Bangladesh Agron. J. 2021, 24(1): 43-55

PHYSIOLOGICAL AND YIELD RESPONSES OF SOME SELECTED RAPESEED/MUSTARD GENOTYPES TO SALINITY STRESS

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(Received: 12 February 2021, **Accepted:** 19 February 2021)

Keywords: Salnity, rapeseed/mustard, toerant genotypes, physiological parameters, seed yield

Abstract

An experiment on rapeseed/mustard genotypes was conducted during 2019-2020 rabi season in vinyl house of Plant Physiology Division of Bangladesh Agricultural Research Institute (BARI), Gazipur to find out the salt-tolerant genotypes based on the responses of their physiological parameters and yield. Five selected rapeseed/ mustard genotypes (V_1= Jun-536, V_2 = BJDH-12, V_3 = BD-10115, V_4 = BARI Sarisha-14, V_5 = BD-6950) were tested at three salinity levels (S_0= 0, S_1= 5 and S_2=10 dS m^{-1}). Irrespective of the genotypes, salinity stress showed a negative effect on the measured physiological parameters as well as seed yield. Leaf chlorophyll contents, leaf area, leaf photosynthetic rate and total dry matter (TDM) were reduced due to salinity stress which ultimately affected seed yield irrespective of the genotypes. However, these parameters were less affected by the salinity in V_1 and V_2 genotypes compared to others. Sodium and potassium ion contents and their ratios (K^+/Na^+) in leaf tissues were significantly affected by salinity stress. Among the genotypes, V_1 and V_2 showed higher K^+/Na^+ ratios in leaf under both the salinity treatments, and that phenomenon indicated their higher tolerance to salinity than the other genotypes. Catalase (CAT), Peroxidase (POD) activity and Malondialdehyde (MDA) content of the genotypes increased due to salinity stress with variability among the genotypes. The higher CAT and POD activity with lower MDA content was found in V_1 and V_2 genotypes which indicated their better salt tolerance ability compared to others. These genotypes also showed higher seed yield under both the salinity levels (5 and 10 dS m^{-1}) compared to other genotypes. Based on the responses of physiological parameters and seed yield to salinity, the genotypes Jun-536(V_1) and BJDH-12(V_2) could be considered relatively tolerant to salinity stress.

Introduction

Salinity is an important limiting factor that causes low crop yield with inferior quality. The adverse effects of salinization cause both osmotic stress and ionic toxicity in plants, leading to secondary stresses such as nutritional disorders and oxidative stress. One of the most detrimental effects of salinity stress is the accumulation of Na^+ and Cl ions in tissues of plants exposed to soils with high NaCl concentrations. Entry of both Na^+ and Cl into the cells causes' severe ion imbalance and the excess uptake of them might cause significant physiological disorder(s). Generation of reactive oxygen species (ROS) like singlet oxygen, superoxide radical, hydrogen peroxide, and hydroxyl radicals exposed to salinity stress causes injury to plants. The genotypes which produce more ROS scavenging enzymes under stress can be considered as comparatively tolerant genotype.

Among the oilseed crops grown in Bangladesh, rapeseed/mustard (*Brassica* spp.) holds the first position acarage and production. It constitutes an important source of edible oil and is grown under diverse agro-ecological situations. This crop can also be grown successfully in the coastal districts of southern Bangladesh where the cropping intensity is lower than in other parts of the country. However, most of the southern districts of the country are under saline zones which cover an area of 25-30% of the total cultivable land (SRDI, 2012). Though soil salinity is the most dominant factors limiting crop production in the coastal areas of Bangladesh during dry season, salt-tolerant rapeseed/mustard can bring substantial changes in the agricultural practices in those saline soils. Genetic variations in salt tolerance exist in the glycophytes, and the degree of salt tolerance varies with plant species and varieties within a species. There also exist differences in sensitivity to salinity among Brassica cultivars which need to be found out in a systematic study. Therefore, the present study was conducted to find the tolerant mustard-rapeseed genotype(s) based ontolerance of physiological and yield parameters.

