolivia, específicamente en la cuenca baja de río Lauca del territorio de Uru Chipaya a 3640 msnm de altitud, geográficamente entre las coordenadas 19°02'17,40" Latitud Sud y 68°05'16,05" Longitud Oeste; temperatura media anual de 10.4°C, precipitación de 200 a 4000 mm, humedad relativa 70%. Se utilizó seis especies forrajeras: cola de ratón (*Hordeum muticum* J. Presl), cebadilla INTA (*Bromus* sp.), cebadilla nativa (*Bromus catharticus* Vahl.), festuca alta (*Festuca arundinacea* Schreber), alkar (*Agropyron elongatum* (Host) P. Beauv.) y pasto llorón (*Eragrostis curvula* (Schrad.) Nees). Las variables evaluadas fueron: emergencia, mortalidad, altura planta (AP), número macollo (NM) y materia seca (MS). Se utilizó un diseño experimental bloques completos al azar con cuatro repeticiones por especie. En trasplante presentaron alta significancia entre las especies, y tuvieron un comportamiento mejor que la técnica de siembra, la AP, NM y MS fueron superiores y la mortalidad fue mínima en todas, la *B. catharticus* Vahl. en 7 dS m^{-1} presentó la mayor biomasa con 166.00 kg MS ha^{-1}, pero a 16 y 22 dS m^{-1} fue afectada gradualmente que solo alcanzó 161.33 y 151.33 kg MS ha^{-1} respectivamente. En la siembra también presentaron diferencias significativas las variables mencionadas, pero fueron inferiores que el trasplante; la especie del trasplante que mostró mejor biomasa en 7 y 16 dS m^{-1}, fue la misma que presentó mayor biomasa de 109.33 y 107.67 kg MS ha^{-1} respectivamente, pero a 22 dS m^{-1} no lograron emerger ninguna especie. Se concluye, niveles altos de salinidad afectan negativamente sobre la germinación, emergencia y desarrollo de las plántulas, con mayor grado en siembra que en trasplante. La mejor opción para implementar especies forrajeras en suelos salinos es mediante la técnica de trasplante de plántulas.

Abstract

The accumulation of soluble salts in the root zone of plants greatly limits the production of fodder in many parts of the world. The objective of this study was to assess the influence of salinity on the development of forage species among planting and transplantation techniques. The research was carried out 204 kilometers from the city of Oruro, Bolivia, specifically in the lower Lauca River basin of the territory of Uru Chipaya at 3640 altitude msnm, geographically between the coordinates 19°02'17,40" Latitude Sud and 68°05'16,05" West Longitude; average annual temperature of 10.4°C, precipitation from 200 to 4000 mm, relative humidity 70%. Six forage species were used: cola de ratón (*Hordeum muticum* J. Presl), INTA cebadilla (*Bromus* sp.), native cebadilla (*bromus catharticus* Vahl.), festuca alta (*Festuca arundinacea* Schreber), alkar (*Agropyron elongatum* (Host) P. Beauv.) and pasto llorón (*Eragrostis curvula* (Schrad.) Nees). The variables evaluated were: emergence, mortality, plant height (PH), number of macollo (NM) and dry matter (DM). A randomized full block experimental design was used with four repetitions per species. In transplant they presented high significance among the species, and had a better behavior than the sowing technique, the PH, NM and DM were superior and the mortality was minimal in all, *B. catharticus* Vahl. in 7 dS m-[1] presented the highest biomass with 166.00 kg DM ha^{-1}, but at 16 and 22 dS m^{-1} it was gradually affected that only reached 161.33 and 151.33 kg DM ha^{-1} respectively. In the sowing the mentioned variables also presented significant differences, but they were lower than the transplant; the species of the transplant that showed better biomass in 7 and 16 dS m^{-1}, was the same that presented bigger biomass of 109.33 and 107.67 kg DM ha^{-1} respectively, but at 22 dS m^{-1} they did not manage to emerge any species. It is concluded, high levels of salinity affect negatively on the germination, emergence and development of the seedlings, with a higher degree in sowing than in transplanting. The best option to implement forage species in saline soils is through the technique of seedling transplantation.

Keywords:

Forage,
sodium saline,
stress,
planting,
transplant.

Introduction

At present, more than 74% of soils with agricultural importance show salinity problems worldwide, of which 33% are under production[1,2]. Around its problem, 3 arable soil ha are being destroyed every minute[3,4] and approximately 1.5 million ha are lost per year, reducing agricultural productivity by around 11 billion dollars[5,6].

Salinity in soils is caused by the accumulation of mineral salts or waters in the form of cationic and anionic electrolytes[7], it can be of natural origin or by anthropogenic actions[8-13], and affect soils physiccochemical properties, which effect adverse in ecological balance[14].

In soil solution, the salts exert on the plant nutrients due to the excessive accumulation of dominant sodium (Na^+) or chloride (Cl^-) ions[15-18], the impact negative is a limit in agricultural soils and forage production, mainly in arid and semi-arid regions[19-22].

High concentrations of salt cause ionic toxicity in plants, water stress, oxidative stress, nutritional disorder, and disorders at the cell membrane[23-25], in addition, reduction in cell development, alterations in metabolic processes and a decrease in the water availability[26-31].

Tolerance or resistance can be defined as the ability of a plant to withstand salinity in the edaphic solution without manifesting adverse effects on developpment[32,33]. Plants have two mechanisms to resist abiotic factors, such as evasion and tolerance, the first consists in avoiding the accumulation of salts and the second consists in the ability not to lose their productive capacity at a determined salinity level[34-39].

The soils of lower basin of the Lauca River, where is the Uru Chipaya indigenous territory. The soils suffer problems by accumulation sodium (Na) (PSI of 27 to 138% and pH> 8). The salts because cause dispersion of organic matter (OM) and clays affecting plant cover and microbial activity[40].

Soil salinity is a significant environmental damage that limits the agroecological potential and represents a considerable socio-economic obstacle for the sustainable development of the different forage species. The objective of this study was to evaluate the influence of salinity on the development of forage species between sowing and transplanting techniques.

Materials and methods

Geographic location. The research was carried out 204 km from the city of Oruro-Bolivia, in the lower basin of the Lauca River in the Uru Chipaya territory, located to the South-West of the Oruro region, North of the Salar of Coipasa and the South of the aquatic axis from Titicaca Lake, Desaguadero River and Poopó Lake and at altitude 3640 m above sea level. Geographically located between the coordinates 19°02'17.40" Latitude South and 68°05' 16.05" Longitude West. 10.4 °C annual mean temperature, maximum 27.2 °C and -18 °C minimum. Average annual precipitation 200 to 4000 mm and 70% annual average humidity relative[40-42].

Soil characteristics. The soils samples were analyzed in Spectrolab Soil and Water Laboratory, Faculty Ciencias Agrarias and Naturales, Technical University of Oruro. The analyzes showed sandy-loamy texture with important Na contents, pH> 8.3 and 2.2 to 2.7% OM content.

Table 1 Physicochemical properties and soil salinity territory at a depth of 3-25 cm

Salinity	dS m^{-1}	pH	Soil texture	ApD g/cm^3	N	OM	Na	Cl^-	Mg	P	K	Ca	CEC
					------ % ------		------------------ meq 100 g^{-1} ------------------						
Moderate	7	9.10	SF	1.35	<0.05	2.20	2.80	6.85	0.80	0.06	0.50	16.30	20.49
Strong	16	8.30	SF	1.31	<0.05	2.70	4.70	12.51	3.90	0.14	0.80	19.20	28.57
Extreme	22	8.60	SF	1.21	<0.05	2.30	6.90	20.69	3.00	0.17	0.80	20.00	30.69

The electrical conductivity was 7 to 22 dS m^{-1} that expresses a high concentration of Na. Nitrogen (N) less than 0.05%, phosphorus (P) between 0.06 to 0.17 meq 100 g^{-1}, potassium (K) from 0.50 to 0.80 meq 100 g^{-1} and cation exchange capacity (CEC) between 20.49 to 30.69. The reports affirm that the lower basin of the Lauca River in Uru Chipaya territory contains high levels of PSI because it is located close to the Salar of Coipasa[40].

Seed. The seeds used in test, were from obtained of semi-arid zones from the department of Oruro and commercial seed. The six forage species evaluated were: cola of ratón (*Hordeum muticum* J. Presl), INTA cebadilla (*Bromus* sp.), native cebadilla (*Bromus catharticus* Vahl.), festuca alta (*Festuca arundinacea* Schreber), alkar (*Agropyron elongatum* (Host) P. Beauv.) and pasto llorón (*Eragrostis curvula* (Schrad.) Nees).

