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# NUTRIENT CONCENTRATION OF FORAGE SORGHUM (SORGHUM BICOLOR L) VARIETIES UNDER INFLUENCED OF SALINITY AND IRRIGATION FREQUENCY

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## ABSTRACT
*The responses of forage sorghum [Sorghum bicolor (L.)Moench] varieties to salinity and irrigation frequency were studied from December 2008 to December 2009 at Universiti Putra Malaysia. Two salt tolerant varieties of forage sorghum, namely Speedfeed and KFS4, were grown under salinity levels of 0, 5, 10, 15 dS $m^{-1}$ and irrigated when the leaf water potential reached -1(control),-1.5 and -2 MPa. Salinity and irrigation frequency significantly ($P \leq 0.01$) affected nutrient concentration of forage sorghum varieties tested. The factorial treatment combinations were arranged in a randomized complete block design with three replications.Sodium content decreased 7 and 17% among the irrigation frequency treatments of -1.5 and -2 MPa, respectively. Abrupt increases in Na contents were noticed at 5 and 10 dS $m^{-1}$ salinity when Na accumulation increased 4 to 9 fold. Potassium diminished 29, 38 and 54% under 5, 10 and 15 dS $m^{-1}$ salinity treatment respectively, and decreased 4 and 10% with increase in water stress to -1.5 and -2 MPa respectively. Accumulation of $K^+$, $Ca^{2+}$ and $Mg^+$ in the shoots was strongly inhibited by salinity.Salinity substantially reduced plant growth as reflected by a decrease in the dry forage yields, and percent of mortality at high salinity levels. The maximum dry forage yields were 45.1, 38.9, and 38.5 g $plant^{-1}$ for frequent, intermediate, and infrequent irrigation regimes, respectively. Based on salinity, the forage dry weight in control plants had the highest yield (44.09 g $plant^{-1}$), while plants under the high salinity treatment gave the lowest yield (32.76 g $plant^{-1}$).*
**Keywords:** Salinity, Irrigation frequency, Nutrient concentration, Forage sorghum.

## 1. INTRODUCTION

Abiotic stress is commonly known to reduce agricultural production (Slavov and Georgiev, 2002). This includes soil salinity which affects plant growth and development by way of osmotic stress, injurious effects of toxic $Na^+$ and $Cl^-$ ions, and to some extent $Cl^-$ and $SO_4^{2-}$ of $Mg^{2+}$, and nutrient imbalance caused by excess of $Na^+$ and $Cl^-$ ions. Salinity and water stress responses are multigenic, as a number of processes are involved in the tolerance mechanisms (Sairam and Tyagi, 2004), such as various compatible solutes/osmolytes, polyamines, reactive oxygen species and antioxidant defense mechanisms, ion transport and compartmentalization of injurious ions. The ash content in plants varies with species. It ranged from below 10% in the shoots of the excluders, to over 40% in the shoots of the varieties which accumulated high mineral levels. It increased with increase in salinity of up to a certain concentration depending on the species (Almodares *et al.*, 2008).

Salt in soil and water can reduce water availability and this can lead to stressful conditions for plants. Water stress restricts crop yields, particularly in the arid and semi-arid zones. However, cultivation of crop plants under salinity and water stress conditions is unavoidable and normally practiced in developing countries (Munns, 2002). Sorghum hugely important to developing countries it has greater salt and drought tolerances than other summer forages. There are a number of potential forage sorghum varieties which may be appropriate for various



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salinity levels of seawater, but the levels of salt tolerance among most of the currently grown forage sorghum varieties have not been adequately characterized (Qadir and Oster, 2004).

Information available on the effects of salinity and water deficit on shoot mineral concentration of forage sorghum cultivars is lacking. We tested the growth and nutritional responses of sorghum to salinity and drought stress, as sorghum is often grown under drought conditions in high salinity soils. Salt (NaCl) and drought affect the water status differentially with respect to each other.

This study was designed to investigate the effect of these abiotic stresses on important physiological processes closely connected with the mechanisms of adaptability of sorghum to environmental factors. The current evaluation attempts to characterize two varieties and improve irrigation management practices for saline arable lands that may be considered uncultivable.

