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PERFORMANCE OF SELECTED SPINACH GERMPLASM AGAINST SALINITY UNDER POT CULTURE

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Abstract

A pot experiment on spinach (*Spinacia oleracea* L.) genotypes was conducted against NaCl salt stress at the research field of Plant Physiology Section, HRC, BARI, Gazipur for three consecutive years (2016-17, 2017-18 and 2018-19) to find out salt tolerant genotypes at vegetative stage. In 2016-17 eight genotypes (SO-0046, SO-0047, SO-0048, BD-4323, BD-4333, BD-4339, BD-1062 and BARI Palongshak-1) and in 2017-18 seven genotypes (SO-0047, SO-0048, BD-4323, BD-4333, BD-4339, BD-1062 and BARI Palongshak-1) were tested against four varying levels of salinity viz. control, 4, 8 and 12 dS/m in pot. In 2018-19, two selected genotypes viz. SO-0047, SO-0048 and BARI Palongshak-1 which performed best in the previous years were examined against control (tap water), 8 and 12 dS/m in pot. The genotypes showed significant variation in plant height, number of leaves/plant, leaf length, leaf width, SPAD value, total dry matter/plant and leaf yield/pot. Among the genotypes, SO-0047 performed better at 8 and 12 dS/m in respect of all the characters studied followed by SO-0048. Therefore, it can be inferred that the genotype SO-0047 is relatively salt tolerant and can be recommended as a variety for cultivation in saline area of Bangladesh and SO-0048 might be used for breeding purpose to develop salt tolerant variety of spinach.

Keywords: Spinach (*Spinacia oleracea* L.), salinity, growth, SPAD value, tolerant.

Introduction

Among the abiotic stresses, drought, salinity, extreme temperatures, chemical pollutants, nutritional deficiency, and oxidative stress are the foremost abiotic stresses that reduce the global productivity of major crops (Kaushal and Wani, 2016; Singh *et al*., 2018). Both stresses can reduce several morphological, physiological, biochemical, and metabolic alterations through various mechanisms, eventually influencing plant growth, development, and productivity. Salinity along with drought is one of the leading abiotic stresses in agriculture which foster growth retardation, physiological abnormalities, and lower production output of field crops throughout the world (Majeed and Muhammad, 2019). Out of 2.85 million hectares of the coastal and off shore areas about 1.00 million hectares are arable lands, which cover over 30% of the total cultivable lands of Bangladesh (Haque, 2006). Salinity intrusion is an increasing problem in the coastal areas of Bangladesh (Mahmuduzzaman *et al*., 2014). Climate change

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and its associated hazards like cyclone, sea level rise, and storm surge have been increasing the salinity problem in many folds. Salinity in the country received very little attention in the past.

Spinach (*Spinacia oleracea* L) in an annual herb belongs to the family Chenopodiaceae. It is locally known as ‘palongshak’ which is one of the most important winter leafy vegetables commercially grown in Bangladesh. It is a good source of minerals (iron, copper, phosphorous, zinc, selenium), vitamin B complex and is a relatively quick-growing vegetable (Roughani and Mri, 2019). It was found that spinach was considerably more salt tolerant under cool season late winter conditions than under warmer climatic conditions (Ors and Suarez, 2016). Among different abiotic stresses, soil or water salinity is the major constraint in reducing vegetable growth and productivity in many vegetable producing areas of the world (Machado and Serralheiro, 2017). Most work on spinach has focused on cultural practices (e.g., irrigation), fertilization, cultivars, and their effect of growth, biomass accumulation (Nemadodzi *et al*., 2017) and the nutritional value of the crop irrigated with low-salinity water. In contrast, recent studies report no significant loss in spinach yield and nutritional value with saline water levels up to 9 dS m^{-1} (Ors and Suarez, 2016; Ferreira *et al*., 2018). In another study, spinach yield was increased at EC levels of 4 and 7 dS m^{-1} and subsequently declined at EC 9.0 dS m^{-1} and above (Ors and Suarez, 2017). In a recent study, Ferreira *et al*. (2020) suggested that the threshold level of EC for spinach was between 7 to 10 dS m^{-1} for water salinity and from 5.6 to 8.9 dS m^{-1} for soil salinity. Little effort has been made where the impact of saline water on spinach crop (*Spinacia oleracea* L.) and potential salt-tolerant spinach cultivars are identified (Turhan *et al*., 2011, 2013). Screening of different genotypes against salinity is one of the accepted methods to select genotypes for saline soil. Therefore, this experiment was carried out to find out the salt-tolerant spinach genotypes.