Soil preparation. 6000 m^2 area (500 m^2 for each specie) of soil has prepared (removed) in each Ayllu (Aransaya, Manasaya and Wistrullani) with a disc plow.

Sow. Each species was sown with a density tripled by handballing. The seeds were passed with the harrow for bury the seed[43,44]. This activity was carried out in December 2018.

Seedling production. In the nursery, the 12 x 18 cm polyethylene bags were filled with salinity-free substrate with a proportion 3:1 soil and manure. Each species was sown with 5 to 8 seeds per bag, then it

was watered with tap water for 60 days until the seedlings develop 8 to 10 cm in height.

Transplant. In January 2019, the seedlings were definitively transplanted to saline soils in 500 m^2 at a density of 20 cm between rows and columns.

Evaluation. The variables evaluated were; emergence, mortality, plant height (PH), number of macollo (NM) and dry matter (DM). For the emergency and mortality evaluation, a 0.50 x 0.50 m[45] gauge frame was used. Emergence was evaluated from 7 days after sowing to 30 days and mortality up to 90 days in the two test techniques. Four months after the development of the seedlings, 200 g of green biomass were collected and it was introduced to the stove at 60 °C for 72 h to determine the DM. During the development of the seedlings, there were no pests or diseases, they only showed symptoms of stress caused by the salts that the soils contain.

Experimental design. A randomized full block experimental design with four replications was used. The data were analyzed through the analysis of variance (ANOVA), the Tukey test was used with a confidence interval of 95% ($p < 0.05$)[46].

Results

Emergency and mortality. At sowing, the emergence showed significant differences between the species, *A. elongatum* (Host) P. Beauv., Is the one that emerged in the highest percentage with 42%, followed by *H. muticum* J. Presl, *B. catharticus* Vahl., *Bromus* sp., and *F. arundinacea* Schreber with 31 and 30% respectively, the species of *E. curvula* (Schrad.) Nees was the one that emerged in the lowest proportion with 14% (fig 1A).

Figure 1 Emergence and mortality of the six forage species (AE = *A. elongatum*, HM = *H. muticum*, BC = *B. catharticus*, B = *Bromus* sp., FA = *F. arundinacea* and EC = *E. curvula*) with the sowing technique

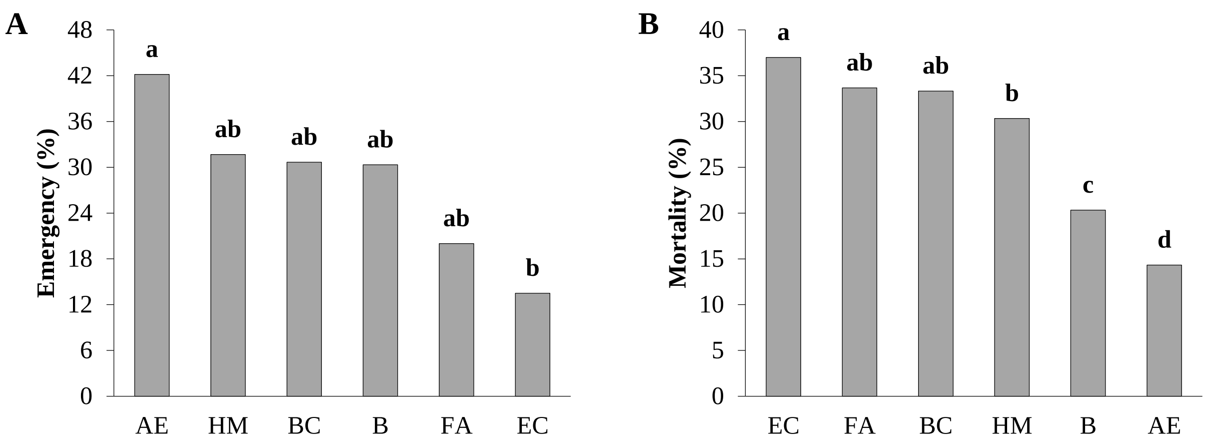
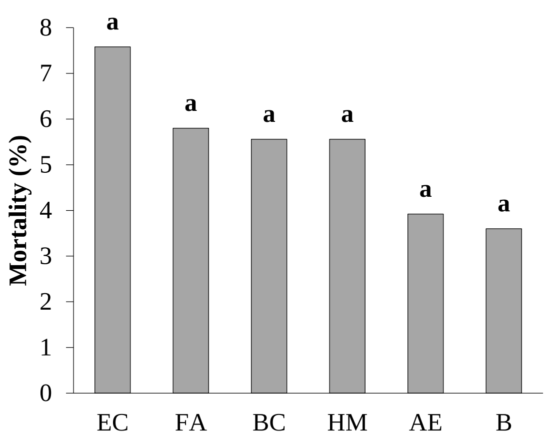
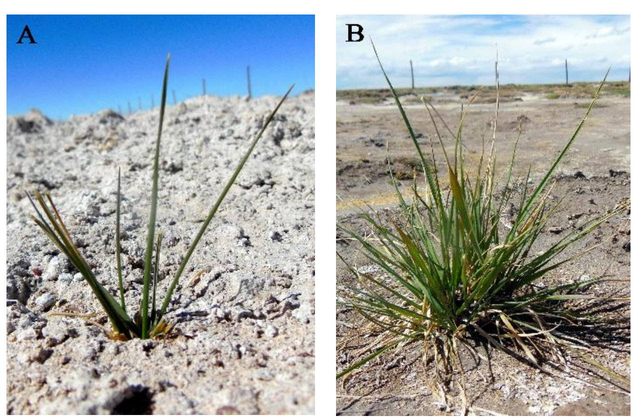


Fig. 2 Mortality of the six forage species (EC = *E. Curvula*, FA = *F. Arundinacea*, BC = *B. catharticus*, HM = *H. Muticum*, AE = *A. Elongatum* and B = *Bromus* sp.) with the soil transplant technique



Mortality showed high differences, the highest mortality that had was *E. curvula* (Schrad.) Nees with 37%, the species of *F. arundinacea* Schreber and *B. catharticus* Vahl., had intermediate mortalities with 34 and 33% respectively and *A. elongatum* (Host) P. Beauv., showed low mortality with 14% (fig 1B).

Fig. 3 Difference between sowing (A) and transplantation (B) in four months of development of *B. catharticus* Vahl. in saline soils



The transplanted seedlings also presented mortalities, but statistically there were no differences, *E. curvula* (Schrad.) Nees presented 8% mortality that is relatively higher compared to the others, the seedlings of *F. arundinacea* Schreber, *B. catharticus* Vahl., *H. muticum* J. Presl, *A. elongatum* (Host) P. Beauv. and *Bromus* sp. showed relatively lower motility (fig 2).

Height, macollo and DM. The sowing technique shows a lower development in PH and NM compared to transplantation (Fig 3A and 3B). In table 2, *B. catharticus* Vahl. presents significant but lower differences than transplantation and *A. elongatum* (Host) P. Beauv. show higher development in PH and NM. *E. curvula* (Schrad.) Nees they had lower development. DM was similar in five species ranging from 101.33 to 109.33 kg ha^{-1}, except *E. curvula* (Schrad.) Nees, showed lower dry biomass in soils of 7 and 16 dS m^{-1}, but in 22 dS m^{-1} none of the species emerged. However, in soils of 7, 16 and 22 dS m^{-1} by means of the transplant technique, the seedlings developed much better than in the sowing, presenting highly significant differences in PH, NM and DM.

Between sowing and transplantation there are significant differences in PH. The transplantation technique showed a high difference with respect to the sowing. *A. elongatum* (Host) P. Beauv. showed remarkable development compared to the sowing technique, likewise *H. muticum* J. Presl, *Bromus* sp., *F. arundinacea* Schreber and *E. curvula* (Schrad.) Nees presented lower development, but superior to sowing (fig 4A).

In transplantation, the species of *A. elongatum* (Host) P. Beauv. showed greater formation of NM against all the species of the sowing (fig. 4B). On the other hand, *B. catharticus* Vahl. and *A. elongatum* (Host) P. Beauv. in transplantation they presented higher DM compared to the others, but the species *E. curvula* (Schrad.) Nees both in sowing and in transplantation presented lower DM (fig 4C).

