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RESPONSE OF PEA (*PISUM SATIVUM*) TO SALINITY AND IRRIGATION WATER REGIME

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Abstract

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The aim of this study was to determine the effects of different salinity and irrigation water regime on yield, plant growth and water consumption of pea (*Pisum sativum*). Commercial variety of Rona was used as plant material. Salinity and irrigation water regime experiments were set up in pots as randomized plot experimantel designs with five replications. The first experiment focused on pea responses to irrigation water salinity by irrigating the crops using five different levels of saline water (0.7, 2.0, 3.0, 4.0 and 7.0 dS m^{-1}) with a constant leaching fraction (LF = 0.30). The other experiment was conducted to determine pea responses to irrigation regime.

For the second experiment, four different amounts of water (1.43, 1.0, 0.75 and 0.50 times of required water) were applied to pea plants throughout the study period. It was determined that seed yield of pea decreased 13.3% for per unit increase in soil salinity after 0.6 dS m^{-1} which is the threshold value of pea. As soil salinity increases due to saline water applications, water consumption of pea decreased. Pea yield response factor to irrigation regime and salinity experiments was determined as 2.2 and 2.5, respectively. According to these results, it can be concluded that pea is very sensitive to water stress either due to irrigation regime or salinity. Since water stress and/or salinity causes high yield losses on pea, cultivation of this crop under limited irrigation water and/or saline conditions should not be suggested. In addition, because of sensitivity of pea to excess water, it should not be cultivated on soil with infiltration problem unless this problem is maintained.

Key words: pea, yield, water consumption, irrigation regime, water salinity, soil salinity

Introduction

Pea (*Pisum sativum*) is an important edible leguminous seed crop for human nutrition. Its seeds contain 18-20% dry matter whose 10-12% is carbohydrate and 5-8% is protein (Vural et al., 2000). Pea is used as a fresh vegetable, frozen or canned. According to FAO 2004 data, about 12.2 million tones of

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pea production were achieved in 6.3 million ha agricultural lands of the world with an average yield of 1.930 kg ha^{-1} (Anonymous, 2007). In Turkey, pea production area was 1.568 ha with a total production of 4373 tones and average yield of 2.79 kg ha^{-1} in 2006 (TUIK, 2007).

Pea is a cool-season vegetable crop of mild climate regions. Therefore, it gives higher yield in cold-humid regions compared to warm-dry areas. Its minimum temperature range for germination is between 1-6°C and it can survive in low temperatures up to -5°C. Even though pea can grow in many soils, the best yield can be obtained in clay-loam, deep, productive, moist, slightly acid (pH 6.5-7.0) soils. When the soil is productive and moist, vegetative growth is advanced, on the other hand pea seed yield decreases. In addition, owing to its taproots, pea can use plants nutrients and water from different soil layers and increase organic mater content of soil. As a legume crop, pea is able to fixate 50-150 kg ha^{-1} nitrogen from air (Sehirali, 1988; Akdag, 2001; Ozdemir, 2006).

Pea is sensitive to salinity. Degree of salinity level affects rate of yield losses (Duke, 1981; Maas, 1986). In a study related to salt tolerance of two pea cultivars, Cerda et al. (1982) concluded that one of the cultivar was classified as moderately salt-sensitive and the other as moderately salt-tolerant. Francois and Maas (1994) rated pea crops as moderately salt-sensitive. Steppuhn et al. (2001) resulted that under severe salinity (solution electrical conductivity of 24.9 dS m^{-1}); neither the field peas nor the dry bean produced any grain.

Some changes in photosynthetic activities of crops grown under saline condition are being occurred. As soil salinity increases due to saline water applications, water consumption of pea decreased. Photosynthetic activity decreases leading to reduced plant growth, leaf area, chlorophyll content and chlorophyll fluorescence when plants are grown under saline conditions. This decrease affects crop performance in different growth stages (Jamil et al., 2007).

The aim of this study is to investigate changes on yield, plant growth and plant water consumption of pea grown under different level of salinity and irrigation water stress.

Material and Method

Site description

In order to determine the effects of different salinity and irrigation water regime on yield, plant growth and water consumption of pea, two experiments were carried out in pots at the experimental field of Gaziosmanpasa University. The geographic coordinate of the experimental area is 40° 20' 07" N latitude and 36° 28' 26" E longitude.

