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Genotypic Response to Salt Stress: II – Pattern of Differential Relative Behaviour of Salt-Tolerant, Moderately Salt-Tolerant and Salt-Sensitive Wheat Cultivars under Salt Stressed Conditions

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Abstract: Screening of 42 wheat (Triticum aestivum L) cultivars for their relative salt tolerance at the early seedling stage showed only 11 cultivars found to have < 60% reduction in shoot growth while majority of the 31 had > 60% reduction at 16 EC dsm-1 in contrast with root growth where almost a reverse trend was noticed as only 15 cultivars showed > 60% reduction whereas 27 had < 60% reduction proving shoot to be more sensitive to salinity than the root demonstrating shoot growth to be a better index of relative salt tolerance. Further, a level of 12 EC was found to be critical level. Based on these observations all the cultivars were categorized into salt–tolerant, moderately salt–tolerant and salt–sensitive groups exhibiting < 40%, 40 – 60% and > 60% reduction respectively in shoot length at 12 EC (dsm-1) over control. Thus, a clear pattern of differential relative behavior of the three groups is visible in the gradual decrease in shoot growth in both the salt-tolerant and moderately salt-tolerant cultivars and a sharp decline in the salt-sensitive cultivars.

Keywords: Wheat cultivars, salt stress, salt-tolerant, moderately salt-tolerant, salt-sensitive

1 Introduction

Almost more than fifty years from now, Bernstein and Hayward [1958] wrote: “An understanding of the physiology of salt tolerance of plants is important for an effective approach to the salinity problem which is of increasing widespread occurrence”. Coupling an understanding of the genetic control of salt tolerance with physiological approach adds another dimension of a promise leading to the development of salt tolerant crops [Epstein, 1963, 1972]. It is axiomatic in modern physiology and biochemistry that specific capabilities of organisms depend on the synthesis of appropriate enzymes, this synthesis in turn being gene-controlled. Assuredly, the specific capabilities possessed by those plants able to tolerate saline conditions _ fatal to other plants are no exception to this generalization.

Furthermore, if strains of crops capable of coping with sea water or brackish water salinity could be generated, what is now a problem could become a vast opportunity for crop production by tapping the immense wealth of water and mineral plant nutrients of the oceans without the energy-costly process of industrial de-salinization. Several authors have drawn attention to genotypic differences between salt-tolerant and salt-sensitive plants in respect to a number of pertinent physiological and biochemical parameters [Epstein, 1972; Ogra, 1981; Sharma, 1982; Nauhbar, 2005 Yadav, 2006; Rani, 2007; Gautam, 2009; Parashar, 2011; Sharma, 2015, 2016]. It is becoming evident that the combined tools of the plant physiologist, geneticist and breeder must be brought to bear on the increasing salinity problems confronting irrigation agriculture on a worldwide scale.

2 Materials and Methods

As reported earlier [Sharma, 2015, 2016] forty two wheat cultivars procured from Wheat Directorate, Division of Genetics and Plant Breeding, I. A. R. I., New Delhi and Chandra Sekhar Azad University of Agriculture and Technology, Kanpur (UP), India were subjected to screening for salt resistance [Garrard, 1945; Sarin and Rao, 1956; Sheoran and Garg, 1978; Sharma, 1982] wherein shoot and root growths of seedlings were recorded at definite intervals. Observations on the influence of salinity levels at 4, 8, 12 and 16 EC dsm-1 of salt solution and the controls on the total length of shoot and root at early seedling stage were recorded at 24 hour intervals from 48 hours after sowing up to the end of 120 hours under green safe light. The relative tolerance of different cultivars was evaluated on the basis of the percentage reduction in shoot growth at 12 EC.

3 Results

As indicated (Table 1) only 11 cultivars showed less than 60 percent reduction in shoot growth while majority of the 31 had more than 60 percent reduction at 16 EC level. This is in contrast with root growth where almost a reverse trend was noticed, in that, out of the 42 cultivars only 15 showed more than 60 percent reduction at 16 EC salinity level whereas 27 had less than 60 percent reduction. This clearly shows that the shoot is more sensitive to salinity than the root growth. This differential response of shoot and root growth is shown in Fig. 1 whence also the mean shoot growth was found to be more adversely affected than root growth clearly demonstrating that shoot

Table. 1 Shoot and rot growth of certain certain wheat cultivars at 16 EC (dsm-1) salinity level (Data expressed as percent over control)

