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Influence of seed size and salt stress on seed germination and seedling growth of wheat (*Triticum aestivum*)

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ABSTRACT

Wheat (*Triticum aestivum* L.) is the second most important cereal crop in India after rice. In the present study, response of wheat variety PBW-154 against three size classes and six salinity levels was assessed at germination and early seedling stages. For this, seeds of wheat variety PBW 154 were categorized into three size classes (large, medium and small) and kept under six salinity levels (0, 2, 4, 6, 8 and 10 g/l NaCl). Salinity stress registered the highest detrimental effects on germination percentage of medium sized seed class (83.3%), whereas small size seed class (91.7 %) experienced least ill-effects on germination percentage. The shoot length, root length and total dry weight were significantly influenced by the salinity stress. The maximum shoot length (18 cm) and root length (15.7 cm) were measured for large seed size class at controlled conditions. In general, most of the measured traits showed a significant decline at higher salinity levels suggesting that the most stress tolerant and stress avoider seed size can be explored and economically implicated in farmers' fields.

Key words: Early seedling growth, Salinity stress, Seed germination, Seed size, *Triticum aestivum*

Wheat (*Triticum aestivum* L.) is one of the major cereal crops of India. The bread wheat contributes approximately 95% to the total wheat production in India while another 4% comes from Durum wheat (*T. durum*) and remaining 1% from Dicoccum wheat (*T. dicoccum*) (Mishra *et al*. 2010). Seed size is an important parameter which influences the seed germination, growth and biomass of the young seedlings besides future crop performance (Vibhuti *et al*. 2015).

Soil salinity is one of the major abiotic stresses that limit the growth and development of salt sensitive plants. This stress leads to deterioration of agricultural lands besides deleterious effects on crop productivity worldwide. Soil salinity also induces water deficit even in well watered soils by decreasing the osmotic potential of soil solutes, thus, making it difficult for roots to extract water from their surrounding media (Singh *et al*. 2007). It decreases seed germination percentage and retards plant development which ultimately results into reduced crop yields. Salt inhibits growth by reducing the plant ability to take up water, subjecting it to a water-deficit effect. Excessive amounts of salt entering the plant tissues injure the cells leading to impaired growth through ion-excess effect (Munns *et al*. 2006). Salt and osmotic stresses are responsible for both inhibition or delayed seed germination and seedling establishment. Germination failures on saline soils are often the resultant of high salt concentrations in the seed planting zone because of upward movement of soil solution and subsequent evaporation at the soil surface (Baybordi and Tabatabaei 2009).

Seed germination is one of the most critical phenophases greatly influenced by soil salinity (Misra and Dwivedi 2004). Cereals express a wide range of variation for salt tolerance with rice being most sensitive and barley the most tolerant (Karan *et al*. 2012). Seed grading based upon their size and weight is a common practice to regulate the germination and subsequent seedling growth (Bargali *et al*. 2009). Therefore, an attempt has been made in the present study to analyze the effect of seed size and salt stress on seed germination and early seedling growth in wheat variety PBW 154.

MATERIALS AND METHODS

The present investigation was conducted in the Department of Botany, DSB Campus, Kumaun University, Nainital, India during the year 2014. This experiment was conducted on root trainers (a root pruning container, an aid to the cultivation of young plants) in a glass house, with 3 different size classes of wheat variety PBW 154. On the basis of diameter, the seeds were categorized into three size classes, viz. small (0.2 - 0.25 cm), medium (0.26 – 0.3 cm) and large size class (0.31 – 0.38 cm). Soil was collected from field, sieved and filled in root trainers.

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Only healthy seeds that sank to the bottom when immersed in water were used in this study. Five levels of salinity stress were produced through five concentrations of NaCl (2, 4, 6, 8 and 10 g/l) against distilled water (0 g/l of NaCl) being run as control. Three replicates for each size class and for each salinity level were used (3 size classes × 2 seed per trainer pot × 6 salinity levels × 3 replicates =108 seeds). 1 ml of the appropriate solution was poured in each root trainer pot and seeds were monitored daily for 15 days. After final count, germination percentage was calculated by the following formulae (Vibhuti *et al*. 2015).

Germination at n^{th} day (%) = 100 × (number of germinated seeds at the n^{th} day/number of total seeds)

Weight reduction percentage: The shoots and roots were separated and the fresh weights were measured. After being oven dried at 60 °C for 24 hr, the dry weights were immediately taken. According to each salt treatment, the fresh and dry weights were calculated in per cent by the following equations (Goumi *et al*. 2014):

Fresh weight percentage reduction (FWPR): FWPR % = 100 × [1 - (fresh weight $_{\text{salt stress}}$ /fresh weight $_{\text{control}}$)]

Dry weight percentage reduction (DWPR): DWPR % = 100 × [1 - (dry weight $_{\text{salt stress}}$ /dry weight $_{\text{control}}$)]

Relative water content (RWC): The water content respective to the fresh weight was calculated as described by Sumithra *et al*. (2006):

$$\text{RWC \%} = 100 \times [(\text{FW} - \text{DW}) / \text{FW}]$$

Salt tolerance index (STI): It is quantified by the ratio of the total dry weight in salt stress in per cent and calculated by the following equation:

$$\text{STI} = 100 \times (\text{Total DW}_{\text{salt stress}} / \text{Total DW}_{\text{control}})$$

where, DW is the dry weight and FW is the fresh weight of seedlings.

