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# Salt Stress Genotypic Response: Wheat Cultivars Relative Tolerance of Certain to Salinity

**Ravi Sharma***

*327/Sector 9, Avas Vikas Colony, Sikandra-Bodla Road, Agra-282 007, UP, India*

***Corresponding author:** Ravi Sharma, 327/Sector 9, Avas Vikas Colony, Sikandra-Bodla Road, Agra-282 007 UP India, Tel: 0562-6447901; 0562-4051472; E-mail: ravisharma327@yahoo.com

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## Abstract

Forty two wheat (*Triticum aestivum* L) cultivars screened for their relative salt resistance raising seedlings in half-Hoagland solution (control) salinized with NaCl and maintained at 4, 8, 12 and 16 dsm-1 showed a wide range of salt resistance. The growth response to salinity, judged by the shoot and root lengths, ranged from a stimulation in the case of some cultivars at lower salinity levels (4 and 8 EC) to a severe suppression in most of the cultivars at higher levels (12 and 16 EC). It was further observed that the shoot growth was often suppressed more than the root growth with this a level of 12 EC also found to be critical for most of the cultivars except HD–2160 which showed good stand even at a salinity level of 16 EC. Based on these observations, cultivar IWP–72 of the 42 cultivars tested was found to have the maximum sensitivity to salt stress whereas cultivar HD–2160 showed highest salt tolerance. The remaining 40 cultivars fell between the two extremes and were categorized into salt–sensitive, moderately salt–tolerant and salt–tolerant groups exhibiting more than 60% , 40–60% and less than 40% reduction respectively in shoot length at 12 EC dsm-1 over control.

**Keywords:** Wheat (*Triticum Aestivum* L); Salt Stress; Critical Level; Salt–Tolerant; Moderately Salt Tolerant; Salt–Sensitive Genotypes

## Introduction

The complexion of salt tolerance and the multitude of ways in which plants adapt to it have caused much confusion. Sodium ($Na^+$) and chloride ($Cl^-$) are among the most common ions found in excess in saline soils, and some plant species are especially sensitive to one or both of these ions [1-9]. A general suppression of growth is probably the most common plant response to salinity [10]. Crop plants differ greatly in their tolerance to salinity. Differences between species and varieties in regard to salt tolerance have been reported by several workers [1-20]. In saline soils [2,5,9,21-23] the control of water, the proper techniques of planting and the choice of tolerant crops are essential for their successful use in crop production. The choice of crops is based on: (1) the tolerance to salt; (2) adaptability to climatic or soil characteristics and (3) value of the crop in the individual farm activity. The chances of a crop failure are less if an adequately salt tolerant crop or its variety is selected. The key to improving salt tolerance in plants and studying its inheritance lies in finding sufficient variation within breeding populations and devising a screening procedure capable of identifying resistant or tolerant genotypes.

Further, as the period of seed germination and early seedling stage is the most crucial and important stage in the life cycle of species growing in saline environment [24] the present investigation was, therefore, undertaken to analyze the relative salt tolerance in wheat (*Triticum aestivum* L) at the early seedling stage and to select varieties that could withstand varying concentrations of the salts in their environment.

## Materials and Methods

Forty two wheat cultivars (*Triticum aestivum* L) were procured from Wheat Directorate, Cummings Laboratory, Division of Genetics and Plant Breeding, Indian Agricultural Research Institute, New Delhi and Chandra Sekhar Azad University of Agriculture and Technology, Kanpur (UP), India. Screening of wheat cultivars for salt resistance was made by Garrad's Technique [25] as modified by Sarin and Rao [26] and Sharma [2] and as per method of Sheoran and Garg [27] wherein shoot and root lengths of seedlings were recorded at definite intervals. Here test tubes of uniform size (30 ml capacity) were fitted with rolls of filter paper folded at the top into a cone to support the seeds. The tubes were filled to one-third part with the test solutions so that the solution might not come in direct contact with the growing roots, the salt solution being supplied to the roots through capillary action of the filter paper. Distilled water (represented the mean loss of water from the blanks) was added to each test tube after every 24 hr of interval in order to maintain salt concentration near the target levels throughout the germination period. The seeds were initially sterilized with 0.1% mercuric chloride ($HgCl^2$) solution and later washed thoroughly with distilled water. Three seeds per tube were then transferred to the edge of the filter paper cone and were allowed to grow between the filter paper roll and the wall of the test tube in dark growth chamber at 25 ± 20C. Fifteen replicates (five tubes each having three seeds) were maintained for each treatment including the controls (half-strength Hoagland solution grown). 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 coleoptile and root at early seedling stage were recorded at 24 hr intervals from 48 hr after sowing up to the end of 120 hr under green safe light. The relative tolerance of different cultivars was evaluated on the basis of the% age reduction in shoot growth at 12 EC.

