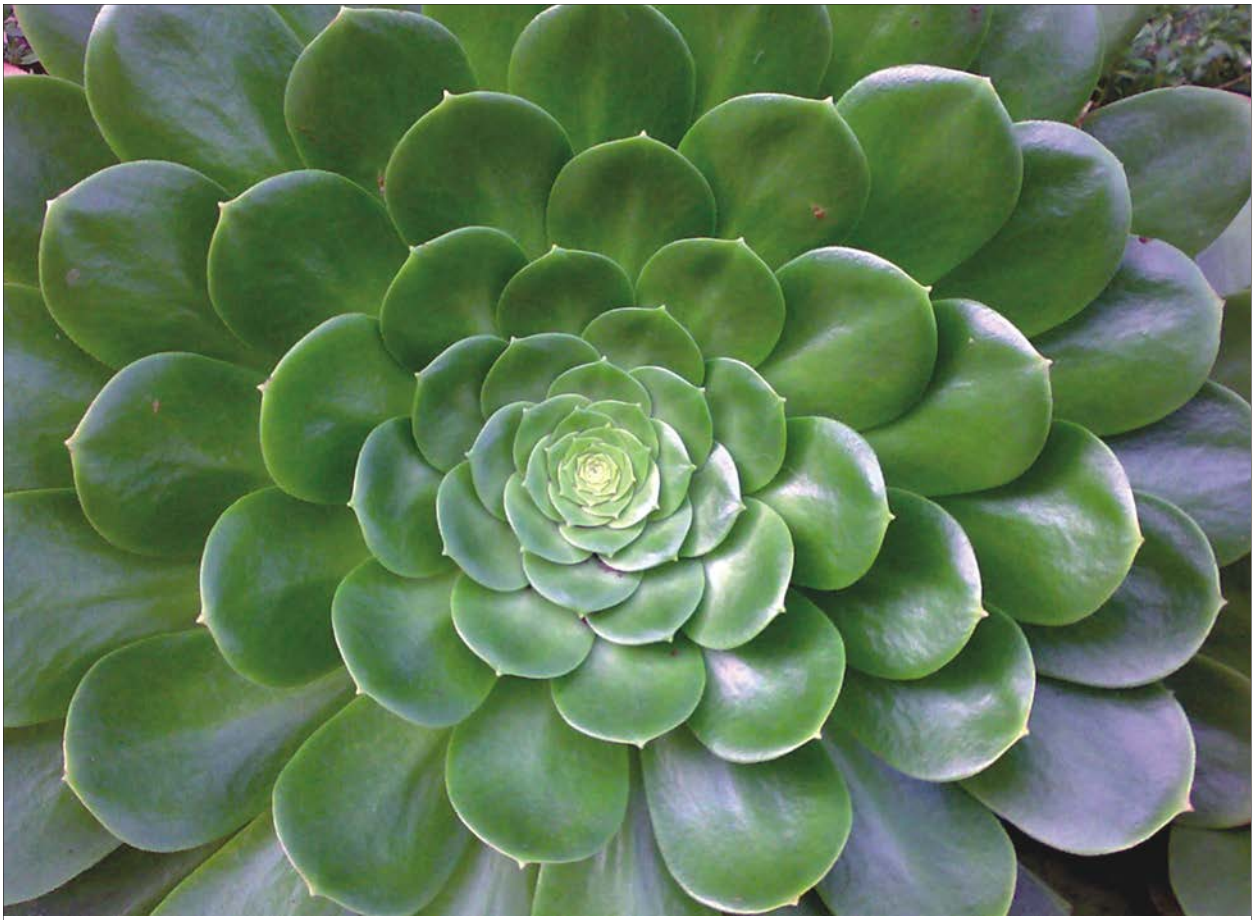

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Effect of Salt Stress on Growth Parameters, Moisture Content, Relative Water Content and Photosynthetic Pigments of Fenugreek Variety RMt-1

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ABSTRACT

Present research was carried out with the aim of identifying effect of salt stress (NaCl 0.0, 50, 100, 150 and 200 mM) on growth and physiological parameters of fenugreek (*Trigonella foenum-graecum* L.) variety RMt-1, a leafy vegetable. Various parameters such as germination percentage, shoot and root length, shoot-root ratio, number of leaves and branches, vigour index, fresh and dry weight, moisture content, relative water content and photosynthetic pigments were analyzed. All the parameters were recorded at 15, 30, 45 and 60 Days After Sowing (DAS). Analysis revealed a significant reduction in all parameters with increased salt concentration. Severity of salinity were also observed with increased age as increase in all growth parameter were non-significant in stressed plant as compared to non-stressed plant. A significant reduction from 100-30% was observed in germination percentage under salt stress. High salt concentration delayed the process of germination. Shoot length and root length was significantly reduced from 38.83 cm (control) to 9.44 cm (200 mM) and from 7.48 cm (control) to 2.44 cm (200 mM) respectively at 60 DAS. This analysis was further supported by fresh and dry weight of shoot and root, shoot/root ratio and moisture content. Present study concluded that the effect of salt toxicity was more prone in shoot as compared to root. The study also signified salt dependent behaviour of different photosynthetic pigments. A positive correlation was observed between stages of growth and reduction in parameters under salt stress. Overall study concluded that fenugreek variety RMt-1 is sensitive towards higher concentration of salts.

