The International Journal of Biotechnology
2013 Vol.2, No.7, pp.130-140
ISSN(e): 2306-6148
ISSN(p): 2306-9864

GROWTH ANALYSIS OF FORAGE SORGHUM (*SORGHUM BICOLOR* L) VARIETIES UNDER VARYING SALINITY AND IRRIGATION FREQUENCY

Saberi A. R.[1] --- Siti Aishah H.[2]

[1]*Agricultural & Natural Resources Research Center of Golestan Province, Gorgan, Iran*

[2]*Department of Crop Science, University Putra Malaysia, Serdang, Selangor*

ABSTRACT

Growth of forage sorghum [Sorghum bicolor (L.) Moench] varieties was assessed under saline conditions (EC 0, 5, 10, 15 dS m^{-1}) and irrigated when the leaf water potential reached -1(control),-1.5 and -2 MPa. The forage sorghum varieties namely Speedfeed and KFS4 were differed significantly for emergence, leaf area index, relative growth rate and net assimilation rate. Plants grown under water stress and saline conditions resulted in decreased leaf area which subsequently led to reduced plant growth. Infrequently watered sorghum plants had reduced dry mater, LAI, NAR and eventually dry matter yield. These reductions were higher when lower irrigation frequency was coupled with salinity. The highly significant declined was mostly at -2 MPa irrigation frequency. This indicates that irrigation at 2 weeks interval or till leaf water potential reaches to -1.5 MPa, is possible for forage sorghum.

Keywords: Saline conditions, Irrigation frequency, LAI, NAR, Sorghum, Growth.

1. INTRODUCTION

Water availability and temperature are important factors that determine seeds germination, growth and development of plants. Water stress causes a decrease in the rate of growth (Misra and Dwivedi, 2004). Salinity and drought affect plants in a similar way (Katerji *et al*., 2004). Salinity limits plant growth and productivity of both irrigated and non-irrigated lands in many areas of the world and includes imposition of ion toxicities (e.g. Na and Cl), ionic imbalances, osmotic stress and soil permeability problems (Ashraf *et al*., 2008). In general, salt tolerance in plants is associated with low uptake and accumulation of Na (Jacoby, 1999).

Soils contaminated with salts (ECe > 4 dS m^{-1} or 40 mM NaCl or osmotic potential < 0.117 MPa) are defined as saline land, which directly affects all stages of plant growth and development (Sairam and Tyagi, 2004; Chinnusamy *et al*., 2005; Ashraf *et al*., 2008) (Allakhverdiev *et al*., 2000; Ashraf, 2009). Only species possessing some level of salt tolerance could provide more acceptable forage in areas where only low quality irrigation water is available or saline soil conditions exist. Salt tolerant genotypes of forage sorghum inherit an ability to evolve a form of salt dependence, as illustrated by greater increases in root and shoot growth under high versus low saline growth conditions (Grieve *et al.*, 2004). Salt tolerant plants are able to minimize detrimental effects by producing a series of anatomical, morphological and physiological adaptations Poljakoff-Mayber (1988a; 1988b) such as growing an extensive root system (Sinha *et al.*, 1986; Marcum and Murdoch, 1990b; Marcum *et al.*, 1998), and through mechanisms restricting the uptake of toxic ions (Ashraf and Haris, 2004). A large proportion of the biomass shows a negative parabolic relationship with the amount of irrigation. This suggests that when water supply is sufficient, excessive vegetative growth may cause less root activity and an unhealthy canopy to high WUE (Zhang and Yang, 2004). That means that high biomass production, supported by high water supply, will not lead on sorghum were focused primarily on grain sorghums. Hence, studies are needed to improve understanding on the effects of salt and water stresses on different forage sorghum varieties. In addition, many factors need to be considered when addressing the suitability of irrigation water with respect to salinity. This study was carried out with objectives of to determine morphology, yield and yield partitioning responses as well as to compare the level of salt tolerance and water resistance of the two forage sorghum varieties (Speedfeed and KFS4) at different growth stages to different levels of salinity and irrigation frequency.

