Salinity effects on nutrients uptake, biochemical content and growth response of Blue Panic (*Panicum antidotale Retz*) and Silage maize (*Zea mays L*)

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Abstract

Saline-tolerant alternative crops develop complex mechanisms under biosaline conditions. We investigated the effect of saline water on nutrient uptake, physiological and biochemical parameters of Blue Panic (*Panicum antidotale Retz*) and silage maize (*Zea mays L*). Mesocosms were established in four replicates for each plant species in an orthogonal design with different levels of saline irrigation water as treatments giving T0 = 0.9 dS m^{-1} (tap water), T1 = 3 dS m^{-1}, T2 = 6 dS m^{-1} and T3 = 10 dS m^{-1}, for 8 weeks. Increasing salinity caused a depressive effect on silage maize's physiological parameters, leading to a significant decrease in growth (up to 37%), aboveground (up to 58%) and root (up to 87%) dry matter biomass compared to control. As well as a decrease of chlorophyll a (up to 71%), chlorophyll b (up to 77%) and carotenoid (up to 49%) compared to control. For blue panic, salinity did not, however, affect the studied physiological and biochemical parameters. Nitrogen, phosphorus, potassium and calcium uptake, of silage maize, decreased with increasing salinity levels to be significant in irrigation water with electrical conductivity ≥ 6 dS m^{-1} relative to control. The sodium content in different parts of silage maize (leaf, stem and root), on the other hand, increased significantly with increasing salinity. The accumulation of calcium, potassium and nitrogen increased slightly in the blue panic, but this was only significant in separate parts of the plant. Overall, our study indicates that silage maize is more sensitive to saline conditions (particularly ≥ 6 dS m^{-1}) compared to blue panic which tolerates well high saline environment ≥ 10 dS m^{-1}. Our results, suggest therefore that the introduction of blue panic as an alternative crop on salt affected soils, such as the irrigated perimeter of Foum El Oued in Laâyoune in Morocco, would exhibit high performance better than traditional crops as silage maize and therefore would improve the local farmers' income.

Keys words: Salinity, Saline water, Mineral uptake, Biosaline agriculture, Adaptation, Absorption, Blue panicum, Silage maize.

Effets de la salinité sur l'absorption des nutriments, les paramètres biochimiques et la croissance du Bleu Panicum (*Panicum antidotale Retz*) et du Maïs d'ensilage (*Zea mays L*)

Résumé

Les cultures alternatives tolérantes à la salinité développent des mécanismes complexes dans les conditions biosalines. Nous avons étudié l'effet de l'eau salée sur l'absorption des nutriments et les paramètres physiologiques et biochimiques du bleu panicum (*Panicum antidotale Retz*) et du maïs d'ensilage (*Zea mays L*). Des mésocosmes ont été établis en quatre répétitions pour chaque espèce de plante dans une conception orthogonale avec différents niveaux d'eau d'irrigation saline comme traitements donnant T0 = 0.9 dS.m^{-1} (eau du robinet), T1 = 3 dS m^{-1}, T2 = 6 dS m^{-1} et T3 = 10 dS m^{-1}, pendant 8 semaines. L'augmentation de la salinité a provoqué un effet dépressif sur le maïs d'ensilage, conduisant à une réduction significative de la croissance (jusqu'à 37%), de la biomasse aérienne sèche (jusqu'à 58%) et racinaire (jusqu'à 87%) par rapport au témoin. Ainsi qu'une diminution de la chlorophylle a (jusqu'à 71 %), de la chlorophylle b (jusqu'à 77 %) et des caroténoïdes (jusqu'à 49 %) par rapport au témoin. Pour le bleu panicum, la salinité n'a par contre pas affecté les paramètres physiologiques et biochimiques étudiés. L'absorption de l'azote, du phosphore, du potassium et du calcium, du maïs d'ensilage a diminué avec l'augmentation des niveaux de salinité pour être significative pour une eau d'irrigation avec une conductivité électrique ≥ 6 dS m^{-1} par rapport au contrôle. La teneur en sodium dans les différentes parties du maïs d'ensilage (feuille, tige et racine), par contre, a augmenté significativement avec l'augmentation de la salinité. L'accumulation du calcium, du potassium et de l'azote a légèrement augmenté chez le bleu panicum, mais n'était significatif que dans des parties distinctes de la plante. Dans l'ensemble, notre étude indique que le maïs est plus sensible aux conditions salines (notamment celles ≥ 6 dS m^{-1}) par rapport au bleu panicum qui tolère bien un environnement de salinité élevé ≥ 10 dS.m^{-1}. Nos résultats suggèrent ainsi que l'introduction du bleu panicum comme culture alternative sur les sols affectés par la salinité, comme le périmètre irrigué de Foum El Oued à Laâyoune au Maroc, résulterait en des rendements élevés meilleurs que les rendements des cultures traditionnelles comme le maïs d'ensilage et améliorerait donc le revenu des agriculteurs locaux.

Mots clé : Salinité, Eau salée, Absorption minérale, Agriculture biosaline, Adaptation, Absorption, Bleu panicum, Maïs d'ensilage.

تأثير الملوحة على امتصاص العناصر الغذائية، المحتوى البيوكيميائي وإستجابة نمو البانيكوم الأزرق (*Panicum antidotale Ret*) والذرة العلفية (*Zea mays L*)

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ملخص

تطور المحاصيل البديلة التي تتحمل الملوحة آليات معقدة في ظل ظروف الزراعة الملحية. درسنا تأثير الماء المالح على امتصاص العناصر الغذائية ، والمعايير الفزيولوجية والكيميائية الحيوية للبانيكوم الأزرق (*Panicum antidotale Retz*)والذرة العلفية (*Zea mays L*). تم إجراء التجربة في حاويات متوسطة. تم ري كل نوع نباتي بأربعة مستويات مختلفة من المياه المالحة $T0 = 0.9\ dS\ m^{-1}$ ، $T1= 3\ dS\ m^{-1}$، $T2 = 6\ dS\ m^{-1}$ و $T3 = 10\ dS\ m^{-1}$ لمدة 8 أسابيع.

أدت زيادة الملوحة إلى تأثير سلبي على المتغيرات المورفولوجية للذرة العلفية ، مما أدى إلى انخفاض كبير في نمو الساق (يصل إلى ٪ 37) ، الكتلة النباتية العلوية الجافة (حتى ٪ 58) و الكتلة النباتية الجذرية الجافة (حتى ٪ 87) مقارنة بالشاهد. بالإضافة إلى انخفاض الكلوروفيل أ (حتى ٪ 71)، الكلوروفيل ب (حتى ٪ 77) والكاروتينويد (حتى ٪ 49) مقارنة بالشاهد. في حين لم تؤثر الملوحة على المتغيرات المورفولوجية والكيميائية الحيوية للبانيكوم الأزرق.

