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Research Article

Screening of Medicinal Crops at Various Salinity and Sodicity Levels

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Abstract

Biosaline agriculture is an alternative approach for effective utilization of salt affected by exploring the genetic potential of suitable salt tolerant plant species thereby growing crop plants ultiamtely resulting into reclamation of problematic soils. In this context, a pot experiment was conducted for consecutive three-years to study the ability of salt tolerance of some medicinal plants having some economical importantance i.e.,Guar (*Cyamopsis tetragonoloba* L.), Niazbo (*Ocimum basilicum*), Alovera (*Aloe barbadensis* Miller),Lemon grass (*Cymbopogon flexuosus*), linseed (*Linum Usitatissium*), Taramira (*Eruca sativa* Mill), Coriander (*Coriandrum sativum* L.) and White Zeeri (*Cuminum cyminum* L.) against different salinity levels having EC_e (0.70, 6 & 8 dS m^{-1}) & SAR (1.93, 25 and 35). Biomass yield data of each medicinal plant was recorded after four months of its cultivation. Results depicted that highest level of salinity (8 dS m^{-1}) & sodicity (35 SAR) reduced the biomass yield of Guar (46.09%), Niazboo (47.96%), Alovera (34.40%), Lemon Grass (48.77%), Linseed (39.57%), Taramira (45.84%), Coriander (28.17%) and White Zeeri by (49.93%) over control. However, combined effect of EC_e & SAR (6 dS m^{-1}+ 25 SAR) resulted in better yield performance of medicinal plants and biomass reduction was only 9.64% in Niazbo to 24.46% in Taramira over control. It is concluded from the results that these herbs can be grown successfully at the medium level of salinity (6 dS m^{-1}) and sodicity (25 SAR).

Keywords: Medicinal crops; Salinity; Sodicity; Tolerance; Screening

Introduction

Salinity and sodicity are one of the major factors responsible for limited crop yields in agriculture of Pakistan. Almost 6.67 million ha of Pakistan is affected by salinity/sodicity (Khan, 1998). Rapid reduction in culturable area of Pakistan as a result of land degradation and urbanization resulted into decreased crop production. The increasing demand for agricultural products is compelling to exploit the barren salt affected lands. Exploring the native genetic potential of economically important local germplasm having some medicinal value which can grow and survive under saline conditions is the most

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suitable solution for utilization of problematic soils. Increased demand of herbal medicines has accentuated the need to explore the hidden potential of the salt tolerant medicinal plants (Manukyan, 2011; Qureshi and Ghufran, 2005) as almost 25% of all the modern drugs are derived from herbal flora (Vitalini *et al.*, 2009).

Pakistan is blessed with great diversity of medicinal plants due to wide range of climatic conditions (Chaudhry *et al.*, 2009). It is therefore imperative to screen out the medicinal plants against salinity/sodicity which can be successfully grown in salt affected soils producing economical yields. Growing the medicinal plants in salt affected soil is more beneficial than arable cropping giving better farm returns for prosperous agriculture. A galaxy of scientists has worked and produced excellent results thereby proving the worth of bioaline agriculture making it more profitable. Ashraf *et al.* (2002) studied the performance of 15 guar accessions against salt stress of 3, 9 and15 dS m^{-1}. They reported that biomass yield was drastically reduced by increasing salinity level as root/shoot fresh weight and plant height of all the guar accessions decreased under salt stress, although, accession 239/2 and 281/3 were more toelrant to salinity and performed better than other accessions at higher salinity level of 15 dS m^{-1}. Similarly, Suthar et al. (2018) evaluated the response of 25 guar genotypes under four salinity levels (control, 3, 6 and 9 dSm^{-1}). They reported 50% yield reduction in yield in all the genotypes at salt concentration of 6 dSm^{-1}. Bernstein *et al.* (2010) exposes sweet basil to six salinity levels i.e., 1, 25, 50, 75, 100 and 130 mM NaCl. A negative effect on growth in response to salinity was apparent with 25 mM NaCl, however, maximum reduction of 63% in biomass yield of basil plants was divulged at elevated level of salt treatment i.e., 130 mM NaCl.