2. MATERIALS AND METHODS

The factorial experiment was conducted under rain shelter at the University Putra Malaysia (02°N 59.476´ 101°E 2.867´ , 51m altitude). The climatic conditions recorded under rain shelter were 31 °C mean temperature, 88% humidity, 4.5 mm evaporation and 71% 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.

Soil media: Properties and preparation

The soil media was prepared by thoroughly mixing top soil, peat moss (KOSAS^{R}) and sand in the ratio of 3:2:1 (v/v), respectively. The prepared media was sieved and visible insect pests and plant propagules were removed. The media was then dried at room temperature, thoroughly mixed and analyzed for physical and chemical properties. Soil was analyzed for total nitrogen following (Kjeldahl, 1883), and soil organic carbon (OC) was determined according to Walkley and Black (1934). Available phosphorus was determined by Molybdenum Blue method (Bray and Kurtz, 1945). Leaching method using one N neutral ammonium acetate solution was used for exchangeable K, Ca, Mg and Na determination (Thomas, 1982).

2.1. Total leaf area (cm^2) and specific leaf area (cm^2g^{-1})

At final sampling time, the total leaf area per plant was measured with a leaf area meter (AM-200, ADC Bio Scientific Ltd., England). The fresh weight of leaves was determined and thereafter they were oven dried at 70 ^{0}C until constant weight for dry weight determination.

The specific leaf area (SLA) was calculated as SLA = LA/LW, where: LA=leaf area (cm^2), and LW=dry leaf weight (g).

2.2. Leaf area index (LAI)

Based on the total leaf area (LA) measured, the LAI was calculated as LA (cm^2)/10000= LA (m^2)/0.42 (shading area per plant).

2.3. Net assimilation rate (NAR; g/cm^2/day)

Net assimilation rate is defined as the increase of plant material per unit of leaf area per unit of time (Equation; Beadle (1987). This formula expresses the net dry weight of the plant per unit leaf area per unit time or the rate of dry matter production per unit leaf area.

$$NAR = \frac{(W_2-W_1)(Ln\,A_2-Ln\,A_1)}{(A_2-A_1)(t_2-t_1)}$$

Where:

W= Dry weight of plant (g)

Ln = Natural logarithm

t = time and

A = Leaf area per plant (m^2)

The NAR values were determined based on ten-day interval during the study.

2.4. Relative growth rate (RGR; g/g/day)

Dry mass at every important growth stage (early vegetative, tillering, stem elongation, heading, and 10% flowering) was determined by destructive sampling. The root, leaf and stem samples were cleaned and oven dried at 70 ^{0}C for 72 h. The last harvest was done at 10% flowering stage, at approximately 170 cm height. The time interval between two consecutive measurements was 10 days. Dry weight was calculated based on cumulative dry weight and the following formula proposed by Gardner *et al.* (1985) was used to calculate relative growth rate (RGR).

$$RGR = \frac{LnW_2 - LnW_1}{t_2 - t_1}$$

Where: Ln = Natural logarithm

W_1 = Dry weight of first harvest (g)

W_2 = Dry weight of second harvest (g)

$t_2 - t_1$ = Time interval between two harvests

2.5. Relative shoot and root growth

At the end of the experiment, leaves, stem and root were separately weighed and dried in an oven at 70 ^{0}C for 3 days until constant weight. The harvested roots were washed with tap water and finally with distilled water. Root to shoot ratio was calculated based on root dry weight and cumulative shoot dry weight. All samples were weighed using a sensitive balance (Model FX-3000 AN, Electronic Balance).

2.6. Water use efficiency (WUE)

Water use efficiency (WUE) is defined as the ratio of biomass to water amount used. WUE was determined by dividing the dry forage yield by the volume of irrigation water applied in each treatment during the experimental period.

2.7. Statistical analysis

The design of this experiment and all the next experiments were RCBD (randomized complete block design). All analysis of variance and means comparison were carried out using the statistical software version 8.2, developed by SAS Institute (SAS, 2004). The data were analyzed using Procedure ANOVA in the SAS package utilizing the RCBD (randomized complete block design). Treatment means were compared using Least Significant Differences (LSD) at the 5% ($P\leq0.05$) significant level. Regression analysis was used to determine the relationship among variables and salinity levels. All statistical tests were conducted at 95% confidence level and differences at $P\leq0.05$ were considered as significant.

