Growth and mineral constituents of prose millet (*Pennisetum glaucum*) irrigated with sea water

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Abstract: The effect of different Sea water salinity levels (0, 25, 50, 75 and 100%) on seed germination, seedling growth and mineral ion concentration (K, Ca, Mg, Na, Cl, Fe, Cu, Mn and Mo) of prose millet (*Pennisetum glauccum*) were studied. Germination of prose millet seed was affected by high salinity levels, the germination percentages were 97, 84, 80, 77 and 57 % for the treatments used 0, 25, 50, 75 and 100% sea water, respectively. Plant growth was also affected by salinity; shoot lengths were more pronounced than on root and leaf. The shoot, root and leaf lengths reached their maximum at 50% seawater salinity before them encounter reduction with increasing salinity. The shoot length was reduced 7.2% at 50% and 24.6% at 100% seawater salinity, root length increased 13.9% at 50% and reduced about 4.6% at 100%, while leaf length was only affected by salinity at 100% seawater salinity compared to plants irrigated with freshwater (control). Seawater salinity had a significant effect on mineral ion concentration in prose millet plants. Concentration of K, Ca, Mg and Fe was reduced in the shoot with increasing salinity levels to 39.9- 83.1%, 49.0-92.2%, 9.9-13.8%, 10.2-33.0%, while Na, Cl, Mn and Mo concentration showed increase in concentration with increasing seawater salinity to 62.3-58.8%, 337.5-4.4%, 0-80%, 22.1-8.1% at 50% and 100% respectively. Also in the root, the concentrations of K, Ca, Mg, Fe, Cl, were significantly reduced to values of 56.3-895.3%, 59.4-95.8%, 0-58.5%, 18.5-13.6%, 5.6-85.2%, and that of Na, Mn and Mo increased to values of 64-64%, 25.7-46.6%, 92.7-117.6% at 50% and 100% increase in seawater salinity respectively.

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1. Introduction

Although saline soils occur in humid regions in areas affected by sea water, the most extensive occurrence is in arid and semi arid regions, where rainfall is not sufficient to wash and transport salts away from the plant root zoon. In such saline regions, cultivation of crop plants could mainly be achieved either after washing of excess salts by repeated flooding with fresh water or by introducing plants adapted to such saline conditions **(Heikal *et al*., 1982; ajar *et al*., 1993 and Howladar, 2010).** Since sufficient amounts of fresh water are not always available the second alternative seems to be more applicable.

The ionic composition of seawater is dominated by Na and Cl ions; it also contains in abundance ions essential to plant growth, i.e. K, Mg, Ca, SO_4; and it is buffered towards alkalinity (pH 8.5) and also usually contains trace elements (Fe, Mn, Zn...) and organic matter: the latter contains a certain amount of the total nitrogen where nitrogen fixation in the saline soil is at a low level **(Al-Zahrani, 1990).** The presence of the ions has consequences, however, for the free energy of water. As the salt concentration increases in any solution, the water becomes less and less accessible to plants (**Harvey, 1966**); therefore, a plant must produce an osmotic potential lower than that of the soil solution to take up water to its tissues (**Larcher, 1980**).

The plant adaptation to salinity started from seed germination. The germination ability of seeds under salinity condition was recorded to be sometimes suppressed under salinity condition (**Khan and Panda, 2002**). Extensive studies have been made concerning the effect of water stress on seed germination using different crop species and different osmotic substances **(Munns and Tester, 2008; Maiti *et al*., 2010 and Yakubu *et al*., 2010).** Generally it was recorded that salinity stress may slow down the rate of germination or may completely inhibit it **(Heikal and Shadded, 1982).** Salinity may also affects concentration of mineral nutrients in plants. Salinity disrupts mineral nutrient acquisition by plants in two ways, the ionic strength of the substrate can influence nutrient uptake and translocation, and by reduction of nutrient availability by completion by major ions (i.e. Na^+ and Cl^-) in the substrate **(Chartzoulakis *et al*., 2002).**

