GROWTH AND IONS (Na⁺, K⁺ AND Cl⁻) ACCUMULATING PATTERN OF SOME
BRASSICA GENOTYPES UNDER SALINE – SODIC FIELD CONDITION

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Abstract

The growth and ionic uptake pattern of some Brassica genotypes i.e., Rainbow, Wester, Durr-e-NIFA, Abaseen 95
(Brassica napus) and NIFA raya (Brassica juncea) under saline-sodic field conditions was studied. Two sets of experiments
on normal and saline-sodic site were conducted at NIA experimental farm, Tandojam, Pakistan during Rabi 2006-07. The
salinity of the experimental site ranged between 11.0–22.9 dS/m and the pH was alkaline (8-8.6). The dominant cation was
sodium (Na). The growth performance was recorded at the time of crop harvest in terms of plant height, grain weight / plant,
grain yield and 100 grain weight. It was observed that the performance of Wester was better followed by NIFA- raya. The
ionic uptake pattern, of leaves, stem and roots showed that the accumulation of Na was less in leaf as compared to stem and
roots. However, the genotypes having better performance were found to have accumulating type of behavior showing
comparatively higher Na contents in all plant parts than other genotypes. This suggests that these genotypes might adjust
their osmotic potential through the accumulation of sodium in vacuole. On the other hand trend in case of K accumulation
was reverse i.e. high in leaves and stem as compared to roots. Higher accumulating pattern of K in leaves might be helpful
for reducing the toxic effects of sodium. However, no correlation was observed between K-Na selectivity or K/Na ratio
among the genotypes tested. It is therefore concluded that better selective mechanism for Na uptake and strict control of
intercellular Na influx for cellular osmotic adjustment could be selected for saline environment.

Introduction

Brassica is an important oil seed crop. In Pakistan, after cotton seed, rape-seed and mustard are the second
most important sources of edible oil. (Haq et al., 2002) It has been cultivated under both irrigated and non-irrigated
areas of Pakistan. In Sindh province it is mostly cultivated as Zaid Kharif (September) crop on residual moisture of
rice on both northern and southern rice tracks (Bhatti & Soomro, 1996). However, the presence of soil salinity on
these tracks affects Brassica yield considerably. Brassica is classified as tolerant to salinity (Mass & Hoffman, 1977).
It has also been reported that though it has higher threshold values, but rate of yield decline above the thresholds
was much greater than most other crops in the tolerant category (Maas, 1990). However the variability in
tolerance limits also exists within the genotypes and species. Variation in salt tolerance within the genotypes
mainly depends upon the ion uptake pattern of genotypes. The tolerance of plant to Sodium chloride is commonly,
but not uniquely, related to the concentration of sodium in the shoot (Flowers, 2004). It has been reported that plants
adopt avoidance mechanism by restricting the higher uptake of Na ions in active parts (i.e. leaves), and accumulate
them in roots and stem. According to Ashraf & Leary (1995), salt tolerance is related to exclusion of Na ion in leaves from
the all ages. The efflux of Sodium at the plasma membrane of root epidermis and cortical cells, and resorption of Na⁺ from
xylem sap and its accumulation by xylem parenchyma cells are the processes involved in Na exclusion (Gorham et al., 1986).
Sensitive cultivars accumulate ions more quickly than tolerant cultivars and this ion accumulation leads to leaf
death and progressively death of the plant (Munns, 2002).

On the other hand, plants of halophytic nature, adopt the mechanism of accumulation and compartmentalizing
ions in leaf vacuole. Van Steveninck et al., (1982) found that the salt tolerant species of Lupinus luteus accumulated more Na⁺ and Cl⁻ in the shoot than sensitive
L. angustifolius. Similar results were also reported by Ashraf et al., (1990), who reported higher concentration of Na in leaves of a selected salt tolerant line of Lolium
perenne than unselected base population. Keeping in view these adaptive mechanisms, a field trial was conducted to
study the growth and ionic uptake pattern in some high yielding genotypes of Brassica.

