Vol. 14(1), pp. 1-12, July-December 2022
DOI: 10.5897/IJPPB2022.0316
Article Number: 7D95D4869827
ISSN 2006-9758

http://www.academicjournals.org/IJPPB

International Journal of Plant Physiology and Biochemistry

Full Length Research Paper

Response of tossa jute (*Corchorus olitorius* L.) salt stressed plants to external application of calcium and potassium

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Received 31 August, 2022; Accepted 13 October, 2022

This study focused on the improving effect of external application of calcium and potassium on growth, ions and organic solutes accumulation in tossa jute plants grown under salt stress. Young plants were subjected in pots to ten treatments including the control without NaCl, 120 mM NaCl and a combination of 120 mM NaCl and an addition of 40 or 60 mM $CaSO_4$, $CaCl_2$, K_2SO_4 or KNO_3. Plant growth, sodium, potassium, proline and soluble sugars contents were determined after two weeks. Results revealed that only the external application of $CaSO_4$ and K_2SO_4 at 40 mM significantly improved the growth reduction induced by NaCl followed by $CaCl_2$; whereas at 60 mM, only $CaSO_4$ induced similar changes in plant growth. Only, the exogenous application of calcium at 40 mM induced a significant decrease ($p<0.05$) in the Na^+ content and a significant increase ($p<0.001$) of the K^+/Na^+ ratio of leaves in comparison with salt stressed plants, while the two forms of calcium and K_2SO_4 induced a significant increase ($p=0.05$) in the K^+ content. $CaSO_4$ had the best improving effects on plants growth under salt stress, followed by K_2SO_4 and $CaCl_2$ at 40 mM. This improving effect is due to a better exclusion of Na^+ from the leaves, the maintenance of a high ionic selectivity ratio K/Na and/or a better accumulation of K^+.

Key words: *Corchorus olitorius*, sodium, potassium, calcium sulphate, calcium chloride, potassium sulphate, potassium nitrate, proline, soluble sugars.

INTRODUCTION

Increasing soil salinity poses a major threat to agricultural growth and production worldwide (Shrivastava and Kumar, 2015; Machado and Serralheiro, 2017), particularly in semi-arid regions. It is considered to be the main abiotic factor that limits plant productivity and agricultural yield (Rozema and Flowers, 2008; Abd-Latef, 2010). The effects of salinity on plants can be osmotic in nature (reduction of water absorption by the plant after high osmotic pressure), toxic (transport and accumulation of excessive amounts of certain ions, in particular Na^+ in the

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aerial parts) or nutritional (deficiency in the absorption of certain essential ions, K^+ and Ca^{++} in particular) (Bacha et al., 2015). Under its stressful effects, plants react by modifying their morpho-physiological, anatomical, metabolic and hormonal behavior (Ramezani et al., 2011; Ambede et al., 2012; Abreu et al., 2013; Qadir et al., 2014; Benidire et al., 2015). Adaptation to this stress is accompanied by metabolic adjustment which results from the accumulation of various organic solutes such as sugars, polyols, betaines and proline (Zivcak et al., 2016) for the maintenance of ionic homeostasis, the trapping of free radicals, the expression of certain proteins and the regulation of their genes (Tuteja, 2007; Munns and Tester, 2008).

In West Africa, market gardening appears to be one of the main components of urban and peri-urban agriculture that is of capital importance in the economic development of cities (FAO, 2012). Considered as a food sovereignty activity (FAO, 2012), market gardening plays a key role in most nutrition and poverty reduction programs and contributes significantly to family incomes (James et al., 2010; Yolou et al., 2015). However, the production of these vegetables is limited by multiple abiotic and biotic constraints that affect yields and subsequent post-harvest operations (Yarou et al., 2017). In Benin, tossa jute (*Corchorus olitorius* L.), commonly called “crincrin” occupies an important place in the diet of the population and is one of the most widely practiced market garden crops (Savi, 2009). In our previous study, we have reported that NaCl salt stress reduced tossa jute plants growth and that the response varied greatly according to the cultivar (Loko et al., 2020). To mitigate the negative effects of salinity on plants and circumvent this stress, one of the techniques consists of adding macro elements such as potassium, calcium, magnesium or phosphorus to enrich the substrate used for growing plants. Particular interest has been focused on calcium because of its ability to induce a protective effect on plants in unfavorable environmental conditions (Manaa et al., 2014). Calcium plays a vital role in salt stress tolerance as it induces the activities of antioxidant enzymes and reduces lipid peroxidation of cell membranes under abiotic stress (Jiang and Huang, 2001; Khan et al., 2010). Several authors have reported that the exogenous application of potassium (K) improves the response to salinity in certain species such as groundnut (Chakraborty et al., 2016) and amaranth (Omami and Hammes, 2006; Atou et al., 2020). To the best of our knowledge, no studies have investigated the improvement of tossa jute salt tolerance through the exogenous supply of mineral compounds. The objective of the study is to evaluate the effect of the exogenous application of calcium and potassium in different forms on growth, mineral nutrition and organic solutes of tossa jute plants grown under salt stress in order to determine the compounds efficient in alleviating salt detrimental effect and the physiological strategy involved in the acquired salt tolerance.

MATERIALS AND METHODS

Plant material

It consists of a local cultivar of tossa jute cultivar called *5 Doigts*. The seeds of this cultivar were provided by the Market Gardening Sub-Program of the National Institute of Agricultural Research of Benin (INRAB).