انخفض امتصاص الأزوت، الفوسفور، البوتاسيوم والكالسيوم للذرة مع زيادة مستويات الملوحة ($\geq 6\ dS\ m^{-1}$) مقارنة مع الشاهد. كما زاد محتوى الصوديوم في أجزاء مختلفة من الذرة (الأوراق والساق والجذور) بشكل ملحوظ مع زيادة الملوحة. في حين زاد تراكم الكالسيوم والبوتاسيوم والنيتروجين بشكل طفيف في البانيكوم الأزرق، و ذلك بشكل مهم فقط في أجزاء منفصلة من النبات.

بشكل عام، تشير دراستنا إلى أن الذرة أكثر حساسية للظروف الملحية (خاصة $\geq 6\ dS\ m^{-1}$) مقارنة بالبانيكوم الأزرق الذي يتكيف في بيئة عالية الملوحة بشكل جيد $>10\ dS\ m^{-1}$. كما تشير هذه النتائج إلى أن إستخدام البانيكوم الأزرق كمحصول بديل في التربة المتأثرة بالملوحة، مثل منطقة فم الواد بالعيون في المغرب، سيؤدي إلى إنتاج أفضل من الإنتاج الحالي للمحاصيل التقليدية كالذرة العلفية، الشيء الذي سيحسن من دخل المزارعين المحليين.

الكلمات المفتاحية: الملوحة، المياه المالحة، امتصاص المعادن، الزراعة الملحية، التكيف، الامتصاص، البانيكوم الأزرق، الذرة العلفية.

Introduction

Salinity has obviously contributed to soil salinization in Morocco, as it has in most Mediterranean countries, particularly in arid and desert areas (Hssaisoune *et al.*, 2020). Rainfall limitation, heavy evapotranspiration, over-expansion of agricultural activities (Ait Kadi and Ziyad, 2018), and salt water irrigation are all related to soil salinization. As a result, forage crop yields were constrained.

Therefore, It is better to grow species that are salt-tolerant in these conditions (Boukhari *et al.*, 1988; FAO, 2008; Shahbaz *et al.*, 2011). This would allow for more productive use of salinity-exposed soils, the growth of new cropping areas, and the use of saline water (Boukhari *et al.*, 1988). These plants, known as halophytes, can grow in high-salt environments and have a comparative edge over non-halophyte plants, known as glycophytes. Furthermore, unlike glycophytes, halophytes evolve three mechanisms to respond to salt stress: osmotic adaptation, exclusion, and inclusion. The first approach entails adjusting the concentrations of compatible solutes (K^+, Ca^{2+}, etc) in tissues in order to achieve a higher ionic concentration in the intracellular medium than in the external medium (Hasegawa *et al.*, 2000). The second mechanism involves preventing salt from reaching the leaves through the internal layer of the root cells (Batanouny, 1993; Munns and Tester, 2008). The third mechanism involves holding the salt in vacuoles using "molecular pump" methods (Zid and Boukhris, 1977; Gorham J. *et al.*, 1985). Halophytes can keep their osmotic potential low, allowing them to absorb water from a solutes rich soil (Raven, 1985). Na^+ and Cl^- ions become toxic to plants at high salinity concentrations (Pang *et al.*, 2007) and induce a water deficit (Desclos, 2008). When essential ions like K^+, Ca^{2+}, or NO_3^- become restricting, this nutritional imbalance can cause growth reductions in the presence of salt (Soltani *et al.*, 1990).

Blue panic and silage maize are two halophytes that have adapted to the pedoclimatic environments of arid and semi-arid regions (Shahbaz *et al.*, 2011; Koyro *et al.*, 2013; Hirich and Choukr-Allah, 2018). In Morocco, silage maize has traditionally been used by farmers in the irrigated perimeter of Foum El Oued in Laayoune to feed livestock. However, with the increasing soil salinity in the perimeter, farmers' production is significantly affected. Using blue panic as cattle fodder in salt affected areas such as the Foum El Oued perimeter (of an average soil salinity of 6 dS m^{-1}) has shown promising results in terms of crop productivity (Hirich and Choukr-Allah, 2018). Blue panic is resistant to drought and salt stress (Ashraf, 2004; Ahmad *et al.*, 2010). Some species can tolerate salinity of up to 15,000 mg L^{-1} and drought, and it uses about half as much water as alfalfa (Boukhari *et al.*, 1988). Blue panic is an excellent forage grass due to its high protein content (15 - 18%) (Boukhari *et al.*, 1988). This study is part of a larger Agroecological megaproject of INRA-Morocco's medium-term program which aims - through a series of field and laboratory experiments (involving the dynamics of soil salinity, different irrigation systems, soil amendments, salt tolerant plant by-products, etc) - the development of a sustainable solution to manage and buffer the effect of salinity on the soils of irrigated areas in marginal lands in order to improve their productivity and upscale the outputs. The aim of the mesocosm experiment detailed here was to isolate the effects of saline water on blue panic and silage maize

from the effects due to saline soil and to emphasize the mechanism of nutrients uptake by leaves, stems and roots using different levels of saline irrigation water.

Materials and methods

Experimental design

To isolate the effects of saline water from the effects of saline soil and to investigate the mechanism of nutrient uptake, peat was used to make the substrate for the experiment. Basic substrate properties are presented in Table 1. pH was determined on 3:50 peat: water (ASTM D 2976-71, 2004), electrical conductivity on 1:5 peat: water, organic matter content by loss on ignition at 550 °C, available phosphorus using the Olsen method and the exchangeable bases with ammonium acetate extract. Blue panicum (*Panicum antidotale Retz.*; public type from Kuwait) and silage Maize (*Zea mays L.*; Dragma variety) were collected from preceding field trials at the INRA experimental station of Foum El Oued in Laâyoune. Seeds were germinated in trays filled with peat until the seedling stage. Two seeds were sown per tray and were daily watered with tap water in a greenhouse for 20 days. The seedlings were transplanted to mesocosms (30 cm x 15 cm x 10 cm) filled with 800 g of peat and irrigated regularly with different saline water treatments.

