

# Investigation of Sodium Chloride Tolerance of Moringa (*Moringa Oleifera Lam.*) Transplants

Ayoub Zeyada Elhag\*, Mohamed Osman Gafar

College of Agricultural Studies, Sudan University of Science and Technology, P.O. Box 71. Khartoum North, Sudan

\*Corresponding Author: zadhag@yahoo.com

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**Abstract** This study was conducted at the nursery of Department of Horticulture, College of Agricultural Studies, Sudan University of Science and Technology. Sodium chloride (NaCl) tolerance of 2-months moringa transplants (*Moringa oleifera* Lam.) was investigated in plastic pots containing 0.0, 0.2, 0.4 and 0.8% NaCl (w/w of soil) resembling 1.8, 4, 8 and 16 dSm<sup>-1</sup> electrical conductivity (Ec) of the soil solution), in a completely randomized design with four replications. The vegetative growth was evaluated as transplant height, number of leaves and root length. The concentrations of Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>2+</sup> and Cl<sup>-</sup> in the transplant parts (stem, leaves and roots) were also recorded. Both shoot and root growth parameters were only slightly affected by the different NaCl concentrations. However, the stem height and number of leaves were significantly reduced (30% and 40%, respectively) by the highest NaCl concentration (0.8% NaCl). Mineral ions uptake reflected that Na<sup>+</sup> and Cl<sup>-</sup> concentrations in the different plant parts (roots, stem and leaves) were almost doubled at the highest NaCl concentration, whereas both K<sup>+</sup> and Ca<sup>2+</sup> were reduced by 24- 64% compared to control. At the highest NaCl concentration there was a tendency of higher concentration of Na<sup>+</sup> and Cl<sup>-</sup> and lower concentrations of K<sup>+</sup> and Ca<sup>2+</sup> in the leaves. It could be concluded that 2-month moringa transplants might be NaCl tolerant up to 8dSm<sup>-1</sup> Ec. Further studies are required to assess the mechanism of salinity tolerance of moringa. 2-month moringa transplants rather than direct seeding could be recommended for utilization of salt affected areas.

**Keywords** Early Growth, *Moringa Oleifera*, Sodium Chloride Tolerance, Toxic Ion Exclusion, 2-Month Old Transplants

## 1. Introduction

Among the 13 known species of the family *Moringaceae*, *Moringa oleifera* is an easily propagated shrub. It is originated in India and extended to most tropical countries (Africa, Asia and America). Its numerous economic uses

(food, fodder medicines ...etc) together with its easy propagation have raised an international interest for it. It tolerates a wide range of soil condition but prefers a neutral to slightly acidic (PH 6.3 - 7) well drained sandy or loamy soils. It is considered as drought resistant but water logging sensitive (Suen, 2008).

Salinity problems affect agricultural production worldwide, especially in arid and semi arid regions and in coastal deserts. Most arable lands were considered unsuitable for farming due to salinity (Hafez 1993 and Davis 2000). The salt tolerance of certain crops varies with growth stages. Some crops are sensitive at germination but are tolerant at advanced growth stages. Follet et al. (1981) and Khan et al. (2009) reported a significant reduction of seedling growth (shoot and root length and shoot/root ratio) of four forest tree species. They recommended *Acacia ampliceps* for saline soils followed by *Acacia nilotica*. Great reductions (50%) in growth of seedlings of a number of forest tree species due to salinity were recorded by Sharma et al. (1992) and Shalan (1997), where a severe mortality of species tested was caused at a salinity level above 6.5 dS/m. Tattini (1994);

Chartzoulakis et al. (2002) and Demural (2005) reported different seedling growth reductions of olive trees, showing that olive cultivars varied in their response to high salinity. The adverse effects of saline medium on different growth stages were attributed to either low water uptake due to low medium water potential (Mauromicale and Licandro, 2002) or certain ion (Na<sup>+</sup> and Cl<sup>-</sup>) toxicity (Flowers and Yeo, 1986) or both. Martin and Koebner (1995) and Werner (2003) reported that the reduction in plant growth by NaCl might be attributed to the inhibitory and toxic effects of ions mainly Na<sup>+</sup> and Cl<sup>-</sup>. Similar results were also obtained by Carter et al. (2005). They reported that greater Cl<sup>-</sup> amounts than that of Na<sup>+</sup> were accumulated at lower salinities. However, high concentrations of both were reported at higher salinities. This was also considered by Misra et al. (1996) and Alarcon et al. (1999) as a mechanism of salt tolerance where the roots avoid the toxic effects of ions by transporting them toward the upper parts and thus maintain their growth. Glenn et al. (1999) and Munns (2002) suggested that salt tolerant plants may have a low rate of Na<sup>+</sup> and Cl<sup>-</sup> transport to leaves. Also

they have the ability to compartmentalize these ions in vacuoles to prevent their buildup in the cytoplasm or cell walls and thus avoid salt toxicity. Accordingly, this study is objected to evaluate sodium chloride tolerance of moringa at early growth. Also how it can tolerate salinity.

