CHAPTER IV

Grain Composition and Growth Analysis

i) Experimental
ii) Results
iii) Discussion
EXPERIMENTAL

Seven accession of common buckwheat (*Fagopyrum esculentum* Moench) viz. IC-18889, IC-13141, IC-13145, IC-13411, BDS-1345, Kulugangri and PRB-8901 were procurred from the North Eastern Regional Station of National Bureau of Plant Genetic Resources, Shillong. Mature grains from each accession were scanned by electron microscope for their seed code structure. The grains were also analyzed for moisture content, grain weight, hull groat ratio, germination percentage and the tissue level of total starch, total sugars, total proteins, free amino acids, phenolics, and total lipids. The concentration of the tissue constituents has been expressed as percent of grain dry weight.
Grains from each accession were germinated in the laboratory and 5 day old seedlings were transplanted in raised beds in the experimental field of the Botanical Garden of North Eastern Hill University, Shillong. The experimental design was a split plot with three replications for each accession. Plants from each of the accessions were harvested, at random, at periodic intervals till seed set. Shoot length, shoot dry weight, root dry weight, leaf dry weight and total leaf area was recorded for each harvested plant. From the data on dry weight and leaf area various indices of growth viz. Relative growth rate (RGR), Net assimilation rate (NAR), Leaf area ratio (LAR), were computed.

Results presented in this chapter are based on studies carried out in the year 1991. Each presented value represents the mean of at least five independent replicates. The data has also been subjected to ANNOVA and least significance calculated at P0.05.

RESULTS

The scanning electron microscopic photograpghs of seeds of seven accessions of buckwheat revealed marked variations in their pattern of surface waxy coating. The accession IC-13141 showed parallel waxy coating, while PRB-8901, IC-13411, IC-13145 and BDS-1345 showed thick waxy coating with high raticulation. However, Kulugangiri and
IC-18889 showed milky waxy coating with medium raticulation (Fig. 4.1). Marginal differences were also observed in the size of the grains from the seven accessions tested. Except for IC-13141 and IC-18889 which measured 0.27 and 0.318 mm respectively. The breadth of grains of PRB-8901, IC-13411, IC-13145, BDS-1354 and Kulugangri ranged between 0.409 to 0.45 mm. The grains of each of the seven accessions, analyzed, did not differ from each other in length. Thus the length of grains of all the accessions ranged between 0.60 to 0.65 mm (Fig. 4.2). The grains of common buckwheat showed an average grain weight ranging from 12 to 15 mg and a moisture content ranging from 10 to 13 percent. However, marked differences in the hull growth ratio between grains from different accessions were observed. While IC-13141 showed a lowest hull groat ratio of 0.31, IC-13145 had the highest hull groat ratio of 0.53 (Table 4.1). Expressed as percent of dry weight, the starch content of grains ranged between 53.1 to 55.0 percent and the content of total sugars ranged between 10.8 to 12.94 percent. The level of non-reducing was, however, more predominant than that of reducing sugars; reducing sugar constituted an average of 5 per cent of the total sugar content of the grains. Expressed as percent of dry weight, the total protein content of the grains was marginally more than 11.3 percent; no marked differences could be observed in the protein content of the grains between different accessions. Marked differences were, however observed in the level of total lipids and total phenolics in the grains of the seven accessions of common
Table 4.1: Changes in the Hull/groat ratio, percent moisture content and percent germination at 72 hours of the grains of seven accessions of common buckwheat (*Fagopyrum esculentum* Moench).

<table>
<thead>
<tr>
<th>Accession</th>
<th>Grain weight (mg)</th>
<th>Hull/Groat Ratio</th>
<th>Moisture Content (%)</th>
<th>Percent Germination (72 hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC-18889</td>
<td>13.7</td>
<td>0.34</td>
<td>13.0</td>
<td>88</td>
</tr>
<tr>
<td>Kulugangri</td>
<td>13.5</td>
<td>0.50</td>
<td>10.0</td>
<td>64</td>
</tr>
<tr>
<td>PRB-8901</td>
<td>14.4</td>
<td>0.42</td>
<td>12.0</td>
<td>92</td>
</tr>
<tr>
<td>IC-13141</td>
<td>15.5</td>
<td>0.31</td>
<td>10.0</td>
<td>80</td>
</tr>
<tr>
<td>IC-13145</td>
<td>13.5</td>
<td>0.53</td>
<td>13.0</td>
<td>84</td>
</tr>
<tr>
<td>BDS-1354</td>
<td>14.5</td>
<td>0.42</td>
<td>12.0</td>
<td>95</td>
</tr>
<tr>
<td>IC-13411</td>
<td>14.0</td>
<td>0.35</td>
<td>13.0</td>
<td>72</td>
</tr>
</tbody>
</table>

Table 4.2: The content of total protein, total lipids, total amino acids, phenolics, reducing sugars, non-reducing sugars and starch in the grains of seven accessions of common buckwheat (*Fagopyrum esculentum* Moench).