Experimental design

In salinity experiments and irrigation regime, irrigation water with different level of electrical conductivities and different amounts, respectively, was used to irrigate the plants grown in pots. The pots used in both experiments were 27 cm in height and 29, and 25 cm in top and bottom diameters, respectively. The pots were located in the experimental area under a polyethylene cover which was about 1.8 m height from the surface for the purpose of eliminating rainfall effect on the experiments.Soil used in the experiments was collected from a nearby field and sieved through a 4 mm screen to remove large particles. An 18.4 kg of air-dried soil was placed in each pot. Some physical and chemical properties of the sandy-loam textured soil used for the experiments were presented in Table 1.

Seeds of pea (Rona cultivar) were sown to each pot on April 7 and harvested on July 5. Until the plants have 3-4 real leaves, they were irrigates with tap water. Fertilizer needs were decided as 20-40 and 40-60 kg ha^{-1} for N and P, respectively (Akcin, 1988). Therefore, 2.0 g diammonium phosphates (DAP) were applied to each pot at the beginning of the experiments.

In salinity experiment, there were five different saline waters as treatments including 0.7 (S_1, tap water as a control treatment), 2.0 (S_2), 3.0 (S_3), 4.0 (S_4) and 7.0 dS m^{-1} (S_5). During preparation of saline waters, sodium adsorption ratios (SAR) were main-

Table 1
Some physical and chemical properties of the experimental soil

Particle size distribution	
Sand, %	64.3
Silt, %	20
Clay, %	15.7
Soil water contents (dry weight basis)	
Saturation, %	38.6
Field capacity, %	21.8
Wilting point, %	5.1
Bulk density, g cm^{-3}	1.49
Electrical conductivity (ECe), dS m^{-1}	0.63
pH (paste)	7.34

tained around 1.0 in order to eliminate the effects of SAR for salinity experiment. To do this, calculated amounts of $CaCl_2$, $MgSO_4$ and NaCl were mixed to prepare irrigation water with desired salinity level for each treatment. Electrical conductivities of waters (ECi) were checked in laboratory and then saline irrigation waters used to irrigate treatments. Saline waters were stored in 100-liter plastic containers as closed throughout the experiment.

For irrigation regime experiment, there were four treatments as irrigation water levels including 1.43 (I_1), 1.0 (I_2), 0.75 (I_3) and 0.50 (I_4) times of the required water to bring the pot soil water content to its field capacity. Tap water (ECi = 0.70dS m^{-1}) was used to irrigate plants for this experiment. The I_1 was exposed to excess, I_2 to complete, I_3, and I_4 treatments to limited water applications. Control treatment of salinity experiment (S_1) was also used as an excess water treatment for irrigation regime experiment (I_1). Both experiments were conducted as randomized plot designs with five replications.

The field capacity weight of each pot was determined before the experiments started. To do this, soil in pots were saturated with tap water and then, soil surface were covered to prevent evaporation. After the drainage ceased, the weight of the each pot was assumed as the field capacity weight (W_{FC}) of that pot. The amounts of irrigation water (IW) that should be applied were calculated by using equation (1) and equation (2) for irrigation water salinity and irrigation regime experiments, respectively:

$$IW = \frac{\frac{W_{FC} - W}{\rho_w}}{1 - LF} \quad (1)$$

$$IW = \frac{(W_{FC} - W)}{\rho_w} \times C_{AW} \quad (2)$$

Where; LF is leaching fraction (as suggested by Ayers and Westcott (1989), a 0.30 for LF was aimed for this experiment), W_{FC} is the pot weight at field capacity (kg), W is the pot weight just before irrigation (kg) and C_{AW} is water application coefficient. Water application coefficients for I_1, I_2, I_3 and I_4 treatments of irrigation water regime experiment are 1.43, 1.0, 0.75 ve 0.50, respectively.

A drain pan was placed underneath each pot and amount of collected drainage water volume was measured for all treatments of salinity experiment and for excess water application treatment (I_1) of irrigation regime experiment. Throughout the experiment, the plants were irrigated at 4- to 7-day intervals, considering the control treatment of the experiments.