## 2. Materials and Methods

This study was carried out in 2010 at the nursery of medicinal and aromatic plants, Department of Horticulture, College of Agricultural Studies, Sudan University of Science and Technology. The mean maximum and minimum temperatures were 36°C and 17°C, respectively. Moringa seeds were obtained from Forestry Research Station, Soba, Agricultural Research Cooperation, Federal Ministry of Agriculture, Sudan. The soil used was a heavy clay soil having a pH of 7.5 and 1.8 dSm<sup>-1</sup> Ec. After its field capacity was recorded, the soil was packed in 16 plastic bags (12x20 cm). Each bag contained 8 kg of soil. Three different quantities of sodium chloride (NaCl) as percentage of soil weight were added and thoroughly mixed with soil to have three different concentrations (0.2, 0.4 and 0.8 % ww<sup>-1</sup>) in addition to a control without NaCl (0.0%). The four NaCl concentrations in the soil solution had 1.8 (control), 4, 8 and 16 dSm<sup>-1</sup> Ec. Two months old and of almost the same size moringa transplants were planted in the plastic bags (one plant/bag) containing four NaCl concentrations. Tap water was added to each bag every other day in almost equal quantities to keep the soil at the field capacity during the experiment.

The experimental units were distributed according to completely randomized design with four replications. The transplants growth was evaluated one month from planting as main stem height, number of leaves per plant, root length, fresh and dry weights of stems, leaves and roots and K<sup>+</sup>, Na<sup>+</sup>, Ca<sup>2+</sup> (after dry digestion using flame photometer) and Cl<sup>-</sup> (by titration) contents of stem, leaves and roots. The data collected were subjected to statistical analyses using the computer programme (SAS). Means were compared using the least significant difference test (LSD) at P ≤ 0.05 (Steel et al. 1997)

## 3. Results

As in Table1 the stem height and number of leaves of young trees were only significantly reduced by the highest NaCl concentration (0.8% NaCl or 16 dSm<sup>-1</sup> Ec). The reductions were 30% and 44% for height and number of leaves, respectively, compared to control. The root length was only slightly affected (less than 30%) by the different NaCl concentrations. The same effects (Table2) were also reflected on fresh weights of stems and leaves but not of the roots. The reductions of both were 62% at the highest concentration compared to control. Only the dry weight of leaves was significantly affected (40% reduction) by the

highest concentration.

**Table 1.** Effect of NaCl on growth (stem height, root length and number of leaves) of two months old moringa transplants

NaCl concentration (% w/w of soil)	Transplant height (cm)	No. of Leaves/plant	Root length (cm)
Control (0 %)	49.6 <sup>ab</sup>	10.6 <sup>a</sup>	8.9 <sup>a</sup>
0.2%	40.5 <sup>bc</sup>	9.2 <sup>a</sup>	7.1 <sup>a</sup>
0.4%	50.9 <sup>a</sup>	9.3 <sup>a</sup>	6.9 <sup>a</sup>
0.8%	34.9 <sup>c</sup>	8.5 <sup>a</sup>	6.0 <sup>a</sup>

Means followed by the same letters are not significantly different using LSD at P ≤ 0.05.

**Table 2.** Effect of NaCl on fresh and dry weights of stems, leaves, and roots of two months old moringa transplants

NaCl concentration (%w/wof soil)	Fresh weight (g)			Dry weight (g)		
	Stems	Leaves	Roots	Stems	Leaves	Roots
Control (0 %)	34.2 <sup>a</sup>	13.4 <sup>a</sup>	17.5 <sup>a</sup>	6.4 <sup>a</sup>	5.5 <sup>a</sup>	3.4 <sup>a</sup>
0.2%	22.8 <sup>b</sup>	8.4 <sup>b</sup>	17.0 <sup>a</sup>	5.4 <sup>a</sup>	4.3 <sup>bc</sup>	3.2 <sup>a</sup>
0.4%	23.6 <sup>b</sup>	8.4 <sup>b</sup>	17.2 <sup>a</sup>	5.5 <sup>a</sup>	4.6 <sup>ab</sup>	3.6 <sup>a</sup>
0.8%	13.0 <sup>c</sup>	5.2 <sup>b</sup>	14.8 <sup>a</sup>	3.4 <sup>a</sup>	3.3 <sup>c</sup>	3.2 <sup>a</sup>

Means followed by the same letters are not significantly different using LSD at P ≤ 0.05.