<table>
<thead>
<tr>
<th>Component</th>
<th>IC-18889</th>
<th>Kul</th>
<th>PRB-8901</th>
<th>IC-13141</th>
<th>IC-13145</th>
<th>IC-13411</th>
<th>BDS-1354</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Protein</td>
<td>11.20</td>
<td>11.30</td>
<td>11.50</td>
<td>11.2</td>
<td>11.30</td>
<td>11.20</td>
<td>11.50</td>
</tr>
<tr>
<td>Total lipids</td>
<td>5.90</td>
<td>7.00</td>
<td>3.00</td>
<td>6.00</td>
<td>4.00</td>
<td>4.00</td>
<td>6.00</td>
</tr>
<tr>
<td>Total amino acids</td>
<td>0.33</td>
<td>0.42</td>
<td>0.38</td>
<td>0.40</td>
<td>0.28</td>
<td>0.32</td>
<td>0.43</td>
</tr>
<tr>
<td>Phenolics</td>
<td>2.68</td>
<td>3.35</td>
<td>2.34</td>
<td>2.63</td>
<td>1.03</td>
<td>1.70</td>
<td>3.57</td>
</tr>
<tr>
<td>Reducing Sugars</td>
<td>4.77</td>
<td>3.88</td>
<td>3.65</td>
<td>4.77</td>
<td>3.71</td>
<td>5.10</td>
<td>4.73</td>
</tr>
<tr>
<td>Non-Reducing Sugars</td>
<td>6.03</td>
<td>8.02</td>
<td>6.88</td>
<td>6.12</td>
<td>7.66</td>
<td>7.84</td>
<td>7.26</td>
</tr>
<tr>
<td>Total Sugars</td>
<td>10.89</td>
<td>11.50</td>
<td>10.53</td>
<td>10.89</td>
<td>11.37</td>
<td>12.94</td>
<td>11.99</td>
</tr>
<tr>
<td>Starch</td>
<td>11.08</td>
<td>59.58</td>
<td>54.95</td>
<td>55.00</td>
<td>53.00</td>
<td>55.00</td>
<td>53.10</td>
</tr>
</tbody>
</table>
Fig. 4.1: The Scanning electron microscopic photographs of seeds of seven accessions of common buckwheat (*Fagopyrum esculentum* Moench).
Fig. 4.2: Differences in the size, breadth and length of seeds of seven accessions of common buckwheat (Fagopyrum esculentum Moench)
buckwheat. While PRB-8901 showed the lowest (3.0%) lipid content, Kulugangri had the highest content of total lipids representing about 7.0 percent of total grain dry weight. Amongst the accessions tested, IC-13145 had the lowest level of (1.03%) of total phenolics. The content of total phenolics was highest in grains of BDS-1354 which had nearly 3.6 mg total phenolics per 100 mg grain dry weight (Table 4.2).

All the seven accessions of buckwheat were analyzed for temporal changes in the pattern of growth. The seven accessions tested in our laboratory for their germination showed a germination percentage ranging between 60 to 90 percent at 72 hours after imbibition. However the grains could be separated into two groups based on their germination behaviour. At 72 hours of imbibition 70 to 90 percent grains of IC-18889, IC-13145, PRB-8901 and BDS-1354 had germinated. However, during the same time only 60 to 70 percent grains of IC-13141, Kulugangri and IC-13411 showed visible signs of germination (Table 4.1, Fig. 4.3).

