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Seed yield and quality of pepper plants grown under salt stress

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The effect of salinity on seed yield and quality of pepper plants were evaluated. Plants were grown in five salt levels (electrical conductivity, EC): 1.0, 1.5, 2.0, 4.0 to 6.0 dSm^{-1} in glasshouse. Seed yield was assessed by seed weight/fruit, seed weight/plant and individual seed weight. Seed quality was measured by germination, mean germination time, seedling growth and germination percentages after cold (10°C, 7 days, 25°C 10 days) accelerated ageing (45°C, 48 h) and high temperature germination (35°C, 14 days) tests. Results indicate that seed yield per fruit greatly reduced from 1990 mg at control to 460 mg at 4 dSm^{-1} but individual seed weight did not change until 1.5 dSm^{-1} EC. Seed quality concerning all criteria maintained high up to 2.0 dSm^{-1} EC while seed germination and vigour were significantly reduced at 4.0 dSm^{-1} EC. Pepper plants did not yield seeds at 6 dSm^{-1} EC. It can be concluded that pepper seed yield reduced significantly at even very low salinity (1 dSm^{-1}), however, quality began to decline after 2.0 dSm^{-1} EC.

Key words: Pepper, fruit yield, seed quality, salinity.

INTRODUCTION

Salinity is one of the basic abiotic stresses particularly effective in arid and semi-arid regions (Maas, 1986). There are large number of studies that deal with the effects of salinity on germination, seedling growth, plant growth and fruit yield in various crops (Maas, 1986; Cayuela et al., 2001; Shannon and Grieve, 1999). Pepper was considered to be moderately sensitive crop and, regarding fruit yield, threshold electrical conductivity level was reported to be 2.0 dSm^{-1} (Maas, 1986). However, this may not necessarily be applicable for seed yield and quality because, seed maturation is a reproductive stage of the pepper plant and requires longer time than that of fruit on the mother plant. Demir and Ellis (1992) reported that pepper fruits reached full marketable size after 30 to 35 days, while maximum seed quality was obtained from fruits harvested 70 days after flowering. Although numerous studies were conducted on the effect of salinity on plant growth and fruit yield, very little is known about the effect of saline environments on seed quality (Maas, 1986; Shannon and Grieve, 1999). In this work, we aimed to determine changes in yield and quality of pepper seeds obtained from plants grown under various salinity levels in greenhouse conditions.

MATERIALS AND METHODS

Seeds were sown in seedling trays then, transplants were transferred to the pots. Plants (*Capsicum annuum* L. cv. Carliston) were grown in plastic pots which were 50 cm in depth and 40 cm diameter in greenhouse conditions in April and September 2006. Each pot was filled withwashed and dried 9 kg of garden soil (43 % clay, 33 % sand and 24 % silt).

Five salinity levels, made by diluting NaCl with tap water and control were used. The electrical conductivity (EC) of the prepared saline water was 1, 1.5, 2.0, 4.0 and 6.0 dSm^{-1} while EC of the

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Table 1. Fruit (fruit number/plant F/P, average fruit weight AFWT (g)) and seed yield (Seed weight/fruit SWT/F (mg), seed weight /plant SWT/P (mg), individual seed weight ISWT (mg)) of pepper plants grown at various salinity levels.

NaCl (dSm-1)	F/P	AFWT (g)	SWT/F(mg)	SWT/P (mg)	ISWT(mg)
0	4.0^{ab}	118^{b}	497^{a}	1990^{a}	6.2^{a}
1.0	5.3^{a}	142^{a}	187^{bcd}	992^{b}	6.0^{a}
1.5	4.1^{ab}	134^{a}	181^{cd}	745^{c}	6.1^{a}
2.0	3.0^{bc}	104^{c}	180^{cd}	542^{d}	5.6^{a}
4.0	2.7^{c}	74^{d}	170^{e}	460^{e}	3.8^{b}
6.0	NA	NA	NA	NA	NA

NA, No seeds were obtained, means with different letters in the same column is significantly different (P=0.05).

control was 0.25 dSm^{-1}. To provide salinity levels 0.09 g/l NaCl, 0.55 g/l $CaCl_2$ for 1 dSm^{-1}, 0.11 g/l NaCl, 0.773 g/l$CaCl_2$ for 1.5 dSm^{-1}, 0.126 g/l NaCl, 1.49 g/l $CaCl_2$ for 2 dSm^{-1}, 0.18 g/l NaCl, 3 g/l $CaCl_2$ for 4 dSm^{-1}, 0.23 NaCl, 4.89 $CaCl_2$ for 6 dSm^{-1} were dissolved in a litter of non-saline water. Specific absorption rate (SAR) values of irrigation water at all salinity level was lower than 1. Plant nutrition needs were met with 0.733 g K/pot and 0.746 g P/pot at the time of planting. N requirement was supplied by adding 1.76 g/pot at planting and flowering stages, respectively. Control plants were irrigated with non-saline water and treated plants with appropriate EC solutions from the time that plants had five true leaves. Soil moisture was observed in 2-3 day intervals by means of weighing the pots. Irrigation was done when 50% of available soil water was extracted. Daily mean maxima and minima in the greenhouse were 38±2 and 21±3°C, respectively. Six plants were grown in each concentration.