Experimental conditions

The experiment was carried out in a screening house at the International Institute of Tropical Agriculture (IITA)/ (Abomey-Calavi, Republic of Benin) from October to November 2020. The plants were grown at a temperature of 32°C/33°C day/night with natural light and 84% relative humidity. The experiment was conducted as described by Atou et al. (2020). The saline treatment consisted of watering the plants every two days with 200 ml/pot of NaCl solution alone or in combination with $CaSO_4$, $CaCl_2$, K_2SO_4 or KNO_3. The experiment was set-up as a completely randomized design with ten (10) treatments and three replicates. These treatments are: Control (C): 0 mM NaCl; Saline treatment (S): 120 mM NaCl; saline treatment plus an application of 40 mM $CaSO_4$; saline treatment plus an application of 60 mM $CaSO_4$; saline treatment plus an application of 40 mM $CaCl_2$; saline treatment plus an application of 60 mM $CaCl_2$; saline treatment plus an application of 40 mM K_2SO_4; saline treatment plus an application of 60 mM K_2SO_4; saline treatment plus an application of 40 mM KNO_3; saline treatment plus an application of 60 mM KNO_3. The experiment was evaluated after two weeks of treatment.

Growth determination

The effect of salt stress on plant growth was determined after two weeks exposition to salt. Growth parameters taking into account were plant height (PH), shoot fresh mass (SFM), shoot dry mass (SDM), root fresh mass (RFM) and root dry mass (RDM). Shoot water content was calculated as [shoot fresh mass – shoot dry mass) / shoot fresh mass] × 100.

Extraction and estimation of ion concentrations

For the determination of ions, the treatment of root and leaf samples and the determination of ion concentrations were carried out as indicated by Gouveitcha et al. (2021). 20 mg of the dry leaf and root powders were placed in 10 ml jars and digested in 1 ml of nitric acid (68%) at room temperature. After 24 h, the volume was made up to 20 ml with distilled water. The solutions were filtered with Whatman paper (85 mm, Grade 1). The filtrate was used for the determination of the concentrations of ions Na^+ and K^+. The amounts of ions were expressed in mg g^{-1} of dry matter (dm) using a flame spectrophotometer (Sherwood Model 360).

Extraction and determination of soluble sugars and proline

The concentration of proline was determined spectrophotometrically using the method of Bates et al. (1973) and the results were expressed in nmol g^{-1} of fresh mass (fm). Total soluble sugars were estimated by the anthrone reagent method according to Yemm and

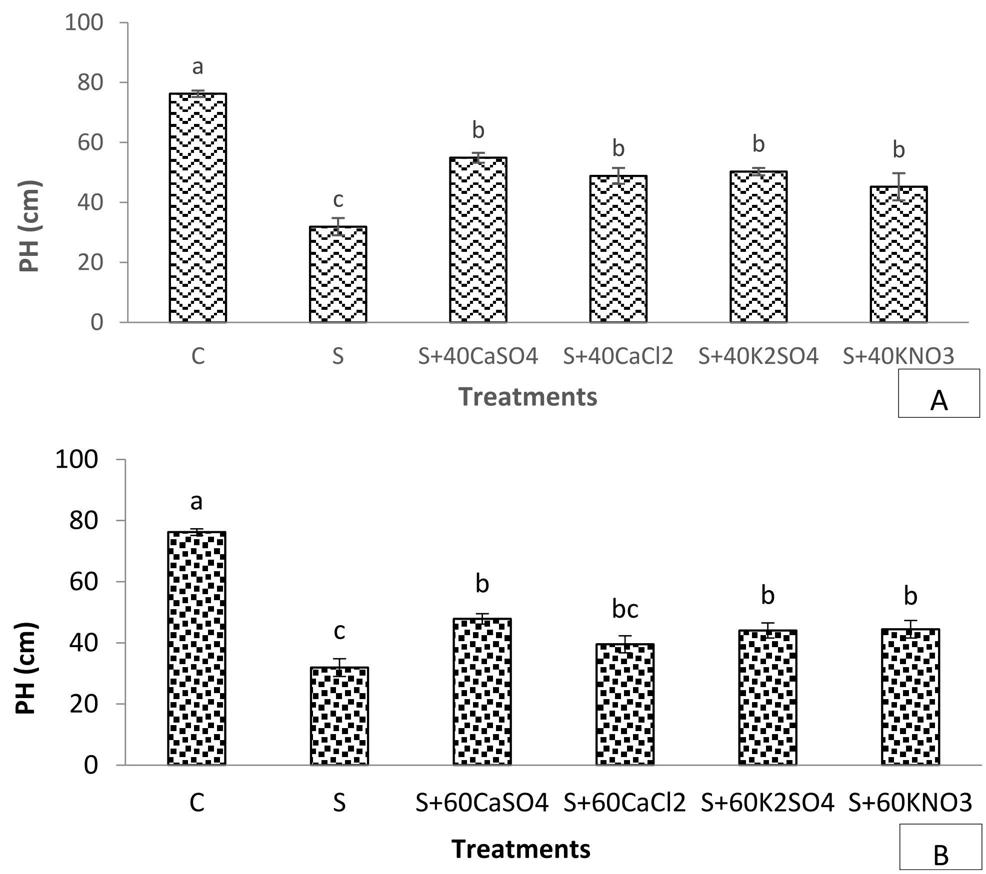

Figure 1. Effect of exogenous application of different forms of calcium and potassium on plant height of tossa jute plants grown under salt after two weeks; A: Exogenous application of 40 mM of compounds; B: Exogenous application of 60 mM of compounds (n= 3; vertical bars are standard errors). Means with different letters are significantly different at P=0.001.
Source: Author

Willis (1954) using a UV-visible spectrophotometer (Jenway 7305). The results were expressed in µg g^{-1} of fresh mass (fm).

Statistical analyses

For all the parameters, the means and standard errors were calculated with three (3) repetitions per treatment using the Excel spreadsheet. The results were subjected to one-way analysis of variance (ANOVA) and the means were compared with the Tukey-Kramer test. Analyses were performed using JMP Pro software (JMP Pro SAS Institute, 2009).

