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Full Length Research

Effects of salinity on yield and yield components of three varieties of rice (*Oryza sativa* L.)

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ABSTRACT: Rice (*Oryza sativa* L.) is one of the vital agricultural food crops cultivated globally and a crop grown under an extensive irrigation scheme. In the semi-arid region of northern Nigeria, the interplay of climatic, geological, and anthropogenic characteristics renders the soil virtually saline. Among the monocot crops, rice is salt sensitive, and its productivity is severely affected by the accumulation of soluble salt in soils, especially in areas where irrigation is an essential aid to agriculture. A field trial experiment under split plot design (SPD) with three replications was carried out to assess the effects of NaCl and $CaCl_2$ at different concentrations (0.22, 4, 6, 8, 10 dSm^{-1}) on yield and yield components of some varieties of rice in Phase II Hadejia-Jama'are River Basin Irrigation Land. The result of the analysis of variance revealed that yield and yield components of rice were negatively affected among varieties and salinity of both salt types at different concentrations, particularly NaCl in the range of 8 to 10 dSm^{-1}. FARO 52 and FARO 44 produced higher yield, thus appeared to be more tolerant in terms of yield and yield components compared to JAMILA. It can be concluded that the yield and yield components of rice varieties studied were strongly affected among the varieties and the two salt types at different concentrations. As different rice varieties respond differently to salinity, it is recommended that more rice varieties need to be screened for salinity tolerance, and agronomic practices, including proper method of irrigation, water management and appropriate use of fertiliser, among others, should be reviewed to control the accumulation of salts in the soil.

Keywords: Rice (*Oryza sativa*), salinity, varieties, yield, yield components.

INTRODUCTION

Rice (*Oryza sativa* L.) is a monocotyledon spermatophyte crop belonging to the genus *Oryza* of the family Poaceae. It is an annual growing grass with round, hollow and jointed culms, flat leaves and a terminal inflorescence (Triphathi *et al.,* 2011). Rice is one of the most essential agricultural food crops cultivated in every part of the world and a crop grown under extensive irrigation regimes (Yeo and Flowers, 1983; Sahi *et al.,* 2006). However, in Nigeria, rice is one of the major staple foods consumed across all geopolitical zones and socioeconomic classes (Kamai *et al.,* 2020). Rice has been cultivated as a major crop for many years, and it currently sustains nearly one-half of the world population (Wu *et al.,* 2004; Joseph *et al.,* 2010).

Among the monocot crops, rice is salt sensitive, and its productivity is severely affected by the accumulation of soluble salts in soils (Maas and Hoffman, 1977; Ashraf, 2009). Salinity is a pervasive threat to crop yields, especially in countries where irrigation is an essential aid to agriculture (Flowers, 2004). Salt stress results from a number of detrimental processes, including the toxic action of Na^+, the impairment of K^+ nutrition, a modification in the plant water status and secondary stresses such as oxidative stress linked to the production of reactive oxygen species (Zhu, 2002; Ndayiragije and Lutts, 2006). High concentrations of salts in soils impose both ionic and osmotic stresses on plants; hence, salt stress has been a serious threat to crop production in irrigated land (Pitman and Lauchli, 2002).

In addition, Photoinhibition coupled with salinity stress causes serious damage to many cellular and physiological processes, including photosynthesis, nutrient uptake, water absorption, root growth and cellular metabolism, which all obviously lead to yield reduction (Darwish *et al*., 2009; Zeng and Shannon, 2000; Zhu, 2001). High salt concentration may lead to plant death and no yield. Research has shown that during fertilisation, salt stress may cause sterility of panicle, which leads to a decline in grain setting, pollen bearing capacity, and decrease of the stigmatic surface, or both (Abdullah *et al*., 2001). The main cause of decreased grain yield under salt stress is a lack of transformation of carbohydrates to vegetative growth and spikelet development. Zeng and Shannon (2000) observed negative linear relationships in many yield components with increased salt stress, such as the number of tillers per plant, number of spiklets per panicle, and per cent of sterile florets (Khatun and Flowers, 1995; Zeng and Shannon, 2000). According to the FAO (2017) and the Plant Nutrition Management Service, over 6 % of the world's land is affected by salinity. Of the current 230 million hectares of irrigated land, 45 million hectares are salt affected (19.5 %), and of the 1,500 million hectares under dry land agriculture, 32 million are salt affected to varying degrees (2.1%).