Key words: Germination percentage, fresh weight, relative water content, salinity, *Trigonella foenum-graecum* L, vigour index

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is an important crop belonging to the legume family and cultivated in semi-arid regions of the world. It is a native of Asia and Southern Europe and contributes a lot as a staple food in India (Acharya *et al.,* 2008; Kapoor *et al.*, 2011; Obour *et al.*, 2015). India is the leading fenugreek producing country in the world and claiming 70-80% of world's export share (Fotopoulos, 2002). In India, it covers an area of 103100 ha with total production (seed) of 95800 t (Aggrwal *et al.*, 2013). Fenugreek is used as spice (seeds), flavoring agent, medicinal plant, vegetable, fodder and green manure as it is rich in protein, vitamins and minerals (Acharya *et al.*, 2008; Nathiya *et al.*, 2014; Laila and Murtaza, 2015).

Fenugreek has different pharmacological attributes because of presence of several secondary metabolites such as diosgenin, saponins, mucilaginous fiber (galactomannans), pyridine-type alkaloids (trigonelline, choline, gentianine and carpaine) and free amino acids (arginine, histidine and lysine) (Mehrafarin *et al*., 2010; Kor *et al*., 2013; Nathiya *et al*., 2014; Laila and Murtaza, 2015). Fenugreek is also used in nitrogen fixation from the atmosphere which reduces the need of harmful fertilizers for subsequent crops. Fenugreek is a dry land crop having low water requirements thus reducing the cost of irrigation, eutrophication of surface waters and limits the use of water as well as contamination of ground water sources (Basu *et al*., 2004; Acharya *et al*., 2008).

Salinity coupled with low rainfall is one of the most serious factors in arid and semi arid regions of the world that adversely affect the productivity of present day agricultural crops (Munns and Tester, 2008). Worldwide, more than 45 million ha of irrigated land have been damaged by salt and 1.5 million ha are taken out of production each year as a result of high salinity levels in the soil (Munns and Tester, 2008). Saline soils and saline irrigation waters adversely affects production of fenugreek (Tuncturk, 2011). Salinity tolerance for fenugreek was reported up to 10 ds m^{-1} salinity level (Niknam *et al*., 2006; Abdelmoumen and El Idrissi, 2009).

Salinity stress causes extensive oxidative damage, affecting several physiological processes which results in significant reduction of different parameters such as germination capacity, radicle and plumule lengths, fresh and dry mass, yields, seed nutritional quality, productivity, chlorophyll, protein and sugar content, antioxidative enzymes activity as well as nodulation (Asaadi, 2009; Ghorbanpour *et al*., 2011; Tuncturk, 2011; Al-Saady *et al*., 2012; Talukdar, 2012; Kapoor *et al*., 2013; Pour *et al*., 2013).

Thus, the present study was carried out on fenugreek variety RMt-1 to understand the toxic effect of salt stress on the growth of this valuable crop. The objectives of this work were to assess the effect of salinity on: (1) Seed germination, (2) Growth parameters and (3) Physiological parameters.

MATERIALS AND METHODS

Experimental material and salt treatments: Fenugreek (*Trigonella foenum-graecum* L.) variety RMt-1 seeds were procured from Jobner research centre, Rajasthan. Experiments were carried out at Department of Biotechnology, Kumaun University, Bhimtal Campus, Bhimtal during rabi seasons of 2012-13 and 2013-14, respectively. Seeds of uniform size were selected and surface sterilized in 70% (v/v) ethanol for 2 min and 3% sodium hypochlorite solution for 20 min followed by washings for several times with distilled water. The seeds were then germinated on moist filter paper in petridishes in the dark at a constant temperature of 25°C. The seeds were exposed to different concentrations (50, 100, 150 and 200 mM) of salt (NaCl). Comparisons of salt exposed plants were made with untreated (control) plants. The germination was recorded at 12 h interval for 5 days. The radicle emergence was taken as the criterion for germination (ISTA., 1993).

After germination, uniform seedlings were selected and inoculated in plastic pots containing sterile sand and vermiculite (1:1 v/v). The pots were placed into a growth chamber under a mean air temperature of 25±1°C, air relative humidity of 75-80% and photoperiod of 16/8 h for growth and physiological parameters analysis. The experiments were conducted with three replicates for each treatment. Irrigation was done with water and respective concentration of saline solution for control and treated plants respectively after 10th days. Various growth and physiological parameters were recorded at 15, 30, 45 and 60 Days After Sowing (DAS).

Growth parameters: Shoot and root length, shoot/root ratio, Number of Leaves/Plant (NLP) and Number of Branches/Plant (NBP) were measured at 15, 30, 45 and 60 DAS.

Vigour index: Vigour index was calculated as the product of seedling length (root length+shoot length) and germination percentage (Abdul-Baki and Anderson, 1973):

$$\text{Vigour index} = \text{Germination percentage} \times \text{Seedling length}$$

Fresh and dry weight measurement: Fresh and dry weight of the shoot and root were measured. For measuring the dry weight the plant parts were exposed to a constant temperature in hot air oven at 100°C for 2 h.

Physiological parameters

Moisture content: Moisture content was tested by gravimetric method (high constant temperature oven method) at 130°C for 1 h (ISTA., 1993).