Considering the water budget equation, total evapotranspiration for each pot was calculated using the following equation:

$$ET = \frac{(W_b - W_s)}{\rho_w} + (\sum Iw - \Sigma R) \quad (3)$$

Where, W_b and W_s are the pot weights at the beginning and end of the experiments, respectively, Iw and R are amounts of applied and drainage water (liter).

At the end of the experiment, harvested plants from each pot were oven-dried at 70°C to a constant dry weight. For each plant, dry vegetative and pod weight, number of pod and seed, and harvest index value were determined. After experiments terminated, soil samples were taken from each pot. These samples sieved using a 2-mm screen after drying under open air conditions. Saturated soil pastes were prepared for soil samples to determine soil salinity (ECe) by using Jenway EC/pH meter (Richards, 1954; Carter, 2000).

Statistical analysis

Experimental data were analyzed by using SPSS statistical analysis software (SPSS, 2002). General Linear Models (GLM) procedure was used to perform analysis of variance and obtain regression coefficients (R^2) to measure the goodness of fit of linear models for the data. Unless otherwise noted, all statistical tests were performed at 0.05 levels of significance. Duncan's Multiple Range Test was utilized where appropriate for mean separations at 0.05 probability level.

Results

Soil salinity

For salinity experiment, irrigation water having different level of salinity was used with a leaching fraction of 0.30 whereas different amounts of irrigation water having an electrical conductivity of 0.7 dS m^{-1} were used for irrigation regime experiment as treatments. At the end of the experiments, while soil salinity values from saturated paste extracts increased with increasing electrical conductivities of applied irrigation water significantly in salinity experiment, irrigation regime experiment has not a significant effect on soil salinity values. As it was expected, the highest and the lowest ECe values were obtained for S_5 and S_1 treatments, respectively. Considering ECe values, Duncan's Multiple Range Test showed that S_5 treatment was significantly different from the other treatments 0.05 probability level. Even though, similar analysis of variance results can be drawn for soil reaction values (pH) from both experiments, the highest soil pH value was determined for the control treatment (S_1) of salinity experiment. This treatment showed significant differences from soil pH values for S_3, S_4 and S_5 treatments (Figure 1). Due increased level of salinity in applied water among treatments from S_1 to S_5 treatment, significant decreases in soil pH values among treatments in the same order was also expected.

Effects of Soil Salinity and Irrigation Regime on Yield

In saliniy experiment, increased soil salinity due to saline water applications resulted in significant decreases in either number of pods and pod dry weights (Figure 2) or number of seeds and dry seed weights (Figure 3). The highest number of pods and seeds was count for the control treatment but it was statistically different from those values of only S_5 treatment

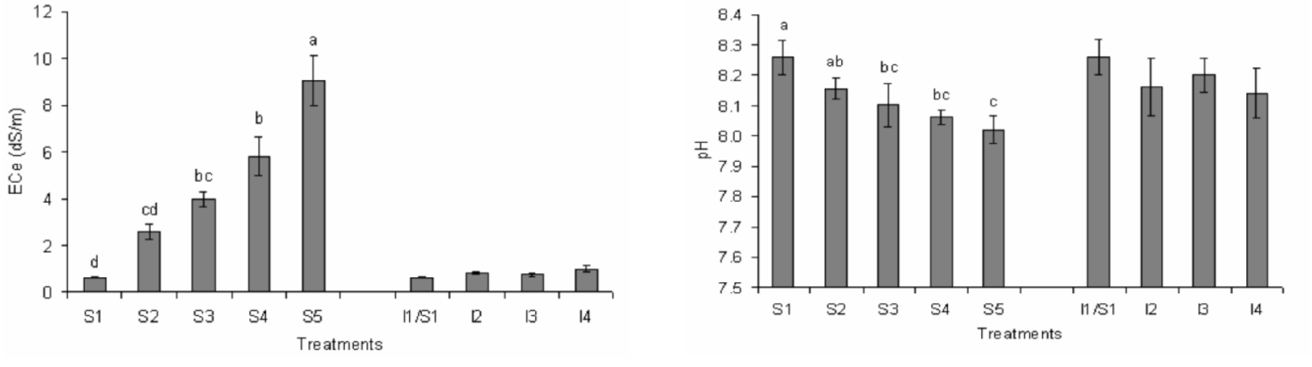

Fig. 1. Soil salinity and pH values from irrigation water salinity and irrigation regime experiments