S.No.	***Cultivar***	**Control**	***Shoot Growth***	***Root Growth***
1	**HD-2236**	100%	05.599	12.905
2	**WL-410**	100%	18.731	47.188
3	**Sharbati sonora**	100%	40.300	59.912
4	**Moti**	100%	09.995	29.576
5	**Sonalika**	100%	43.217	66.694
6	**HD-2160**	100%	82.600	71.188
7	**HD-2135**	100%	09.892	28.569
8	**IWP-503**	100%	13.939	31.834
9	**HS-43**	100%	29.261	40.818
10	**UP-262**	100%	08.150	26.168
11	**HD-2177**	100%	06.716	36.919
12	**WG-1559**	100%	09.358	6.588
13	**HD-2267**	100%	08.245	02.870
14	**IWP-72**	100%	05.144	05.826
15	**HD-2282**	100%	35.213	56.434
16	**WL-711**	100%	46.128	54.350
17	**Raj-1482**	100%	32.378	44.231
18	**HD-2260**	100%	22.894	40.201
19	**WH-246**	100%	33.929	49.960
20	**WL-2200**	100%	35.279	60.244
21	**K-7634**	100%	52.179	59.321
22	**Raj-1556**	100%	44.063	55.695
23	**UP-154**	100%	49.523	68.645
24	**HD-1977**	100%	40.456	41.449
25	**WG-1558**	100%	35.207	43.319
26	**HD-2204**	100%	34.948	55.594
27	**WL-1531**	100%	33.061	40.895
28	**K-7631**	100%	47.321	58.887
29	**Raj-1409**	100%	17.708	27.941
30	**Raj-1493**	100%	26.721	37.093
31	**Raj-1494**	100%	11.217	22.251
32	**WL-903**	100%	38.822	57.263
33	**UP-171**	100%	14.612	28.072
34	**HD-2275**	100%	17.329	37.768
35	**HD-1593**	100%	14.944	20.465
36	**HD-2252**	100%	35.381	42.741

37	**HP-1303**	100%	39.090	42.038
38	**UP-115**	100%	40.169	42.637
39	**HD-1980**	100%	44.369	40.599
40	**CC-464**	100%	24.080	47.878
41	**HD-2009**	100%	39.097	50.406
42	**Kharchia**	100%	30.542	55.269
			CD at 5% P = 0.064 **SEm ± 0.023**	**CD at 5% P = 0.351** **SEm ± 0.126**

growth is a better index of relative salt tolerance of different cultivars at early seedling stage. Also, 12 EC salinity level was found to be a critical level for majority of the cultivars. Thus, on the basis of the percent reduction in shoot growth at 12 EC salinity level over respective control all the cultivars were categorized into three groups, viz., salt-tolerant, moderately salt-tolerant and salt-sensitive, showing less than 40 percent, 40 – 60 percent and more than 60 percent reduction respectively (Table 2 and Fig 1).

The different rates of shoot growth of the three groups as affected by increasing level of salinity could be observed as depicted in Table 3 and Fig 2 – 5. There was a gradual decrease in shoot growth up to 16 EC level in both the salt-tolerant (HD-2160) and moderately salt-tolerant (Sonalika) cultivars. On the other hand, the salt-sensitive (IWP-72) cultivar showed a sharp decline in growth with increasing salt concentration proves a differential pattern of relative behavior of the three groups of salt tolerance.

4 Discussion

As discussed by several workers [Ayers et al., 1952; Bernstein and Hayward, 1958; Uprety, 1970; Ogra, 1981; Sharma, 1982, 1987; Sharma and Baijal, 1984a,b, 1985a, b; Nauhbar, 2005; Yadav, 2006; Rani, 2007; Rani et al., 2007, 2009; Gautam, 2009; Parashar, 2011; Sharma, 2013, 2015, 2016] reduction in shoot and root growth is one of the most commonly observed responses to salinity. Further, all the plant parts are not equally affected by salt stress, shoot growth is often suppressed more than the root growth in spite of the fact that roots are in direct exposure to saline environments [Meiri and Poljakoff-Mayber, 1970; Ogra and Baijal, 1978; Sharma, 1982, 1987; Sharma and Baijal, 1985; Nauhbar, 2005; Yadav, 2006; Rani, 2007; Rani et al., 2007, 2009; Gautam, 2009] These observations and others [Eaton, 1942; Bernstin and Hayward, 1958; Sharma, 1987; Nauhbar, 2005; Yadav, 2006; Rani, 2007; Rani et al., 2007, 2009; Gautam, 2009; Sharma, 2015, 2016] have reported more inhibition in shoot growth as compared to the root growth as a result of salt stress.