Caliskan *et al.* (2017) appraised the effect of five salt treatments (0.4, 1.00, 2.50, 4.00 and 8.00 dSm^{-1}) on sweet basil. They stated that increasing levels of salt stress had significantly negative effects on growth attributes of sweet basil. Aloe Vera has high economic value and is commonly used in pharmaceuticals industry (Reynolds and Dweck, 1999). It can tolerate the many environmental stresses. Murillo-Amador *et al.* (2015) evaluated the response of physiological and morphological traits of Aloe Vera against five salinity treatments (0, 30, 60, 90 and 120 mM NaCl). They reported that growth characteristics of Aloe Vera were not significantly influenced at lower salinity levels (30 and 60 mM) however, increasing salinity levels (90 and 120 mM NaCl) had remarkable effect on growth. In a study, (Arshad Ullah *et al.*, 2019, 2018a, 2018b) evaluated the effect of EC_e (4, 5, 10 dSm^{-1}) and SAR (13.5, 25, 30) on biomass yield of coriander, linseed and niazboo. Dual stress of sodicity and salinity significantly reduces the biomass yield of medicinal crops and reduction was 10.19% to 25.05%, 20.25% to 39.05% and 11.83% to 29.62% in coriander, linseed and niazboo respectively, over the non-saline treatment (control). Kumar and Chauhan (2017) studied the effect of salinity (control, 5, 10, 15 and 20 dSm^{-1}) on lemon grass. They stated that increasing level of salinity significantly reduced the number of tillers, plant height and biomass yield of lemon grass. Likewise, response of a black cumin against different levels of sodicity (12.80, 25 and 35) and salinity (2.40, 6 and 8 dS m^{-1}) was studied by Ahmed et al. (2015). They reported that elevated level of salinity (8 dS m^{-1}) and sodicity (35 SAR) proved more

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hazardous for black cumin and decreased the shoot fresh weight (43.73%) and plant height (69.81%) respectively over control (non-saline).

So, an experiment in pots was designed to explore the ability of salt tolerance of some plants having medicinal value which can survive in slightly to moderately salt affected soils and will give better economic return to farmers.

Methodology

Soil Analysis

A pot study was conducted for three consecutive years in glass house at Soil Salinity Research Institute, Pindi Bhattian, Pakistan (31.8951° N, 73.2808° E). A normal soil was analyzed for (pH_s = 8.20, EC_e = 0.70 dS m^{-1}, SAR = 1.93, Saturation percentage = 30.40, Texture = Sandy loam, Organic matter (%) = 0.72, Extractable K (mg kg^{-1}) = 110.0 and Available P (mg kg^{-1}) = 9.60).

Treatments

Standard quadratic equation was used to develop desired levels of salinity (EC_e and SAR) by using Na_2SO_4, NaCl, $CaCl_2$ and $MgSO_4$ (Ghafoor *et al.*, 1988). Following treatments were used for experimentation.

T_1= EC_e, 0.70dS m^{-1} + SAR, 1.93

T_2 = EC_e, 6 dS m^{-1} + SAR, 25

T_3 = EC_e, 6 dS m^{-1} + SAR, 35

T_4 = EC_e, 8 dS m^{-1} + SAR, 25

T_5 = EC_e, 8 dS m^{-1} + SAR, 35

Experimental design

After development of desired levels of salinity & sodicity, pots were filled with 20 kg soil each. During Kharif Guar (*Cyamopsis tetragonoloba* L.), Niazbo (*Ocimum basilicum*), Alovera (*Aloe barbadensis* Miller) andLemon Grass (*Cymbopogon flexuosus*), while in Rabi season Linseed (*Linum Usitatissium*), Taramira (*Eruca sativa*Mill), Coriander (*Coriandrum sativum* L.) and White Zeeri (*Cuminum cyminum* L.) were sown. Ten seeds of each crop while slips of lemon grass were planted in every pot. Experiment was arranged with Completely Randomized Design (CRD) having four replications. After thirty days thinning was carried out and four plants were maintained in each pot. Biomass yield data of each medicinal plant was recorded after four months of sowing. The data was analyzed through analysis of variance (ANOVA) and means comparison was at 5% LSD (Steel, 1997).