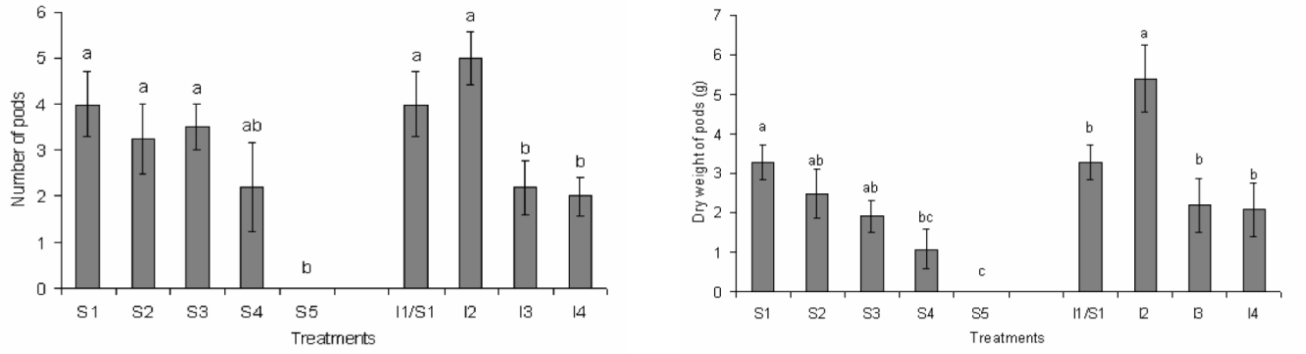

Fig. 2. Number and dry weight of pods from irrigation water salinity and irrigation regime experiments

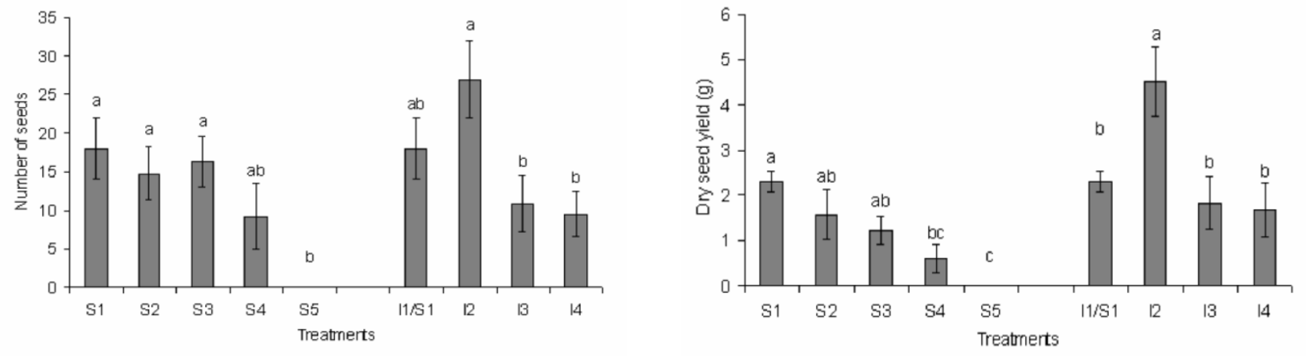

Fig. 3. Number and dry weight of seeds from irrigation water salinity and irrigation regime experiments

in which there was no pod harvested. Similarly the highest pod and dry seed weight was measured for S_1, S_2 and S_3 treatments which are significantly different from those of S_4 and S_5. Compared to S_1 treatment, seed yield losses were 74 and 100% for these treatments, respectively.

Like salinity experiment, treatments of irrigation regime experiment have a significant effect on pod number, pod dry weight (Figure 2), seed number and dry seed weight (Figure 3). Water stress was caused decreases in pod and seed numbers significantly. The highest pod and dry seed weights was measured for I_2 treatment in which soil water content brought to field capacity in each water application. Excess water application has a significanty effect on pod and dry seed weights but not on pod and seed numbers. Compared to I_2 treatment, seed yield losses were 49, 60 and 63% for I_1, I_3 and I_4 treatments, respectively.