All parameters were analyzed by 'Analysis of Variance' (ANOVA) method as given by Panse and Sukhatme [28] wherein Critical Differences (CD at 1 and 5% probability were calculated wherever the results were significant.

## Results and Discussion

The observations summarized here clearly demonstrate that exposure to salinity during early seedling stage resulted in stunting of growth of the shoot and root at higher salinity levels. This reduction in shoot and root growth is one of the most commonly observed responses to salinity [1-9,13-20,29,30].

In agreement with Richards [31] it is observed that the changes induced by addition of NaCl to the growth medium became more distinct with increasing salinity and with prolongation of the period of exposure to salinity. This is perhaps due to a higher intake of ions [2-9,14-20] which resulted in toxicity [32-34]. Osmotic effects might also have contributed to the low growth rates under saline conditions [35].

Seed lots of 42 wheat cultivars screened for salinity tolerance at the early seedling stage for shoot and root lengths under varying salinity levels (0, 4, 8, 12 and 16 dsm-1) induced by NaCl as indicated (ANOVA Table 1), all the main effects viz., variety, treatment and seedling age and their interactions (V x D, V x T, D x T and V x D x T) were highly significant at 0.01 probability with significant differences noticed in the shoot and root growth of all the cultivars studied (Figure 1).

| Source of Variation | DF | Characters (MSS) | |
|---|---|---|---|
| | | Shoot Length | Root Length |
| Replication (R) | 4 | 0.486375** | 0.061000 |
| Varieties (V) | 41 | 45.705478** | 161.962530** |
| Duration (D) | 3 | 1477.620900** | 5062.824300** |
| Treatment (T) | 4 | 298.855950** | 884.461750** |
| V X D | 123 | 10.662409** | 12.680032** |
| V X T | 164 | 3.96484** | 7.322207** |
| D X T | 12 | 70.434100** | 87.099666* |
| V X D X T | 492 | 0.989345** | 0.970510** |
| Error | 3356 | 0.053137** | 0.319951** |

**Table 1:** ANOVA Table (Shoot and Root Growth in 42 Wheat Cultivars). Shoot Length: G.M. =1.259 S.Em. ± 0.231 C.V=18.310 ** P=0.01, Root Length: G.M=3.093 S.Em. ± 0.566 C.V. =18.289 ** P=0.01

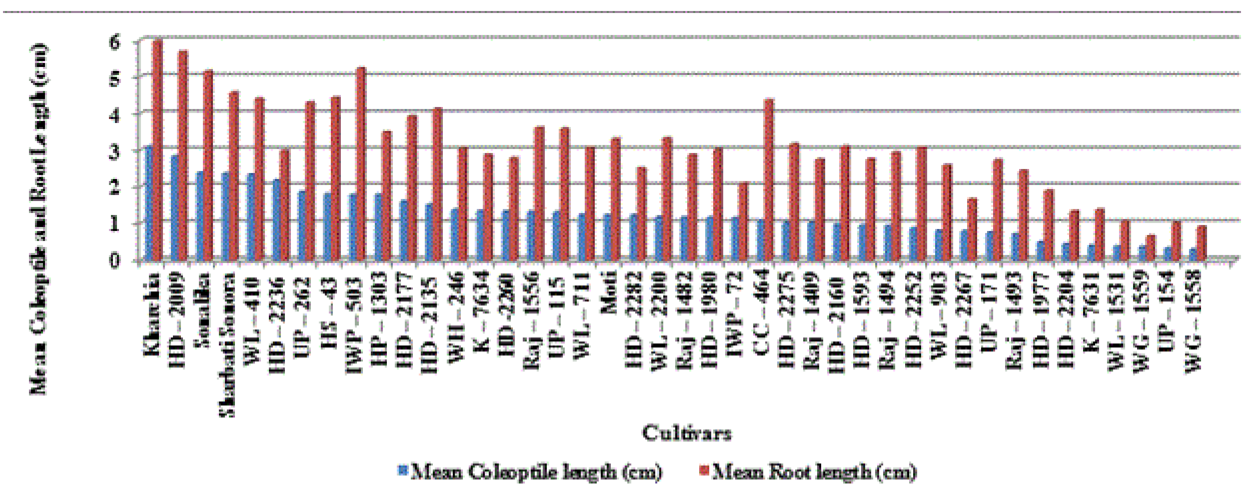


**Figure 1:** Relative Shoot and Root Growths of Certain Wheat (*Triticum Aestivum* L) Cultivars under Salt Stress at the Early Seedling Stage.