Being a short duration crop, the plants achieved a maximum dry weight in about 40 days after planting. Increase in the dry weight of the shoot followed a typical sigmoid curve with the lag phase lasting up to 7th day after planting. The logarithmic phase of dry matter accumulation in shoot lasted between 7th and 30th day when a more than 15 fold increase in dry weight of the shoot was observed. Beyond 40th day, however, no further increase in dry weight of the
Fig. 4.3: Percentage of germination of seeds of common buckwheat (*Fagopyrum esculentum* Moench) under laboratory conditions at 72 hours of imbibition.
shoot could be observed (Table 4.3, Fig. 4.4). Increase in the dry weight of the roots in plants of common buckwheat followed a hyperbolic pattern without any lag phase; the maximum dry weight being recorded 40 days after planting (Table 4.3, Fig. 4.5). The changes in the pattern of dry matter accumulation in stem and leaf followed a trend similar to that shown by shoot. The logarithmic phase of dry weight accumulation in leaves, however, lasted from 7 to 20 days only beyond which the total leaf dry weight did not increase markedly (Table 4.4, Fig. 4.6 & 4.7). The total leaf area in each of the seven accessions increased linearly with time up to 30 days after planting recording a nearly 20 fold increase during the period. Beyond 30 days there was a slight decrease in the total leaf area of the plants (Table 4.5, Fig. 4.8). The leaf area ratio (cm² mg shoot dryweight⁻¹) of the plants showed a progressive increase with time during initial seven days after planting the seedlings. During this period a more than 6 fold increase in the LAR was observed. Difference was however, observed on the 7th day in LAR between different accessions with BDS-1354 showing the least LAR, when compared with other accessions. After 7th day the LAR registered a marginal decrease up to 19th day. After 19th day there was no appreciable change with time in the LAR for each of the seven accessions (Table 4.6, Fig. 4.9).

In each of the seven accessions the rate of accumulation of dry matter (RGR) expressed as mg mg dry weight⁻¹ d⁻¹ showed positive increments up to 43 days. The
Table 4.3: Changes in the dry weight of shoot and dry weight of root with time in 7 accessions of buckwheat (*Fagopyrum esculentum* Moench) grown under field conditions.

<table>
<thead>
<tr>
<th>Accession</th>
<th>Days after planting</th>
<th>7</th>
<th>19</th>
<th>31</th>
<th>43</th>
<th>55</th>
<th>67</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC-18889</td>
<td>Dry Weight of Shoot (mg)</td>
<td>7.1</td>
<td>50.8</td>
<td>89.9</td>
<td>91.4</td>
<td>85.1</td>
<td>85.0</td>
</tr>
<tr>
<td>Kulugangri</td>
<td>Dry Weight of Shoot (mg)</td>
<td>6.8</td>
<td>52.6</td>
<td>87.5</td>
<td>81.0</td>
<td>88.1</td>
<td>87.8</td>
</tr>
<tr>
<td>FRB-8701</td>
<td>Dry Weight of Shoot (mg)</td>
<td>7.2</td>
<td>54.2</td>
<td>87.5</td>
<td>93.0</td>
<td>91.6</td>
<td>87.3</td>
</tr>
<tr>
<td>IC-13141</td>
<td>Dry Weight of Shoot (mg)</td>
<td>7.3</td>
<td>55.5</td>
<td>83.1</td>
<td>90.5</td>
<td>88.3</td>
<td>86.0</td>
</tr>
<tr>
<td>IC-13145</td>
<td>Dry Weight of Shoot (mg)</td>
<td>6.9</td>
<td>57.3</td>
<td>82.6</td>
<td>87.3</td>
<td>85.5</td>
<td>83.0</td>
</tr>
<tr>
<td>IC-13411</td>
<td>Dry Weight of Shoot (mg)</td>
<td>7.3</td>
<td>59.0</td>
<td>82.6</td>
<td>86.1</td>
<td>84.3</td>
<td>83.3</td>
</tr>
<tr>
<td>BDS-1354</td>
<td>Dry Weight of Shoot (mg)</td>
<td>7.0</td>
<td>56.0</td>
<td>83.5</td>
<td>85.7</td>
<td>84.7</td>
<td>83.8</td>
</tr>
</tbody>
</table>