Table. 2 Relative tolerance of certain cultivars of wheat based on the percent reduction in shoot growth at 12 EC (dsm-1) salinity level

	Group I *Salt-tolerant* (***Less than 40% reduction***)		**Group II** *Moderately Salt-tolerant* (***40 – 60% reduction***)		**Group III** *Salt-sensitive* (***More than 60% reduction***)	
Wheat Cultivars	**1. HD-2160**	85.219	**1. WL-903**	59.726	**1. Raj-1409**	38.980
	2. K-7634	80.353	**2. HD-2282**	57.470	**2. Raj-1482**	38.573
	3. WL-711	71.437	**3. HD-2009**	57.321	**3. HD-2135**	35.555
	4. WL-1531	71.020	**4. K-7631**	56.250	**4. IWP-503**	29.346
	5. HD-2260	70.284	**5. HD-1980**	54.406	**5. UP-262**	28.956
	6. UP-115	66.535	**6. HP-1303**	54.166	**6. HD-2177**	28.527
	7. HD-2252	65.759	**7. Raj-1556**	52.875	**7. Raj-1494**	28.353
	8. UP-154	60.714	**8. Raj-1493**	50.815	**8. HD-1593**	27.746
			9. Sharbati Sonora	48.574	**9. HD-2275**	25.738
			10. Sonalika	48.179	**10. WG-1559**	20.454
			11. CC-464	46.866	**11. UP-171**	17.195
			12.WL-2200	46.654	**12. HD-2267**	11.873
			13. HS-43	43.948	**13. HD-2236**	11.491
			14. WL-410	43.746	**14. Moti**	11.423
			15. WH-246	43.644	**15. IWP-72**	7.818
			16. WG-1558	43.276		
			17. Kharchia	43.035		
			18. HD-1977	43.010		
			19. HD-2204	42.878		

As indicated in the Table 1 only 11 cultivars showed less than 60 percent reduction in shoot growth while majority of the 31 cultivars had more than 60 percent reduction at 16 EC. This is in contrast with root growth where almost a reverse trend was noticed, i.e., out of the 42 cultivars only 15 showed more than 60 percent reduction at 16 EC whereas 27 had less than 60 percent reduction. This clearly showed that the shoot is more sensitive to salinity than the root growth. This differential response of shoot and root growth is shown in Table 1 where the mean shoot growth was found to be more adversely affected than the root growth. Thus, it was interesting to find that not all plant parts were equally affected. In spite of the fact that the roots were directly exposed to the saline environment it seemed significant that shoot growth was affected more adversely than the root growth. With this also 12 EC was found to be a critical level for most of the cultivars. Thus, shoot growth seemed to be better criterion for relative salt tolerance of the cultivars of the same species at early seedling stage. Based on these observations all the 42 wheat (Triticum aestivum L) cultivars were categorized into three groups viz., salt–tolerant, moderately salt–tolerant and salt–sensitive, showing <40 percent, 40–60 percent and >60 percent reduction in shoot growth at 12 EC over respective controls (Table 2 and Fig 1). Further, the different rates of shoot growth of the three groups as affected by increasing level of salinity showed a gradual decline in both the salt–tolerant and moderately salt–tolerant cultivars. On the other hand, the salt–sensitive cultivars had a sharp decline in growth with increasing salt concentrations (Table 3 and Fig 2 - 5).