Materials and Methods

A pot experiment on mustard-rapeseed was conducted in the vinyl house of Plant Physiology Division, BARI, Gazipur during the rabi season of 2019-2020. Five selected mustard/rapeseed genotypes, namely: V_1= Jun-536, V_2= BJDH-12, V_3= BD-10115, V_4= BARISarisha-14, V_5= BD-6950 was grown in three salinity levels (S_0 = 0, S_1 = 5 and S_2 =10 dS m^{-1}) in pots inside a plastichouse of Plant Physiology Division, BARI, Gazipur during rabi season of 2019-2020. Salinity was imposed at 20 days after sowing by adding NaCl solution. Salt solution was prepared by dissolving calculated amount of Lab grade NaCl with pond water. Salt solution was applied with an increment of 5dS m^{-1} every alternate day until desired salinity levels were attained. In the control treatment, pond water was used which salinity level was 0.2 dS m^{-1}. Salinity levels were maintained by monitoring and adding salt solution when required up to maturity. The experiment was laid out in a Factorial Randomized Complete Block design with 5 replications. Plastic pots (top dia: 25 cm, bottom dia: 18 cm and height 25 cm; 12 kg soil) were filled up with soil and cowdung (4:1). Seeds were sown in each pot on 12 November 2019. Fertilizers were applied @100-30-80-20-3-1 $kgha^{-1}$NPKSZnB. Half of N and all other fertilizers were applied as basal and the remaining N was applied at 20 days after sowing (DAS). Irrigation was done as and when required for maintaining adequate soil moisture. After emergence plants were thinned to three plants in each pot. Plants from three pots were sampled for leaf area and dry matter measurement at different growth stages. Sampled plants were separated into leaf, stem, and siliqua depending on growth stages. Leaf area was measured by an automatic area meter (LI-3100 C; LI-Cor, USA). Plant parts were dried in an oven for 72 hours at 70°C and dry weight was recorded. At harvest yield and yield components data were collected from three pots and analyzed statistically and mean separation was done by LSD test at 5% level of significance using data processing software.

Chlorophyll estimation

Leaves of each genotype were properly cut into small pieces and weighed 0.5 g and were taken for chlorophyll estimation at 55 DAS. Chlorophyll a, chlorophyll b and total chlorophyll were estimated following Arnon's method (Arnon, 1949). The absorbance of the solution was read at 645 and 663 nm for Chlorophyll a, Chlorophyll b and total chlorophyll.

Calculation:
Chlorophyll a (mg g^{-1}) = {12.7 (D663) - 2.69 (D645)}×V/(1000×w)
Chlorophyll b (mg g^{-1}) = {22.9 (D645) - 4.68 (D663)}×V/(1000×w)

Total chlorophyll (mg g^{-1}) = 20.2 (D645) + 8.02 (D663)×V/(1000×w)
Where, D = optical density; V = final volume of 80% acetone (ml); w = fresh weight of sample taken (g)

Leaf photosynthesis measurement: Leaf photosynthetic rate was measured on 50 DAS by a portable photosynthesis system (Li-6800, USA). Fully expanded third leaf from the top was used for this purpose and the measurement was carried out from 10 am to 11.30 pm.

Sodium and potassium ion uptake measurement: At 55 DAS, fully expanded third leaf from the top was collected from each treatment for determining of sodium and potassium ion content in leaf tissue. Cell sap of leaf was extracted from the leaf using mortar and pistil. LAQUAtwin Sodium Ion Meter (Na-11, Horiba, Japan) and LAQUAtwin Potassium Ion Meter (K-11, Horiba, Japan) were used for Na^+ and K^+ determination, respectively.

Enzyme Extraction and Assays

Using a pre-cooled mortar and pestle, 0.5 g of leaf tissue was homogenized in 1 ml of 50 mMice-cold K-phosphate buffer (pH 7.0) containing 100 mMKCl, 1 mMascorbate, 5 mMβ-mercaptoethanol, and 10% (w/v) glycerol. The homogenates were centrifuged at 11,500 *g* for 10 min, and the supernatants were used for determining of enzyme activity. All procedures were performed at 0°C to 4 C.

Determination of Protein

The protein concentration of each sample was determined following the method of Bradford (1976) using BSA as a protein standard where 5, 10, 15, 20, 25 $\mu g \mu l^{-1}$ protein concentrations were used to prepare the standard curve.

Peroxidase (POD, EC 1.11.1.7): POD activity was estimated according to Hemeda and Klein (1990). The reaction mixture contained 25 mM K-P buffer (pH 7.0), 0.05% guaiacol, 10 mM H_2O_2 and enzyme. The activity was determined by the increase in absorbance at 470 nm due to guaiacol oxidation for 1 min using extinction coefficient of 26.6 mM^{-1} cm^{-1}.

Catalase (CAT, EC: 1.11.1.6): CAT activity was measured according to the method of Hossain *et al.* (2010) by monitoring the decrease of absorbance at 240 nm for 1 min caused by the decomposition of H_2O_2. The reaction mixture contained 50 mM K-phosphate buffer (pH 7.0), 15 mM H_2O_2, and enzyme solution in a final volume of 0.7 ml. The reaction was initiated with enzyme extract, and the activity was calculated using the extinction coefficient of 39.4 M^{1} cm^{1}.