LSD PO.05 for Accessions = 4.27

<table>
<thead>
<tr>
<th>Accession</th>
<th>Dry Weight of Root (mg)</th>
<th>1</th>
<th>2.5</th>
<th>4.1</th>
<th>4.4</th>
<th>4.3</th>
<th>4.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC-18889</td>
<td>Dry Weight of Root (mg)</td>
<td>1.6</td>
<td>2.5</td>
<td>4.1</td>
<td>4.4</td>
<td>4.3</td>
<td>4.2</td>
</tr>
<tr>
<td>Kulugangri</td>
<td>Dry Weight of Root (mg)</td>
<td>1.8</td>
<td>2.2</td>
<td>4.3</td>
<td>5.6</td>
<td>4.2</td>
<td>4.1</td>
</tr>
<tr>
<td>FRB-8701</td>
<td>Dry Weight of Root (mg)</td>
<td>1.7</td>
<td>2.7</td>
<td>4.3</td>
<td>4.7</td>
<td>4.4</td>
<td>4.2</td>
</tr>
<tr>
<td>IC-13141</td>
<td>Dry Weight of Root (mg)</td>
<td>1.7</td>
<td>2.7</td>
<td>4.1</td>
<td>4.4</td>
<td>4.1</td>
<td>4.3</td>
</tr>
<tr>
<td>IC-13145</td>
<td>Dry Weight of Root (mg)</td>
<td>1.7</td>
<td>2.3</td>
<td>5.1</td>
<td>5.5</td>
<td>4.8</td>
<td>4.5</td>
</tr>
<tr>
<td>IC-13411</td>
<td>Dry Weight of Root (mg)</td>
<td>1.7</td>
<td>2.8</td>
<td>5.3</td>
<td>5.6</td>
<td>4.6</td>
<td>4.1</td>
</tr>
<tr>
<td>BDS-1354</td>
<td>Dry Weight of Root (mg)</td>
<td>1.6</td>
<td>2.7</td>
<td>5.0</td>
<td>5.8</td>
<td>4.8</td>
<td>4.4</td>
</tr>
</tbody>
</table>

LSD PO.05 for Accessions = 0.51
Table 4.4: Changes in the dry weight of stem and dry weight of leaf with time in 7 accessions of common buckwheat (*Fagopyrum esculentum* Moench) grown under field conditions.

<table>
<thead>
<tr>
<th>Accession</th>
<th>Days after planting</th>
<th>7</th>
<th>19</th>
<th>31</th>
<th>43</th>
<th>55</th>
<th>67</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC-18889</td>
<td>Dry Weight Stem (mg)</td>
<td>4.1</td>
<td>30.9</td>
<td>63.3</td>
<td>63.8</td>
<td>59.0</td>
<td>59.5</td>
</tr>
<tr>
<td>Kulugangri</td>
<td>4.1</td>
<td>29.7</td>
<td>62.5</td>
<td>51.3</td>
<td>60.0</td>
<td>61.5</td>
<td></td>
</tr>
<tr>
<td>PRB-8901</td>
<td>4.1</td>
<td>31.0</td>
<td>62.5</td>
<td>63.2</td>
<td>62.0</td>
<td>61.3</td>
<td></td>
</tr>
<tr>
<td>IC-13141</td>
<td>4.2</td>
<td>33.3</td>
<td>58.1</td>
<td>60.6</td>
<td>58.8</td>
<td>58.5</td>
<td></td>
</tr>
<tr>
<td>IC-13145</td>
<td>4.0</td>
<td>32.8</td>
<td>56.6</td>
<td>58.0</td>
<td>57.5</td>
<td>56.0</td>
<td></td>
</tr>
<tr>
<td>IC-13411</td>
<td>4.2</td>
<td>33.3</td>
<td>56.8</td>
<td>58.1</td>
<td>57.3</td>
<td>56.5</td>
<td></td>
</tr>
<tr>
<td>BDS-1354</td>
<td>4.1</td>
<td>33.0</td>
<td>57.1</td>
<td>58.1</td>
<td>57.6</td>
<td>57.0</td>
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</table>