Eventhough level of salinity and amount of applied water have a significant effect on seed yield, effect of these factors on vegetative dry weight of pea was statistically insignificant at 0.05 probability level (Figure 4). For irrigation water salinity and irrigation regime experiments dry vegetative weights were ranged from 8.65 - 4.27 and 10.6 – 6.7 g per plant with an average of 7.76 and 8.5 g per plant, respectively.

Harvest index which is a ratio of dry seed yield to total vegetative dry weight was affected significantly from salinity experiment but not from irrigation regime experiment (Figure 4). Harvest indexes were calculated as 21.1, 12.7, 10.7 and 6.4 for S_1, S_2, S_3 and S_4, respectively. Irrəgation water having high salinity concentration led to more development of vegetative parts of the plants.

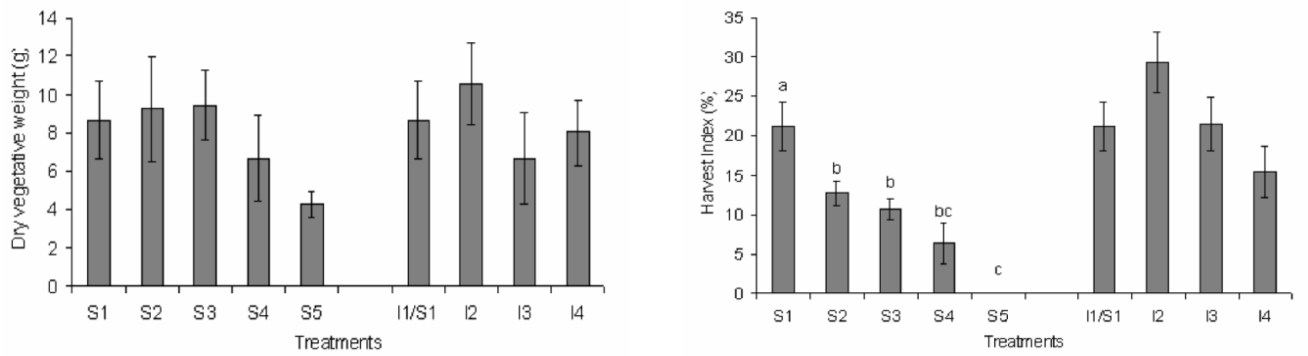

Fig. 4. Dry vegetative weight and harvest index from irrigation water salinity and irrigation regime experiments

Effects of Soil Salinity and Irrigation Regime on Plant Water Consumption

Due to the nature of the experiment, different amounts of water were applied as treatments in irrigation regime experiment. As a result of this, significant differences in plant water consumption were observed among treatments of irrigation regime experiment (Figure 5). Plant water consumptions were 19.0, 18.8, 15.5 and 12.4 liter pot^{-1} for I_1, I_2, I_3 and I_4 treatments, respectively. Compared to I_2 treatment, reletive decreases in I_3 and I_4 treatments were 17.5 and 34%, respectively. In terms of plant water consumption, there was no significant difference among S_1, S_2 and S_3 treatments of the salinity experiment, however, they were signicantly different from those of S_4 and S_5 treatments.

Discussion

The ratio of soil salinity value to salinity level of applied water (ECe / ECi) was calculated as 0.9, 1.3, 1.33, 1.45 and 1.4 for S_1, S_2, S_3, S_4 and S_5 treatments, respectively. Ayers and Westcot (1989) claimed that ECe/ECi ratio wold be around 1.5 for a leaching fraction of 0.15-0.20. In salinity experiment, eventhough a LF of 0.30 was aimed, this value ranged from 0.34 to 0.37 for the treatments. Therefore, ECe/ECi values lover than 1.5 for higher leaching fraction values were expected. As it was aimed, plants were exposed to different level of soil salinity values due to application of irrigation water with different salinity levels.

In salinity experiments, it is necessary to apply irrigation water with a certain leching fraction value in order to obtain differences among treatments and similar conditions at the field. Water application efficiency shows differences depend on irrigation method. Even in drip irrigation method that has one of the highest irrigation efficiency among other methods, it is expected that water application efficiency is between 80-90% (Evsahibioglu and Unlukara, 2003). In other word, by considering 10-20% water loss, excess water application is realized in order to bring soil water content of the rootzone to the field capacity. This excess water causes some leaching in the plant rootzone. Irrigation methods with low irrigation effieciencies causes more leaching. Ayers and Westcot (1989) presented salinity tolerance values of plants considering a leaching fraction of 0.15-0.20.

