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Research Article

Impact of Different Levels of NaCl Induced Salinity on Seed Germination and Plant Growth of Fodder Oats (*Avena sativa* L.)

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ABSTRACT

Oat (*Avena sativa* L.) is a hardy crop suitable to cultivate in stress conditions, such as drought, poor soil fertility, high salinity, and alkalinity. Thus, it might be a good selection for salt-affected and climatically vulnerable coastal regions of Bangladesh. To justify its suitability in saline soils, two separate experiments were conducted following a completely randomized design with five replications. Seven concentrations (0, 100, 150, 200, 250, 300 and 350 mM) of NaCl salt were considered as the treatments. Germination study was conducted under laboratory condition in Petri dish and for vegetative growth study, pot experiment was conducted in net house. Increased level of salinity remarkably decreased the seed germination as well as the vegetative growth of oat. Higher Timson Germination Index (TGI) was recorded for most of the treatments. A significant variation was also found in the salt tolerance index (STI) based on the seedling dry weight. Significantly lower length and weight of shoot and root in 15 days old seedlings were observed with an increased salt concentration in the substrate. Increased concentration of salt exerted inhibitory effects on plant growth. But with the findings of the experiment, it could be concluded that the oat would be recommended as a fodder crop for the salinity level up to 100 mM for NaCl salt.

Introduction

South–western coastal part of Bangladesh has become a vulnerable region in the world having specific climatic problems, like sea level raise, increased salinity in soil and water, unusual rain fall pattern etc. About 53% of the agricultural lands are affected here by salinity (Haque, 2006) and a significant increase in the amount of land experiencing high-range salinity levels (Lam et al., 2021). Fallow-fallow-transplanted *Aman* rice is a common cropping pattern in these areas, where cropping intensity is much lower than country's average (Mondal et al., 2006). Thus, selection of salt tolerant crop genotypes is a prime need to cope with the vulnerable climatic conditions. Earlier animal raring was a common practice in this area and various milk based small economic initiatives were prominent. In course of time salinity intrusion with other factors aggravated and destroyed the whole fodder production system that consequently greatly hampered the animal raring in these coastal areas (Alam et al., 2017). However, less attention has been paid to regain the status and improve the situations through selecting suitable fodder crops for this region.

Oats (*Avena sativa* L.) is a nontraditional crop in Bangladesh although it is grown in different countries as grain and/or fodder crops. Importance of this crop is increasing worldwide for both the purposes for its ease of cultivation and profitability. Oats can be grown in problematic conditions such as drought, poor soil fertility, high salinity and alkalinity. Its salt tolerant capacity was proved much better than most other cereals *viz.,* rice, wheat, barley, etc. (Mishra and Shitole, 1986). It can also be used for saline soil reclamation as its high capacity to accumulate salt ions in its straw biomass (Wang and Song, 2006). Oats are grown for use as grain as well as forage and fodder, straw for bedding, hay, haylage, silage and chaff. December-January is considered as the lean period for green fodder and animals are fed with dry fodder in Bangladesh (Ali et al., 2004) and hence oats can be a good choice for green

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fodder. It is a fast growing plant with average yield of 45-55 ton of green fodder or 2.5-3.0 tons of grain per hectare (Alemayehu, 1997). In terms of yield and nutritive value it is also ideal for animal. It is rich in energy, protein, vitamin B1, phosphorus and iron content (Relwani, 1979; Hussain et al., 2002).

As saline soil widely distributes in more than 100 countries, and covers about 10% of arable area over the world, soil salinization becomes one of the environmental problems over the world (Shahid et al., 2018). Cations of soluble salts in saline-alkaline soil mainly include Na^+,Ca^{2+},Mg^{2+} and K^+, anions mainly include $SO_4{}^{2-}$, Cl^-, $HCO_3{}^-$, $CO_3{}^{2-}$ and $NO_3{}^-$ (Vargas et al., 2018). The damage effect of saline stress on plant is obvious caused by neutral salts such as NaCl (Ji-Tao Zhang and Chun-Sheng Mu, 2009). Soil salinization in grassland and farmland becomes more seriously, which cause losses in agricultural productivity and pose an ecological crisis. Abiotic stresses imposed by salinity pose serious threats to growth and productivity of crop plants worldwide. Some reports on oat (*Avena sativa* L.) response to salinity (NaCl) address plant growth and its physiological response to varying salt stresses.

The most fundamental and vital phases that determine plant establishment and the yield of the crops is seed germination. Salinity stress has a great effect on germination process as this stress alters the imbibition of water by seeds due to lower osmotic potential of germination media (Khan and Weber, 2008), causes toxicity which changes the activity of enzymes of nucleic acid metabolism (Gomes-Filho et al., 2008), alters protein metabolism (Dantas et al., 2007), disturbs hormonal balance (Khan and Rizvi, 1994), and reduces the utilization of seed reserves (Othman et al., 2006). In view of ever increasing demand of oats, it becomes imperative to undertake extensive studies to understand the extent of salinity tolerance of this crop. Such evaluation would ensure its widespread cultivation in this country. Considering these perspectives, investigation was made to evaluate the performance of oats seeds in germination and seedling growth in different levels of salinity. An evaluation was also made to assess its suitability as fodder in saline soils on the basis of biomass production at vegetative stage.

