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Echinochloa Colona (L.) Link, A Promising Species to Cultivate Salt Affected Soils in Arid Lands

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Abstract: This study focused on the evaluation of wild herb species, *Echinochloa colona*, for its cultivation in the salt affected soil in Egypt as fodder. The effect of salinity on *E. colona* growth in the field and under laboratory conditions was studied. Field observations showed that *E. colna* grow very well in salt affected soil with high presence than other species known with their salt tolerance. Seed germination did not significantly affected at 75 mM NaCl and reduced only by about 25 % at 100 mM NaCl. 50 % reduction in shoot growth obtained at 150 mM. Root growth exhibited stimulation under salinity levels till 150 mM. The study recommends the cultivation of *E. colona* in salt affected soil as a fodder.

Key words: Salt affected · Reclamation · grasses · fodder · Egypt

INTRODUCTION

Salinity is a major environmental and economic problem in the world, increasing year after year especially in arid and semi-arid regions and has created major challenges in production of food crops [1-6].

Egypt lies in the northeastern corner of the African continent between latitudes 22° and 32° N and longitudes 25° and 36° E with a total area of about 1 million km^2 (Fig. 1) and consider one of the countries suffering from severe salinity problems. For example, 33% of the cultivated land which comprises only 3 % of total land area of Egypt is already salinized [7]. This salinization is mainly due to low precipitation, high temperature, poor drainage system (with 98% of the cultivated land under irrigated, rising water table less than one meter below the soil surface [8]. The importance of cultivated land in Egypt appears from the fact that Egyptian economy has traditionally relied heavily on the agriculture sector as a source of growth and support for the non-agricultural sector.

Reclamation of salty affected lands is a costly problem. The alternative approach to the economic utilization of these lands is the use of native species to reclaim the saline areas would not only be economically beneficial but would be also ecologically relevant. There is a need to identify promising species, which are both productive and provide good quality feed, to vegetate large areas of the salt- affected lands in Egypt. Poaceae has more than 7,500 species inhabiting the earth and have a greater range of Chlorideimatic adaptation than any other plant family [9, 10]. Therefore, it is expecting that grasses show an extreme range in salinity tolerance, from salt-sensitive (ex. meadow foxtail *Alopecurus pratensis* L.), to salt-tolerant halophytic (ex. saltgrass *Distichlis spicata* L.) [11, 12]. The grass genus *Echinochloa* P. Beauv. *(Poaceae)* includes two domesticated species, the Japanese barnyard millet *(Echinochloa utilis)* and the Indian or sawa millet (E. *frumentacea*) [13]. The domesticated species are often cultivated for grain and forage in places where rice does not grow well. In addition to the two domesticated -+-species, *Echinochloa* includes about 20-30 annual and perennial wild species distributed widely in the warmer parts of the world [14]. *Echinochloa colona* (L.) Link (jungle rice), is a common weed in Egypt, associated with summer crops, mainly with rice, irrigated canal, moist ground, gardens and orchards [15-17]. It is observed that *E. colona* grow well in salty affected soils in Egypt and historically have been used as fodder for grazing livestock [15]. It also recorded as a cultivated fodder in other countries [17, 18]. The aim of the present study is the determination of the effect of salinity on *E. colona* under field and Laboratory conditions for its evaluation to cultivate it in the huge area of salt affected soil in Egypt as fodder.

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MATERIALS AND METHODS

Field Studies: Study area: Four sites were selected, 2 salt affected soils and 2 healthy soils, distributed in 2 locations within Beni Suef Governorate, Egypt (Fig. 1). They were selected to represent habitats of *E. colona* with the same crops and soil properties (differ mainly in salt content). Samples were collected during two successive growing seasons; summer 2005 and summer 2006. For the vegetation surveys a simplified method of species presence for the two different habitats was calculated, the mean number of species/stand (species richness) and the species turnover (total number of species/ mean species richness) [19] of each salt affected and healthy soil were calculated. The total number of stands sampled was 35: 15 for salt affected soils and 20 for healthy one; each stand consists of 20 (0.5 m X 0.5 m) quadrates. Sampling stands were selected to cover the different floristic composition. Specimens were identified with the help of the local standard Floras [20, 21]. In each of the 35 stands *E. colona* biomass was harvested in three randomly distributed quadrates, when the crop was mature and oven dried to constant weight at 70°C. Soil samples were collected from each of the two habitats at two different depths, 1-5 cm and 20 cm depth.