In Nigeria, one of the reasons for the failure of agricultural productivity is underestimating the importance of soil status. In the semi-arid region of northern Nigeria where the Hadejia-Jama'are River Basin is located, the interplay of climatic, geological and anthropogenic characteristics makes surface water virtually saline, and many farmers have been forced to invest exploitation of the water for the cultivation of many crops (Dammo *et al.,* 2015; Tukur *et al.,* 2016). It was also reported by Imam and Omar (2020) that the fertility status of soils in eastern Jigawa State, including Auyo, Birniwa, Guri, Hadeja, Kafin Hausa, Kaugama, Kirikasamma and Malam Madori, results in an increase in concentration of exchangeable sodium and most of the other exchangeable cations, which made the soil slightly alkaline and saline, respectively. Furthermore, most of the local farmers depend on the use of inorganic fertiliser and chemical herbicides as well as poor irrigation methods in their farming activities, which have deleterious effects on the soil used for the cultivation of crops, predominantly rice. Therefore, extensive research or information data available is required on abiotic factors, especially salinity, which may have significant effects on soil and thus affect the yield and yield components of rice plants.

MATERIALS AND METHODS

Study area

The research was carried out in the Phase II Irrigation Project of Hadejia-Jama'are River Basin Development Authority, Jigawa State, Nigeria, at Bangeli Irrigation Sector (latitude 12°33'41" N and longitude 9°68'34"), located 3.4 kilometres away from Auyo Town in Auyo Local Government Area, using an Irrigation tube well for five Months (March-July 2020).

Treatment combinations

A field trial experiment under Split plot design (SPD) with three replications was conducted. The research involved three different varieties of rice: FARO 44, JAMILA and FARO 52 obtained from Leventus Foundation Panda, Kano State. The treatment given included four different concentrations (4, 6, 8 and 10 dS m^{-1}) of NaCl and $CaCl_2$, each and a control of 0.22 dS m^{-1}. Each of the two salts, five concentrations, including control and the three varieties of rice were combined factorially, giving twenty-seven (27) treatment combinations. Varieties served as the main plot while salt type and concentrations served as subplots.

Preparation of salt solution

Four different concentrations of sodium chloride and calcium chloride (4, 6, 8 and 10 dSm^{-1}) were prepared in addition to a control using pure salts of NaCl and $CaCl_2$, adopting the method described by Auyo *et al.* (2020). Na^+ in the form of NaCl and Ca^{2+} in the form of $CaCl_2$ were prepared into five electrical conductivities (ECe) values in addition to a control, i.e. 0.22 dSm^{-1}, 4 dSm^{-1}, 6 dSm^{-1}, 8 dSm^{-1} and 10 dSm^{-1} to provide the desired levels of salinity as per treatment.

Agronomic practices

A portion of land measuring 250 m^2 from the experimental area was properly cleared using a tractor and other accessory farm tools such as a hoe and rake. Soil was well tilled, all trash of grasses was cleaned, and clots were broken into fine pieces, then treated with *glyphosate* (recommended herbicide). At each replicate, twenty-seven (27) plots of 1m x 1m and 0.5m between each were made using a hoe; plots were demarcated so as to minimise excess contamination between neighbouring plots (Sangita *et al*., 2018). Water was allowed to enter each plot with the aid of a water hose (2 inches in diameter) connected to the generator from the irrigation tube well. At each plot, pre-germinated seeds of uniform size were sown by hand (Pradheeban, 2017) as nursery preparation. Three weeks after germination, seedlings were uprooted manually using hand to remove weak and excessive numbers of seedlings germinated, then washed and transplanted manually at 20 cm x 20 cm spacing between each and 15 cm between the rows, three seedlings were transplanted, as described by Pradheeban (2017). Weeding activities were carried out manually whenever necessary throughout the experimental period. Fertiliser (N.P.K) at 120:60:60 kg h^{-1} and 130 kg h^{-1} of urea (46% Nitrogen) were applied at an appropriate time to each experimental unit (FAO, 2017).

Treatment application

After two weeks of transplanting as described by Hakim *et al.* (2014). Treatments were applied to the water in each plot accordingly, monitoring with an electric conductivity meter, to make the desired ECe values, while the control received no addition of salt. The salt concentrations were raised gradually until the desired concentration was achieved so as to prevent salt shock to the plant. The treatment application was carried out in the late evening to minimise damage.