RESULTS

Effect of added compounds on plant growth and water content

Effect on plant growth

Salt stress induced a significant reduction ($p<0.001$) in plant height (PH). At 40 mM, the four compounds induced a significant improvement ($p=0.001$) in PH at about 72.02, 53.06, 57.6 and 41.71% in comparison with stressed plants respectively with $CaSO_4$, $CaCl_2$, K_2SO_4 and KNO_3 (Figure 1-a). At 60 mM, the height growth improvement was about 49.89, 23.88, 38.01 and 39.27% in comparison with stressed plants but this improvement was only significant ($p<0.001$) with $CaSO_4$; K_2SO_4 and KNO_3 (Figure 1-b).

Salt stress induced a significant reduction ($p<0.001$) in shoot fresh mass (SFM). At 40 mM, SFM improvement was about 188.44, 147.72, 160.79 and 122.8% in comparison with stressed plants respectively with $CaSO_4$, $CaCl_2$, K_2SO_4 and KNO_3 (Figure 2-a). However, this improvement was significant ($p<0.001$) only with $CaSO_4$ and K_2SO_4. At 60 mM, SFM improvement was significant ($p<0.001$) only with $CaSO_4$ (Figure 2-b).

For shoot dry mass (SDM), salt stress induced a significant decrease ($p<0.001$) but the supply of calcium and potassium in different forms at 40 mM induced a significant improvement ($p<0.001$) of 197.22, 166.67 and 155.56% in comparison with the stressed plants

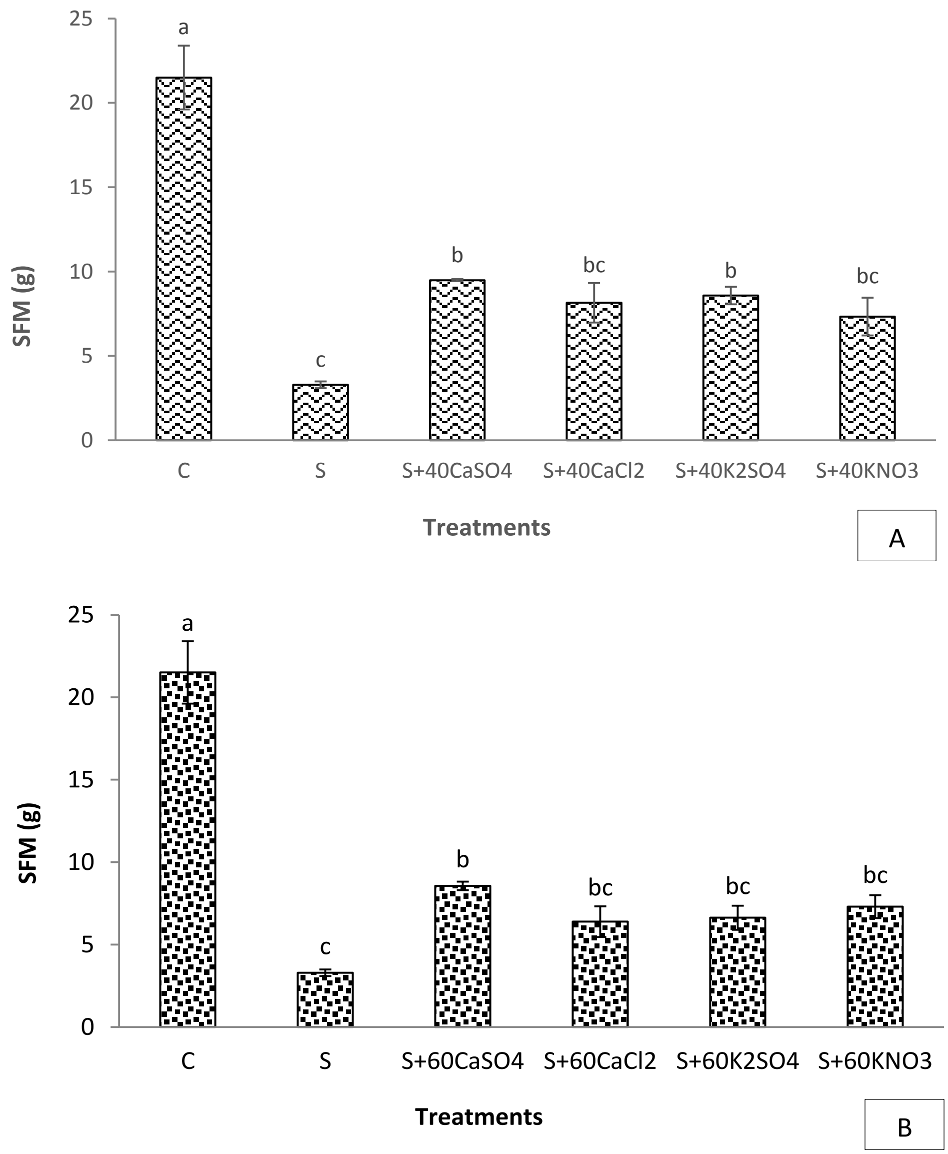

Figure 2. Effect of exogenous application of different forms of calcium and potassium on shoot fresh mass of tossa jute plants grown under salt after two weeks; A: Exogenous application of 40 mM of compounds; B: Exogenous application of 60 mM of compounds (n= 3; vertical bars are standard errors). Means with different letters are significantly different at P=0.001.
Source: Author

respectively with $CaSO_4$, $CaCl_2$ and K_2SO_4 (Figure 3-a). At 60 mM, SDM improvement was significant ($p<0.001$) only with $CaSO_4$ (Figure 3-b).