The specific objectives of this study were: To determine shoot nutrient concentration and biochemical responses of forage sorghum varieties to salinity and irrigation frequency.

## 2. MATERIALS AND METHODS

The experiment was conducted under a rain shelter at University Putra Malaysia (02°N 59.476´ 101°E 2.867´ , 51m altitude), from December 2008 to December 2009. The climatic conditions recorded under the rain shelter were 30°C mean temperature, 90% humidity, 4.5 mm evaporation and 72.5% light at 12 am. Two selected (Fouman *et al.*, 2003) salt tolerant varieties, namely Speedfeed and KFS4, of forage sorghum [*Sorghum bicolor* (L.) Moench] were subjected to the salinity levels of 0, 5, 10 and 15 dS $m^{-1}$ of NaCl concentrations, and irrigated when the leaf water potential reached -1(control),-1.5 and -2MPa.

The treatments were arranged in a randomized complete block design with three replications. Polybags (40 cm × 45 cm) were filled with a mixture of top soil, peat moss and sand at the ratio of 3:2:1 (v/v), respectively. The soil mixture had a pH of 5.4. During mixing, 60 g of $CaCO_3$, 10 g complete fertilizer (15% N, $P_2O_5$, $K_2O$), 1 g of triple super phosphate (45% $P_2O_5$) and 2.4 g of urea (46% N) were added to each polybag. Soil field capacity (FC) and permanent wilting point (PWP) were measured before and after the end of the experiment. The plants were irrigated with non-saline water for seedling establishment and with saline water starting from the 2 weeks after germination according to the treatments.

The amount of water required for the irrigation of each treatment was calculated using the following equation:**V= SMD×A**

(Aslam *et al.*, 2008) Where:

V= volume of water to be applied (litre); A= polybag area =$\pi r^2$

SMD = ($\theta_{FC}$ - $\theta_i$) D Bd / 100: SMD = Soil Moisture Deficit

$\theta_{FC}$ = gravimetric soil moisture content at field capacity (%)

$\theta_i$ = Soil moisture content before irrigation (%);

D = rooting depth (cm)

Bd =bulk density (in this soil 1.5 g $cm^{-3}$).

Plants were harvested at the pre flowering stage and washed with deionized water. Samples for nutritive quality were stored frozen (at 0°C) and same part of 72 samples of them were dried for laboratory analysis during September to December 2009.

Fully expanded leaf (8th leaf from soil surface) and stem samples from each variety were dried in the oven at 70 °C for 72 hours prior to mineral nutrient analysis. Oven-dried shoot (mix of stem and leaf). samples were ground, digested and analyzed for $Na^+$, $K^+$, $Ca^{++}$, and $Mg^{++}$ using an Atomic Absorption Spectrophotometer (Perkin Elmer, 3110, USA). Data were analyzed using SAS Institute (2004) by proc.GLM. Means test was performed using LSD ($P \leq 0.05$).

## 3. RESULTS

### 3.1. Shoot Sodium Concentration (Na)

Sodium (Na) content varied significantly ($P \leq 0.05$) among the salinity and irrigation frequency, interaction of varieties and irrigation frequency, interaction of varieties and salinity as well as interaction of irrigation frequency and salinity. Sodium content between the two sorghum



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varieties was not significantly different. The two varieties responded significantly to salinity levels with 50, 70 and 75% increase of sodium content at salinity levels of 5, 10 and 15 dS $m^{-1}$ respectively. Sodium content decreased 7 and 17% among the irrigation frequency treatments of -1.5 and -2 MPa, respectively. Abrupt increases in Na contents were noticed at 5 and 10 dS $m^{-1}$ salinity when Na concentration increased 4 to 9 fold (Tables 1, 2 and 3).

### 3.2. Shoot Potassium Concentration (K)

Potassium (K) content in shoots of the forage sorghum varieties varied significantly due to salinity, irrigation frequency and interaction of variety and water stress treatments. Potassium was the abundant nutrient in shoots which under salinity ranging from 10.07 to 4.63 mg $g^{-1}$ DW, diminished 29, 38 and 54% under 5, 10 and 15 dS $m^{-1}$ salinity treatment, respectively. K content in shoots decreased 4 and 10% with increase in water stress to -1.5 and -2 MPa, respectively (Tables 1 and 2).