Materials and Methods

The experiment was conducted at the research field of Plant Physiology Section, Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI) (23.99297 N, 90.41227 E) during three consecutive years of 2016-17, 2017-18 and 2018-19. Eight genotypes of spinach (SO-0046, SO-0047, SO-0048, BD-4323, BD-4333, BD-4339, BD-1062, and BARI Palongshak-1) were screened out of 21 germplasm which were collected from Olericulture Division of Horticulture Research Centre and Plant Genetic Resources Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur were used in the study during 2016-17 and 2017-18 against four NaCl concentrations (control, 4 dS/m, 8 dS/m, 12 dS/m). In 2018-19, the selected three genotypes SO0047, SO0048 and BARI Palongshak-1 were studied against three NaCl concentrations viz; control (tap water), 8 dS/m and 12 dS/m. The average values of three years of SPAD, plant dry weight and leaf yield were presented graphically. Soil salinity was measured during experimental periods at two days intervals by soil EC Meter (HI 9833, direct soil conductivity & temperature meter, HANNA instruments) and EC Meter (Model 6061, Made in Taiwan). The study was evaluated under Randomized Complete Block Design (RCBD) with three replications. Spinach was grown in plastic pot (height 25 cm, dia 25 cm at the top and 12.5 cm at the bottom; capacity 10 L) in every year which contained around 10 kg air dried soil collected from Kodda, Kaliakoir, Upazilla, Gazipur district. Fertilizers were applied to each pot @ Urea 2.25 g, TSP 1.5 g, MOP 1.70 g, Gypsum 1.5 g and Boric Acid 1.0 g during pot filling with air dried soil (7.5 % moisture). Weeding was done as per requirements. In each pot, 10 seeds were sown on 1st week of December in every year. The seedlings were emerged within 6-7 days after sowing. The pots used five small holes at the bottom where some pieces of broken bricks kept and the brick pieces were covered with a small piece of mosquito net. Initial soil properties of pot soil are Sand 40.22%, Silt 29.64%, Clay 3.45%, Texture- clay loam p^H-6.12, Organic carbon1.60%, Total nitrogen 0.56%, Available P1.18 (mg /100g dry soil), Exchangeable K 0.25 (meq/100g dry soil) and CEC 14.60 (meq/100g dry soil). Thinning of seedling was done at 15 days after sowing by keeping five plants in each pot. Salinity treatment was imposed at 4 leaf stage at 25 days after sowing. Salt solution was prepared by dissolving calculated amount of commercially available NaCl with tap water. The salt solution was applied with an increment of 2.5 dS/m in every alternate day till respective salinity level was attained. Treatment solution was applied in excess so that the extra solution dripped from the bottom of the pots. The root and shoot sample were collected prior to harvest. The collected sample was oven dried at 72^{0}C, for 1 week. For root sampling, plastic pots were soaked in water, soil was washed with water and the roots were recovered by passing the soil water suspension through a 2 mm mesh sieve. Electrical conductivity of the top pot soil at different time after the treatment imposition during 2016-2019 (mean value of 2016-2017, 2017-2018 and 2018-2019) are given in Table 1. Data on plant height, number of leaves/plant, leaf length of the biggest leaf, leaf width of the biggest leaf, SPAD value, dry weight of plant, leaf yield (g/pot) were recorded. SPAD value was recorded by SPAD meter (502 plus, Konika, Minolta, Japan). All the recorded data were analyzed with the help of R-soft wear and mean separation was done by least significant different (LSD) test at 5% level of probability.

Table 1. Electrical conductivity of the top pot soil at different time after the treatment imposition at two days interval (mean value).

Treatment	Electrical conductivity (dS/m) at different days after sowing												
	1	3	5	7	9	11	13	15	17	19	21	23	25
Control	0.34	0.33	0.43	0.28	0.34	0.33	0.34	0.33	0.38	0.37	0.33	0.33	0.34
4 dS/m	1.87	2.36	3.90	3.80	3.74	4.00	3.67	4.00	3.80	3.90	3.64	4.20	4.22
8 dS/m	3.48	3.55	4.50	4.88	4.67	5.25	4.80	6.10	6.80	6.80	7.30	7.55	7.80
12 dS/m	5.55	5.83	6.63	6.80	8.00	8.50	9.00	10.8	10.00	10.50	10.28	10.45	10.53

Results and Discussion

Plant height

In the present investigation, plant height of all the genotypes decreased with the increased levels of salinity over the years, however there exist variability among the genotypes. In 2016-2017, plant height of eight genotypes under control and different levels of salinity is shown in Table 2. Significant variation among the genotypes was observed in plant height. The maximum plant height was found in SO-0047 (24.87 cm) followed by SO-0048 (22.86 cm), BARI Palongshak-1 (22.80 cm) at control treatment. At 4 dS/m, SO-0047 produced the maximum plant height (22.33 cm) followed by BARI Palongshak-1 (21.67 cm), SO-0048 (21.43 cm) and the shortest by the genotype BD-4333 (6.80 cm). At 8 dS/m, SO-0047 produced the tallest plant (15.67 cm) and the shortest by BD-4339 (5.10 cm). At 12 dS/m, the genotype SO-0047 also produced the maximum plant height (11.13 cm) followed by SO-0048 (10.47 cm) and BARI Palongshak-1 (10.00 cm) and the shortest by the genotype BD-4339 (5.03 cm).

Significant variation among the genotypes was also observed in plant height during 2017-2018 (Table 2). The maximum plant height was found in SO-0047 (24.26 cm) followed by BARI Palongshak-1 (22.54 cm), SO-0048 (22.38 cm) and minimum by BD-4339 (12.38 cm) in control treatment. At 4 dS/m, SO-0047 also produced the maximum plant (22.63 cm) followed by SO-0048 (20.57 cm), BARI Palongshak-1 (20.71 cm) and the minimum by BD-4339 (9.48 cm). At 8 dS/m, SO-0047 also produced the maxunun plant (15.62 cm) followed by SO-0048 (13.43 cm) and BARI Palongshak-1(13.52 cm) and the shortest by BD-4323 (6.75 cm). At 12 dS/m, the genotype SO-0047 also produced the maximum plant (11.35 cm) followed by SO-0048, (10.59 cm) BARI Palongshak-1(10.27 cm) and the minimum plant was obtained from BD-4339 (5.31 cm).

Significant variation among the genotypes was observed in plant height during 2018-2019 (Table 2). The maximum plant height was found in SO-0048 (23.30 cm) which was statistically similar to BARI Palongshak-1 (23.01 cm), SO-0047 (23.25 cm) in control treatment. At 8 dS/m, SO-0047 produced the tallest plant (16.99 cm), which was identical with SO-0048 (16.21cm) and the shortest by BARI Palongshak-1 (15.29 cm). At 12 dS/m, the genotype SO-0047 also produced the tallest plant (13.36 cm) followed by SO-0048 (12.34 cm) and the shortest by BARI Palongshak-1 (11.29 cm). Bhatti *et al*., 2021 reported that the growth and yield parameters of spinach genotypes were constantly decreased with an increase in EC levels of irrigation water. Ors and Suarez (2016) studied spinach (cv. Racoon) response under saline water treatments and reported that higher salinity decreased shoot height of the plant.