LSD PO.05 for Accessions = 9.44

<table>
<thead>
<tr>
<th>Accession</th>
<th>Dry Weight of Leaf (mg)</th>
<th>7</th>
<th>19</th>
<th>31</th>
<th>43</th>
<th>55</th>
<th>67</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC-18889</td>
<td>3.1</td>
<td>19.7</td>
<td>26.6</td>
<td>27.6</td>
<td>26.1</td>
<td>25.5</td>
<td></td>
</tr>
<tr>
<td>Kulugangri</td>
<td>2.7</td>
<td>22.2</td>
<td>25.0</td>
<td>29.7</td>
<td>28.1</td>
<td>26.3</td>
<td></td>
</tr>
<tr>
<td>PRB-8901</td>
<td>3.1</td>
<td>23.2</td>
<td>25.0</td>
<td>29.9</td>
<td>29.6</td>
<td>26.0</td>
<td></td>
</tr>
<tr>
<td>IC-13141</td>
<td>3.1</td>
<td>22.2</td>
<td>25.0</td>
<td>29.9</td>
<td>29.5</td>
<td>27.5</td>
<td></td>
</tr>
<tr>
<td>IC-13145</td>
<td>2.9</td>
<td>24.5</td>
<td>26.0</td>
<td>29.3</td>
<td>28.0</td>
<td>27.0</td>
<td></td>
</tr>
<tr>
<td>IC-13411</td>
<td>3.1</td>
<td>24.8</td>
<td>25.8</td>
<td>28.1</td>
<td>27.0</td>
<td>26.8</td>
<td></td>
</tr>
<tr>
<td>BDS-1354</td>
<td>2.9</td>
<td>23.0</td>
<td>26.4</td>
<td>27.6</td>
<td>27.1</td>
<td>26.8</td>
<td></td>
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LSD PO.05 for Accessions = 1.60
Table 4.5: Changes in the leaf area with time in 7 accessions of common buckwheat (*Fagopyrum esculentum* Moench) grown under field conditions.

<table>
<thead>
<tr>
<th>Accession</th>
<th>3</th>
<th>7</th>
<th>19</th>
<th>31</th>
<th>43</th>
<th>55</th>
<th>67</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days after planting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaf Area (cm²)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IC-18889</td>
<td>1.20</td>
<td>4.1</td>
<td>12.3</td>
<td>21.8</td>
<td>27.3</td>
<td>28.1</td>
<td>27.0</td>
</tr>
<tr>
<td>Kulugangri</td>
<td>1.25</td>
<td>4.5</td>
<td>13.1</td>
<td>21.6</td>
<td>26.0</td>
<td>23.6</td>
<td>22.8</td>
</tr>
<tr>
<td>PRB-8901</td>
<td>1.40</td>
<td>4.6</td>
<td>13.0</td>
<td>24.0</td>
<td>28.3</td>
<td>27.3</td>
<td>24.6</td>
</tr>
<tr>
<td>IC-13141</td>
<td>1.20</td>
<td>5.0</td>
<td>13.8</td>
<td>23.3</td>
<td>28.0</td>
<td>25.3</td>
<td>24.0</td>
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<td>1.20</td>
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<td>13.5</td>
<td>23.0</td>
<td>27.3</td>
<td>25.3</td>
<td>24.3</td>
</tr>
<tr>
<td>IC-13411</td>
<td>1.50</td>
<td>4.8</td>
<td>14.3</td>
<td>23.3</td>
<td>27.1</td>
<td>25.3</td>
<td>24.1</td>
</tr>
<tr>
<td>BDS-1354</td>
<td>1.30</td>
<td>4.8</td>
<td>13.3</td>
<td>19.6</td>
<td>27.0</td>
<td>26.8</td>
<td>25.0</td>
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</table>

LSD P0.05 for Accessions = 1.72
Table 4.6: Changes in the relative growth rate, net assimilation rate and leaf area ratio with time of 7 accessions of common buckwheat (*Fagopyrum esculentum* Moench) grown under field conditions.

<table>
<thead>
<tr>
<th>Accessions</th>
<th>Days After Planting</th>
<th>RGR (mg mg dry weight$^{-1}$ d$^{-1}$)</th>
<th>NAR (mg/cm$^2$ leaf area d$^{-1}$)</th>
<th>LAR (cm$^2$ leaf area/dry weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>7</td>
<td>19</td>
<td>31</td>
</tr>
<tr>
<td>IC-18889</td>
<td>0.007</td>
<td>0.04</td>
<td>0.159</td>
<td>0.047</td>
</tr>
<tr>
<td>Kalu</td>
<td>0.029</td>
<td>0.028</td>
<td>0.159</td>
<td>0.042</td>
</tr>
<tr>
<td>PRB-8901</td>
<td>0.014</td>
<td>0.043</td>
<td>0.154</td>
<td>0.039</td>
</tr>
<tr>
<td>IC-13141</td>
<td>0.01</td>
<td>0.046</td>
<td>0.156</td>
<td>0.033</td>
</tr>
<tr>
<td>IC-13145</td>
<td>0.007</td>
<td>0.035</td>
<td>0.16</td>
<td>0.003</td>
</tr>
<tr>
<td>BDS-1354</td>
<td>0.03</td>
<td>0.034</td>
<td>0.16</td>
<td>0.034</td>
</tr>
<tr>
<td>IC-13411</td>
<td>0.017</td>
<td>0.045</td>
<td>0.158</td>
<td>0.031</td>
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LSD PO.05 for accession = 0.028

