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SODICITY TOLERANCE OF JATROPHA (*JATROPHA CURCAS* L.) SEEDLINGS

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ABSTRACT

Jatropha *(Jatropha curcas* L.*)* is recently introduced as a bio-fuel crop-plant in Pakistan. It can withstand and survive on a wide variety of soils. However, detailed information regarding its growth in sodic soils is lacking. We evaluated sodicity tolerance of 60-days old saplings of jatropha. The seedlings were initially raised in a nursery and then transferred into the earthen pots. The pots were filled with artificially prepared sodic soils with four exchangeable sodium percentage (ESP) levels: 5.0 (control), 25, 35 and 45. The sodicity treatments were administered by spraying a 1:1 solution of Na_2CO_3 and $NaHCO_3$ on normal soil. The seedlings were allowed to grow for four months after transplantation. The results obtained from the study showed remarkable reductions in various growth parameters of jatropha seedlings due to sodicity stress, viz. at high sodicity (ESP 45) the reductions were: 75%, 69%, 67%, 92% and 78%, in plant height respectively number of leaves, root length, stem grith and seedling dry biomass. Increasing sodicity enhanced leaf Na^+ concentration, while the reverse was true for the leaf concentration of K^+, Ca^{2+} and Mg^{2+} and K^+/Na^+ ratio. It is concluded that sodicity adversely affects the growth and biomass production of jatropha seedlings; mainly by decreasing the ratios of K^+, Ca^{2+}, and Mg^{2+} to Na^+.

Keywords: Biofuel crop, ESP levels and K^+ contents, *Jatropha curcas* L, Na^+, seedling growth

INTRODUCTION

Worldwide energy resources are depleting. Enormous efforts are being made to find out best alternate sources of petroleum/gasoline. Due to high prices and rising demand of petrolium/gasoline, government of Pakistan is taking serious efforts to find out alternate energy sources to meet the country's fuel/energy demand. In this regard, technical experts are working on the exploitation of natural energy resources, including natural coal, solar and wind energy. Similarly, plant scientists are also working very hard to identify and introduce new and environmentally safe fuel/energy producing plant species. In this regard, Jatropha is an important drought-resistant perennial plant of the family Euphorbiaceae (Kumar and Sharma, 2008). It is a well-known source of energy in tropical and subtropical regions of the world (Martin, 1985; Openshow, 2000; Jayasingh, 2004). As a valuable and multipurpose biofuel crop (Benergji, *et al*., 1985), jatropha requires very low water (Heller, 1996). Jatropha produces about 8.0 tons seed ha^{-1} with an oil content of 35% and oil yield of 2720 kg ha^{-1} (Jongschaap, 2008). Its fuel emissions are safe to environment as compared to other fuel types (Bhardwaj, 2009). It is under cultivation on some private and public farms and experimental stations of the Sindh province.

Jatropha except waterlogged may grow almost on a variety of soils such as sandy, gravelly, stony and saline soils (Kumar and Sharma, 2008). In reality, such fuel producing crops cannot be grown on normal fertile lands which are marked for food and fiber cultivation. Hence, marginal, sandy desert and salt-affected soils of the country can only be spared for cultivation of biofuel plant species such as jatropha. Although, an extensive research has been done on salt-tolerance of cereals, vegetables, fruits, grasses, trees, shrubs, halophytes and other major and minor field crops (Rajpar *et al*., 2010). Very limited information exists on sodicity tolerance of biofuel plant species, including jatropha. Compared to salinity, the mechanisms of sodicity tolerance among plant species varies widely (Brady and Well, 2002) due to

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adverse chemical properties (toxicity of Na^+, OH^- and HCO_3^- ions) and deteriorated physical conditions (poor soil structure, lack of free O_2, slow permeability, etc.), sodic soils are much more adverse to plants than saline soils. The plants that are tolerant to salinity may become sensitive to sodicity (Rajpar *et al*., 2003). The sensitivity of some plant species to sodicity stress is highest at early growth stages than later (Rajpar and Wright, 2000). The objective of our study was to evaluate the sodicity tolerance potential of jatropha seedlings.

MATERIALS AND METHODS

To evaluate the effect of four levels (5, 25, 35 and 45) of exchangeable sodium percentage (ESP) on the growth of jatropha seedlings, a pot experiment was conducted at the Department of Soil Science, Sindh Agriculture University, Tandojam.