Relative Water Content (RWC): Relative Water Content (RWC) was determined by the methods described by Barrs and Weatherley (1962). Cut leaves were weighed (Fresh Weight, FW), then left saturated in distilled water inside a closed petri dish for three hours and their Turgid Weights (TW) were calculated. At the end of the imbibition period, leaf samples were placed in a pre-heated oven at 80°C for 24 h in order to obtain the Dry Weight (DW). All mass measurements were made using an analytical scale, with precision of 0.0001 g. Values of FW, TW and DW were used to calculate RWC, using the following equation:

$$\text{RWC} = \frac{\text{FW-DW}}{\text{TW-DW}} \times 100$$

Photosynthetic pigments: Various photosynthetic pigment such as chlorophyll a, chlorophyll b and total chlorophyll content were estimated by Arnon (1949) and carotenoid content by Maclachlan and Zalik (1963) at 15, 30, 45 and 60 DAS. Fresh leaf material (200 mg) was taken from the second and third nodes of the shoot tip and crushed with the mortar and pestle in 10 mL 80% chilled acetone and centrifuge at 2500 rpm for 10 min. This step was repeated until the pellet became colourless. The supernatant was collected and used for analysis. Different photosynthetic pigments concentrations were measured using a UV visible double beam spectrophotometer (SPUV-26) SCO-TECH, Germany at 645 and 663 nm wavelengths. A solution of 80% acetone was used as a blank. The chlorophyll a, chlorophyll b and total chlorophyll (mg g^{-1} FW) concentrations in the leaf tissues were calculated according to the following equation:

$$\text{Chl a} = \frac{(12.7 \times \text{A663})-(2.63 \times \text{A645})}{\text{Weight (g)}} \times 1000$$

$$\text{Chl b} = \frac{(22.9 \times \text{A645})-(4.48 \times \text{A663})}{\text{Weight (g)}} \times 1000$$

$$\text{Total chlorophyll} = \frac{(20.2 \times \text{A645})-(8.02 \times \text{A663})}{\text{Weight (g)}} \times 1000$$

Statistical analysis: Data were subjected to the analysis of variance (ANOVA) by agries programme and Microsoft excel for standard deviation.

RESULTS AND DISCUSSION

Effect of salt stress on growth parameters

Germination percentage: Knowledge of crop plant biology, particularly germination requirements, is important while developing effective management programs. The response pattern of germination are regarded as a key feature because it is a sensitive stage in the life cycle of plants as the seed makes the transition from a metabolically quiescent to an active and growing entity. The process of germination involves: imbibitions of water, activation of enzymes, hydrolysis of stored material, initiation of growth, breakage of seed coat and emergence of the seedling. Based on the two years pooled data, the mean performance of the fenugreek variety RMt-1 seeds in salt stressed condition with respect to control were depicted in Fig. 1a. It was observed that salt stress induced by 50-200 mM NaCl led to a progressive gradual decrease in the percentage of germination with increasing concentration as compared with the control. Maximum germination (100%) was observed in control as well as low (50 mM) salt concentration. Higher salt concentration i.e. 100, 150 and 200 mM enabled only 97, 41 and 30% germination, respectively. Ratnakar and Rai (2013) reported that the higher concentrations of NaCl (80 mM onwards) completely retarded the process of germination in fenugreek variety Pusa Early Bunching (PEB) Our result does not coincide with them as we observed low germination upto 200 mM salt concentration. The variation in germination may be attributed to genotypic differences. Germination of seed depends on the utilization of reserved food material of the seed. Salinity interferes with the process of water absorption by the seeds. This subsequently inhibits the hydrolysis of seed reserves which ultimately delays and decreases seed germination (Begum *et al*., 2010).

Kinetics of germination: Result presented in Fig. 1a shows the deleterious effect of salinity on germination kinetics of fenugreek seeds. In control and low concentration of salt (50-100 mM), germination started after 12 h of imbibitions which is 50, 30 and 8%, respectively. Further, increase in salt concentration resulted in delayed germination process and the extent of delay depends on the salt concentration used. Germination rapidly retarded above 100 mM with no seed germination upto 24 and 36 h at 150 and 200 mM, respectively. These results were further correlated with delayed in occurrence of maximum germination in salt stressed seeds as compared to control. Maximum germination was observed at 48, 108, 120, 120 and 120 h in control, 50, 100, 150 and 200 mM salt concentration, respectively. Salt stress causes toxic effects on the embryo which results in delayed germination and/or reduced germination rate, which is true in the present study. Delay in germination by increased salt concentration may be explained by the lower osmotic potential of the solution (Todd, 2001), decline of primary absorption rate, decreased photosynthetic activity due to decreased hill reaction, inhibition of enzymes of calvin cycle and/or loss of photosynthetic pigments (Gabbrielli *et al*., 1990).

Shoot length: Result expressed in Fig. 1b shows that with increased salt concentration there was a significant decrease in shoot length. At initial stage (15 DAS) shoot length was decreased from 6.19 cm (control) to 2.96 cm (200 mM). Severity of salinity was also significantly increased with subsequent growth stages. After 60 DAS maximum (38.83 cm) and minimum (9.44 cm) shoot length were observed in control and 200 mM concentration, respectively. Percentage decrease in shoot

