International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(3): 734-737

Received: 07-03-2019
Accepted: 08-04-2019

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Responses of oat (*Avena sativa* L.) genotypes under salt stress

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Abstract
One of the main menaces to agriculture is the adverse environmental conditions that threaten plant growth and development. Salt stress is one of the major threats to agriculture. The experiment was conducted under screen house conditions in CCS Haryana Agricultural University, Hisar to evaluate the responses of ten oat genotypes under different levels of salt stress. The main physiological parameters studied were dry weight (g), relative water content (RWC %), osmotic potential (-bars), total chlorophyll content (mg g^{-1}), chlorophyll stability index (CSI %) and assimilation rate (µmol CO_2 $m^{-2}s^{-1}$) under different salt stress (5 and 10 dS m^{-1}). Genotypes were grown under screen house conditions by maintaining desired levels of salt stress. Observations were recorded at 50% flowering. Dry weight (g) decreased with increasing levels of salt i.e. from control to 10 dS m^{-1} and values ranged from 10.81 to 4.54. Maximum dry weight (g) $plant^{-1}$ was noticed in HJ-8 (6.20) followed by HFO 716 (5.37), HFO 529 (5.30) and minimum in HFO 607 (2.93) at 10 dS m^{-1} of salinity. Similar trend was noticed in relative water content (RWC %). Highest RWC was observed in HFO 114 (66.29) followed by OS 377 (65.71), HJ-8 (61.21) and least in HFO 607 (51.36) at 10 dSm^{-1} of salinity. Osmotic potential (Ψs) values become more negative and values ranged from 11.05 to 17.29 from control to 10 dS m^{-1} of salinity. Declining trend was also noticed in total chlorophyll content (mg g^{-1}) with the increasing levels of salinity (control to 10 d Sm^{-1}) of salinity. Maximum chlorophyll content was observed in OS 377 (0.85) followed by OS 6 (0.80), HJ-8 (0.79) genotypes at 10 dS m^{-1} of salinity. Similar trend was observed for chlorophyll stability index (CSI) and photosynthetic rate (µmol CO_2 $m^{-2}s^{-1}$). Highest assimilation rate was found in OS 377 (4.87) followed by HJ-8 (4.43), OS 405 (4.36) genotypes at 10 dS m^{-1} of salinity. Overall, based on the above parameters two genotypes (OS 377 and HJ-8) performed better than others. Based on the above results these genotypes can be used in breeding programme for the development of agronomically important oat genotype that could perform under salt stress.

Keywords: *Avena sativa*, salt stress, osmotic potential, assimilation rate

Introduction
Oat (*Avena sativa* L.) belonging to family *Poaceae* is the most important cereal crop used as a multipurpose crop *i.e.* for fodder, food, feed and medicine (Chauhan *et al*. 2016; Devi *et al*. 2018) [2, 3]. Oat products are well throughout healthy because of the high dietary fiber content predominantly beta-glucan (Martínez-Villaluenga and Peñas, 2017) [6]. However, oat crops are less lucrative than wheat and maize crop. As a consequence, oats are usually grown in regions with short growing seasons or in challenging conditions such as rainfed areas, less fertile and salinity affected soils. Such soil and climatic circumstances are less appropriate for commercial crops.

Salt stress is one of the major abiotic stresses which adversely affect crop production. Soil salinity is constantly increasing and will be a challenge for agriculture in coming years. So, to feed the burgeoning population of livestock and human beings, the management of soil salinity is becoming more important. More than 6% of the world's total land area is affected by salinity (Gao *et al*., 2016) [4]. In India, about 6.73 million hectare of the cultivated land is affected by salinity and sodicity. In Haryana alone, it is 0.50 million hectare. It is estimated that every day between 2,000 and 4,000 hectare of irrigated land in arid and semi-arid areas across the globe are degraded by salinity and become unsuitable for crop production (Qadir *et al.,* 2014) [8]. Oat crops are considered to be moderately tolerant to salinity and alkalinity. Oat yield can be sustained in saline soils if timely irrigation is applied. Soil salinity occurs in arid and semi-arid regions where frequent irrigations are not possible and further if it is done, it may not be an economically viable option. A sustainable solution is to grow location specific salinity tolerant oat cultivars.

Few literatures are available on the screening of oat genotypes under salt stress and categorization of tolerance levels (Oraby and Ahmad, 2012; Devi *et al*. 2018) [7, 3]. So there is a strong need to screen the oat genotypes for salinity levels.