Material and Methods

Two sets of experiments (Site-1 and Site-2) were conducted at NIA experimental farm, Tandojam during Rabi
2006-07. The salinity of the Site-2 was ranging from medium
to highly saline (ECe =11 – 22.9 dS/m), however it was tried
that saline-sodic patch must have more or less similar salinity
levels ranges (11 – 15 dS/m). Other physio chemical
properties are presented in Table 1. Five varieties of brassica,
(i). Rainbow (ii) Waster (iii) Durr-e-NIFA (iv) Abaseen-95
(Brassica napus) and (v) NIFA raya (Brassica juncea) were
tested. The experiment was laid out according to randomized
complete block design (RCBD) in subplots of
size 1x 1.5m² having row spacing of 30cm. The growth
observations were recorded at the time of maturity of crop in
terms of Plant height (cm), grain wt. / plant, grain yield/ plot
and 100 grain weight.

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To study the ionic (Na+, K+ and Cl-) uptake pattern of brassica varieties, Samples of leaves, stem and roots were collected at the time of flowering/pod formation. After thorough washing with distilled water, the plant samples were dried in hot air oven (±70°C) for 72 hours. For the determination of (Na+, K+ and Cl-) in plant solute extraction was done in (0.5%) toulene water, according to Weimberg et al., (1981). Sodium (Na+) and Potassium (K+) were determined by flame Photometer and Cl- were determined titrimatrically by Silver nitrate (0.0098N) solution, according to the standard methods as reported by Jackson (1962). The data was analyzed statistically, Analysis of Variance (ANOVA) according to Mstat-C computer package.

Table 1. Physio-chemical analysis of the experimental sites at surface layer (0 – 30cm).

<table>
<thead>
<tr>
<th>S.#</th>
<th>Analysis</th>
<th>Site-I</th>
<th>Site-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Saturation % age</td>
<td>35-36</td>
<td>31-36</td>
</tr>
<tr>
<td>2.</td>
<td>E Ce (dS/m)</td>
<td>1.3-1.36</td>
<td>11.1-22.9</td>
</tr>
<tr>
<td>3.</td>
<td>PH</td>
<td>8.0-8.5</td>
<td>8.0-8.6</td>
</tr>
<tr>
<td>4.</td>
<td>Na (meq /L)</td>
<td>5.0-11.30</td>
<td>84.78-271.74</td>
</tr>
<tr>
<td>5.</td>
<td>Ca + Mg (meq /L)</td>
<td>4.0-35.5</td>
<td>37.5-78.5</td>
</tr>
<tr>
<td>6.</td>
<td>Sodium adsorption ratio (SAR)</td>
<td>4.85 --- 15.45</td>
<td>47.93 --- 147.96</td>
</tr>
<tr>
<td>7.</td>
<td>Soil category</td>
<td>Non saline</td>
<td>Saline-sodic</td>
</tr>
</tbody>
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Table 2. Growth performance of some Brassica varieties under saline condition (2006-07).

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Plant height (cm)</th>
<th>Grain yield/plant (g)</th>
<th>Grain yield/plot (g)</th>
<th>100 grain weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non saline</td>
<td>Saline</td>
<td>Non saline</td>
<td>Saline</td>
</tr>
<tr>
<td>Rainbow</td>
<td>168.3 (70)</td>
<td>160.0 (49.3)</td>
<td>12.17 (10.4)</td>
<td>5.04 (58.58)</td>
</tr>
<tr>
<td>Wester</td>
<td>179.0 (75.3)</td>
<td>169.3 (7.59)</td>
<td>13.51 (9.73)</td>
<td>7.3 (27.98)</td>
</tr>
<tr>
<td>Durre NIFA</td>
<td>180.3 (21.41)</td>
<td>141.7 (5.59)</td>
<td>16.78 (6.47)</td>
<td>9.3 (27.98)</td>
</tr>
<tr>
<td>Abaseen-95</td>
<td>168.3 (21.41)</td>
<td>136.7 (8.78)</td>
<td>24.96 (8.09)</td>
<td>6.09 (6.47)</td>
</tr>
<tr>
<td>NIFA-raya</td>
<td>191.7 (0.9)</td>
<td>190 (0.9)</td>
<td>29.75 (15.34)</td>
<td>13.54 (15.34)</td>
</tr>
</tbody>
</table>

LSD (0.05) 0.970 0.5505 0.364 0.0540
Values in the parenthesis are relative decrease (%) over control

