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Full Length Research Paper

Effect of salt stress on growth, gas exchange attributes and chlorophyll contents of pea (*Pisum sativum*)

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Ten pea (*Pisum sativum*) genotypes (Samarina Zard, Euro, Early Green, Climax, 2001-20, Meteor, Olympia, 9200-1, 9800-5 and PF-400) were used to study the effects of salt stress on the growth, photosynthesis rate, stomatal conductance, transpiration rate and chlorophyll contents. Pea seeds of different genotypes were grown in pots having fine sand as growth medium. After 30 days of germination, the plants were subjected to salt stress under 0, 25, 50 and 75 m*M* NaCl. At the end of the experiment, the plant growth was significantly decreased with increasing salinity. After one week of salt application, photosynthesis rate, stomatal conductance, transpiration rate, and chlorophyll contents of the plant were remarkably decreased with increasing salinity in all the genotypes. However, the Na ions accumulation was increased with increasing salt stress, which changed the Na:K ratio, and it seems to affect the bioenergetic processes of photosynthesis. Among different cultivars, Climax and 9800-5 were found to be salt tolerant whereas both 2001-20 and Euro showed salinity sensitive behaviour. Tolerant genotypes (Climax and 9800-5) were successful in maintaining high plant dry matter, less concentrations of leaf Na, while high concentration of leaf phosphorus and potassium contents under the saline environment.

Key words: Pea, photosynthesis, stomatal conductance, transpiration, chlorophyll.

INTRODUCTION

Plants exhibit various adaptive strategies in response to different abiotic stresses such as salinity, drought, cold and heat, which ultimately affect the plant growth and productivity (Allakhverdiev et al., 2000). Among these stresses, salinity is on the top, which limits the plant growth and productivity (Munns, 2002). It is a major abiotic stress in arid, semi-arid regions and irrigation areas. Approximately 7% of the world's land, 20% of the world's cultivated land (Zhu, 2001) and nearly half of the irrigated land is salt-affected (Rhoades and Loveday, 1990; Szabolcs, 1994). Salinity limits the growth and production by affecting physiological processes, including modification of ion balance, water status, mineral nutrition, stomatal behaviour and photosynthetic efficiency (Munns, 1993). Most plants are salt sensitive with either a relatively low salt tolerance or severely inhibitory growth at low levels. The salt tolerance potential varies from genotype to genotype and species to species within the plant kingdom (Moisender et al., 2002; El-Sheekh and Omer, 2002). Salt stress affects plant physiology at both whole plant and cellular levels through osmotic and ionic stress (Murphy et al., 2003). High concentrations of salts in the

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root zone decrease soil water potential and the availability of water (Lloyd et al., 1989). This deficiency in available water under saline conditions causes dehydration at cellular level and ultimately osmotic stress occurs. The excessive amounts of toxic ions like Na^+ and Cl^- create an ionic imbalance by reducing the uptake of beneficial ions such as K^+, Ca^{2+}, and Mn^{2+} (Hasegawa et al., 2000). The higher ratios of toxic salts in leaf apoplasm lead to dehydration, turgor loss and degradation of leaf tissues (Marschner, 1995). Salt stress has various effects on plant physiological processes such as increased respiration rate and ion toxicity, changes in plant growth, mineral distribution, membrane instability due to the calcium and potassium displacement by sodium (Grattan and Grieve, 1992) membrane permeability (Gupta et al., 2002) and decreased efficiency of photosynthetic apparatus (Ashraf and Shahbaz, 2003; Kao et al., 2003; Sayed, 2003). Among all the physiological processes salinity significantly had an inhibiting influence on the photosynthetic activity. Reduced photosynthesis under salinity is not only attributed to stomatal closure leading to a reduction of intercellular CO_2 concentration, but also to non-stomatal factors like reduction in green pigments and leaf area. It is also depicted from literature that salt affects photosynthetic enzymes, chlorophylls and ionic contents (Misra et al., 1997). Pea was selected for this experiment because it is very important commercial vegetable and its production is limited by irrigation quality. Basically it is a salt-sensitive plant (Najafi et al., 2007). Pea plant at earlier growth stages is more sensitive to salinity (Cerda et al., 1995), which affects the water relations and nutritional status of plant. The disturbance in nutritional status of plant by salt stress creates the ionic stress. This ionic stress will reduce the leaf expansion which ultimately leads to reduction in chlorophyll content and reduced photosynthetic area. During long term exposure to salinity, ionic stress causes the premature senescence of adult leaves and thus reduction in photosynthetic rate (Cramer and Nowak, 1992). Salinity changes photosynthetic parameters, including osmotic and water potential, transpiration rate, leaf temperature and relative leaf water content. Pea (*Pisum sativum*) is very vital winter vegetable because it is enriched with proteins, minerals and various vitamins. Due to the excessive use of the brackish underground water coupled with excessive fertilization, the pea growing areas are subjecting to the salinity. This salinity not only limits the pea yield but also deteriorate its quality. So, there is a dire need to investigate the toxic effects of salinity on pea and find out the ways, which can minimize the toxic effects of salinity on pea yield and quality. The breeding for salt tolerance is also an approach but it is quite lengthy and laborious. Therefore, screening of pea genotypes on the basis of various growth and physiological attributes is a short gun approach. In this experiment we study the drastic effects of salt stress on growth and various physiological attributes of nine pea genotypes. On the basis of these findings, we very easily categorized the tested pea genotypes into tolerant and sensitive ones. This information is useful for the pea growers and will also strengthen the breeding programmes regarding salt tolerance of pea. The findings of this present investigation will definitely play a role in poverty alleviation and upgrade the economic status of the pea growers, as they will grow the salt tolerant genotypes which will defiantly give better yield. On the other hand the screened salt tolerant genotypes can be grown on the marginal lands, in this way an extra benefit would be achieved due to this study. The aim of this present experiment was to study the physiological responses of pea under saline conditions.

