Journal of Agronomy 11 (1): 1-8, 2012
ISSN 1812-5379 / DOI: 10.3923/ja.2012.1.8
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Salinity and Water Effects on Growth, Seed Production and Oil Content of *Kochia scoparia*

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Abstract: In order to study the effect of salinity and water stress on biomass production, growth parameters, seed yield and seed oil of kochia, kochia was grown in the spring and summer of 2009 with four levels of water supply and seven levels of saline water with three replications. During non-stress conditions kochia produced remarkable dry matter (37 t ha^{-1}) and still produced up to 8 t ha^{-1} during severe drought and saline conditions. The effect of maximum crop growth rate was higher than maximum crop growth duration on biomass production. Green biomass of kochia increased compared to shoot biomass and then, more assimilate partitioning to the leaves under salinity and drought stress helped kochia to keep its photosynthesis organs otherwise improve the forage quality. Kochia produced 2.5 and 1.5 t ha^{-1} seed under nonsaline and saline conditions, respectively. Kochia seed contains reasonable oil content, particularly during extreme stress conditions. Kochia could produce 120 kg ha^{-1} oil during the excessive stress condition of this experiment. Kochia's seeds contain 84% unsaturated fatty acid. This result indicates that kochia is a potential forage and oil crop under saline and dry conditions in semi-arid areas.

Key words: Growth parameter, oil, shoot biomass, seed yield, water quality, water quantity

INTRODUCTION

The conventional water resources and crops do not meet all the requirement of human society in dry and saline areas. Sea water or brackish water and salt tolerant plant should be considered for research (Breckle, 2009). In view of the current situation of food insecurity, factors such as availability of agricultural land, fresh water resources, increasing biotic and abiotic stresses are the most important factors that cause a further decrease in crop productivity (Athar and Ashraf, 2009). Slightly to moderately salt affected soils of Iran cover about 25.5 million ha and soil having severe salinity occupy 8.5 million ha (FAO, 2000).

Flowers and Flowers (2005) suggested that domestication of halophytes is the best alternative to produce economical plants that could be grown in the saline deserts. Kochia (*Kochia scoparia* L. Schrad) is a mesohalophyte, an annual plant of the family chenopodiaceae and has recently attracted the attention of researchers worldwide. The fast vegetative growth and its drought and salinity tolerance caused kochia to be adopted as important forage and fodder crop especially in desert areas (Al-Ahmadi and Kafi, 2008). Kochia is a rapidly emerging and growing plant that is widely adapted to many parts of Iran (Kafi *et al*., 2010). Nutritive value of kochia harvested at or before full bloom and alfalfa, harvested at 20% bloom is quite similar (Coxworth *et al*., 1988; Knipfel *et al*., 1989). Evaluating the growth analysis of forage plant is important for making good management decision. Plant growth analysis has been extensively used for quantifying patterns of dry matter production in plants. This provides a reliable index of the intrinsic physiology of plant growth and development. The productivity of the plants in a community as a whole may be related to various growth parameters. The growth parameters vary between and within species and also vary widely with mineral nutrition and water supply (Hegde, 1987; Berzsenyi, 2009; Chanda *et al*., 1987).

Despite kochia is not grown for seed production, its seeds contain considerable amounts of protein (20-25%) and oil (8-10%) (Coxworth and Salmon, 1972; Kafi *et al*., 2010). The protein content, composition and oil content indicated that kochia seed might be a useful protein and energy source (Coxworth and Salmon, 1972). Seeds of many of halophytes may contain edible oil (Glenn *et al*., 1991); however, the knowledge about fatty acid content of kochia's oil is scanty.

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Although it is widely recognized that salt and drought stress are major constraints for crop productivity, knowledge about nature and magnitude of both stresses is scanty to develop sustainable agriculture (Athar and Ashraf, 2009). The objectives of this study were evaluating the effect of salinity and drought stress on growth parameters, partitioning of dry matter production, evaluating the factor controlling productivity, measuring forage and seed production and oil content of kochia.