Ozturk (2002) conducted a study to determine eggplant responses to irrigation water having 0.26 (control) and 5.0 dS m^{-1} (saline water) of electrical conductivities without leaching. At the end of the experiment, he determined that soil salinities were 4.2 dS m^{-1} for control treatment application in all period, 13.9-27.2 dS m^{-1} for saline water application in one-period, 25.0-25.4 dS m^{-1} for saline water application in two-period and 30.0 dS m^{-1} for saline water application in three-period. Considering these results Ozturk (2002) concluded that soil salinities can reach very

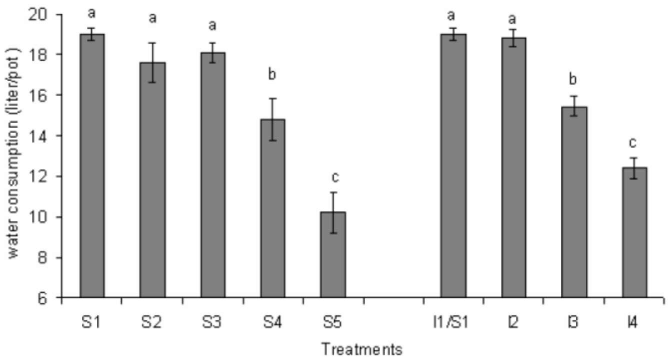

Fig. 5. Effects of soil salinity and irrigation regime on plant water consumption

high values and affect plant growth negatively. This study clearly shows importance of leaching in salinity studies.

On the other hand, investigation of Figure 3 clearly showed that excess water application for leaching purposes negatively affected seed yield of pea. Dry seed yield from I_1 and I_2 treatments were 2.31 and 4.52 g plant^{-1}, respectively. English et al. (1992) concluded that reductions in water applications may have a favorable effect on yields by reducing the incidence of disease, improving the storage and handling properties of a crop, minimizing the leaching of fertilizers from the root zone, and improving aeration of the soil.

Salt tolerance model developed by Maas and Hoffman (1977) was commonly used to express salt tolorence of the crops. According to the model, plants tolerate or stand soil salinity until a threshold value and then a linear yield reduction occur for per unit increase in soil salinity. Salt tolerance models for vegetative and seed dry yields of pea were presented in Figure 6. As shown in Figure 6, up to an ECe value of 4.0 dS m^{-1}, there was no decrease in vegetative dry yield but beyond this value a 9.8% reduction was observed for per unit increase in soil salinity. Also it is clear from Figure 4 that no decrease in vegetative dry yield was observed up to T_3 treatment which has an ECe value of 3.97 dS m^{-1}. According to the model, pea can survive up to soil salinity value of 14 dS m^{-1}.

Compared to vegetative dry yield, seed yield of pea is more sensitive to salinity (Figure 6). A Threshold soil salinity value of 0.6 dS m^{-1} with a slope value of %13.3 was calculated for seed yield of pea. According to the model, pea cannot produce any seed around an ECe value of 8.0 dS m^{-1}. Likewise, according to the salinity experiment, no seed yield was obtained from T5 treatment which has an ECe value of 9.0 dS m^{-1}.

Plant parts can give different responses to salinity. Threshold values of 3.48 and 4.24 dS m^{-1} with slope