MATERIALS AND METHODS

Plant materials and growth conditions

Pea (*P. sativum*) was used for this study as experimental materials. The experiment was carried out in a green house. Seeds of ten different genotypes were allowed to germinate in plastic pots filled with fine sand as growth medium. Pots were placed in growth chamber adjusted to 75/60°F day/night, RH 85% with light intensity of 2200 lux through florescent tubes. Eight seeds per pot were sown but after 15 days of germination, the plants were thinned to five. The experiment was carried out with three replications. Plants were grown in Hoagland solution under non saline conditions for 30 days after germination. Afterwards, the plants were subjected to salinity stress. Sodium chloride was added to double distilled water to obtain final concentrations of 0 (control), 25, 50 and 75 m*M*. In order to prevent the osmotic shock, salinity was created in 25 m*M* increments every day until final concentrations were reached. Plants were grown for 15 days under salt stressed conditions. Irrigation along with Hoagland solution was applied according to the need of the plants.

Growth measurement

Internodal distance in each plant was measured with the help of measuring tape in centimeters (cm). Average of internodal distance was calculated for each treatment. Fresh weight of each plant was taken by using electric balance. Average of fresh weight was calculated for each treatment. Dry weight of whole plant was measured after keeping it in an oven at 70°C for 72 h. Dry weights were taken using digital electric balance and means were calculated for each treatment.

Gas exchange and chlorophyll contents

Gas exchange was recorded using an infra-red gas analyser (Analytical Development Company, Hoddesdon, England). The net photosynthetic rate (Pn), stomatal conductance (g_s) and transpiration rate (E) were measured on intact leaves. Measurements were performed from 9.00 a.m. to 11.00 a.m. with the following specifications/adjustments: molar flow of air per unit leaf area 403.3 mM $m^{-2}s^{-1}$, atmospheric pressure 99.9 kPa, water vapor pressure into chamber ranged from 6.0 to 8.9 mbar (PAR) at leaf surface was maximum up to 1711 (mol m^{-2} s^{-1}), temperature of leaf ranged from 28.4 to 32.4 °C, ambient temperature ranged from 22.4 to 27.9°C, ambient CO_2 concentration was 352 mol mol^{-1}.