MATERIALS AND METHODS

Experiment layout: Field study was conducted in 2009 at the Mazrae Nemoneh Research Station of Golestan province in the north of Iran adjacent to the Caspian Sea. This station is located at 54° 42′E latitude and 37° 12′ N longitude and at an elevation of 5 m below sea level. The mean annual rainfall in this region is 330 mm of which more than 80% occurs in autumn and winter from November to April. The mean relative humidity of this area is 70%. The total rainfall was 165 mm during the course of the experiment. According to Emberger's classification, the climate of this area can be classified as semi-arid.

The seven experiments were arranged by a randomized complete block design with three replications. Each experiment consisted of four levels of water supply of kochia water requirements: (AW) 50 (AW_1), 75 (AW_2), 100 (AW_3) and 125% (AW_4). Saline water consisted of seven levels of irrigation water salinity: 1.5 (S_1), 7 (S_2), 14 (S_3), 21 (S_4), 28 (S_5), 35 (S_6) and 42 dS m^{-1} (S_7). The volume of water applied for each water deficient treatment was measured using a water flow meter with 0.1 L accuracy. Saline waters for different irrigation salinity levels were obtained by mixing various ratios of nonsaline (0.9 dS m^{-1}) and drainage (325 dS m^{-1}) waters. The chemical compositions of nonsaline and drainage water are given in Table 1.

The plot sizes were 3×3 m separated by 3 m spacing. Kochia was sown on 4th April 2009. Plants thinned to 20 plants m^{-2} (10 cm within and 55 cm between rows) density 1 month after sowing. Irrigation with good quality water was applied for getting the plants established and four irrigations with saline water were applied. Irrigation water requirement was estimated based on the measurement of soil water deficit (SWD) in nonstress treatment and multiplied by desirable coefficient for the other water quantity treatments. Irrigation was done when the Maximum Allowed Depletion (MAD) reached 45-55% level and then a soil sample was taken twice a week:

$$SWD = (\theta_{fc} - \theta_i) B_d . D \quad (1)$$

In this equation SWD is soil water deficit (mm); θ_{fc} and θ_i are gravimetric water content at FC and before irrigation, respectively; B_d is bulk density (g.cm^{-3}) and D is root depth (mm).

Sampling process and calculation of growth parameters: Every other week three plants were randomly selected from each plot regularly from 30 days after planting up to leaf color change. Leaf area was estimated by measuring the specific leaf area (SLA). The dry weight of plant materials was measured after drying for 3 days at 72°C. The logistic function was used for estimating shoot dry weight (Yusuf *et al*., 1999). In this equation a, b and c are coefficients and t is the time (day after seeding):

$$\text{Shoot dry biomass} = \frac{a}{\left[1 + b\exp^{(-ct)}\right]} \quad (2)$$

The function method was used to estimate the crop growth rate (CGR), because it minimizes harvest to harvest variation in each growth characteristic (Poorter, 1989; Bullock *et al*., 1988). The duration of the maximum crop growth rate (MCGRD) was derived from the black area in Fig. 1 (90-100% of maximum crop growth rate (MCGR)). Time to maximum crop growth rate (TMCGR) is the days from planting up to the MCGR.

After seed ripening stage, plant harvested from 0.275 m^2 of each plot. Seed weight was calculated based on 98% purity and 12% moisture content. Fatty acid content of control treatment seeds was measured by GC method (Whitney *et al*., 2000). Seed production (yield) was expressed on a relative basis (Y_r) in which Y is the absolute yield and Y_m equals to the production where salinity has very little or no influence on the yield (Maas, 1990) (Eq. 3):

$$Yr = Y/Ym \quad (3)$$

Equation 4 was used for describing Yr as a function of irrigation water salinity (Ec_{iw}):

Table 1: Chemical composition of irrigation water resources

Water resources	EC (dS m^{-1})	pH	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+
		(Meq L^{-1})							
Nonsaline	0.9	7.3	0.0	5.5	0.4	3.1	3.0	2.8	3.2
Drainage	325.0	8.0	0.0	5.6	940.0	3014.4	4.0	206.0	3750.0