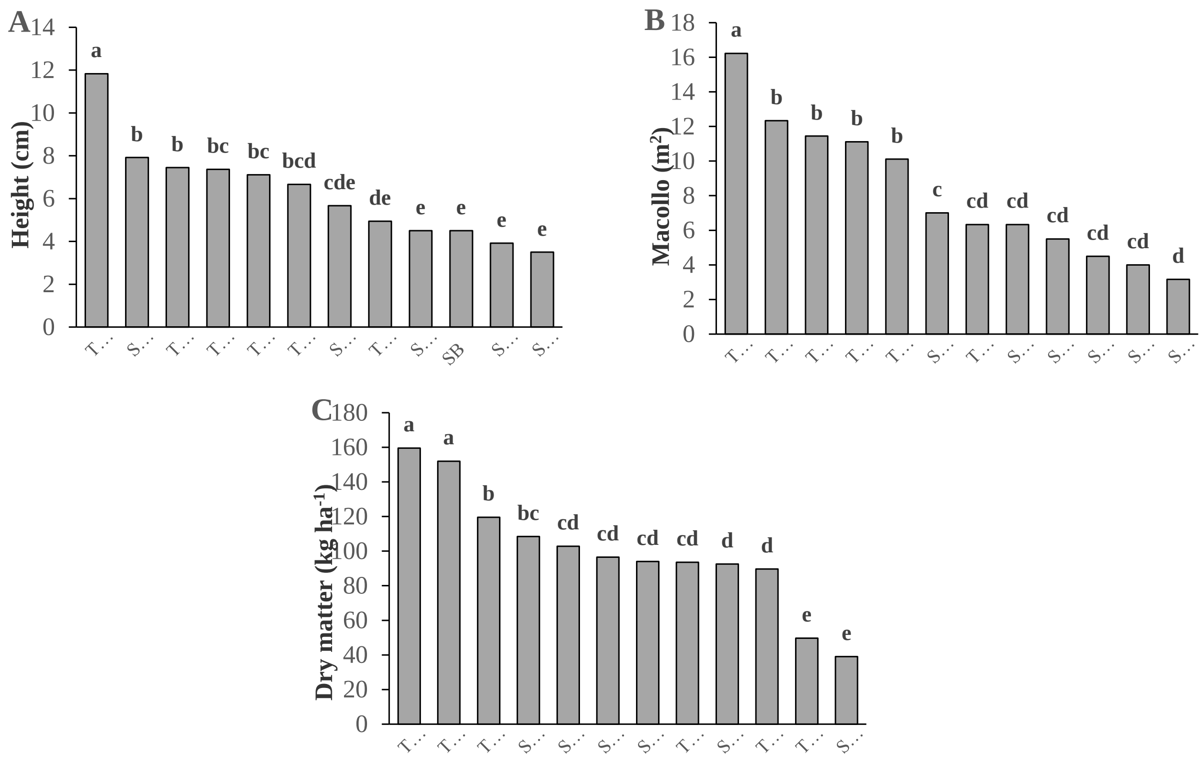
Discussion

Table 2 PH, NM y DM sowing and transplanting in four months of development

Salinity (dS m^{-1})	specie	Sowing			Trasplanting		
		PH (cm)	NM (m^2)	DM (Kg ha^{-1})	PH (cm)	NM (m^2)	DM (Kg ha^{-1})
7	*A. elongatum*	9.00 a	7.67 a	103.30 a	15.50 a	19.67 a	163.33 a
	B. catharticus	6.73 ab	7.00 a	109.33 a	10.67 ab	13.33 ab	166.00 a
	H. muticum	4.50 b	4.67 ab	87.67 a	8.33 ab	10.67 ab	93.00 bc
	Bromus sp.	4.67 b	6.00 ab	86.33 a	10.00 ab	14.33 ab	121.67 ab
	F. arundinacea	4.50 b	4.33 ab	91.67 a	8.67 ab	14.00 ab	103.33 ab
	E. curvula	4.33 b	4.00 b	41.00 b	6.83 b	7.00 b	56.33 c
16	*A. elongatum*	6.80 a	6.33 a	102.33 a	12.00 a	18.00 a	151.00 a
	B. catharticus	4.60 a	5.67 a	107.67 a	6.50 b	12.33 ab	161.33 a
	H. muticum	4.50 ab	4.33 ab	97.33 a	7.33 b	10.33 ab	120.00 bc
	Bromus sp.	4.33 b	5.00 ab	101.67 a	5.67 b	10.00 ab	119.67 b
	F. arundinacea	3.33 b	3.67 ab	101.33 a	5.67 b	9.67 ab	91.67 c
	E. curvula	2.67 b	2.33 b	37.00 b	4.00 b	6.33 b	52.67 d
22	*A. elongatum*	0.00	0.00	0.00	8.00 a	11.00 a	141.67 a
	B. catharticus	0.00	0.00	0.00	5.17 ab	11.33 a	151.33 a
	H. muticum	0.00	0.00	0.00	5.17 ab	9.33 ab	85.67 c
	Bromus sp.	0.00	0.00	0.00	4.83 ab	10.00 ab	117.33 b
	F. arundinacea	0.00	0.00	0.00	4.33 ab	9.67 ab	74.00 c
	E. curvula	0.00	0.00	0.00	3.83 b	5.66 b	40.00 d

All the species planted in saline soils were reduced in their emergence. No species managed to emerge more than 42%, emergence has been limited reaching even 14% in *E. curvula* (Schrad.) Nees (fig 1A), it is confirmed that each species has genetic variability to the tolerance of salinity, and that the most vulnerable stage to adapt is during germination and early development. The results are similar to the statements where they indicate that each seed requires a certain percentage of water for its activation[47-49]

Fig. 4 Difference of PH, NM and DM between sowing (SEC = *E. curvula*, SFA = *F. Arundinacea*, SBC = *B. catharticus*, SHM = *H. muticum*, SAE = *A. elongatum* and SB = *Bromus* sp.) and transplantation (TEC = *E. curvula*, TFA = *F. arundinacea*, TBC = *B. catharticus*, THM = *H. muticum*, TAE = *A. elongatum* and TB = *Bromus* sp.) on four months of development



Tolerance of the species to salinity during the germination and emergence stage depends on their capacities to support the water potential of the surrounding environment. With toxic ions can inhibit the absorption of water by the roots[50-53]. Species that were subjected to different saline concentrations, showed greater sensitivity than others at the time of the beginning of their development[54-59]. In a flat area with outcrops of salts at more than 3600 altitude with extreme climatic factors, it has been observed that salinity negatively affects the epidermal cell division of the root and the elongation rate, these effects affected the area part of the species causing a decrease in their yields

The sowing technique, six species were seriously affected by salinity and had heterogeneous behaviors in the emergence of 58 to 86%, it should be clarified that in 22 dS m^{-1} they did not manage to emerge (table 2), these results reveal that the high concentrations of salts increase the potential forces of the water in the soil solution and are consistent with the announcements that the presence of solutes produces the decrease of the osmotic potential of the soil solution[12,60-62], it is also mainly related to the low hydric potential of the solution surrounding the seed[63-66], which suggests that there is a combination of osmotic and toxic effects of the salinity. Report that there are species that are more sensitive to salinity in the emergence stage and at the beginning of seedling development than in germination[67,68]. The effect of osmotic stress on plants depends both tolerance of each species as well as on the state of its development.

Three days after emerging, the seedlings suffered mortality due to the effect of soil salinity, the species with the highest sensitivity to salinity was *E. curvula* (Schrad.) Nees, which reached 37% mortality, while *A. elongatum* (Host) P. Beauv., was the one that behaved more tolerant to soil salts (fig 1B). The transplanted seedlings also suffered mortality due to the effect of salt, but it was lower than those of the sowing, only the species that in sowing showed higher mortality reached 7.6%, *Bromus* sp., Presented 3.6% mortality (fig. 2). Therefore, it is validated that the best option to implement forage species in saline soils is through the seedling transplant technique to reduce mortality (fig. 3). The results are similar to other studies where they indicate if the roots of the plants are exposed to high concentrations of salts, cause osmotic and ionic stress[57,65,69-71], to survive in adverse conditions of stress, the plants have developed physiological mechanisms, morphological, biochemical and genetic that allows them to resist without drastically affectting their metabolism[5,57,72-75]. High accumulations of Na^+ or Cl^- ions cause toxicity damage, negatively affecting physiological processes, mainly the absorption of water and nutrients, as well as photosynthesis[36,73,76-79]. Furthermore, it leads to the low absorption of K^+ and stimulates its release, reducing enzymatic reactions and osmotic adjustments within cells[36,73,80-82]. Salinity, by hindering the absorption of water (physiological drought), causes cellular damage through the leaf perspiration inhibiting their growth.

The species that were sown in soils with 7 and 16 dS m^{-1}, showed differences in development of PH, NM and DM, *A. elongatum* (Host) P. Beauv., was superior in PH reaching 9.00 and 6.80 cm and with 7.67 and 6.33 NM respectively, while the species of *E. curvula* (Schrad.) Nees presented a lower development in PH, which only reached up to 4.33 and 2.67 cm and with 4.00 and 2.33 NM respectively (table 2). These findings are similar to the versions that mention that salinity affects the development of the roots and affects development and reduces yields due to the low extraction of nutrients from the soil[83-87]. The tolerance to salinity of a species involves a gradual acclimatization to this phenomenon and not direct exposure to a high salt concentration.