<table>
<thead>
<tr>
<th>Accessions</th>
<th>Days After Planting</th>
<th>RGR (mg mg dry weight$^{-1}$ d$^{-1}$)</th>
<th>NAR (mg/cm$^2$ leaf area d$^{-1}$)</th>
<th>LAR (cm$^2$ leaf area/dry weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC-18889</td>
<td>0.021</td>
<td>0.43</td>
<td>0.487</td>
<td>0.212</td>
</tr>
<tr>
<td>Kalu</td>
<td>0.068</td>
<td>0.398</td>
<td>0.488</td>
<td>0.200</td>
</tr>
<tr>
<td>PRB-8901</td>
<td>0.037</td>
<td>0.400</td>
<td>0.490</td>
<td>0.174</td>
</tr>
<tr>
<td>IC-13141</td>
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<td>0.398</td>
<td>0.483</td>
<td>0.134</td>
</tr>
<tr>
<td>IC-13145</td>
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<td>0.401</td>
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</tr>
<tr>
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<td>0.600</td>
<td>0.187</td>
</tr>
<tr>
<td>IC-13411</td>
<td>0.043</td>
<td>0.410</td>
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</table>

LSD PO.05 for accession = 0.042

<table>
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<tr>
<th>Accessions</th>
<th>Days After Planting</th>
<th>RGR (mg mg dry weight$^{-1}$ d$^{-1}$)</th>
<th>NAR (mg/cm$^2$ leaf area d$^{-1}$)</th>
<th>LAR (cm$^2$ leaf area/dry weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC-18889</td>
<td>0.085</td>
<td>0.50</td>
<td>0.230</td>
<td>0.240</td>
</tr>
<tr>
<td>Kalu</td>
<td>0.100</td>
<td>0.66</td>
<td>0.249</td>
<td>0.246</td>
</tr>
<tr>
<td>PRB-8901</td>
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<td>0.274</td>
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<tr>
<td>IC-13141</td>
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<td>0.68</td>
<td>0.240</td>
<td>0.280</td>
</tr>
<tr>
<td>IC-13145</td>
<td>0.082</td>
<td>0.65</td>
<td>0.230</td>
<td>0.270</td>
</tr>
<tr>
<td>BDS-1354</td>
<td>0.104</td>
<td>0.65</td>
<td>0.246</td>
<td>0.282</td>
</tr>
<tr>
<td>IC-13411</td>
<td>0.110</td>
<td>0.68</td>
<td>0.230</td>
<td>0.230</td>
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</table>

LSD PO.05 for accession = 0.284
Fig. 4.4: Changes in the shoot dry weight with time in 7 accessions of common buckwheat (*Fagopyrum esculentum* Moench) during growth under natural field condition.

Fig. 4.5: Changes in the root dry weight with time in common buckwheat (*Fagopyrum esculentum* Moench) during growth under natural field conditions.
Days after planting:

- IC-18889
- Kulu
- PRB-8901
- IC-13141
- IC-13145
- IC-13411
- BDS-1354

Shoot dry weight (mg):

Days after planting:

- 7
- 19
- 31
- 43
- 55
- 67

Root dry weight (mg):

Days after planting:

- IC-18889
- IC-13141
- IC-13145
- PRB-8901
- Kulu
- BDS-1354
- IC-13411
Fig. 4.6: Changes in the stem dry weight with time in 7 accessions of common buckwheat (*Fagopyrum esculentum* Moench) during growth under natural field condition.

Fig. 4.7: Changes in the leaf dry weight with time in 7 accessions of common buckwheat (*Fagopyrum esculentum* Moench) during growth under natural field condition.
The graphs show the stem dry weight and leaf dry weight of different varieties of plants over 70 days after planting. The x-axis represents days after planting, ranging from 0 to 70. The y-axis for stem dry weight is from 0 to 70 mg, and for leaf dry weight, it is from 0 to 35 mg.