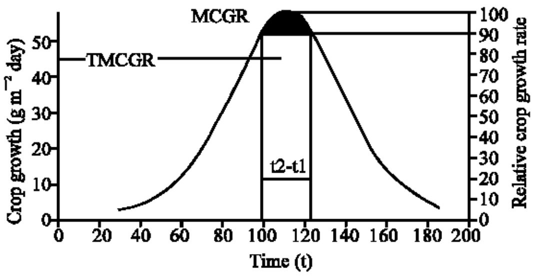

Fig. 1: Function of CGR, MCGR, MCGRD at 90% CGR (time between t1 and t2) and TMCGR derived from nonlinear growth function

$$Yr = \frac{1}{1+(C/C_{50})^{\exp(sC_{50})}} \tag{4}$$

In this experiment, C is the electrical conductivity of water in dS/m; C_{50} defines C at Yr = 0.5; and S represents the response curve steepness. The salt tolerance index (ST) was used to evaluate salt tolerance of crops (Eq. 5) (Steppuhn *et al*., 2005):

$$\text{ST index} = C_{50} + SC_{50} \tag{5}$$

Data analysis: For functions, coefficients were derived using the proc NLIN and REG procedures of the computer package SAS with treatment means. The data were analyzed and the mean comparison was made at p = 0.05. Interaction effects were perceived by slicing interactions method in SAS. SPSS 11.5 software was used for regression analysis by stepwise method.

RESULT AND DISCUSSION

Effect of saline water and water application on growth parameters: Salinity effect on shoot biomass production was significant, but the effect of drought stress was not significant (Table 2). The highest shoot biomass was harvested at 1.5 and 75% AW with 37 t ha^{-1} dry biomass and the lowest was harvested at 42 dS m^{-1} and 50% AW with 8.14 t ha^{-1} shoot dry biomass. Shoot biomass production of kochia in this experiment was higher than the biological yield reported earlier. Kafi *et al.* (2010) reported that the shoot biomass production of kochia was 8 t ha^{-1} at a low salinity level. Al-Ahmadi and Kafi (2008) reported 10 t ha^{-1} dry matter production of kochia in the arid areas of Birjand, Iran.

Flowering of Kochia started 118 days after planting on 25th August. Knipfel *et al.* (1989) showed that the nutritive value of kochia at mid bloom is the same as alfalfa at 20% bloom stage. As kochia is mainly used as animal feed, evaluation on the effect of salt and drought

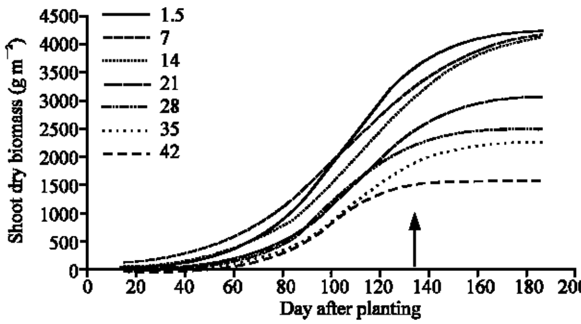

Fig. 2: Total shoot dry biomass (g m^{-2}) of Kochia grown with seven levels of saline water in 2009. Average data of three replications and water applications were fitted with Eq. 2. The arrow indicates the harvesting time for forage

stress on plant production was done at this stage. Salinity shortened the duration of the linear phase of growth and consequently, the sigmoid phase of growth started sooner than that of control plants (Fig. 2). The linear phase duration was 40 days for 42 dS m^{-1} and prolonged to 70 days at 1.5 dS m^{-1}. The sigmoid phase of growth started 120 and 140 days after planting at 42 and 1.5 dS m^{-1} of saline water treatment, respectively. The slop of dry matter productions in the linear phase of growth were 59.3, 43.21, 47.89, 43.78, 42.50, 35.8 and 33.1 at 1.5, 7, 14, 21, 28, 35 and 42 dS m^{-1} treatments, respectively.