Keeping in view the detrimental effects of salt stress on agricultural productivity and to encourage the use of salt tolerant species the present study was initiated to generate the data regarding the performance of oat genotypes under salt stress.

Materials and Methods

Ten genotypes of oat *viz*. HJ-8, HFO 114, OS 6, OS 403, OS 405, OS 377, HFO 529, HFO 607, HFO 514 and HFO 716 were grown in pots under screen house conditions of Department of Botany and Plant Physiology, CCS Haryana Agricultural University, Hisar, India. Before sowing, the desired levels of salinity *i.e*. 5, and 10 dS m^{-1} were maintained by saturating the pots besides this the control pots were irrigated with canal water. Hoagland solution was given at different time interval. The sampling was done at 50% flowering stage. The plant dry weight was determined after drying the tissues in an oven at 60ºC and expressed as g $plant^{-1}$. The relative water content (RWC %) of leaf was calculated as described by Weatherley (1950) [11]. Leaf discs of 200 mg were cut and weighed immediately to record the fresh weight (FW) of the sample. Then, the leaf discs were hydrated to full turgidity by floating on de-ionized water in a closed petri-dish for 3-4 hours at room temperature. After 3-4 hours, the leaf discs were taken out of water and any surface moisture is removed quickly with filter paper lightly and immediately weighed to obtain fully turgid weight (TW). The leaf discs were dried in an oven at 60°C for 24 h and weighed the sample to determine dry weight (DW) of the leaf discs. The RWC (%) was calculated by using the following formula.

$$\text{RWC (\%)} = \left(\frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}}\right) \times 100$$

The osmotic potential (Ψs) of leaf was determined by using psychrometric technique with a Vapour Pressure Osmometer (Model-5100, Wescor, Logan, USA) and was expressed in '-bars'. The third leaf from the top was stored in air tight eppendorf tubes. The leaves were crushed at room temperature. A filter paper disc was immediately dipped in the sap and placed in the concave depression of the sample holder, avoiding the touching of wet disc on the outer surface of the sample holder. The sample slide was pushed gently in to the instrument and sealed the chamber by rotating the knob clockwise. After about one minutes a beep tone sounded. The osmotic potential reading (mmole kg^{-1}) displayed on the digital meter was recorded. The osmometer was calibrated by using osmolarity reference standards of sodium chloride (Wescor Inc, USA) and calculation was done as follows.

1000 mmol kg^{-1} = 2.5 MPa

2.5MPa = 25 bars

Chlorophyll content was estimated according to the method of Hiscox and Israelstam (1979) [5] using Dimethyl sulfoxide (DMSO). Leaves were washed, blotted dry then cut into discs 200 mg and dipped in test tubes containing 5 ml of dimethyl sulfoxide (DMSO) overnight. The extracted chlorophyll in DMSO was estimated by recording its absorbance at 663 and 645 nm, respectively and its content was calculated from the formula:

$$\text{Chl "a"} = \frac{12.3\ A_{663} - 0.86\ A_{645}}{a \times W} \times V$$

$$\text{Chl "b"} = \frac{19.3A_{645} - 3.6\ A_{663}}{a \times W} \times V$$

Chlorophyll stability index (CSI %) was determined by the formula according to Sairam *et al*. (1997) [9].

$$\text{CSI (\%)} = \frac{\text{Total chlorophyll under stress}}{\text{Total chlorophyll under}} \times 100$$

Photosynthetic rate of fully third expended leaf was measured by infrared gas analyzer (IRGA LCi-SD, ADC Biosciences). The leaf was enclosed in the assimilation chamber and position was shifted such that maximum PAR was obtained then photosynthetic rate (A) was monitored while CO_2 concentration changed over a definite time interval. The system automatically calculated the photosynthetic rate on the basis of preloaded flow rate and leaf area. Measurements were taken when relative humidity, temperature, photosynthetic photon flux density and amp; CO_2 concentration ranged from 50–60%, 25–35°C, 1200 µmole (photon) $m^{-1}s^{-1}$ and amp; 350–360 $umole^{-1}$, respectively.

Statistical Analysis- Data were subjected to analysis of variance (ANOVA) using Online Statistical Analysis Package (OPSTAT, Computer Section, CCS Haryana Agricultural University-125004, Hisar, India) with level of significance at P= 0.05.