Results and Discussion

Kharif crops

Guar

Salinity and sodicity adversely affected the biomass yield of guar. Cumulative data of three seasons revealed that an inhibitory effect on growth of guar was observed among the different treatment of salinity/sodicity (Table 1). Control treatment produced the maximum biomass yield (56.86 g) which was significantly *($p < 0.05$)* reduced under dual stress of EC_e and SAR. Lowest biomass yield (30.65 g) was recorded in T_5 with highest salinity and sodicity level of EC_e 8 dSm^{-1} and SAR 35. Reduced biomass yield was recorded in treatments T_2, T_3, T_4 and T_5 by 19.59%, 31.34%, 37.35% and 46.09% respectively over control.

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Table 1: Effect of EC_e / SAR on Guar biomass (g pot^{-1}).

Treatments	1st year	2nd year	3rd year	Mean	% decrease over control
T_1 - Control	54.50 a	59.50 a	56.60 a	56.86 A	_
T_2 - (6 : 25)	244.33 b	47.33 b	45.50 b	45.72 B	19.59
T_3 - (6 : 35)	39.66 c	39.93 c	37.53 c	39.04 C	31.34
T_4 - (8: 25)	34.16 d	37.50 d	35.20 c	35.62 D	37.35
T_5 - (8 : 35)	30.16 d	31.13 e	30.66 d	30.65 E	46.09

Values followed by same letters are statistically similar at 5% of probability

Niazbo

Salinity and sodicity negatively affected the growth of Niazbo and biomass yield reduced linearly in response to salt stress. Consequently, maximum stress on yield was generated by higher level of EC_e and SAR (Table 2). Control (non- saline) treatment produced the highest biomass yield of 58.37 g and T_5 with EC_e 8 dS m^{-1} and SAR 35 the lowest biomass yield of 30.38g. Yield reduction of 9.64%, 21.82%, 34.62% and 47.96% was recorded in T_2, T_3, T_4 and T_5 respectively.

Table 2: Effect of EC_e / SAR on Niazbo biomass (g pot^{-1}).

Treatments	1st year	2nd year	3rd year	Mean	% decrease over control
T_1 - Control	43.10 a	66.40 a	65.63 a	58.37 A	_
T_2 - (6 : 25)	38.00 b	60.26 a	59.96 b	52.74 AB	9.64
T_3 - (6 : 35)	36.33 b	49.86 b	50.70 c	45.63 ABC	21.82
T_4 - (8: 25)	35.83 b	37.36 c	41.30 d	38.16 BC	34.62
T_5 - (8 : 35)	30.33 c	29.56 d	31.233 e	30.38 C	47.96

Values followed by same letters are statistically similar at 5% of probability

Alovera

Biomass yield of Alovera was also affected adversely with combined effect of salinity and sodicity. Mean value data (Table 3) showed that Alovera produces maximum biomass (185.19 g) in non-saline conditions i.e., control, however statistically, it was non-significant *($p < 0.05$)* with T_2, T_3,andT_4. Minimum biomass yield (121.48 g) was observed where the Alovera plants were exposed to EC_e 8 dSm^{-1} and SAR 35 in T_5. Biomass of Alovera was reduced by 11.95%, 17.09%, 26.08% and 34.40% respectively in T_2, T_3, T_4 and T_5 over control.

Table 3: Effect of EC_e / SAR on Alovera biomass (g pot^{-1}).