The amount of water required for the irrigation of each treatment was calculated using the following equation: ***V= SMD×A*** where; V= volume of water to be applied (liter);

A= polybag area =πr^2; SMD = (θ_{FC} - θ_i) D Bd / 100: SMD = Soil moisture deficit;

θ_{FC} = gravimetric soil moisture content at field capacity (%); θ_i = Soil moisture content before irrigation (%); D = rooting depth (cm); Bd =bulk density (in this soil 1.5 g cm^{-3}) (Aslam *et al*., 2008).

3. RESULTS

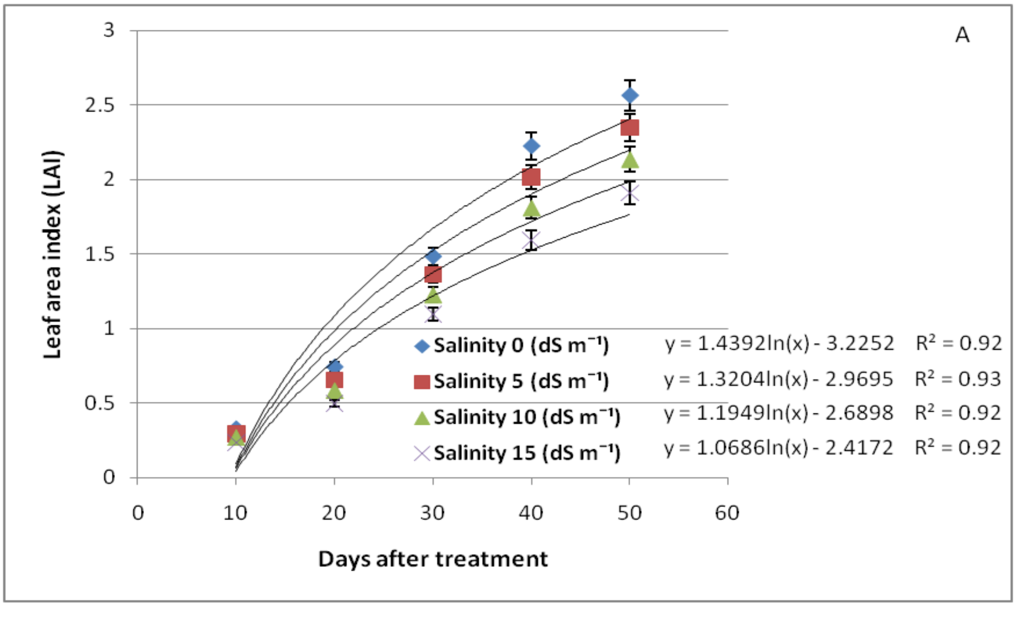
3.1. Leaf area index (LAI)