The experimental design was a randomized complete block involving four irrigation water treatments in four replicates for each crop. The treatments (T0, T1, T2, and T3 corresponding to 0.9, 3, 6, and 10 dS m^{-1}) were prepared by adding different sea salt to tap water. The Plants were daily irrigated with salt water (from 150 to 300 ml $mescosm^{-1}$ day^{-1} depending on the plants' requirements) to compensate for water depletion due to evapotranspiration (Leye *et al.*, 2012). The amount of water needed to compensate for evaporation losses from a cylindrical tank filled with water was extrapolated to the surface of the mesocosm and then was supplied to the plants. The reservoir was put under the same conditions as the mesocosms.

Table 1: Physical and chemical properties of the peat used to grow blue panic and silage maize (mean ± standard deviation, *n* = 3)

	pH	**Electrical conductivity (dS m^{-1})**	**Organic matter (%)**	**Available phosphorus P_2O_5 (ppm)**	**Potassium K_2O (ppm)**	**Sodium Na^+ (ppm)**	**Calcium Ca^{2+} (ppm)**	**Humidity (%)**
Peat	5.17 ± 0.06	2.8 ± 0.44	76.43 ± 2.67	31.32 ± 4.93	84.99 ± 0.67	11.86 ± 2.67	482.76 ± 4.94	37.84 ± 0.12

Measurements

Plant growth and biomass

Plant material of both species was collected at the end of experiment. Leaves, stems, and roots were harvested with roots washed free of substrate.

The stems cut at the soil surface level were measured for length using a graduated ruler. The fresh plant material of both species was weighed then oven dried at 80 °C to constant weight (Cornelissen *et al.*, 2003)**.**

Chlorophyll pigments

The chlorophyll contents were determined from green leaves by Lichtenthaler (1983) method. Fresh leaf material (100 mg) was extracted in 100 % acetone and incubated in ice for 15 minutes. The extract was centrifuged at 3000 rpm for 5 min at 4°C. Using UV-Visible Spectrophotometer (Optizen 3220UV, Daejeon, Korea), absorption from the surnatants was measured at λa = 645 nm, λb = 662 nm for chlorophyll a and b and λc = 470 nm for carotenoids. The values are given in µg ml^{-1} of fresh matter (Lichtenthaler and Wellburn, 1985).

$$\text{Chlorophyll a } (\mu g\ ml^{-1}) = (11.24 \times DO\ \lambda b) - (2.04 \times DO\ \lambda a)$$

$$\text{Chlorophyll b } (\mu g\ ml^{-1}) = (20.13 \times DO\ \lambda a) - (4.19 \times DO\ \lambda b)$$

$$\text{Carotenoids } (\mu g\ ml^{-1}) = (1000 \times DO\ \lambda c - 1.90\ Chl\ a - 63.14\ Chl\ b) / 214$$

Total leaf proline

The proline content was quantified according to Troll and Lindsley (1955) method simplified and developed by Dreier and Göring (1974). The fresh leaf materiel (100 mg) was digested with 2 ml of ethanol 40% and placed in heated water bath at 85°C for 1 hour.

After cooling, 1 ml of extract was mixed with 1 ml of a solute composed of 300 ml of acetic acid, 120 ml distilled water, and 80 ml orthophosphoric acid, 2 ml of acetic acid and 25 mg ninhidrin. The mixture was heated again at 100°C for 30 min, until the solution turned red. The whole is cooled and 5 mL of toluene were added. Two phases separate after shaking, the upper phase containing proline is recovered with a pasteur pipette and a small spoonful of anhydrous sodium sulfate is added. The optical density was determined using a spectrophotometer (UV Visible - modèle Optizen 3220UV) set at wavelength of 528 nm. The reading is taken according to the calibration curve and values are given in mg g^{-1} fresh matter.

Plant mineral content

Oven dried plant material, stems, leaves and roots, were milled to a fine powder < 500 µm. The homogenized powder was used to determine the main mineral content following the standard plant analysis methods described in the INRA laboratory manual. The total nitrogen (N) and phosphorus (P) contents were determined following the Kjeldahl and sulfuric extraction methods respectively (Pinta, 1973). Samples were digested using automatic Kjeldahl Digestion Unit (Velp scientifica, Italy) then distillated using steam distillation system (Gerhardt Vapodest VAP20, Germany). The measurements of phosphorus were made using UV-Visible Spectrophotometer (Jenway 6305, United Kingdom)**.**

The potassium (K^+), calcium (Ca^{2+}), and sodium (Na^+) contents were determined from digested dry plant material (shoot or root) using sulphuric acid and hydrogen peroxide according to Wolf (1982). The digests were diluted to 1:50 with distilled water and analyzed using a flame photometer (BWB-XP, United Kingdom).

Statistical analysis

The obtained data were analyzed using one-way analysis of variance (ANOVA) with different irrigation water treatments as the main factor and Tukey's post hoc pairwise comparison. Normality was checked and data were log-transformed to achieve homogeneity of variance when required. SPSS program (IBM Corp. Released in 2011, Version 20) was used to assess the statistical significance of mean variations between treatments. The threshold for significance was set at < 0.05 *p* values.

Results

Plant height

Figure 1 shows the mean stem height of blue panic and silage maize for all the irrigation water treatments. Stem height varied significantly between treatments in blue panic ($p = 0.012$) and silage maize ($p < 0.001$). For blue panic, the height slightly decreased at 3 dS m^{-1} compared to control treatment then significantly increased at 6 dS m^{-1} and 10 dS m^{-1}. However, these variations were not significantly different from the control. For silage maize, stem height significantly decreased with increasing salinity, resulting in a height difference of 33.5 cm between T3 (10 dS m^{-1}) and the control treatment. Figure 2 illustrates the difference in growth between representative replicates of different treatments for the two plant species. (Figure 2).