Table 1 presents the effect of an exogenous application of calcium and potassium in different forms on the root growth of tossa jute plants. Salt stress induced a significant decrease ($p<0.001$) in root fresh mass (RFM) and root dry mass (RDM). None of the four compounds used induced an improvement in root growth either at 40 mM or at 60 mM.

Overall, roots were not sensitive to the improving effect of the four compounds used. Moreover, at 40 mM, $CaSO_4$ and K_2SO_4 had a significant improving effect on the three aerial part growth parameters taken into account, $CaCl_2$ on two growth parameters and KNO_3 only on one growth parameter. At 60 mM, $CaSO_4$ had similar effect on aerial part growth as at 40 mM but K_2SO_4 and KNO_3 had significant effect only on one growth parameter (plant height). Thus, 40 mM had the best improving effect in plant growth under salt stress conditions whatever the compound used. For this reason, researchers decided to continue the study with the four compounds at 40 mM.

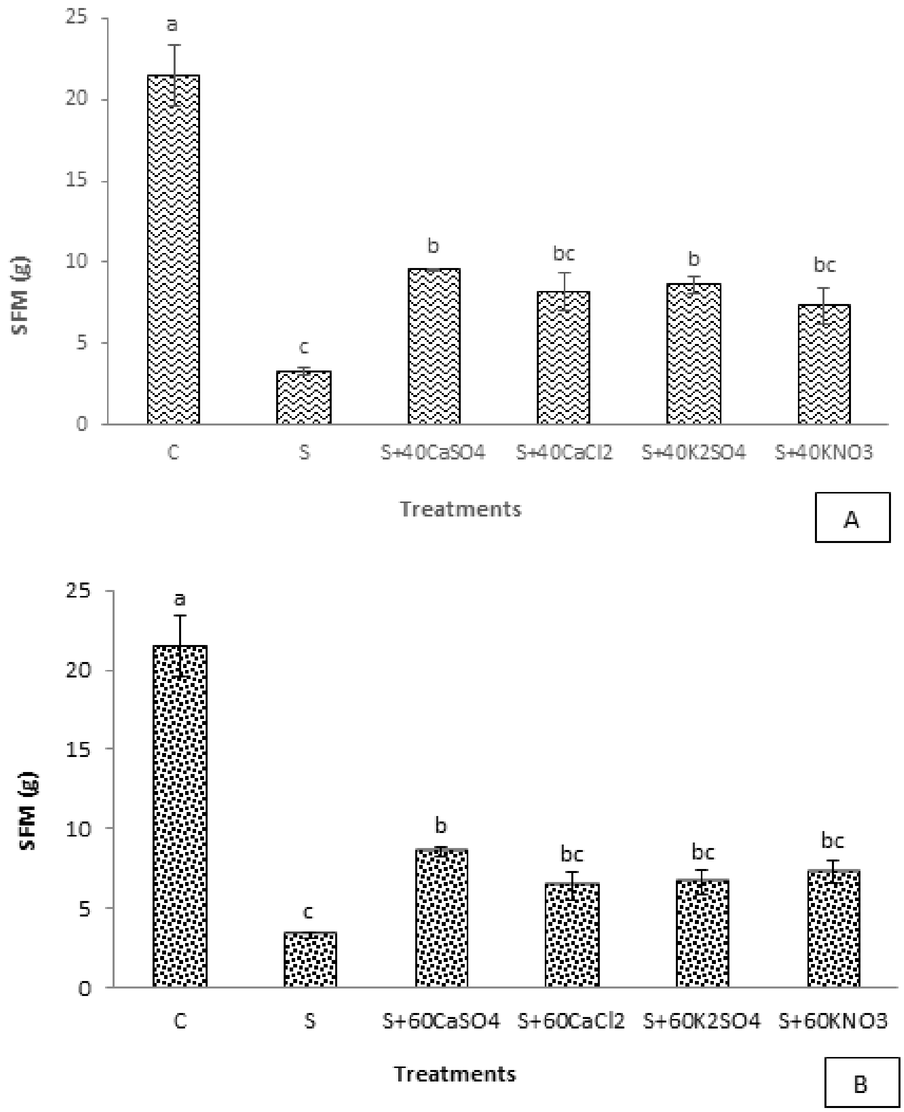

Figure 3. Effect of exogenous application of different forms of calcium and potassium on shoot dry mass of tossa jute plants grown under salt after two weeks; A: Exogenous application of 40 mM of compounds; B: Exogenous application of 60 mM of compounds (n= 3; vertical bars are standard errors). Means with different letters are significantly different at P=0.001.
Source: Author

Effect on shoot water content

NaCl stress induced a significant decrease ($p<0.05$) of shoot water content in tossa jute plants but the external application of none of the four compounds induced a significant improvement of shoot water content (Table 2).

Effect of NaCl and added compounds on the ion content of plants

Figure 4 shows the effect of an external supply of the four compounds on the sodium and potassium contents of the leaves and roots of the tossa jute plants grown in the presence of salt stress for two weeks. Under the effect of NaCl, sodium content of leaves and roots underwent a significant increase ($p<0.001$). With the compounds provided at 40 mM, this content underwent in leaves a decrease of 50, 50, 25 and 25% compared to the stressed plants respectively with $CaSO_4$, $CaCl_2$, K_2SO_4 and KNO_3. However, the 40 mM, this content underwent in leaves a decrease of 50, 50, 25% and 25% compared to the stressed plants respectively with $CaSO_4$, $CaCl_2$, K_2SO_4 and KNO_3. However, the decreases observed

Table 1. Effect of exogenous application of different forms of calcium and potassium on root growth of tossa jute plants grown under salt after two weeks (n= 3; values are means ± standard errors).