After beginning to use saline water up to 100 days after planting, the shoot dry biomass at 7 dS m^{-1} was found to be the highest. The low salt stress (7 dS m^{-1}) improved the dry matter production of kochia in summer cropping (Salehi *et al*., 2009) but in spring cropping the duration of salinization was prolonged and reduced the biomass production 100 days after planting (Fig. 2).

The effects of water deficit were not significant but shoot biomass increased at 100% AW compared to other levels of water supply. Zahran (1993) subjected *K. indica* to two different irrigations at 20 and 30 days intervals and did not observe any significant differences. Al-Ahmadi and Kafi (2008) also studied the yield of Kochia with 7 and 14 days irrigation intervals, but they did not find significant differences between irrigation intervals on shoot dry biomass. Results of the work by Kafi *et al.* (2010) showed that 60% water application reduced shoot dry biomass of kochia.

On using saline water the CGR decreased over the entire sampling period but the effect of drought stress on CGR was not significant (Fig. 3). The highest and lowest CGR with salinity treatments were approximately 58 and 25 g m^{-2} day^{-1}, respectively. The CGR was reduced to 26, 20, 25, 29, 39 and 48% at 7, 14, 21, 28, 35 and 42 dS m^{-1},

Table 2: The effect of saline water and water application on shoot biomass (g m^{-2}), MCGR (g m^{-2} day), MCGRD (day) and Time to 90% CGR (day) of kochia

Saline water (dS/m)	Shoot Biomass (g m^{-2})	MCGR (g m^{-2} day)	MCGRD (day)	Time to 90% CGR (day)
50% water application				
1.5	3353.6a	63.38	15	90
7	3288.0a	68.78	15	85
14	2754.2ab	61.47	10	85
21	2514.2ab	57.65	15	90
28	2085.9abc	46.46	15	95
35	1690.3bc	44.34	10	100
42	883.6c	19.02	4	100
75% water application				
1.5	3723.3a	63.93	25	95
7	2891.7ab	65.00	20	85
14	2924.6ab	61.61	15	90
21	2522.1ab	45.70	20	95
28	2373.0b	45.37	15	95
35	1850.6bc	35.28	20	100
42	897.9c	15.97	15	100
100% water application				
1.5	3330.6a	63.48	15	90
7	3171.7a	56.25	15	85
14	2575.8ab	51.22	15	90
21	2518.2ab	45.41	20	95
28	2518.9ab	40.89	20	95
35	1326.4b	40.55	15	95
42	1357.9b	31.99	10	95
125% water application				
1.5	3350.9a	56.55	20	95
7	2720.9ab	50.93	15	90
14	2550.3abc	50.93	15	90
21	1731.2bc	40.33	15	90
28	1820.4bc	40.14	10	95
35	1500.6bc	53.11	10	95
42	1404.5c	44.00	5	95

The shoot biomass (g m^{-2}) followed by the same letter for salinity levels within each water application level are not statistically different according to the least significant differences (LSD) between all pairs at the α-probability of 0.05

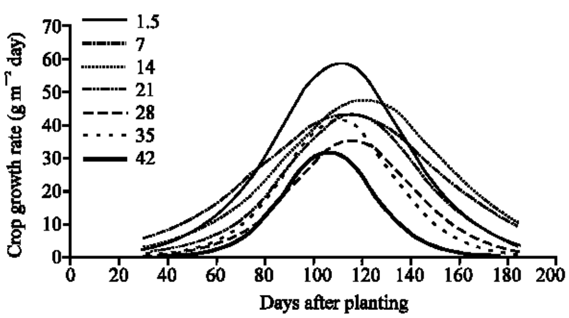

Fig. 3: CGR (g m^{-2} day) of kochia affected by saline water during the growing season. Data show the mean of three replications and four levels of water application

respectively, compared to control (1.5 dS m^{-1}). The peak CGR was observed 114 days after planting, which coincides with the start of the blooming of kochia.