Materials and Methods

The experiments were carried out in the Plant Breeding and Biotechnology Laboratory and in a net house of Agrotechnology Discipline, Khulna University, Khulna (lat. 22°79′88″ E, long. 89°53′44″ N and elevation: 18 m) during October 2019 to February 2020.

Experimental Materials, their Pretreatment and Design of Experiment

Seeds of a popular oat cultivar (Kent), collected from Central Cattle Breeding and Dairy Farm (CCBDF), Dhaka, was used as the planting material in this study. The seeds were treated with Provex-200 at the rate of 3 g kg^{-1} of seeds for 24 hours before placing in Petri dishes as well as before sowing in pots. The experiments were laid out in completely randomized design (CRD) with five replications for the treatments. Two separate experiments were conducted in Petri dishes and pots, respectively evaluating the germination parameters and biomass production of oat at different levels (100, 150, 200, 250, 300 and 350 mM) of NaCl salt. Distilled water with no salt was considered as control.

Germination and Seedling Growth Study

Healthy and uniform seeds were selected and 450 seeds per treatment were placed on sterilized Whatman No. 1 filter paper in Petri dishes (9 cm). The seeds were soaked with 10 ml of salt solutions according to the treatments. The treatment solutions were applied separately in each Petri dish regularly. The seeds were allowed to germinate at 25 ± 2 °C in dark/light (2500 lux light intensity) cycle in laboratory conditions. The number of seeds that were germinated was recorded at 24 hours interval for 10 days.

After 15 days of growth, shoot and root length, and fresh weight and dry weight of root and shoot were recorded. The germination parameters were calculated by the following formulae:

Germination percentage (GP) = $\frac{\text{Total seeds germinated}}{\text{Number of initial seeds}} \times 100$ (Raun et al., 2002).

Germination rate index (GRI) = $\frac{G1}{1} + \frac{G2}{2} + \cdots \ldots \ldots + \frac{Gi}{I}$, where germination percentage $G1$ is germination percentage at day 1, $G2$ is that of at day 2 and so on (Raun et al., 2002).

The spread of germination (SG) = the time elapsing between the first day of germination and the last day of germination (Al-Mudaris, 1998).

Salt tolerance index (STI) was calculated as, STI = $100 \times \left\{\frac{(Total\ DW\ salt\ stress)}{Total\ DW\ control}\right\}$ (Abdul and Anderson, 1970).

Shoot and root length of five randomly selected seedlings from each replication was measured by using a slide calipers (Mega Digital Clipper: 6" × 150 mm) after 15 days of applying the treatments. Dry weight of shoot and root of five randomly selected seedlings were recorded after drying at 60°C for 72 hours in a hot air oven (WTC binder, 78532 Tuttlingen/Germany)) and were weighed with the help of a four digit electric balance (OHAUS Adventure™, model: AR2140). Data on germination behavior and seedling characteristics for each treatment were compared with that of the control.

Fodder Growth Study

A pot experiment was conducted to find out the effect of salinity stress on fodder yield of oats by using a mixture of non-saline garden soil and vermin compost (3:1) as potting media. A total of 35 (5 replication × 7 treatments) earthen pots (about 24 cm in diameter and 21 cm in depth) were used. Recommended dose of fertilizers was applied @ 80:40:0 kg of NPK ha^{-1} (Eagri.org, 2012). Half dose of the nitrogen and full of P and K were applied during pot filling and remaining half dose of nitrogen was applied after 30 days of seed sowing. Ten seeds were planted in each pot in early December at about 10-12 mm depth and after germination and establishment seedling of each pot were thinned to five.

Weeding was done as and when necessary to keep the experimental pots free from weeds. A light irrigation was applied next day after sowing for better seed germination. The pots were irrigated with salt solution before sowing according to the treatments, and also during growing and tillering stages following flood system of irrigation and maintained optimum soil moisture with fresh water. Data on plant height (from the base of the stem to tip of the longest leaf), leaf number, tiller number and stem thickness were recorded at 60 days after planting.

Data Analysis

The data were analyzed for one way ANOVA (Analysis of Variance) at 5% level of significance to determine the influence of each treatment by using the computer package program R 4.1.0. The pair-wise Pearson's correlation plots and other graphical plots were constructed by using Sigmaplot 14.0 program. The differences among the treatment means were compared by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) at 95% confidence level.

Results and Discussion

Effect of salinity on germination of oat seeds

All of the germination parameters, *viz*., germination percentage, germination rate index, mean germination time (MGT), co-efficient of velocity of germination, time spread of germination, germination index, salt tolerance index (STI) and Timson germination index were decreased gradually with the gradual increase of salinity levels (Table 1 and Table 2).