The highest mean shoot growth (3.091 cm) was recorded in the cultivar Kharchia followed by HD-2009, Sonalika, Sharbati sonora, WL-410, HD-2236, UP-262, HS-43, IWP-503, HP-1303, HD-2177, HD-2135, WH-246, K-7634, HD-2260, Raj-1556, UP-115, WL-711, Moti, HD-2282, WL-2200, Raj-1482, HD-1980, IWP-72, CC-464, HD-2275, Raj-1409, HD-2160, HD-1593, Raj-1494, HD-2252, WL-908, HD-2267, UP-171, Raj-1493, HD-1977, HD-2204, K-7631, WL-1531, WG-1559, UP-154 and lastly WG-1558 with the lowest shoot length of 0.282 cm (Table 2). Similarly, significant differences were also noticed in the root growth of the cultivars studied. The maximum root length (5.974 cm) was observed in the cultivar Kharchia followed by HD-2009, IWP-503, Sonalika, Sharbati sonora, HS-43, WL-410, CC-464, UP-262, HD-2135, HD-2177, Raj-1556, UP-115, HP-1303, WL-2200, Moti, HD-2275, HD-2160, HD-2252, WL-711, WH-246, HD-1980, IWP-72, Raj-1494, Raj-1482, K-7634, HD-2260, HD-1593, Raj-1409, UP-171, WL-903, HD-2282, Raj-1493, HD-2236, HD-1977, HD-2267, K-7631, HD-2204, WL-1531, UP-154, WG-1558, and minimum (0.658 cm) was observed in WG-1559 (Table 2).