The MCGR and MCGRD reduced with increase in salinity and the effect of salinity was dependent on the amount of water application. A 35 and 42 dS m^{-1} increase in water application improved the CGR (Table 2). At 42 dS m^{-1}, MCGRD reduced to 54.7% compared to control. The lowest and highest duration were observed at 42 dS m^{-1}, 50% AW and 1.5 dS m^{-1}, 75% AW, respectively. Increase in water application increased the MCGRD and the highest amount was observed at 75% AW; at 50% AW, the MCGRD reduced to 35% in comparison to 75% AW. The TMCGR was not greatly changed by salinity. Results showed that the MCGR and MCGRD had a great effect on biomass production. Analysis of regression by stepwise method showed that the effect of MCGR was higher than MCGRD on shoot biomass production. The coefficient of determination (R^2) of biomass production with MCGR was 0.731 and increased to 0.845 by adding MCGRD to model R^2.

Effect of water quality and quantity on stem dry weight, height, lateral stem number, leaf dry weight, green area index and leaf weight ratio: The effect of drought stress on the Green Area Index (GAI) was not significant but the effect of salinity was significant. With increase in salinity, the GAI reduced to 65, 66.8, 48 and 40% at 50, 75, 100 and 125% AW, respectively (Table 3). The decreased rate of leaf growth after an increase in soil salinity is primarily due to the osmotic effect of salt around the

Table 3: The effect of saline water and water application on lateral stem number (LSN), plant height (H), stem dry weight (SDW), leaf dry weight (LDW), green area index (GAI) and leaf weight ratio (LWR) of kochia.

			$g\ m^{-2}$			
Saline water ($dS\ m^{-1}$)	LSN	H cm	SDW	LDW	GAI	LWR
50% water application						
1.5	71.67ab	265.3a	2592.2ab	842.4a	19.03a	0.199c
7	76.33a	228.8ab	2619.7ab	668.3ab	15.10ab	0.205c
14	68.17ab	255.7a	2778.8a	703.9ab	15.90ab	0.192c
21	62.67b	195.2ab	1876.3abc	637.9ab	14.41ab	0.256cb
28	67.83ab	193.7ab	1512.8bcd	738.5a	16.68a	0.361ab
35	47.67c	170.5bc	1261.2dc	429.1ab	9.69ab	0.255bc
42	41.83c	104.7c	594.5d	289.1b	6.53b	0.481a
75% water application						
1.5	70.00a	257.7a	2840.3a	883.0a	19.95a	0.237b
7	71.83a	259.0a	2232.3abc	599.0abc	13.53abc	0.209b
14	65.83a	253.2a	2311.7ab	612.9ab	13.84ab	0.210b
21	64.33ab	202.5b	1908.5bc	613.6ab	13.86ab	0.245b
28	60.33ab	196.5b	1773.9bc	599.1abc	13.53abc	0.250b
35	49.50bc	183.3b	1378.9d	471.7bc	10.65bc	0.254b
42	41.83c	91.5c	604.8d	293.0c	6.62c	0.449a
100% water application						
1.5	76.17a	273.0a	2643.6a	687.0a	15.52a	0.202a
7	68.83a	255.7ab	2462.5a	709.2a	16.02a	0.227a
14	65.00a	203.7bc	1928.3ab	647.5ab	14.63ab	0.259a
21	66.67a	224.0ab	2011.5ab	506.7ab	11.44ab	0.210a
28	64.50a	217.3bc	1945.8ab	573.1ab	12.95ab	0.226a
35	47.50b	169.0cd	966.4b	360.0b	8.13b	0.268a
42	46.83b	144.8d	1004.2b	353.6b	7.99b	0.289a
125% water application						
1.5	73.67a	266.8a	2650.6a	700.3a	15.82a	0.212b
7	70.50a	267.2a	2166.1ab	554.9ab	12.53ab	0.203b
14	68.50ab	235.7ab	1952.4abc	597.9ab	13.51ab	0.234b
21	59.00bc	200.7cb	1270.3bc	460.9ab	10.41ab	0.263ab
28	63.67abc	200.7cb	1370.4bc	450.0ab	10.16ab	0.245b
35	52.67dc	171.3cd	1126.7c	373.9b	8.44b	0.260ab
42	46.00d	143.2d	985.8c	418.8ab	9.46ab	0.325a