Data collection and analysis

At harvest, when the grains have reached the maturity stage, three stands of plants in the middle of the plot were selected randomly for measurement of yield components. The number of effective tillers per stand, number of spikelets per panicle and number of grains per panicle were determined and recorded through manual counting, length of panicle per plant was measured using 30 cm plastic ruler. However, after threshing and winnowing, 1000- grain weight and grain yield per stand were determined in the laboratory using digital weighing balance while grain yield per plot was determined in the laboratory using digital weighing balance while grain yield per plot was determined after individual plots were harvested, threshed and winnowed then, weighed and eventually computed into hectare basis to obtain the actual yield per hectare. Data collected were subjected to the Genstat Statistical software package (Version 17.1.0.13780) for analysis of variance (ANOVA). The treatment means were compared through employing the least significant difference test at 5% level of significance.

RESULTS AND DISCUSSION

Effects of varieties on yield and yield components of rice

The results in Table 1 show the effect of varieties, salt type and concentrations and the interactions on yield and yield components of rice at harvest in a field trial at Bangeli Irrigation Land.

Panicle length (cm)

In terms of panicle length, there was a significant difference observed among the varieties. FARO 44 recorded the highest panicle length (20.6 cm), while FARO 52 recorded the lowest panicle length (19.4 cm). The reduction in panicle length might be a result of the negative effects of the induced salinity during seedling growth, especially at the panicle initiation stage. This result was in agreement with the findings of Hakim *et al.* (2013), who reported that panicle length was different in different rice varieties. It was also reported that yield components such as spikelets per panicle, panicle length, number of tillers per plant, number of florets per panicle, and 1000-grain weight are all severely affected due to increasing salt stress (Khatun and Flowers, 1995; Farshid and Hassan, 2012). Similarly, differential behaviour of panicle length under salt stress in different varieties of rice has been reported by Marassi *et al.* (1989). In contrast, Ali *et al.* (2004) reported that there is an increase in percentage for the number of primary branches per panicle, panicle length and fertility percentage in six genotypes tested.

Number of spiklets per panicle

When compared based on the number of spiklets per panicle, FARO 44 and FARO 52 recorded the maximum number (10.9 and 10.6), while the minimum number of spiklets per panicle (10.4) was recorded by JAMILA. This indicated that FARO 44 and FARO 52 showed more resistance to the induced salinity compared to JAMILA; this could be due to the fact that different rice varieties were identified to retain stress tolerance alleles in their genetic composition when they are facing harsh environmental conditions. This confirmed the findings of Makihara *et al.* (1999), who revealed that the yield component most responsible for the yield decrease under salinity varied among the varieties; the number of spikelets per plant was most responsible in IR28 and Pokkali. Several researchers also reported that there was a significant reduction in the number of spikelets per panicle in rice (Khan *et al.,* 1997; Cui *et al.,* 1995; Rad *et al.,* 2012).

Number of grains per panicle

With regard to the number of grains per panicle, there was no significant difference recorded among the three rice varieties studied in the research. This could be due to the genetic makeup of the varieties and efficient assimilation of photosynthetic products. Chamely *et al.* (2015) also observed the same criteria for the grain production per panicle. This result was in contradiction with the findings of Islam and Hossain (2020), who stated that different rice varieties respond differently to salinity of different concentrations in terms of grains per panicle.

Number of effective tillers per stand

In terms of the number of effective tillers per stand, there

Table 1. Effect of varieties, salt type and concentrations and the interactions on yield and yield components of rice at harvest in a field trial at Bangeli Irrigation Land.