**Table 3.** Effect of NaCl on Na<sup>+</sup>, K<sup>+</sup>, Cl<sup>-</sup>, and Ca<sup>2+</sup> concentrations in the roots of two months old moringa transplants

NaCl concentration (% w/w of soil)	Mineral ion concentration (mg/g dm)			
	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>2+</sup>	Cl <sup>-</sup>
Control (0 %)	19.3 <sup>c</sup>	17.4 <sup>a</sup>	11.0 <sup>a</sup>	31.6 <sup>c</sup>
0.2%	24.4 <sup>b</sup>	15.2 <sup>b</sup>	9.5 <sup>b</sup>	42.0 <sup>b</sup>
0.4%	27.2 <sup>b</sup>	14.2 <sup>b</sup>	8.0 <sup>c</sup>	48.5 <sup>b</sup>
0.8%	31.9 <sup>a</sup>	11.6 <sup>c</sup>	7.0 <sup>c</sup>	63.1 <sup>a</sup>

Means followed by the same letters are not significantly different using LSD at P ≤ 0.05.

Mineral ions uptake (Table3) reflected that Na<sup>+</sup> and Cl<sup>-</sup> concentrations in the roots were increased with increased NaCl concentrations. Their concentrations were 1.5 and twice higher at the highest concentration compared to control. Also both K<sup>+</sup> and Ca<sup>2+</sup> concentrations were reduced by 30% and 40%, respectively. Almost the same was observed for the four mineral ions concentrations in stem and leaves (Table4). The concentrations of both Na<sup>+</sup> and Cl<sup>-</sup> were almost doubled in both parts at the highest NaCl concentrations. Both K<sup>+</sup> and Ca<sup>2+</sup> concentrations were reduced by 24% and 34% in the stem and 64% and 50% in the leaves, respectively.

**Table 4.** Effect of NaCl on Na<sup>+</sup>, K<sup>+</sup>, Cl<sup>-</sup>, and Ca<sup>2+</sup> concentrations in the stems and leaves of two months old moringa transplants

NaCl concentration (%w/w of soil)	Mineral ion concentration(mg/g dm)							
	Stem				Leaves			
	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>2+</sup>	Cl <sup>-</sup>	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>+</sup>	Cl <sup>-</sup>
Control (0 %)	13.7 <sup>b</sup>	19.5 <sup>a</sup>	17.8 <sup>a</sup>	31.3 <sup>b</sup>	12.2 <sup>c</sup>	28.9 <sup>a</sup>	28.3 <sup>a</sup>	64.1 <sup>b</sup>
0.2%	17.4 <sup>b</sup>	17.4 <sup>b</sup>	14.5 <sup>b</sup>	42.0 <sup>b</sup>	20.4 <sup>b</sup>	24.7 <sup>b</sup>	22.5 <sup>ab</sup>	75.0 <sup>c</sup>
0.4%	20.5 <sup>b</sup>	16.9 <sup>b</sup>	13.5 <sup>bc</sup>	46.2 <sup>a</sup>	26.1 <sup>ab</sup>	20.8 <sup>c</sup>	18.4 <sup>bc</sup>	121.7 <sup>b</sup>
0.8%	28.5 <sup>a</sup>	14.9 <sup>c</sup>	11.9 <sup>c</sup>	67.2 <sup>a</sup>	32.7 <sup>a</sup>	10.5 <sup>d</sup>	14.3 <sup>c</sup>	137.0 <sup>a</sup>

At the highest NaCl concentration there was a tendency of higher concentration of Na<sup>+</sup> (28.5 mgg<sup>-1</sup> dry matter “dm”) and Cl<sup>-</sup> (67.1 mgg<sup>-1</sup> dm) and lower concentrations of K<sup>+</sup> (14.9mgg<sup>-1</sup> dm) and Ca<sup>2+</sup> (11.9 mgg<sup>-1</sup> dm) in the leaves. The accumulation of Cl<sup>-</sup> (67.1 mgg<sup>-1</sup> dm) in the leaves was higher than that of Na<sup>+</sup> (28.5 mgg<sup>-1</sup> dm).