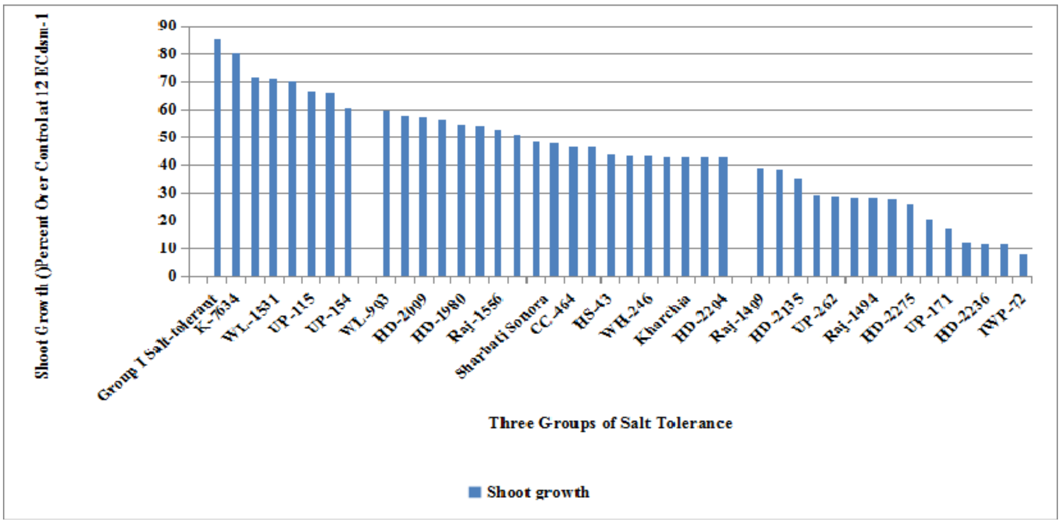

Fig. 1 Relative tolerance of three groups (salt-tolerant; moderately salt-tolerant and salt-sensitive) cultivars of wheat based on the percent reduction in shoot growth at 12 EC (dsm-1) salinity level

The relative comparisons of seedling growth between different wheat cultivars indicated better performance of HD–2160 at almost all levels of salinity when compared with controls. It showed highest tolerance to salinity (i.e., 82.60 percent shoot growth at 16 EC over control) and IWP–72 showing highest inhibition in shoot growth (i.e., only 5.14 percent growth at 16 EC over control). The next cultivars which were relatively lesser tolerant but close to HD–2160 were K–7634, WL–711, WL–1531, HD–2260, UP–115, HD–2252 and UP–154. Based on these growth responses other cultivars of wheat followed a sequence of decrease as shown in Table 2 as far as their resistance to salt stress was concerned.

It was observed that the changes induced by addition of NaCl to the growth medium became more distinct with increasing salinity perhaps due to a higher intake of ions [Sharma, 1982, 1987; Sharma and Baijal, 1984a, b; Nauhbar, 2005; Yadav, 2006; Rani, 2007; Rani et al., 2007, 2009; Gautam, 2009; Parashar, 2011; Sharma et al., 2011; Sharma, 2013, 2015, 2016] which resulted in toxicity [Ayers and Hayward, 1948; Ota and Yasue, 1957; Wahhab, 1961]. Osmotic effects might also have contributed to the low growth rates under saline conditions [Dumbroff and Cooper, 1974].

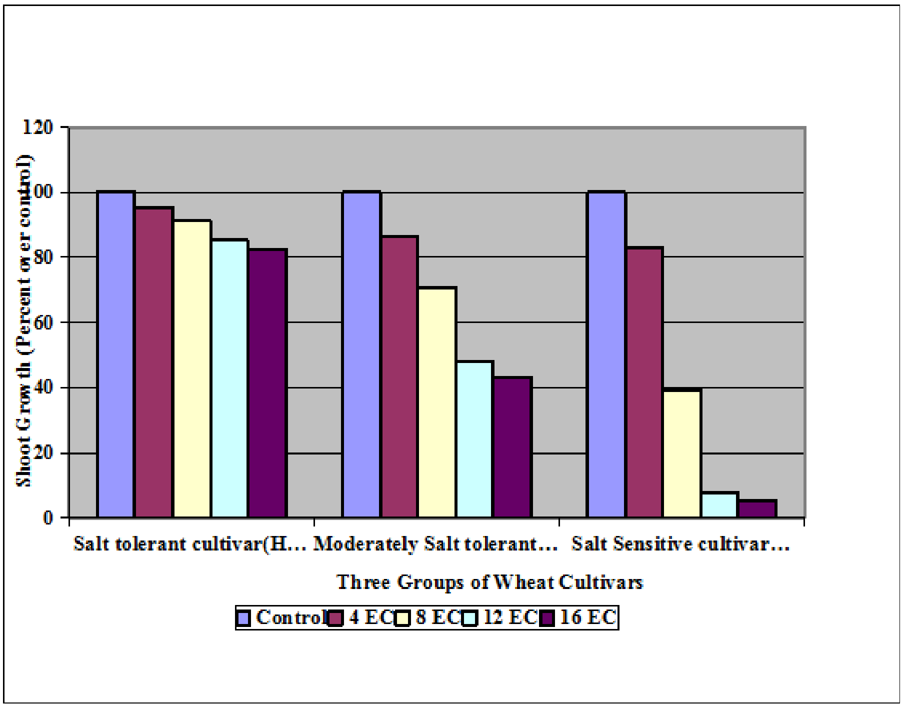

Fig. 2 Shoot growth behaviour of three salt tolerance groups in wheat cultivars

Table. 3 Relative salt tolerance of three groups （salt-tolerant; moderately salt-tolerant and salt-sensitive） wheat(Triticum aestivum L) cultivars under salt stress at the early seedling stage (data expressed as percent over control)