Table 2. Effect of different levels of salinity on plant height of spinach genotypes

Genotypes	2016-2017 Plant height (cm) Salinity levels (dS/m)				2017-2018 Plant height (cm) Salinity levels (dS/m)				2018-2019 Plant height (cm) Salinity levels (dS/m)		
	Control	4	8	12	Control	4	8	12	Control	8	12
SO-0046	22.06	21.00	9.17	8.90	-	-	-	-	-	-	-
SO-0047	24.87	22.33	15.67	11.13	24.26	22.63	15.62	11.35	23.25	16.99	13.36
SO-0048	22.86	21.43	10.84	10.47	22.38	20.57	13.43	10.59	23.30	16.21	12.34
BD-4323	12.60	11.13	5.37	5.20	12.46	10.48	6.75	5.59	-	-	-
BD-4333	19.05	6.80	6.10	5.36	16.38	12.73	6.76	5.59	-	-	-
BD-4339	9.90	9.47	5.10	5.03	12.38	9.48	7.46	5.31	-	-	-
BD-1062	17.93	12.46	8.27	8.13	15.59	12.47	8.62	6.69	-	-	-
BARI Palongshak-1	22.80	21.67	10.93	10.00	22.54	20.71	13.32	10.27	23.01	15.29	11.29
CV (%) 11.26					2.24				3.24		
LSD (0.05) 2.38					2.27				1.38		

In 2017-18, SO-0046 was not germinated. Only three best genotypes (SO-0047, SO-0048 and BARI Palongshak-1) were used in 2018-19.

Number of leaves/plant

Number of leaves/plant of eight genotypes in 2016-2017 under control and different levels of salinity is shown in Table 3. In control treatment, number of leaves/plant was found maximum in SO-0047 (15.20) followed by SO-0048 (14.97), BARI Palongshak-1 (14.92) and the lowest number of leaves/plant was found in BD-4333 (11.25). At 4 dS/m, SO-0047 also produced the maximum number of leaves/plant (13.69) which was statistically similar to SO-0048 (13.54), BARI Palongshak-1 (13.48 cm) and BD-4333 produced the least number of leaves/plant (8.58). At 8 dS/m, SO-0047 produced the maximum leaves/plant (8.85) which was statistically identical to SO-0046 (8.84), SO-0048 (8.84) and BARI Palongshak-1 (8.80). But at 12 dS/m, maximum number of leaves/plant was obtained from the genotype SO-0047 (7.84) followed by SO-0048 (7.80) and minimum leaves/plant (5.25) was obtained from BD-4333 and BD-4339 genotypes.

In 2017-2018, number of leave/plant of seven genotypes under control and different levels of salinity is shown in Table 3. Number of leaves/plant was found maximum in SO-0047 (14.67) followed by SO-0047 (14.60), BARI Spinach-1 (14.52) and minimum number of leaves/plant (11.25) was obtained from BD-4333 in control treatment. At 4 dS/m, SO-0047 also produced the maximum number of leaves/plant (12.93) followed by SO-0048 (12.86), BARI Palongshak-1 (12.86) and BD-4323 produced the least number of leaves/plant (9.25). At 8 dS/m, SO-0047 also produced the maximum number of leaves/plant (12.25) and minimum (5.67) was found in BD-1062. At 12 dS/m, maximum number of leaves/plant was also obtained from the line SO-0047 (8.93) followed SO-0048 (8.93), BARI Palongshak-1 (8.87) and the minimum number of leaves/plant (5.31) was obtained from BD-1062. The genotype SO0048 and BARI Palongshak-1 also did not differ significantly in terms of number of leaves/plant at 12 dS/m salinity level.

Performance of three genotypes in respect of number of leaves/plant in 2018-2019 under control and different levels of salinity are shown in Table 3. Maximum number of leaves/per plant was found in SO0047 (14.84) followed by SO-0048 (14.80) and BARI palongshak-1 (14.31), but there was no significant difference among them in control treatment. At 8 dS/m, SO-0047 also produced the maximum number of leaves/plant (11.08) followed by SO0048 (10.57) and BARI Palongshak-1 produced the least number of leaves/plant (8.63). At 12 dS/m, maximum number of leaves/plant was obtained from the line SO-0047 (10.31) followed by SO0048 (9.93) and minimum was obtained from BARI Palongshak-1 (7.51). The growth and yield parameters of spinach plants were decreased with increasing EC levels of saline water. The decline in growth and yield parameters in spinach genotypes may be attributed to many factors including lowering of water potential by the salts (Flowers and Flowers, 2005). Bhatti *et al*., (2021) reported that the plants irrigated with EC 6.0 and 8.0 dS/m had less number of leaves than the plants that were irrigated with canal water.