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| S No | Cultivar | Shoot Growth ( cm) | | | | | | Root Growth ( cm) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cont | 4EC | 8EC | 12EC | 16EC | Mean | Cont | 4EC | 8EC | 12EC | 16EC | Mean |
| 1 | HD-2236 | 3.768 | 4.279 | 2.142 | 0.433 | 0.211 | 2.167 | 4.502 | 5.004 | 3.783 | 1.017 | 0.581 | 2.977 |
| 2 | WL-410 | 3.326 | 3.767 | 2.488 | 1.455 | 0.623 | 2.332 | 5.122 | 5.856 | 4.736 | 3.849 | 2.417 | 4.396 |
| 3 | Sharbati sonora | 3.263 | 2.956 | 2.639 | 1.585 | 1.315 | 2.352 | 5.271 | 5.190 | 5.017 | 4.221 | 3.158 | 4.571 |
| 4 | Moti | 2.171 | 2.063 | 1.441 | 0.248 | 0.217 | 1.228 | 5.075 | 4.463 | 3.591 | 1.886 | 1.501 | 3.303 |
| 5 | Sonalika | 3.406 | 2.947 | 2.409 | 1.641 | 1.472 | 2.375 | 5.945 | 5.661 | 5.319 | 4.813 | 3.965 | 5.140 |
| 6 | HD-2160 | 1.069 | 1.017 | 0.974 | 0.911 | 0.883 | 0.970 | 3.627 | 3.432 | 3.038 | 2.814 | 2.582 | 3.098 |
| 7 | HD-2135 | 2.790 | 2.052 | 1.452 | 0.992 | 0.276 | 1.512 | 6.451 | 5.287 | 4.232 | 2.783 | 1.843 | 4.119 |
| 8 | IWP-503 | 3.135 | 2.527 | 1.869 | 0.921 | 0.437 | 1.778 | 7.118 | 6.626 | 5.745 | 4.340 | 2.266 | 5.219 |
| 9 | HS-43 | 2.710 | 2.509 | 1.557 | 1.191 | 0.793 | 1.792 | 6.012 | 5.568 | 4.517 | 3.555 | 2.454 | 4.421 |
| 10 | UP-262 | 3.374 | 2.647 | 2.003 | 0.977 | 0.275 | 1.855 | 6.630 | 5.683 | 4.429 | 2.969 | 1.735 | 4.289 |
| 11 | HD-2177 | 2.948 | 2.329 | 1.719 | 0.841 | 0.198 | 1.607 | 5.019 | 5.482 | 4.488 | 2.790 | 1.853 | 3.926 |
| 12 | WG-1559 | 0.748 | 0.623 | 0.193 | 0.153 | 0.070 | 0.357 | 1.442 | 1.211 | 0.293 | 0.227 | 0.095 | 0.653 |
| 13 | HD-2267 | 1.516 | 1.358 | 0.745 | 0.180 | 0.125 | 0.785 | 3.658 | 2.891 | 1.039 | 0.619 | 0.105 | 1.662 |
| 14 | IWP-72 | 2.430 | 2.015 | 0.950 | 0.190 | 0.125 | 1.142 | 4.119 | 3.496 | 2.006 | 0.607 | 0.240 | 2.093 |
| 15 | HD-2282 | 1.613 | 1.543 | 1.445 | 0.927 | 0.568 | 1.219 | 3.046 | 2.902 | 2.844 | 2.007 | 1.719 | 2.503 |
| 16 | WL-711 | 1.537 | 1.429 | 1.373 | 1.098 | 0.709 | 1.229 | 3.678 | 3.586 | 3.259 | 2.756 | 1.999 | 3.055 |
| 17 | Raj-1482 | 1.711 | 1.654 | 1.229 | 0.660 | 0.554 | 1.161 | 3.909 | 3.762 | 3.072 | 1.893 | 1.729 | 2.873 |
| 18 | HD-2260 | 1.935 | 1.491 | 1.406 | 1.360 | 0.443 | 1.327 | 3.470 | 3.213 | 3.096 | 2.692 | 1.395 | 2.773 |
| 19 | WH-246 | 2.069 | 1.909 | 1.227 | 0.903 | 0.702 | 1.362 | 3.811 | 4.353 | 2.964 | 2.152 | 1.904 | 3.036 |
| 20 | WL-2200 | 1.644 | 1.028 | 1.850 | 0.767 | 0.580 | 1.174 | 3.934 | 3.342 | 4.148 | 2.796 | 2.370 | 3.318 |
| 21 | K-7634 | 1.583 | 1.533 | 1.465 | 1.272 | 0.826 | 1.336 | 3.449 | 2.941 | 3.132 | 2.776 | 2.046 | 2.869 |