A considerable number of studies were conducted to investigate the effects of salinity on growth of plants. Morphologically the most typical symptoms of saline injury to plants are stunted growth **(Parida and Das, 2010).** A reduction in growth was also recorded by number of researchers. **Abdel Azim and Ahmed (2009)** indicated that salinity concentration of 4000 ppm significantly depressed plant height fresh and dry weights, plant fresh and dry yield /fed, crude protein, total ash, proline, phenol, essential oil and potassium percentage of *Achillea fragrastissima*. **Mozafar and Oertil (1990)** recorded that increasing of NaCl in the nutrient solution increased the concentration of Na, Cl, total P, PO_4 and Zn and reduced the concentration of

K, Ca, total N, NO_3 and SO_4, but did not affect the concentration of total S in the barley tops. Also **(Carmer *et al.*, 1985, Lynch and Lauchli, 1988)** reported that NaCl salinity displace Ca from the membranes and make them leakier for Rb and Ca but Zn concentration increased. **Koyro (2006)** demonstrated a high concentration of Ca ions in the root of halophyte *Plantago coronopus* (L). Salinity may disrupt nutrient acquisition by plants by reduction in nutrient availability by completion with major ions (i.e. Na^+ and Cl^-) in the substrate **(Flowers and Colmer, 2008).**

The aim of the present study is to investigate the effect of different concentrations of sea water on germination, growth and some mineral ion concentrations of prose millet (*Pennisetum glauccum*).

2. Materials and Methods

Germination experiment:

The germination experiment of prose millet (*Pennisetum glauccum*) seeds was performed, continued for one week. The following seawater salinity levels (0, 25, 50, 75 and 100 % of sea water) corresponding to (0, 8250, 17500, 26250 and 35000 ppm) were used together with tap water. Seawater percentages were prepared by mixing seawater with fresh non saline tap water at different ratios (v/v) under room temperature.

Thirty seeds of prose millet were placed on absorbent pads in each Petri dish to which 30 ml of the experimental solution were added (3 Petri dishes in each treatment) , and seeds were considered to be germinated after radical emergence from the tests.

Growth experiment:

Seeds of prose millet were sown in perforated plastic pots, each containing 10 kg of mixed, sieved, acid washed sand and peat moss soil (3:1 by volume). The pots were irrigated with fresh water till complete germination and seedling emergence. The pots were divided into five groups, three pots for each treatment. Five seedlings per pot were left to grow in open field at about 40^{o}c and at soil water potential near field capacity, then watered with half Strength Hoagland nutrient solution prior to seawater irrigation with the corresponding salinity levels (0, 8250, 17500, 26250 and 35000 ppm). Plants were irrigated at two days intervals. In order to prevent accumulation of salts, the soil in each pot was leached every ten days with fresh water.

At the end of experimental period (one month from imposing salinity), shoot, leave and root lengths were measured in each pot. Shoot and root were then dried in aerated oven at 70^{o}C and the dry samples were ground into fine powder for determination of mineral ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2-}, $Cu2^+$, Mn^{2-}, Mo^{2-} and Cl^-) concentrations using wet digestion method of **Hamphries (1956)** In every case three replicates were used and data were statistically analyzed to calculate the least significant differences.

3. Results and Discussion

Effect of seawater on germination:

Germination is a critical period in the plant life cycle, and inhibition of seeds germination of crop plants by any environmental factors leads to reduction in the yield; so germination and seedlings characteristic are the most useful criteria used for selecting salt tolerance species. From Tables (1 and 2) it can be noticed that the highest salinity levels (75% and 100%) effected the germination which resulted a high decrease in seed germination rates of prose millet compared to the lower sea water salinity levels (0.25 and 50%). There was a delay in the beginning of germination and a reduction in germination percentage with increase in salinity levels. Percentage of germination decreased with increasing salinity concentrations. The highest germination rate was observed in the seeds exposed to fresh water (43.3 % after 24 hours and 97% after 72 hours). While the lowest germination rates were for those exposed to 75 and 100% seawater (0% after 24 hours and 23.3 and 13.3% after 72 hours, respectively). Salinity up to 50% level delayed germination but did not significantly reduce the final percentage to the critical phase. It was reduced significantly at 100% salinity level.