Results

Growth performance: The growth performance was recorded at the time of crop maturity. It was observed that there was a decrease in plant height with the increase in soil salinity (Table 2). Under non-saline patches the plant height ranged between 168 to 192cm, whereas under saline field condition, it ranged from 136 to 190cm. The genotype NIFA raya had the maximum plant height under both soil types (i.e. saline and non-saline). Almost all the varieties exhibited less than 25% reduction in plant height, with NIFA raya having the minimum decrease i.e. only 1% followed by Rainbow and Wester. Maximum reduction in plant height was observed in Durr-e-NIFA variety (i.e. 25%).

The increase in salinity had a significant effect on grain weight/plant in brassica varieties, showing more the 50% reduction in Rainbow, Durre–NIFA and Abaseen-95. The only variety, which has exhibited comparatively less reduction, was Wester (i.e. 28%). It was also observed that although the variety NIFA raya has exhibited 48% reduction in grain weight but was found comparatively better in their absolute grain weight production as the variety have produced maximum grain weight (i.e.15.34g/plant) among all the varieties tested. This finding supports the general concept that salt tolerance should always be associated with high yield.

The trend in case of grain yield was also more or less similar in both the varieties (Wester and NIFA- raya), showing less than 50% reduction at saline-sodic site. The variety Wester had maximum grain yield (397g/plot), with minimum reduction under saline condition i.e., 9.44%, followed by NIFA–raya (299g/plot i.e., 25.77% decrease). Maximum decrease (74.45%) was observed in variety Rainbow having minimum yield (180.0g/plot).

The effect of salinity on 100-grain weight were not so pronounced as most of the genotypes had shown nominal relative reduction in 100 grain weight (i.e. 2–3%), except in Durr-e-NIFA where 30% reduction was observed.