| 22 | Raj-1556 | 1.895 | 1.542 | 1.267 | 1.002 | 0.835 | 1.308 | 4.855 | 3.957 | 3.618 | 2.901 | 2.704 | 3.607 |
| 23 | UP-154 | 0.420 | 0.381 | 0.319 | 0.255 | 0.208 | 0.316 | 1.196 | 1.092 | 1.034 | 0.898 | 0.821 | 1.008 |
| 24 | HD-1977 | 0.744 | 0.620 | 0.409 | 0.320 | 0.301 | 0.479 | 2.842 | 2.506 | 1.556 | 1.366 | 1.178 | 1.889 |
| 25 | WG-1558 | 0.409 | 0.388 | 0.292 | 0.177 | 0.144 | 0.282 | 0.988 | 1.290 | 1.191 | 0.645 | 0.428 | 0.908 |
| 26 | HD-2204 | 0.681 | 0.447 | 0.524 | 0.292 | 0.238 | 0.436 | 1.716 | 1.332 | 1.573 | 1.068 | 0.954 | 1.328 |
| 27 | WL-1531 | 0.490 | 0.445 | 0.412 | 0.348 | 0.162 | 0.371 | 1.384 | 1.265 | 1.105 | 0.926 | 0.566 | 1.049 |
| 28 | K-7631 | 0.560 | 0.410 | 0.385 | 0.315 | 0.265 | 0.387 | 1.834 | 1.411 | 1.338 | 1.164 | 1.080 | 1.365 |
| 29 | Raj-1409 | 1.824 | 1.263 | 0.849 | 0.711 | 0.323 | 1.006 | 4.377 | 3.571 | 2.583 | 1.952 | 1.223 | 2.741 |
| 30 | Raj-1493 | 1.104 | 0.839 | 0.716 | 0.561 | 0.295 | 0.703 | 3.599 | 2.636 | 2.415 | 2.189 | 1.335 | 2.427 |
| 31 | Raj-1494 | 2.095 | 0.925 | 0.825 | 0.594 | 0.235 | 0.935 | 5.685 | 3.311 | 2.393 | 2.013 | 1.265 | 2.933 |
| 32 | WL-903 | 1.172 | 0.883 | 0.797 | 0.700 | 0.455 | 0.801 | 3.187 | 2.969 | 2.711 | 2.222 | 1.825 | 2.583 |
| 33 | UP-171 | 1.355 | 1.116 | 0.814 | 0.233 | 0.198 | 0.743 | 4.435 | 3.592 | 2.643 | 1.693 | 1.245 | 2.722 |
| 34 | HD-2275 | 1.760 | 1.463 | 1.127 | 0.453 | 0.305 | 1.021 | 4.840 | 3.869 | 3.138 | 2.085 | 1.828 | 3.152 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35 | HD-1593 | 2.148 | 0.665 | 0.986 | 0.596 | 0.321 | 0.943 | 5.365 | 2.390 | 3.030 | 1.870 | 1.098 | 2.750 |
| 36 | HD-2252 | 1.139 | 1.216 | 0.858 | 0.749 | 0.403 | 0.873 | 3.830 | 4.189 | 2.935 | 2.736 | 1.637 | 3.065 |
| 37 | HP-1303 | 2.640 | 2.275 | 1.504 | 1.430 | 1.032 | 1.776 | 4.886 | 3.869 | 3.366 | 3.288 | 2.054 | 3.493 |
| 38 | UP-115 | 1.775 | 1.523 | 1.289 | 1.181 | 0.713 | 1.296 | 4.808 | 4.312 | 3.934 | 2.803 | 2.050 | 3.581 |
| 39 | HD-1980 | 1.634 | 1.536 | 0.987 | 0.889 | 0.725 | 1.154 | 4.335 | 4.048 | 2.534 | 2.295 | 1.760 | 2.994 |
| 40 | CC-464 | 1.931 | 1.103 | 0.985 | 0.905 | 0.465 | 1.078 | 6.199 | 4.515 | 4.293 | 3.835 | 2.968 | 4.362 |
| 41 | HD-2009 | 4.077 | 3.627 | 2.583 | 2.337 | 1.514 | 2.824 | 7.755 | 6.441 | 5.383 | 4.891 | 3.909 | 5.675 |
| 42 | Kharchia | 5.291 | 3.661 | 2.610 | 2.277 | 1.616 | 3.091 | 7.838 | 7.070 | 5.522 | 5.110 | 4.332 | 5.974 |
| | Means | 1.997 | 1.666 | 1.267 | 0.834 | 0.527 | 1.259 | 4.315 | 3.799 | 3.167 | 2.416 | 1.767 | 3.092 |
| | CD at 5% P=0.064 S.Em. ± 0.023 | | | | | | | CD at 5% P=0.351 S.Em. ± 0.126 | | | | | |