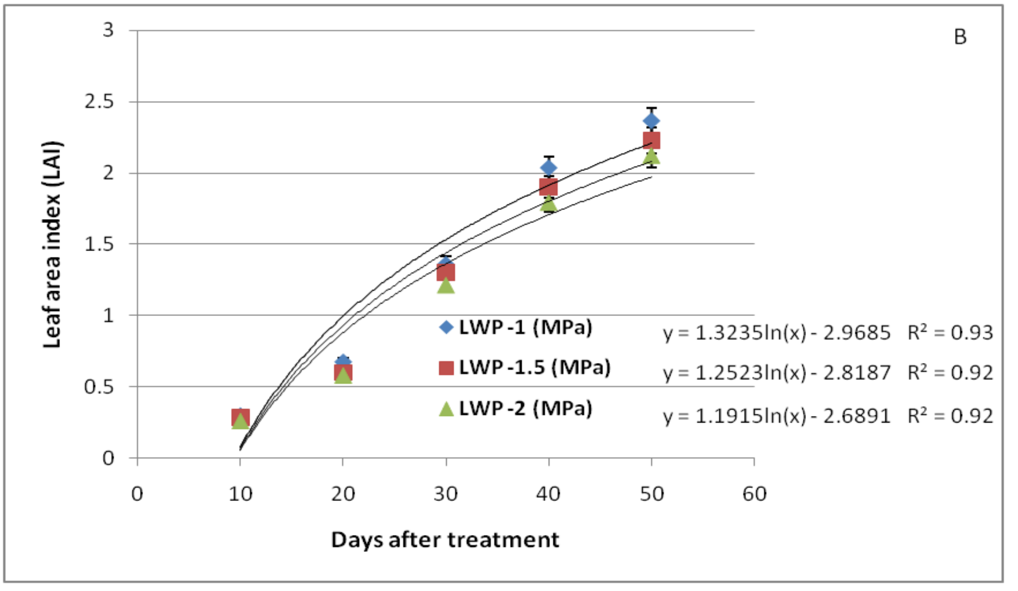
The results indicated that there were significant differences ($P\leq0.01$) in LAI between variety, irrigation frequency and salinity treatments over the five sampling dates during the study. The LAI mean values over salinity treatments of 0, 5, 10 and 15 dS m^{-1} for both varieties at 10, 20, 30, 40 and 50 days after treatment were 0.27, 0.61, 1.28, 1.90 and 2.23, respectively. At 10, 20, 30, 40 and 50 days of treatments application, the LAI values under salinity level of 10 dS m^{-1} decreased by 18.7, 21.6, 17.5, 18.4 and 16.7% and under salinity of 15 dS m^{-1} declined by 28.1, 35.1, 26.3, 28.3 and 25.3% compared to non-saline treatments, respectively.

The results showed changes in average LAI over time for the three irrigation treatments. The LAI mean values over irrigation, with irrigation at leaf water potentials of -1, -1.5 and -2 MPa were 0.28, 0.61, 1.28, 1.90 and 2.23, respectively (Figure 1). The LAI values were decreased 6.6, 104, 3.7, 6.4 and 5.9% under moderate water stress and 13.3, 13.4, 10.3, 11.8 and 10.1% under severe water stress compared to frequent irrigation at 10, 20, 30, 40 and 50 days after treatment respectively.

The LAI values were significantly reduced by prolonging the irrigation interval. Water treatments -1.5 and -2 MPa resulted in 10% and 23% mean reductions in LAI, respectively. The LAI values of KFS4 variety were 10.3, 10.7, 6.0, 7.0 and 5.6% higher than Speedfeed at 10, 20, 30, 40 and 50 days after treatment respectively.

Figure-1. Effects of salinity (A) and irrigation frequency (B) on LAI values of forage sorghum varieties at different growth stages