Laboratory experiments: Seed germination: Healthy uniform seeds of *E. colona* were collected from the field, Beni Suef Governorate, Egypt at maturity (August 2005). For the germinability tests, the seeds were sown in sterilized Petri dishes on a double layer of filter paper moistened with 5 ml of the treatment solution. The treatment solutions for salinity test were distilled water (control), 75 mM, 100 mM, 150 mM and 200 mM NaCl.

Three replicates of 50 seeds were used in each treatment; germination was under conditions of natural light and room temperature (during May 2006, with average temperature 26.1°C (see Appendix). Seeds were considered to be germinated after the radicle emerged from the testa. Germination speed was also calculated. It is a very important parameter from the ecological point of view [22]. It may be calculated by different ways, however, the Vigour Value (V) has been chosen for the present study. It can be calculated using the following formula [23]: V= (a/1 + b/2 + c/3 +d/4 +....+ x/n) x 100/S, Where a, b, c....., respectively, represent the number of seeds which germinated after 1, 2, 3 days of imbibitions, x is the number after n days and S is the total number of germinated seeds. The experiment was replicated three times and extended for 15 days.

Pot experiment: Seedlings were transplanted into pots (15 cm diameter) filled with sterilized soils and watered by the mineral nutrient solution twice a week. The mineral solution contained the following, in mmolar / liter, $CaCl_2.2H_2O$, 1.0; $MgSO_4.7H_2O$, 1.65; K_2SO_4, 0.50 and $NaH_2PO_4.2H_2O$ 0.65; and micronutrient (in micromolar/litre) $FeSO_4.7H_2O$, 27.0; $MnCl_2.4H_2O$, 1.13; $CuSO_4.5H_2O$ 0.08; $ZnSO_4.7H_2O$, 0.19; $NaMoO_4.2H_2O$, 0.05 and H_3BO_3, 5.77, the pH of the nutrient solution was adjusted to 7.0. Pots were arranged in a complete randomized design in the greenhouse. The average mean temperatures were 26.1°C. Daytime was about 12 hrs, no artificial illumination (light) was supplied.

The following concentrations of NaCl: (0, 75, 100, 150 and 200 mM) were applied (50 ml) twice a week to the soil. The salt treatments continued for three weeks. The pots were flushed thoroughly with distilled water once a week to avoid salt accumulation in root zone. As the plant grew in size, the volume of liquid was increased and the differences between salt concentrations were kept constant.

Growth measurement: Root and shoot lengths were measured as extension (in cm) from the base of the cup to the farthest extending point, then washed with deionized water and dried at 70°C for 24 h to determine their dry weight and kept in glass bottles till chemical analysis. Root to shoot ratio was calculated based on root dry weight and cumulative shoot dry weight.

Chemical analysis of plant and soil: The N content of *E. colona* was determined in dry matter (shoot system) by using an elemental analyzer (Perkin-Elmer ICP 400). The concentration of the minerals Na^+, K^+, Ca^{2+} and Mg^{2+} in plant material (shoot and root systems) and soil were determined by using atomic absorption spectrophotometer, Perkin 403 [24]. pH and conductivity of the soil samples were determined in a soil/distilled water suspension (1: 5 wt/vol.) by pH and conductivity meters respectively, chlorides by titrating 5 ml of the 1: 5 soil/distilled water extract against 0.01 N silver nitrate solution using potassium chromate (1%) as indicator, carbonates and bicarbonates by titrating 5 ml of the 1.5 soil/distilled water extract against 0.01 N HCl using phenolphthalein and methyl orange as indicators [25].

Statistical analysis: Analysis of variance of data was done on an IBM compatible computer programmed and the least significant differences between the mean values were calculated as recommended by Bailey [26]. Terms were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

Field studies: Table 2 show that soils collected from the salty habitats showed higher concentrations of Na^+ and Cl^- than those of healthy one, by 189 % and 131 % respectively. While K^+, Ca^{2+}, $Mg^{2+}$and soil texture showed no differences. The salinity of salty habitats was 6 fold that of healthy one in the top surface (1 -5 cm depth) and about 3 fold at 20 cm depth. Organic C of healthy soil was about twice that of salt affected soil.