**Table 2:** Shoot and Root Growth of Forty two Wheat Cultivars at Different Salinity Levels.

As indicated in the Table 3 only 11 cultivars showed less than 60% reduction in shoot growth while majority of the 31 cultivars had more than 60% reduction at 16 EC. This is in contrast with root growth (Table 3) where almost a reverse trend was noticed, i.e, out of the 42 cultivars only 15 showed more than 60% reduction at 16 EC whereas 27 had less than 60% reduction. This clearly showed that the shoot is more to salinity than the root growth. This differential response of shoot and root growth is shown in Table 4 and Figure 2 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% , 40–60% and >60% reduction in shoot growth at 12 EC over respective controls (Table 3). Further, the different rates of shoot growth of the three groups (Figures 3 and 4) 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.

| S.No. | Cultivar | Shoot Growth | | | | Root Growth | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 4EC | 8EC | 12EC | 16EC | 4EC | 8EC | 12EC | 16EC |
| 1 | HD-2236 | 113.561* | 56.847 | 11.491 | 05.599 | 111.150* | 84.029 | 22.589 | 12.905 |
| 2 | WL-410 | 113.259* | 74.804 | 43.746 | 18.731 | 114.330* | 92.463 | 75.146 | 47.188 |
| 3 | Sharbati sonora | 90.591 | 80.876 | 48.574 | 40.300 | 98.463 | 95.181 | 80.079 | 59.912 |
| 4 | Moti | 95.025 | 66.374 | 11.423 | 09.995 | 87.940 | 70.758 | 37.162 | 29.576 |
| 5 | Sonalika | 86.523 | 70.728 | 48.179 | 43.217 | 95.222 | 89.470 | 80.958 | 66.694 |
| 6 | HD-2160 | 95.135 | 91.113 | 85.219 | 82.600 | 94.623 | 83.760 | 77.584 | 71.188 |
| 7 | HD-2135 | 73.548 | 52.043 | 35.555 | 09.892 | 81.956 | 65.602 | 43.140 | 28.569 |
| 8 | IWP-503 | 80.606 | 59.617 | 29.346 | 13.939 | 93.087 | 80.710 | 60.972 | 31.834 |
| 9 | HS-43 | 92.583 | 64.833 | 43.948 | 29.261 | 92.614 | 75.133 | 59.131 | 40.818 |
| 10 | UP-262 | 78.452 | 59.844 | 28.956 | 08.150 | 85.716 | 66.802 | 44.781 | 26.168 |
| 11 | HD-2177 | 79.002 | 58.310 | 28.527 | 06.716 | 109.224* | 89.420 | 55.588 | 36.919 |
| 12 | WG-1559 | 83.288 | 25.802 | 20.454 | 09.358 | 83.980 | 20.319 | 15.742 | 6.588 |
| 13 | HD-2267 | 89.577 | 49.142 | 11.873 | 08.245 | 79.032 | 28.403 | 16.921 | 02.870 |
| 14 | IWP-72 | 82.921 | 39.094 | 7.818 | 05.144 | 84.874 | 48.701 | 14.736 | 05.826 |
| 15 | HD-2282 | 95.600 | 89.584 | 57.470 | 35.213 | 95.272 | 93.368 | 65.889 | 56.434 |
| 16 | WL-711 | 92.973 | 89.329 | 71.437 | 46.128 | 97.498 | 88.607 | 74.932 | 54.350 |
| 17 | Raj-1482 | 96.668 | 71.829 | 38.573 | 32.378 | 96.239 | 78.587 | 48.426 | 44.231 |
| 18 | HD-2260 | 77.059 | 72.661 | 70.284 | 22.894 | 92.593 | 89.221 | 77.579 | 40.201 |
| 19 | WH-246 | 92.266 | 59.304 | 43.644 | 33.929 | 114.221* | 77.774 | 56.468 | 49.960 |
| 20 | WL-2200 | 62.530 | 112.530 | 46.654 | 35.279 | 84.951 | 105.439* | 71.072 | 60.244 |
| 21 | K-7634 | 96.841 | 92.545 | 80.353 | 52.179 | 85.271 | 90.808 | 80.487 | 59.321 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 22 | Raj-1556 | 81.372 | 66.860 | 52.875 | 44.063 | 81.503 | 74.521 | 59.752 | 55.695 |
| 23 | UP-154 | 90.714 | 75.952 | 60.714 | 49.523 | 91.303 | 86.454 | 75.083 | 68.645 |
| 24 | HD-1977 | 83.333 | 54.973 | 43.010 | 40.456 | 88.177 | 54.750 | 48.064 | 41.449 |
| 25 | WG-1558 | 94.865 | 71.393 | 43.276 | 35.207 | 130.566* | 120.546* | 65.282 | 43.319 |
| 26 | HD-2204 | 65.638 | 76.945 | 42.878 | 34.948 | 77.622 | 91.666 | 62.237 | 55.594 |
| 27 | WL-1531 | 90.816 | 84.081 | 71.020 | 33.061 | 91.401 | 79.841 | 66.907 | 40.895 |
| 28 | K-7631 | 73.214 | 68.750 | 56.250 | 47.321 | 76.935 | 72.955 | 63.467 | 58.887 |
| 29 | Raj-1409 | 69.243 | 46.546 | 38.980 | 17.708 | 81.585 | 59.013 | 44.596 | 27.941 |
| 30 | Raj-1493 | 75.996 | 64.855 | 50.815 | 26.721 | 73.242 | 67.101 | 60.822 | 37.093 |
| 31 | Raj-1494 | 44.152 | 39.379 | 28.353 | 11.217 | 58.240 | 42.093 | 35.408 | 22.251 |
| 32 | WL-903 | 75.341 | 68.003 | 59.726 | 38.822 | 93.159 | 85.064 | 69.720 | 57.263 |
| 33 | UP-171 | 82.361 | 60.073 | 17.195 | 14.612 | 80.992 | 59.594 | 38.173 | 28.072 |
| 34 | HD-2275 | 83.125 | 64.034 | 25.738 | 17.329 | 79.938 | 64.834 | 43.078 | 37.768 |
| 35 | HD-1593 | 30.959 | 45.903 | 27.746 | 14.944 | 44.547 | 56.477 | 34.855 | 20.465 |
| 36 | HD-2252 | 106.760* | 75.329 | 65.759 | 35.381 | 109.373* | 76.631 | 71.436 | 42.741 |
| 37 | HP-1303 | 86.174 | 56.969 | 54.166 | 39.090 | 79.185 | 68.890 | 67.294 | 42.038 |
| 38 | UP-115 | 85.802 | 72.619 | 66.535 | 40.169 | 89.683 | 81.821 | 58.298 | 42.637 |
| 39 | HD-1980 | 94.002 | 60.403 | 54.406 | 44.369 | 93.379 | 58.454 | 52.941 | 40.599 |
| 40 | CC-464 | 57.120 | 51.009 | 46.866 | 24.080 | 72.834 | 69.253 | 61.864 | 47.878 |
| 41 | HD-2009 | 88.962 | 60.902 | 57.321 | 39.097 | 83.056 | 69.413 | 63.068 | 50.406 |
| 42 | Kharchia | 69.192 | 49.329 | 43.035 | 30.542 | 90.201 | 70.451 | 65.195 | 55.269 |

**Table 3:** Shoot and Root Growth of Forty two Wheat Cultivars at Different Salinity Levels (Data expressed as percentage over control).

A significant reduction in shoot and root growth with increasing salinity levels was observed irrespective of cultivars and seedling age (Table 4 and Figure 2). The reduction was more pronounced after 8 EC salinity level. It was observed that the cultivars showed the first sign of germination at 48 hr after sowing irrespective of salinity level and thereafter shoot growth increased significantly with seedling age till 120 hr (Table 4 and Figure 2).