Treatment		RFM	RDM
	T	2.27±0.54[a]	0.17±0.03[a]
	S	0.74±0.20[b]	0.04±0.02[b]
$CaSO_4$	S+40	1.11±0.13[ab]	0.13±0.01[ab]
	S+60	0.83±0.10[b]	0.11±0.00[ab]
$CaCl_2$	S+40	1.08±0.22[ab]	0.12±0.01[ab]
	S+60	0.79±0.07[b]	0.10±0.01[ab]
K_2SO_4	S+40	1.07±0.04[ab]	0.12±0.01[ab]
	S+60	0.66±0.06[b]	0.12±0.05[ab]
KNO_3	S+40	1.01±0.14[ab]	0.11±0.01[ab]
	S+60	0.72±0.11[b]	0.10±0.01[ab]

Means with different letters are significantly different at P=0.001.
Source: Author

Table 2. Effect of external application of different forms of calcium and potassium on shoot water content (%) of tossa jute plants grown under salt stress after two weeks (n= 3; values are means ± standard errors).

Treatments		Shoot water content
	C	91.85±0.46[a]
	S	89.13±0.57[b]
$CaSO_4$	S+40	88.77±0.37[b]
	S+60	88.65±0.34[b]
$CaCl_2$	S+40	88.23±0.18[b]
	S+60	87.85±0.88[b]
K_2SO_4	S+40	89.28±0.45[b]
	S+60	88.89±0.50[ab]
KNO_3	S+40	88.46±0.38[b]
	S+60	88.75±0.82[b]

Means with different letters are significantly different at P=0.05.
Source: Author

were significant ($p<0.01$) only for $CaSO_4$ and $CaCl_2$. No significant change was observed for root sodium content with the compounds used. Thus, only the exogenous application of $CaSO_4$ and $CaCl_2$ induced an exclusion of sodium ion from leaves in salt stressed plants.

Under the effect of NaCl, potassium content of the leaves and roots underwent a significant decrease ($p<0.001$) (Figure 5). With the compounds supplied at 40 mM, this content showed an increase of 95.65, 69.57, 40.58 and 11.59% in leaves compared to stressed plants respectively for $CaSO_4$, $CaCl_2$, K_2SO_4 and KNO_3. The increases observed were significant ($p<0.001$) for $CaSO_4$, $CaCl_2$ and K_2SO_4. Thus, only the application of KNO_3 did not induce an accumulation of K^+ in leaves. In roots, only $CaSO_4$ induced a significant increase ($p<0.001$) in K^+ content.

Salt stress induced a significant decrease ($p<0.001$) in the K/Na ratio of leaves and roots. The application of $CaSO_4$, $CaCl_2$, K_2SO_4 and KNO_3 induced an increase in this ratio but this increase was significant only with

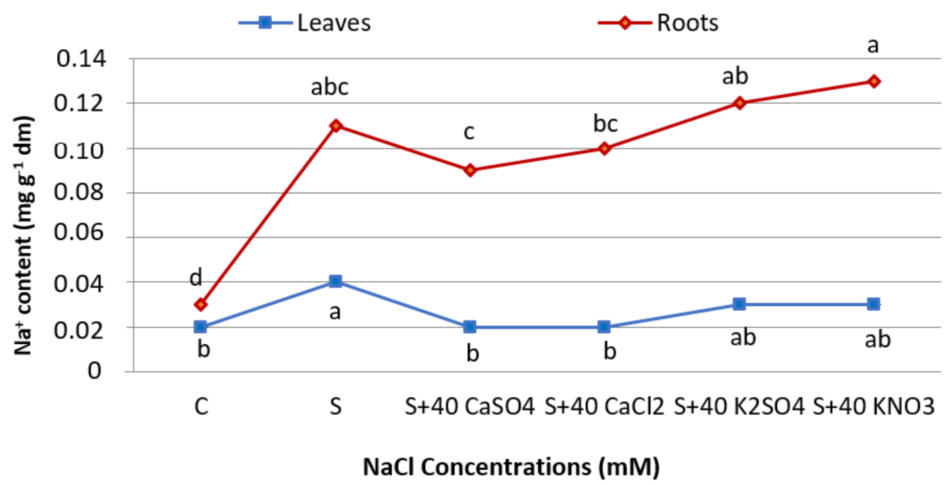

Figure 4. Effect of exogenous application of different forms of calcium and potassium on sodium ions (Na^+) content in leaves and roots of tossa jute plants grown under salt stress after two weeks (n= 3; vertical bars are standard errors). Means with different letters are significantly different at P=0.01 or P=0.001.
Source: Author