Lipid peroxidation

The level of lipid peroxidation in plant tissues was expressed as 2-thiobarbituric acid (TBA) reactive metabolites, mainly malondialdehyde (MDA), and was determined according to Hodges *et al.* (1999). Fresh samples (leaves) of around 0.5 g were homogenized in 4.0 ml of 1% trichloroacetic acid (TCA) solution and centrifuged at 10,000×g for 10 min. The supernatant was added to 1ml 0.5% (w/v) TBA made in 20% TCA. The mixture was heated in boiling water for 30 min, and the reaction was stopped by placing the tubes in an ice bath. The samples were centrifuged at 10,000 g for 10 min, and the absorbance of the supernatant was recorded at 532 nm. Correction of non-specific turbidity was made by subtracting the absorbance value read at 600 nm. The level of lipid peroxidation was expressed as nmol g^{1} fresh weight, with a molar extinction coefficient of 0.155 $mMcm^{1}$.

Results and Discussion

Leaf chlorophyll content

Interaction effect of genotypes and salinity showed significant influence on chlorophyll a content (Fig. 1). Under control conditions (non saline) chlorophyll-a content of the genotypes were identical while chlorophyll-b differed significantly.

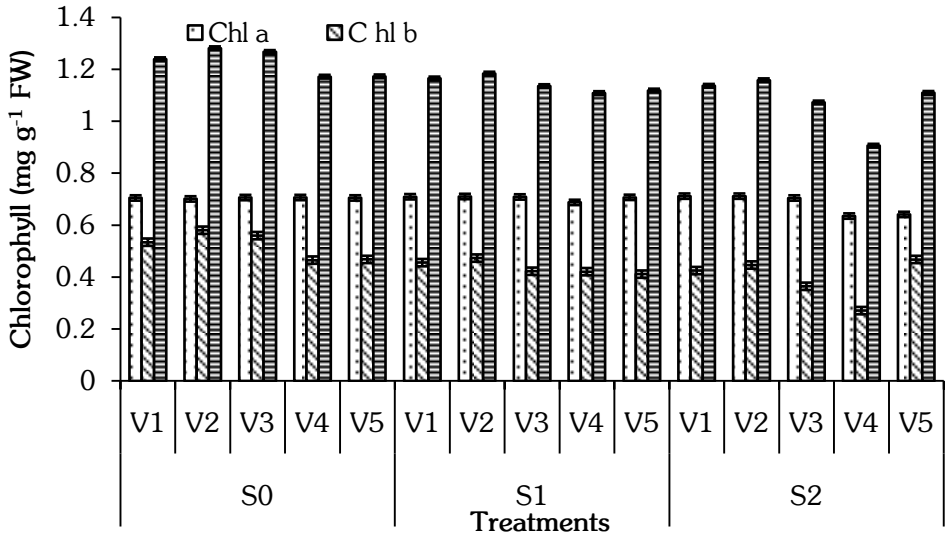

Fig.1. Interaction effect of genotype and salinity on leaf chlorophyll content of mustard/rapeseed at 55 DAS (Vertical bars indicate SE). V_1= Jun-536, V_2 = BJDH-12, V_3 = BD-10115, V_4 = BARISarisha-14, V_5 = BD-6950 (S_0= 0, S_1= 5 and S_2=10 dS m^{-1}salinity).

The maximum chlorophyll-b content was found in V_2 which was identical with V_3 but significantly higher than others. The lowest chl b was detected in V_4 which was identical to that of V_5. Total chlorophyll content was the highest in V_2 which was identical with V_3 but significantly higher than others and the lowest value was found in V_4. At 5dS m^{-1} salinity, all the genotypes showed statistically similar chlorophyll-content except V_4 which showed the lowest value. Chlorophyll-b content of V_1 and V_2 were identical and these values were significantly higher than V_3, V_4 and V_5 genotypes which showed statistically similar values. The total chlorophyll content of V_1 and V_2 were identical but significantly higher than others. At 10dS m^{-1} salinity, chlorophyll-a content of V_1, V_2 and V_3 was identical which were significantly higher than the other two genotypes. Again chlorophyll-a content of V_4 and V_5 were statistically similar. The lowest value was found in V_4. Chlorophyll-b content was the highest in V_2 which was identical with V_1 and V_5 but significantly higher than others. The lowest value was found in V_4. The total chlorophyll content was the highest in V_2 which was identical with V_1 but significantly higher than others. Total chlorophyll content of V_3 and V_5 genotypes were identical and the lowest value was found in V_4. In general, the photosynthetic pigments i.e. chlorophyll content decreased with the increase of salinity. Shah (2007) also reported reduced chlorophyll content in mustard under salinity stress.

Photosynthesis

Interaction effect of genotype and salinity showed significant influence on leaf photosynthetic rate (Fig. 2). Under control conditions, the highest photosynthetic rate was found in V_5 (23.55

µmol $m^{-2}s^{-1}$) which were identical with all other genotypes except V_4 which showed the lowest value. At 5dS m^{-1} salinity, the highest photosynthetic rate was observed in V_5 which was identical with V_3 and V_2. Again, V_2 and V_1 were identical and the lowest value was found in V_4 genotype. At 10 dS m^{-1} salinity, the highest rate was recorded in V_2 (15.05 µmol$m^{-2}s^{-1}$) which were identical with other genotypes, except V_4, which showed the lowest value (12.67 µmol m^{-2} s^{-1}). In general, with the increase of salinity levels photosynthetic rate was reduced irrespective of the genotypes. Salt-induced reduction in photosynthesis is associated with the partial stomatal closure and/or the non-stomatal limitation which is involved in the dark enzymatic processes of CO_2 assimilation e.g. the decrease in Rubisco activity and content, or Pi-regeneration capacity (Ashraf and Harris, 2013).