The DM, the *B. catharticus* Vahl. species was superior of all, which reached 109.33 and 107.63 kg ha^{-1} respectively, the species that had the lowest development in both PH and NM, was the one that presented the lowest DM with 41.00 and 37.00 kg ha^{-1} respectively (table 2). When the content of the salts in the soil solution is higher than the water content of the plant cells, the roots cannot absorb the water from the soil, which is consistent with the claims that salts cause alterations in various physiological and metabolic processes due to ionic imbalance and osmotic stress, these effects reduce the development and production of biomass[88-97]. The salts considerably reduce the amount of adsorbent hairs, because of this reduction the absorption of water and nutrients from the soil solution is affectted, which affects the biomass.

The seedlings that were transplanted in soils of 7, 16 and 22 dS m^{-1} presented statistical differences in PH, NM and DM, the species *A. elongatum* (Host) P. Beauv. was higher in the three salinity concentrations with 15.50, 12.00 and 8.00 cm of PH and with 19.67, 18.00 and 11.00 NM respectively, the *E. curvula* (Schrad.) Nees showed less development with 6.83, 4.00 and 3.83 cm of PH and with 7.00, 6.33 and 5.66 NM respectively. The results found have a similar coincidence with reports that indicate that plants in high salt concentrations have difficulties in the extraction of water through the roots, this inhibits cell growth and elongation, as well as stomatal closure[15,16,29, 91,98-102], as well as Ca^{2+} and K^+ undergoes homeostasis[103,104] so that survival to complete the vegetative cycle will depend on the ability to maintain low internal osmotic potential[105-109]. Furthermore, Na^+ may inhibit the function of enzymes in plant metabolism[110,111]. Tolerance to salinity can be maintained or decreased depending on the species and the time of exposure to saline stress. However, the problem of salinity is complex and requires proper soil management, as well as the use of salt-tolerant species.

In DM biomass, the species of *B. catharticus* Vahl. and *A. elongatum* (Host) P. Beauv., they presented superiority compared to the others, while *E. curvula* (Schrad.) Nees showed low performance in the three salinity levels (table 2). The proper management of saline soil for plant growth depends on the mixture of the different factors, as well as the amount of salts present. The results are similar to reports from other trials, where they indicate that excessive concentrations of Na^+ or Cl^- in plant tissues prevent the uptake and absorption of K^+, Ca^{2+} and NO_3^-. Many factors influence the limitations to the production of forage species due to salinities that have an impact on the decrease in productivity[81,80,112-117]. To maintain a positive turgor pressure, plants need to adjust osmotically to remain in saline soils and not be adversely affected by biomass production.

Between the sowing and transplanting technique of seedlings in saline soils they showed significant differences in PH, NM and DM. The transplanted species showed superiority compared to the sowing, the *A. elongatum* (Host) P. Beauv. showed greater development in PH with 11.83 cm, but at sowing it only reached 7.90 cm; followed by *B. catharticus* Vahl. that grew 7.45 cm, the same species in sowing reached only 5.67 cm. The species *E. curvula* (Schrad.) Nees both in transplantation and in sowing had a lower development with 4.89 and 3.50 cm respecttively (fig. 4A). It has been observed that, by means of the sowing technique, the species did not manage to develop normally because they suffered stress from the moment of germination and emergence. The salts were concentrated enough to adversely affect the initial development of the seedlings. These results found are similar to the claims that plant cells lose water and reduce cell elongation for osmotic adjustment[72,78,98,106] and the accumulation of NaCl in plant cells affects their functions[118,119], which decreases epidermal cell division roots [120-122]. The accumulation of salts in the organelles of the seedlings, can cause a delay or an inhibition in the development, so that they can tolerate saline soils, the root development is essential.

Likewise, the species *A. elongatum* (Host) P. Beauv. manages to get out with 16.22 in the development of NM in transplantation, but in the sowing it has only 7.00 macollos, followed by *B. catharticus* Vahl. which formed 12.33 NM in transplantation and 6.34 in sowing. The same species that had less development in PH both transplantation and sowing have low formation of NM with 6.33 in transplantation and 3.17 in sowing (fig. 4B). During the development of NM, it has been observed that high concentrations of salinity have caused alterations in cell membranes. These results are similar to other statements where they indicate that Na^+ causes depolarization of the electrical potential of the cell membrane, causing the entry of K^+ and causing serious physiological disorders[123-126]. Plants in their evolution have developed several mechanisms to be able to adapt to salinity, for example, some halophytes can accumulate large amounts of inorganic salts in their organelles (vacuole) of cells, this response is common in the adaptation process of plants.

In DM, the species *B. catharticus* Vahl. and *A. elongatum* (Host) P. Beauv. transplanted plants showed higher yields of 159.55 and 143.00 kg ha^{-1} respectively, but at sowing it was lower with 108.50 and 102.82 kg ha^{-1} respectively. The *E. curvula* (Schrad.) Nees both in transplantation and in sowing showed lower yields with 49.67 and 39.00 kg ha^{-1} respectively (fig. 4C). The salts present in the soil solution cause the plants to be smaller and can even cause death before completing their vegetative cycle, which has a direct impact on the decrease in yields. The best option to implement forage species in saline soils is through the transplant technique, since the seedlings have a better chance of adapting and surviving. The results of this study are similar to the reports where they mention that the different species in saline conditions are harmed in development and biomass due to osmotic effect-ts[24,87,127-132]. The understanding of plants to an abiotic or biotic stimulus is complex, since in the face of this external stimulus, the plant triggers the activation of multiple signal pathways mediated by plant hormones and that have complex interactions with each other. The energy cost generated by the plant to cope with stress will depend on having a greater or lesser impact on its development.

The six forage species sown at 7 and 16 dS m^{-1} had an emergency decrease of more than 50% due to the high concentrations of salts in the soil, *A. elongatum* (Host) P. Beauv. and *B. catharticus* Vahl. are the ones that they adapted better to these two concen-trations of salinity, and the one that showed the most susceptibility was *E. curvula* (Schrad.) Nees, but at 22 dS m^{-1} neither species were successful. All suffered mortality, the most affected was *E. curvula* (Schrad.) Nees with 37% and the one that perfor-med the best was *A. elongatum* (Host) P. Beauv. which was only reduced by 14.3%.

In the transplant, the six species were adapted to saline concentrations of 7, 16 and 22 dS m^{-1}, but they also showed mortality in a lower proportion than in sowing, the species *E. curvula* had 7.6%, while *Bromus* sp. 3.6%.

There was a great difference between sowing and transplantation, it was observed both in the development of PH, NM and DM, those of trans-plantation had superiority compared to sowing. Therefore, the best option to implement forage species in saline soils is by transplanting seedlings with capacities that can tolerate salinity.

The seedlings showed a reduction in the absorption of water and nutrients due to the effects of Na^+ ions that are dissolved in the soil solution. On the other hand, the ions transported into the intercellular spaces of the leaves dehydrated the cells and inhi-bited the enzymatic reactions that are generated by photosynthesis.

The species that were subjected to different concentrations of salinity by the transplantation technique, have survived until completing their ve-getative development, this reflects that their roots have the ability to exclude a large amount of Na^+ so that it cannot enter the interior of their tissues and accumulate especially in the aerial parts.

Funding source

This work was funded by the Ministerio of Medio Ambiente and Agua (MMAyA), the Gobierno Autónomo Departamental of Oruro (GADO) and Gobierno Autónomo Indígena Originario of the Nación Uru-Chipaya (GAIONUC).

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgments

We thank the Gobierno Autónomo Indígena Originario of the Nación Uru-Chipaya (GAIONUC) for the support provided for the execution of the project.

Ethical aspects

All experimental procedural aspects were approved by the Ethics Committee of the Dirección of Investigación Científica and Tecnológica (DICyT) of the Universidad Técnica of Oruro (UTO).