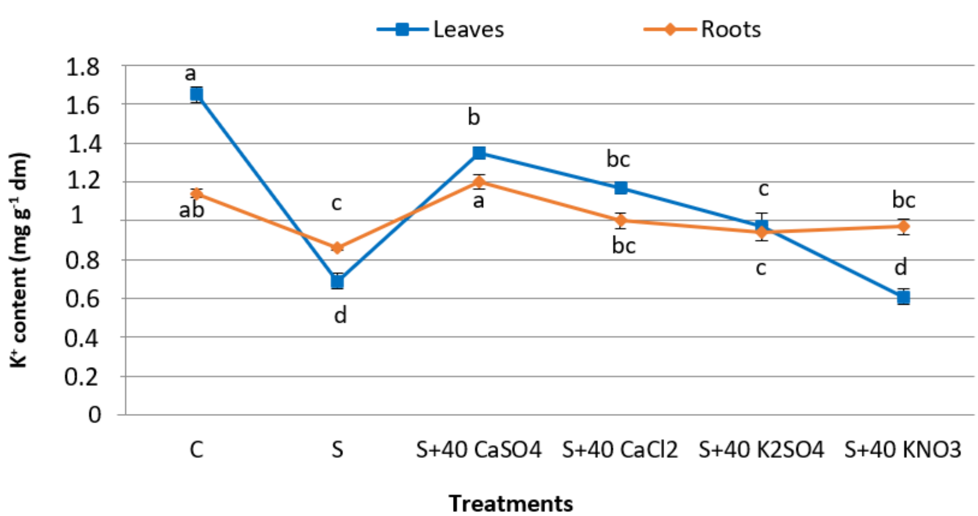

Figure 5. Effect of exogenous application of different forms of calcium and potassium on potassium ions (K^+) content in leaves and roots of tossa jute plants grown under salt after two weeks (n= 3; vertical bars are standard errors). Means with different letters are significantly different at P=0.001.
Source: Author

$CaSO_4$ and $CaCl_2$. In the roots, no significant change was observed for the K/Na ratio. Thus, only the exogenous application of $CaSO_4$ and $CaCl_2$ induced a maintenance of high K/Na ratio in leaves.

Effect of NaCl and added compounds on organic solutes content

Figure 6a and b shows the effect of an external supply of the four compounds on the proline contents of the leaves and roots of tossa jute plants grown in the presence of salt stress for two weeks. Under the effect of NaCl, proline content underwent a significant increase ($p<0.001$) in leaves and in roots. With the added compounds, this content underwent a decrease significant ($p<0.001$) in leaves for $CaSO_4$, $CaCl_2$ and KNO_3 and in roots only for $CaSO_4$ and $CaCl_2$ in comparison with the stressed plants.

Figure 7a and b shows the effect of an external supply

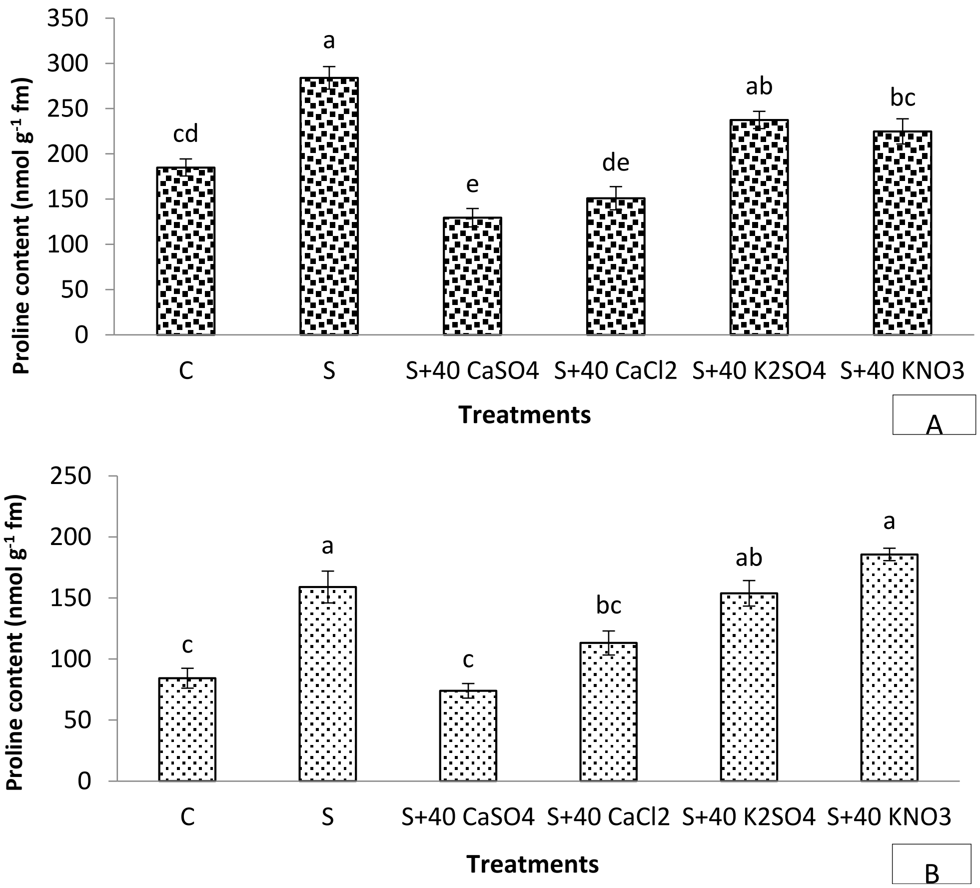

Figure 6. Effect of exogenous application of different forms of calcium and potassium on proline content in leaves (A) and roots (B) of tossa jute plants grown under salt after two weeks (n= 3; vertical bars are standard errors). Means with different letters are significantly different at P=0.001.
Source: Author

of the four compounds on the soluble sugars contents of the leaves and roots of tossa jute plants grown in the presence of salt stress for two weeks. Under the effect of NaCl, soluble sugars content underwent a significant increase in leaves ($p<0.001$) and in roots ($p<0.01$). With the added compounds, this content underwent a significant decrease in leaves ($p<0.001$) and in roots ($p<0.01$) for $CaSO_4$, $CaCl_2$ and KNO_3 in comparison with the stressed plants.