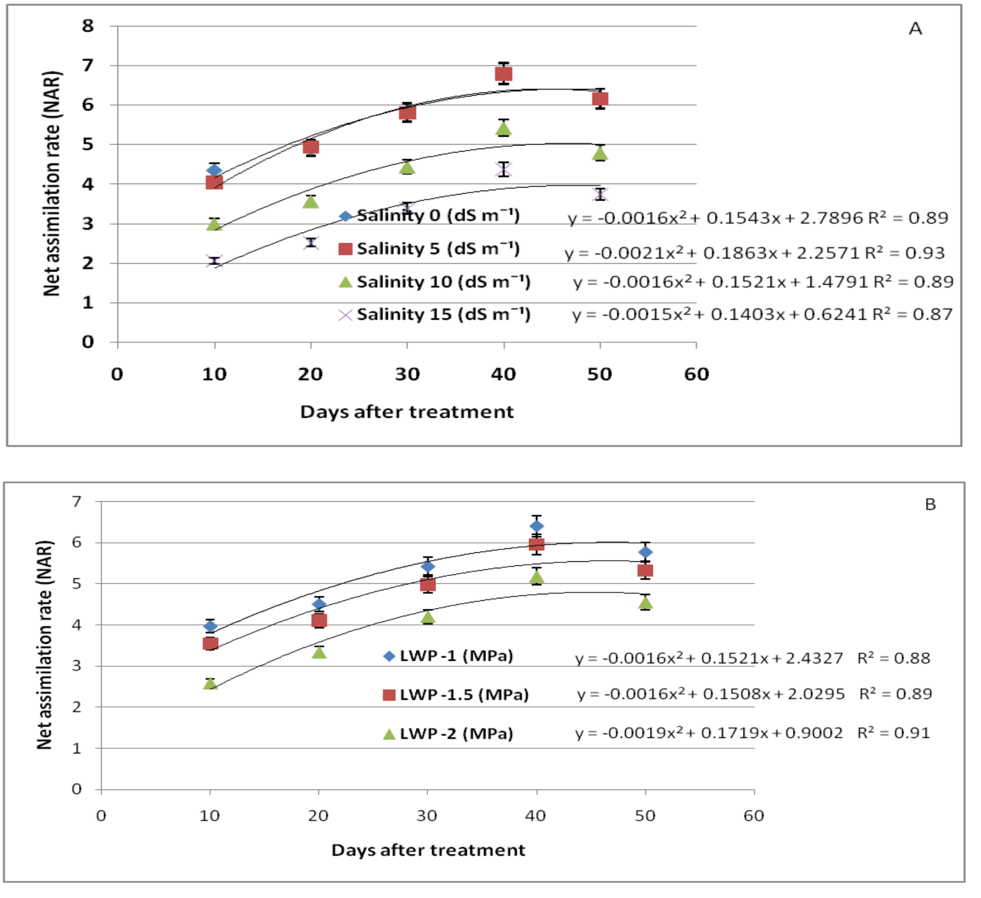


3.2. Net assimilation rate

The results showed that there were significant differences ($P \leq 0.01$) in NAR value between variety, irrigation frequency and salinity levels at 10, 20, 30, 40 and 50 days after treatment. The NAR mean values under salinity conditions of 0. 5, 10 and 15 dS m^{-1} at different growing stages were 3.36, 3.97, 4.98, 5.84 and 5.21 (g/g/day), respectively. The NAR values were decreased by 30.8, 27.5, 23.7, 20.2 and 22.3% under salinity 10 dS m^{-1} as well as 52.5, 49.0, 33.3, 35.7 and 39.5% under salinity15 dS m^{-1} at 10, 20, 30, 40 and 50 days after treatment application, respectively.

The NAR values of plants receiving irrigation at leaf water potentials of -1, -1.5 and -2 MPa over the 10, 20, 30, 40 and 50 days after treatment were 3.36, 4.02, 4.86, 5.84and 5.21 (g/g/day), respectively (Figure 2). The NAR values were decreased 10.8, 10.8, 8.3, 7.0 and 7.7% under moderate water stress and 35.2, 26.5, 22.4, 19.0 and 21.1% under severe water stress at 10, 20, 30, 40 and 50 days after treatment respectively. The NAR values of KFS4 variety were 13.8, 19.3, 16.9, 14.0 and 15.5% higher than Speedfeed at 10, 20, 30, 40 and 50 days after treatment respectively.

Figure-2. Effects of salinity (A) and irrigation frequency (B) on NAR values of forage sorghum varieties at different growth stages