With increasing salt concentration, the germination percentage (GP) decreased. In control, all seeds (100%) of oat germinated. The strongest reduction of germination was observed in the presence of 350 mM salt concentration. The GRI, reflecting the percentage of germination on each day of the germination period, decreased under both salts. The strongest decrease was observed in high (350 mM) salt stress. Conversely, with increasing salt concentration, the MGT increased, reaching values about 3 times greater for salt treatments than the control. The strong significant inverse relationship between salt concentrations and germination indexes confirmed the detrimental effects of the salts on seed germination. Coefficient of velocity of germination (CVG) has significantly reduced with increasing salt concentration as compared with control.

GRI, MGT and CVG are well known as three indices that assess germination rate of seed. Higher CVG and GRI, and lower MGT represent higher and faster germination of seed (Panuccio et al., 2014). The results of the study indicated that high salinity remarkably inhibited the germination of seed and delayed germination time in oat. Akbarimoghaddam et al. (2011) also reported a decreased germination with increased salt levels. The negative effects of high salinity may be due to ion toxicity on seed germination, as a consequence of a coincident increase in anion and cation (Panuccio et al., 2014). The time spread of germination was decreased as the salinity levels increased and the highest mean SG was found at 350 mM concentration. The decreasing tendency of SG due to increasing salinity was in the conformity with the report of Hakim et al. (2010). The reduction of spread of germination at high salt levels might be mainly due to osmotic stress.

The germination index (GI) of oats seeds decreased with increasing salt concentration. Higher rate of reduction was particularly at the higher level of salt concentration when compared with the control. Thus, germination index and salt concentration were negatively correlated. These findings are in line with the findings of Khayatnez and Gholamin (2011). An increased germination index is indicative of decreased phytotoxicity and thus of a more mature germinated seeds (Khayatnez and Gholamin, 2011). Salt tolerance index (STI) based on seedling dry weight varied significantly with varying concentrations of salt stress for the NaCl salt. These STI values indicated a wide difference in tolerance of oats in salt stress.

Table 1. Effect of NaCl induced salinity stress on seed germination of oat

Salt type	Concentration (mM)	GP	GRI	MGT	CVG	TSG	GI	STI
NaCl	**00**	100±0^{a}	3.0±0.05^{a}	3.34±0.08^{d}	29.11±0.57^{a}	8.0±1.30^{a}	205.80±21.60	-
	100	100±0^{a}	2.63±0.13^{ab}	4.06±0.27^{cd}	25.05±1.59^{ab}	6.80±1.63^{ab}	133.0±23.92	87.27±0^{a}
	150	94.0±2.45^{a}	2.19±0.06^{bc}	4.44±0.20^{cd}	22.72±0.99^{bc}	5.40±0.75^{ab}	121.4±45.71	80.19±0^{b}
	200	84.0±8.71^{a}	1.99±0.20^{c}	4.28±0.15^{cd}	23.46±0.77^{b}	5.20±1.47^{ab}	116.60±26.53	35.77±0^{c}
	250	84.0±5.10^{a}	1.69±0.12^{cd}	5.38±0.25^{bc}	18.83±0.91^{cd}	3.40±0.93^{ab}	107.60±24.65	18.78±0^{d}
	300	80.0±7.07^{a}	1.40±0.15^{d}	6.38±0.35^{b}	16.82±1.58^{d}	2.20±0.49^{b}	84.40±27.63	2.51±0^{e}
	350	46.0±10.30^{b}	0.54±0.12^{e}	9.34±0.59^{a}	10.90±0.70^{e}	2.60±0.60^{b}	81.60±14.89	1.12±0^{e}
CV (%)		**16.60**	**14.22**	**13.67**	**10.85**	**53.04**	**50.70**	**4.08**
Level of significance		**	**	**	**	*	NS	**

Means are represented as ± standard error (SE). GP- Germination Percentage, GRI-Germination Rate Index, MGT- Mean Germination Time, CVG- Co-efficient of Velocity of Germination, TSG- Time Spread of Germination, GI- Germination Index, TGI- Timson Germination Index, STI- Salt Tolerance Index. Means with the same letter in a column do not differ significantly by DMRT (*P*>0.05).