	Shoot						**Root**				
	Control	**4EC**	**8EC**	**12EC**	**16EC**		**Control**	**4EC**	**8EC**	**12EC**	**16EC**
GROUP I Salt Tolerant	100%	95.135	91.113	85.219	82.600		100%	94.623	83.760	77.584	71.188
GROUP II Moderately Salt Tolerant	100%	86.523	70.728	48.179	43.217		100%	95.222	89.470	80.958	66.694
GROUP III Salt Sensitive	100%	82.921	39.094	7.818	05.144		100%	84.874	48.701	14.736	05.826
	CD at 5% P = 0.064 SEm ± 0.023						**CD at 5% P = 0.351 SEm ± 0.126**				

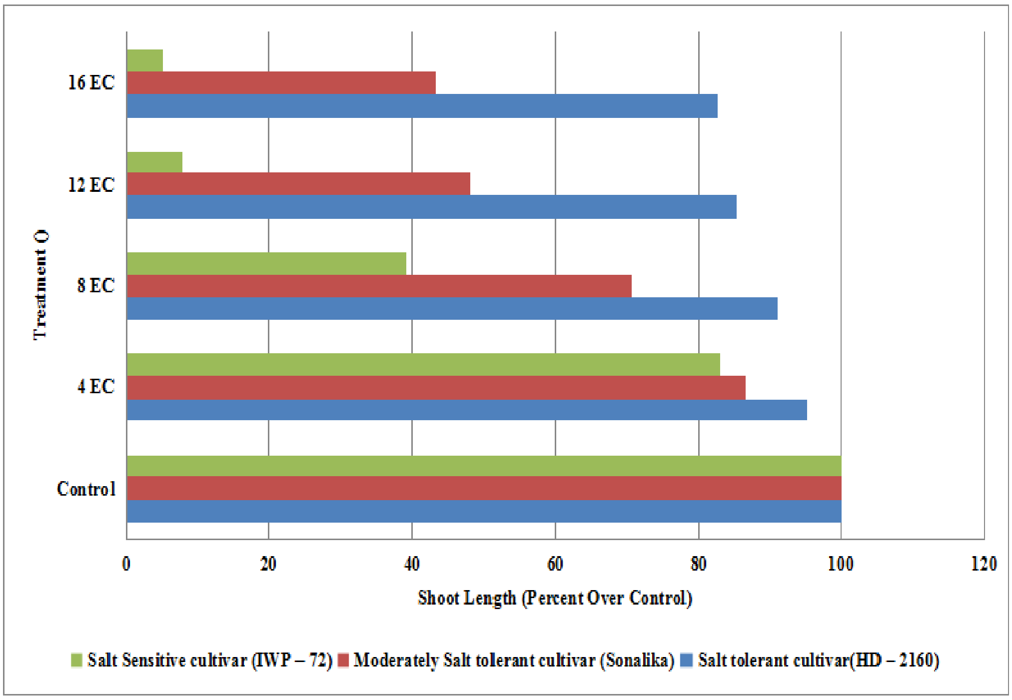

Fig. 3 Shoot growth behaviour of three salt tolerance groups in wheat cultivars

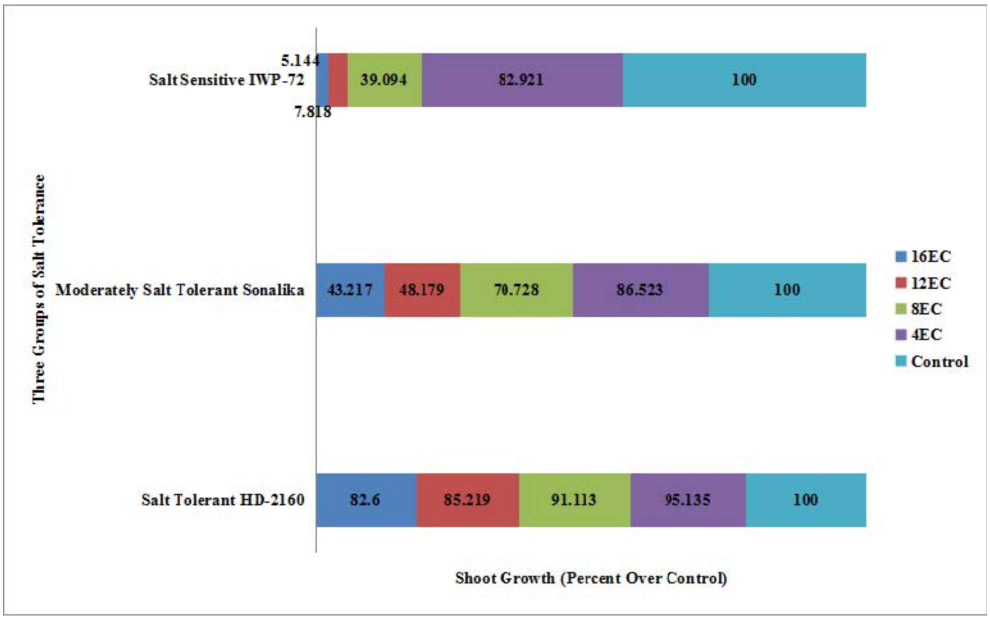

Fig. 4 Shoot growth behaviour of three salt tolerance groups in wheat cultivars

Thus, it is clear from the data that the cultivars differed in their ability to grow as seedlings under high salinity levels. That wheat showed fairly large varietal differences to salt stress had also been reported earlier by Bhardwaj [1961], Sarin and Narayanan [1968], Sharma [1982, 1987, 2015, 2016], Sharma and Baijal [1984a, b, 1985a, b], Yadav [2006]. Varietal differences to salt stress were also reported in other agricultural crops by several workers [Ayers, 1953; Wahhab, 1961; Sarin, 1962; Bhumbla and Singh, 1965; Puntamkar et al., 1970; Taylor, 