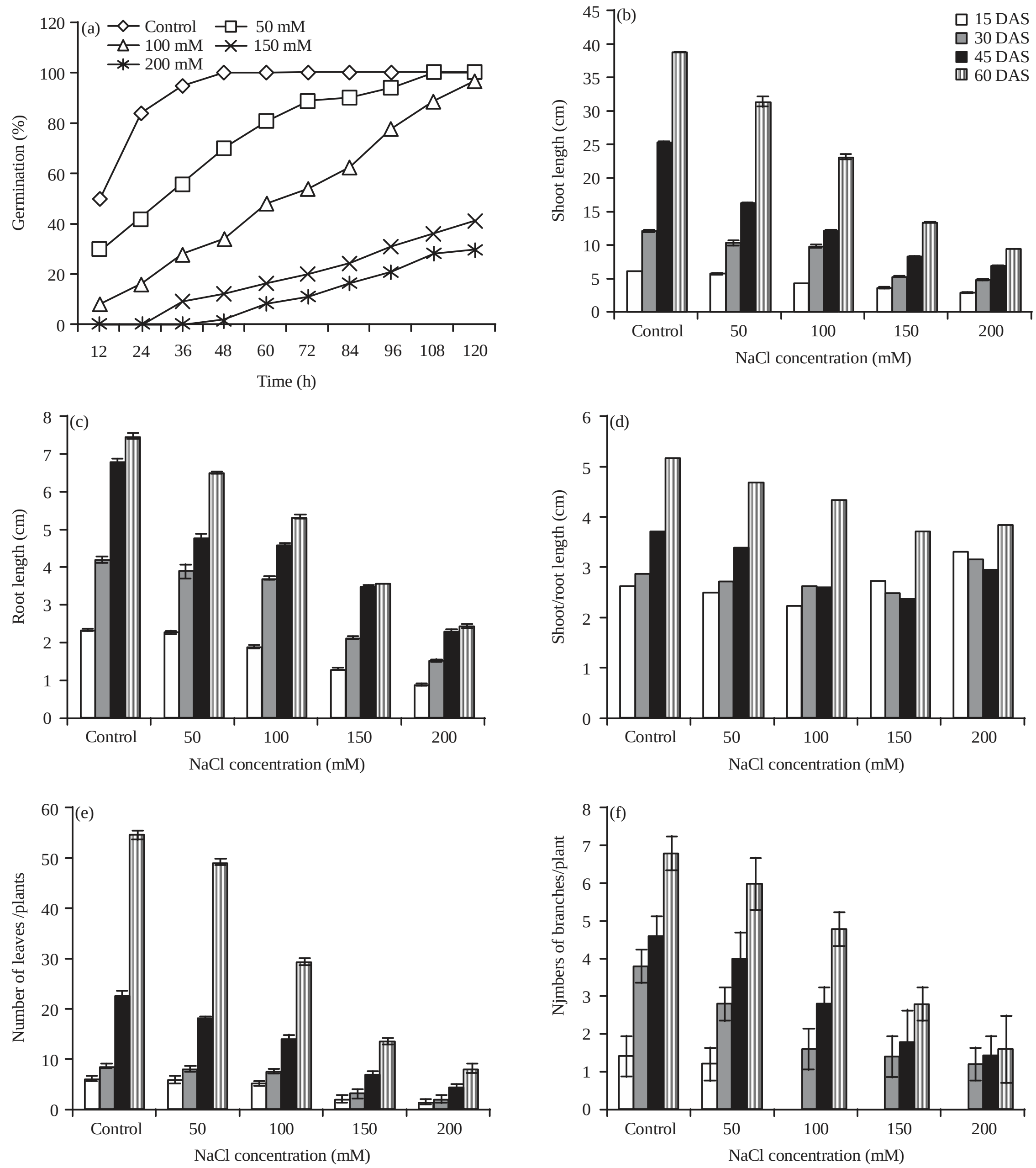

Fig. 1(a-f): Effect of different concentration of salt on different growth parameters of fenugreek variety RMt-1, (a) Germination percentage, (b) Shoot length, (c) Root length, (d) Shoot/root ratio, (e) Number of leaves/plant and (f) Number of branches/plant. Values Mean±SD, n = 3), DAS: Days after sowing, SL: Shoot length and RL: Root length

length was 52.21, 60.26, 72.88 and 75.7% at 15, 30, 45 and 60 DAS, respectively (Fig. 2a). Control plants appeared green and healthy as compared to the stressed plants. These results are in harmony with Niknam *et al*. (2006), Mehrafarin *et al*. (2011) and Talukdar (2012) working on fenugreek. They studied the effect of salinity in the physiological parameter and found that increase in salt concentration significantly affects the shoot lengths and its growth.

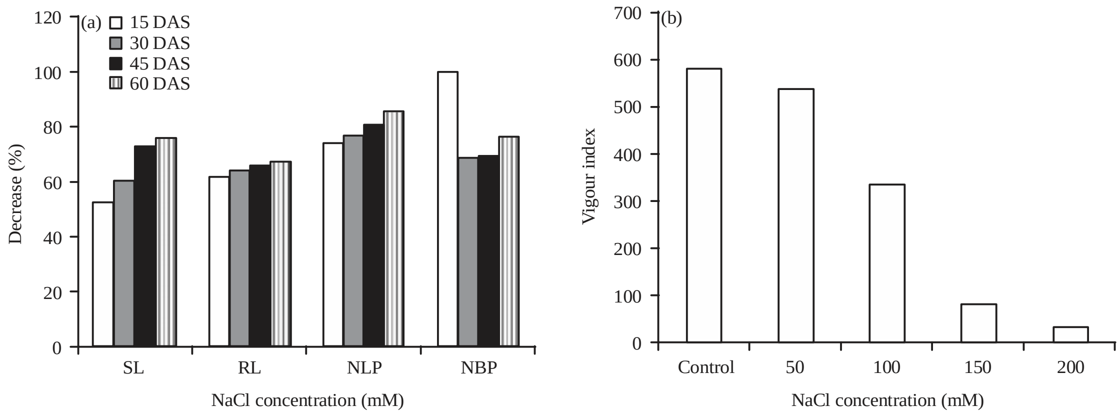

Fig. 2(a-b): Effect of different concentration of salt on different growth parameters of fenugreek variety RMt-1, (a) Percentage decrease and (b) Vigour index, DAS: Days after sowing, SL: Shoot length, RL: Root length, NLP: Number of leaves per plant, NBP: Number of branches per plant and VI: Vigour index

Root length: Data shown in Fig. 1c regarding root lengths shows a similar pattern to shoot length. The pattern of salt treated seeds shows gradual decrease in root length with increasing salt concentration as compared to control. The root length was increased from 2.34-7.48 and 0.89-2.44 cm in control and salt stressed plant respectively from 15-60 DAS. But significant reduction was observed in root length from 7.48 cm in control to 2.44 cm in 200 mM salt solution at 60 DAS. The similar decline pattern was also observed during different time intervals but there were no significant changes occurred in root development in stressed and non-stressed plant with respect to time duration (Fig. 2a). These data shows that root length was less affected than shoot length, thus performance of root is better than shoots under salt stress in fenugreek variety RMt-1. These results are in harmony with previous findings of Mehrafarin *et al*. (2011), who reported that soil salinity suppresses shoot growth more than the root growth. Roots play an important role in shoot growth under saline conditions. Better growth of root may be due to active translocation of salt and ions from root to shoot (Asaadi, 2009).