Table 3. Effect of different levels of salinity on number of leaves/plant of spinach genotypes

Genotypes	2016-2017				2017-2018				2018-2019		
	Number of leaves/plant				Number of leaves/plant				Number of leaves/plant		
	Salinity levels (dS/m)				Salinity levels (dS/m)				Salinity levels (dS/m)		
	Control	4	8	12	Control	4	8	12	Control	8	12
SO-0046	11.65	10.25	8.84	6.80	-	-	-	-	-	-	-
SO-0047	15.20	13.69	8.85	7.84	14.67	12.93	12.25	8.93	14.84	11.08	10.31
SO-0048	14.97	13.54	8.84	7.80	14.60	12.86	11.26	8.93	14.80	10.57	9.93
BD-4323	11.42	9.25	7.25	6.48	11.33	9.25	7.25	6.85	-	-	-
BD-4333	11.25	8.58	6.25	5.25	11.25	8.27	6.93	6.51	-	-	-
BD-4339	12.52	9.65	6.93	5.25	12.33	9.80	6.82	5.63	-	-	-
BD-1062	12.93	9.65	7.25	6.47	12.33	9.25	5.67	5.31	-	-	-
BARI Palongshak-1	14.92	13.48	8.80	6.84	14.52	12.86	10.00	8.87	14.31	8.63	7.51
CV (%) 3.70					2.12				7.24		
LSD (0.05) 0.29					0.17				0.65		

In 2017-18, SO-0046 was not germinated. Only three best genotypes (SO-0047, SO-0048 and BARI Palongshak-1) were used in 2018-19.

Leaf length and leaf width

There was significant variation in leaf length and leaf width among the genotypes under control and saline condition in 2016-2017 (Table 4 and 5). The maximum leaf length was obtained from SO-0047 (25.75 cm) followed by SO-0048 (25.47 cm) and the minimum from BD-4339 (15.06 cm) in control treatment. At 4 dS/m, SO-0047 also gave the maximum t leaf length (21.81 cm) followed by SO-0048 (21.50 cm) and the lowest in BD-4339 (8.36 cm). At 8 dS/m, SO-0047 again gave the highest leaf length (19.11 cm) and the lowest in BD-4339 (6.95 cm). At 12 dS/m, the maximum leaf length (17.57 cm) was obtained from SO-0047 and the lowes(5.38 cm) in BD-4323. The maximum leaf width (10.63 cm) was obtained from SO-0046 followed by SO-0047 (10.59 cm) and the minimum (5.66 cm) from BD-4339 at control treatment. At 4 dS/m, SO-0047 gave the maximum leaf width (9.54 cm) followed by SO-0048 (9.18 cm) and the lowest (5.16 cm) was obtained from BD-4333. At 8 dS/m, SO-0047 gave the maximum leaf width (7.85 cm) closely followed by SO-0048 (7.54 cm), BARI Palongshak-1. (7.50 cm) and the lowest (3.33 cm) in BD-1062. At 12 dS/m, SO-0047 also gave the highest leaf width (7.24 cm) and the lowest (2.21 cm) from the genotype BD-4323.

In 2017-2018, the maximum leaf length (24.28 cm) was obtained from SO-0047 followed by SO-0048 (24.24 cm) and the minimum (16.36 cm) from BD-4339 in control treatment (Table 4). At 4 dS/m, SO-0047 gave the highest leaf length (22.65 cm) followed by SO-0048 (22.37 cm) and the lowest (8.28 cm) from the genotype BD-4339. At 8 dS/m salinity level, SO-0048 gave the maximum leaf length (18.33 cm) followed by SO-0047 (18.28 cm) and the lowest (5.85 cm) was recorded from BD-4323. At 12 dS/m, SO-0047 gave the highest leaf length (17.52 cm) and the lowest (5.24 cm) was recorded from BD-4323. The maximum leaf width (9.68 cm) was obtained from SO-0047 followed by SO-0048 (9.57) and the minimum (6.03 cm) from BD-4339 in control treatment (Table 5). At 4 dS/m, SO-0047 gave the maximum leaf width (8.85 cm) followed by SO-0048 (8.83 cm) and the lowest (4.78 cm) in BD-4339. At 8 dS/m, BARI Palongshak-1 gave the maximum leaf width (7.77 cm) followed by SO-0047. (7.67 cm), SO-0048 (7.57 cm) and the lowest (3.28 cm) was recorded in BD-4339. At 12 dS/m, SO-0047 gave the maximum leaf width (7.25 cm) which was identical to SO-0048 (7.25 cm) and the lowest (2.22 cm) was recorded in BD-4339 (Table 5).

In 2018-2019, there was significant variation in leaf length and leaf width among the genotypes under control and saline conditions and these parameters decreased with the increasing salinity level up to 12 dS/m in all the genotypes (Table 4 and 5). Maximum leaf length was recorded from SO-0047 (24.66 cm) and the lowest from BARI Palongshak-1 (23.00 cm) at control. At 8 dS/m salinity level, the genotype SO-0047 gave maximum leaf length (22.09 cm) followed by SO-0048 (19.69 cm) and BARI Palongshak -1 produced the lowest leaf length (16.22 cm) At 12 dS/m, maximum leaf length (17.31 cm) was found in SO-0047 followed by BARI Palongshak-1 (14.34 cm) and minimum (13.07 cm) in SO-0048. There was no significant difference among SO-0047, SO-0048 and BARI Palongshak-1 in leaf width in control treatment. At 8 dS/m, the genotype SO-0047 gave the highest leaf width (8.38 cm) and SO-0048 produced the lowest leaf width (7.11 cm). At 12 dS/m, maximum leaf width (8.27 cm) was found in SO-0047 and minimum (6.28 cm) in BARI Palongshak-1. Batti *et al*. (2021) reported that a significant decrease in growth, leaf length, width was observed when spinach plants were irrigated with saltwater of 8.0 dS m^{-1} salinity level.

SPAD value

In 2016-2017, the maximum SPAD value (48.35) was obtained from SO-0047 followed by BARI Palongshak-1 (48.33) and the minimum (46.13) from the genotype BD-4339 in control treatment (Table. 6). At 4 dS/m salinity level, SO-0047 gave the highest SPAD value (51.49) and the lowest SPAD value (47.83) from the genotype BD-1062. At 8 dS/m, SO-0047 gave the highest SPAD value (53.97) and the lowest SPAD value (47.89) in BD-1062. At 12 dS/m, SO-0047, SO-0048 gave the highest SPAD value (46.96) and the lowest SPAD value (38.03) from the genotype BD-1062.