### 3.3. Shoot Potassium/Sodium (K/Na) Ratio

The effects of different salinity and irrigation frequency levels as well as interaction of both treatments on shoot K/Na ratio of forage sorghum were significant. The K/Na ratio decreased 89, 96 and 98% with increasing salinity to 5, 10 and 15 dS $m^{-1}$, respectively and 18% reduction observed at irrigation frequency of -2 MPa (Table 1). Irrigation frequency of -1 and -1.5 MPa did not show significant effects on shoot K/Na ratio of forage sorghum (Table 3).

### 3.4. Shoot Calcium Concentration (Ca)

There was a significant difference in Ca content of both forage sorghum varieties between non-saline and saline conditions, and Ca content decreased 32, 46 and 55% with increasing salinity to 5, 10 and 15 dS $m^{-1}$, respectively (Table 1). KFS4 variety had slightly higher Ca content (4.42 mg $g^{-1}$ DW).

### 3.5. Shoot Magnesium Concentration (Mg)

The magnesium (Mg) content in shoots of forage sorghum varieties differed significantly due to irrigation frequency and salinity at $P \leq 0.05$. Magnesium content in the leaf and stem tissue at highest salinity level (15 dS $m^{-1}$) showed maximum reduction (76%) and decreases at salinity 5 and 10 dS $m^{-1}$, were 36 and 57% respectively. As water stress enlarged from -1 MPa to -1.5 and -2 MPa the magnesium (Mg) content in shoots declined 14 and 21%, respectively. The forage sorghum varieties studied differed and the highest Mg content was found in KFS4 (2.75 mg $g^{-1}$, DW). The trend in decreasing Mg content with increasing salinity was similar to Ca, another divalent ion (Table 1).

**Table-1.** Sodium, potassium, calcium and magnesium content in shoots of forage sorghum varieties following NaCl and irrigation treatments.

| Treatments | Sodium (mg $g^{-1}$, DW) | Potassium (mg $g^{-1}$, DW) | K/Na | Calcium (mg $g^{-1}$, DW) | Magnesium (mg $g^{-1}$, DW) | Dry forage (g $plant^{-1}$) |
|---|---|---|---|---|---|---|
| Variety | | | | | | |
| KFS4 | 9.55 a | 7.11 a | 3.19 a | 4.42 a | 2.75 a | 42.25 a |
| Speedfeed | 9.43 a | 6.85 a | 2.98 a | 4.28 a | 2.41b | 39.41 b |
| LSD $_{0.05}$ | 0.40 | 0.34 | 0.31 | 0.30 | 0.31 | 2.66 |
| Irrigation frequency | | | | | | |
| at LWP (MPa) -1.0 | 8.66 c | 7.33 a | 3.30 a | 4.51 a | 2.93 a | 45.12 a |



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| | | | | | | |
|---|---|---|---|---|---|---|
| at LWP -1.5 (MPa) | 9.32 b | 7.03 a | 3.27 a | 4.29 a | 2.50 b | 38.88 b |
| at LWP -2.0 (MPa) | 10.49 a | 6.58 b | 2.69 b | 4.24 a | 2.30 b | 38.48 b |
| LSD $_{0.05}$ | 0.62 | 0.44 | 0.76 | 0.39 | 0.40 | 3.42 |
| Salinity (dS $m^{-1}$) | | | | | | |
| 0 | 3.61 d | 10.07 a | 10.74 a | 6.56 a | 4.47 a | 45.73 a |
| 5 | 7.30 c | 7.06 b | 1.11 b | 4.40 b | 2.86 b | 43.61a |
| 10 | 12.22 b | 6.16 c | 0.36 bc | 3.50 c | 1.92 c | 39.79b |
| 15 | 14.82 a | 4.63 c | 0.15 c | 2.93 d | 1.05 d | 34.17c |
| LSD $_{0.05}$ | 0.13 | 0.53 | 0.91 | 0.46 | 0.47 | 4.08 |
| | | F value | | | | |
| V×I | $4.99^{*}$ | $3.25^{*}$ | $0.61^{ns}$ | $2.03^{ns}$ | $0.70^{ns}$ | $4.37^{*}$ |
| V×S | $2.95^{*}$ | $0.01^{ns}$ | $0.69^{ns}$ | $0.41^{ns}$ | $0.08^{ns}$ | $0.03^{ns}$ |
| I×S | $5.28^{**}$ | $0.37^{ns}$ | $0.68^{ns}$ | $0.34^{ns}$ | $1.06^{ns}$ | $0.29^{ns}$ |
| V×I×S | $2.0^{ns}$ | $0.74^{ns}$ | $1.57^{ns}$ | $0.50^{ns}$ | $0.17^{ns}$ | $0.70^{ns}$ |
| | | MS error & CV | | | | |
| Error | 0.72 | 0.53 | 0.43 | 0.41 | 0.43 | 31.43 |
| CV (%) | 8.98 | 10.43 | 39.54 | 14.75 | 25.40 | 13.73 |