Shoot/root ratio: Effects of salinity were also compared in terms of shoot/root ratio (Fig. 1d). Maximum and minimum shoot/root ratio was observed to be 5.19 and 3.87 at 60 DAS in control and 200 mM salt concentration respectively. Similar retardation in growth parameters have been previously reported in fenugreek (Niknam *et al*., 2006; Talukdar, 2012). Ghorbanpour *et al*. (2011) also evaluated the effect of drought and salinity stress on fenugreek germination and some growth indices and reported a detrimental effect of salinity on all scored parameters.

Number of leaves (NLP) and branches per plant (NBP): Reduction in shoot and root length under salt stress were also confirmed with analysis of leaves and branches number. Results presented in Fig. 1e showed that higher concentrations of salinity decrease the leaf number throughout the experiment. Maximum Number of leaves per plant NLP and NBP was 54.8 and 6.8, respectively at 60 DAS in control plant (Fig. 1e and f). These results corroborate with those reported by Aggrwal *et al*. (2013) in fenugreek. Tuncturk (2011) reported the effect of different concentrations of NaCl (0-250 mM) on mineral ions content in various plant organs of fenugreek and found that the nutrient concentrations in plant tissues like leaves, roots, shoots and pods of fenugreek was strongly affected by all salt treatments which also affects the leaf development.

It was also observed that the general trend of the treatment reflects a gradual decrease in NBP with the increase of salt concentration, compared with the plants of the control experiment. At higher salt concentration (100-200 mM) branch development was initiated at 30 DAS (Fig. 1f). Statistical analysis also exhibit significant differences, as decrease of NLP and NBP for plants exposed to salt stress, compared with the control plants at different time durations. At 60 DAS a maximum decline of 85.04 and 76.47% were observed in number of leaves and branches respectively (Fig. 2a). Abdul Qados (2011) also reported that the treatment of sodium chloride reduced the number of leaves compared with control plants while working on bean plant (*Vicia faba* L.). The decrease of leaf numbers occur due to the accumulation of sodium chloride in the cell walls and cytoplasm of the older leaves. At the same time, their vacuole sap cannot accumulate more salt and, thereby decreases the concentration of salt inside the cells, which ultimately leads to their quick death and cut down (Munns and Tester, 2008).

Vigour index: The deleterious effects of salinity were further confirmed by analyzing vigour index. With the decrease in germination percentage and seedling length in fenugreek variety RMt-1 vigour index also showed a significant decline pattern during salinity stress (Fig. 2b). Vigour index decreased from 584-35.4 in control and 200 mM salt stress. Thus, it is clear that the germination percentage shoots and root length showed a positive and significant correlation with vigour index.

Shoot and root fresh weight and dry weight: Similar to reduction in shoot and root length, addition of salt significantly reduced biomass of fenugreek (Table 1). From the respective table it

Table 1: Effect of different concentration of salt on different physiological parameters of fenugreek variety RMt-1

Parameters	SFW	SDW	RFW	RDW
NaCl concentration (mM)				
15 DAS				
Control	0.78±0.006	0.11±0.015	0.33±0.011	0.011±0.003
50	0.72±0.014	0.081±0.003	0.313±0.012	0.013±0.006
100	0.56±0.026	0.061±0.003	0.287±0.006	0.007±0.001
150	0.391±0.017	0.029±0.002	0.26±0.01	0.006±0.001
200	0.193±0.016	0.017±0.001	0.157±0.006	0.004±0.001
Decrease (%)	75.26	84.55	52.4242	63.6364
30 DAS				
Control	1.41±0.017	0.21±0.01	0.41±0.025	0.029±0.001
50	1.21±0.026	0.19±0.026	0.394±0.015	0.023±0.006
100	1.16±0.018	0.09±0.027	0.035±0.001	0.017±0.001
150	0.88±0.015	0.054±0.002	0.293±0.015	0.013±0.006
200	0.263±0.001	0.021±0.002	0.193±0.012	0.009±0.001
Decrease (%)	81.3475	90	52.9268	68.9655
45 DAS				
Control	6.78±0.04	2.72±0.016	1.20±0.133	0.091±0.003
50	3.843±0.019	1.033±0.006	1.077±0.015	0.043±0.012
100	3.123±0.015	0.817±0.012	0.81±0.01	0.039±0.002
150	2.64±0.012	0.243±0.006	0.63±0.01	0.021±0.001
200	1.22±0.01	0.183±0.006	0.533±0.012	0.028±0.001
Decrease (%)	82.0059	93.2721	55.6941	69.2308
60 DAS				
Control	12.46±0.021	5.47±0.023	1.61±0.005	0.093±0.006
50 mM	10.1±0.015	3.91±0.017	1.313±0.012	0.073±0.015
100 mM	7.78±0.08	2.63±0.025	1.12±0.015	0.054±0.002
150 mM	5.32±0.009	1.01±0.006	0.99±0.017	0.034±0.001
200 mM	2.03±0.015	0.22±0.018	0.74±0.01	0.029±0.002
Decrease (%)	83.76	95.9963	54.0373	68.8172