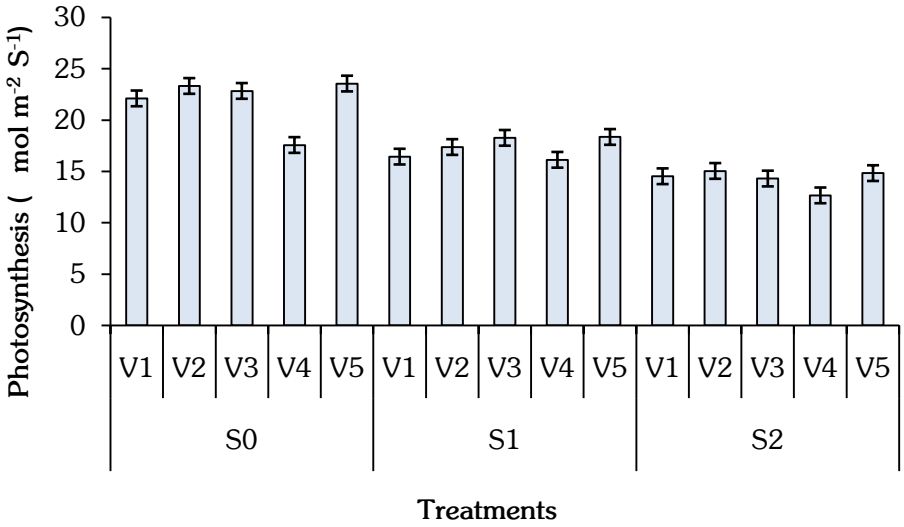

Fig. 2. Interaction effect of genotype and salinity on leaf photosynthesis of mustard/ rapeseed at 55 DAS (Vertical bars indicate SE) V_1= Jun-536, V_2 = BJDH-12, V_3 = BD-10115, V_4 = BARI-14, V_5 = BD-6950S_0= 0, S_1= 5 and S_2=10 dSm^{-1} salinity.

Leaf area and dry matter production

Leaf area$plant^{-1}$ of the mustard-rapessdgenotypes differed significantly under different levels of salinity stress (Table 1). Under control conditions at 45 DAS, the maximum leaf area was observed in V_2 (410 cm^2), which was identical with V_1 and V_3. At 5 dS m^{-1}salinity, the highest leaf area was found in V_2 (396.67 cm^2), which was identical with V_1, V_3 and V_5 genotypes. The lowest value was found in V_4 (217.67 cm^2) genotype. Under 10 dS m^{-1}, V_2 produced the highest leaf area (248.33 cm^2), which was identical with all other genotypes and the lowest value was observed in V_4 (167.67 cm^2). In general leaf area was reduced with increased salinity levels irrespective of the genotypes. Salinity-induced osmotic stress is considered responsible for the reduced leaf area in Canola and wild mustard (Huang and Redmann, 1995). Furthermore, high salinity is known to induce ionic stress, which causes premature abscission and senescence of adult leaves, thus reducing the available photosynthetic area (Munns, 2002).

At 55 DAS, under control condition (no salinity), the maximum leaf area was found in V_2 (438.33 cm^2), which was identical with all other genotypes, except V_4 which produced the lowest leaf area. At 5 dS m^{-1}salinity, V_2 (401.67 cm^2) produced the highest leaf area which was identical with all other genotypes except V_4 which produced the lowest leaf area (246.67 cm^2).

At 10 dS m^{-1} salinity, the highest leaf area was found in V_2 and was identical with all other genotypes except V4 which produced the lowest leaf area (197 cm^2). Total dry matter production of the genotypes was identical at 45 DAS under control conditions, although comparatively higher values were observed in V_2 (8.0 g $plant^{-1}$) and V_1 (7.83 g$plant^{-1}$) and the lowest (6.93 g $plant^{-1}$) in V_4. At 5 dSm^{-1} salinity, the highest TDM was found in V_2 (6.98 g$plant^{-1}$) which were identical with all other genotypes except V_4 which produced the lowest dry matter.