In 2017-2018, the maximum SPAD value (47.15) was obtained from SO-0047 followed by SO-0048 (47.14) and the minimum (45.05) from BD-4323 in control treatment (Table. 6). At 4 dS/m salinity level, SO-0047 gave the highest SPAD value (50.58) and the lowest SPAD value (45.84) was recorded in BD-4339. At 8 dS/m, SO-0047 gave the maximum SPAD value (55.44) followed by SO-0048 (55.28) and the lowest SPAD value (48.87) in the genotype BD-4323. At 12 dS/m, SO-0047 gave the maximum SPAD value (44.23) followed by SO-0048 (44.15) and the lowest SPAD value (37.25) in BD-1062.

In 2018-2019, the maximum SPAD value (48.75) was obtained from SO-0047 followed by SO-0048 (45.20) and the minimum (38.91) from BARI Palongshak-1 in control treatment (Table. 6). At 8 dS/m, SO-0048 gave the maximum t SPAD value (56.32) followed by SO-0047 (56.15) and the lowest SPAD value in BARI Palongshak-1 (45.09). At 12 dS/m, and SO-0048 gave the maximum SPAD value (50.98) followed by SO-0047 (50.05) and the lowest SPAD value (35.85) in BARI Palongshak-1.

In avearage SPAD value of three years, the maximum SPAD was obtained from SO-0047 (48.08) followed by SO-0048 (46.33) and the least from BARI Palongshak-1 (44.18) at control treatment (Figure 1). At 8 dS/m, the maximum SPAD value was recorded from SO-0047 (55.19) followed by SO-0048 (54.48) and minimum value (49.43) from BARI Palongshak-1. At 12 dS/m, the maximum SPAD value (47.36) was obtained from SO-0048 followed by SO-0047 (47.08) and minimum value (39.82) BARI Palongshak-1. Salinity treatment decreased chlorophyll content and increased chlorophyll content without salt stress (Xu and Mou, 2016). Spinach plants treated with saline irrigation water maintained their SPAD chlorophyll levels up to 8 dS/m, but high saline concentration it was decreased.

Table 4. Effect of different levels of salinity on leaf length of spinach genotypes

Genotypes	2016-2017				2017-2018				2018-2019		
	Leaf length (cm)				Leaf length (cm)				Leaf length (cm)		
	Salinity levels (dS/m)				Salinity levels (dS/m)				Salinity levels (dS/m)		
	Control	4	8	12	Control	4	8	12	Control	8	12
SO-0046	25.30	14.75	10.39	6.61	-	-	-	-	-	-	-
SO-0047	25.75	21.81	19.11	17.57	24.28	22.65	18.28	17.52	24.66	22.09	17.31
SO-0048	25.47	21.50	18.47	16.79	24.24	22.37	18.33	15.16	24.45	19.69	13.07
BD-4323	22.21	17.39	6.33	5.38	21.16	17.82	5.85	5.24	-	-	-
BD-4333	18.50	15.69	8.97	6.33	17.73	13.62	7.84	6.01	-	-	-
BD-4339	15.06	8.36	6.95	6.26	16.36	8.28	6.14	5.84	-	-	-
BD-1062	18.02	16.73	9.01	6.63	18.24	14.98	9.36	6.25	-	-	-
BARI Palongshak-1	24.40	21.29	16.27	13.71	23.89	20.77	17.15	15.24	23.00	16.22	14.34
CV (%)	2.81				2.54				5.78		
LSD (0.05) 0.33					0.31				4.17		

In 2017-18, SO-0046 was not germinated. Only three best genotypes (SO-0047, SO-0048 and BARI Palongshak-1) were used in 2018-19

Table 5. Effect of different levels of salinity on leaf width of spinach genotypes

Genotypes	2016-2017				2017-2018				2018-2019		
	Leaf width (cm)				Leaf width (cm)				Leaf width (cm)		
	Salinity levels (dS/m)				Salinity levels (dS/m)				Salinity levels (dS/m)		
	Control	4	8	12	Control	4	8	12	Control	8	12
SO-0046	10.63	6.90	3.20	2.54	-	-	-	-	-	-	-
SO-0047	10.59	9.54	7.85	7.24	9.68	8.85	7.67	7.25	8.39	8.38	8.27
SO-0048	8.74	9.18	7.54	6.67	9.57	8.83	7.57	7.25	7.82	7.11	6.55
BD-4323	8.91	5.68	4.28	2.21	7.93	6.15	5.28	3.56	-	-	-
BD-4333	6.96	5.16	4.60	3.35	6.42	5.24	4.33	3.18	-	-	-
BD-4339	5.66	5.31	3.37	2.52	6.03	4.78	3.28	2.22	-	-	-
BD-1062	7.94	6.67	3.33	2.28	8.07	7.16	4.16	2.23	-	-	-
BARI Palongshak-1	8.91	8.89	7.50	5.83	8.15	7.86	7.77	6.25	7.78	7.34	6.28
CV (%)	8.06				2.84				4.67		
LSD (0.05) 0.41					0.13				0.98		

In 2017-18, SO-0046 was not germinated. Only three best genotypes (SO-0047, SO-0048 and BARI Palongshak-1) were used in 2018-19.