Data followed by the same letter for salinity levels within each water application level are not statistically different according to the least significant differences (LSD) at the α-probability of 0.05

roots. Prolonged days of salinity result in reductions in cell elongation as well as cell division leading to slower leaf appearance and smaller final size (Munns and Tester, 2008). The reduction in leaf growth must be regulated by long distance signals in the form of hormones, because reduction in leaf growth rate is independent of carbohydrate supply (Munns *et al*., 2000) and water status (Munns *et al*., 2000; Fricke and Peters, 2002). Reduction in leaf expansion resulting in a buildup of unused photosynthetic assimilation in growing tissues may generate feedback signals to down-regulate photosynthesis. The reduction in leaf area due to salinity means that photosynthesis per plant is always reduced (Munns and Tester, 2008).

The effect of salinity on stem dry weight (SDW) 135 days after planting (mid-bloom stage) was significant and SDW reduced to 77-78% at 50 and 75% AW and 62% at 100 and 125% AW (Table 3). A great reduction on SDW was observed at 42 $dS\ m^{-1}$ and 50% AW.

The effect of water application on plant height was not significant, but the effect of salinity was significant (Table 3). Salinity decreased plant height by 66, 64, 47 and 46% at 50, 75, 100 and 125% AW, respectively. Increasing water application improved the plant height of kochia up to 100% AW. The effect of salinity on the Lateral Stem Number (LSN) was significant and increasing salinity up to 42 $dS\ m^{-1}$ reduced 42, 40, 38 and 37% of the LSN at 50, 75, 100 and 125% AW, respectively. The greatest decrease in LSN was observed at 35 and 42 $dS\ m^{-1}$ (Table 3). With increase in salinity lateral buds develop slowly or remain quiescent; then fewer branches or lateral stem are formed (Munns and Tester, 2008). Salinity and drought stress effect on plant height was higher than the LSN. Analysis of regression by stepwise method showed that the effect of LSN was higher than plant height on stem weight. The coefficient of determination (R^2) of SDW with LSN was 0.864 and did not change by adding plant height to model R^2 (R^2 = 0.868).

Salinity reduced the leaf dry weight to 55, 67, 48 and 40% at 50, 75, 100 and 125% AW (Table 3). The leaf weight ratio (LWR) is an index of the leafiness of a plant on a dry weight basis; a measure of the productive investment of the plant dealing with the relative

Table 4: Coefficient of determination (R^2), mean square error (MSER) and 95% confidential interval (95% CI) of C_{50} (dS/m) and response curve steepness (S) of nonlinear regression fit of the modified discount function arranged by water treatments (50, 75, 100 and 125%) for relative seed yield of kochia. Salt tolerance index (STI) derived from eq.5 was shown for each water treatment

Water treatments	Coefficient	Estimate	SE	95% CI		R^2	MSER	STI
50	C_{50}	49.72	9.97	22.11	77.34	0.99**	0.0067	50.24
	S	0.0103	0.0089	-0.014	0.035			
75	C_{50}	61.02	17.97	11.09	110.9	0.98**	0.0051	61.14
	S	0.0022	0.0062	-0.015	0.019			
100	C_{50}	56.35	6.77	38.93	73.75	0.99**	0.0014	56.82
	S	0.0083	0.0042	-0.002	0.019			
125	C_{50}	56.68	14.52	16.34	97.01	0.99**	0.0025	56.72
	S	0.0020	0.0053	-0.012	0.016			