Treatment	Yield and Yield Components							
	Length of Panicle (cm)	Number of spikelets/ panicles	Number of grains/ panicle	Number of effective tillers	1000 Grain weight (g)	Yield per stand (g)	Yield per plot (Kg)	Yield per hectare (Kg)
Varieties								
FARO 44	20.6^{a}	10.9^{a}	105.4^{a}	26.3^{a}	18.3^{a}	56.0^{a}	0.5^{a}	4665^{a}
JAMILA	20.0^{b}	10.4^{b}	104.5^{a}	22.8^{b}	19.0^{a}	58.7^{a}	0.5^{a}	4812^{a}
FARO 52	19.4^{c}	10.6^{a}	106.3^{a}	23.4^{b}	17.5^{b}	58.0^{a}	0.5^{a}	5164^{a}
LSD	0.46	0.34	1.88	1.74	0.78	2.86	0.04	642.3
Salt type and concentrations								
NaCl 4dSm^{-1}	21.7^{b}	12.3^{b}	119.2^{b}	34.2^{c}	19.6^{c}	92.9^{c}	0.8^{b}	8287^{b}
NaCl 6 dSm^{-1}	19.6^{c}	10.7^{d}	103.2^{d}	22.6^{d}	18.4^{e}	51.2^{d}	0.4^{d}	4478^{c}
NaCl 8 dSm^{-1}	18.2^{d}	8.9^{e}	93.6^{e}	16.7^{e}	16.8^{g}	29.4^{e}	0.3^{e}	2630^{d}
NaCl 10dSm^{-1}	17.3^{e}	8.6^{f}	88.1^{f}	13.6^{f}	16.2^{h}	21.9^{f}	0.20^{f}	1957^{d}
$CaCl_2$ 4dSm^{-1}	21.9^{b}	12.6^{b}	122.0^{b}	35.6^{b}	20.1^{b}	95.9^{b}	0.8^{b}	8427^{b}
$CaCl_2$ 6 dSm^{-1}	20.0^{c}	11.4^{c}	106.7^{c}	23.4^{d}	18.8^{d}	52.9^{d}	0.5^{c}	4613^{c}
$CaCl_2$ 8 dSm^{-1}	18.2^{d}	9.3^{e}	95.0^{e}	17.0^{e}	17.2^{f}	31.1^{e}	0.3^{e}	2706^{d}
$CaCl_2$10dSm^{-1}	17.4^{e}	8.3^{f}	89.6^{f}	14.1^{f}	16.3^{h}	22.8^{f}	0.2^{f}	2183^{d}
Control	25.5^{a}	13.4^{a}	131.3^{a}	40.6^{a}	20.9^{a}	119.9^{a}	1.1^{a}	8641^{a}
LSD	0.39	0.55	2.04	1.23	0.29	1.65	0.01	1405.3
Interactions								
Variety x Salt types and conc.	**	NS	**	*	**	**	**	NS

*Values in a column followed by the same superscript do not differ significantly at 5% level of significance.

was a significant difference among the varieties. FARO 44 recorded the maximum number of effective tillers (26.3) while FARO 52 and JAMILA recorded the minimum number of effective tillers. The number of tillers per plant is an important yield parameter under salinity because it determines the number of grain-bearing panicles of the rice plants, which eventually reflects on the total yield of the plant (Tanveer *et al.,* 2009). This result also indicates the tolerance behaviour of FARO 44 to salinity conditions and the sensitivity of FARO 52 and JAMILA. This reduction could be a result of salinity stress imposed at the tillering stage, resulting in a reduction in photosynthesis. The present result confirmed the findings of Uyoh *et al.* (2020), who reported that Salinity treatment caused a highly significant reduction in the number of tillers in the treated genotypes. Similar results were also revealed by Hassanuzzaman *et al.* (2016); there was a significant variation in the number of tillers per hill amongst the varieties. It was also stated by Abhilash and Mohanan (2013) that the number of total tillers produced showed a significant reduction in three cultivars due to salt stress. Other researchers also reported the reduction of tiller number in different rice cultivars (Linghe *et al.,* 2000; Weon *et al.,* 2003; and Akram *et al.,* 2013).

1000-grain weight (g)

Based on 1000 grains weight (g), there was a significant difference recorded between the three rice varieties, JAMILA and FARO 44 recorded the highest value (19.0 and 18.3 g, respectively), while the lowest value (17.5 g) was recorded by FARO 52. This reduction in 1000-grain weight might be due to the negative effect of the salinity stress that decreases the translocation of food materials to the grain or lower accumulation of carbohydrates and other food materials that result in a lowering of grain weight. This was in accordance with the findings of Pradheeban (2017), who reported that among the varieties studied, significant differences were observed in 1000-grain weight due to salinity stress, compared with other varieties.