Chlorophyll contents were estimated according to the method by

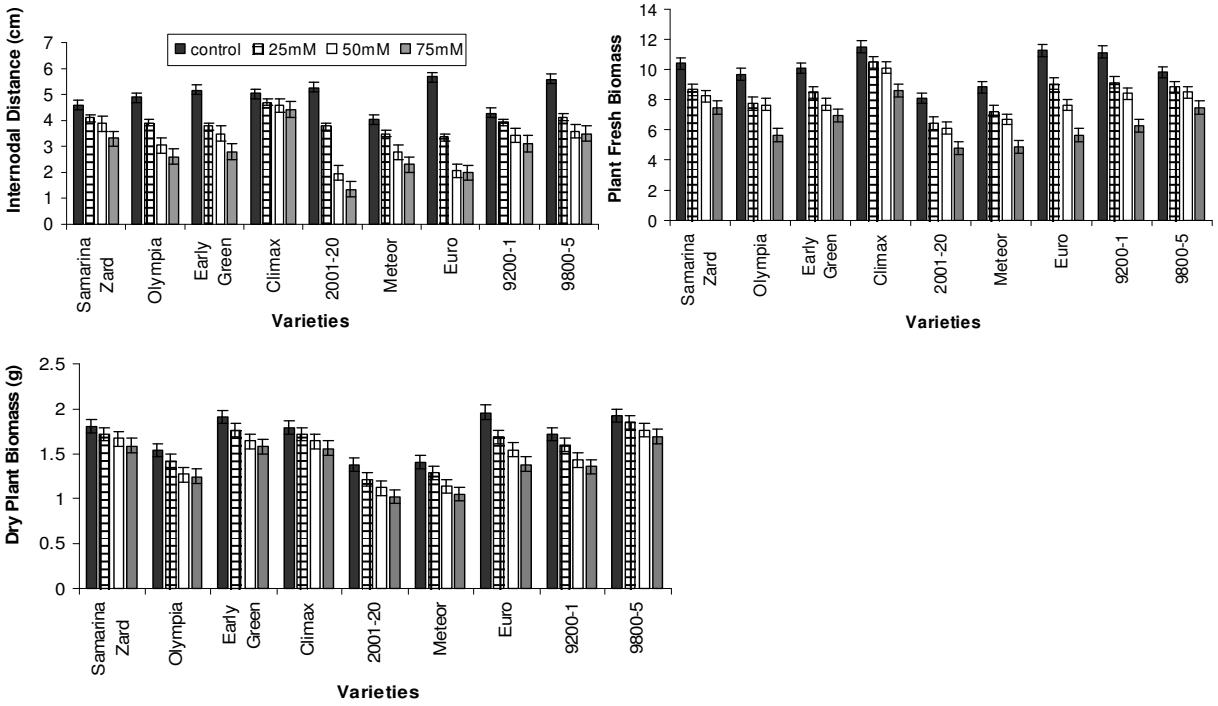

Figure 1. Effect of salt stress on internodal distance, plant fresh and dry biomass. Vertical bars are standard errors (SE) of the means. HSD (Tuckey Test) for genotypes.

Arnon (1979). Fresh leaves were cut into 0.5 cm segments and extracted over night by dipping in 80% acetone at -40°C. Centrifuge the extract at 14000 *g* for 5 min and absorbance of the supernatant was taken at 645 and 663 nm by spectrophotometer (PerkinElmer-201).

Chlorophyll a, b and total were calculated using the following formulae:

Chl a = [12.7 (OD 663) - 2.69 (OD 645)] x V/1000 x W
Chl b = [22.9 (OD 645) - 4.68 (OD 663)] x V/1000 x W
Total Chl = [20.2 (OD 645) + 8.02 (OD 663)] x V/100 x W
V = Volume of extract
W = Weight of the sample

Determination of Na^+, K^+ and P contents

Dried leaves were grinded to a powder for mineral analysis. The powder was taken in digestion tubes having 5 ml of H_2SO_4 (Wolf, 1982). All the tubes were incubated overnight at 68°F. Then 0.5 mL of H_2O_2 (35%) poured down the sides of the digestion tube, placed the tubes in a digestion block and heated at 260°C (using hot plate) until fumes were produced. They were continued to heat for another 30 min. The digestion tubes were removed from the block and cooled. The H_2O_2 (0.5 ml) was slowly added and placed the tubes back into the digestion block. The above step was repeated until the cooled digested material became colorless. The volume of the extract was maintained up to 50 ml in volumetric flasks. The extract was filtered and used for determining Na^+ by Flame photometer. A graded series of standards (ranging from 10 to 100 ppm) of Na^+ were prepared and standard carve were drawn. The values of Flam Photometer for unknown samples were compared for standard curve and total quantities were computed. Phosphorus (P) was determined on a spectrophotometer (Jackson, 1962). To an aliquot of extracted material (2 ml), 2 ml of Barton's reagent was added and total volume was made to be 50 ml. These samples were kept for half an hour before analyzing phosphorus. In this digestion procedure, H_2O_2 was just as an oxidizing agent so it did not affect ionic concentrations within the samples. The values of phosphorus were calculated by using standard curve.

Data analysis

A completely randomized design (CRD) with four salinity levels was used as treatments in this experiment. There were five replications per treatment and one pot was regarded as single replicate**.** The data was analyzed statistically by using two-way analysis of variance and comparisons with *P*-values ≤ 0.05 were considered significantly different by using HSD values (Tuckey Test). Data were presented as mean ± SE at the top of each column in figures while ionic contents were presented in tables as means of five replicates with % increase or decrease over control in parenthesis. Collected data was analyzed statistically by using package Statistix version 8.1 (Analytical Software, Tallahassee, Florida).

RESULTS

Plant growth parameters

Salt tolerant cultivars exhibited the maximum internodal distance, higher fresh and dry plant weights and number of leaves per plant (Figures 1 and 2), as compared to the sensitive ones under salt stressed conditions. Climax exhibited the highest salt tolerance potential by maintaining maximum number of leaves, branches, internodal