The total number of recorded species was 35: two species (*Spergularia marina (L.)* Griseb and *Chenopodium album* L.) were confined to salt affected soil, 21 species along healthy soil and the other along both. Table 1 shows that *Alhagi graecorum* Bioss. And *Beta vulgaris* L. have higher presence in salt affected soil, while others are restricted to healthy soil such as *Malva parviflora* L., *Cyperus rotundus* Benth., *Amaranthus ascendens* Hornem. and *Convolvulus arvensis* L. The total recorded number of the associated species is low because summer crops in Egypt is usually subjected to regular weeding either mechanically or by using herbicide [27]. Healthy soil has the highest total number of species and species richness which can be related to prevailing environmental conditions and the two species, (*Spergularia marina (L.) Griseb* and *Chenopodium album L.*) confined to salt affected soil because of their salt tolerant [28]. The mean dry weight biomass recorded in salt affected soil was more than two folds of that recoded at healthy soil, which can not be taken as an indicator of its better growth in salt affected soils than healthy one because of weed control by farmers in the later.

Experimental studies

Effect of salinity on Seed germination: The germination percentage did not significantly affect at 75 mM NaCl, ($P < 0.05$) and reduced by only 25 % at 100 mM NaCl (Fig. 2a). While it recorded 85 % reduction at 150 mM NaCl and completely inhibited at 200 mM NaCl. Germination speed (vigour value) increased, not statistically significant, at 75 and 100 mM and reduced by about 19 % at 150 mM NaCl. Because of early stages of plant growth are particularly sensitive to substrate salinity [29,30-33], seed germination represent a bottleneck in the species life cycle, restricting the range of possible micro sites that the species can occupy in its typical habitat. Khan and Ungar [34] recorded that grasses usually are not very highly tolerant of salinity at germination. The

Table 1: Percent presence of the species (that have > 10 % in at least one stand at salt affected and healthy soil), Species richness, Species turnover and biomass of *E. colona*

	Salt affected soil	Healthy soil
Echinochloa colona (L.) Link	60.0	53.3
Spergularia marina (L.) Griseb.	50.0	0.0
Beta vulgaris L.	40.0	19.8
Cynodon dactylon (L.) Pers.	40.0	33.3
Alhagi graecorum Boiss.	30.0	1.0
Echinochloa crusgalli (L.) P. Beauv.	30.0	33.3
Lolium perenne L.	30.0	26.6
Chenopodium album L.	20.0	0.0
Polypogon monspeiensis (L.) Desf.	20.0	13.3
Rumex dentatus L.	20.0	46.6
Brassica nigra (L.) koch	10.0	6.6
C. murale L.	10.0	1.0
Convolvolus arvensis L.	10.0	60.0
Portulaca oleraceae L.	10.0	46.6
Amaranthus lividus L.	0.0	40.0
Cyperus rotundus L.	0.0	26.6
Corchorus olitorius L.	0.0	20.0
Sonchous oleraceous L.	0.0	0.0
Solanum nigrum L.	0.0	66.6
Euphorbia acalyphoides Boiss.	0.0	33.3
Cichorium endivia L.	0.0	13.3
Emex spinosa (L.) Campd.	0.0	6.6
Euphorbia peplis L.	0.0	60.0
Malva parviflora L.	0.0	53.3
Xanthium strumarum L.	0.0	13.3
Xanthium stumarium L.	0.0	6.6
Total Species	15.0	31.0
Species richness	5.3	8.2
Species turnover	2.8	3.7
Maximum biomass of *E. colona* gm/m^2 dry weight	201.5±25.3*	85.2±13.2

Species arranged according to their presence in salt affected soil. * Mean±S.E

Table 2: Soil characters for two different habitats where *E. colona* was found.

	Salt affected soil		Healthy soil	
	1-5 cm depth	20 cm depth	1-5 cm depth	20 cm depth
E.C. m mohs/cm	26.0±1.15*	11.23±1.23	4.2±0.11	3.99± 1.01
HCO_3 %	4.28±0.11	3.85±0.85	4.56±0.17	4.32±1.52
SO_4 %	91.07±1.15	75.05±2.13	21.93±0.17	20.65±2.41
Cl^- %	243.04±1.73	185.12±1.45	17.64±0.17	15.85±2.01
Ca^{++} mg/kg	81.32±1.15	80.21±3.15	19.90±0.72	17.26±2.01
Mg^{++} mg/kg	29.96±0.11	23.014±3.56	6.41±0.11	6.23±1.22
Na^+ mg/kg	224.77±1.15	129.09±8.12	16.17±0.05	14.36±1.31
K^+ mg/kg	2.34±0.05	2.99±0.02	1.65±0.05	3.1±0.97
pH	7.8±0.12	7.56±1.62	7.31±1.85	7.07±1.42
Organic C %	0.95±0.06	1.01±0.51	1.82±0.078	1.95±0.75
Sand %	38.5±2.30	39.2±3.40	37.1±3.21	38.5±4.10
Silt %	28.9±1.5	29.5±2.41	29.2±3.12	28.1±4.30
Clay %	32.6±2.30	32.7±4.12	33.7±2.45	23.4±3.12
Soil texture	Clay loamy	Clay loamy	Clay loamy	Clay loamy

* Mean (four replicates ± S.E.)