DISCUSSION

Effect of salinity on plant growth

Salt stress caused a reduction in the growth of all the parameters of the aerial part and the roots of tossa jute plants. This observation is commonly reported for glycophytes such as wheat (Alaoui et al., 2013), tomato (Zhang et al., 2017) rice (Prodjinoto et al., 2018); okra (Ayub et al., 2018; Gouveitcha et al., 2021). In tossa jute, other authors have reported that plant growth was inhibited by salt stress (Ghosh et al., 2013; Ben yakoub et al., 2019). Similar results have also been reported in other vegetable species such as eggplant (Kaya et al., 2003); pepper (Rubio et al., 2010; R'him et al., 2013) amaranth (Wouyou et al., 2017); and African eggplant (Sounou et al., 2021). Furthermore according to Bouchoukh (2010), salinity limits the growth and development of plants. This reduction in growth seems to be associated with a high accumulation of Na^+ in the plant. According to Odjegba and Chukwunwike (2012), the reduction in plant growth, especially in the accumulation of biomass, could be the consequence of water stress resulting from a decrease in the external osmotic potential and / or the accumulation of toxic ions. Results revealed that roots growth was not sensitive to the improving effect of the four compounds used and that at 40 mM. $CaSO_4$ and K_2SO_4 had the best and similar improving effect, followed by $CaCl_2$ and at 60 mM only $CaSO_4$ had the best improvement. Overall, 40 mM had the best improving effect in plant growth under salt stress conditions whatever the compound and whatever the concentration. These results showed that the improving

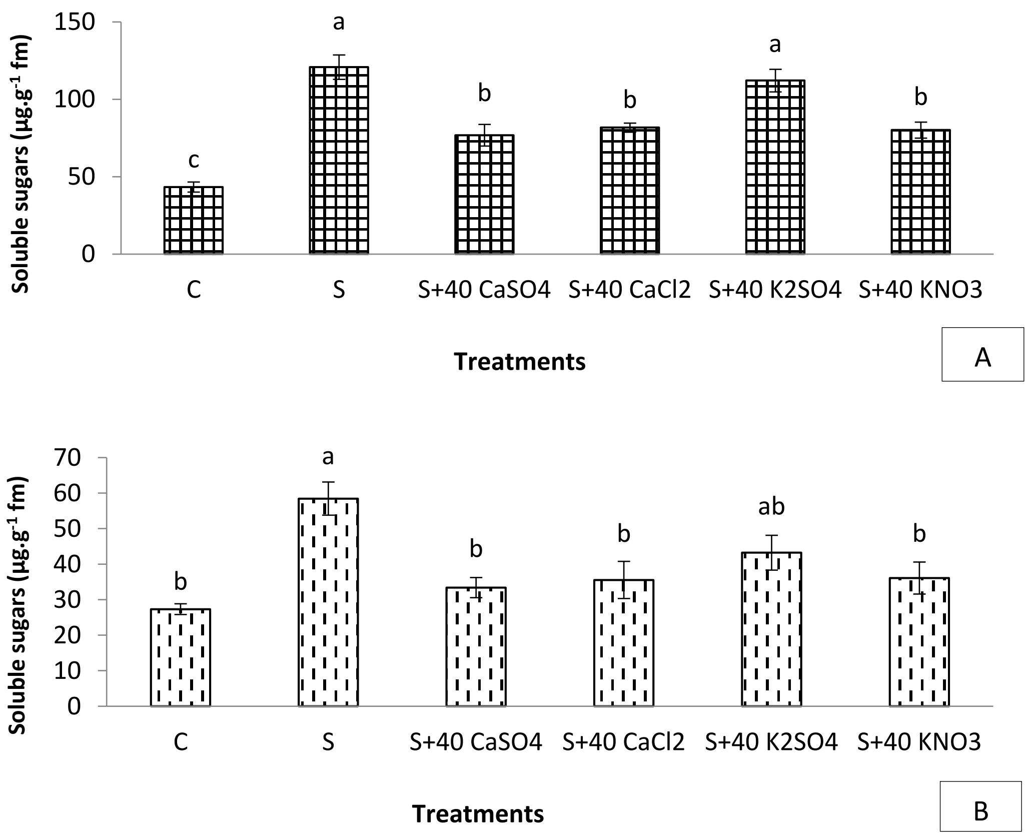

Figure 7. Effect of exogenous application of different forms of calcium and potassium on soluble sugars content in leaves (A) and roots (B) of tossa jute plants grown under salt after two weeks (n= 3; vertical bars are standard errors). Means with different letters are significantly different at P=0.001 (leaves) or P=0.01 (roots).
Source: Author

effect of calcium and potassium in tossa jute plants depends as well on the form in which the compound is supplied than the concentration used. Similar results were reported in tomato (Henry et al., 2020) and amaranth (Omami and Hammes, 2006; Atou et al., 2020).

Effect of NaCl and exogenous application of calcium and potassium on plant growth

Results revealed that the compounds used improved plant aerial part growth of salt stressed plants but had no effect on root growth indicating that the improving effect of calcium and potassium depends on the organ taken into account. At 40 mM, $CaCl_2$ had the efficacy to reduce the detrimental effect of NaCl on plant growth but this efficiency is lesser than that of $CaSO_4$ whereas at 60 mM, $CaCl_2$ was not efficient in reducing the detrimental effect of NaCl on plant growth as done $CaSO_4$. These results showed that between both forms of Ca, $CaSO_4$ was more efficient than $CaCl_2$. Similar results were reported in amaranth (Omami and Hammes, 2006; Atou et al., 2020) and tomato (Henry et al., 2021) where authors justified this difference by the additional contribution of Cl^- by $CaCl_2$ which is itself toxic for plants. However, it has been reported in sunflower that calcium supplementation was not able to improve NaCl damage (Sohan et al., 1999). This result indicates that the improving effect of calcium on the damage caused by NaCl depends not only on the form in which it is supplied but also on the plant species concerned.