At the end of September, fruit number/plant and fruit weight (g) were determined. Seeds were extracted from fruits at the day of harvest (first and second layer of the plants, 65-70 days after anthesis) and dried at 20±2°C for 24 h (10 % moisture content) then, seed weight/fruit (mg), seed weight/plant (mg) and individual seed weight(mg) were determined in six plants of each concentration. All seeds obtained from the plants grown in the same concentration were mixed up and seed quality tests were carried out. Plants that were watered with 6 $dScm^{-1}$ EC were shrivelled and fruits were severely malformed and seeds were not obtained. Germination of seeds were carried out in Petri dishes (9 cm diameter) containing two Whatman (No:1) filter paper imbibed with 5 ml of distilled water. Three replicates of 50 seeds were germinated in each seed lot. Seeds were allowed to germinate at 25°C in the dark for 14 days. Radicle protrusion (2 mm), normal seedling (firm, well developed hipocotyl and root structure), and abnormal seedling (deformed seedlings) were determined. Mean germination time was calculated according to Ellis and Roberts (1980) on the basis of daily counts and expressed as hours.

At the end of the germination test, normal seedlings were separated in each of three replicates of each concentration and seedling fresh (mg/plant) and dry weight (mg/plant) were determined. Dry weight was determined after 24 h at 80°C. Root length measurements were conducted on seedlings that germinated at 7th day of germination test and expressed as cm/plant. Cold test was carried out on each lot three replications of 50 seeds were sown 2 cm deep in compost in sandwich boxes (18x10x5 cm) and wetted with 50 ml water. Sandwich boxes with lid on were kept at 10°C for 7 days in the dark. They were then transferred to 25°C and normal seedlings that appeared at the surface were counted after 10 days. Accelerated ageing test was carried out on three replicates of 50 seeds in each lot. Forty ml of distilled water added at the bottom of plexiglass box (11x 11x 4 cm). Seeds were placed on wire mesh trays approximately 2 cm above the bottom of the tray and aged at 45°C for 48 h. Following this period, the seeds were removed and a germination test (radicle protrusion) conducted as described above.

High temperature germination test in each lot was conducted on three replicates of 50 seeds at 35°C. Radicle protrusion was counted after 14 days. Means of the replicates of the each test in each concentration were compared with Duncan multiple range test. Germination percentage was angle transformed before analyses.

RESULTS

Fruit weight, fruit number, seed weight per plant and fruit and individual seed weight are presented in Table 1. This study indicates that pepper seed yield in either fruit or plant was gradually declined as salinity increased. The maximum reduction occurred at 4 dSm^{-1} EC compared to the control at 51%. Individual seed weight did not change up to 2.0 dSm^{-1} EC (Table 1). Seeds that were obtained from plants grown at 1.0, 1.5 and 2.0 dSm^{-1} EC salinity had as high quality (Normal germination, cold test, accelerated ageing test, high temperature germination test) as those of the control. However, the lowest seed quality was obtained from plants that were irrigated with water of 4.0 dSm^{-1} EC (Tables 2 and 3).

Seedling dry weight and root length were not significantly changed in seeds produced up to 2.0 dSm^{-1} EC but both declined greatly by 4.0 dSm^{-1} and being 1.3 mg/plant and 1.9 cm, respectively (Table 2). Maximum seedling fresh weight was recorded in between 1 and 2.0 dSm^{-1} EC as 28 to 31 mg/plant. Seedling fresh weight of both seeds of control and at 4.0 dSm^{-1} EC were significantly lower than these three lots and found as 25 and 20 mg/plant, respectively (Table 2). Cold test results show that seed germination is not significantly affected by irrigating plants with saline water up to 2.0 dSm^{-1} EC while, slightly higher salinity (1-2.0 dSm^{-1}) increased germination percentages after ageing test compared to that of control. Similar effect was also observed in high temperature germination test. The lowest values were obtained from those seeds grown at 4.0 dSm^{-1} EC as 25,

Table 2 Changes in the radicle protrusion (RP, %), normal and abnormal germination (NG and AG %) and mean germination time (MGT h), seedling fresh (SFW, mg/plant), seedling dry weight (SDW, mg/plant) and root length (RL, cm/plant) of pepper seeds that obtained from plants grown at various salinity levels.