At 10 dSm^{-1} salinity, all the genotypes showed identical values except V_4 which showed the lowest TDM (4.07 g $plant^{-1}$). At 55 DAS under control condition, TDM production of V_1, V_2, V_3 and V5 was identical and the lowest value was found in V_4. At 5dS m^{-1}salinity, statistically similar TDM was observed in all the genotypes except V_4 which was lowest among the genotypes. At 10 dS m^{-1}salinity, the maximum TDM was observed in V_1 which was identical with V_2, similarly V_2 and V_3 were identical and the lowest value was found in V_4. At harvest under control condition, TDM production of the genotypes was identical except V_4 which produced the lowest. At 5dS m^{-1} salinity TDM of the genotypes were statistically identical. Under 10 dS m^{-1} salinity, the maximum TDM was found in V_1 which was identical with V_2, V_3 and V_5 but lowest in V_4. Dry matter production which is considered as an index of photosynthetic activity (Essa and Al-Ani, 2001) was reduced under saline conditions. Reduction in total dry matter accumulation under saline conditions was also reported by Shamsul *et al.* (2011) in Indian mustard (*Brassica juncea*).

Table 1. Interaction effect of genotype and salinity on leaf area and TDM of mustard/ rapeseedgenotypes

Salinity	Genotype	Leaf area (cm^2)		Total dry matter (g $plant^{-1}$)		
		45 DAS	55 DAS	45 DAS	55 DAS	Harvest
S_0	V_1	396.67	437.33	7.83	9.24	10.80
	V_2	410.00	438.33	8.00	9.17	10.20
	V_3	389.67	401.77	7.50	9.00	10.47
	V_4	326.00	342.67	6.93	7.27	9.90
	V_5	380.33	410.67	7.10	9.00	10.20
S_1	V_1	380.00	398.67	6.83	8.88	9.33
	V_2	396.77	401.67	6.98	8.98	9.53
	V_3	378.33	388.33	6.22	8.10	9.10
	V_4	217.67	246.67	5.49	6.83	8.20
	V_5	365.00	391.67	6.20	8.77	9.17
S_2	V_1	244.33	303.67	5.85	7.80	8.87
	V_2	248.33	310.00	5.98	7.65	8.63
	V_3	240.00	302.00	5.63	7.67	8.25
	V_4	167.67	197.00	4.07	5.99	7.98
	V_5	243.33	298.67	5.87	7.77	8.60
LSD (0.05)		27.68	38.51	1.42	1.27	1.50
CV (%)		5.2	6.6	11.2	9.4	9.6

S_0=0, S_1=5 and S_2=10 dS m^{-1} salinity. V_1= Jun536, V_2 = BJDH-12, V_3 = BD-10115, V_4 = BARI-14, V_5 = BD-6950.

Potassium and Sodium ion in leaf tissue

The interaction effect of genotype and salinity on potassium content in leaf tissue was significant (Table 2). Under control conditions, the maximum K^+ was observed in V_3 (2700 ppm) which

was identical with V_1 and V_2 but significantly higher than others. At 5dS m^{-1}, the highest K^+ was recorded in V_4 (2900 ppm) and the lowest value was found in the V_5 (2300 ppm) genotype. At 10dS m^{-1} salinity, the highest K^+ was recorded in V_1 (4800 ppm) genotype and the lowest value was found in V_4 which was identical with V_2. The adverse effect of salinity on plant growth may be due to ion cytotoxicity and osmotic stress. High levels of K^+in young expanding tissue are associated with salt tolerance in many plant species (Bandeh-Hagh *et al.*, 2008; Shabala, 2009). Sodium content in leaf tissue was significantly lower in the control treatment than other salinity levels irrespective of the genotypes, and the maximum Na^+ content under no salinity condition was found in V_4 which was identical with V_5 but significantly higher than others. Sodium content in leaf tissues increased significantly due to salinity stress irrespective of the genotypes. At 5dS m^{-1} salinity, the highest Na^+ content was found in V_4 (650 ppm) and the lowest value was observed in V_3 (170 ppm) which was identical with V_2. At 10dS m^{-1} salinity, the highest Na^+ content was found in V_4 (1400 ppm) which was significantly higher than all other genotypes. The lowest Na^+ content was found in V_2 (260 ppm).

The potassium and sodium ion ratio in leaf tissue was drastically reduced due to salinity stress. Genotypes showed significant variability in K^+/Na^+ ratios in leaf tissue under control conditions. The highest value was found in V_2 (44.14) which was significantly higher than others. Genotypes V_2 and V_5 showed moderate ratios of K^+/Na^+ content in leaf tissue and the lowest in V_4 (14.34). At 5dS m^{-1} salinity, the maximum value was observed in V_2 (13.73) which was identical with all other genotypes and the lowest value was found in V_4 (4.50). At 10 dS m^{-1} salinity, the maximum value was observed in V_2 (12.70) which was identical with V_1 (10.97) and V_3 (10.92) but significantly higher than other genotypes. The lowest value of K^+/Na^+ ratio was found in V_4 (2.23 ppm) and V_5 showed the moderate value. A decrease in uptake of potassium (K) and consequent decrease in growth at higher sodium (Na) concentration has been reported earlier by Ashraf and McNeilly (2004).