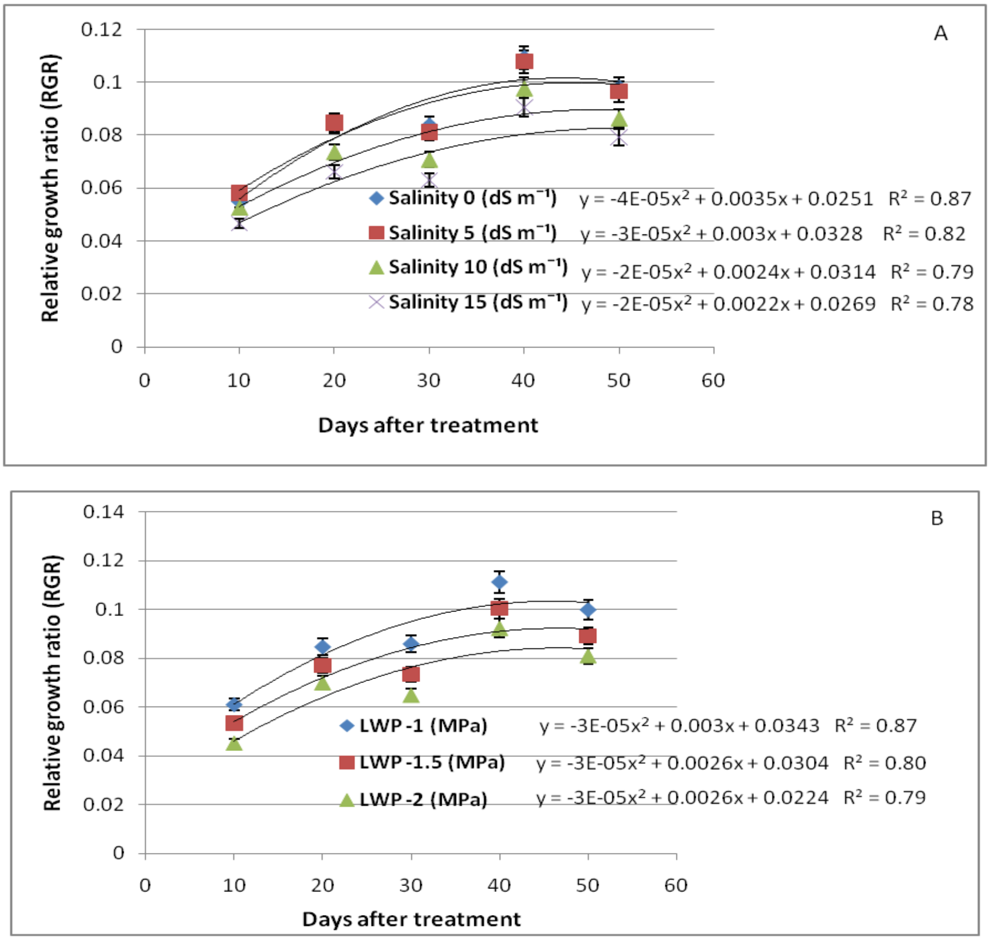
3.3. Relative Growth Rate

There were significant differences ($P \leq 0.01$) in RGR values between variety, irrigation frequency and salinity levels at 20, 30, 40 and 50 days after treatment. In all growth stages, the RGR mean values for salinity treatments of 0, 5, 10 and 15 dS m^{-1} in both varieties were 0.052, 0.076, 0.074, 0.100 and 0.089 (g/g/day), respectively. The RGR values decreased by 3.7, 13.0, 15.6, 11.0 and 11.3% under salinity 10 dS m^{-1} as well as 14.8, 21.4, 24.0, 17.4 and 18.5% under salinity of 15 dS m^{-1} at 10, 20, 30, 40 and 50 days after treatment respectively.

The corresponding RGR values with irrigation at leaf water potentials of -1, -1.5 and -2 MPa were 0.053, 0.076, 0.101 and 0.089 (g/g/day), respectively (Figure 3). The RGR values decreased by 13.1, 8.3, 14.1, 9.9 and 10.1% under moderate water stress, and declined by 26.2, 17.8, 24.7, 17.1 and 18.1% under severe water stress compared to non-stress irrigation at 10, 20, 30, 40 and 50 days after treatment respectively.

The RGR values of KFS4 variety were 18.9, 8.7, 15.0, 9.4 and 11.5% higher than Speedfeed at 10, 20, 30, 40 and 50 days after treatment respectively.

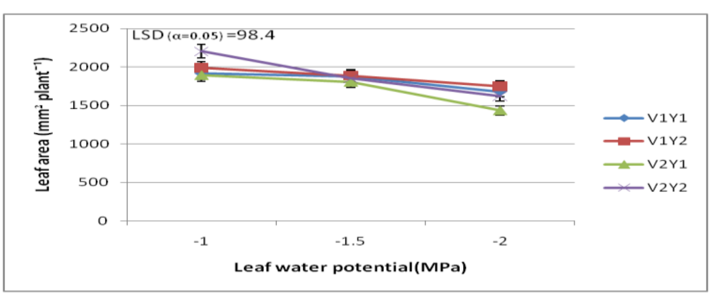
Figure-3. Effects of salinity (A) and irrigation frequency (B) on RGR values of forage sorghum varieties at different growth stages



3.4. Total Leaf Area

The total leaf area was significantly (P<0.01) affected by irrigation frequency, salinity and interaction effect of variety, irrigation frequency and year. Averaged over the two seasons, maximum total leaf area was obtained in the control plants, and was decreased by 13 and 14% respectively with increasing water stress to -1.5 and -2 MPa.