**Significant at 0.01

expenditure on potentially photosynthesizing organs (Hunt, 2003). The effect of drought on LWR was not significant but to some extent increased the LWR (Table 3). LWR at 50% AW was 0.28 and decreased to 0.24 at 125% AW. Salinity significantly increased the LWR, especially at 50 and 75% AW. The highest LWR was observed at 50% AW with 42d S m^{-1} treatment. This mechanism helps kochia to cope with the salinity effect on photosynthesis organs. (Al-Ahmadi and Kafi, 2008) showed that increasing salinity improved the forage quality of kochia to some extent by restricting the stem weight and increasing assimilate partitioning to the leaves. Leaves of kochia had 58% higher protein and digestibility and 48% lower neutral detergent fiber and acid detergent (Kernan *et al*., 1986). Kafi *et al*. (2010) showed that the leaf-to-stem ratio of the Sabzevar genotype of kochia was approximately 50% and salinity up to 20 dS m^{-1} did not cause a significant effect.

Effect of saline water and water application on seed yield and oil content: Effect of salinity on seed yield was significant but the effect of water stress was not significant; however, salinity effect depended on the amount of water application. The effect of salinity was significant at 50% AW but there were no significant differences at 75, 100 and 125% AW. The highest seed yield was observed at 75% AW, 1.5 dS m^{-1} with 2.3 t ha^{-1} and the lowest seed yield was observed at 50% AW, 42 dS m^{-1} with 1.5 t ha^{-1}. Kafi *et al*. (2010) reported that seed yield at complete irrigation was 2.8 t ha^{-1} and reduced significantly at 80% AW. It seems that the response of seed production to water requirement is dependent on the climate condition.

Discount function was used to evaluate the effect of saline water and drought stress on seed production. Steppuhn *et al*. (2005) submitted that the yield of crop under saline conditions relates more closely to a modified discount function rather than to the threshold slope model. Regression fits of the modified discount equation (Eq. 4) with the relative shoot biomass plotted for each water application resulted in R^2 value of 0.98 or higher and mean square error of 0.012 or lower (Table 4, Fig. 4). Based on this equation, a 50% reduction of seed yield (SE) was

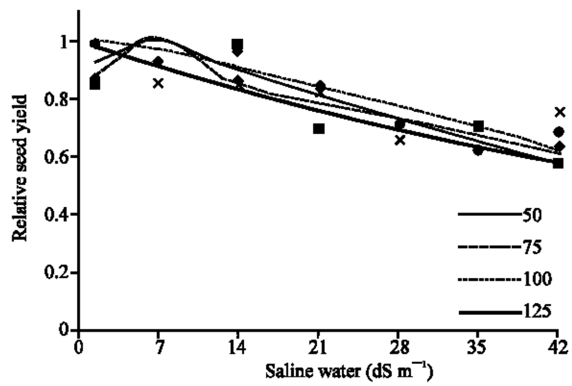

Fig. 4: Kochia relative seed production at four levels of water application (50, 75, 100 and 125%) fitted to the discount equation (Eq. 4) as a function of saline water (EC_{iw})

observed at 49.7 (9.94), 61.02 (17.97), 56.34 (6.77) and 56.67 (14.52) dS m^{-1} and the steepness of the equation was 0.0103, 0.0021, 0.0083 and 0.0020 at the 50, 75, 100 and 125% AW, respectively (Table 4). The salinity tolerance index (STI) derived from equation 4 increased on increasing water application (Table 4).

The oil content of kochia seeds was between 8.4% in the nonsaline and 7.8% under 42 dS m^{-1} salinity and the effect of treatments on oil content was not significant. Kafi *et al*. (2010) showed that drought stress up to 40% of water application did not have significant effect on oil content. Kochia could produce 192 kg ha^{-1} oil at 75% AW and 1.5 dS m^{-1} and 120 kg ha^{-1} at 42 dS m^{-1} and 50% AW. In comparison to canola 50% yield reduction occurred at 16.91 dS m^{-1} of solution conductivity and the ST index was 18.02 (Steppuhn *et al*., 2010). Thus, canola could not produce seed at 35 dS m^{-1} but kochia produced 138 kg ha^{-1} oil.