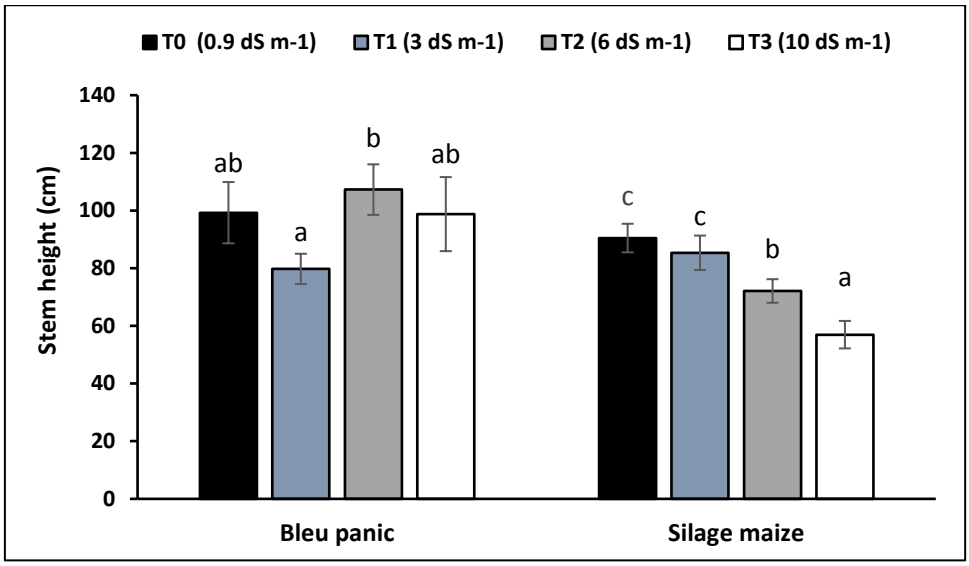


Figure 1: Mean stem height of blue panic and silage maize by tested treatments. The symbols T0 (0 dS m^{-1}), T1 (3 dS m^{-1}), T2 (6 dS m^{-1}), and T3 (10 dS m^{-1}) refer to the four saline irrigation water treatments. Lowercase letters on columns (a, b, c) refer to statistical differences between treatments (T0, T1, T2 and T3) for each plant species. Columns with the same letter over them are not significantly different. (Mean ± standard deviation; *n* = 4)

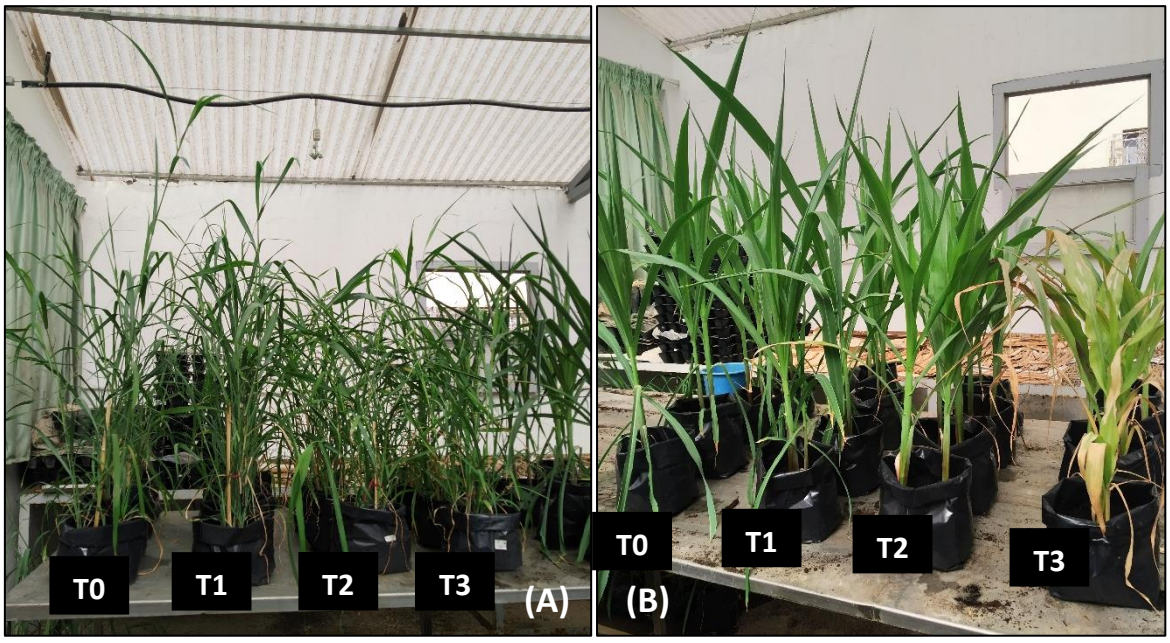


Figure 2: Growth of blue panic (A) and silage maize (B) by tested treatments. The symbols T0, T1, T2, and T3 refer to the four saline irrigation water treatments with T0 = 0.9 dS m^{-1}, T1 = 3 dS m^{-1}, T2 = 6 dS m^{-1} and T3 = 10 dS m^{-1}.

Plant dry biomass

The means of aboveground and root dry biomass of blue panic and silage maize for each treatment are shown in Figure 3. There was no significant difference in the aboveground dry biomass between treatments for blue panic (p = 0.210). For silage maize however, the aboveground dry biomass, significantly decreased with increasing irrigation water salinity compared to the control (p < 0.001). Root dry biomass on the other hand significantly decreased for both blue panic and silage maize (p = 0.009, p < 0.001 respectively) relative to control.