Table 2. Germination indices of fodder oats in response to varying degrees of NaCl induced salinity stress

Salt type	Concentration (mM)	LDG±SD	MGR±SD	TGI (No)±SD	SV±SD	RWC (%)±SD	FWPR (%)±SD	DWPR (%)±SD
NaCl	**00**	4.60±1.34^{c}	30.02±1.63^{a}	6.67±0^{a}	27.55±2.8^{a}	90.86±1.99	-	-
	100	7.20±3.27^{bc}	24.99±3.44^{b}	6.67±0^{a}	18.27±6.99^{b}	82.51±15.08	27.37±0^{e}	92.40±0^{c}
	150	6.40±2.07^{c}	22.72±2.24^{bc}	6.27±37^{a}	11.78±4.70^{c}	85.81±5.01	43.88±0^{d}	93.20±0^{c}
	200	5.20±1.10^{c}	23.46±1.77^{b}	5.60±1.3^{a}	4.50±4.37^{d}	84.56±5.24	74.62±0^{c}	96.67±0^{b}
	250	8.40±1.67^{abc}	18.74±1.93^{cd}	5.60±0.76^{a}	1.49±0.61^{d}	74.61±11.21	92.83±0^{b}	98.50±0^{a}
	300	11.40±3.05^{ab}	15.82±1.83^{d}	4.93±0.76^{a}	0.41±0.11^{d}	81.34±6.57	97.28±0^{a}	99.78±0^{a}
	350	12.40±0.89^{a}	10.90±1.56^{e}	3.06±1.53^{b}	0.15±0.10^{d}	86.97±1.84	98.65±0^{a}	99.82±0^{a}
CV (%)		**30.50**	**9.40**	**16.21**	**33.17**	**8.67**	**1.34**	**0.83**
Level of significance		**	**	**	**	NS	**	**

Means are represented as ± standard error (SE). LDG- Last Day of Germination, MGR- Mean Germination Rate, TGI- Timson Germination Index, SV- Seed Vigor, RWC- Relative Water Content, FWPR- Fresh Weight Percentage Reduction, DWPR- Dry Weight Percentage Reduction, SE- Standard Error. Means with the same letter in a column do not differ significantly by DMRT (*P*>0.05)

Correlations analyses of germination indices

The correlation analyses were conducted between TGI and other six indices under investigation. The aim was to assess the agreement of each index with the most commonly used germination index (*i.e.* TGI).

For *A. sativa* in NaCl salt stress, four among the six indices significantly correlated with TGI at *P*<0.001 (Figure 1 and Table 3). But the highest Pearson correlation was observed between TGI and the germination percentage (GP) at *P*<0.001. The correlation between TGI and germination rate index (GRI) revealed a Pearson correlation of 0.88 (*P*<0.001). The lowest correlation was between TGI and the mean germination time (MGT) with an average of -0.71 followed by with an average of -0.20 between TGI and time spread of germination (TSG) at *P*<0.001 and *P*>0.05, respectively.

Effect of salinity on seedling growth of oats

Seedling growth was largely affected by varying concentrations of salts. The initial effect of salinity on plants was the reduction of growth rate. The shoot and root length of oat declined significantly (*P*≤0.01) in salt treatments relative to the control and with increase in salinity (Figure 2). Significantly tallest shoot (17.67 cm) and longest root (9.9 cm) were found in control. The shortest shoot (0.20 cm) and root (0.12 cm) were recorded with the salt concentration of 350 mM salt indicating an increased negative impact on early seedling characters of oats with an increased concentration of salt.

Length of root was more suppressed in the current study than of shoot by salinity as the roots are the first organs to face the stress. Reduction of seedling height is a common phenomenon of many crop plants grown under saline conditions (Amin et al., 1996). Mu et al. (2015) investigated that root and shoot growth of oats decreased with the increase of salinity level. The gradual decrease in root length with the increase in salinity as observed might be due to more inhibitory effect of salts to root growth compared to that of shoot growth.