Table 2. Interaction effect of genotype and salinity on potassium and sodium ion uptake and their ratios in mustard/rapeseed genotypes at 55 DAS

Salinity	Genotype	K^+ (ppm)	Na^+(ppm)	K^+/Na^+
S_0	V_1	2500	68	36.87
	V_2	2600	59	44.14
	V_3	2700	120	22.78
	V_4	2400	170	14.34
	V_5	2200	110	20.03
S_1	V_1	2500	210	11.91
	V_2	2600	190	13.73
	V_3	2300	170	13.55
	V_4	2900	650	4.50
	V_5	2500	220	11.52
S_2	V_1	4800	440	10.97
	V_2	3300	260	12.70
	V_3	4000	370	10.92
	V_4	3100	1400	2.23
	V_5	4400	580	7.61
$LSD_{(0.05)}$		225.86	72.25	2.78
CV (%)		4.5	11.9	10.5

S_0=0, S_1=5 and S_2=10 dS m^{-1} salinity. V_1= Jun536, V_2 = BJDH-12, V_3 = BD-10115, V_4 = BARI-14, V_5 = BD-6950.

Antioxidant activity

Antioxidant activity was significantly affected due to salinity stress (Fig. 3). Under control treatment, higher catalaze (CAT) activities were found in V_5 and lower in V_2. At 5dS m^{-1} salinity, the highest CAT activity was observed in V_2 which was significantly higher than others.

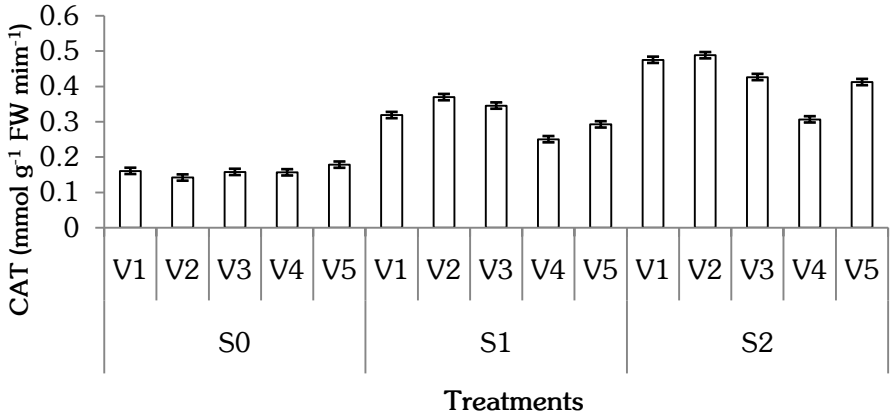

Fig. 3. Effect of salinity stress on the catalyze activity in rapeseed/mustard genotypes at 55DAS. (Vartical bar indicate SE). V_1= Jun-536, V_2 = BJDH-12, V_3 = BD-10115, V_4 = BARI-14, V_5 = BD-6950.S_0= 0, S_1= 5 and S_2=10 dS m^{-1}salinity.

At 10 dS m^{-1}salinity CAT activity was higher than control and 5dS m^{-1}salinity and the maximum activity was observed in V_2 which was identical with V_1 but significantly higher than others. CAT activity of V_3 and V_5 were identical and the lowest was found in V_4. Peroxidase (POD) activity also increased due to temperature stress compared to control (Fig.4). Under control conditions, comparatively higher POD activity was found in V_5 followed by V_2 and V_1 and the lower in V_4 and V_3. At 5dS m^{-1}salinity the highest POD activity was observed in V_2 which was significantly higher than other. At 10 dS m^{-1}salinity POD activity of V_1, V_2 and V_5 were satirically identical, V_3 showed moderate activity while the lowest was found in V_4. The reduced rate of photosynthesis increases the formation of reactive oxygen species (ROS) and increases the activity of enzymes (CAT and POD) that detoxify the ROS (Foyer and Noctor, 2005).

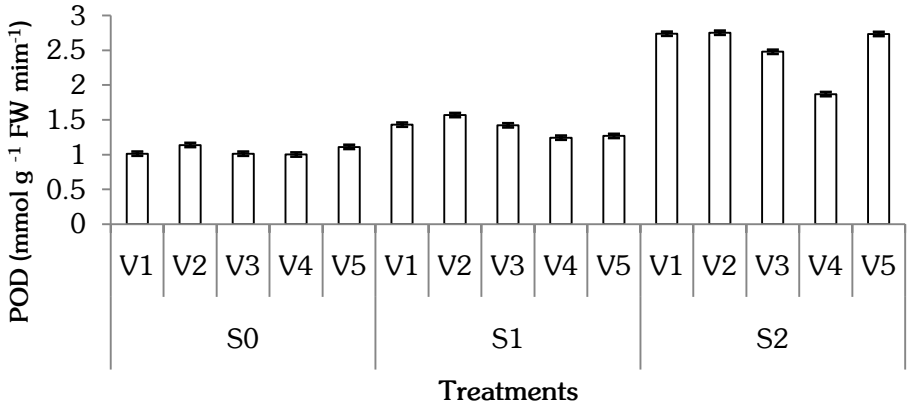

Fig. 4. Effect of salinity stress on the POD activity in rapeseed/mustard genotypes at 55 DAS (Varticalbars indicateSE).V_1= Jun-536, V_2 = BJDH-12, V_3 = BD-10115, V_4 = BARI-14, V_5 = BD-6950S_0=0, S_1= 5 and S_2=10 dS m^{-1}salinity.