Table 6. Effect of different levels of salinity on SPAD value of spinach genotypes

Genotypes	2016-2017				2017-2018				2018-2019		
	SPAD value				SPAD value				SPAD value		
	Salinity levels (dS/m)				Salinity levels (dS/m)				Salinity levels (dS/m)		
	Control	4	8	12	Control	4	8	12	Control	8	12
SO-0046	47.56	48.78	49.17	38.41	-	-	-	-	-	-	-
SO-0047	48.35	51.49	53.97	46.96	47.15	50.58	55.44	44.23	48.75	56.15	50.05
SO-0048	46.65	50.63	51.84	46.96	47.14	48.67	55.28	44.15	45.20	56.32	50.98
BD-4323	46.37	48.55	49.20	40.50	46.15	48.85	48.87	38.67	-	-	-
BD-4333	46.65	48.40	48.57	37.45	45.05	48.53	50.24	37.25	-	-	-
BD-4339	46.13	48.58	49.20	38.25	45.25	45.84	50.47	38.06	-	-	-
BD-1062	46.61	47.83	47.89	38.03	46.05	48.28	50.58	37.25	-	-	-
BARI Palongshak-1	48.33	50.60	50.94	42.47	45.25	48.56	52.25	41.15	38.91	45.09	35.85
CV (%) 4.75					2.44				8.27		
LSD (0.05) 0.23					0.17				5.96		

In 2017-18, SO-0046 was not germinated. Only three best genotypes (SO-0047, SO-0048 and BARI Palongshak-1 were used in 2018-19.

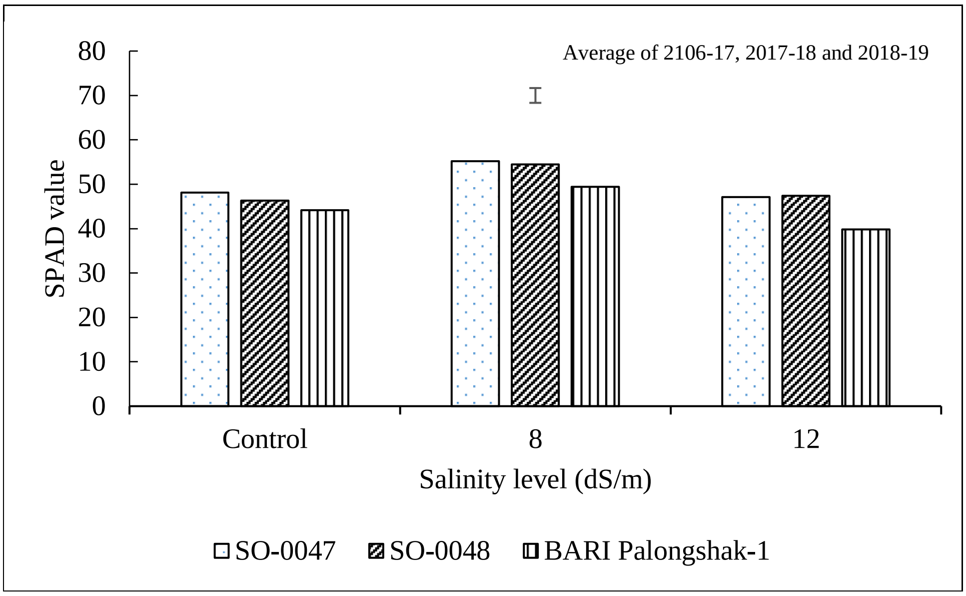

Figure 1. Influence of different levels of salinity on SPAD value of spinach genotypes.

Dry weight of plant

In 2016-2017 maximum dry weight was found in control treatment in all genotypes compared to salt concentrations (Table 7). Dry matter was dcreased gradually with the increasing salinity levels. The genotype SO-0047 produced the maximum total dry matter/plant (4.07 g) and minimum dry weight (1.70 g) from BD-4339 at control (Table 7). At 4 dS/m salinity level, the genotype SO-0047 produced the maximum dry matter (3.51 g) and minimum dry weight (1.19 g) from BD-4339. At 8 dS/m salinity level, the genotype SO-0047 produced the maximum dry matter (2.54 g) followed by SO-0048 (2.50 g) and minimum dry weight (0.45 g) from BD-4333. At 12 dS/m salinity level, the genotype SO-0047 also produced the maximum total dry matter (1.54 g) and minimum dry weight (0.35 g) from the genotype BD-4333.

In 2017-2018 dry matter was dcreased gradually with the increasing salinity levels and the genotype SO-0047 produced the maximum total dry matter/plant (4.12 g) and minimum dry weight (2.52 g) from BD-4323 in control treatment (Table 7). At 4 dS/m salinity level, the genotype SO-0047 produced the maximum dry matter (3.40 g) followed by SO-0048 (3.35 g), BARI Palongshak-1 (3.24 g) and the lowest dry matter (1.14 g) from the genotype BD-4333. Dry matter was found higher in control treatment in all genotypes . At 8 dS/m salinity level, the genotype SO-0047 produced the maximum dry matter (2.64 g) followed by SO-0048 (2.43 g) and the lowest dry matter (0.53 g) in BD-4333. At 12 dS/m salinity level, the genotype SO-0047 also produced the maximum dry matter (1.47 g) and the lowest dry matter (0.37 g) from the genotype BD-1062.