Preparation of sodic soils

The soil used in this study was clayey loam (37.70% clay), non-saline (EC_e 2.7 dS m^{-1}), non-sodic (ESP 5.0), calcareous ($CaCO_3$ 9.70%) and slighlty alkaline in reaction (pH 7.4). The soil contained 0.97% organic matter, 0.048% nitrogen and 134 $mgkg^{-1}$ extractable potassium. The soil was brought from the field, air-dried, passed through a garden sieve (¼ inches) and splitted into four equal lots. One lot was regarded as control (ESP 5). In the remaining three lots, three ESP levels i.e. 25, 35 and 45 were established. To achieve required levels of ESP, soils were spread over black colored polyethylene sheets and thoroughly sprayed with required concentrations and volume of $NaHCO_3$ and Na_2CO_3 (1:1 ratio) solutions. The sprayed soil lots were incubated for 15 days by covering with polyethylene sheets as reported earlier (Bains and Fireman, 1964; Rajpar *et al*., 2010). These soils were then air-dried and mixed by giving hand rakings. Finally the treated soils were filled in 10kg plastic pots.

Raising and transplantation of seedlings

Two months old jatropha seedlings established from dry seed raised in soil filled earthen trays were carefully transferred into soil filled plastic pots. Each pot contained six seedlings with 10 cm average height of each seedling. The plants were allowed to grow for four months; then the experiment was terminated and the plants were carefully removed from the pots to record seedling height (cm), stem girth (cm), number of leaves $plant^{-1}$, root length (cm) and shoot and root dry matter $plant^{-1}$. Cations like Na^+, K^+, Ca^{2+} and Mg^{2+} contents and K^+/Na^+ ratio were determined in leaf dry matter.

Soil sampling and analysis

Before developing sodicity levels, original soil was analyzed for some basic physico-chemical properties. Soil samples were also taken from each treated lot to determine electrical conductivity, pH, Na^+, Ca^{2+} and Mg^{2+}. Exchangeable sodium percentage was estimated from exchangeable sodium ratio (ESR) and sodium adsorption ratio (SAR) drawn from the concentration values of soluble Na^+, Ca^{2+} and Mg^{2+}. Soil texture was determined by Bouyocos Hydrometer method of Kanwar and Chopra (1968). Electrical conductivity and pH were determined with digital meters (Suntex and Lab-960). Soil organic matter (SOM) was estimated by Walkley-Balck method, nitrogen and lime contents were determined by Kjeldhal (Rowell, 1994) and acid neutralization (Kanwar and Chopra, 1969) methods, respectively. Sodium was determined through flamephotometery, whereas Ca^{2+} and Mg^{2+} were determined by titration methods as given in USSL (1954).

Statistical analysis

The plant data were analyzed for analysis of variance (ANOVA) using MINITAB statistical software version 13. Treatment means were compared using L.S.D tests at 5% probability level.

RESULTS AND DISCUSSION

Soil properties

The soil treated with salt solutions was typical to that of sodic soils of Sindh (Table 1). Compared to un-treated control, the soils alkalinized with sodic salts appeared to be alkaline in nature with high pH and ESP. Although, there was rise in EC_e of the treated soils, but that was very slight to be considered adverse to plants. As described in the methodology, the original soil used in this study was poor in organic matter and rich in lime, this reflects the origin of soil formed from alluvium, transported and deposited by River Indus and its tributaries under arid and semi-arid environment. High lime content indicates the nature of parent material possibly derived from wide variety of rocks such as calcareous shales, limestones, etc. from the Himalayas and the adjoining uplands (Razaq and Herbillon, 1987). Several other studies including Sial (1985); Rajpar and Sial (1997) indicate that the alluvium driven soils of Sindh are calcareous in nature, low in organic matter and are deficient in nitrogen content.

Table 1. Soil EC_e, pH and ESP determined before and after alkalinization.