Figure-4. Variety by year interaction at different irrigation frequency on total leaf area of forage sorghum varieties (V1=KFS4 and V2=Speedfeed)



Under low water regime the total leaf area of Speedfeed variety decreased, and the irrigation frequency had a greater impact on Speedfeed compared to KFS4 variety (Figure 4). The impact was strongly evident in the second year when the irrigation schedule changed from -1.5 to -2 Mpa.

4. DISCUSSION

High salinity and severe water stress can cause wilting, necrosis, chlorosis and even complete kill of the sorghum (Hasegawa *et al.*, 2000; Munns, 2002) In the present study less and least frequent irrigation when associated with high salinity (15 dS m^{-1}) caused severe leaf injury. Highest leaf injury was observed in Speedfeed variety. Results from the current experiment were consistent in demonstrating that plant height, LAI, NAR and eventually dry matter yields of forage sorghum decreased with increased irrigation interval.

Rosenthal *et al.* (1987) reported adverse effects on cumulative leaf area, LAI and biomass production as soil water deficit developed. The results of the present study are in agreement with the results reported by Mustafa and Abdel Magid (1982) who observed decreased growth with infrequent irrigation. The consequence of infrequently watered sorghum plants were associated with lower LAI and less biomass accumulation. In contrast, light frequent irrigation resulted in higher values for these parameters (Saeed and El-Nadi, 2004).

5. CONCLUSION

Salinity and irrigation frequency were significantly *($P \leq 0.01$)* affect LAI, relative growth rate and net assimilation of sorghum varieties based on stress level.

The reduction in leaf water potential under stress conditions was found to be associated with decrease in growth stages. Plants grown under water stress and saline conditions resulted in decreased leaf area which subsequently resulted in reduced growth of plants. Relative growth rate and net assimilation rate were reliable indicators to differentiate sorghum varieties for salt tolerance. Forage sorghum varieties showing low emergence in the field compensated the loss by an increase in subsequent growth during later growth stages.

Infrequently watered sorghum plants had reduced dry mater, LAI and biomass accumulation; these reductions were higher when lower irrigation frequency was coupled with salinity. Under saline and water stress conditions, variety KFS4 marginally gave better vegetative growth performance as compared to Speedfeed, although variety Speedfeed had slightly greater leaf area.

REFERENCES

Allakhverdiev, S.I., A. Sakamoto, Y. Nishiyama, I. M. and N. Murata, 2000. Ionic and osmotic effects of NaCl-induced inactivation of photosystem I and II in Synechococcus sp. Plant Physiology, 123(3): 1047–1056.

Ashraf, M., 2009. Biotechnological approach of improving plant salt tolerance using antioxidants as markers. Biotechnology Advances, 27(1): 84-93.

Ashraf, M., H.R. Athar, P.J.C. Harris and T.R. Kwon, 2008. Some prospective strategies for improving crop salt tolerance. Advances in Agronomy, 97: 45-110.

Ashraf, M. and P.J.C. Haris, 2004. Potential biochemical indicators of salinity tolerance in plants. Plant Science, 106: 3-16.

Aslam, M., K. Haji, H. Ahmad, A. Muhammad, A. Ejaz and M. A., 2008. Effec of available soil moisture depletion levels and topping treatments on growth rate total dry biomass in chickpea. Journal of Agricultural Research, 46(3): 229-243.

Beadle, C.L., 1987. Plant growth analysis. Techniques in bio-productivity and photosynthesis. 2nd Edn., New York: Pergamon press, Oxford.