| | **Interaction Duration** | | | | **Interaction Treatment** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Seedling Age (hr)** | | | | **Salinity Level dsm-1** | | | | |
| | 48hrs | 72hrs | 96hrs | 120hrs | Control | 4EC | 8EC | 12EC | 16EC |
| Shoot | 0.192 | 0.562 | 1.419 | 2.863 | 1.997 | 1.666 | 1.267 | 0.835 | 0.529 |
| | CD at 5% P=0.048 SEm ± 0.017 | | | | CD at 5% P=0.022 SEm ± 0.008 | | | | |
| Root | 0.693 | 2.122 | 3.759 | 5.798 | 4.314 | 3.799 | 3.167 | 2.147 | 1.767 |
| | CD at 5% P=0.020 SEm ± 0.007 | | | | CD at 5% P=0.054 SEm ± 0.020 | | | | |

**Table 4:** Relative Shoot and Root Growth (cm) of Certain Wheat Cultivars at Varying Salinity Levels (dsm-1).

In the significant interaction of varieties with treatment the cultivars showed a decrease in shoot growth with salinity levels; however, the varietal variations were quite evident. All the cultivars except HD-2160, Sharbati sonora, Sonalika, WL-171, K-7634, Raj-1556, UP-154, HD-1977, K-7631, UP-115, and HD-1980 showed more than 60% reduction in shoot growth at 16 EC salinity level (Table 3). Like shoot growth, salinity in general, resulted in a reduction in root growth irrespective of cultivars and duration. This decline in root growth was significant at all EC levels. On the other hand, root growth increased significantly with the age of the seedling (Table 5 and Figure 3). Further, it was observed that the cultivars differed significantly in their response to increasing salinity levels and all other cultivars except HD-2160, UP-154, Sonalika, and WL-2200 showed less than 60% root growth at 16 EC level (Table 6).

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% shoot growth at 16 EC over control) and IWP–72 showing highest inhibition in shoot growth (i.e., only 5.14% 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 3 as far as their resistance to salt stress was concerned.

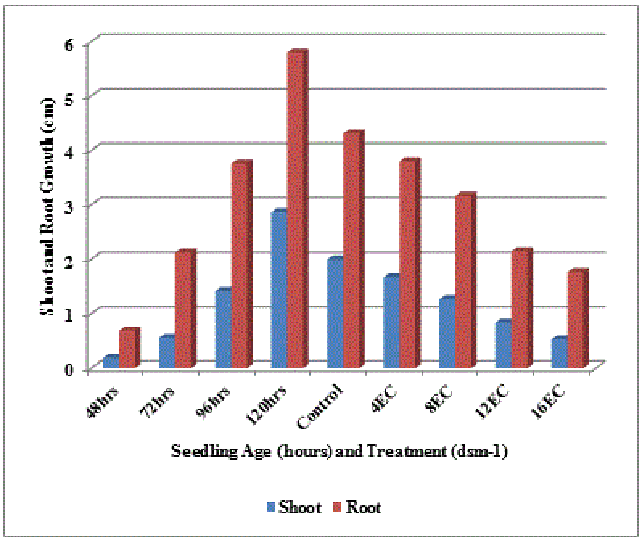


**Figure 2:** Relative Shoot And Root Growths Of Certain Wheat (*Triticum Aestivum* L) Cultivars Under Salt Stress At The Early Seedling Stage.

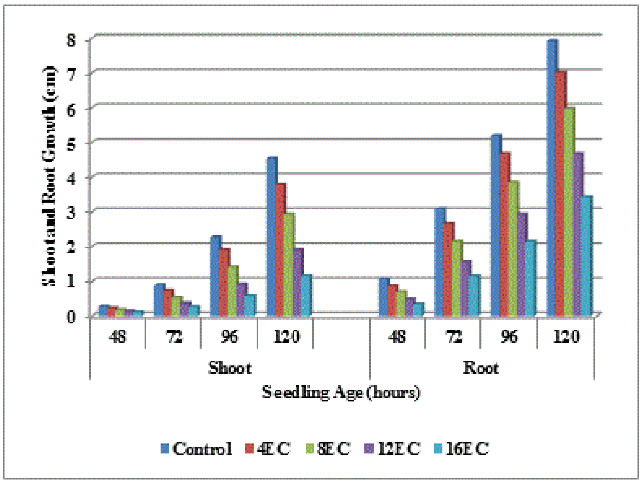


**Figure 3:** Effect of varying salinity levels on progressive shoot and root growth (cm) of certain wheat (*Triticum aestivum* L) cultivars at the early seedling stage (Treatment × Duration). [36]

On the other hand, all the cultivars showed an increase in shoot growth with seedling age. It was evident that the different cultivars exhibited marked differences in their early seedling growth with increasing age of the seedling and that with advancement of seedling age the effect of salt declined and that, in general, tolerance to salinity increased. It was observed that root length increased with age of the seedlings in all the 42 cultivars studied irrespective of the salinity levels. This table also shows that the cultivars differed significantly in their relative root growth. Like shoot, it was observed in the present investigation that irrespective of the cultivars studied the seedlings exhibited increase in salt tolerance with the advancement of age (Tables 4 and 5 and Figures 2 and 3).