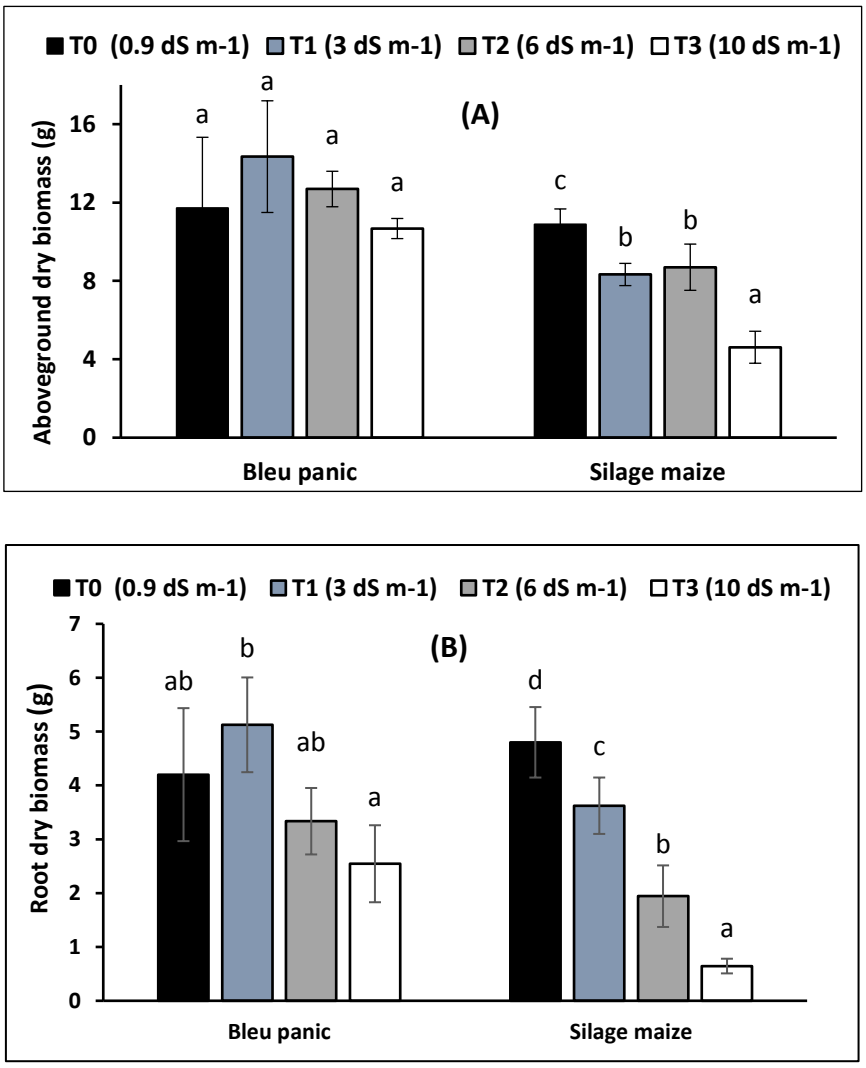
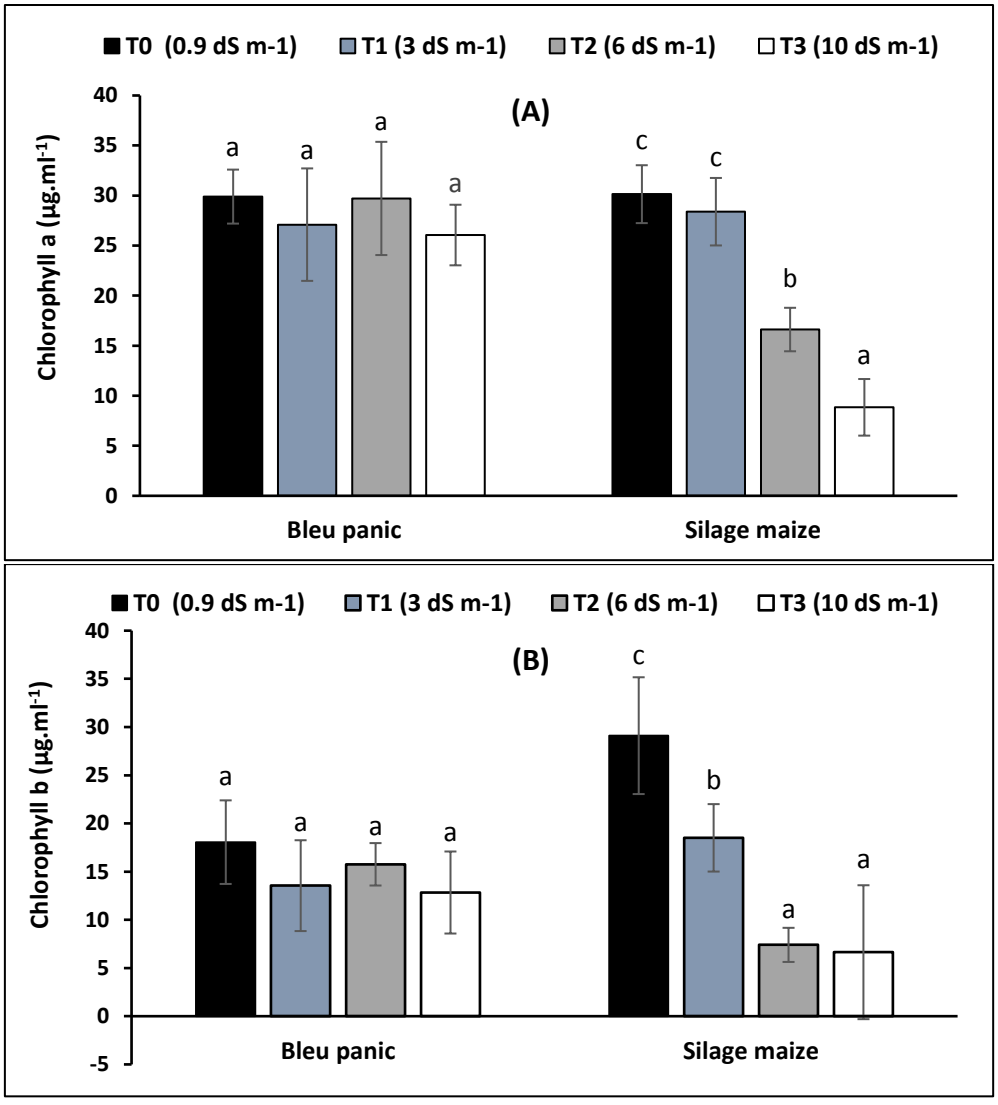


Figure 3: Mean aboveground dry biomass (A) and root dry biomass (B) of blue panic and silage maize by tested treatment. The symbols T0 (0.9 dS m^{-1}), T1 (3 dS m^{-1}), T2 (6 dS m^{-1}), and T3 (10 dS m^{-1}) refer to the four saline irrigation water treatments. Lowercase letters on columns (a, b, c) refer to statistical differences between treatments (T0, T1, T2 and T3) for each plant species. Columns with the same letter over them are not significantly different. (Mean ± standard deviation; n = 4).

Chlorophyll pigments

Salinity treatment had no effect on the chlorophyll a and chlorophyll b content of blue panic. Except the increase in treatment T2, no significant differences were recorded in carotenoid content in T1 and T3 compared to control (Figure 4). For silage maize however, all the chlorophyll pigment content decreased significantly as the irrigation water salinity increased ($p < 0.001$).