NaCl (dSm^{-1})	RP (%)	NG (%)	AG (%)	MGT (h)	SFW (mg/plant)	SDW (mg/plant)	RL (cm/plant)
0	97^{a}	71^{b}	26^{b}	91^{e}	25^{b}	2.2^{a}	2.6^{a}
1.0	97^{a}	79^{a}	18^{c}	93de	28^{ab}	2.2^{a}	2.8^{a}
1.5	91^{a}	78^{ab}	13^{d}	100^{c}	30^{a}	2.3^{a}	2.6^{a}
2.0	95^{a}	81^{a}	14^{d}	103^{bc}	31^{a}	2.3^{a}	2.7^{a}
4.0	82^{a}	40^{c}	42^{a}	118^{a}	20^{c}	1.3^{b}	1.9^{b}
6.0	NA	NA	NA	NA	NA	NA	NA

NA, No seeds were obtained; means with different letters in the same column is significantly different (P=0.05).

Table 3. Changes in germination percentage of pepper seeds after cold, (CT, %) accelerated ageing (AAT, %) and high temperature germination (HTGT, %) tests that were obtained from plants grown at various salinity levels.

NaCl (dSm^{-1})	CT (%)	AAT (%)	HTGT (%)
0	42^{a}	63^{c}	61^{b}
1.0	43^{a}	72^{b}	76^{a}
1.5	39^{a}	79^{a}	71^{a}
2.0	43^{a}	76^{ab}	70^{a}
4.0	25^{b}	32^{d}	34^{c}
6.0	NA	NA	NA

NA, No seeds were obtained; means with different letters in the same column is significantly different (P=0.05).

32 and 34%, for cold, accelerated ageing and high temperature germination test, respectively (Table 3).

DISCUSSION

Large number of studies in various vegetable crops investigated the effect of salinity on vegetative plant development stages such as germination and seedling growth, plant shoot and root dry weight and yield (Maas, 1986; Shannon and Grieve, 1999; Demir et al., 2003; Santamaria et al., 2004). Maas (1986) classified pepper as a moderately sensitive crop and maximum permissible concentration in soil water without yield reduction was given as 1.0-2.0 dSm^{-1} EC. Concerning fruit yield, the present results are in agreement with this finding. However, seed yield declined greatly even at 1 dSm^{-1} EC compared to those of the control plants (Table 1). Therefore, it can be concluded that the level of salt tolerance based on vegetative plant growth stages or fruit yield may not necessarily be a good indicator of reproductive criteria of seed yield and quality in pepper. Reduction in seed yield and quality preceded that of fruit yield under salt stress. This may be due to limitation in assimilate allocation to seeds by salinity. The reduction of the individual mass of seeds under high salinity levels has also been observed in wheat (Saini and Aspinall, 1981).

Salt injury symptoms, such as chlorosis, burning leaves, and necrotic areas were found severely in plants grown at 6 dSm^{-1} EC and no seeds were obtained from that concentration. Salinity stress during plant development might cause scorching, firing of leaves, shorter stature which cause slow seed maturation rate (Wahid et al., 1999). Reduced seed yield and quality at higher salinity levels in this work might originate from physiological occurrences that reduce dry matter accumulation and partitioning (Fenner, 1992; Dkhil and Denden, 2010). Increase in fruit number/ plant and average fruit weight were observed at 1 and 1.5 dSm^{-1} EC compared to those of the control (Table 1). This is in agreement with conclusions of some earlier reports which showed that moderate salinity applied during fruit development changed the partitioning of photosynthesis and improve soluble solids in melon and tomato fruits (Shannon and Grieve, 1999; Mizrahi et al. 1988). This agrees with findings of the previous reports which showed that moderate salinity applied during fruit development improves not only soluble solids but also seed vigour (Shannon and Grieve, 1999).

Pepper is a warm climate crop and requires relatively high temperatures, that is, 27 to 30°C, for optimum crop growing (George, 1985). In glasshouse pepper seed crop growing, temperatures in summer months raises up to 40 to 45°C which exacerbates the effect of soil salinity. Such high temperatures are common phenomenon in

Mediterranean region and accelerate salt stress due to increase evaporation and the remaining soil water becomes more concentrated. However, the present results are valuable for seed producers who wish to produce pepper seeds in moderately saline areas. But further work is required in order to determine the interactive effect of environmental factors (that is, temperature, soil type) with salt tolerance in pepper seed crop.

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