Cited Literature

1. Almeida DM, Oliveira MM, Saibo NJM. Regulation of Na^+ and K^+ homeostasis in plants: towards improved salt stress tolerance in crop plants. Ge net Mol Biol 2017;40(Suppl 1):S326-S45. DOI: https://doi.org/10.1590/1678-4685-GMB-2016-0106
2. Almeida Machado RM, Serralheiro RP. Soil Sali nety: effect on vegetable crop growth. Management practices to prevent and mitigate soil salinization. Horticulturae 2017;3(2):30. DOI: https://doi.org/10.3390/horticulturae3020030
3. Schroeder JI, Delhaize E, Frommer WB, Guerinot ML, Harrison MJ, Herrera Estrella L, et al. Using membrane transporters to improve crops for sustainable food production. Nature 2013;497 :60-6. DOI: https://doi.org/10.1038/natu re11909
4. Qadir M, Quillérou E, Nangia V, Murtaza G, Singh M, Thomas RJ, et al. Economics of salt-induced land degradation and restoration. Nat Resour Forum 2014;38(4):282-95. DOI: https://doi.org/10.1111/1477-8947.12054
5. Bronwyn JB, Vera Estrella R, Balderas E, Pantoja O. Mecanismos de tolerancia a la salinidad en plantas. Biotecnología [Internet]. 2007 [citado 5 de abril de 2020]; 14:263-72. Recuperado a partir de: http://www.ibt.unam.mx/computo/pdfs/libro_ 25_aniv/capitulo_23.pdf
6. Munns R, Tester M. Mechanisms of salinity tole rance. Ann Rev Plant Biol 2008;59:651-81. DOI: https://doi.org/10.1146/annurev.arplant.59. 032607.092911
7. Manchanda G, Garg N. Salinity and its effects on the functional biology of legumes. Acta Physiol Plant 2008;30:595-618. DOI: https://doi.org/10.1007/s11738-008-0173-3
8. Rengasamy P. World salinization with emphasis on Australia. J Exp Bot 2006;57(5):1017-23. DOI: https://doi.org/10.1093/jxb/erj108
9. Odeh IOA, Onus A. Spatial analysis of soil salinity and soil structural stability in a semiarid region of New South Wales, Australia. Environ Manage 2008;42(2):265-78. DOI: https://doi.org/10.1007/s00267-008-9100-z
10. Ashraf M. Biotechnological approach of improving plant salt tolerance using antioxidants as mar-kers. Biotechnol Adv 2009;27(1):84-93. DOI: https://doi.org/10.1016/j.biotechadv.2008.09.003
11. Villavicenso NM, López Alonzo CV, Sotelo Basurto M, Pérez Leal R. Efectos por salinidad en el desarrollo vegetativo. Tecnociencia 2011;5(3): 156-61.
12. Lamz Piedra A, González Cepero MC. La salinidad como problema en la agricultura: la mejora vegetal una solución inmediata. CulTrop 2013; 34(4):31-42.
13. Abiala MA, Abdelrahman M, Burritt DJ, Tran LP. Salt stress tolerance mechanisms and potential applications of legumes for sustainable reclamation of salt-degraded soils. Land Degrad Dev 2018;29(10):3812-22. DOI: https://doi.org/10.1002/ldr.3095
14. Hu Y, Schmidhalter U. Limitation of salt stress to plant growth. En: Hock B, Elstner EF, editors. Plant Toxicology. New York: Taylor & Francis Group; 2004. p. 191-224. DOI: https://doi.org/10.1201/9780203023884.ch5
15. Greenway H, Munns R. Mechanisms of salt tole rance in nonhalophytes. Ann Rev Plant Physiol 1980;31:149-90. DOI: https://doi.org/10.1146/annurev.pp.31.060180.001053
16. Ashraf MB, McNeily T, Bradshaw AD. The response of selected salt-tolerant and normal lines of four grass species to NaCl in sand culture. New Phytol 1986;104(3):453-61. DOI: https://doi.org/10.1111/j.14698137.1986.tb02912.x
17. Iyengar ERR, Patolia JS, Kurian T. Varietal differences in barley to salinity. Z Pflanzenphysiol 1997;84(4):355-61. DOI: https://doi.org/10.1016/S0044-328X(77)80149-9

18. Grattan SR, Grieve CM. Mineral element acquisition and growth response of plants grown in saline environments. Agric Ecosyst Environ 1992; 38(4):275-300. DOI: https://doi.org/10.1016/0167-8809(92)90151-Z
19. Zahran HH. Rhizobium-legume symbiosis and nitrogen fixation under severe conditions and in arid climate. Microbiol Mol Biol Rev 1999; 63(4):968-89.
20. Munns R. Comparative physiology of salt and water stress. Plant Cell Environ 2002;25(2):239-50. DOI: https://doi.org/10.1046/j.0016-8025.2001.00808.x
21. Liang Y, Si J, Nikolic M, Peng Y, Chen W, Jiang Y. Organic manure stimulates biological activity and barley growth in soil subject to secondary salinization. Soil Biol Biochem 2005;37(6):1185-95. DOI: https://doi.org/10.1016/j.soilbio. 2004.11.017
22. Corwin DL, Rhoades JD, Simunek J. Leaching requirement for soil salinity control: Steady-state versus transient models. Agric Water Manag 2007;90(3):165-80. DOI: https://doi.org/10.1016/j.agwat.2007.02.007
23. Madhava Rao KV, Raghavendra AS, Janardhan Reddy K. Physiology and molecular biology of stress tolerance in plants [Internet]. Dordrecht: Springer; 2006 [citado 22 de mayo de 2020]. 351 p. Recuperado a partir de: http://fmipa.umri.ac.id/wp-content/uploads/2016/03/K.V._Madhava_Rao_A.S._Raghavendra_K._Janardhan_BookFi.org_.pdf
24. Organización de las Naciones Unidas para la Alimentación y Agricultura. Estado mundial del recurso suelo: Resumen técnico [Internet]. Roma: Organización de las Naciones Unidas para la Alimentación y Agricultura y Grupo Técnico Intergubernamental del Suelo; 2015 [citado 22 de mayo de 2020]. 29 p. Recuperado a partir de: http://www.fao.org/3/a-i5126s.pdf
25. Courel GF. Guía de estudio: Suelos salinos y sódicos [Internet]. Cátedra de Edafología. Facultad de Agronomía y Zootecnia. Universidad Nacional de Tucumán. 2019 [citado 3 de mayo de 2020]. p. 1-8 Recuperado a partir de: https://www.edafologia.org/descargas/
26. Zhu JK. Regulation of ion homeostasis under salt stress. Curr Opin Plant Biol 2003;6(5):441-5. DOI: https://doi.org/10.1016/S1369-5266(03)00085-2
27. Ashraf M, Harris PJC. Potential biochemical indicators of salinity tolerance in plants. Plant Sci 2004;166(1):3-16. DOI: https://doi.org/10.1016/j.plantsci.2003.10.024
28. Poustini K, Siosemardeh A. Ion distribution in wheat cultivars in response to salinity stress. Field Crops Res 2004;85(2-3):125-33. DOI: https://doi. org/10.1016/S0378-4290(03)00157-6
29. Flowers TJ. Improving crop salt tolerance. J Exp Bot 2004;55(396):307-19. DOI: https://doi.org/10.1093/jxb/erh003
30. Chinnusamy V, Jagendorf A, Zhu JK. Understanding and improving salt tolerance in plants. Crop Sci 2005;45(2):437-48. DOI: https://doi. org/10.2135/cropsci2005.0437
31. Munns R, Day DA, Fricke W, Watt M, Arsova B, Barkla BJ, et al. Energy costs of salt tolerance in crop plants. New Phytol 2020;225(3):1072-90. DOI: https://doi.org/10.1111/nph.15864
32. Shannon MC, Grieve CM. Tolerance of vegetable crops to salinity. Sci Hortic 1998;78(1-4):5-38. DOI: https://doi.org/10.1016/s0304-4238(98) 00189-7
33. Wani SH, Hossain MA. Managing salt tolerance in plants: Molecular and genomic perspectives. New York: CRC Press. Taylor & Francis Group; 2016. p. 426.
34. Mahajan S, Tuteja N. Cold, salinity and drought stresses: an overview. Arch Biochem Biophys 2005;444(2):139-58. DOI: https://doi.org/10.1016/j.abb.2005.10.018

35.Taiz L, Zeiger E. Plant Physiology. Fifth edition. Massachusetts: Sinauer Associates Inc., Publisher ;2010. p. 782.