Actual yield (Kg)

However, in terms of yield per stand (g), yield per plot (kg), and yield per hectare (kg), there was no significant difference among the three rice varieties studied. This equal tolerance observed amongst the rice varieties might be due to the presence of large number of genetic resources, genes and quantitative trait loci (QTLs) for abiotic stress tolerance in rice which were identified by rice breeders or the genes involved in Na^+/ K^- transport, ABA dependent and independent pathways, signaling and some miRNAs have been implicated in governing salinity tolerance, these could better the viability of pollens and eventually result in high yield. The present result agreed with findings of Pradheeban *et al.* (2017) who stated that there was no significant difference in yield between Adakari, At 353, Bg 352 and Pokkali rice varieties. However, in contrast to this finding, Ali *et al.* (2004) revealed that yield per plant decreased significantly in response to salinity in all rice genotypes studied.

Effects of salt type and concentrations on yield and yield components

Amongst the salinity levels, in terms of panicle length and number of spiklets per panicle, the highest concentration of both salt types ($CaCl_2$ 10 dSm^{-1} and NaCl 10 dSm^{-1}) recorded the minimum value compared with the control condition (0.22 dSm^{-1}). This result confirmed the findings of Farshid (2012). Based on the number of grains per panicle, number of effective tillers per stand and 1000 grains weight (g), the highest values were recorded in the control condition (0.22 dSm^{-1}), while the lowest values were recorded at $CaCl_2$10 dSm^{-1} and NaCl 10 dSm^{-1}. The high effectiveness of salinity on the number of grains has been reported by many researchers. The research carried out by Hasanuzzaman *et al.* (2012) reported that control treatment had the largest amounts (1475); increased salinity resulted in a decreased total number of grains per panicle. Purnendu *et al.* (2004) also stated that there was a significant effect of salinity on the number of tillers per hill, and the number increased from control to 7.81 dSm^{-1} salinity levels. Furthermore, Karami *et al.* (2010) reported that by increasing salinity levels, the total number of tillers, number of fruitful tillers, number of full grains per cluster and kernel weight decreased.

However, contrary to the findings of Kaddah (1963), who reported that salinity has less adverse effects on the number of tillers than on grain and panicle production. Another study reported by Mahmood *et al.* (2009) also revealed the effect of salinity on rice and reported that the 1000-grain weight of rice was least affected by high concentrations of salinity. With regard to yield per stand, yield per plot and yield per hectare, the control condition with 0.22 dSm^{-1} recorded the highest value (119.9g, 1.1kg and 8641kg respectively), compared with higher levels of both salt types. This significant reduction in yield at high concentrations of salinity could be a result of a reduction in translocation of soluble sugar contents to superior and inferior spiklets and inhibition of starch synthetase activity during grain development. These results confirmed the findings of Hakim *et al*. (2014), who reported that rice yield was significantly varied due to different salinity levels, ranging from 0.57 to 14.45 g $hill^{-1,}$ having the highest (14.45 g $hill^{-1}$) in the control condition. Similarly, Pradheeban *et al.* (2017) stated that different salinity levels showed significant effects on the yield of rice as the salinity levels increased. According to Young *et al. (*2003 and Gain *et al. (*2004), grain yield decreased with rising salinity levels. In addition, Farshid (2013) stated that control treatment irrigated by fresh water (at 1 dSm^{-1} salinity) had the highest yields.

Interactions of varieties, salt type and concentrations on yield and yield components

The result of interaction of rice varieties and salt type at different concentration on yield and yield components revealed that, in terms of 1000-grains weight, JAMILA recorded the highest grain weight (22.4g) at 0.22 dSm^{-1} (control), while the lowest grain weight (15.9 and 15.7 g) was recorded by FARO 52 at $CaCl_2$ 10 dSm^{-1} and NaCl 10 dSm^{-1} respectively. The result agreed with Hakim *et al.* (2014), who stated that the average weight of 1000 grains of different rice varieties grown under control and three different salinity conditions. Furthermore, Pradheeban *et al.* (2017) also stated that there was a significant difference between Pachaperumal, Pokkali and Adakari at 4 dSm^{-1} and 6 dSm^{-1}.