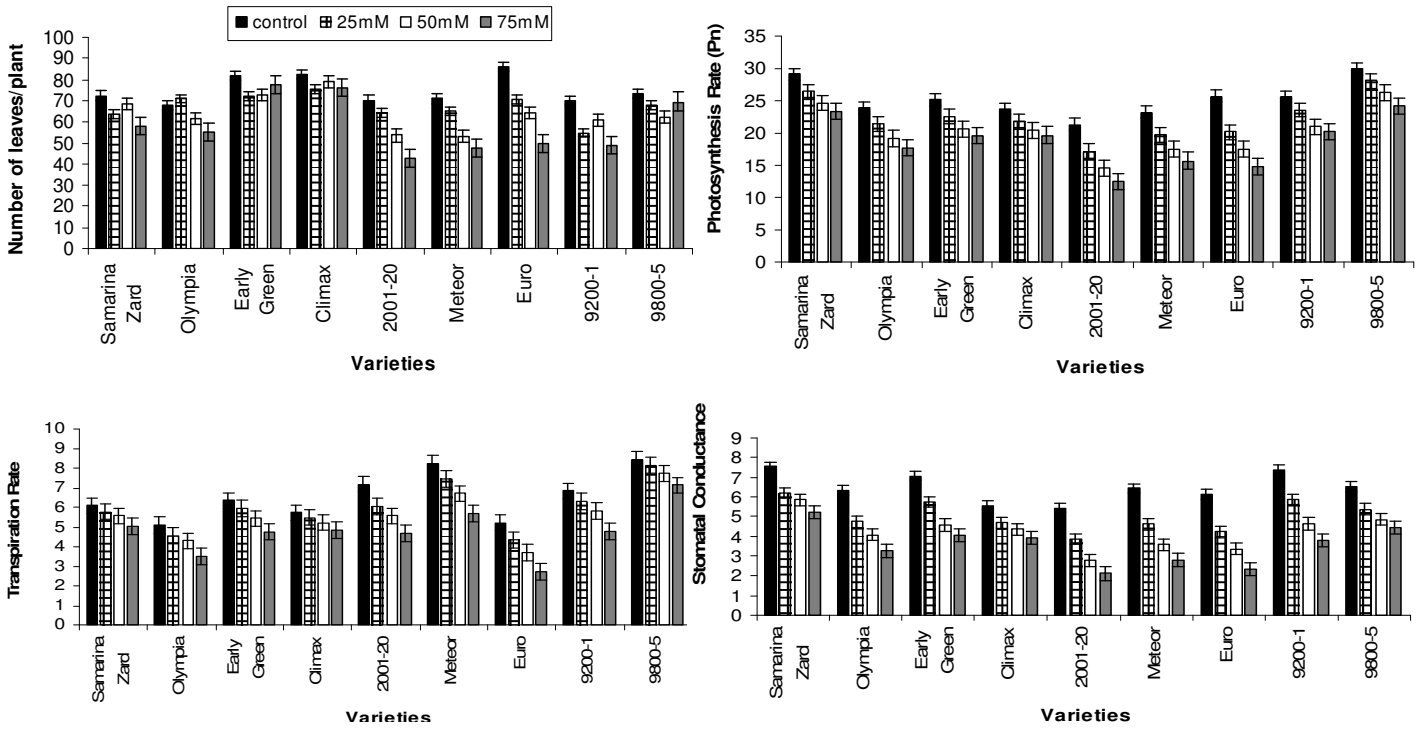

Figure 2. Effect of salt stress on number of leaves, photosynthesis, transpiration rate and stomatal conductance. Vertical bars give the standard error (SE) of the mean. HSD (Tuckey Test) for genotypes.

distance, fresh and dry weights per plant while Euro had the maximum susceptibility.

Leaf gas exchange and chlorophyll content

Salinity treatment caused a significant reduction in gas exchange attributes (Figure 2) In the 25 m*M* saline treatment, net photosynthesis rates for Climax and 9800-5 were reduced by 7 and 6%, respectively, as compared to their control while maximum reduction of 13 and 19% was recorded for Euro and 2001-20, respectively. In case of 50 m*M* treatment the greatest reduction was observed in 2001-20 (31%) and Euro (40%) and the least in Climax (10%) along with 9800-5 (12%). However 75mM treatment decreased the photosynthesis rate by (17%) in all the pea varieties but the highest reduction was noted for Euro (40%) while Climax exhibited the highest photosynthetic activity because it gave minimum reduction of 17% in this attributes. Under non-saline conditions, the highest transpiration rates and stomatal conductance were found in Samarina Zard and 9200-1 (Figure 2). Salinity progressively reduced both transpiration rate and stomatal conductance in all the pea varieties but at higher salinity level of 75 m*M* maximum reduction was observed in Euro (47 and 61%) and 2001-20 (34 and 61%). On the other hand, Climax and 9800-5 showed the lowest reduction in these attributes at all the salinity treatments. The highest salinity reduced the concentrations of chlorophyll “a”, “b” and total chlorophyll in all pea genotypes (Figure 3). Under 25 m*M*, Climax exhibited the minimum reduction (about 4, 12 and 6%) for chlorophyll, a, b and total, respectively while maximum reduction by 13, 25, and 16%, respectively was noted Euro. Similarly under 50 and 75 m*M* salt stress, climax and 9800-5 showed the excellent performance by showing minimum reduction in chlorophyll contents as compared to the other selections (Figure 3).