Ionic contents and uptake pattern: Plant samples analyzed for ionic contents showed a general trend of increasing sodium in plant under saline condition (Table 3). There were almost more or less similar values (0.53 – 0.64%) for Na in all plant parts (leaf, stem and roots), under non-saline condition. On the other hand the mean values under saline-sodic condition, ranged from 0.81 to 1.12%. Comparatively low sodium contents were observed in leaves than stem and roots. The pattern of sodium uptake varied among the genotypes. It was observed that under saline-sodic condition, the better performing genotypes (i.e. Wester and NIFA-raya) have accumulating type of behavior showing comparatively higher Na+ contents in all plant parts than other genotypes. This suggests that these genotypes might maintain their osmotic potential through the accumulation of sodium in vacuole.
The pattern for K⁺ uptake was reversed i.e., comparatively high K⁺ accumulation in leaf samples than stem and root both under normal and non-saline conditions. Potassium values in leaves, stem and in roots were (2.47, 2.41 and 1.21%) and (2.68 1.69 and 1.59% n) under normal and saline conditions, respectively. It was also observed that root samples had comparatively less potassium contents than leaf and stem under normal and saline conditions, respectively. This indicates the active transport of potassium towards photosynthetic parts of plant to cope the toxic effects of sodium. Potassium contents with respect to individual varieties showed that K⁺ uptake in leaf samples in Wester, Durre-e-NIFA and NIFA-raya increased under saline-sodic soil than under normal conditions. On the other hand, in stem samples it was also observed that there was higher accumulation of salts under saline-sodic patches as compared to non-saline soil. When the plant parts were compared for different ions it was observed that salt stress leads to higher accumulation of Na and Cl and less uptake of K in all parts of plants. It was also observed that the accumulation of Na was less in leaf as compared to stem and roots. This net accumulation of Na into root cells might be due to a balance between influx through ion channels and efflux through a probable Na/H antiporter, as reported by Tester & Davenport (2003). The rapid expansion of the growing cells would also help to stop the salt building up to high concentrations (Munns, 2002). According to Pitman (1984), high shoot: root ratio and high intrinsic growth rates will reduce the rate at which salt enters the transpiration stream and accumulates in the shoot. The extent of an apoplastic pathway in roots will also influence the movement of salts across the root and to the xylem (Garcia et al., 1989). Plant growth is ultimately the direct result of massive and rapid expansion of the young cells produced by meristematic division (Neumann, 1977). The growth performance was recorded at the time of crop harvest showed that the performance of Wester was better followed by NIFA-raya, Munns et al. (1995), suggest that any varietal diversity in plant growth responses to salinity appears slowly and caused by genotypic differences in rates of salt accumulation. The analytical data of plant samples showed that there was higher accumulation of salts under saline-sodic patches as compared to non-saline soil. When the plant parts were compared for different ions it was observed that salt stress leads to higher accumulation of Na and Cl and less uptake of K in all parts of plants. It was also observed that the accumulation of Na was less in leaf as compared to stem and roots. This net accumulation of Na into root cells might be due to a balance between influx through ion channels and efflux through a probable Na/H antiporter, as reported by Tester & Davenport (2003). The rapid expansion of the growing cells would also help to stop the salt building up to high concentrations (Munns, 2002). According to Pitman (1984), high shoot: root ratio and high intrinsic growth rates will reduce the rate at which salt enters the transpiration stream and accumulates in the shoot. The extent of an apoplastic pathway in roots will also influence the movement of salts across the root and to the xylem (Garcia et al., 1989). Plant growth is ultimately the direct result of massive and rapid expansion of the young cells produced by meristematic division (Neumann, 1977). The growth performance was recorded at the time of crop harvest showed that the performance of Wester was better followed by NIFA-raya, Munns et al. (1995), suggest that any varietal diversity in plant growth responses to salinity appears slowly and caused by genotypic differences in rates of salt accumulation. The analytical data of plant samples showed that there was higher accumulation of salts under saline-sodic patches as compared to non-saline soil. When the plant parts were compared for different ions it was observed that salt stress leads to higher accumulation of Na and Cl and less uptake of K in all parts of plants. It was also observed that the accumulation of Na was less in leaf as compared to stem and roots. This net accumulation of Na into root cells might be due to a balance between influx through ion channels and efflux through a probable Na/H antiporter, as reported by Tester & Davenport (2003). The rapid expansion of the growing cells would also help to stop the salt building up to high concentrations (Munns, 2002). According to Pitman (1984), high shoot: root ratio and high intrinsic growth rates will reduce the rate at which salt enters the transpiration stream and accumulates in the shoot. The extent of an apoplastic pathway in roots will also influence the movement of salts across the root and to the xylem (Garcia et al., 1989).
increase in salinity. The increase in Cl− concentration was attributed to massive uptake of Cl− ion by the plants as well as reduced growth under adverse environment. Chloride content also varied among the genotypes. Comparatively higher values were observed in Abaseen-95, Weser and Durr-e-NIFA genotypes. Higher accumulation of Cl− in better performing genotype (i.e., Weser) is an exception but can be expected as also reported by Croughan et al (1978), who produced a salt tolerant line of Medicago sativa using tissue culture technique and found this line to be Cl− accumulating.

Similarly results were reported by Ashraf et al., (1986), in a M. sativa salt tolerant line, produced through conventional selection and breeding.

The trend for K+ accumulation was also same i.e., high in leaves and stem as compared to roots. Higher accumulation pattern of K+ in might be helpful for reducing the toxic effects of Na+. The mechanism for maintenance of adequate K+ uptake in plant tissue under salinity stress seems to be dependent upon selective K+ uptake and selective cellular K+ and Na+ compartmentation and distribution in the shoots (Poljakoff-Mayber & Lerner, 1999; Munns et al., 2000; Carden et al., 2003). On the other hand, He & Cramer (1993) did not find any relationship between K/Na ratio and salt tolerance in Brassica species. They concluded that neither K+/Na+ nor K−/Na− selectivity was correlated with relative tolerance of six rapid cycling Brassica species either at whole plant or callus level, suggesting that these parameters are unreliable selection criteria. As far as our results are concerned the above findings are true, where genotype Durre-e-NIFA, which also had high K+ contents and high K/Na ratio in leaf and Stem but could not perform well under saline-sodic environments. It is therefore concluded that the better selective mechanism for Na+ uptake and strict control of intercellular Na+ influx for cellular osmotic adjustment (which must be compartmentalized into the vacuole to prevent cytotoxicity) might be a selective criteria for the selection of brassica species for saline environments.

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References


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