Treatments	1st year	2nd year	3rd year	Mean	% decrease over control
T_1 - Control	153.33 a	200.47 a	201.77 a	185.19 A	_
T_2 - (6 : 25)	138.00 b	174.57 ab	176.57 b	163.05 AB	11.95
T_3 - (6 : 35)	133.17 bc	161.63 bc	165.80 c	153.53 ABC	17.09
T_4 - (8: 25)	124.83 c	141.80 cd	144.03 d	136.89 BC	26.08
T_5 - (8 : 35)	98.100 d	133.33 d	133.00 e	121.48 C	34.40

Values followed by same letter statistically similar at 5% of probability

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Lemon grass

A quick glance to data in (Table 4) revealed that lemon grass performed well in T_1 (control), whereas, saline/sodic treatments negatively affected the growth of lemon grass. Maximum biomass yield of 67.31 g was documented in T_1 followed by T_2, T_3, T_4 and all these treatments were statistically non-significant. T_5i.e., EC_e 8 dSm^{-1}& SAR 35 produced lowest biomass of 34.48 g. Reduction of biomass yield was observed by19.04%, 32.03%, 44.61% and 48.77% respectively in T_2, T_3, T_4 andT_5as compared to T_1.

Table 4: Effect of EC_e / SAR on Lemon grass biomass (g pot^{-1}).

Treatments	1st year	2nd year	3rd year	Mean	% Decrease over control
T_1 - Control	79.33 a	60.40 a	62.20 a	67.31 A	_
T_2 - (6 : 25)	74.66 ab	43.23 b	45.60 b	54.49 AB	19.04
T_3 - (6 : 35)	68.33 b	34.13 c	34.80 c	45.75 AB	32.03
T_4 - (8: 25)	60.00 c	26.40 d	25.46 d	37.28 AB	44.61
T_5 - (8 : 35)	52.66 d	26.33 d	24.46 d	34.48 B	48.77

Values followed by same letters are statistically similar at 5% of probability

Rabi crops

Linseed

Data regarding the biomass yield of linseed showed that growth of linseed plants was very good under non saline conditions, whereas salinity + sodicity negatively affected the biomass yield (Table 5). Pooled data showed that maximum biomass yield (48.41 g) was evident in control, whereas minimum biomass yield (29.25 g) was reported in T_5 (EC_e 8 dSm^{-1}+SAR 35), however, it was statistically similar to T_4.Salinity stress reduces the biomass yield by 14.76%, 29.29%, 36.70% and 39.57% respectively in T_2, T_3, T_4 andT_5 when compared to non-saline treatment (control).

Table 5: Effect of EC_e / SAR on Linseed biomass (g pot^{-1}).

Treatments	1st year	2nd year	3rd year	Mean	% Decrease over control
T_1 - Control	45.53 a	48.53 a	48.41 a	48.41 A	_
T_2 - (6 : 25)	36.30 b	40.90 b	41.26 b	41.26 B	14.76
T_3 - (6 : 35)	33.59 bc	34.46 c	34.23 c	34.23 C	29.29
T_4 - (8: 25)	33.29 bc	31.30 d	30.64 d	30.64 D	36.70
T_5 - (8 : 35)	27.75 c	29.02 e	29.25 d	29.25 D	39.57

Values followed by same letters are statistically similar at 5% of probability

Taramira

Salinity and sodicity also adversely affected the growth of Taramira, pooled data in (Table 6) showed that maximum biomass yield (38.43 g) of Taramira was produced in control (non- saline) and lowest biomass of 20.81 g was observed at higher level of salinity/sodicity (8 dSm^{-1}+ 35 SAR). Compared with control, biomass decreased by 24.46%, 30.00%, 35.70% and 45.84% respectively in T_2, T_3, T_4 and T_5.

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Table 6: Effect of EC_e / SAR on Taramira biomass (g pot^{-1}).