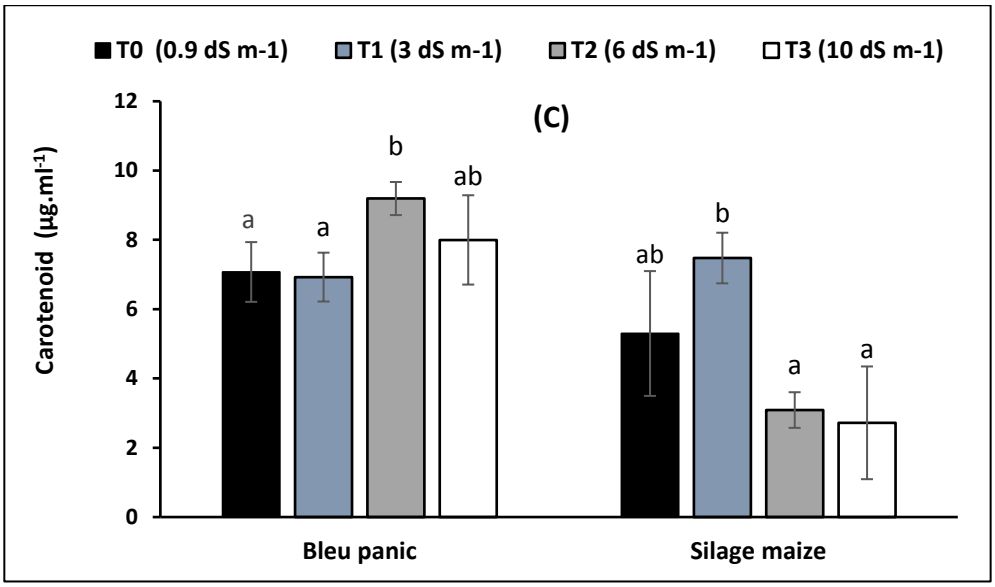


Figure 4: Mean Chlorophyll a (A), chlorophyll b (B) and carotenoid (C) content of blue panic and silage maize leaves by tested treatment. The symbols T0 (0.9 dS m^{-1}), T1 (3 dS m^{-1}), T2 (6 dS m^{-1}), and T3 (10 dS m^{-1}) refer to the four saline irrigation water treatments. Lowercase letters on columns (a, b, c) refer to statistical differences between treatments (T0, T1, T2 and T3) for each plant species. Columns with the same letter over them are not significantly different. (Mean ± standard deviation; *n* = 4).

Total leaf proline

Figure 5 shows the mean proline content of blue panic and silage maize leaves by tested treatments. The proline content increased in blue panic and gradually decreased in silage maize with increasing salinity of irrigation water. However, the variation was not significantly different for both plant species.

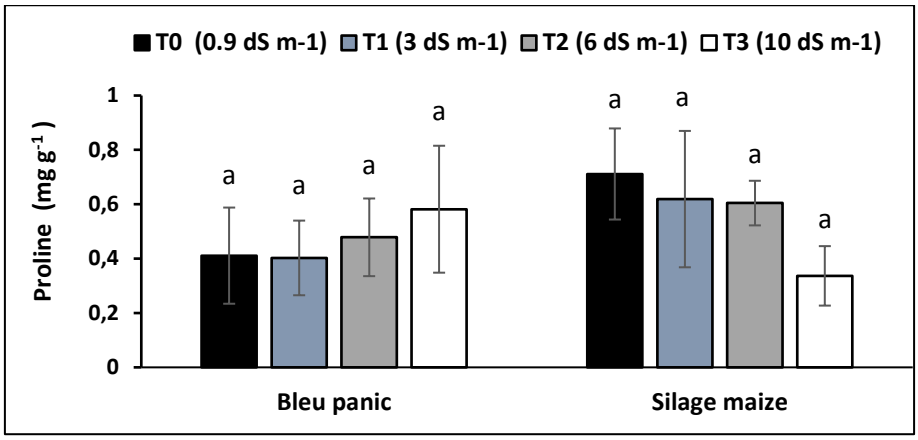


Figure 5: Mean proline content of blue panic and silage maize leaves by tested treatment. The symbols T0 (0.9 dS m^{-1}), T1 (3 dS m^{-1}), T2 (6 dS m^{-1}), and T3 (10 dS m^{-1}) refer to the four saline irrigation water treatments. Lowercase "a" letter on columns refers to the no significantly differences between treatments (T0, T1, T2 and T3) for each plant species. (Mean ± standard deviation; *n* = 3).

Mineral content

Table 2 shows the nitrogen (% N), phosphorus (% P), potassium (% K^+), sodium (% Na^+) and calcium (% Ca^{2+}) content in the leaves, stems and roots of blue panic and silage maize by tested treatments.

Nitrogen content (% N) in leaves and roots of blue panic was not significantly different between treatments. However, a significant accumulation of nitrogen occurred at treatment T2 = 6 dS m^{-1} (p = 0.026) relative to the control to attain values similar to those in T3 (10 dS m^{-1}). For silage maize, the % N gradually decreased in leaves and roots but increased in the stems with increasing irrigation water salinity. However, these variations were not statistically significant.

Concerning Phosphorus content (% P), it decreased in leaves, stems, and roots of blue panic with increasing saline treatment although the effects were not significant. For silage maize, irrigation water salinity significantly decreased % P in the leaves (p = 0.001), roots (p < 0.001), and stems (p = 0.02) with the lowest content recorded for T3 = 10 dS m^{-1}.

Potassium content (% K^+) significantly increased in blue panic stems (p = 0.023) as irrigation water salinity increases, but was not significantly different in leaves and roots compared to control. For silage maize, the decrease of potassium content K^+ was highly significant (p < 0.001) in leaves and roots with increasing irrigation water salinity. The % K^+ contents were however similar within the stem. The irrigation water salinity resulted in a significant accumulation of Na^+ in the leaves, stems and roots of blue panic and silage maize (p = 0.001) compared to control with the highest values recorded for T3. The sodium content Na^+ was though higher in silage maize material than in blue panic (Table 2). Calcium content (% Ca^{2+}) on the other hand increased in blue panic and decreased in silage maize for all treatments compared to control. This was however only significant in leaves and roots of both crop species (p < 0.001).

Table 2: Nitrogen (% N), phosphorus (% P), potassium (% K^+), sodium (% Na^+), and calcium (% Ca^{2+}) content in the leaves, stems and roots of Blue panic and silage Maize by tested treatments. The symbols T0 (0.9 dS m^{-1}), T1 (3 dS m^{-1}), T2 (6 dS m^{-1}), and T3 (10 dS m^{-1}) refer to the four saline irrigation water treatments. Lowercase letters (a, b, c) next to values refer to statistical differences between treatments (T0, T1, T2 and T3) for each plant species. Values with the same letter next to them are not significantly different. (Mean ± standard deviation; *n* = 3).