The result also revealed that FARO 44 recorded the maximum number of effective tillers at $CaCl_2$ 4 dSm^{-1} and NaCl 4 $dSm^{-1,}$ respectively, while the minimum number of effective tillers was recorded by JAMILA at NaCl 10 dSm^{-1} and $CaCl_2$ 10 dSm^{-1}. This confirmed the findings of Mahmood (2009), who stated that Basmati Pak produced the highest number of tillers per plant in control and 5.2 dSm^{-1}, while PK 4048 produced maximum tillers at 10.5 dSm^{-1}. A significant decrease in the number of tillers at 15.62 dSm^{-1} salinity levels in BR11 rice has been reported by Gain *et al.* (2004).

The result of interaction of rice varieties and salt levels on length of panicle presented that, the highest panicle length (26.4cm and 25.9cm) was recorded by JAMILA and FARO 52 at the lowest salinity level (0.22 dSm^{-1}), while JAMILA and FARO 52 at $CaCl_2$ 10 dSm^{-1} and NaCl 10 dSm^{-1} recorded the lowest panicle length (17.0cm, 17.0cm and 16.9cm respectively). This was in line with findings of Abhilash and Mohanan (2013), who reported that Panicle length showed a significant reduction in one of the cultivars starting from 50 mM salt concentration onwards. Hakim *et al.* (2014) stated that panicle length was different in different rice varieties, but the longest was produced in Pokkali and the shortest in IR20.

The result of the interaction of rice varieties and salt levels on the number of grains per panicle showed that under normal conditions, JAMILA and FARO 52 recorded the highest number of grains per panicle (137.7 and 134.3), while, at higher levels of salinity, lowest number of grains per panicle were also recorded by JAMILA and FARO 52. Hence, FARO 44, which recorded 92.3 at higher levels of salinity, showed less susceptibility to salinity than the other two varieties. It was reported by Mahmood *et al.* (2009) that increased salinity significantly reduced the grain number per panicle in PK 49951 and PK 33892.

Significant interaction between the rice varieties and salt levels on yield per stand (g) revealed that, at control, JAMILA produced the highest yield per stand (128.4 g), while the lowest yield per stand was produced by JAMILA and FARO 52 at the highest levels of salinity. However, the interaction of rice varieties and salt levels on yield per plot (Kg) presented in Table 1 showed that, at the control condition (0.22 dSm^{-1}), JAMILA recorded the highest yield (1.156kg), and the lowest yield per plot was recorded by all three varieties studied at the highest levels of salinity. The reduction in yield observed amongst the rice varieties could be a result of ion toxicity of the imposed salinity at high concentrations that decreases yield through decreasing filled grains per rice panicle. Reducing seed set in the panicle, possibly as a consequence of decreased pollen viability or decreased receptivity of the stigmatic surface, or both, due to high salinity levels, has been reported by many researchers (Abdullah *et al*., 2001; Khatun and Flowers, 1995). The result of the present research was in accordance with that of Mahmood *et al.* (2009), who revealed that Basmati 370 and Basmati 385 were least affected by the salinity, while PK 49626 was most affected with respect to grain yield. Furthermore, Hakim *et al.* (2014) also revealed that high salinity treatment led to a significant reduction in the grain yield in all varieties, with the most drastic reduction being observed at 12 dSm^{-1} salinity level. In another study conducted by Farshid and Hassan (2012), yield components such as spikelets per panicle, panicle length, number of tillers per plant, number of florets per panicle, and 1000-grain weight are all severely affected due to increasing salt stress. Similarly, Uyoh *et al.* (2019) revealed that salinity treatment at different concentrations caused a highly significant reduction in yield components by affecting the number of tillers in the treated rice genotypes.

Conclusions

The research established that varietal characteristics and salinity of different salt types (NaCl and $CaCl_2$) at different concentrations have negative effects on yield and yield components of all rice varieties studied in the research, particularly the number of effective tillers, 1000-grain weight and panicle length, especially in the range of 8 to 10 dSm^{-1}. It has been observed that among the three varieties of rice studied, FARO 44 and FARO 52 were the best varieties that can withstand salinity.

Recommendations

It can be seen from the research work that salinity is a serious problem that require urgent attention looking by the way it affects yield and yield components especially at high concentrations, as observed in previous studies and also in this research; varieties of rice were seen to respond differently to salinity of different salt types, as such it is advisable that agronomic practices responsible for soil salinity such as excessive use of inorganic fertilizers and chemical herbicides, improper method of irrigation, mono cropping among others should be reviewed to control excess accumulation of salt in the soil and their negative effects on agricultural crops as it can be a threat to food security.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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