Treatments	1st year	2nd year	3rd year	Mean	% Decrease over control
T_1 - Control	35.12 a	38.77 a	41.41 a	38.43 A	_
T_2 - (6 : 25)	27.86 b	28.83 b	30.41 b	29.03 B	24.46
T_3 - (6 : 35)	26.81 b	27.20 b	26.70 c	26.90 BC	30.00
T_4 - (8: 25)	24.06 bc	24.63 c	25.46 c	24.71 C	35.70
T_5 - (8 : 35)	19.30 c	20.56 d	22.57 d	20.81 D	45.84

Values followed by same letters are statistically similar at 5% of probability

Coriander

An inhibitory effect of salt stress was observed among the different treatments of salinity/sodicity on biomass yield of Coriander (Table 7). Control i.e., non-saline treatment produced the maximum biomass yield (33.50 g) which diminished linearly under dual stress of salinity and sodicity and lowest biomass (24.06 g) was noted at higher level of EC_e and SAR (T_5). Percent decrease over control was observed by 12.41%, 20.83%, 22.62% and 28.17% respectively in T_2, T_3, T_4 and T_5.

Table 7: Effect of EC_e / SAR on Coriander biomass (g pot^{-1}).

Treatments	1st year	2nd year	3rd year	Mean	% Decrease over control
T_1 - Control	32.56 a	33.33 a	34.63 a	33.50 A	_
T_2 - (6 : 25)	29.25 ab	29.50 b	29.29 b	29.34 B	12.41
T_3 - (6 : 35)	26.82 bc	26.50 c	26.26 c	26.52 C	20.83
T_4 - (8: 25)	26.20 bc	25.38 cd	26.19 c	25.92 C	22.62
T_5 - (8 : 35)	24.41 c	24.25 d	23.52 d	24.06 D	28.17

Values followed by same letters are statistically similar at 5% of probability

White Zeeri

Biomass yield of White Zeeri was also affected significantly with different treatments of EC_e and SAR (Table 8). Expectedly, maximum biomass yield (23.13 g) was observed in control and minimum (11.58 g) in treatment $T_5$with EC_e 8 dSm^{-1}+ SAR 35. When compared with control biomass decreased by 12.19%, 27.84%, 41.54% and 49.93% respectively in T_2, T_3, T_4 and T_5.

Table 8: Effect of EC_e / SAR on White Zeeri biomass (g pot^{-1}).

Treatments	1st year	2nd year	3rd year	Mean	% Decrease over control
T_1 - Control	23.40 a	22.87 a	23.13 a	23.13 A	-
T_2 - (6 : 25)	20.40 b	19.84 b	20.70 b	20.31 B	12.19
T_3 - (6 : 35)	16.64 c	16.21 c	17.23 c	16.69 C	27.84
T_4 - (8: 25)	13.78 d	12.44 d	14.36 d	13.52 D	41.54
T_5 - (8 : 35)	11.74 e	11.54 d	11.46 e	11.58 E	49.93

Values followed by same letters are statistically similar at 5% of probability

Use of medicinal plants as natural substitutes to synthetic medicine is becoming increasingly popular in modern society (Van Wyk and Wink, 2018). These plants need to

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be grown commercially to fulfill the increasing demand of pharmaceutical industry, but environmental stresses like salinity/sodicity are serious threats limiting their production (Qureshi *et al.*, 2005). Therefore, it might be worthwhile to identify potential of medicative plants for salinity tolerance. The morphological appearance of a plant under saline conditions is good enough criteria to determine its tolerance against a particular salt level. Current results clearly demonstrated a negative relationship between the growth of plants and salt stress, because biomass yield of all the tested medicinal plants decreased under dual stress of salinity/sodicity. Biomass yield of medicinal plants diminished linearly with each increment of sodicity and salinity level and maximum reduction was recordedeatEC_e8 dSm^{-1} + SAR 35 which range from 28.17% to 49.93% in Coriander and White Zeeri respectively. While T_2 (6 dSm^{-1} + 25 SAR) gave better results among all the saline-sodic treatments and showed minimum reduction in biomass yield over control ranging from 9.64% in Niazboo to 24.46% in Taramira. This decreased biomass yield under saline conditions is a physiological response of the plant against salt stress (Garrido *et al.*, 2014). Because salinity disturb different physiological and biochemical processes resulting in poor germination, irregular crop stands and ultimately lower the final yield (Munns and Gilliham, 2015). Elevated level of salinity also provokes a series of morphological changes like chlorosis, necrosis and reduced shoot length (Amjad *et al.*, 2015).