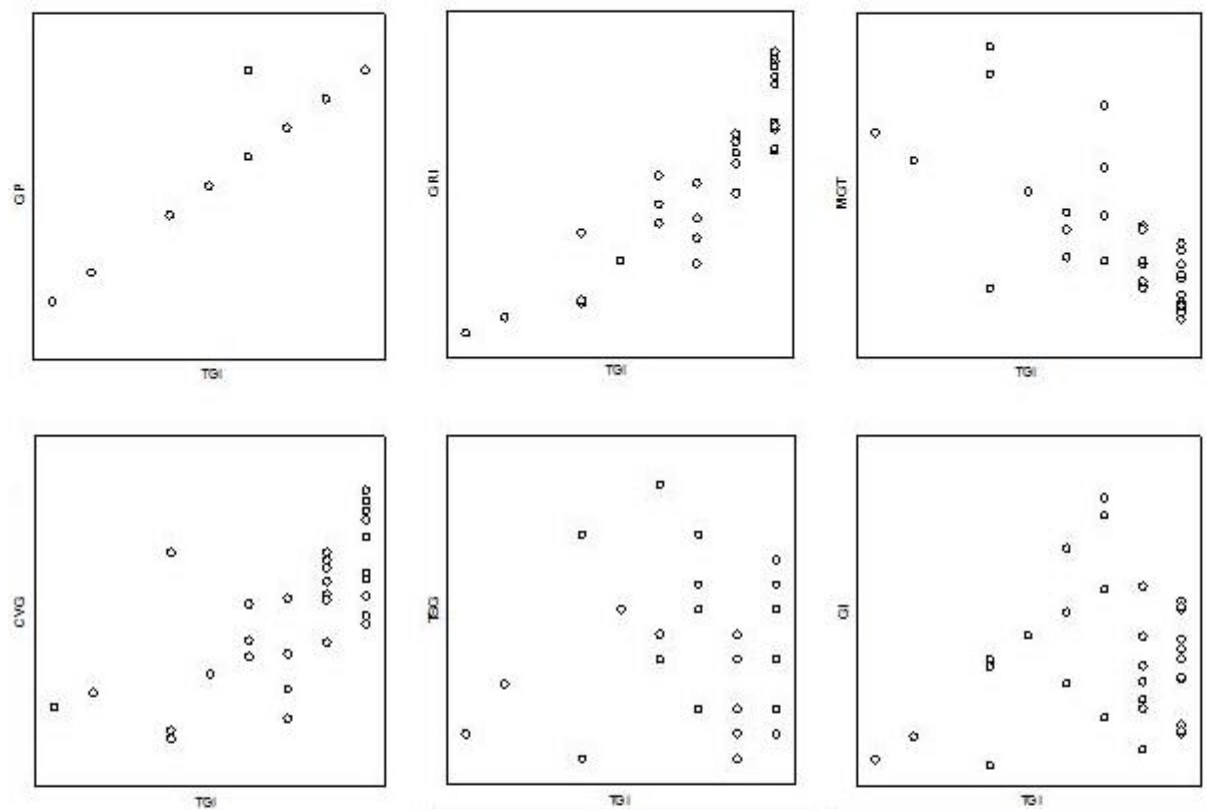

Figure 1. Pearson's correlations between Timson Germination Index (TGI) and the other six indices: Germination Percentage (GP), Germination Rate Index (GRI), Mean Germination Time (MGT), Co-efficient of Velocity of Germination (CVG), Time Spread of Germination (TSG) and Germination Index (GI) relating to germination data for oat in NaCl salt stress

Table 3. Correlation coefficients between TGI on one hand and other six germination parameters: (*i.e.* GP, GRI, MGT, CVG, TSG and GI) for oat in NaCl and Na_2SO_4 salt stress

Salt type	GP	GRI	MGT	CVG	TSG	GI
NaCl	0.97*	0.88*	-0.71*	0.70*	-0.20	-0.14

Stars (*) indicate significant coefficients at *P*<0.001

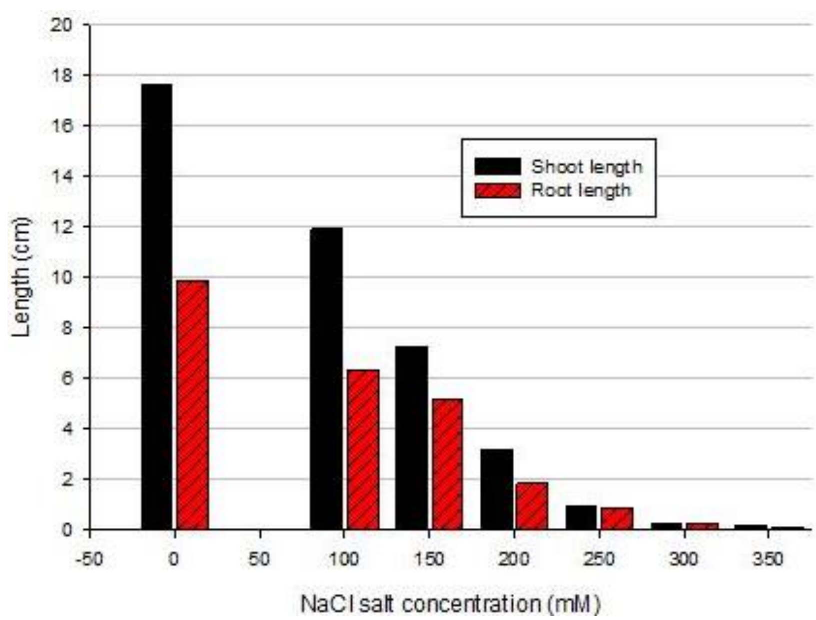

Figure 2. Effect of NaCl salt stress on shoot and root length (cm) of fodder oats

Effect of salinity on fresh and dry weight of shoot and root of oats

Seedling growth is one of the most important characters for screening salt tolerance at early stage of growth. It was observed that salt stress significantly reduced both shoot and root weight of oat (*P*<0.01) (Figure 3 and Figure 4). Fresh weight of shoot and root showed a reducing trend with increased salinity. The highest shoot (0.748 g) and root (0.540 g) fresh weight as well as shoot (0.079 g) and root (0.038 g) dry weight of oat was recorded in control. The lowest shoot (0.004 g) and root (0.009 g) fresh weight, and shoot (0.001 g) and root (0.001 g) dry weight was recorded at 350 mM salinity level.