Leaf and root mineral nutrition

Sodium concentration in leaves increased with increasing NaCl concentration (Table 1). The variety that accumulated Na most in leaves was Euro while Climax accumulated the least sodium in leaves. In 75 m*M* treatment, Na concentration in Climax, 9800-5 and Samrina Zard were increased by 38, 42 and 42% respectively, followed by Euro (275%) and 2001-20 (191%). Under 25 and 50 m*M,* climax showed the lowest percentages of sodium accumulation but 2001-20 and Euro exhibited the highest percentage of sodium in their leaves under 25 and 50 m*M,* respectively (Table 1). In the control, leaf nutrient concentrations showed the significant differences between varieties. For instance tolerant cultivars (Climax and 9800-5) had lower Na contents in their leaves than did sensitive like Euro and 2001-20. Root Na concentrations also tend to increase

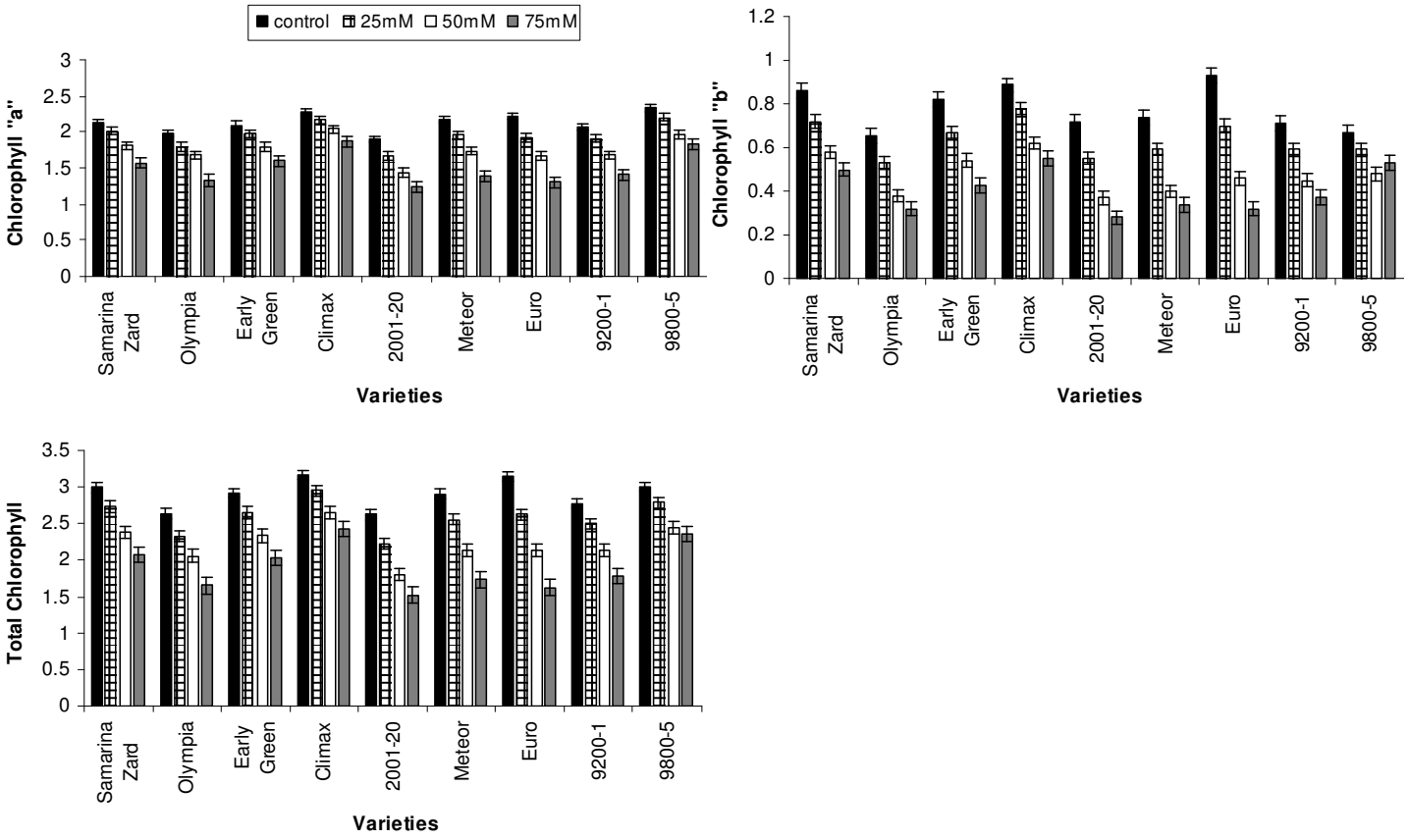

Figure 3. Effect of salt stress on stomatal conductance and chlorophyll contents. Vertical bars give the standard error (SE) of the mean. HSD (Tuckey Test) for genotypes.

Table 1. Effect of salinity on Na contents of both leaves and roots (along with % reduction).