A stimulation observed in growth of some cultivars as shown in Table 3 marked with asterisk (*) at moderate levels of salinity (4 and 8 dsm-1) confirmed similar observations of [2,5,10,16-2036,37] In certain crop plants. Poljakoff-Mayber and Gale [38] reported that Na+ and Cl-ions play important roles in the life of the plant within the range of suitable concentrations. The stimulation in growth might be attributed to the nutritional supplementation at low concentrations of the salt [2-5,14-20,39].

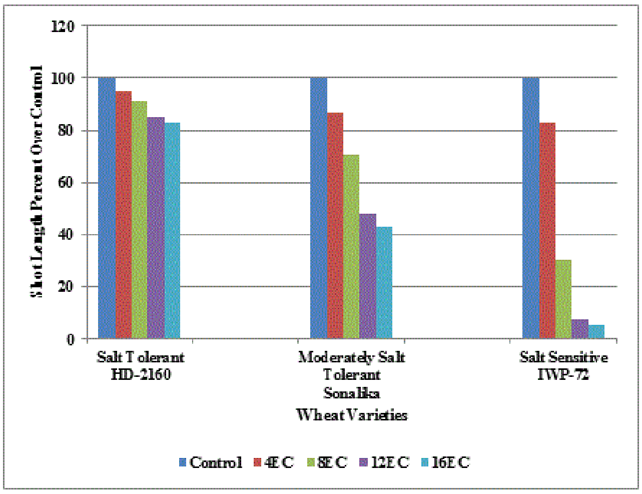


**Figure 4:** Relative Salt Tolerance of Three Groups (Salt-Tolerant; Moderately Salt-Tolerant and Salt-Sensitive Wheat (*Triticum Aestivum* L) Cultivars Under Salt Stress at the Early Seedling Stage (Data Expressed As percentage Over Control).

| | Seedling Age (hr) | Salinity Level dsm-1 | | | | |
|---|---|---|---|---|---|---|
| | | Control | 4EC | 8EC | 12EC | 16EC |
| Shoot | 48 | 0.280 | 0.236 | 0.184 | 0.145 | 0.114 |
| | 72 | 0.901 | 0.741 | 0.531 | 0.372 | 0.266 |
| | 96 | 2.263 | 1.905 | 1.417 | 0.922 | 0.588 |
| | 120 | 4.544 | 3.783 | 2.935 | 1.903 | 1.148 |
| CD at 5% P=0.044 SEm ± 0.016 | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Root | 48 | 1.065 | 0.868 | 0.697 | 0.486 | 0.347 |
| | 72 | 3.083 | 2.653 | 2.152 | 1.571 | 1.148 |
| | 96 | 5.192 | 4.674 | 3.848 | 2.934 | 2.148 |
| | 120 | 7.915 | 7.002 | 5.972 | 4.675 | 3.425 |
| CD at 5% P=0.039 SEm ± 0.108 | | | | | | |

**Table 5:** Relative Shoot and Root Growth ( cm) of Certain Wheat Cultivars at Varying Salinity Levels (dsm-1) (Treatment × Duration)

| | **Group I**<br>**Salt-tolerant**<br>**(Less than 40% reduction)** | **Group II**<br>**Moderately Salt-tolerant**<br>**(40–60% reduction)** | **Group III**<br>**Salt-sensitive**<br>**(More than 60% reduction)** |
|---|---|---|---|
| CULTIVARS | HD-2160 | WL-903 | Raj-1409 |
| | K-7634 | HD-2282 | Raj-1482 |
| | WL-711 | HD-2009 | HD-2135 |
| | WL-1531 | K-7631 | IWP-503 |
| | HD-2260 | HD-1980 | UP-262 |
| | UP-115 | HP-1303 | HD-2177 |
| | HD-2252 | Raj-1556 | Raj-1494 |
| | UP-154 | Raj-1493 | HD-1593 |
| | | Sharbati Sonora | HD-2275 |
| | | Sonalika | WG-1559 |
| | | CC-464 | UP-171 |
| | | WL-2200 | HD-2267 |
| | | HS-43 | HD-2236 |
| | | WL-410 | Moti |
| | | WH-246 | IWP-72 |
| | | WG-1558 | |
| | | Kharchia | |
| | | HD-1977 | |
| | | HD-2204 | |

**Table 6:** Showing Relative Tolerance of Certain Cultivars of Wheat Based on the% Reduction in Coleoptile Growth at 12 EC (dsm-1) Salinity Level.

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 [40], Sarin and Narayanan [41], Sharma, et al. [2], Sharma, et al. [5], Sharma and Baijal, et al. [3,4,15,16], Yadav [18]. Varietal differences to salt stress were also reported in other agricultural crops by several workers [2,5,13,16-20,34,41-47].

## 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 % 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.

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