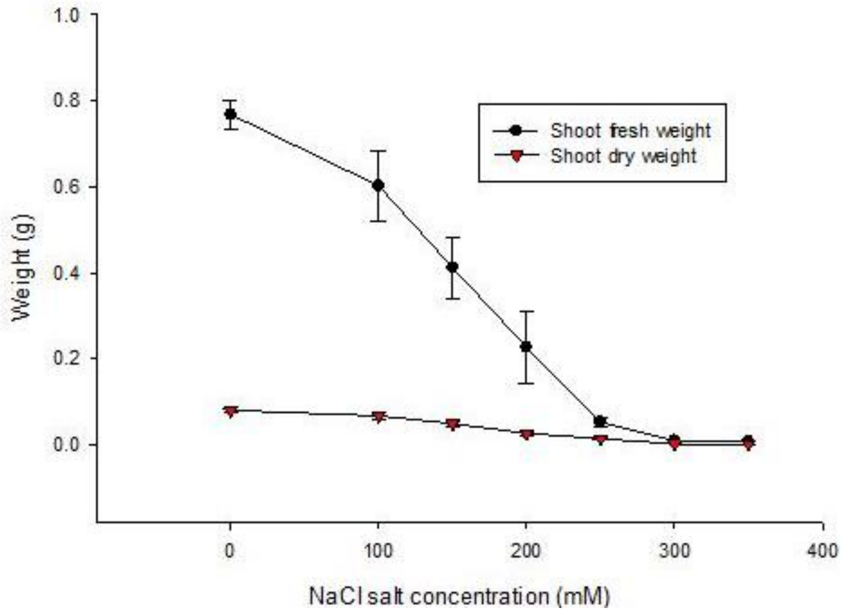

Figure 3. Effect of different level of stress of NaCl salt on fresh weight (g) and dry weight (g) (±SE) of shoot of oat seedlings

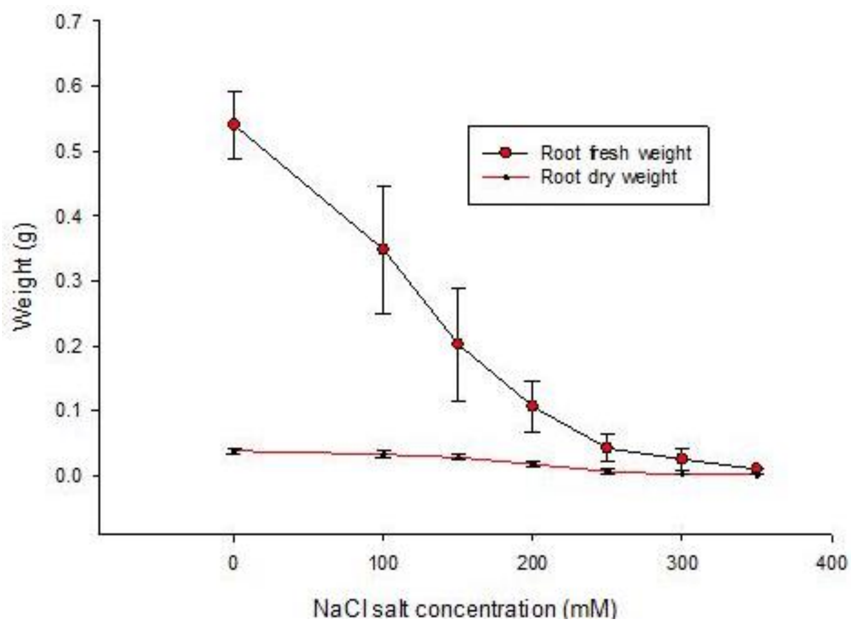

Figure 4. Effect of different level of NaCl salt stress on fresh weight (g) and dry weight (g) (±SE) of root of oat seedlings

Reduction in fresh weight at high salinity might be due to poor absorption of water from the growth medium due to physiological drought (Munns and Tester, 2008). Seedling dry weight is the ultimate result of all physiological and biochemical activities of plant. It has been reported that salinity stress significantly reduces net photosynthetic rates and increases energy losses for salt exclusion mechanism. It also largely decreases nutrient mobilization, suspends the cell division and enlargement and finally reduces plant growth (Long and

Baker, 1986). High accumulation of Na^+ in saline soils causes lowering of water potential and thus makes the plant unable to extract water from soil (Misra and Gupta, 2005). In the present study, seedling dry weight was found to be affected by salt stress. But the adverse effect on seedling dry weight was different in different salt concentration which was the indicative of different sensitivity of oats to salt stress. Murty et al. (1984) concluded that salinity stress can suppress almost all growth-related factors which in turn limit oats biomass and yield production by limiting seed germination and growth. Han et al. (2013) demonstrated that the oats biomass decreased rapidly with increasing soil salinity.