Values Mean±SD, n = 3, DAS: Days after sowing, SFW: Shoot fresh weight, SDW: Shoot dry weight, RFW: Root fresh weight and RDW: Root dry weight

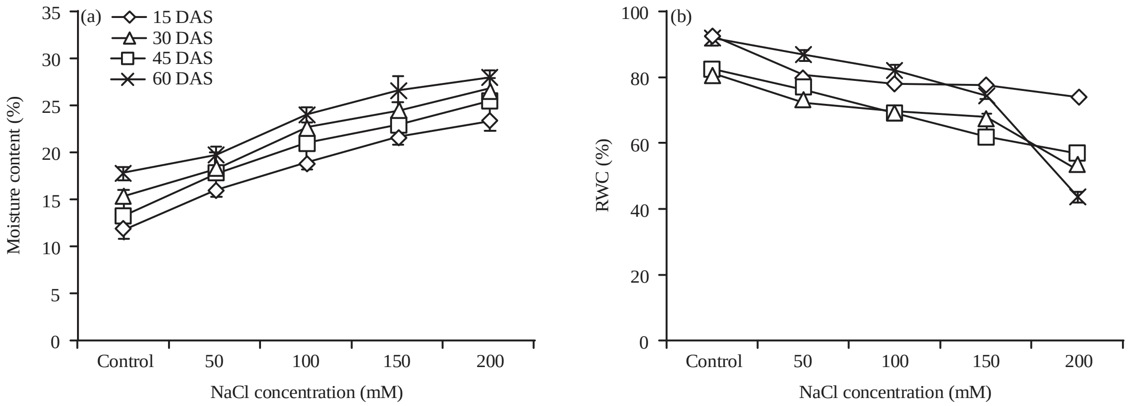

Fig. 3(a-b): Effect of different concentration of salt on different physiological parameters of fenugreek variety RMt-1, (a) Moisture content (%) and (b) Relative water content (%). Values Mean SD, n = 3, DAS: Days after sowing, RWC: Relative water content

can be observed that fresh and dry weight of both shoot and root decreased with increasing salt concentrations as compared to the control. A significant decrease from 12.46 g (control) to 2.03 g (200 mM) and 5.47 g (control) to 0.22 g (200 mM) at 60 DAS were observed in fresh weight and dry weight of shoot respectively. A significant reduction from 1.61-0.74 and 0.093-0.029 g were observed in fresh weight and dry weight of root respectively at 60 DAS. Percentage decrease in shoot and root fresh weight is positively correlated with shoot and root length. Salinity resulted in restriction in water absorption which may be responsible for decrease in biomass. The results obtained are in agreement with previous studies reporting increase on salt concentration negatively affects root and shoot development (Ashraf and Orooj, 2006; Niknam *et al*., 2006). Salinity inhibits plant growth for two reasons: first, water deficit and second, salt-specific or ion-excess effects (Munns and Tester, 2008). Dry weight of plants has been considered as one of the realistic criteria in determining salt responses in plants. Several workers also reported that salt stress causes very significant reduction in all growth variables, including fresh and dry weight in fenugreek (Niknam *et al*., 2006; Talukdar, 2012).

Effect of salt stress on various physiological parameters

Moisture content: Figure 3a shows the effect of salt concentration on moisture content. The increase in moisture content was 49.53, 47.86, 42.39 and 36.49% at 15, 30, 45 and 60 DAS, respectively. Moisture content of control was 1.89% (15 DAS), 17.86% (60 DAS) and that of 200 mM concentration was observed as 23.56% (15 DAS), 28.12% (60 DAS) in fenugreek variety RMt-1. This increase was also observed in similar manner at different growth stages in stressed plants but the difference was less at 60 DAS which explain that later stages of development tends to withstand the increased salt stress (Table 2). Significant increase in moisture content in fenugreek explains deterioration due to salt stress.

Relative Water Content (RWC): The analysis of various salinity levels on relative leaf water content showed that, increase in salinity concentration caused significant reduction in RWC (Fig. 3b). The reductions become more severe with time duration. The decline in RWC was 19.87, 31.05, 35.49 and 52.39% at 15, 30, 45 and 60 DAS, respectively (Table 2). Relative leaf water

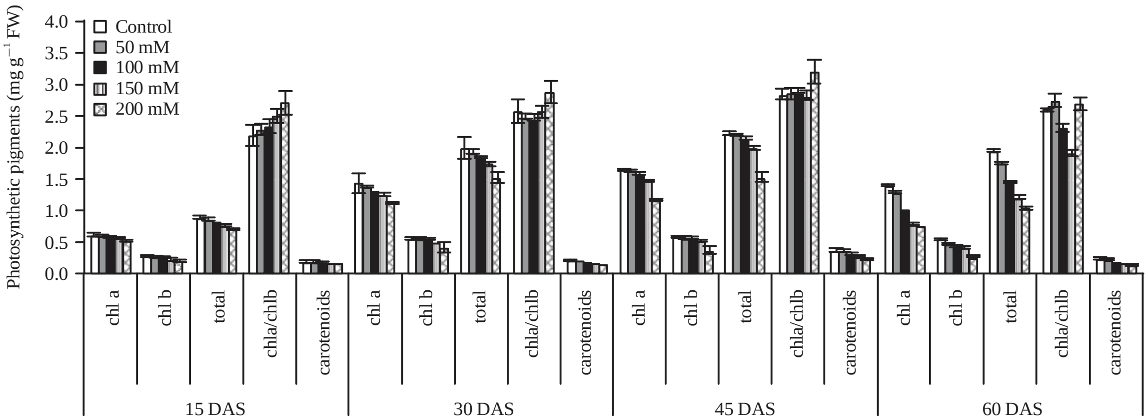

Fig. 4: Effect of different concentration of salt on different photosynthetic pigments of fenugreek variety RMt-1. Values Mean±SD, n = 3, DAS: Days after sowing, chl a: Chlorophyll a and chl b: Chlorophyll b