		Bleu panic			Silage maize		
		Leaf	Steam	Root	Leaf	Steam	Root
% N	T0	0,003± 0,000a	0,002± 0,001a	0,002± 0,001a	0,048± 0,010a	0,012± 0,012a	0,014± 0,006a
	T1	0,002± 0,001a	0,002± 0,001a	0,003± 0,002a	0,035± 0,012a	0,018± 0,014a	0,015± 0,007a
	T2	0,003± 0,000a	0,024± 0,013b	0,004± 0,003a	0,025± 0,000a	0,022± 0,012a	0,012± 0,005a
	T3	0,003± 0,003a	0,013± 0,012ab	0,004± 0,005a	0,028± 0,006a	0,043± 0,015a	0,004± 0,004a
% P	T0	0,172± 0,038a	0,129± 0,000a	0,094± 0,046a	0,094± 0,021c	0,182± 0,044b	0,208± 0,016c
	T1	0,200± 0,023a	0,210± 0,053a	0,044± 0,017a	0,008± 0,009a	0,144± 0,034b	0,108± 0,032bc
	T2	0,243± 0,103a	0,185± 0,053a	0,049± 0,023a	0,056± 0,011b	0,035± 0,024a	0,044± 0,032b
	T3	0,124± 0,057a	0,109± 0,038a	0,043± 0,019a	0,014± 0,010a	0,007± 0,008a	0,002± 0,002a
% K^+	T0	0,077± 0,004a	0,062± 0,010ab	0,017± 0,009a	0,268± 0,022c	0,146± 0,032a	0,114± 0,012c
	T1	0,087± 0,006a	0,040± 0,014a	0,017± 0,004a	0,178± 0,014b	0,152± 0,044a	0,063± 0,017b
	T2	0,081± 0,004a	0,064± 0,009ab	0,013± 0,005a	0,102± 0,008a	0,154± 0,030a	0,033± 0,012ab
	T3	0,073± 0,010a	0,071± 0,003b	0,008± 0,002a	0,092± 0,005a	0,147± 0,010a	0,014± 0,004a
% Na^+	T0	0,007± 0,001a	0,012± 0,001a	0,011± 0,003a	0,018± 0,008a	0,232± 0,036a	0,036± 0,006a
	T1	0,016± 0,001b	0,013± 0,001ab	0,033± 0,004b	0,058± 0,007b	0,198± 0,034a	0,061± 0,011b
	T2	0,016± 0,003b	0,015± 0,002ab	0,036± 0,011b	0,174± 0,011c	0,330± 0,044b	0,275± 0,027c
	T3	0,021± 0,004b	0,018± 0,003b	0,062± 0,007c	0,251± 0,014d	0,455± 0,028c	0,422± 0,020d
% Ca^{2+}	T0	0,001± 0,001a	0,006± 0,003a	0,008± 0,002a	0,105± 0,009c	0,110± 0,017a	0,103± 0,008c
	T1	0,016± 0,004b	0,015± 0,006a	0,018± 0,007ab	0,070± 0,019b	0,090± 0,010a	0,098± 0,001b
	T2	0,016± 0,006b	0,008± 0,002a	0,022± 0,003bc	0,067± 0,007b	0,085± 0,008a	0,123± 0,004b
	T3	0,017± 0,003b	0,006± 0,003a	0,035± 0,006c	0,033± 0,006a	0,091± 0,001a	0,049± 0,007a

Discussion

Physiological parameters

Blue panic showed high tolerance to irrigation water salinity in terms of growth and production as it has been observed in many studies (Al-Khateeb, 2006; Koyro *et al.*, 2013; Atia *et al.*, 2019). In our study the crop showed a slightly increase in height as irrigation water salinity increases (except for T1) but was not significantly different compared to control (Figure 1). The shorter plants under 3 dS m^{-1} (T1) irrigation water treatments would be attributed to a couple of T1 mesocosms being moved unwittingly to a shadowed spot within the greenhouse because of lack of space. The decrease in hight is consistent with the decrease in the chlorophyll a and b content in treatment T1 as shown in Figure 4. The highest value was recorded in T2, but was not significantly different relative to control and T3 (Figure 1). Similarly, the shoot dry biomass (Figure 3) was not affected by the salinity treatments. Blue panic is a halophyte plant, characterized by its capacity to grow under different levels of salinity of irrigation water where they develop stress-response systems (Khan, 2000; Al-Khateeb, 2006; Flowers and Colmer, 2015). In our study blue panic root dry biomass decreased with increasing salinity to be significant at 10 dS m^{-1}. This adaptive response enables prolonging plant survival in drying salinized environments. Toxic ions are excluded and compartmentalized in the cell vacuole, where they do the least harm as well as competitive displacement of essential Ca^{2+} from plasma membrane binding sites in expanding tip tissue (Neumann, 1995). Some authors have shown that the inhibition of root elongation growth is not attributed to toxicity but to salt-inducing regulated biophysical restraints to cell wall expansion, which in turn inhibit root expansion growth (Neumann, 1995). Once the stress level is intense (> 10 dS m^{-1} in our study for blue panic) and the plant has a low ion exclusion capacity (the case of silage maize at 6 dS m^{-1}) the effects show up on leaf production and on the roots (dehydration of the plant) (Atia *et al.*, 2019).

By comparison, the height of silage maize decreased by increasing salinity with a significant effect at 6 dS m^{-1}. The aboveground dry biomass and root dry biomass of silage maize significantly decreased in all treatments compared to control. The inhibitory action of NaCl, at certain salinity levels (> 3 dS m^{-1} for the silage maize variety “Dragma” used in our experiment), on the development of the aerial parts, which manifests itself by a delay in tillering (Gate, 1995). Thus, the nitrogen and phosphorus deficit (Table 2) manifests itself by a reduced growth of the vegetative apparatus, followed by a yellowing and sometimes senescence of the lowest leaves (Lafitte *et al.*, 2004). If the total nitrogen supply to the grain falls below a certain level, the flow of carbohydrates is also affected (Below et al., 1997).

Biochemical parameters

In blue panic, all treatments showed similar chlorophyll a and b leaf content (Figure 4) and the carotenoid content significantly increased only in the T2 (6 dS m^{-1}) treatment compared to the control, which is consistent with the results of Koyro et al. (2013). According to these authors, the growth of blue panic (*P. turgidum*) is correlated with chlorophyll content, net photosynthetic rate, transpiration, and water use efficiency. In

this species, the relative chlorophyll content is highest at moderate salinity (12.5 dS m^{-1} NaCl) and decreased significantly at high salinity (50 dS m^{-1} NaCl). In our experiment, the highest irrigation water salinity used was 10 dS m^{-1} which would be considered moderate salinity and explain the insignificant differences for blue panic. The chlorophyll a and b and carotenoid content in silage maize showed a significant decrease at salt treatments > 6 dS m^{-1}, where the plants show stress signs (Figure 2b). According to Santos (2004), the decline in chlorophyll levels in silage maize is caused by the high enzymatic activity of chlorophyllase, particularly with rising NaCl concentrations. Or, it might be due to the generation of ROS (Reactive oxygen species) in the chloroplast, such as O^-, OH^-, or H_2O_2, which might limit photosynthesis (Debez *et al.*, 2008; Koyro *et al.*, 2013).