Effect of salinity on growth parameters of oats

Plant height, leaf number, number of tillers and stem thickness are important growth parameters which are directly correlated with the productivity of plants in terms of forage yield. Different salt concentrations showed highly significant variation in growth of oats (Table 4 and Table 5). The values of growth parameters were higher for control compared to NaCl salt stress throughout the growing period. The growth of plant decreased with increasing the salinity concentration as salinity can also affect plant growth and higher salt concentration in the soil solution interferes with balanced absorption of essential nutritional ions by plants (Chauhan et al., 2016). The results of the current study agreed partially with Hirich et al. (2014) who confirmed that saline water decreased vegetative growth.

Table 4. Effect of varying levels of NaCl salt stress on vegetative growth of fodder oat

Salt type	Concentration (mM)	Plant height (cm)				Leaf number			
		15 DAS	30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS	60 DAS
NaCl	00	34.53^{a}	39.70^{a}	49.63^{a}	59.07^{a}	7.07^{a}	13.80^{a}	16.33^{a}	20.77^{a}
	100	33.53^{ab}	37.87^{ab}	45.57^{b}	56.54^{b}	6.50^{ab}	10.83^{ab}	13.73^{b}	19.00^{ab}
	150	32.00^{bc}	36.00^{abc}	43.10^{bc}	54.10^{c}	6.13^{bc}	9.77^{bc}	12.43^{bc}	17.33^{bc}
	200	30.67^{cd}	34.23^{bcd}	41.50^{cd}	52.50^{d}	5.60^{cd}	9.03^{bcd}	11.93^{bcd}	16.27^{cd}
	250	29.00^{de}	33.67^{cd}	39.23^{de}	50.10^{e}	5.27^{de}	7.90^{cde}	11.20^{bcd}	15.23^{de}
	300	28.04^{ef}	32.56^{cd}	37.47^{ef}	47.77^{f}	5.00^{de}	7.13^{de}	10.53^{cd}	13.87^{ef}
	350	26.20^{f}	31.09^{d}	35.43^{f}	45.87^{g}	4.53^{e}	6.27^{e}	9.47^{d}	12.54^{f}
Coefficient of variation (%)		**5.57**	**7.74**	**6.34**	**3.20**	**9.78**	**15.83**	**15.18**	**8.95**
LSD		**2.33**	**3.71**	**3.61**	**1.50**	**0.77**	**2.00**	**2.54**	**2.01**
Level of significance		**	**	**	**	**	**	**	**

Stars (**) indicate significant coefficients at P<0.01

Table 5. Tiller production efficiency and stem thickness of fodder oats at varying levels of NaCl induced salt stress

Salt type	Concentration (mM)	Tiller plant^{-1}				Stem thickness (cm)			
		15 DAS	30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS	60 DAS
NaCl	00	1.90^{a}	3.87^{a}	4.37^{a}	5.23^{a}	0.36^{a}	0.47^{a}	0.56^{a}	0.65^{a}
	100	1.70^{ab}	2.93^{ab}	3.60^{b}	4.77^{a}	0.35^{a}	0.41^{b}	0.49^{ab}	0.58^{b}
	150	1.20^{bc}	2.37^{bc}	3.07^{bc}	3.97^{b}	0.33^{ab}	0.38^{bc}	0.45^{bc}	0.54^{bc}
	200	0.90^{cd}	1.97^{bcd}	2.63^{cd}	3.33^{c}	0.30^{bc}	0.35^{cd}	0.41^{cd}	0.51^{cd}
	250	0.70^{de}	1.57^{cde}	2.30^{de}	2.83^{cd}	0.29^{bcd}	0.33^{cd}	0.39^{cde}	0.46^{de}
	300	0.50^{de}	1.03^{de}	1.77^{ef}	2.27^{de}	0.26^{cd}	0.32^{cd}	0.37^{de}	0.43^{ef}
	350	0.23^{e}	0.77^{e}	1.50^{f}	1.87^{e}	0.25^{d}	0.29^{d}	0.32^{e}	0.39^{f}
Coefficient of Variation (%)		**41.21**	**36.41**	**19.89**	**13.09**	**11.65**	**12.26**	**12.68**	**7.69**
LSD		**0.57**	**1.03**	**0.75**	**0.62**	**0.05**	**0.06**	**0.07**	**0.05**
Level of Significance		**	**	**	**	**	**	**	**

Stars (**) indicate significant coefficients at P<0.01

Vegetative growth of oat including plant height, leaf number, number of tillers and stem thickness are found to be decreased significantly with different concentrations of salts. Ashraf and Parvin (2002) stated that plant growth decreased in the stress treatments which might be due to the fact that cell division or cell enlargement was inhibited due to salinity stress.

The harmful effect of salt stress was mainly led to Na^+ toxicity and the physiological drought caused by high osmotic stress, resulting from the declined water potential of plants under high concentration salt stress (Munns, 2002). The saline growth medium caused many adverse effects on plant growth, which was due to the low external water potential (osmotic stress). Under salt stress, plants have to cope with stress imposed by low osmotic potential and with ion toxicity due to the accumulation of ion inside the plants.