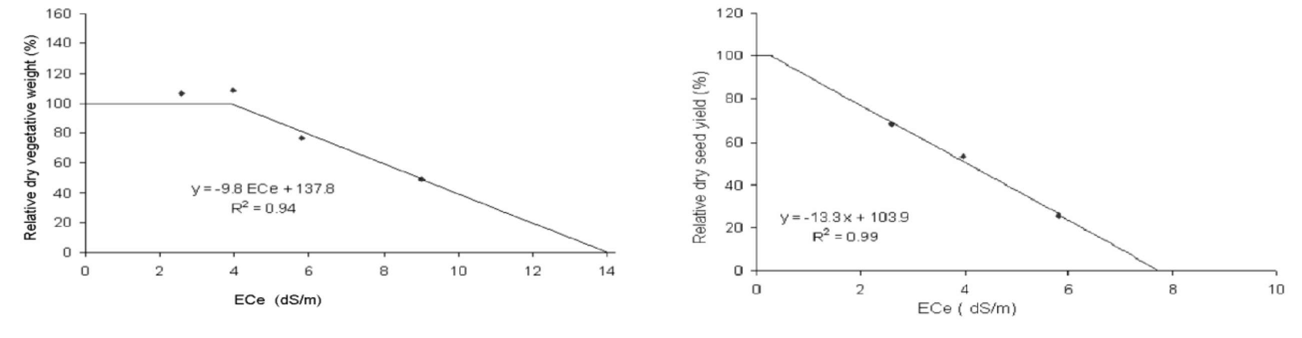

Fig. 6. Salinity tolerance models for vegetative and seed dry yields of pea

values of 4.2 and 7% were reported for fruit yield and vegetative dry weight, respectively of okra by Unlukara et al. (2008). In terms of evaluating salinity tolerance, therefore, it is necessary to consider the production purpose of the plant.

Rhoades et al. (1992) stated that excess salinity within the plant root zone has a deleterious effect on plant growth which is manifested as nearly equivalent reductions in the transpiration and growth rates. This effect is mainly related to electrolyte concentration and is largely independent of specific solute composition. They also claimed that the hypothesis that best seems to fit observation is that excessive salinity reduces plant growth mainly because it increases the energy that must be expanded to acquire water from the soil of the rootzone and to make the biochemical adjustments necessary to survive under stress. In this study, pod and seed yields of cowpea were negatively affected from salinity that also caused decrease in ET. This situation was also caused differences in water use efficiency which shows pod and seed yields produced for per unit of consumed water (Figure 2). Even though there was not important decrease in yield up to S_3 treatment, decreased ET caused increases in water use efficiencies.

However, in extreme salinity levels, water use efficiencies were decreased in important degrees. In irrigation regime experiment, water use efficiency showed a clear difference in excess water application treatment. This energy is diverted from the process which leads to growt and yield. As it can be seen in Figure 7, plant water consumption decreased linearly with increasing soil salinity. This decreasing effect of salinity on plant water consumption should be considered and excess irrigation water application should be prevented. This will provide that drainage has markedly decreased and as a result, saline water rich in plant nutrients and hazardous to environment will be reduced. For this reason plant water consumption should be adjusted with stress coeffient (Allen et al., 1998). To adjust evapotranspiration for pea due to irrigation water salinity, following equation offered by Allen et al. (1998) can be used;

$$ET_{adj} = K_s \,.K_c \,.ET_c = K_s \,.\, ET_m \qquad (4)$$

Where; $K_c.ET_c$ (or ET_m) is the evapotranspiration observed in the control treatment, K_s are stress coefficient. To determine K_s coefficient, ET_{adj} / ET_m for saline treatments were found and plotted against soil salinity values (Figure 7). A linear relationship was obtained between ET_{adj} / ET_m and EC_e. From this relationship, the following equation for K_s coefficient obtained for pea:

$$K_s = 1.07 - 0.056\,(EC_e) \qquad (5)$$

Under optimum soil moisture conditions, plants are not exposed to water stress and evapotranspiration reaches to its maximum level, thus, maximum yield can be obtained. In other case, if irrigation practices are not done on time and at the required level, plants start to struggle with water stress caused a decrease in evapotranspiration and yield. Steward and Hagan