This reduction in germination percentage with increasing salt stress is in agreement with results obtained for anther plant species by **Hajar *et al.* (1993); Chiroma *et al.* (2007) and Yakubu *et al.*, (2010).** This means that seed germination of prose millet was not affected by relatively low and moderate salinization levels used (0, 25 and 50%). The reduction in germination percentage may be attributed to the combined effect of osmotic stress and specific ion toxicity (**Haung and Redmann, 1995).** High salt concentration is also known reducing water potential in the medium which hinders absorption of water by seeds of plants and thus reduces germination **(Maas and Grieve, 1987 and Yakubu *et al.*, 2010).**

Effect of seawater on plant height and leaf area:

Shoot length and leave area increased with increasing seawater salinity from zero to 25 % and then significantly reduced as seawater salinity increased (Table 3). The results also showed that the maximum shoot and root lengths and leaf area were recorded at the 25% seawater salinity level, then the results showing gradual reduction with increasing salinity in all plant parts. But the decreasing in root lengths still higher with comparison with plants irrigated with fresh water, except the last treatment (100 % seawater). On the other hand leaf lengths did not show any significant reductions compared to control, except the last treatment (100 % seawater). This results were in agreement with those obtained by **(Afifi *et al.*, 2010;**

Hakim *et al*., 2010; Maiti *et al*., 2010 and Yakubu *et al*., 2010) whom explained that the increase in root lengths may be due migration of carbohydrates to the lowest plant parts in salinity, where is the reduction in shoot lengths may be due to many reasons such as increase in the osmotic pressure of soil solution which reduce water availability, interference of nutrient uptake, or due to toxic effect of the NaCl used in the irrigation and finally, unbalanced nutrient uptake by seedlings. **Chartzoulakin *et al.,* (2002)** postulated the same result working on the effect of seawater salinity on growth of 6 olive cultivars, and found reduction in shoot height.

Table (1): Effect of sea water salinity on daily germination of prose millet seeds

Salinity levels %	**Days of germination**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
0	13	26	29	29	29	29	29
25	0	16	24	25	25	25	25
50	0	8	16	17	21	24	24
75	0	3	7	14	18	23	23
100	0	1	4	10	12	14	16

Table (2): Effect of sea water salinity on the final germination of prose millet seeds, deviation from the mean

Salinity levels %	**No. of seed germination**	**Germination %**
0	29±1.2	97
25	25±1.6	84
50	24±1.1	80
75	23±3.2	77
100	17±2.5	57

Table (3): Effect of sea water salinity on shoot, root an leaf lengths (cm) of prose millet, deviation from the mean

Salinity levels %	Lengths (cm)		
	Shoot	Root	Leaf
0	62.7±7.8	43±8.3	41±6.9
25	64.7±4.2	52±2.9	43±5.8
50	58.2±4.4	49±3.5	42±2.6
75	57.0±2.6	47±6.5	41±3.8
100	47.3±4.1	41±1.3	31±2.4

Effect of seawater on ion concentration:

Seawater had a significant effect on the ion concentrations in prose millet plant parts (shoot and root), the results are shown in Tables (4 and 6). Regarding plant shoot ion concentrations there were increase in Na^+ to (62.3 and 58.8%), Cl^- to (337.5 and 58.8%), Mo to (22.1 and 8.1%) at 50% and 100% seawater salinity respectively, compared to plants irrigated with fresh water. Mn ion concentrations increased with the very high seawater levels (75 and 100%) to an 80% increase compared to plants irrigated with fresh water. On the other hand there were significant reductions in metal ion concentrations in plant shoot as regard K, Ca, Mg, Na. K^+ was reduced by (39.9 and 83.1%), Ca2+ by (49 and 92.2%) , Mg^{2+} by (9.9 and 13.8%) and Fe^{2+} by (10.2 and 33.0%) at 50% and 100% seawater level respectively. While Cu ion concentrations in the plant shoot remained unaffected by seawater salinity, the increase in Na^+ and reduction in K^+, Ca^{2+}, Mg^{2+} concentrations in the plant shoot is in agreement with the findings of **Ismail (1998)** who found the same trend in *Atriplex* species irrigated with seawater.

As for root content of nutrients Na^+, Mn^{2+} and Mo_{2+} showed increased concentration with increase in seawater salinity, while K+, Ca^{2+}, Mg^{2+}, Cl^-, concentrations were reduced in roots with increase in seawater salinity compared to plants irrigated with fresh water. Na+ increased in root with increase in all seawater salinity levels without any significant differences between its concentrations. On the other hand Fe^{2+} concentration showed an increase in root up to 75% salinity level before it drops down at 100% seawater level compared to control. Mg^{2+} in the root was not affected by seawater salinity only at the highest levels (75 and 100%).

Na^+, Mn^{2+}, Mo^{2+} showed following concentration increases in plant root with increase in seawater salinity levels (64 and 64%; 25.5 and 46.6%; 92.7 and 117.6%) at 25 and 100% salinity level respectively. And the following metals showed reduction in root concentration, Ca^{2+} (59.4 and 95.8%), K^+ (56.3 and 895.3%), Mg^{2+} (zero and 58.5%), Cl^- (5.6 and 85.2%), at 50% and 100% seawater salinity level respectively compared to plants irrigated with fresh water.

Fe^{2+} gave an increase in root with increase in seawater salinity up to 75% before it dropped to 13.6% at 100% salinity level. These results are in agreement with results obtained by **Yakubu *et al.*, (2010); Hajar *et al.,* (1993) and Abdel Azim and Ahmed, (2009)** whom reported that extent of elements accumulation with saline solution vary among shoots and roots and the highest estimated in the roots may be due to many glycophytes being retained in the roots.

The relation between the ions accumulated in shoot and root of *Pennisetum glauccum* are shown in Table (5) all ion ratios are very small and most of the ratio less than one which give indication that *Pennisetum glauccum* have the ability to prevent Na to accumulate at the plant shoot or root. Cl was slightly higher than Na but Na/Cl varied little between treatments.

The increase in some elements and decrease in others in the tissues of prose millet may be due to the effect of salinity on the physiological phenomenon. The Na and Cl accumulated in the shoot showed no big change between zero and 35000 ppm NaCl external concentration. Excess of Na^+ to an even greater extent and excess Cl^- in the protoplasm leads to disturbances in ionic balance (k^+ and Ca^{++} to Na^+) as ion specific effects on enzyme proteins and membrane as a result, too little energy is produced by photophosphorylation and phosphorylation in the respiratory chain (**Flowers, 1990**). Therefore, the above discussion permits to some extent to the relatively low and moderate salinity levels.

Different plant species have different mechanisms for preventing excessive accumulation of Na and Cl in the leaves: for example, in *Aegialitis annulata* and *Tamarix aphylla* the leaf concentration of Na and Cl remained unchanged due to an equivalent excretion (mainly of NaCl) from the salt glands **(Berry and Thomson, 1967).** Some other plants absorb a sufficient amount of water, during growth, to prevent the increase of salt concentration in their leaves. This dilution of the cell sap has been found, for example, in the halophyte *Rhizophora mucronata* (**Levitt, 1980**) and in some of the non-halophytes when grown under salt conditions-such as tobacco (**Flowers *et al.*, 1986**).