$^{**,*}$ and $^{ns}$ are significant at 0.01, 0.05 level and non significant, respectively

Means within columns followed by same letters are not significantly different at 5% level (LSD Test)

**Table- 2.**Varietal differences in forage sodium and potassium content as influenced by irrigation frequency.

| **Irrigation frequency (MPa)** | **Na (mg $g^{-1}$, DW)** | | **K (mg $g^{-1}$, DW)** | |
|---|---|---|---|---|
| | KFS4 | Speedfeed | KFS4 | Speedfeed |
| at LWP -1 | 8.92 cd | 8.39 d | 7.50 a | 7.17 a |
| at LWP -1.5 | 9.62 bc | 9.01 cd | 6.87 a | 7.18 a |
| at LWP -2 | 10.10 b | 10.88 a | 6.96 a | 6.21 b |
| LSD $_{0.05}$ | 0.79 | | 0.67 | |

Means within columns followed by same letters are not significantly different at 5% level (LSD Test)



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**Table 3.** Varietal differences in forage sodium content and potassium to sodium ratio as influenced by salinity.

| Salinity (dS $m^{-1}$) | Na (mg $g^{-1}$, DW) | | K/Na ratio | |
|---|---|---|---|---|
| | KFS4 | Speedfeed | KFS4 | Speedfeed |
| 0 | 3.92 d | 3.29 d | 10.27 a | 11.21 a |
| 5 | 6.91 c | 7.69 c | 1.16 b | 1.06 b |
| 10 | 12.57 b | 11.87 b | 0.35 b | 0.36 b |
| 15 | 14.78 a | 14.86 a | 0.16 b | 0.14 b |
| $LSD_{0.05}$ | 0.93 | | 1.37 | |

Means within columns followed by same letters are not significantly different at 5% level (LSD Test)

## 4. DISCUSSION

In the present study Kcontent decreased and Na content increased significantly with increasing salinity level (Table 1). Although Mg content increased significantly at the salinity levels of 5 to 15 dS $m^{-1}$ and irrigation levels of -1.5 and -2 MPa in both forage sorghum varieties, this might be due to the low entry of Na without interfering with K selective channels or transporters. This would explain the high K/Naratio (Table 1). The K reduction was pronounced in salinity stressed forage species over controls. These results could be explained in the following ways: (i) high external Na negatively affects K acquisition due to similar physiochemical properties of Na and K (Maathuis and Amtmann, 1999); (ii) KUP (potassium uptake permease)/HAK (High Affinity K) transporters are extremely selective for Kand they are blocked by Na when present in mM concentrations (Santa-Maria *et al.*, 1997); (iii) HKT1 (High Potassium Transporters) represents a putative pathway for high affinity K transport and low affinity Na transport. At high Na, HKT1 may be relevant for Na rather than K uptake (Maathuis and Amtmann, 1999); (iv) massive influx of $Na^+$ into the cells via non-selective cation channels (NSCCs) which occurs in the presence of excess Na in typical saline environments (Amtmann and Sanders, 1999). Sodium (Na) ion toxicity appeared unlikely in the two forage sorghum varieties, which was reflected in the shoot dry matter yields and leaf firing. The results revealed that tissue tolerance might be greater in some varieties, but further studies are needed to clarify the above issues (Hester *et al.*, 2001). However, the accumulation of osmolytes during stress is well documented. Several studies have demonstrated that the adaptation to stress varies among varieties and species. Kacar *et al.* (2002) indicated that as salt concentration increases plants take up less water and the ion balance ($K^{+}$+$Ca^{++}$ /$Na^+$) in protoplasm is disrupted with the increase in $Na^+$cation and $Cl^-$ and $SO4^{-2}$ anions, enzyme activity is depleted and protein synthesis decreases.