Analysis of kochia's seed oil showed the presence of 14 fatty acids of which five were saturated and nine were unsaturated fatty acids (Table 5). Saturated and unsaturated fatty acid contained 12% and 84% of seed oil content, respectively. Palmetic ($C_{16:0}$) was the dominant saturated fatty acid (8.4%) and linoleic (50%) and oleic

Table 5: Saturated and unsaturated fatty acid fractions (%) in the oil of kochia seeds

Fatty acid		Percent
Saturated		
Hexadecanoic acid methyl ester (palmetic)	$C_{16:0}$	8.39
Octadecanoic acid methyl ester (stearic)	$C_{18:0}$	2.74
Eicosanoic acid methyl ester (arachdic)	$C_{20:0}$	0.92
Docosanoic acid methyl ester (behenic)	$C_{22:0}$	0.06
Tetracosanoic acid methyl ester (lignoceric)	$C_{24:0}$	0.12
Total		12.23
Unsaturated		
5- Hexadecanoic acid methyl ester	$C_{16:1}$	4.59
9- Hexadecanoic acid methyl ester (palmitoleic)	$C_{16:1}$	0.14
9- Octadecanoic acid methyl ester (oleic)	$C_{18:1}$	19.69
5- Octadecanoic acid methyl ester	$C_{18:1}$	2.22
11- Eicosanoic acid methyl ester (gadoleic)	$C_{20:1}$	1.32
5, 9- Octadecanoic acid methyl ester	$C_{18:2}$	0.69
9, 12- Octadecanoic acid methyl ester (linoleic)	$C_{18:2}$	49.90
5, 9, 12- Octadecanoic acid methyl ester	$C_{18:3}$	0.63
9, 12, 15- Octadecanoic acid methyl ester (a-linolenic)	$C_{18:3}$	4.67
Total		83.85

(20%) acids were the dominant unsaturated fatty acids. Kochia seeds also contained 4.7% α-linolenic acid. Linoleic and a-linolenic acids are the two essential fatty acids that the human body needs and cannot manufacture (Snow, 2004). Kochia oil contains 4.6%, 5- Hexadecanoic acid. Whitney *et al*. (2000) reported that this fatty acid can be used to control the disease carrying mosquito *Cluex quinquefaciatus*. This unusual fatty acid is produced in the seed of *Kochia scoparia*. Canola produces the best oil for human consumption, which contains 90% unsaturated fatty acid with 4% palmetic acid, 61% mono-unsaturated and 21% poly-unsaturated fatty acids (Mayers, 2008). Kochia oil contains 28% mono-unsaturated and 56% poly-unsaturated fatty acids; therefore, kochia seeds have the potential to be used as a source of edible oil.

CONCLUSION

The results showed that kochia adapted to drought and salinity especially in semi-arid areas. The highest shoot biomass was observed at nonstress conditions with 37 t ha^{-1} and reduced to 78% during extreme saline and drought stress conditions of this experiment. More assimilate partitioning to the leaves under salinity and drought stress helped kochia to keep its photosynthesis organs.

Increasing water application improved salt tolerance of kochia for seed and biomass production by increasing MCGR; thus, irrigation management is in kochia important for improving quality and quantity of forage production. Kochia can produce 138 kg ha^{-1} oil at 35 dS m^{-1} and oil contains 84% unsaturated fatty acid; thus, it could be used as a source of oil for human consumption. This result indicates that kochia should seriously be considered as a forage and oil crop in semi-arid conditions by applying unused saline wastes waters and land.

ACKNOWLEDGMENTS

This study was funded by Ferdowsi University of Mashhad- Iran. The authors thank the director of Mazrae Nemoneh Research Station, Irrigation Lab. of Agriculture Research Center of Golestan-Iran, Mrs. Najafi and her students and Terry Brabender for correcting the paper.

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