At sowing after alkalinization				
Sodicity treatments	EC_e (dS m^{-1})	pH (H_2O)	ESP Desired	ESP Obtained
T_1: Untreated (Control)	2.70	7.3	5.0	5.0
T_2: Treated with 0.5*mM* concentration (Na_2CO_3: $NaHCO_3$)	4.76	8.8	25.0	18.0
T_3: Treated with 0.75*mM* concentration (Na_2CO_3: $NaHCO_3$)	5.35	9.6	35.0	37.5
T_4: Treated with 1.0*mM* concentrations (Na_2CO_3: $NaHCO_3$)	6.00	10.5	45.0	46.2

Growth and development of jatropha seedlings on sodic soils

The data pertaining to agronomical observations presented in Table 2 indicate that increasing soil sodicity significantly decreased seedling height, root length, number of leaves plant^{-1}, stem girth, petiole length, dry shoot and root weights plant^{-1}. Compared to untreated control, the jatropha seedlings grown in sodic soils with 25, 35 and 45 ESP levels were 54, 67 and 75% shorter in height, developed 40, 60 and 69 % fewer leaves, showed 29, 51 and 68% reduction in stem girth and 30, 46 and 62% reduction in petiole length. The seedlings grown in 25, 35 and 45 ESP treatments had very small root system. Compared to control untreated soil treatment, seedlings grown in 25, 35 and 45 ESP treatments had 55, 78 and 92% shorter tap root system and 65, 83 and 94% shorter lateral root system. The response of jatropha seedlings to increasing ESP levels in terms of dry weights of shoot and root also remained negative. All ESP levels greatly decreased dry shoot and root weights. Seedlings grown in 25, 35 and 45 ESP treatments gave 48, 64 and 78% lower shoot dry weight and 59, 75 and 92% lesser root dry weight. It is evident from various research reports (Ray and Khaddar, 1995) that due to change in soil redox conditions, pH and concentrations of toxic ions such as Na+ and HCO_3^-, soil sodicity becomes adverse to root development and function (Rajpar and Wright, 2000; Wright and Rajpar, 2000).

Table 2. Effect of different soil-ESP levels (5, 25, 35, and 45) on some growth and biomass traits of jatropha seedlings. The values represent means of 03 replicates.

ESP	Seedling height (cm)	No. of leaves (plant^{-1})	Stem girth (mm)	Petiole length (cm)	Shoot dry weight (g plant^{-1})	Vertical tap roots length (cm)	Primary lateral roots length (cm)	Root dry weight (g plant^{-1})
05	51.21	43.33	2.00	4.90	12.75	9.20	16.3	4.05
25	23.75	26.00	1.43	3.45	6.65	4.10	5.6	1.68
35	16.67	17.17	0.98	2.67	4.46	2.01	2.8	1.00

45	13.00	13.50	0.67	1.85	2.78	0.75	1.1	0.33
LSD	2.30	2.35	0.125	0.158	1.10	0.52	0.57	0.32

Ion accumulation of jatropha seedlings under sodic condition

The effects of increasing soil-ESP on the contents of toxic (Na^+) and some nutrient cations (K^+, Ca^{2+} and Mg^{2+}) are shown in Table 3. The seedlings grown in sodic soils accumulated significantly more Na^+ and less K^+, Ca^{2+} and Mg^{2+} in their top fully matured leaves. Thus under sodicity stress seedlings did not maintain normal leaf K^+/Na^+ ratio. Accumulation of more Na^+ (cytotoxic element) under sodic condition was the result of treating soils with Na_2CO_3 and $NaHCO_3$ salts. In addition to ionic (Na^+, CO_3^{2-} and HCO_3^-) toxicity, sodic soils also develop poor physical conditions, where organic and inorganic soil colloids become dispersed and de-flocculated, thus plants in sodic environment face problem of poor soil structure, poor drainage, depletion of free O_2, waterlogging, etc.

Table 3. Effect of different ESP levels on ion contents and K^+/Na^+ ratio in jatropha leaf dry matter. The values represent means of 03 replicates.

ESP	Na^+ (%)	K^+ (%)	K^+/Na^+	Ca^{2+} (%)	Mg^{2+} (%)	Ca^{2+}/Na^+
05	0.89	1.4	1.61	0.0470	0.03	0.0562
25	2.7	1.3	0.48	0.0289	0.01	0.0111
35	2.9	0.97	0.31	0.0271	0.02	0.0103
45	3.3	0.63	0.19	0.0261	0.01	0.0090
LSD	0.11	0.02	0.03	0.0200	0.02	---

CONCLUSION

Based on the results, it is concluded that sodicity strongly affects the early growth and biomass production of jatropha. The reduction in growth parameters under sodicity stress is governed by the ratios of K^+ and Ca^{2+} to Na^+.

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