Salts in soil and water can reduce water availability to crops at all stages of plant development and affect physiological and biochemical processes via ion toxicity, osmotic stress and mineral deficiencies to such an extent that yields can be affected (Hasegawa *et al.*, 2000; Munns, 2002).

Irrigation of the forage sorghums can be delayed for about two weeks till leaf water potential reaches -1.5 MPa. Generally, salinity tolerance is related to maintaining higher levels of K and Ca, because under saline condition these ions are involved in turgor control and cell wall integrity, respectively (Cramer *et al.*, 1985; Flowers and Yeo, 1986; Wolf *et al.*, 1991). This was also reflected in the present study with showing greater value of K and Ca in KFS4 variety however it was not statistically significant.

Osmotic adjustment through synthesis of organic compounds has been postulated to have a significant role in salt tolerance (Marcum and Murdoch, 1994) Some studies showed; salinity tolerance is related to maintaining higher levels of K and Ca, because under saline condition these ions are involved in turgor control and cell wall integrity, respectively (Cramer *et al.*, 1985; Flowers and Yeo, 1986; Wolf *et al.*, 1991). The results of the present study suggest involvement of dissimilar processes and functions.

The results showed that both shoot-Ca and shoot-K increased with more frequent irrigation. The responses in both shoot-Ca and shoot-K to salinity were significantly linear and a linear response in dry matter yield to leaf-N was also observed. The present findings showed that $K^+$ content not only stimulated the negative effects of salinity on growth, but also reduced dry matter



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accumulation particularly at low and medium stress. This is in contrast to other studies which report ameliorative effect of $K^+$ on salinity tolerance (Ottow and Polle, 2005; Shirazi *et al*., 2005). Concentrations of major cations*viz*. K, Ca and Mg were found to decrease, but Na content was drastically increased with increasing salinity levels. Dudeck and Peacock (1985; 1993) also reported that increasing Na affected Mg and K more than Ca content in tissue of two forage sorghums varieties studied. Calcium plays important roles in membrane integrity and maintenance of ion selectivity for plants (Marschner, 1995). However, in the present study no significant difference in shoot Ca content was found between varieties. The overall shoot K: Na ratio was highest in Speedfeed variety. The relative salt tolerance between species is related to the maintenance of higher root growth and a high K: Na ratio in the shoot (Storey and Wyn Jones, 1979; Qian *et al*., 2001). It is clear that minimum accumulation of Na is reflected by the maximum K: Na ratio. Jacoby (1999) stated that salt tolerance in plants is generally associated with low uptake and accumulation of $Na^+$, which is mediated through the control of influx and/or by active efflux from the cytoplasm to the vacuoles and back to the growth medium. Many research groups reported that salt tolerant plants which are ion includers, often adapt to low water potentials by accumulation of inorganic solutes to maintain turgor pressure and total water potential (Flowers *et al*., 1990; Alien *et al*, 2000).

Due to limited knowledge on economic benefits in adopting corrective measures, many prefer to leave their lands and look for off-farm income employment. With increasing dependence of irrigated agriculture on saline water sources, effective strategies can be undertaken to overcome/mitigate the adverse effects of different abiotic stresses and use alternative sources of water for irrigation. This issue possibly gives a fuzzy picture of the role of some aspects of drought resistance of sorghum, as a crop equipped with several mechanisms of drought tolerance (Abdul Majid *et al*., 2007).

## 5. CONCLUSIONS

The less and least frequent irrigation as well as salinity significantly affected shoot nutrient elements present, especially with reduction in K and increasing in Na concentration. Managing irrigated saline soils requires knowledge of salt tolerance in plants. KFS4 variety recorded higher values for yield (42.25 g plant$^{-1}$) compared to Speedfeed variety which implies better resistance or tolerance to drought and salinity. The results obtained in this study would serve as a useful guide for managing forage sorghums in saline stressed field conditions.

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