Table 7. Effect of different level of salinity on total dry weight of spinach genotypes

Genotypes	2016-2017				2017-2018				2018-2019		
	Dry weight/plant (g)				Dry weight/plant (g)				Dry weight/plant (g)		
	Salinity levels (dS/m)				Salinity levels (dS/m)				Salinity levels (dS/m)		
	Control	4	8	12	Control	4	8	12	Control	8	12
SO-0046	3.10	2.54	0.67	0.47	-	-	-	-	-	-	-
SO-0047	4.07	3.51	2.54	1.54	4.12	3.40	2.64	1.47	3.60	2.95	2.19
SO-0048	3.81	3.05	2.50	1.08	3.97	3.35	2. 43	1.17	2.93	2.28	1.15
BD-4323	2.38	1.47	1.12	0.50	2.52	1.40	1.24	0.54	-	-	-
BD-4333	1.70	1.19	0.45	0.35	2.63	1.14	0.53	0.38	-	-	-
BD-4339	2.19	1.34	0.60	0.49	2.91	1.34	0.62	0.51	-	-	-
BD-1062	2.85	1.31	1.01	0.39	2.99	1.22	1.11	0.37	-	-	-
BARI Spinach-1	3.70	3.01	1.96	1.03	3.6	3.24	2.29	1.14	2.49	2.05	1.11
CV (%)	12.79				4.99				4.84		
LSD (5%)	0.18				0.23				0.33		

In 2017-18, SO-0046 was not germinated. Only three best genotypes (SO-0047, SO-0048 and BARI Palongshak-1) were used in 2018-19.

In 2018-19, dry weight of plant i.e. total dry matter/plant (TDM) was dcreased gradually with the increasing salinity level and the genotype SO-0047 (3.60 g) produced the maximum total dry matter/plant and the lowest in BARI Palongshak-1 (2.49 g) in control treatment (Table 7). At 8 dS/m salinity level, SO-0047 (2.95 g) gave the maximum TDM and minimum from BARI Palongshak-1 (2.05 g). At 12 dS/m salinity level, SO-0047 (2.19 g) also gave the highest TDM and minimum from BARI Palongshak-1 (1.11 g). In 2018-19, at 8 and 12 dS/m, maximum TDM (2.95 g and 2.19 g respectively) was recorded from SO0047.

In avearage dry weight of three years, the maximum dry weight of plant was obtained from SO0047 (3.93 g) followed by SO-0048 (3.57) and the least (3.26 g) from BARI Palongshak-1 in control treatment (Figure 2). At 8 dS/m, the highest TDM (2.71 g) was recorded from SO-0047 and minimum from BARI Palongshak-1 (2.10 g). At 12 dS/m, SO-0047 also produced maximum TDM (1.73 g) and SO-0048, BARI Palongshak-1 gave identical TDM. Salinity significantly decreased dry weight of leaf relative to controls after 4 weeks of treatment (Xu and Mou, 2016). In a greenhouse study on spinach, irrigated by a range of saline waters, the fresh and dry weights were decreased with increasing the salinity levels of saline waters (Suleiman *et al*., 2002). Bhatti *et al*., 2021 reported that the growth and yield parameters (number of leaves, and fresh and dry weight) of spinach genotypes were significantly decreased with increasing the EC levels of saline water.

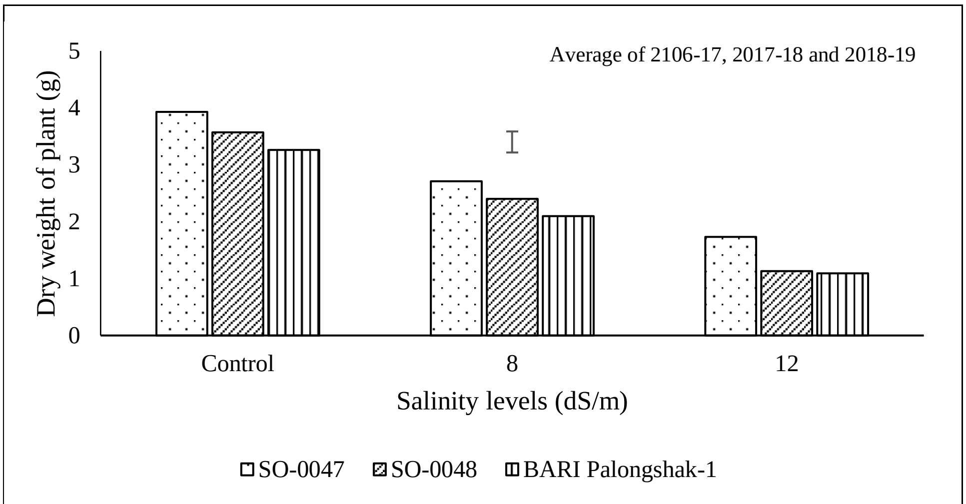

Fig. 2. Influence of different levels of salinity on plant dry weight of spinach genotypes.

Leaf yield

Leaf yield/pot in all the genotypes was dcreased gradually with the increasing salinity levels (Table. 8). In 2016-2017, SO-0047 significantly recorded the highest leaf yield/pot (234.21 g/pot) and the genotype BD-4333 gave the lowest leaf yield (179.25 g/pot) in control treatment. At 4 dS/m saliity level, the highest leaf yield (223.25 g/pot) was recorded from SO0047 and minimum (145.24 g/pot) from the genotype BD-4333.

In 2017-2018, the genotype SO-0047 significantly recorded the maximum leaf yield/pot (211.81 g/pot) followed by SO-0048 (210.52 g/pot) and BD-4333 gave the lowest leaf yield (180.43 g/pot) at control treatment (Table. 8). At 4 dS/m salinity level, maximum leaf yield (189.10 g/pot) was recorded from SO0047 followed by SO-0048 (187.61 g/pot) and minimum from BD-4333 (138.31 g/pot). At 8 dS/m salinity level, maximum leaf yield (135.72 g/pot) was recorded from SO-0047 followed by SO-0048 (134.51 g/pot) and minimum from BD-4333 (75.44 g/pot). At 12 dS/m, the maximum leaf yield was recorded from SO-0047 (81.60 g/pot) followed by SO-0048 (79.84 g/pot) and minimum from the genotype BD-4323 (53.27 g/pot).