Results and discussion

Expansion of plant is one of the key indices of salt stress tolerance as indicated by different studies (Chauhan *et al*., 2016; Devi *et al*. 2018) [2, 3]. When the oat genotypes subjected to salt stress *i.e*. from 5 dS m^{-1} to 10 dS m^{-1}, the dry weight $plant^{-1}$ decreased. Values ranged from 10.81 to 4.54 from control to 10 dS m^{-1} of salt stress (Table 1). Maximum dry weight (g) was noticed in HJ-8 (6.20) followed by HFO 716 (5.37), HFO 529 (5.30) and minimum in HFO 607 (2.93) at 10 dS m^{-1} of salinity. Similar trend was noticed in relative water content (RWC %) (Table 1). Highest RWC was observed in HFO 114 (66.29) followed by OS 377 (65.71), HJ-8 (61.21) and least in HFO 607 (51.36) at 10 dS m^{-1} of salinity. Osmotic potential (Ψs) values become more negative and values ranged from 11.05 to 17.29 from control to 10 dS m^{-1} of salinity (Table 1). Declining trend was also noticed in total chlorophyll content (mg g^{-1}) with the increasing levels of salinity (control to 10 dS m^{-1}) of salinity (Table 2). Maximum chlorophyll content was observed in OS 377 (0.85) followed by OS 6 (0.80), HJ-8 (0.79) genotypes at 10 dS m^{-1} of salinity. Similar trend was observed for chlorophyll stability index (CSI) and assimilation rate (µmol CO_2 $m^{-2}s^{-1}$). Highest photosynthetic rate was found in OS 377 (4.87) followed by HJ-8 (4.43), OS 405 (4.36) genotypes at 10 dS m^{-1} of salinity (Fig. 1).

Responses of leaf water relations parameters to salt treatments differed between the genotypes. The results of present study were also in concomitant with the findings of Devi *et al*. (2018) [3] in oat genotypes under salt stress. The more '-ve' values of Ψs help in the process of osmoregulation *i.e*. improve the physiological efficiency of plants under adverse conditions by maintaining better RWC. The low RWC and Ψs of leaves were apparently adjusted by accumulating sugars and proline which were known for their osmotic influences in

plants (Seif *et al*., 2015; Devi *et al*. 2018) [10, 3]. Similar results were reported in wheat and naked oat (Zhao *et al*., 2007) [12]. The ability of species to accumulate and adapt to different environments is directly or indirectly associated with their ability to acclimate at the level of photosynthesis (Seif *et al*., 2015; Cai *et al*., 2010) [10, 1] which in turn affects the biochemical and physiological processes of leaf and whole plant.

Table 1: Effect of salt stress on dry weight, RWC and osmotic potential of oat genotypes.

Genotype	Salinity Levels (dS m^{-1})								
	Dry weight (g)			RWC (%)			Osmotic potential (-bars)		
	Control	5 dS m^{-1}	10 dS m^{-1}	Control	5 dS m^{-1}	10 dS m^{-1}	Control	5 dS m^{-1}	10 dS m^{-1}
HJ-8	10.57	6.40	6.20	80.54	70.65	61.21	10.63	17.26	17.69
HFO 114	7.67	6.07	4.17	71.47	69.16	66.29	10.47	16.70	18.10
OS 6	9.57	7.57	4.53	78.85	62.22	56.08	10.38	17.00	17.64
OS 403	13.03	5.87	3.87	84.02	67.34	54.33	11.29	15.56	17.86
OS 405	11.77	7.53	3.90	86.22	75.73	54.69	11.46	16.63	18.06
OS 377	11.53	5.87	4.00	84.37	74.47	65.71	10.08	16.00	17.00
HFO 529	10.67	8.61	5.30	78.71	69.05	57.05	11.50	17.00	18.00
HFO 607	11.27	6.57	2.93	80.92	67.16	51.36	11.49	15.23	15.60
HFO 514	10.57	7.50	5.10	81.43	69.17	58.10	11.66	16.36	17.36
HFO 716	11.50	8.63	5.37	83.46	74.33	53.57	11.54	16.19	15.60
Mean	10.81	7.06	4.54	81.00	69.93	57.84	11.05	16.39	17.29
CD at 5 %	G= NS, S= 0.92 & GxS			G= 3.52, S= 1.92 & GxS= 6.12			G= 0.81, S= 0.45 & GxS= 1.41		