Table 2: Phytotoxic analysis of effect of different concentration of salt at different growth stages on fenugreek variety RMt-1

	Phytotoxicity						
	Decrease (%)					Increase (%)	
Time	chl a	chl b	Total	Carotenoids	RWC	MC	chla/chlb
15 DAS	15.85	32.14	20.97	13.21	19.87	49.53	19.45
30 DAS	21.86	27.49	23.43	33.13	31.05	47.86	10.45
45 DAS	29.70	36.21	31.39	39.09	35.49	42.39	11.00
60 DAS	46.32	48.15	46.83	43.06	52.39	36.49	3.481

DAS: Days after sowing, chl a: Chlorophyll a, chl b: Chlorophyll b, RWC: Relative water content and MC: Moisture content

content is considered as a reliable criterion to measure water in plant tissues because relative leaf water content can show better balance between plant water and transpiration rate through direct relation with cell volume (Schonfeld *et al*., 1988).

Photosynthetic pigments: To verify the results of growth parameters, estimations of chlorophyll and carotenoids were performed. Salt stress caused a marked decrease in the chlorophyll content of fenugreek variety RMt-1 (Fig. 4 and Table 2). However, comparing control, the decrease became significant at 100 mM for fenugreek variety RMt-1. Chlorophyll a content fell significantly at higher concentration (200 mM) after 30 DAS. Maximum chlorophyll a, chlorophyll b and Carotenoids content were observed in control at 45 DAS which is 1.65, 0.58 and 0.37, respectively. Plant synthesized sugar during vegetative stage, which is broken down during respiration by plants. Increase in total chlorophyll content up to 45 DAS cope with increased carbohydrate content requirement of plants. Reduction in chlorophyll content after 45 DAS occurs due to transportation of sugars carbohydrate towards sink (immature pod) and increased activity of chlorophylase enzyme resulted in degradation of chlorophyll molecules (Aggrwal *et al*., 2013). Plant showed necrosis at 60 DAS and thus all photosynthetic pigment were affected. Comparative analysis revealed that among all photosynthetic pigment studied chlorophyll b is maximum affected (48.15%) followed by chlorophyll a (46.32%) and then Carotenoids (43.06%). This parameter was found in full support to our growth parameters. Decrease in total chlorophyll content was also found highly significant in saline soil grown fenugreek plants with respect to normal soil grown plants. These results corroborate with those reported by Ghorbanpour *et al*. (2011), Al-Saady *et al*. (2012), Talukdar (2012) and Aggrwal *et al*. (2013) for fenugreek and grass pea.

CONCLUSION

In respect to fulfill the increased global demand of medicinal plants, understanding and extending approaches for increase salinity resistance in such plants is important, so that they are able to grow in tropical and salty regions. Thus, present study was conducted on fenugreek (*Trigonella foenum-graecum* L.) variety RMt-1, in order to analyze the influence of salt stress on growth. The resultant plants from salt treated seeds recorded lower values for all the growth attributing parameters. All results obtained indicated that different growing characteristics were also significantly affected by salinity stress at different growth stages. The first plant part interacts with salt is the roots but they triggers the avoidance mechanism hence less affected by salt stress as compared to shoot.

Further, analysis of salt stress on physiological parameters at different growth stage revealed a positive correlation. Among all photosynthetic pigments chlorophyll b is highly affected by salt stress. The cumulative study based on results of all the parameters concluded that the present experimental crop is sensitive towards higher concentration of salt.

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REFERENCES

Abdelmoumen, H. and M.M. El Idrissi, 2009. Germination, growth and nodulation of *Trigonella foenum graecum* (Fenu Greek) under salt stress. Afr. J. Biotechnol,, 8: 2489-2496.

Abdul Qados, A.M.S., 2011. Effect of salt stress on plant growth and metabolism of bean plant *Vicia faba* (L.). J. Saudi Soc. Agric. Sci., 10: 7-15.

Abdul-Baki, A.A. and J.D. Anderson, 1973. Vigor determination in soybean seed by multiple criteria. Crop Sci., 13: 630-633.

Acharya, S.N., J.E. Thomas and S.K. Basu, 2008. Fenugreek, an alternative crop for semiarid regions of North America. Crop Sci., 48: 841-853.

Aggrwal, K.B., J.K. Ranjan, S.S. Rathore, S.N. Saxena and B.K. Mishra, 2013. Changes in physical and biochemical properties of fenugreek (*Trigonella* sp. L.) leaf during different growth stages. Int. J. Seed Spices, 3: 31-35.

Al-Saady, N.A., A.J. Khan, L. Rajesh and H.A. Esechie, 2012. Effect of salt stress on germination, proline metabolism and chlorophyll content of fenugreek (*Trigonella foenum gracium* L.). J. Plant Sci., 7: 176-185.

Arnon, D.I., 1949. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. Plant Physiol., 24: 1-15.

Asaadi, A.M., 2009. Investigation of salinity stress on seed germination of *Trigonella foenum-graecum*. Res. J. Biol. Sci., 4: 1152-1155.