Salinity primarily disturbs the plant osmotic balance in which plant roots are unable to absorb water from growing media (Abbas *et al.*, 2021) this creates a water stress in plants as a results plant growth is reduced because shoot and root elongation depend on maintaining osmatic balancing and turgor pressure (Flowers *et al.*, 2010; Abbas *et al.*, 2018). Results of current study are re-inforced by the earlier findings of different researchers in which they stated the salinity stress-mediated growth reduction in *Majorana hortensis* (Shalan *et al.*, 2006), *Foeniculum vulgare* (Abd El-Wahab, 2006), pennyroyal and peppermint (Aziz *et al.*, 2008). This decrease in biomass can be explained by accumulation of toxic Na^+in the leaves (Munns, 2002) that has an inhibitory effect on cell division, cell wall extensibility and leaf elongation (Hu and Schmidhalter, 2004; Hniličková *et al.*, 2019) thus reducing the plant growth and development. Excessive toxic concentration of Na^+ damage the cells of transpiring leaves, (Munns *et al.*, 2006) disturb the plant metabolism, inhibited synthesis of protein and enzymatic process (Munns and Tester, 2008; Iftikhar *et al.*, 2022) and lowered the net photosynthetic rate (Chrysargyris *et al.*, 2021). Salinity stressed stunted plant growth was also reported in marjoram, basil, chamomile, black cumin and fenugreek (Baatour *et al.*, 2010; Ramin, 2006; Ali *et al.*, 2007; Ahmed *et al.*, 2015; Saberali and Moradi, 2019)).

Plants grown in saline environment show high content of Na^+ and Cl^- which antagonizes the uptake of other essential plant nutrients like NO_3^-, Ca, K, Mg and Mn (Grattan and Grieve, 1998; Maathuis, 2006; Lao *et al.*, 2013). This imbalances in plant-available nutrients under salinity cum sodicity conditions perform a significant role in growth reduction (Qadir and Schubert, 2002). According to Maathuis and Sanders (1996) potassium is required for opening and closing of stomata, maintaining osmotic pressure within cell which is used to drive cellular and leaf expansion, so this potassium

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deficiency causes chlorosis, necrosis and poor plant growth (Gopal *et al.*, 2003). Tabatabaie and Nazari (2007) also reported a significant biomass yield reduction in lemon verbena and peppermint under salt stress. Likewise Ghavami and Ramin (2008) reported that growth characteristics of milk thistle were significantly reduced at salt stress of 9 dS m^{-1}. According to Razmjoo *et al.* (2008), number of branches, plant height and fresh weight of flowers in *Matricaria chamomilla* were significantly reduced under salt stress. Similarly, a reduction of 21.5% in biomass yield of geranium was reported at salinity level of 75 mM NaCl (Chrysargyris *et al.*, 2021).

Reduced photosynthetic activity of stressed plants is another important factor for stunted plant growth (Zhao *et al.*, 2007). Toxic ionic concentration interferes the activity of photosynthetic enzymes, decreases chlorophyll contents (Taffouo *et al.*, 2010) and synthesis of the protein (Yang *et al.*, 2002) so ultimately the plant growth is reduced. Similarly many researchers have reported the strong implication of reduced plant growth under saline conditions in different medicinal plants like cumin (Nabizadeh, 2002), sweet fennel (Zaki *et al.*, 2009); basil (Said-Al Ahl and Mahmoud, 2010) and *Mentha pulegium* (Oueslati *et al.*, 2010).

Conflict of Interest

The authors have not declared any conflict of interest.

Authors Contributions

All the authors contributed equally in the manuscript.

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