## 4. Discussion

All transplant growth parameters were negatively affected with increased NaCl concentration. The reduction of plant height, number of leaves and stem and leaves fresh weights were significant at the highest NaCl concentration (0.8% NaCl). The reduction was 30%, 44% and 62% for transplant height, number of leaves and stem and leaves fresh weights, respectively, compared to control. The root growth was less affected. Similar results were obtained by Hussain and Rehman (1997). They concluded that the roots of plants were more tolerant than the shoots. The reduction of growth was reflected by the fresh weight rather than the dry weight of the plant parts. Also Demir and Arif (2003) showed that the root growth of safflower was less adversely affected by salinity compared to shoot growth. Moreover, Jamil (2004) reported that salt stress inhibited plant growth (shoot and root length and shoot and root fresh weights). The first reduction in plant growth may be attributed to initial sudden increase of osmotic pressure as stated by Hajibagheri (1989), suggesting that high salinity might inhibit root and shoot elongation due to slowing down of water uptake by the plant. 2- month old moringa trees could tolerate that effect without further reduction of growth except at the highest NaCl concentration (0.8%).

However, Martin and Koebner (1995) and Werner (2003) reported that the reduction in plant growth by NaCl might be attributed to the inhibitory effects of toxic ions mainly Na<sup>+</sup> and Cl<sup>-</sup>. The same was reflected by the results, where there was a tendency of increased Na<sup>+</sup> and Cl<sup>-</sup> concentrations and reduced K<sup>+</sup> and Ca<sup>2+</sup> in all transplant parts with increased NaCl concentrations. Their concentrations were almost doubled at the highest NaCl concentrations compared to control. However, the leaves showed the highest concentrations of both Na<sup>+</sup> and Cl<sup>-</sup> and the lowest ones of both K<sup>+</sup> and Ca<sup>2+</sup>. Similar results were shown by Carter *et al.*

(2005). They found that as salinity increased leaf Cl<sup>-</sup> and Na<sup>+</sup> of *L. perezii* increased. They concluded that plants accumulated a greater amount of Cl<sup>-</sup> than Na<sup>+</sup> at lower salinities but high concentration of both at higher ones. Imamul Huq (1984) found that salt tolerance or possibility to adjust to highly cellular concentration of Na<sup>+</sup> was always accompanied by a decrease in the concentration of K<sup>+</sup> and Ca<sup>2+</sup> and an increase of Mg<sup>2+</sup>. As shown by the assessment of the plant growth moringa trees could be considered tolerant to higher NaCl concentrations up to 0.4% or 8dS/m Ec. This tolerance could be attributed to its ability to restrict the transport of toxic

Na<sup>+</sup> and Cl<sup>-</sup> to the shoot at lower NaCl concentration and accumulation of them in the older leaf and branches at higher ones to get rid of them by considerable shedding of older leaves and branches. This was also considered by Misra *et al.* (1996) and Alarcon *et al.* (1999) as a mechanism of salt tolerance where the roots avoid the toxic effects of ions by transporting them towards upper parts and thus maintain their growth. Flowers and Yeo (1986), Glenn *et al.* (1999) and Munns (2002) suggested that salt tolerant plants may have a low rate of Na<sup>+</sup> and Cl<sup>-</sup> transport to leaves and have the ability to compartmentalize these ions in vacuoles to prevent their buildup in cytoplasm or cell walls and thus avoid salt toxicity. It could be concluded that young moringa trees (2- month or perhaps older) were less affected by NaCl concentrations up to 0.4% or 8 dSm<sup>-1</sup>Ec showing that moringa trees at that age or growth stage might be tolerant to NaCl concentrations of 8dSm<sup>-1</sup>. Like other glycophytes it might avoid salt toxicity by having low rate of Na<sup>+</sup> and Cl<sup>-</sup> transport to the leaves or their compartment in the vacuoles to prevent their buildup in the cytoplasm or cell walls and thus avoid salt toxicity. However, further field studies on saline soils and on the higher accumulation of toxic ions (Na<sup>+</sup> and Cl<sup>-</sup>) in the older and their restricted translocation to the younger parts of moringa are required. However, it could be concluded that moringa transplants are NaCl up to 8 dSm<sup>-1</sup>Ec. The mechanism of salinity tolerance of moringa might be the avoidance of toxic ions. Further studies are required to assess mineral ion (Na<sup>+</sup>, Cl<sup>-</sup>, K<sup>+</sup> and Ca<sup>2+</sup>) concentration in the young and old moringa leaves and their transportation and accumulation in the different plant parts. 2-month moringa transplants than direct seeding could be recommended for the utilization of salinity affected areas.

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