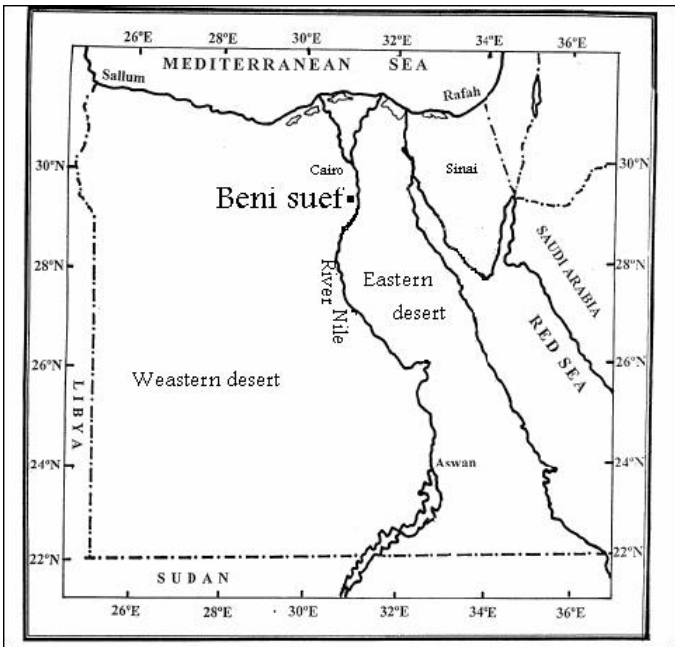

Fig.1: Location map showing the study area

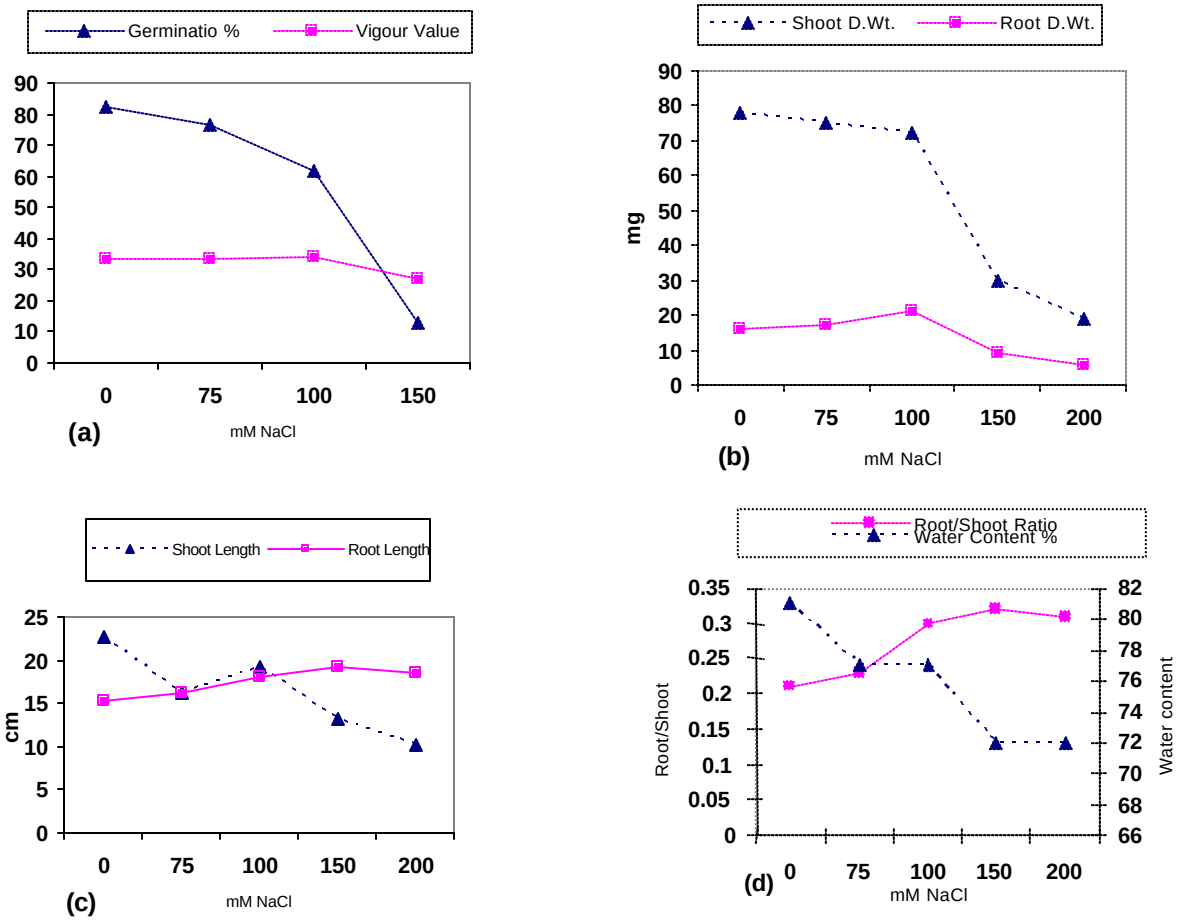

Fig. 2: Effect of salinity on seed germination and some growth parameters of *E. colona* (a) Germination speed and vigour value (b) Shoot and root dry weights (gm) (c) Shoot and root lengths (cm) (d) Root/ shoot ratio and water content %

maximum salt tolerance usually ranges between 250 and 350 mmol/L NaCl [35, 36]. *Spartina alterniflora* is an exception; it can germinate at concentrations higher than 400 mmol/L NaCl [37]. The studied species showed good germination percent at 75 mM and 100 mM NaCl (about 7 and 9 dS/m EC).

Effect of salinity on Growth: Growth parameters, such as shoot growth, root mass and root length, have been reported to be excellent criteria to determine salinity tolerance among turf grasses [38-41].

Figure 2b shows that control plants had a higher shoot biomass than those of the other salinity levels, but did not show a significantly difference between control and those treated by 75 and 100 mM NaCl ($P < 0.05$), while 50 % and 75 % reduction was obtained at 150 and 200 mM NaCl, respectively. Root dry weight exhibited slightly increases at 75 and 100 mM and then was decreased as salinity increased further (Fig. 2b). Also root length showed an increase at salinity by 6%, 19% and 26% at 75, 100 and 150 mM NaCl, respectively and recorded 29% reduction at 200 mM NaCl (Fig. 2c). Root growth stimulation and the extensive root system of *E. colona* in the present studies at moderate salinity may be adaptive mechanisms enabling this plant to maintain water balance [42, 43]. Maas and Hoffman [44] stated that root growth stimulation (increased root mass, rooting depth, or both) in salt tolerant grasses is typically a more common, accentuated