36.Hasegawa PM. Sodium (Na^+) homeostasis and salt tolerance of plants. Environ Exp Bot 2013; 92:19-31. DOI: https://doi.org/10.1016//j.envexpbot. 2013.03.001

37.Shabala S. Learning from halophytes: physiological basis and strategies to improve abiotic stress tolerance in crops. Ann Bot 2013; 112(7):1209-21. DOI: https://doi.org/10.1093/aob/mct205

38.Almeida P, Feron R, de Boer GJ, de Boer AH. Role of Na^+, K^+, Cl^-, proline and sucrose concentrations in determining salinity tolerance and the-ir correlation with the expression of multiple genes in tomato. AoB Plants 2014;6:plu039. DOI: https://doi.org/10.1093/aobpla/plu039

39.Flowers TJ, Munns R, Colmer TD. Sodium chloride toxicity and the cellular basis of salt tolerance in halophytes. Ann Bot 2015;115(34): 4 19-31. DOI: https://doi.org/10.1093/aob/mcu 217

40.Blanes Jiménez J, Pabón Balderas EA. Qnas Soñi (hombres del agua) Chipaya: Entre tradición y tecnología, hacia un municipio resiliente [Internet]. La Paz: Centro Boliviano de Estudios Multidisciplinarios; 2018 [citado 22 de mayo de 2020]. 182 p. Recuperado a partir de: https://chipaya.org/wp-content/uploads/2018/10/chipaya-1994.pdf

41.Bernabé Uño A. Revalorización de sabidurías Uru Chipaya: Experiencias de apoyo [Internet]. Cochabamba: Programa Regional BioAndes; 2010 [citado 22 de mayo de 2020]. 50 p. Recuperado a partir de: http://atlas.umss.edu.bo:8080/ xmlui/bitstream/handle/123456789/76/revalorizaci%c3%b3n.pdf?sequence=1&isAllowed=y

42.Jordan W, Castedo L, Chuquimia C, Jiménez S, Vega VH. La Nación Uru en Bolivia; Irohito Urus-Uru Chipaya-Urus del Lago Poopó [Internet]. La Paz: Fundación Machak Amauta; 2011 [citado 22 de mayo de 2020]. 101 p. Recuperado a partir de: http://fmachaqa.org/index.php?option=com_ mtree&task=att_do wnload&link_id=4&cf_id=24

43.Velásquez Martínez M, Hernández Guzmán FJ, Cervantes Becerra JF, Gámez Vázquez HG. Establecimiento de pastos nativos e introducidos en zonas semiáridas de México [Internet]. Mexico D.F.: Secretaria de Agricultura, Ganadería, Desarrollo Rula, Pesca y Alimentación; 2015 [citado 22 de mayo de 2020]. 36 p. Recuperado a partir de: http://www.inifapcirne.gob.mx/Biblio teca/Publicaciones/998 .pdf

44.Mena M. Pastos y forrajes [Internet]. Mangua: Programa de Gestión Rural Empresarial, Sanidad y Ambiente; 2015 [citado 22 de mayo de 2020]. 96 p. Recuperado a partir de: https://cgspace.cgiar.org/handle/10568/70087

45.Noreña Grisales JM. Metodologías para la evaluación de praderas de Kikuyu *Pennisetum clandestinum* Hochst. ex Chiov. Revista Despertar Lechero [Internet]. 2009 [citado 5 de mayo de 2020]; 31:20-33. Recuperado a partir de: http:// temaspastos.weebly.com/uploads/8/7/6/0/8760 901/metodologias_para_la_evaluacion_de_prade ras_de_kikuyo_ok.pdf

46.Easterling RG. Fundamentals of Statistical Experimental Design and Analysis. New York: John Wiley & Sons, Ltd; 2015. p. 245.

47.Casierra Posada F, Pérez WA, Portilla F. Relaciones hídricas y distribución de materia seca en especies de fique (*Furcraea* sp. Vent.) cultivadas bajo estrés por NaCl. Agron Colomb 2006; 24(2):280-9.

48.Goykovic Cortés V, Saavedra del Real G. Algunos efectos de la salinidad en el cultivo del tomate y prácticas agronómicas de su manejo.

Idesia 2007;25(3):47-58. DOI: https://doi.org/10.4067/ S0718-34292007000300006

49. Gaylord B, Egan TP. How salts of sodium, potassium, and sulfate affect the germination and early growth of *Atriplex acanthocarpa* (Chenopodiaceae). In: Khan MA, Weber DJ, Darrell J, editors. Ecophysiology of high salinity tolerant plants. Tasks for Vegetation Science. Dordrecht: Springer; 2008. p. 1-9. DOI: https://doi.org/10.1007/1-4020-4018-0_1
50. Abari AK, Nasr MH, Hojjati M, Bayat D. Salt effects on seed germination and seedling emergence of two Acacia species. Afr J Plant Sci 2011;5(1):52-6. DOI: https://doi.org/10.5897/AJPS.9000213
51. Lastiri Hernández MA, Álvarez Bernal D, Soria Martínez LH, Ochoa Estrada S, Cruz Cárdenas G. Efecto de la salinidad en la germinación y emergencia de siete especies forrajeras. Rev Mex Cienc Agríc 2017;8(6):1245-57. DOI: https://doi.org/10.29312/remexca.v8i6.291
52. Paudel A, Chen JJ, Sun Y,Wang Y, Anderson R. Salt tolerance of sego supreme™ plants. Hort Science 2019;54(11):2056-62. DOI: https://doi.org/10.21273/HORTSCI14342-19
53. Murillo Amador B, Troyo Diéguez E, López Cortés A, Jones HG, Ayala Chairez F, Tinoco Ojanguren CL. Salt tolerance of cowpea genotypes in the emergence stage. Aust J Exp Agric 2001;41(1):81-8. DOI: https://doi.org/10.1071/ EA00055
54. Hernández Avera Y, Soto Pérez N, Florido Bacallao M, Delgado Abad C, Ortiz Pérez R, Enríquez Obregón G. Evaluación de la tolerancia a la salinidad bajo condiciones controladas de nueve cultivares cubanos de soya (*Glycine max* (L.) Merril). CulTrop 2015;36(4):120-5.
55. Reyes Pérez JJ, Murillo Amador B, Nieto Garibay A, Troyo Diéguez E, Reynaldo Escobar IM, Rueda Puente EO. Germinación y características de plántulas de variedades de albahaca (*Ocimum basilicum* L.) sometidas a estrés salino. Rev Mex Cienc Agríc 2013;4(6):869-80. DOI: https://doi. org/10.29312/remexca.v4i6.11 55
56. Smith PT, Cobb BG. Physiological and enzymatic activity of pepper seeds (*Capsicum annuum*) during priming. Physiol Plant 1991;82(3):433-9. DOI: https://doi.org/10.1111/j.1399-3054.1991.tb02929.x
57. Ramírez Suárez WM, Hernández Olivera LA. Tolerancia a la salinidad en especies cespitosas. Past Forr 2016;39(4):235-45.
58. Kheloufi A, Mansouri LM, Zerrouni R, Abdelhamid O. Effect of temperature and salinity on germination and seedling establishment of *Ailanthus altissima* (Mill.) Swingle (Simaroubaceae). Reforesta 2020;9:44-53. DOI: https://doi.org/10.21750/REFOR.9.06.80
59. Batista Sánchez D, Nieto Garibay A, Alcaraz Meléndez L, Troyo Diéguez E, Hernández Montiel L, Ojeda Silvera CM, et al. Uso del FitoMas-E® como atenuante del estrés salino (NaCl) durante la emergencia y crecimiento inicial de *Ocimum basilicum* L. Nova Scientia 2015;7(15):265-84. DOI: https://doi.org/10.21640/ns.v7i15.399
60. Bizhani S, Salehi H. Physio-morphological and structural changes in common bermudagrass and Kentucky bluegrass during salt stress. Acta Physiol Plant 2014;36(3):777-86. DOI: https://doi.org/ 10.1007/s11738-013-1455-y
61. Manuchehri R, Salehi H. Physiological and biochemical changes of common bermudagrass (*Cynodon dactylon* [L.] Pers.) under combined salinity and deficit irrigation stresses. S Afr J Bot 2014;92:83-8. DOI: https://doi.org/10.1016/j.sajb.2014.02.006