Malondialdehyde (MDA) content also increased due to salinity stress compared to control (Fig. 5). Under control conditions, the genotypes showed variability in MDA activity which increased with the increase in salinity levels. At 5dS m^{-1}salinity, the maximum MDA activity was foun in V_4 followed by V_5 and V_3, and the lowest was found in V_2. At 10 dS m^{-1}salinity, almost a similar trend was observed where the highest MDA was found in V_4 and the lowest in V_2. Higher MDA content in the cell is correlated with salt stress sensitivity while lower MDA content displays higher antioxidative ability, reflecting higher tolerance to stress (Noreen and Ashraf, 2009).

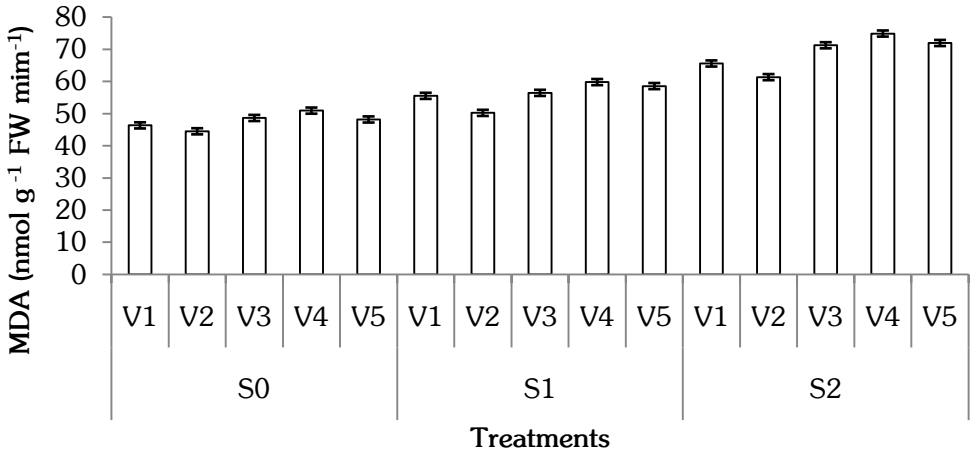

Fig. 5. Effect of salinity stress on the MDA activity in rapeseed-mustard genotypes at 55 DAS (Vertical bars indicate±SE). V_1= Jun-536, V_2 = BJDH-12, V_3 = BD-10115, V_4 = BARI-14, V_5 = BD-6950. S_0= 0, S_1= 5 and S_2=10 dS m^{-1}salinity.

Yield and yield contributing characters

Effect of genotypes

Genotypes showed significant difference in plant height (Table 3). The tallest plant was found in V_3 (127.33 cm) which was significantly higher than all other genotypes. Siliquaplant^{-1} of the genotypes also varied significantly. The highest number of siliquaplant^{-1} was recorded in V_5 (115.82) and the lowest siliquaplant^{-1} was recorded in V_4 (57.37) genotype. The number of seedssiliqua^{-1} of the genotypes differed significantly.

Table 3. Effect of genotype on yield and yield component of mustard/rapeseed

Genotype	Plant height (cm)	No. of siliqua plant^{-1}	No. of seeds siliqua^{-1}	1000-seed weight (g)	Seed yield plant^{-1} (g)
V_1	117.96	94.56	13.44	2.97	3.55
V_2	100.59	95.26	13.99	3.19	3.91
V_3	127.33	79.74	15.69	3.10	3.59
V_4	73.56	57.37	25.84	3.27	2.91
V_5	110.37	115.82	13.24	2.80	3.26
LSD $_{(0.05)}$	7.56	13.45	2.22	0.27	0.31
CV (%)	7.50	10.50	11.40	9.30	9.60

V_1= Jun536, V_2 = BJDH-12, V_3 = BD-10115, V_4 = BARI-14, V_5 = BD-6950.

The highest number of seedssiliqua^{-1} was observed in V_4 (25.84) which were significantly higher than other genotypes and the lowest value was observed in V_5 (13.24). The seed size of the genotypes varied significantly. The highest 1000-seed weight was recorded in V_4 (3.27 g) which was significantly higher than others and the lowest was recorded in V_5 (2.80 g). Seed yieldplant^{-1} of the genotypes varied significantly. The highest seed yield was found in V_2 which significantly higher than others. But the lowest yield was observed in V_4.