1975; Epstein, 1976; Maas and Hoffman, 1977; Ogra, 1981; Sharma, 1982, 1987; Nauhbar, 2005; Yadav, 2006; Rani, 2007; Gautam, 2009; Parashar, 2011; Sharma et al., 2011; Sharma, 2013, 2015, 2016].

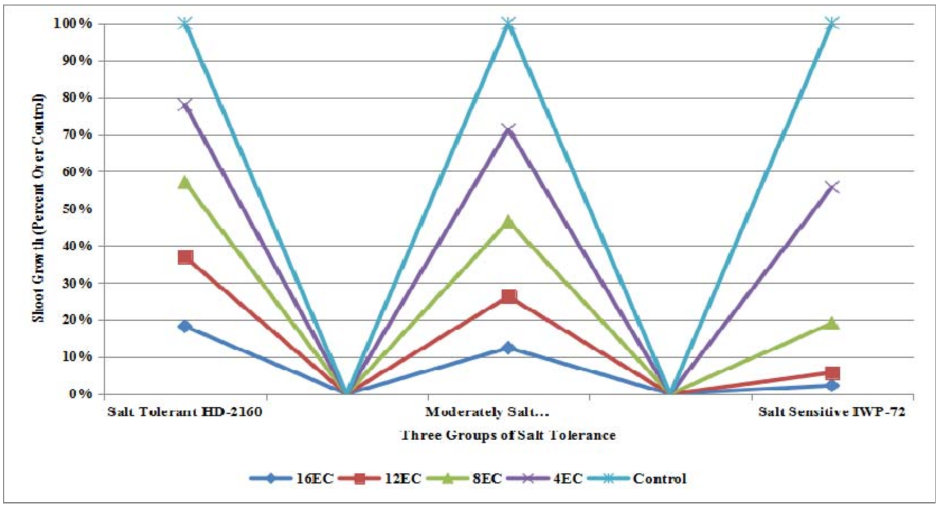

Fig. 5 Shoot growth behaviour of three salt tolerance groups in wheat cultivars

5 Conclusion

The observations recorded clearly indicated that the shoot is more sensitive to salt stress than the root and that shoot growth is a better index of relative salt tolerance of different cultivars of the same species at early seedling stage with this also 12 EC salinity level was found to be a critical level for majority of the cultivars. Thus, on the basis of the percent reduction in shoot growth at 12 EC salinity level over respective control all the cultivars were categorized into three groups viz., salt-tolerant, moderately salt-tolerant and salt-sensitive, showing less than 40%, 40–60% and more than 60% reduction respectively. Conclusively, a clear pattern of differential relative behavior of the three groups is visible in the gradual decrease in shoot growth in both the salt-tolerant and moderately salt-tolerant cultivars and a sharp decline in the salt-sensitive cultivars.

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