Ashraf, M. and A. Orooj, 2006. Salt stress effects on growth, ion accumulation and seed oil concentration in an arid zone traditional medicinal plant ajwain (*Trachyspermum ammi* [L.] Sprague). J. Arid Environ., 64: 209-220.

Barrs, H.D. and P.E. Weatherley, 1962. A re-examination of the relative turgidity technique for estimating water deficits in leaves. Aust. J. Biol. Sci., 15: 413-428.

Basu, S., S. Acharya, M. Bandara and J. Thomas, 2004. Agronomic and genetic approaches for improving seed quality and yield of fenugreek (*Trigonella foenum-graecum* L.) in western Canada. The Proceedings Science of Changing Climates-Impact on Agriculture Foresty and Wetlands, July 20-23, 2004, University of Alberta, Edmonton, Canada.

Begum, F., I.M. Ahmed, A. Nessa and W. Sultana, 2010. The effect of salinity on seed quality of wheat. J. Bangladesh Agric. Univ., 8: 19-22.

Fotopoulos, C., 2002. Marketing. In: Fenugreek - The genus *Trigonella*, Petropoulos, G.A., Taylor and Francis, London, pp: 183-195.

Gabbrielli, R.M., T.M. Pandolfini, O. Vergnano and M.R. Palandri, 1990. Comparison of two serpentine species with different nickel tolerance strategies. Plant Soil, 122: 271-277.

Ghorbanpour, A., Y. Mami, M. Ashournezhad, F. Abri and M. Amani, 2011. Effect of salinity and drought stress on germination of fenugreek. Afr. J. Agric. Res., 6: 5529-5532.

ISTA., 1993. International rules for seed testing. Seed Sci. Technol., 21: 1-288.

Kapoor, N., D.K. Awasthi and Y. Vimala, 2011. Effect of iron toxicity on growth of fenugreek. J. Plant Dev. Sci., 3: 297-300.

Kapoor, N., M. Arif and V. Pande, 2013. Antioxidative defense to salt stress in *Trigonella foenum-graecum* L. Curr. Discovery, 2: 123-127.

Kor, M.N., M.B. Didarshetaban and H.R.S. Pour, 2013. Fenugreek (*Trigonella foenum-graecum* L.) as a valuable medicinal plant. Int. J. Adv. Biol. Biomed. Res., 1: 922-931.

Laila, O. and I. Murtaza, 2015. Fenugreek: A treasure of bioactive compounds with promising antidiabetic potential. Int. J. Food Nutr. Sci., 4: 149-157.

Maclachlan, S. and S. Zalik, 1963. Plastid structure, chlorophyll concentration and free amino acid composition of a chlorophyll mutant of barley. Can. J. Bot., 41: 1053-1062.

Mehrafarin, A., A. Qaderi, S. Rezazadeh, H.N. Badi, G. Noormohammadi and E. Zand, 2010. Bioengineering of important secondary metabolites and metabolic pathways in fenugreek (*Trigonella foenum-graecum* L.). J. Med. Plants, 9: 1-18.

Mehrafarin, A., H.N. Badi, G. Noormohammadi, E. Zand, S. Rezazadeh and A. Qaderi, 2011. Effects of environmental factors and methanol on germination and emergence of Persian Fenugreek (*Trigonella foenum-graecum* L.). Afr. J. Agric. Res., 6: 4631-4641.

Munns, R. and M. Tester, 2008. Mechanisms of salinity tolerance. Annu. Rev. Plant Biol., 59: 651-681.

Nathiya, S., M. Durga and T. Devasena, 2014. Therapeutic role of *Trigonella foenum-graecum* [Fenugreek]-a review. Int. J. Pharmaceut. Sci. Rev. Res., 27: 74-80.

Niknam, V., N. Razavi, H. Ebrahimzadeh and B. Sharifizadeh, 2006. Effect of NaCl on biomass, protein and proline contents and antioxidant enzymes in seedlings and calli of two *Trigonella* species. Biologia Plantarum, 50: 591-596.

Obour, A.K., E. Obeng and J.D. Holman, 2015. Influence of different seeding dates on fenugreek (*Trigonella foenum-graecum* L.) forage yield and nutritive value. Kansas Agric. Exp. Station Res. Rep., 1: 1-5.

Pour, A.P., H. Farahbakhsh, M. Saffari and B. Keramat, 2013. Response of Fenugreek plants to short-term salinity stress in relation to photosynthetic pigments and antioxidant activity. Int. J. Agric.: Res. Rev., 3: 80-86.

Ratnakar, A. and A. Raib, 2013. Effect of sodium chloride salinity on seed germination and early seedling growth of *Trigonella foenum-graecum*, L. Var. PEB. Octa J. Environ. Res., 1: 304-309.

Schonfeld, M.A., R.C. Johnson, B.F. Carver and D.W. Mornhinweg, 1988. Water relations in winter wheat as drought resistance indicators. Crop Sci., 28: 526-531.

Talukdar, D., 2012. Modulation of plant growth and leaf biochemical parameters in grass pra (*Lathyrus sativus* L.) and fenugreek (*Trigonella foenum-graecum* L.) exposed to NaCl treatments. Indian J. Fund. Applied Life Sci., 2: 20-28.

Todd, A.R., 2001. Salt avoidance and tolerance in beach pea (*Lathyrus maritimus* L. Bigelow): A study of the effect of salinity on germination, growth, photosynthesis and respiration in comparison to common forage legumes. Department of Biology, Memorial University of New Foundland.

Tuncturk, R., 2011. Salinity exposure modifies nutrient concentrations in fenugreek (*Trigonella foenum graecum* L.). Afr. J. Agric. Res., 6: 3685-3690.