Table 2: Effect of salt stress on chlorophyll content and CSI of oat genotypes

Genotype	Total Chlorophyll content (mg g^{-1})			CSI (%)	
	Control	5 dS m^{-1}	10 dSm^{-1}	5 dS m^{-1}	10 dSm^{-1}
HJ-8	1.04	0.98	0.79	75.00	46.99
HFO 114	0.91	0.80	0.47	87.87	52.21
OS 6	1.57	1.03	0.80	65.55	51.25
OS 403	0.94	0.62	0.40	66.20	42.29
OS 405	1.02	0.85	0.48	82.85	46.54
OS 377	1.42	1.14	0.85	79.92	59.79
HFO 529	1.39	1.18	0.72	84.69	51.89
HFO 607	1.53	0.73	0.47	64.15	54.12
HFO 514	0.75	0.59	0.38	78.44	50.71
HFO 716	1.45	0.91	0.66	62.92	45.71
Mean	1.20	0.88	0.60	74.76	50.15
CD at 5 %	G= 0.16, S= 0.09 & GxS= 0.27				

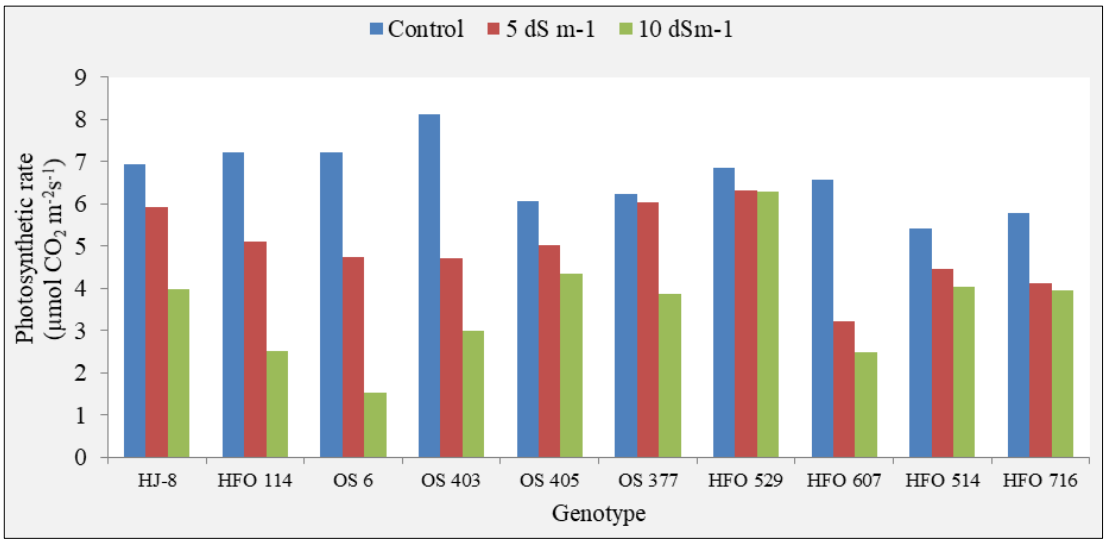
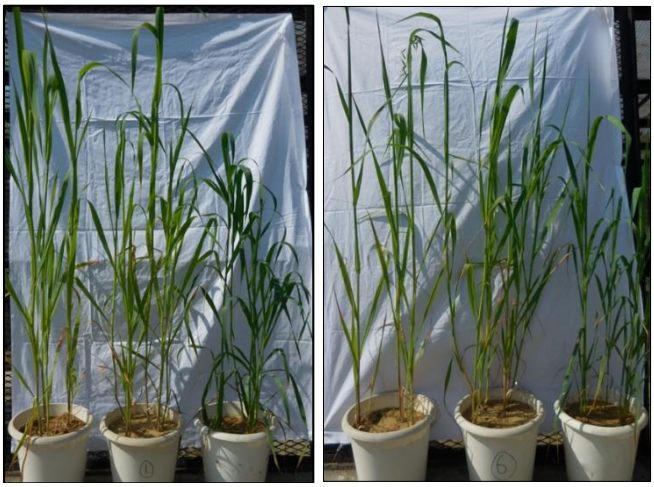


Fig 1: Effect of salt stress on photosynthetic rate of oat genotypes. [G= 0.47, S= 0.26 & GxS= 0.82]



HJ-8 OS 377

Plate 1: Growth performance of oat genotypes (HJ-8 and OS 377)

Conclusion

Based on the results, it can be concluded that out of the ten oat genotypes screened at 10 dS m^{-1} only two genotypes HJ-8 and OS 377 performed better (Plate 1) but at 5 dS m^{-1} all the ten oat genotypes did well at 50 per cent flowering. Their better performance can be attributed to more dry weight, plant water status, chlorophyll stability index and photosynthetic rate.

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