RESULTS AND DISCUSSION

Effect on shoot and root length

The maximum shoot length (18 cm) was measured for large seed size class of wheat variety PBW 154 at controlled condition. However, in the case of medium seed size class, it was highest (14.2 cm) at 2 g/l salinity stress level (Fig 1). For large seed size class, the root length was highest (15.7 cm) at controlled condition, while for medium seed size class it was highest (14.5 cm) at 4 g/l salinity. In large seed size class, the root length ranged from 15.7 to 3.2 cm with increasing salinity levels (Fig 2). The effect of salinity stress on shoot length, root length and total dry weight were significant (P< 0.05) (Table 1). The shoot and root length of seedlings showed a declining pattern with increasing salinity, indicating that the salt stress adversely affects the germination, seedling growth and dry matter production of the seedlings. Jaleel *et al*. (2007) also reported decreased root length with increasing NaCl concentrations.

Table 1 Variance analysis (ANOVA) for the traits investigated for the three size classes in response to salinity stress

Parameter	Mean of square			
	df	SL (cm)	RL (cm)	TDW (g)
Salinity stress	5	238.12*	112.38*	0.001*
Size	2	46.30ns	62.73*	0.001ns

SL, Shoot length; RL, root length; TDW, total dry weight; *significant at P< 0.05; ns, not significant at P< 0.05.

Effect on total dry weight: The highest total dry weight (0.14 g) was recorded for large seed size class at controlled condition and it ranged from 0.03 to 0.14 g for all three seed size classes (Fig 3).

Effect on seedling growth: The large seed size class showed better performance in controlled condition (33.7 cm) and 2 g/l salinity stress level (27.2 cm); whereas the medium seed size class showed better seedling growth in

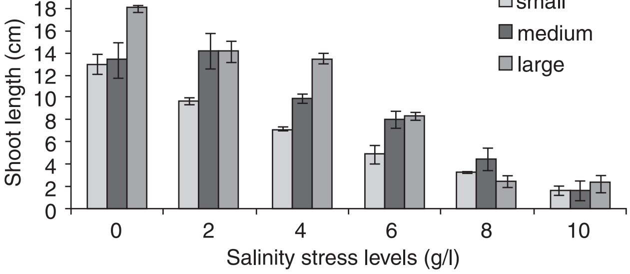

Fig 1 Effect of seed size and salinity stress levels on shoot length of wheat (PBW 154) (Bar represents CD values at P = 0.05).

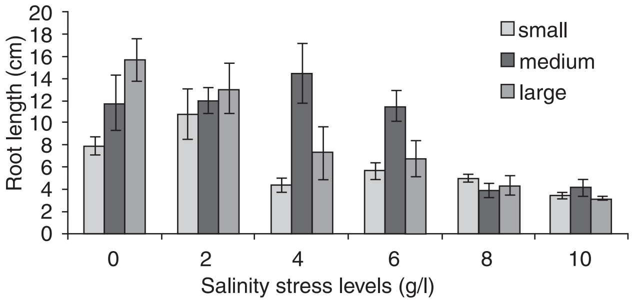

Fig 2 Effect of seed size and salinity stress on root length of wheat (PBW 154) (Bar represents CD values at P = 0.05).

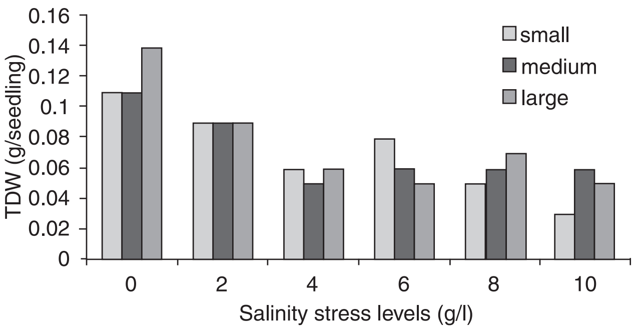

Fig 3 Effect of seed size and salinity stress levels on total dry weight of wheat (PBW 154) (Bar represents CD values at P = 0.05).

4, 6, 8 and 10 g/l salinity stress levels. The seedling growth was significantly affected by the higher salinity stress levels. In the present study, with increase in salinity level, a decline in seedling growth was observed. Reduced seedling growth under salt stress conditions has also been reported in barley by Huang and Reddman (1995), in wheat by Maghsoudi and Maghsoudi (2008). Thus, reduction in seedling growth is a common phenomenon in crop plants grown under saline conditions.