Varieties	Leaf				Root			
	Control	25 m*M*	50 m*M*	75 m*M*	Control	25 m*M*	50 m*M*	75 m*M*
Samarina Zard	2.42	3.05 (26.03)	3.32 (37.19)	3.46 (42.98)	1.96	4.56 (132.65)	5.28 (169.39)	6.1 (211.22)
Olympia	2.15	3.48 (61.86)	3.74 (73.95)	4.16 (93.49)	4.09	7.74 (89.24)	8.19 (100.24)	7.94 (94.13)
Early Green	1.93	2.88 (49.22)	3.07 (59.07)	3.23 (67.36)	3.23	6.45 (99.69)	6.87 (112.69)	7.55 (133.75)
Climax	2.32	2.89 (24.57)	3.01 (29.74)	3.21 (38.36)	1.04	2.46 (136.54)	2.68 (157.69)	3.24 (211.54)
2001-20	2.16	3.83 (77.31)	6.14 (184.26)	6.29 (191.20)	2.11	3.45 (63.51)	3.6 (70.62)	3.87 (83.41)
Meteor	3.06	5.45 (78.10)	6.27 (104.90)	7.26 (137.25)	1.17	2.18 (86.32)	2.27 (94.02)	2.52 (115.38)
Euro	1.32	2.45 (85.61)	3.12 (136.36)	4.96 (275.76)	1.96	3.34 (70.41)	3.52 (79.59)	4.12 (110.20)
9200-1	2.22	3.26 (46.85)	3.67 (65.32)	4.19 (88.74)	3.45	6.56 (90.14)	7.14 (106.96)	7.67 (122.32)
9800-5	1.78	2.31 (29.78)	2.42 (35.96)	2.53 (42.13)	2.16	5.34 (147.22)	5.88 (172.22)	6.46 (199.07)

under all salinity levels (Table 1). In 25 and 50 m*M,* the genotypes Climax (136%) and 9800-1 (147%) respectively showed maximum percentages of Na as compared to their controls. Whereas, the variety 2001-20 showed the minimum values of 63 and 70% under the salt-stressed conditions of 25 and 50 m*M,* respectively. In 75 m*M* treatment 2001-20 (83%) showed the least Na accumulation in roots as compared to the Climax (211%). Increasing salinity in irrigation water from 0 to 75 m*M* NaCl decreased both the leaf and root K concentration in all the pea varieties (Table 2). The lowest reduction percentage was recorded for Climax and Samrina Zard but Meteor and 2001-20 gave maximum reduction in leaf and root K concentrations as compared to the non saline control. Salt stress also caused a remarkable reduction in leaf and root phosphorous contents in all the pea

Table 2. Effect of salinity of K contents of both leaves and roots (along with % reduction).

Varieties	Leaf				Root			
	Control	25 m*M*	50 m*M*	75 m*M*	Control	25 m*M*	50 m*M*	75 m*M*
Samarina Zard	22.56	20.75 (18.34)	18.34 (17.06)	17.06 (24.38)	17.85	17.14 (3.98)	15.88 (11.04)	15.32 (14.17)
Olympia	22.36	18.69 (16.72)	16.72 (14.61)	14.61 (34.66)	16.54	14.44 (12.71)	13.76 (16.82)	12.92 (21.86)
Early Green	21.42	18.96 (17.13)	17.13 (15.47)	15.47 (27.78)	17.84	16.41 (8.05)	16.14 (9.56)	14.82 (16.96)
Climax	23.16	22.06 (20.81)	20.81 (19.39)	19.39 (16.25)	15.25	14.64 (4.04)	13.91 (8.81)	13.33 (12.63)
2001-20	22.01	17.45 (16.93)	16.93 (13.04)	13.04 (40.75)	18.53	15.52 (16.28)	14.11 (23.88)	12.48 (32.68)
Meteor	20.7	17.30 (14.76)	14.76 (13.45)	13.45 (35.02)	17.37	14.73 (15.23)	14.23 (18.11)	12.76 (26.57)
Euro	24.07	18.46 (16.31)	16.31 (15.73)	15.73 (34.65)	19.15	16.24 (15.21)	15.01 (21.59)	13.24 (30.87)
9200-1	22.83	19.34 (17.73)	17.73 (15.55)	15.55 (31.89)	15.96	14.68 (8.02)	14.40 (9.73)	12.98 (18.67)
9800-5	21.33	19.32 (17.45)	17.45 (16.05)	16.05 (24.75)	16.43	15.29 (6.98)	14.71 (10.51)	14.01 (14.77)

Table 3. Effect of salinity of P contents of both leaves and roots (along with % reduction).