The proline level in blue panic and silage maize was similar, with increasing irrigation water salinity. Indeed, proline in aerial organs under salinity stress is considered to be an adaptation trait developed by the plant to cope with both salt stress (Kramer, 1974; Su and Wu, 2004; Megdiche *et al.*, 2007) and water stress (Hsiao, 1973). The proline concentration of blue panic tends to build with increasing salinity, which is consistent with previous findings (Turan *et al.*, 2010; Abideen *et al.*, 2014; Bouassaba and Chougui, 2018). In silage maize, even not significant, the proline content exhibits a deficit trend with increasing salinity. This might be related to the silage maize's genetic characteristics, to the halophytic characteristic against extreme salinity, or to the fact that the silage maize plants had not yet enough time to complete their development cycle, reaching an acceptable stage of maturation to accumulate proline.

Mineral content

Overall, the nitrogen content of blue panic was not affected by the salinity of irrigation water. This might be due to the activation of Na^+ ions in pyruvate phosphodikinase, an enzyme involved in nitrogen fixation (Guignard, 1998). It may also be due to the high solubility of proline in water which functions as a nitrogen and energy accumulator (Stewart and Lee, 1974; Treichel, 1975). The increasing proline concentrations in blue panic leaves with increasing salinity (Figure 5) would increase this effect.

Nitrogen uptake in silage maize was also not affected by salinity, but trends suggest a decrease in content within the roots. It might be caused by a nutritional imbalance where certain important ions such as K^+, Ca^{2+}, or NO_3^- become limited (Soltani, 1988). The presence of Cl^- inhibits the absorption of NO_3^- (Smith, 1973; Abdiyev Vilayet and Gasumov Nemet, 2012).

The salinity of the irrigation water not affecting phosphorus uptake in blue panic would be due to the membrane phospholipids inducing large degradation in which high phosphatidylinositol (Pi) might be produced under salt stress conditions (Collins, 2001; Nordberg and Arnér, 2001; Guo *et al.*, 2019). Naceur et al. (2003) recorded a high accumulation of Pi in forage plants subjected to stressful conditions. They argued that phosphorus may be released after a degradation of phospholipid integrity in cell membranes (Lee and Ratcliffe, 1983; Bennaceur, 1994) which would explain the phosphate concentration's stability. The decrease in phosphorus content in different parts of silage maize (leaf, stem and root), is consistent with the findings of Bernstein

and Pearson (1956). Both authors ascribe the decrease in % P uptake to the antagonistic impact of Cl^- (produced during irrigation with high NaCl concentration water). As a result, the plant's number of leaves and growth were limited (Figure 1 and Figure 3).

The use of a salt water treatment at various concentrations causes an increase in Na^+ in plant tissues. The difference between the treatments was significant for both blue panic and in silage maize. However, silage maize showed a significantly higher Na^+ content than blue panic (Table 2). This would be attributed to the ability differences of both crops to involve both mechanisms, (expulsion and compartmentalization,) of adaptation to salt stress (Batanouny, 1993; Munns and Tester, 2008). Silage maize of treatment T2 onwards has a limited salt resistance, so that it does not have the ability to re-excrete Na^+ ions in the soil. Blue panic has rather the capacity to exclude the toxic ions Na^+ at 10 dS m^{-1} without affecting the growth, the metabolism and K^+ uptake.

For the potassium content, the leaves and roots of blue panic were not significantly affected by salinity. While there was a significant variation in K^+ content at the stem, we couldn't identify any trends. In contrast to Na^+ uptake, the K^+ content significantly decreases in silage maize leaves and roots as salinity increases. Shabala et al. (2013) reported that the capacity of plants to exclude toxic ions such as Na^+ and Cl^- from transport systems is correlated to their salt tolerance. They involve transport systems contributing to Na^+ and K^+ homeostasis, which would explain the non-significant impact of salinity on K^+ uptake in blue panic. In the case of intense salt stress, as for silage maize, Na^+ competes with K^+ for uptake into the cell, as both ions are transported across the plasma membrane by several identical transport systems. The absence of K^+ variation at the steam of silage maize could be due to a delay in the onset of symptoms.

Irrigation water salinity induces a significant increase in Ca^{2+} content in blue panic and this could be due to the low concentration of Na^+ in the plant tissues (Table 2) (Parida *et al.*, 2004). Salinity tolerant crops, such as blue panic, regulate the Na^+ content and therefore the Ca^{2+} content is not affected. For silage maize, salinity induces a significant decrease in Ca^{2+} content. This is due to the accumulation of Na^+ ions in the cytoplasm of the cells, which limits the uptake of cations such as K^+ and Ca^{2+}. Soltani et al. (1988) reported that there is competition between Na^+ and Ca^{2+} for the same apoplasmic binding sites.

Conclusion

This experiment investigated physiological and biochemical traits and nutrients uptake associated with salt tolerance of blue panic and silage maize. Our results support previous findings that blue panic tolerate high salt concentrations in irrigation water. Only slightly significant differences were found for few measured parameters. The physiological parameters showed that the irrigation water salinity of 10 dS m^{-1} was not enough to significantly impact the growth and biomass of blue panic. However, Irrigation water salinity of 3 dS m^{-}1 was the threshold of salinity tolerance we found for silage maize biomass. The biochemical analysis showed no effect of the applied salt concentrations on proline content for both crop species. However, the blue panic stabilized the chlorophyll content in the leaves while it decreased significantly in the silage maize. While the Ca^{2+} and K^{+} content increased in blue panic and decreased in silage maize, Na^{+} uptake increased with increasing salinity for both species. These results suggest that, rather than traditional silage maize, blue panic is a suitable saline-tolerant alternative crop for growing in saline areas such the irrigated perimeter of Foum El Oued in Laâyoune where the average soil and water salinity are 6 dS m^{-1} and 7 dS m^{-1} respectively. Further large-scale experiments are required to better understand the effects and their implications. The effects of higher concentrations of NaCl than 10 dS m^{-1} on blue panicum should also be investigated. It would be particularly important to examine the salinity-nutrient uptake interaction under different types of soil.

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