62. Turan S, Cornish K, Kumar S. Salinity tolerance in plants: Breeding and genetic engineering. Aust J Crop Sci 2012;6(9):1337-48.
63. Allen SG, Dobrenz AK, Bartels PG. Physiological response of salt-tolerant and nontolerant alfalfa to salinity during germination. Crop Sci 1986; 26(5):1004-8. DOI: https://doi.org/10.2135/ cropsci1986.0011183X0026000500 33x
64. Azhdari G, Tavili A, Zare MA. Effects of various salts on the germination of two cultivars of *Medicago sativa*. Front Agric China 2010;4(1):63-8. DOI: https://doi.org/10.1007/s11703-009-0078-y
65. Flowers TJ, Gaur PM, Gowda CL, Krishnamurthy L, Samineni S, Siddique KH, et al. Salt sensitivity in chickpea. Plant, Cell Environ 2010; 33(4):490-509. DOI: https://doi.org/10.1111/j.1365-3040 .2009.02051.x
66. Ruiz M, Terenti O. Germinación de cuatro pastos bajo condiciones de estrés salino. Phyton 2012; 81(2):169-76.
67. Villa Castorena M, Catalán Valencia EA, Inzunza Ibarra MA, Ulery AL. Absorción y traslocación de sodio y cloro en plantas de chile fertilizadas con nitrógeno y crecidas con estrés salino. Rev Fitotec Mex 2006;29(1):79-88.
68. Campos G, García M, Pérez D, Ramis C. Respuesta de 20 variedades de caraota (*Phaseolus vulgaris* L.) ante el estrés por NaCl durante la germinación y en la fase plantular. Bioagro 2011; 23(3):215-24.
69. Munns R, Gilliham M. Salinity tolerance of crops -what is the cost? New Phytol 2015; 208(3): 668-673. DOI: https://doi.org/10.1111/nph.13519
70. Isayenkov SV, Maathuis FJM. Plant salinity stress: many unanswered questions remain. Front Plant Sci 2019;10:80. DOI: https://doi.org/10.3389/fpls.2019.00080
71. Shahid MA, Sarkhosh A, Khan N, Balal RM, Ali S, Rossi L, et al. Insights into the physiological and biochemical impacts of salt stress on plant growth and development. Agronomy 2020; 10(7):938. DOI: https://doi.org/10.3390/agronomy10070938
72. Roy SJ, Negrão S, Tester M. Salt resistant crop plants. Curr Opin Biotechnol 2014;26:115-24. DOI: https://doi.org/10.1016/j.copbio.2013.12.004
73. Ashraf M, Hameed M, Arshad M, Ashraf Y, Akhtar K. Salt tolerance of some potential forage grasses from Cholistan desert of Pakistan. In: Khan MA, Weber DJ, Darrell J, editors. Ecophysiology of high salinity tolerant plants. Tasks for Vegetation Science. Dordrecht: Springer; 2008. p. 31-54. DOI: https://doi.org/10.1007/1-40 20-4018-0_3
74. Bueno M, Lendínez ML, Aparicio C, Cordovilla MP. Germination and growth of *Atriplex prostrata* and *Plantago coronopus*: Two strategies to survive in saline habitats. Flora 2017;227:56-63. DOI: https://doi.org/10.1016/j.flora.2016.11.019
75. Lamers J, van der Meer T, Testerink C. How plants sense and respond to stressful environments. Plant Physiol 2020;182(4):1624-35. DOI: https://doi.org/10.1104/pp.19.01464
76. Liu X, Duan D, Li W, Tadano T, Khan MA. A comparative study on responses of growth and solute composition in halophytes *Suaeda salsa* and *Limonium bicolor* to salinity. In: Khan MA, Weber DJ, Darrell J, editors. Ecophysiology of high salinity tolerant plants. Tasks for Vegetation Science. Dordrecht: Springer; 2008. DOI: https://doi.org/10.1007/1-4020-4018-0_9
77. Zhu JK. Plant salt tolerance. Trends Plant Sci 2001;6(2):66-71. DOI: https://doi.org/10.1016/s1360-1385(00)01838-0
78. Tujeta N. Mechanisms of high salinity tolerance in plants. Methods Enzymol 2007;428:419-38.

DOI: https://doi.org/10.1016/S0076-6879(07)28024-3

79. Abdelaal KA, El Maghraby LM, Elansary H, Hafez YM, Ibrahim EI, El Banna M, et al. Treatment of sweet pepper with stress tolerance-inducing compounds alleviates salinity stress oxidative damage by mediating the physio-biochemical activities and antioxidant systems. Agronomy. 2020;10(1):26. DOI: https://doi.org/10.3390/agronomy10010026
80. Ketehouli T, Idrice Carther KF, Noman M, Wang FW, Li XW, Li HY. Adaptation of plants to salt stress: characterization of Na^+ and K^+ transporters and role of CBL gene family in regulating salt stress response. Agronomy 2019; 9(11):687. DOI: https://doi.org/10.3390/agronomy9110687
81. Alam SM. Nutrient uptake by plants under stress condition. In: Sharma NK, editor. Handbook of Plant and Crop Stress [Internet]. New York: Marcel Dekker Inc; 1999. p. 285-314. Recuperado a partir de: https://www.academia.edu/ 3409537/Nutrient_uptake_by_plants_under_ stress_conditions
82. Cramer GR, Alberico GJ, Schmidt C. Salt tolerance is not associated with sodium accumulation of two maize hybrids. Aust J Plant Physiol 1994; 2185):675-92. DOI: https://doi.org/10.1071/pp99 40675
83. Tester M, Davenport R. Na^+ tolerance and Na^+ transport in higher plants. Ann Bot 2003;91(5): 503-27. DOI: https://doi.org/10.1093/aob/mcg058
84. Jamil M, Deog Bae L, Kwang Yong J, Ashraf M, Sheong Chun L, Eui Shik R. Effect of salt (NaCl) stress on germination and early seedling growth of four vegetables species. J Cent Eur Agric 2006;7(2):273-82.
85. González Romero SL, Quero Carrillo AR, Franco Mora O, Ramírez Ayala C, Ortega Escobar HM, Trejo López C. Efecto de la salinidad y la temperatura sobre el crecimiento del pasto Banderita [*Bouteluoa curtipendula* (Michx.) Torr.]. Ciencia Ergo Sum 2011;18(1):59-69.
86. Hasanuzzaman M, Nahar K, Fujita M. Plant response to salt stress and role of exogenous protectants to mitigate salt-induced damages. In: Ahmad P, Azooz MM, Prasad MNV, editors. Ecophysiology and responses of plants under salt stress. Switzerland: Springer; 2013. p. 89-114. DOI: https://doi.org/10.1007/978-1-4614-4747-4
87. Orosco Alcalá BE, Núñez Palenius HG, Pérez Moreno L, Valencia Posadas M, Trejo Téllez LI, Díaz Serrano FR, et al. Tolerancia a salinidad en plantas cultivadas: una visión agronómica. Agro Produc 2018;11(7):51-7.
88. Lockhart J. Salt of the earth: Ethylene promotes salt tolerance by enhancing Na/K homeostasis. Plant Cell 2013;25:3150. DOI: https://doi.org/10.1105/tpc.113.250911
89. Munns R. Genes and salt tolerance: bringing them together. New Phytol 2005; 167(3):645-63. DOI: https://doi.org/10.1111/j.1469-8137.2005.01487.x
90. Shabala S, Cuin TA. Potassium transport and plant salt tolerance. Physiol Plant 2008; 13384):651-69. DOI: https://doi.org/10.1111/j.1399-3054.2007.01008.x
91. Ben Amor N, Megdiche W, Jiménez A, Sevilla F, Abdelly C. The effect of calcium on the antioxidant systems in the halophyte *Cakile maritime* under salt stress. Acta Physiol Plant 2010; 32:453-61. DOI: https://doi.org/10.1007/s11738-009-0420-2
92. Aslam R, Bostan N, Nabgha-e-Amen MM, Safdar W. A critical review on halophytes: salt tolerant plants. J Med Plants Res 2011; 5(33): 7108-18. DOI: https://doi.org/10.5897/jmprx11.009