Varieties	Leaf				Root			
	Control	25 m*M*	50 m*M*	75 m*M*	Control	25 m*M*	50 m*M*	75 m*M*
Samarina Zard	1.71	1.61 (5.85)	1.57 (8.19)	1.50 (12.28)	3.64	3.45 (5.22)	3.17 (12.91)	3.03 (16.76)
Olympia	2.03	1.83 (9.85)	1.79 (11.82)	1.63 (19.70)	3.94	3.54 (10.15)	3.29 (16.50)	2.97 (24.62)
Early Green	1.4	1.30 (7.14)	1.28 (8.57)	1.19 (15.00)	4.02	3.66 (8.96)	3.48 (13.43)	3.28 (18.41)
Climax	1.87	1.76 (5.88)	1.73 (7.49)	1.69 (9.63)	4.58	4.33 (5.46)	4.23 (7.64)	4.11 (10.26)
2001-20	1.46	1.27 (13.01)	1.21 (17.12)	1.16 (20.55)	1.96	1.73 (11.73)	1.52 (22.45)	1.37 (30.10)
Meteor	1.4	1.27 (9.29)	1.21 (13.57)	1.05 (25.00)	3.13	2.68 (14.38)	2.36 (24.60)	2.53 (19.17)
Euro	1.59	1.38 (13.21)	1.29 (18.87)	1.15 (27.67)	3.25	2.79 (14.15)	2.5 (23.08)	2.25 (30.77)
9200-1	1.92	1.78 (7.29)	1.69 (11.98)	1.58 (17.71)	3.39	3.08 (9.14)	2.74 (19.17)	2.72 (19.76)
9800-5	2.06	1.92 (6.80)	1.87 (9.22)	1.79 (13.11)	3.94	3.76 (4.57)	3.65 (7.36)	3.51 (10.91)

varieties (Table 3), but maximum reduction was recorded in Euro and Meteor under saline conditions. The genotypes, Climax and Samarina Zard exhibited the maximum salt tolerance potential in terms of high phosphorus concentration in their root and leaf tissues.

DISCUSSION

Reduction in internodal distance and number of leaves per plant is a common phenomenon under salinity stress in most of plants (Zhu, 2001). The pea genotype climax was not much influenced by the salinity even at its highest level and exhibited the maximum number of leaves and internodal distance at higher salinity levels. The reduction in internodal distance and number of leaves may be due to the reduction in turgor potential, necessary for cell elongation (Iqbal and Ashraf, 2005) and turgor pressure was reduced due to salinity (Ashraf and Harris, 2004). Salinity stress severely influenced the plant hormone action and their synthesis. So the reduction in internodal distance in the pea genotypes may be due to the reduction in gibberelin synthesis, responsible for cell elongation and IAA for cell division (Wang et al., 1997; Wang and Nil, 2000). Under saline conditions, fresh and dry matter accumulation is the ultimate goal to enhance the plant productivity in pea. The reduction may be due to many reasons such as lack of maintenance of turgor, sodium/chloride ion toxicity and disturbances in metabolic path ways. Fresh and dry weight reduction under saline conditions may be due to the reduction in above ground biomass allocation (Sagi et al., 1997). The results of present investigation are also in accordance with the findings of Noreen and Ashraf (2008) and Ashraf et al. (2010) in sunflower and wheat respectively. Climax performed better because it maintained its turgor potential and accumulated the toxic ions less as compared to the Euro cultivar which failed to tolerate the higher salinity levels due to lack of turgor potential maintenance and more toxic ions accumulation that created reduction in the fresh and dry biomass production. Under saline conditions, photosynthetic rate decreased because salinity causes the ion accumulation in different parts of the plant which exerts toxic effects on physiological processes in plant. Ahmad (2000) reported that leaf area and photosynthesis rate reduced while leaf diffusive resistance increased in plants growing under salt stress. This is common phenomenon previously reported by (Ashraf, 2001). Ahmad (2000) observed that increased level of salinity stress reduced photosynthetic

rate (42%) due to reduction in transpiration rate (48%) and stomatal conductance (70%) in wheat plants. Huang et al. (2000) also observed decreased evapo-transpiration rate and stomatal conductance in wheat plants grown under saline conditions. Bano (2010) also observed the reduction in stomatal conductance in rice grown under salt stress. Salinity stress decreased turgor potential resulting in stomatal closure to extent that those plants could not adjust themselves and photosynthetic rate reduced (Shannon and Grieve, 1999).