Bray, R.H. and L.T. Kurtz, 1945. Determination of total, organic and available form of phosphorus in soils. Soil Science, 59: 39-45.

Chinnusamy, V., A. Jagendorf and J.K. Zhu, 2005. Understanding and improving salt tolerance in plants. Crop Science, 45: 437-448.

Fouman, A., E. Majidi Heravan and Y. Nakano, 2003. Evaluation forage sorghum varieties for salt tolerance. pp: 14-17.

Gardner, F.P., R.B. Pearce and R.L. Mitchell, 1985. Physiology of crop pants. Iowa State, University Press.

Grieve, C.M., J.A. Poss, S.R. Grattan, D.L. Suarez, S.E. Benes and P.H. Robinson, 2004. Evaluation of salt-tolerant forages for sequential water reuses systems. Ii. Plant-ion relations. Agricultural Water Management, 70: 121-135.

Hasegawa, P.M., R.A. Bressan, J.K. Zhu and H.J. Bohnert, 2000. Plant cellular and molecular response to high salinity. Annual Review of Plant Physiology and Plant Molecular Biology, 51: 463–499.

Jacoby, B., 1999. Mechanism involved in salt tolerance of plants. In handbook of plant and crop stress. New York: Marcel Dekker, Inc.

Katerji, N., H. Van, J. W. , A. Hamdy and M. Mastrorilli, 2004. Agricultural Water Management, 65(2): 95-101.

Kjeldahl, J., 1883. A new method for the determination of nitrogen in organic matter. Z. Fresenius. Journal of Analytical Chemistry 22(1): 366-382.

Marcum, K.B., S.J. Anderson and M.C. Engelke, 1998. Salt gland ion secretion: A salinity tolerance mechanism among five zoysiagrass species. Crop Science, 38: 806-810.

Marcum, K.B. and C.L. Murdoch, 1990b. Salt glands in the zoysieae. Annals of Botany, (Lond) 66: 1-7.

Misra, N. and U.N. Dwivedi, 2004. Genotypic differences in salinity tolerance of green gram cultivars. Plant Science, 166(5): 1135-1142.

Munns, R., 2002. Comparative physiology of salt and water stress. Plant, Cell and Environment, 25(2): 239–250.

Mustafa, M.A. and E.A. Abdel Magid, 1982. Effects of irrigation interval, urea and gypsum on N, P and K uptake by forage sorghum on highly saline-sodic clay. Experimental Agriculture, 18(2): 177-182.

Poljakoff-Mayber, A., 1988a; 1988b. Ecological-physiological studies on the responses of higher plants to salinity and drought. Science-Reviews Arid Zone Research, 6: 163-183.

Rosenthal, K.L., J.R. Smiley, S. South and D.C. Johnson, 1987. Cells expressing herpes simplex virus,glycoprotein gC but not gB, gD, or gE are recognized by murine virus-specific cytotoxic T lymphocytes. Journal of Virology, 61(8): 2438-2447.

Saeed, A.M. and A.H. El-Nadi, 2004. Forage sorghum yield and water use efficiency under variable irrigation. Irrigation Science, 18(2): 67-71.

Sairam, R.K. and A. Tyagi, 2004. Physiology and molecular biology of salinity stress tolerance in plants. Current Science, 86(3): 407-421.

SAS, I., 2004. Sas/stat user's guide. 4th Edn.: Release 9.0. Statistical Analysis Institute, Cary, NC.

Sinha, A., S.R. Gupta and R.S. Rana, 1986. Effect of soil salinity and soil water availability on growth and chemical composition of sorghum halepense l. Plant and Soil, 95(3): 411-418.

Thomas, G.W., 1982. Exchangeable cations in methods of soil analysis part ii Madison, Wi. U.S.A: American Society of Agronomy and Soil Science Society.

Walkley, A. and I.A. Black, 1934. An examination of degtjaref method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37: 29-38.

Zhang, J. and J. Yang, 2004. Improving harvest index is an effective way to increase crop water use efficiency. Proceedings of the 4th International Crop Science Congress on the Theme Crop Science for Diversified Planet, Brisbane: 1-7.