The concentrations of Na accumulated in the shoot and root of this crop plant are relatively constant over a period of one month following salinization to an external salinity which is optimal for growth and in agreement with those reported by **Yakubu *et al.* (2010).** The decline in plant growth (and early plant death) under high external salinities may be due to: (a) NaCl toxicity (b) insufficient uptake of other ions in the presence of high NaCl concentrations (c) osmotic effect of salts or (d) any combination of these; so, the plant dehydrated earlier at higher salinity.

Table (4): Effect of sea water salinity on the shoot and root ion content (mg/g dw) of prose millet, deviation from the mean

Salinity levels %		K	Ca	Mg	Na	Cl
0	Shoot	161±26	7.7±1.2	10.1±1.6	0.51±0.13	0.48±0.04
	Root	93.5±6.9	9.6±1.5	8.2±1.3	0.50±0.13	0.88±0.11
25	Shoot	115±17	2.6±0.8	9.4±2.1	0.80±0.10	1.35±0.26
	Root	63.2±6.4	1.8±0.2	8.5±1.4	0.82±0.10	1.83±0.12
50	Shoot	96.7±8.8	3.9±0.5	9.1±0.7	0.83±0.08	2.1±0.14
	Root	41.1±3.8	5.3±0.4	8.2±0.8	0.82±0.07	0.83±0.09
75	Shoot	41.6±3.7	4.7±0.9	9.2±1.7	0.82±0.07	0.50±0.03
	Root	23.2±2.1	2.2±0.9	3.1±0.3	0.83±0.05	0.75±0.03
100	Shoot	27.2±2.4	0.6±0.1	8.7±0.8	0.81±0.03	0.50±0.13
	Root	4.5±0.4	0.4±0.1	3.4±0.3	0.82±0.07	0.13±0.08

Table (5): Effect of sea water salinity on ion ratios accumulated in the shoot and root of prose millet

Salinity levels %		Na/K	Na/Ca	Na/Mg	Na/Cl
0	Shoot	0.0032	0.066	0.051	1.06
	Root	0.0053	0.052	0.061	057
25	Shoot	0.007	0.308	0.085	0.59
	Root	0.013	0.456	0.097	0.45
50	Shoot	0.0068	0.213	0.091	0.40
	Root	0.02	0.155	0.100	0.99
75	Shoot	0.02	0.175	0.089	1.64
	Root	0.036	0.377	0.259	1.11
100	Shoot	0.03	1.35	0.093	1.62
	Root	0.18	2.05	0.241	6.31

Table (6) Effect of sea water salinity on the shoot and root ion content (µg/g dw) of prose millet, deviation from the mean

Salinity levels %		Fe	Cu	Mn	Mo
0	Shoot	45.1±1.9	45.5±1.9	11.5±4.5	8.6±3.4
	Root	18.3±3.4	84.5±1.3	10.5±1.6	5.1±0.8
25	Shoot	42.8±4.4	44.6±1.8	11.2±3.5	12.5±2.5
	Root	22.6±3.1	42.9±1.5	10.5±1.6	9.6±1.5
50	Shoot	40.5±2.3	44.5±9.1	11.1±4.4	10.5±4.2
	Root	21.7±2.9	44.1±7.2	13.2±2.1	10.6±1.6
75	Shoot	30.3±3.1	46.3±2.6	13.3±5.3	8.4±3.6
	Root	18.5±1.1	89.1±9.2	14.3±2.2	16.6±2.5
100	Shoot	30.2±3.3	43.6±1.2	20.7±8.3	9.3±3.7
	Root	15.8±3.6	32.7±5.2	15.4±2.3	11.1±1.7

Conclusion

The most important results obtain from this study and would be emphasis that is this crop species (*Pennisetum glauccum*) not only grow in a high salinity concentration (which irrigated directly with seawater) but also did not accumulate either Na nor Cl in their parts (shoot and root) more than that in the control plants, which need to do more studies in this direction to variety of this species can be irrigated with seawater to face the lack of fresh water in arid and semi arid regions.

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