Climax cultivar was at the top because it showed the minimum decrease in photosynthetic rate. This minimum decrease in photosynthetic rate was due to the less toxic ion accumulation which affects the gaseous exchange by disturbing the mechanism of stomata opening and closing. The Euro cultivar proved to be salt sensitive by showing maximum reduction in photosynthesis rate under salt stress. This reduction was due to more accumulation of toxic ions that inhibits the gaseous exchange between leaf and outside environment; on the other hand working ability of stomatal guard cells was badly affected by these toxic ions especially Na^+ and Cl^-. There was a positive correlation between photosynthesis rate and dry biomass. The plants maintaining maximum dry biomass showed higher rates of photosynthesis. However, the behavior of each pea genotype is similar for stomatal conductance and rate of photosynthesis. The genotypes (Climax and Samrina Zard) that showed minimum reduction in photosynthesis rate also had the highest stomatal conductance, on the other hand the Euro and 2001-20, had the lowest value for rate of photosynthesis and stomatal conductance which proved that there is a positive correlation between the rate of photosynthesis and stomatal conductance. Similar kind of results was discussed by Centritto et al. (2005), Filella et al. (2004) and Noreen and Ashraf (2008). Pea genotypes with higher stomatal conductance maintained the higher rate of photosynthesis. Transpiration rate decreasesed with increase in salinity in all the pea genotypes, however maximum reduction was at the higher levels of salinity. The genotype Climax was successful in maintaining the high transpiration rate. Tezara et al. (2002) also reported decrease in transpiration rate with the increase in salinity that may be due to the reduction in turgidity of guard cells, which is very common in almost all the stresses (Stepin and Klobus, 2006). The reduction in turgidity may be due to the decrease in uptake of potassium and unavailability of other nutrients necessary to maintain the turgor of guard cells (Burman et al., 2003).

It is well documented fact that due to the ion toxicity created by NaCl, uptake of many essential nutrients reduced (Najafi et al., 2007). Sodium and potassium have an antagonistic mechanism regarding uptake of nutrients by the plants. The growth media with excessive sodium ion reduced potassium uptake as a result of which turgor potential of guard cells decreased and stomata become closed even in sun light. Consequently transpiration decreased. Transpiration is a necessary evil to maintain optimum photosynthetic activity and gas exchange, so reduction in transpiration may reduce the stomatal conductance and photosynthetic activity, which resulted in the reduction in plant productivity. The cultivars which maintained their transpiration rate and stomatal conductance under adverse conditions are successful to adjust them osmotically by accumulating some osmolytes and osmoprotectants like proline, glycinebetaine, sugars etc. Ion accumulation in leaves adversely affects Chl content (Loggini et al., 1999; Meloni et al., 2003). The decrease in chlorophyll content in the pea plants grown under saline conditions may be attributed to both an increased degradation and inhibited synthesis of that pigment (Sultana et al., 1999; Garcia-Sanchez et al., 2002). Chlorophyll "*a*" was less sensitive or better protected against salt stress than Chl *b*. Due to less toxic ions accumulation in leaves the Climax performed better as compared to the Euro. A positive correlation was observed between chlorophyll contents and plant biomass production. Under salt stress, sodium concentration increased in all the pea varieties. The higher uptake of sodium may be due to enhanced accumulation of solutes that decreased osmotic potential. Zeid and El-Semary (2001) noted accumulation of sodium in plants growing under stress conditions. Under saline conditions higher accumulation of Na^+ in all the pea cultivars may be due to the presence of higher sodium ion in root media. Sodium uptake is more, where its salts are present in high amounts. Meneguzzo et al. (2000) reported that sodium uptake increased in wheat plants under salt stress.

In salt tolerant cultivar, sodium accumulation was less as compared to salt sensitive. Salt tolerant plants create the hindrance for the entry of toxic ions like Na so they show higher concentration in their roots as compared to the leaves while on the other hand it is opposite in salt sensitive plants which show higher Na in leaves instead of roots (Maggio et al., 2004). Climax cultivar exhibited good performance at higher salinity levels because low amount of Na^+ was accumulated in its leaves as compared to roots. However Euro and PF-400 cultivars failed to survive at high salt stress due to higher accumulation of sodium in leaves in comparison to root (Table 1). With the increase in salinity K contents in root and leaves were decreased, however K^+ was higher in leaves than that of roots in all the tested pea varieties (Table 2). The decrease in K contents in leaves and roots may be due to the antagonistic effect of Na. The decrease in K contents in both leaves and roots occurs because Na^+ competes with K^+ for uptake through common transport system, since the Na^+ concentration in saline media is usually very high than K^+ (Netondo et al., 2004; Shabala et al., 2007). The varieties like Climax and Samrina Zard having more K contents in leaves showed more plant biomass and photosynthesis rate as compared to Euro. Phosphorus contents were also

affected under saline conditions but least reduction was observed in tolerant varieties like Climax and Samrina Zard. It is a vital constituent of proteins and amino acids so its constant supply to plants is necessary for growth and development (Kong et al., 2002). So the varieties which are successful in maintaining the required amounts of P are salt tolerant. On the basis of performance of the varieties for P uptake, Climax, Samrina Zard and 9800-5 can be categorized as the tolerant pea genotypes.

Conclusion

From the present investigation it is concluded that salt stress has a significant drastic effect of growth and development of pea. The pea growth and development is proportional to the concentration of toxic salts within the root zone. The genotypes that had well maintained the beneficial ions (K and P) in their tissues, exhibited the excellent performance in terms of high plant biomass, photosynthetic activity, stomatal conductance and chlorophyll contents. So, it can be extracted that potassium and sodium ions have a strong correlation with the salt tolerance potential of pea. The current study also proved that photosynthesis, stomatal conductance, chlorophyll contents, Na, K and P are the useful screening tools for salt tolerance.

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