response to moderate salinity stress than shoot growth stimulation. Root growth stimulation under saline conditions has been observed in many grasses, such as bermudagrass [45], Augustine grass and seashore paspalum [46], salt marsh grass [47], alkali sacaton [41] and *Distichlis spicata*, saltgrass [48].

There was 29%, 41%, 62% and 56% decrease of shoot length at 75, 100, 150 and 200 mM NaCl respectively. The studied species showed 50% reduction in shoot growth at 150 mM NaCl (about 14 dS/m), showing more tolerance than that recorded by Ashraf *et al.* [18] at 11.2 dS/m, for the same species and more than that recorded by Horst and Taylor [49] by Kentucky bluegrass (50 % reduction at 11 dSm^{-1}). As salinity increased from Zero to 200 mM NaCl root / shoot ratio showed an increase by 9%, 42%, 52% and 47% at 75, 100, 150 and 200 mM NaCl respectively. The increase in root/shoot ratios may be also a salinity tolerance mechanism to counter low external water potential by increasing plant absorptive area [42, 50]. Shoot water content exhibited reduction by only 5 % at 75 and 100 mM NaCl and by 12 % at 150 and 200 mM NaCl (Fig. 2d). Declining shoot water content is commonly observed in grasses under salinity [39, 51, 52]. Growth limitation at high salinity (200 mM NaCl) may be due to depletion of energy that is needed for growth and /or the loss of turgor [53-55].

Effect of salinity on chemical compositions: *E. colona* plants collected from the salt affected field showed more K^+ and Na^+ content in their root system than those of healthy one, by 152% and 200%, respectively. Within the same habitat, Na^+, K^+ and total N exhibited reduction in roots than shoots, by 11%, 48% and 60% in salt affected soil and by 51%, 72% and 70% in healthy soil, respectively (Table 3).