Effect of salinity

Salinity stress significantly affected yield and yield contributing characters of rapeseed/mustard genotypes (Table 4). Plant height was significantly reduced due to salinity stress. The tallest plant was recorded in control (125.44 cm) condition while the shortest in 10 dS m^{-1}salinity treatment (86.29 cm).

Table 4. Effect of salinity on yield and yield components of rapeseed/mustard

Salinity	Plant height (cm)	No. of siliqua plant^{-1}	No. of seeds siliqua^{-1}	1000-seed weight (g)	Seed yieldplant^{-1} (g)
S_0	125.44	91.64	17.39	3.29	4.16
S_1	100.16	85.18	16.50	3.09	3.38
S_2	86.29	76.82	15.42	2.82	2.79
$LSD_{(0.05)}$	5.85	10.42	1.72	0.21	0.24
CV (%)	7.50	10.50	11.40	9.30	9.60

S_0= 0, S_1= 5 and S_2=10 dS m^{-1}

The most common undesirable effect of salinity on the crop of *Brassica* is the reduction in plant height, component characters of yield as well as deterioration of the product quality (Zamani *et al.*, 2010). Siliquaplant^{-1} was significantly reduced due to salinity stress, the highest number was observed in the control (91.64) condition which was identical with 5dS m^{-1}salinity level and the lowest (76.82) in 10 dSm^{-1}. A negative effect of salinity on the number of siliqua plant^{-1} of Indian mustard was also observed by Kripa *et al.* (2011). The highest number of seedssiliqua^{-1} was found in the control conditions (17.39) which was identical with 5 dS m^{-1}and the lowest (15.42) in 10 dS m^{-1}salinity. These results corroborate the findings of Ahmad (2010). Reduced seed size was observed due to salinity stress. The highest 1000-seed weight was found in the control conditions (3.29 g) which was significantly higher than others and the lowest (2.82 g) in 10 dS m^{-1}salinity. Seed yield was also reduced due to salinity stress and the highest seed yield (4.16gplant^{-1}) was recorded in the control conditions and the lowest (2.79 gplant^{-1}) in 10 dS m^{-1} salinity. This finding is supported by Kripa *et al.* (2011).

Interaction effect of genotype and salinity on seed yield

Interaction effect of genotype and salinity showed significant influence on seed yieldplant^{-1} (Fig.6). Under control conditions, the seed yield of V_1 and V_2 were identical. At 5 dS m^{-1}salinity the maximum seed yield was found in V_2 which was identical with V_1, V_3 and V_5 but significantly higher than V_4. At 10 dS m^{-1}salinity V_2 showed the highest seed yield which was significantly higher than other. The lowest yield was found in V_4 genotype. Salinity may reduce the crop yield by upsetting the water and nutritional balance of plants (Francois, 1994; Islam *et al.*, 2001).

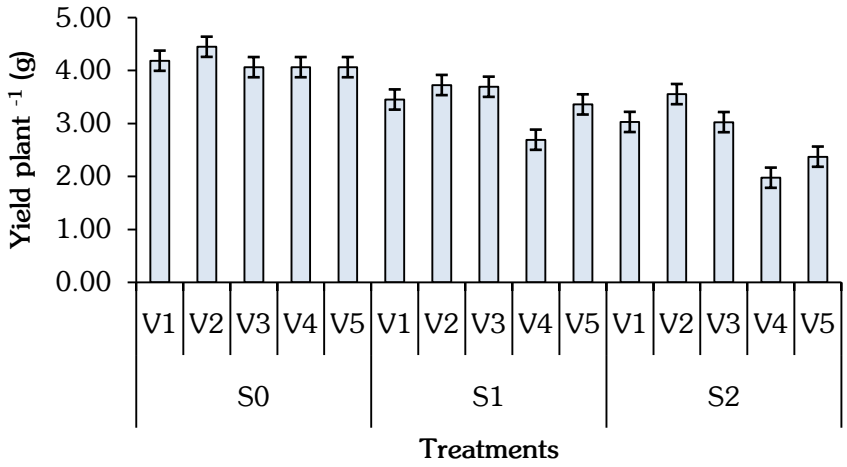

Fig. 6. Interaction effect of genotype and salinity on the seed yield of rapeseed/mustard (Vertical barsindicate SE) V_1= Jun-536, V_2 = BJDH-12, V_3 = BD-10115, V_4 = BARI Sarisha-14, V_5 = BD-6950. S_0= 0, S_1= 5 and S_2=10 dS m^{-1}salinity.

Conclusion

Results revealed that genotypes Jun-536 and BJDH-12 were comparatively salt-tolerant as evaluated based on seed yield and important physiological parameters.

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