There were always linear and negative relationships among the growth parameters with varying degree of salt stress (Figure 5). The higher value of R^2 ($R^2 \geq 0.98$) suggests that the variations in growth parameters of fodder oats could mostly be explained by salt stresses during its growing period. Plant height, leaf and tiller production efficiency as well as stem thickness were negatively affected with an increased salt stress.

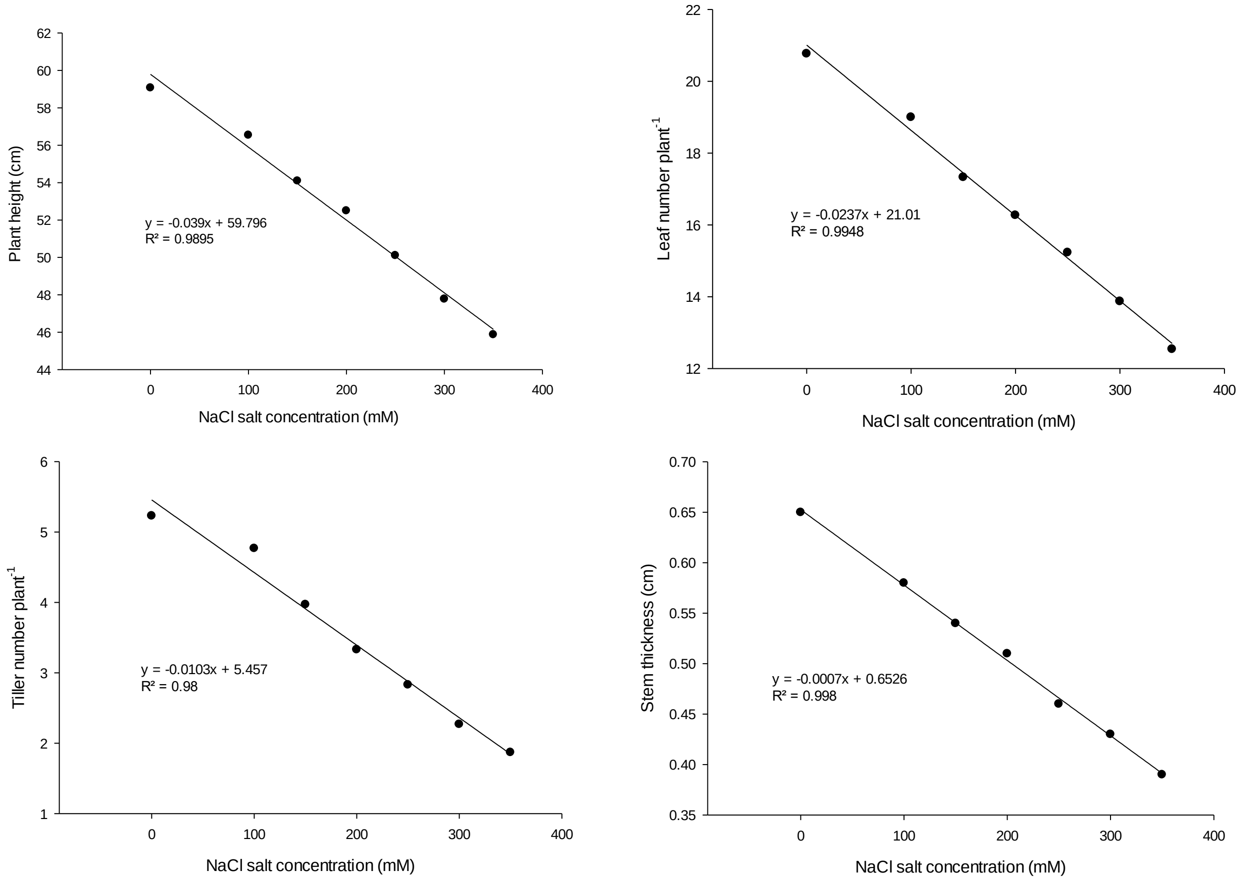

Figure 5. Functional relationships of NaCl salt concentrations with other growth parameters of fodder oats

Conclusion

Salinity has an obvious detrimental effect on the germination and growth of oats for tested salt in the current study. Different germination and physiological parameters, and performance of fodder oats were better in control. As salinity level increased the plants showed more susceptibility to salt in respect of both germination and growth. Oat plants could survive and perform under different salinity levels and for fodder production, up to 100 mM level of salinity induced by NaCl salt may be accepted. Crop production is unpleasantly affected by soil salinity in coastal areas and oat can be an alternative crop to bring these problematic fallow lands under cultivation.

Authors' Contribution

M.M. Islam and A.A. Mamun advanced the research concept and planned the experiments. S.M.T. Islam executed the experimentation, collected and compiled the data. A.A. Mamun analyzed and formatted the data. S.M.T. Islam contributed to writing the manuscript. M.M. Islam and A.A. Mamun revised the manuscript critically for important intellectual content. All authors read the article and approved the final version to be published in Journal of Bangladesh Agricultural University.

Competing interests

The authors have declared that no competing interests exist.

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