Table 2 Effect of seed size and salinity stress levels on various traits of PBW-154 wheat variety

Seed size	Treatment (g/l)					
	0	2	4	6	8	10
SV						
Small	9.16	9	6	8	5	2
Medium	9.16	9	5	6	6	6
Large	14	9	6	5	3.5	4.2
RWC%						
Small	90.8	91.8	93.9	88.2	90	81.3
Medium	92.7	92	91.9	88.5	88.1	76.9
Large	92.2	94.4	96	94.9	87.5	89.7
FWPR%						
Small		8	17	43	59	87
Medium		25	59	65	71	83
Large		12	17	46	69	73
DWPR%						
Small		18	45	28	55	73
Medium		18	55	46	46	46
Large		36	57	64	50	64
STI %						
Small		81.8	54.5	72.7	49.5	27.3
Medium		81.8	49.5	54.5	54.5	54.5
Large		64.3	42.3	39.7	50	39.7

SV, Seedling vigor, RWC %, relative water content, FWPR %, fresh weight percentage reduction, DWPR %, dry weight percentage reduction, STI, salt tolerance index.

Effect on germination percentage: The highest effect of salinity stress (50%) was recorded in medium seed size class at 10 g/l and in large seed size class at 8 g/l salinity stress level. The germination percentage for all three seed size classes ranged from 50 to 100%. The effect of salinity on germination percentage showed a dramatic pattern at controlled conditions where the value of germination percentage in small and medium seed size classes of variety PBW-154 was lower than the other salinity stress levels; whereas at 10 g/l salinity, an increase in germination percentage was reported. Ayaz *et al*. (2000) reported a decrease in germination percentage owing to reduction in water absorption by the seeds at imbibitions and seed turgescence stages. Thus, salinity may affect seed germination by decreasing the ease with which the seeds take up water because the activity and events normally associated with germination get either delayed and/ or proceed at a reduced rate.

Effect on relative water content: The maximum relative water content (94.9%) was recorded for large seed size at 6 g/l salinity stress level. The minimum relative water content (76.9%) was measured for medium seed size at 10 g/l salinity level (Table 2). Large seeds need more water absorption than small seeds and because of which it takes more time to germinate and finally result in decline in germination rate (Sadeghi *et al*. 2011).

Effect on fresh and dry weight percentage reduction: The fresh weight percentage reduction was highest for small seed size class (87%) at 10 g/l salinity stress. It was lowest for the small seed size class at 2 g/l salinity stress level (Table 2). The dry weight percentage reduction was observed least (18%) for small and medium seed size class at 2 g/l salinity stress. It was highest (73%) for small seed size class at 10 g/l salinity stress level (Table 2).

Table 3 Comparison of effects of size and salt stress level on various growth parameters of wheat

	Traits					
	SL (cm)	RL (cm)	TDW (g)	GP (%)	RWC (%)	SV
Size class						
Small	6.6±1.7a	6.2±1.1a	0.07±0.01a	91.7±9.7a	89.3±1.8a	6.52±1.1a
Medium	8.6±2.0b	9.9±1.8b	0.07±0.009a	83.3±8.6b	88.3±2.4a	6.86±0.72b
Large	9.7±2.6c	10.1±2.5b	0.08±0.01b	88.9±8.2c	92.9±1.3b	6.95±1.6b
Treatments (g/l)						
0	14.8±1.6b	11.81±2.2b	0.12±0.01b	88.9±5.6b	91.9±0.56b	10.8±1.8b
2	12.6±1.4c	11.9±0.86b	0.09±0c	100±0c	92.7±0.83b	9±0b
4	10.22±1.8d	12.06±3.9b	0.06±0.003e	100±0c	93.9±1.2c	5.9±0.3c
6	7.1±0.98e	8.02±1.8c	0.06±0.008e	100±0c	90.5±2.2d	6.3±0.8d
8	3.4±0.98f	4.5±0.32d	0.06±0.006e	72.2±14d	88.5±0.75e	4.8±0.72e
10	1.9±0.2a	3.6±0.31a	0.05±0.008f	66.7±9.8e	82.6±3.7a	4.1±1.2e

*Means (± SE) followed by the same letter in a column are not significantly different at $P< 0.05$ (ANOVA followed by LSD post test); SL, shoot length; RL, root length; TDW, total dry weight, GP, germination percentage; RWC, relative water content; SV, seedling vigor.

Effect on seedling vigor and salt tolerance index: Seedling vigor had exhibited highest value (14) for large seed size class at controlled condition and the least (2) for small seed size class at 10 g/l salinity level. The small and medium seed size class at controlled condition registered highest value (81.8%) of STI % and it was minimum (27.3%) for small seed size class at highest (10 g/l) salinity stress (Table 2). Salinity stress occurring during the course of seed formation lead to small and shriveled seeds which cause reduction in seed vigor (Galeshi and Bayat 2005).

Overall, the seedling growth was adversely affected by the higher salinity stress levels. Different salinity stress levels showed that the shoot length, total dry weight and seedling vigor were highest in control condition, whereas, the root length was highest (12.06 cm) at 4 g/l salinity level. Based on the observations, it is inferred that the large seed size class of wheat variety PBW-154 was least affected by salinity stress compared to small seed size class with respect to root and shoot parameters except germination percentage. In nutshell, seed size is an important factor that influences the germination, growth and biomass of seedlings under normal as well as salinity stress conditions.

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