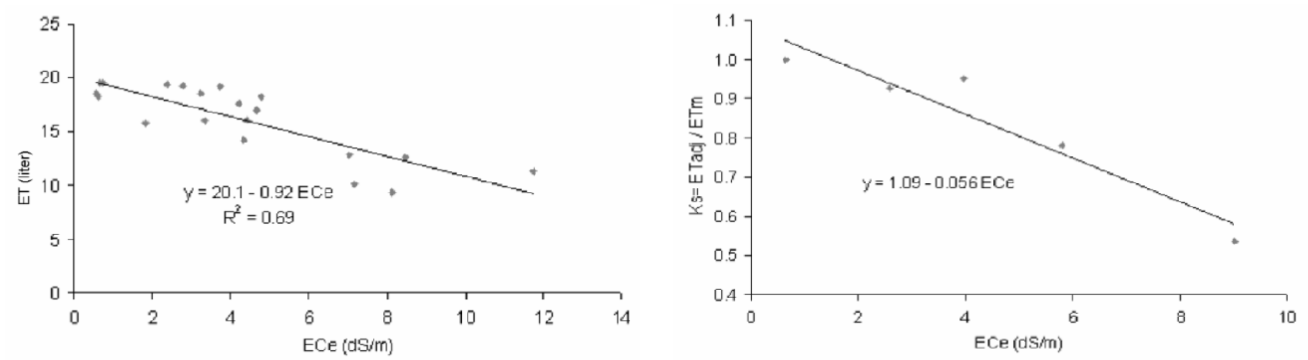

Fig. 7. Effects of soil salinity on evapotranspiration of pea and the stress coefficient

$$\frac{Y_m - Y_a}{Y_m} = K_y \frac{ET_m - ET_a}{ET_m} \; ; \quad \frac{\Delta Y}{Y_m} = K_y \frac{\Delta ET}{ET_m} \qquad (6)$$

(1973) formulated yield decrease for per unit decrease in ET as yield response factor:

Where; Y_a and ET_a are actual crop yield and evapotranspiration, respectively, under deficit irrigation conditions; Y_m and ET_m are maximum crop yield and evapotranspiration under non deficit water conditions; and K_y is the crop yield response coefficient.

Yield response factor (K_y) has been used to evaluate plant tolerance to water stress (Doorenbos and Kassam, 1986). For $K_y > 1$, plant is sensitive and $K_y < 1$, plant is tolerant to water stress. From I_2 treatment of irrigation regime experiment, if the yield value as Y_m and evapotranspiration as ET_m is used in equation 6, yield response factors for seed yield of pea can be obtained as 2.2 (Figure 8a). According to this result, pea is very sensitive to water stress in terms of seed yield.

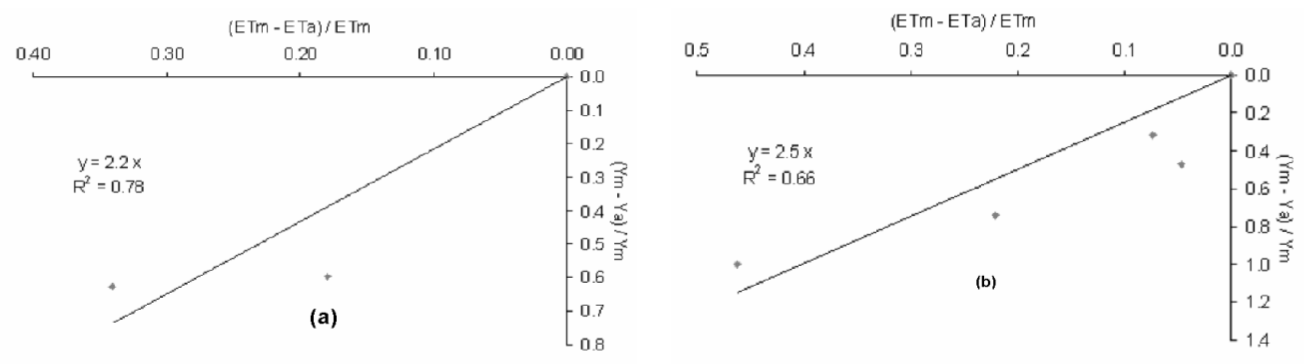

Fig. 8. Relationship between relative ET and relative seed dry yield loss for water stress (a) and for salinity (b)

Plant water uptake is difficult either under saline conditions because of decreasing osmotic potential of soil. Katerji et al. (1998) applied equation 6 for maize, sunflower, potatoes and soybean grown under saline conditions. They resulted that the yield estimation for maize and sunflower was quite accurate, for potatoes somewhat less but unsatisfactory for soybean. In this study, results from salinity experiement were applied to equation 6 (Figure 8b) and yield response factors for seed yield of pea was obtained as 2.5 for salinity experiment. Although different forces affect on plant water uptake under salinity and irrigation regime conditions, a very close K_y coefficients were obtained for salinity and irrigation regime.

According to these results, since water stress and/or salinity causes high yield losses on pea, cultivation of this crop under limited irrigation water and/or saline conditions should not be suggested. In addition, because of sensitivity of pea to excess water, it should not be cultivated on soil with infiltration problem unless this problem is maintained.

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