The results show that potassium in its two forms (K_2SO_4 and KNO_3) applied at 40 mM improves aerial part growth of plants but K_2SO_4 was more efficient than KNO_3, whereas at 60 mM both forms of potassium had similar improving effect. These results showed that the improving effect of potassium on the growth of tossa jute plants depends as well as on the form in which it is supplied and on the dose applied. However, in amaranth it has been shown that it is only in the form of KNO_3 that potassium improves the growth of the aerial part of plants (Atou et al., 2020).

An increase in the dose of all the compounds induced a reduction in their efficiency showing that this dose of 60 mM is excessive for these compounds (except for $CaSO_4$). Thus, the dose of 40 mM of the various

Table 3. Effect of exogenous application of different forms of calcium and potassium on ionic selectivity ratio K^+/Na^+ in leaves and roots of tossa jute plants grown under salt after two weeks (n= 3; vertical bars are standard errors).

	Treatment					
	C	**S**	**S+40 $CaSO_4$**	**S+40 $CaCl_2$**	**S+40 K_2SO_4**	**S+40 KNO_3**
Leaves	75.10±4.28^a	19.56±2.28^c	68.05±5.08^{ab}	49.54±3.95^b	43.58±10.89^{bc}	23.30±2.20^c
Roots	39.39±4.47^a	7.55±0.39^b	12.88±0.34^b	10.10±0.83^b	8.11±0.31^b	7.60±0.18^b

Means with different letters are significantly different at P=0.001.
Source: Author

compounds applied is quite sufficient to attenuate the harmful effects of salinity on tossa jute plants. Moreover, whatever the compound, the supply of 40 mM had the best improving effect; and whatever the concentration, $CaSO_4$ had the best improving effect. Therefore, $CaSO_4$ appears to be the best candidate for mitigating the effects of salinity in tossa jute followed by K_2SO_4.

Involvement of ions accumulation in the improving effect of calcium and potassium

Results indicate that salt stress induced an increase in sodium uptake and a decrease in potassium uptake in leaves and roots inducing consequently a decrease in K/Na ratio. Similar results have been observed in amaranth (Atou et al., 2020) and tomato (Arbaoui, 2016). The improving effect of an external supply of calcium or potassium on salinity-induced damage has generally been associated with the maintenance of an optimal K^+/Na^+ ratio and homeostasis in the cytosol in relation to an inhibition of Na^+ influx, K^+ efflux or promotion of Na^+ efflux (exit from the cell) and K^+ influx (enter the cell) across the plasma membrane (Elphick et al., 2001; Demidchik and Tester, 2002; Shalaba et al., 2006; Hussain et al., 2013; Chakraborty et al., 2016). Results showed that only $CaSO_4$ and $CaCl_2$ supply had the best improving effects on the mineral nutrition of plants in leaves (reduction of Na^+ and increase of K^+ compared to stressed plants). The supply of $CaCl_2$ favored only a reduction of Na^+ content in leaves whereas the supply of K_2SO_4 favored only an increase of K^+ content in leaves. In roots, only $CaSO_4$ induce an improvement of mineral nutrition (increase of K^+ compared to stressed plants). These results show, on one hand that the effectiveness of $CaSO_4$ and $CaCl_2$ in attenuating the negative effects of salinity particularly in aerial part is associated either to an inhibition of the influx of Na^+ or the promotion of Na^+ efflux (cell exit) and K^+ influx (cell entry) across the plasma membrane and maintaining a higher K^+/Na^+ ratio; and on the other hand that the improving effect of K_2SO_4 was due only to a promotion of K^+ influx in leaves. These results supposed that the first mode of action of the compounds applied to mitigate salt stress effect on tossa jute plant growth is the improvement of their K^+ supply in leaves; and that reducing the Na^+ content in leaves and maintaining a high K^+/Na^+ ratio occurs in the second step (Shabala et al., 2006) (Table 3).. The importance of the promotion of Na^+ exclusion from leaves and that of K^+ accumulation in the improving effect of external application of potassium was reported in peanuts cultivars (Chakraborty et al., 2016).

Involvement of organic solutes accumulation in the improving effect of calcium and potassium

Salt stress induced an increase in proline and soluble sugars content in leaves and roots. This behavior is common in plants exposed to salt stress as reported in several vegetable species such as tomato (Rivero et al., 2014), sweet basil (Mousa et al., 2020), African basil (Loko et al., 2022) and okra (Gouveitcha et al., 2021). These organic solutes are known to play a key role in plant osmotic adjustment (Bouatrous, 2013; Bouassaba et al., 2018) as well as in the stabilization of certain proteins for proline (Bouatrous, 2013). Their accumulation is suggested as an indicator of tolerance to salt stress (Munns et al., 2006; Sakhanokho and Kelley, 2009). Results showed that the application of calcium and potassium reduced proline and soluble sugars content in comparison with salt stressed plants either in leaves or in roots showing that these organic solutes did not mediate the improving effect of the compounds used. Similar results were observed in two peanut cultivars where the external supply of potassium in a saline environment reduced proline accumulation compared to stressed plants, especially with the tolerant cultivar (Chakraborty et al., 2016).

Conclusion

Salt stress induced a significant reduction in the growth of tossa jute plants and the external supply of calcium and potassium attenuated the effects caused by salinity on plant growth. The improving effect of these compounds depends not only on the form in which they are applied and the dose applied, but also on the plant organ taken into account. Calcium in the form of $CaSO_4$ had the best improving effects followed by K_2SO_4, $CaCl_2$ and KNO_3. This improving effect is mainly due to better exclusion of Na^+ from the leaves, maintenance of a better K/Na ratio and/or better accumulation of K^+ in leaves. Proline and soluble sugars seem not to be involved in this improving effect.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

This study was partially funded by *Projet d'Appui au Développement du Maraîchage* (PADMAR). The authors appreciate Mr. Patrice Amoussou for proof-reading the present manuscript.

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