93. Bewley JD. Germination. En: Bewley JD, Bradford K, Hilhorst H, Nogaki H, editors. **Seeds.** New York: Springer; 2013. p. 133-181. DOI: https://doi.org/10.1007/978-1-4614-4693-4_4
94. Tuteja N, Sahoo RK, Garg B, Tuteja R, OsSUV3 dual helicase functions in salinity stress tolerance by maintaining photosynthesis and antioxidant machinery in rice (*Oryza sativa* L. cv. IR64). Plant J 2013;76(1):115-27. DOI: https://doi.org/10.1111/tpj.12277
95. Álvarez Aragón R, Haro R, Benito B, Rodríguez Navarro A. Salt intolerance in Arabidopsis: shoot and root sodium toxicity, and inhibition by sodium-plus-potassium overaccumulation. Planta 2016;243(1):97-114. DOI: https://doi.org/10.1007/s00425-015-2400-7
96. Zivcak M, Brestic M, Sytar O. Osmotic adjustment and plant adaptation to drought stress. En: Hossain M, Wani S, Bhattacharjee S, Burritt D, Tran LS, editors. Drought Stress Tolerance in Plants. Cham: Springer; 2016. p. 105-143. DOI: https://doi.org/10.1007/978-3-319-28899-4_5
97. Liu Q, Liu R, Ma Y, Song J. Physiological and molecular evidence for Na^+ and Cl^- exclusion in the roots of two *Suaeda salsa* populations. Aquat Bot 2018;146:1-7. DOI: https://doi.org/10.1016/j.aquabot.2018.01.001
98. Zhu JK. Salt and drought stress signal transduction in plants. Annu Rev Plant Biol 2002;53:247-73. DOI: https://doi.org/10.1146/annurev.arplant.53.091401.143329
99. Munns R, James RA, Xu B, Athman A, Conn SJ, Jordans C, et al. Wheat grain yield on saline soils is improved by an ancestral Na^+ transporter gene. Nat Biotechnol 2012;30(4):360-4. DOI: https://doi.org/10.1038/nbt.2120
100. Deinlein U, Stephan AB, Horie T, Luo W, Xu G, Schroeder JI. Plant salt-tolerance mechanisms. Trends Plant Sci 2014;19(6):371-9. DOI: https://doi.org/10.1016/j.tplants.2014.02.001
101. Mancarella S, Orsini F, Van Oosten MJ, Sanoubar R, Stanghellini C, Kondo S, et al. Leaf sodium accumulation facilitates salt stress adaptation and preserves photosystem functionality in salt stressed *Ocimum basilicum*. Environ Exp Bot 2016;130:162-73. DOI: https://doi.org/10.1016/j. envexpbot.2016.06.004
102. van Zelm E, Zhang Y, Testerink C. Salt tolerance mechanisms of plants. Annu Rev Plant Biol 2020;71:403-33. DOI: https://doi.org/10.1146/ annurev-arplant-050718-100005
103. Hasegawa PM, Bressan RA, Zhu JK, Bohnert HJ. Plant cellular and molecular responses to high salinity. Annu Rev Plant Physiol 2000; 51:463-99. DOI: https://doi.org/10.1146/annurev.arplant.51. 1.463
104. Rodriguez Navarro A. Potassium transport in fungi and plants. Biochim Biophys Acta 2000; 1469(1):1-30. DOI: https://doi.org/10.1016/s0304-4157(99)00013-1
105. Verslues PE, Agarwal M, Katiyar Agarwal S, Zhu J, Zhu JK. Methods and concepts in quantifying resistance to drought, salt and freezing, abiotic stresses that affect plant water status. Plant J 2006;45(4):523-39. DOI: https://doi.org/10.1111/j.1365-313X.2005.02593.x
106. Kalaji HM, Bosa K, Koscielniak J, Zuk Gołaszewska K. Effects of salt stress on photosystem II efficiency and CO_2 assimilation of two Syrian barley landraces. Environ Exp Bot 2011; 73:64-72. DOI: http://doi.org/10.1016/j.envexpbot.2010.10.009
107. Orsini F, Alnayef M, Bona S, Maggio A, Gianquinto G. Low stomatal density and reduced transpiration facilitate strawberry adaptation to salinity. Environ Exp Bot 2012;81:1-10. DOI: http:// doi.org/10.1016/j.envexpbot.2012.02.005
108. Gupta B, Huang B. Mechanism of salinity tolerance in plants: physiological, biochemical, and molecular characterization. Int J Genomics

2014; 2014:701596. DOI: https://doi.org/10.1155/2014/ 701596

109. Assaha DVM, Ueda A, Saneoka H, Al Yahyai R, Yaish MW. The role of Na^+ and K^+ transporters in salt stress adaptation in glycophytes. Front Physiol 2017;8:509. DOI: https://doi.org/10.3389/fphys. 2017.00509
110. Serrano R. Salt tolerance in plants and microorganisms: toxicity targets and defense responses. Int Rev Cytol 1996;165:1-52. DOI: https://doi. org/10.1016/s0074-7696(08)62219-6
111. Negrão S, Schmöckel SM, Tester M. Evaluating physiological responses of plants to salinity stress. Ann Bot 2017;119(1):1-11. DOI: https://doi.org/ 10.1093/aob/mcw191
112. Jacoby B. Mechanisms involved in salt tolerance by plants. In: Pessarakli M, editor. Handbook of plant and crop stress. New York; Marcel Dekker; 1994.p. 97-123.
113. Marschner H. Mineral nutrition of higher plants [Internet]. London: Academic Press; 1995. p. 672. DOI: https://doi.org/10.1016/C2009-0-63043-9
114. Niu X, Bressan RA, Hasegawa PM, Pardo JM. Ion homeostasis in NaCl stress enviroments. Plant Physiol 1995;109(3):735-42. DOI: https://doi.org /10.1104/pp.109.3.735
115. Hanin M, Ebel C, Ngom M, Laplaze L, Masmoudi K. New insights on plant salt tolerance mechanisms and their potential use for breeding. Front Plant Sci 2016;7:1787. DOI: https://doi. org/10.3389/fpls.2016.01787
116. Al Karaki GN. Growth, water use efficiency, and sodium and potassium acquisition by tomato cultivars grown under salt stress. J Plant Nutr 2000;23(1):1-8. DOI: https://doi.org/10.1080/01904160009381992
117. Zhao C, Zhang H, Song C, Zhu JK, Shabala S. Mechanisms of plant responses and adaptation to soil salinity. The innovation 2020;1(1):100017. DOI: https://doi.org/10.1016//j.xinn.2020.100017
118. Shabala S, Pottosin I. Regulation of potassium transport in plants under hostile conditions: implications for abiotic and biotic stress tolerance. Physiol Plant 2014;151(3):257-79. DOI: https:// doi.org/10.1111/ppl.12165
119. Gong Z, Xiong L, Shi H, Yang S, Herrera Estrella LR, Xu G, et al. Plant abiotic stress response and nutrient use efficiency. Sci China Life Sci 2020;63(5):635-74. DOI: https://doi.org/10. 1007/s11427-020-1683-x
120. Jung JKH, McCouch S. Getting to the roots of it: genetic and hormonal control of root architecture. Front Plant Sci 2013;4:186. DOI: https:// doi.org/10.3389/fpls.2013.00186
121. Seifikalhor M, Aliniaeifard S, Shomali A, Azad N, Hassani B, Lastochkina O, et al. Calcium signaling and salt tolerance are diversely entwined in plants. Plant Signal Behav 2019;14(11): 1665455. DOI: https://doi.org/10.1080/15592324 .2019.1665455
122. Vives Peris V, López Climent MF, Pérez Clemente RM, Gómez Cadenas A. Root involvement in plant responses to adverse environmental conditions. Agronomy 2020; 10(7): 942. DOI: https://doi.org/10.3390/agronomy100 70942
123. Cramer GR, Lynch J, Läuchli A, Epstein E. Influx of Na^+, K^+ and Ca^{2+} into roots of salt-stressed cotton seedlings. Effects of supplemental Ca^{2+}. Plant Physiol 1987;8383):510-6. DOI: https: //doi.org/10.1104/pp.83.3.510
124. Grieve CM, Mass EV. Diferential effects of sodium/calcium ratio on sorghum genotypes. Crop Sci 1988;28(4):659-65. DOI: https://doi.org/10.2135/cropsci1988.0011183X002800040021x
125. Maathuis FJM, Amtmann A. K^+ nutrition and Na^+ toxicity: the basis of cellular K^+/Na^+ ratios.

Ann Bot 1999;84(2):123-33. DOI: https://doi.org/10.1006/anbo.1999.0912

126. Kaya C, Higgs D. Supplementary potassium nitrate improves salt tolerance in bell pepper plants. J Plant Nutr 2003;26(7):1367-82. DOI: https://doi.org/10.1081/PLN-120021048
127. Mesa D. Obtención de plantas resistentes a la salinidad para los suelos salinos cubanos. Revista Cubana de Ciencia Agrícola. 2003;37(3):217-26.
128. Ratnakara A, Raib A. Effect of sodium chloride salinity on seed germination and early seedling growth of *Trigonella foenum-graecum* L. Var. Peb. Oct Jour Env Res 2013;1(4):304-9.
129. Harter B, Motis T. Conociendo los suelos afectados por sales [Internet]. Echo Community. 2016 [citado 3 de mayo de 2019]. Recuperado a partir de: https://www.echocommunity.org/es/resources/114701c3-3d54-487d-a0c4-439e100516 76
130. Morton MJL, Awlia1 M, Al-Tamimi N, Saade S, Pailles Y, Negrão S, Tester M. Salt stress under the scalpel - dissecting the genetics of salt tolerance. Plant J 2019;97(1):148-63. DOI: https://doi.org/10.1111/tpj.14189
131. Calone R, Sanoubar R, Lambertini C, Speranza M, Antisari LV, Vianello G, et al. Salt tolerance and Na allocation in *Sorghum bicolor* under variable soil and water salinity. Plants 2020;9(5): 561. DOI: https://doi.org/10.3390/plants9050561
132. Pérez Romero JA, Mateos Naranjo E, López Jurado J, Redondo Gómez S, Torres Ruiz JM. Importance of physiological traits vulnerability in determine halophytes tolerance to salinity excess: a comparative assessment in *Atriplex halimus*. Plants 2020;9(6):690. DOI: https://doi.org/10.3390/plants9060690

Editor's Note:
***Journal of the Selva Andina Biophere* (*JSAB*) remains neutral with respect to jurisdictional claims published on maps and institutional affiliations.**