In 2018-19, Leaf yield/pot was dcreased gradually with the increasing salinity level (Table. 8). At control treatment, SO-0047 significantly recorded the maximum leaf yield/pot (216.66 g) followed by SO-0048 (216.61 g/pot) and BARI Palongshak -1 (205.22 g/pot) lowest leaf yield. At 8 dS/m salinity level, maximum leaf yield was recorded from SO0047 (180.97 g/pot) followed by SO-0048 (179.23 g/pot) and minimum from BARI Palongshak-1 (128.45 g/pot). At 12 dS/m salinity level, the highest leaf yield was also recorded from SO-0047 (83.83 g/pot) followed by SO-0048 (82.77 g/pot) and its minimum value (66.50 g/pot) was obtained from BARI Palongshak-1.

In avearage leaf yield of three years, the maximum leaf yield was obtained from SO-0047 (220.89 g/pot) followed by SO-0048 (218.04 g/pot) and the least from BARI Palongshak-1 (205.23 g/pot) in control treatment (Figure 3). At 8 dS/m salinity level, the highest leaf yield was recorded from SO-0047 (150.61 g/pot) and minimum (128.71 g/pot) from BARI Palongshak-1. At 12 dS/m, the genotype SO-0047 also produced maximum leaf yield (82.34 g/pot) followed by the genotype SO-0048 and BARI Palongshak. Increasing soil and/or irrigation water salinities can decrease spinach (*Spinacia oleracea* L.) yield (Ors and Suarez, 2017). Bhatti *et al*. (2021) reported that the growth and yield parameters of spinach genotypes were constantly decreased with an increase in EC levels of irrigation water. The decline in yield parameters in spinach genotypes may be attributed to many factors including lowering of water potential by the salts (Flowers and Flowers, 2005). Negative impacts of salinity on spinach growth, yield and physiological attributes have been documented previously (Turhan *et al*., 2013; Xu and Mou, 2016). Ors and Suarez (2016) studied spinach (cv. Racoon) response under saline water treatments and reported that higher salinity decreased all vegetative and yield parameters.

Table 8. Effect of different level of salinity on leaf yield of spinach genotypes during 2016- 17, 2017-18 and 2018-19

Genotypes	2016-2017				2017-2018				2018-2019		
	Leaf yield (g)				Leaf yield (g)				Leaf yield (g)		
	Salinity levels (dS/m)				Salinity levels (dS/m)				Salinity levels (dS/m)		
	Control	4	8	12	Control	4	8	12	Control	8	12
SO-0046	219.45	135.14	85.25	64.87	-	-	-	-	-	-	-
SO-0047	234.21	223.25	135.14	81.58	211.81	189.10	135.72	81.60	216.66	180.97	83.83
SO-0048	226.98	162.61	80.19	75.66	210.52	187.61	134.51	79.84	216.61	179.23	82.77
BD-4323	188.56	145.24	76.22	52.24	185.25	138.90	78.26	54.24	-	-	-
BD-4333	179.25	155.32	74.65	50.27	180.43	138.31	75.44	53.27	-	-	-
BD-4339	188.65	148.25	75.00	62.65	185.50	150.20	77.18	61.77	-	-	-
BD-1062	200.25	165.24	80.00	60.28	198.48	167.51	78.25	62.64	-	-	-
BARI Palongshak-1	209.84	203.24	128.54	65.45	200.62	168.90	129.15	74.80	205.22	128.45	66.50
CV (%)	6.74				1.75				1.32		
LSD (5%)	7.53				1.83				1.81		

In 2017-18, SO-0046 was not germinated. Only three best genotypes (SO-0047, SO-0048 and BARI Palongshak-1 were used in 2018-19.

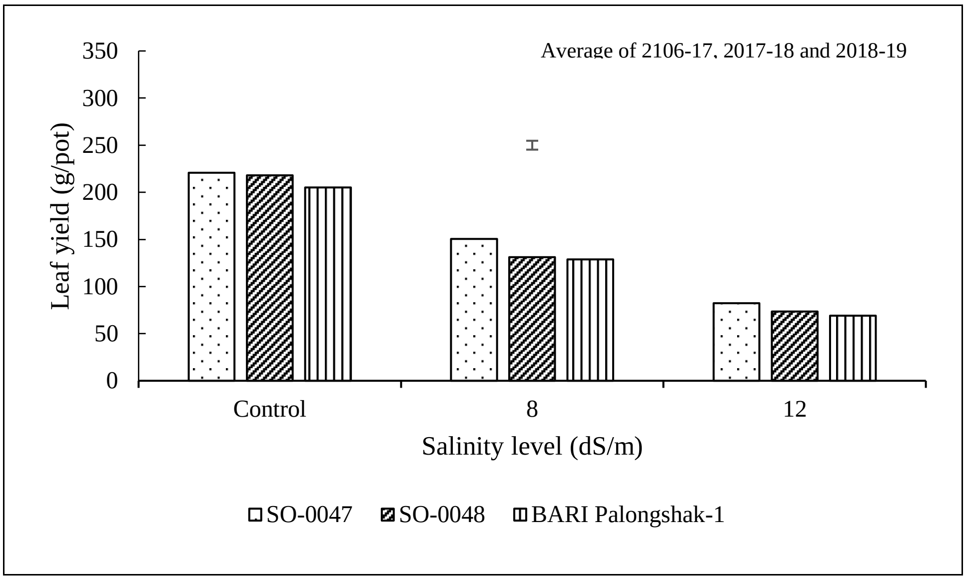

Figure 3. Influence of different levels of salinity on leaf yield/pot of spinach genotypes.

Conclusion

Based on the above results, it might be concluded that the genotype SO-0047 was more salt tolerant than other genotypes. This genotype might be recommended as a variety for cultivation in the saline areas of Bangladesh. The genotype SO-0048 could be used as breeding material for development of saline tolerant spinach variety.

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