In Pot experiment, in general Na^+ content was significantly increased ($P < 0.05$) with increasing salinity while K exhibited a reduction ranging between 13-17%

Table 3: Chemical composition of root and shoot systems of *E. colona* collected from two different habitats.

	Root system		Shoot system	
	Salt affected soil	Healthy soil	Salt affected soil	Healthy soil
N %	0.60±0.05*	0.57±0.01	1.51±0.05	1.91±0.11
K %	1.37±0.11	0.90±0.08	2.66±0.11	3.28±0.05
Na %	1.06±0.05	0.53±0.17	1.20±0.05	1.10±0.05
Na / K	0.773±0.82	0.588±0.04	0.451±0.01	0.335±0.024
Ca %	0.4±0.03	0.48±0.02	0.56±0.06	0.54±0.01
Mg %	0.64±0.02	0.57±0.05	0.63±0.001	0.42±0.03

* Mean (four replicates ± S.E.)

Table 4: Effect of salinity on chemical composition of *E. colona*

	N %	K %	Na %	Na / K ratio	Ca %	Mg %
Control	2.47 ± 0.05 a	2.05 ± 0.05 a	1.98 ±0.57 a	0.965± 0.01a	0.43±0.04a	0.49±0.02a
75 mM NaCl	2.52 ± 0.05 a	1.78 ± 0.03 b	2.56± 0.05b	3.28 ± 0.09b	0.46± 0.05a	0.63± 0.10a
100 mM NaCl	3.47 ± 0.11 b	1.76 ± 0.05 b	2.95± 0.05b	1.676 ± 1.1c	0.41± 0.10a	0.71± 0.3b
150 mM NaCl	3.31 ± 0.11 b	1.75 ± 0.05 b	3.10± 0.11b	1.77 ± 0.3c	0.51± 0.03a	0.62± 0.09a
200 mM NaCl	2.28 ± 0.09 a	1.70 ± 0.11 b	3.16± 0.17b	1.85 ± 0.02c	0.50± 0.01a	0.56± 0.04a

*Mean (four replicates ± S.E.).

Results with the same letter within column not significantly different and results with different letters are significantly different ($P < 0.05$)

at all salinity levels (Table 4). Nitrogen content exhibited an increased by 2, 40 and 34% at 75, 100 and 150 mM NaCl salinity, while at higher salinity (200 mM) there was 7% reduction. No definite pattern was observed in the content of Ca^{+2} and Mg^{+2} and these ranged between 0.41-0.51 and 0.49-0.71, respectively.

The ion accumulation by the studied species could be a result of osmotic regulation. Osmoregulation under saline conditions might utilize ions from the soil and analyses show that osmotic adjustment via ion uptake is more energy efficient than adjustment through the production of organic solutes [56]. Tester and Davenport [57] stated that higher Na^{+} content in the shoot system of plants collected from salt affected soil than that in their root system because of roots tend to maintain fairly constant levels of NaCl over time and can regulate NaCl levels by export to the soil or to the shoot

CONCLUSIONS

The present study confirm and recommend the ability of *E. colona* to grow in salt affected soil as a fodder in summer season in Egypt especially there is a shortage in forage at this season. The results disagreement with the result obtained by Tomar *et al.* [58] who stated that *E. colona* was very poor performance during initial stages of their experiment (8.5-10 dS/m) and support the finding of Qadir *et al.* [59], who stated that *E. colona* produced a good quantity biomass in salt affected soil.

Appendix: Temperature degrees recorded during the study period in the Meteorological station at Beni Suef.

	2005			2006		
Year	Min.	Max.	Mean	Min.	Max.	Mean
Jan.	6.6	20.9	13.8	6.4	18.9	12.6
Feb.	8.3	22.3	15.2	6.8	20.3	13.5
Mar.	10.2	25.9	18.2	8.5	23.4	15.9
Apr.	13.4	30.2	21.7	15.3	31.6	23.3
May	18.5	35.1	26.8	18.0	34.2	26.1
Jun	20.3	36.3	28.7	20.6	36.8	29.0
Jul.	22.9	37.8	30.3	22.8	39.5	31.2
Aug.	23.5	37.9	30.12	22.3	36.9	29.6
Sep.	21.5	35.8	28.9	20.7	35.4	27.6
Oct.	18.3	31.6	25.2	16.8	30.0	23.6
Nov.	12.4	27.5	14.6	12.9	26.5	19.8
Dec.	7.9	22.4	15.1	8.8	21.1	15.0

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