The symbols used to represent the varieties are:
- IC-18889
- IC-13141
- IC-13145
- IC-131411
- PRB-8901
- Kulu
- BDS-1354

The graphs depict the growth patterns of these varieties over time, with IC-18889 and IC-13141 showing slightly higher stem dry weight compared to others, while IC-13145 and IC-131411 show a similar trend. In the leaf dry weight graph, IC-18889 and IC-13141 again show a slight advantage over the other varieties.
Fig 4.8: Changes in the leaf area with time in 7 accessions of common buckwheat (*Fagopyrum esculentum* Moench) during growth under natural field condition.

Fig 4.9: Changes in the leaf area ratio with time in 7 accessions of common buckwheat (*Fagopyrum esculentum* Moench) during growth under natural field condition.
Days after planting
values for RGR showed a progressive increase till 19 days, recording a more than 3 fold increase during the period. After 20th day, however, the relative growth rate of plants started to decline with progressing time. While, the values showed a positive sign between 20 and 43 days, a negative deviation for the relative growth rate was observed between 43 and 67 days. The highest values for RGR were recorded on 19th day. Even though Kulugangri and BDS-1354 showed slightly higher values for RGR during the first week of growth, there were no significant differences in RGR between the accessions at any stage of growth (Table 4.6, Fig. 4.10). The net assimilation rate (NAR) expressed as mg cm$^2$ leaf area d$^{-1}$ for each of the seven accessions increased between 3rd and 19th day of growth after which it started to decline with time. However, the magnitude of increase was more marked between 3rd and 7th day than during the time interval between 7 and 19 days. Positive values for the parameter were, however observed till 43 days after planting. Beyond 43rd day of growth values for NAR showed a negative deviation. While IC-18889, Kulugangri, PRB-8901, IC-13141, IC-13145 and IC-13411 showed a similar pattern and rates of net assimilation of dry matter, the values for NAR for BDS-1354 showed marked differences from those recorded for other accessions. In case of BDS-1354 the NAR showed a longer duration for higher values (Table 4.6, Fig. 4.11).
Fig 4. 10: Changes in the relative growth rate with time in 7 accessions of common buckwheat (*Fagopyrum esculentum* Moench) during growth under natural field conditions.

Fig 4. 11: Changes in the net assimilation rate with time in 7 accessions of common buckwheat (*Fagopyrum esculentum* Moench) during growth under natural field condition.
Discussion

Our results on the chemical composition of buckwheat grains reveals that the various nutritive components of the crop are comparable to those reported for cereals like rice and wheat. Joshi and Parada in their monograph "buckwheat in India" reported that while the grain is variously used as an article of food in different countries the forage of the crop is extensively used as fodder for cattle. Proteins being one of the determinants of nutritive value of any food grain, numerous workers have analysed the protein content in different cultivators of buckwheat. While Pomeranz and Robbins (1972) have found 13.7 percent protein in ten buckwheat cultivars, Kraft and Javornik (1979) have reported a maximum of 11.5 percent protein in thirteen cultivars of buckwheat. Kirilenko (1981) has determined the grain protein content in some varieties of common buckwheat derived from various breeding techniques. He could not find significant differences in protein content in the same variety grown in different years. The range of protein content was from 15 percent to 18 percent. In the present investigation the seven accessions of common buckwheat Fagopyrum esculentum Moench showed an average of 11.5 percent of protein content on grain dry weight basis. There were no significant differences in the protein content in the grain from the seven accessions of buckwheat analysed in our laboratory.
Various investigators in their studies with buckwheat grains, have reported that besides containing a high level of protein the grains also a good source of carbohydrate and fats. Farooq and Tahir (1988) reported that the leaves of F. esculentum, F. Sagittatum, F. tataricum and F. kashmirianum had higher levels of sugars and starch and relatively lower levels of total phenolics than the other species indicating that it is more suitable as a green vegetable. The total carbohydrates content of 70 percent in grains of common buckwheat as observed in the present study was comparable to the amount of 72.9 percent as reported by Joshi and Paroda in their monograph "Buckwheat in India". The lipid and phenolics content of 6 percent and 2.5 percent respectively makes the plant suitable for human consumption.

Even though the buckwheat seeds constitute an important source of dietary proteins and carbohydrates and high biological value (Pomeranz 1973, Pomeranz et al., 1975) it carries an inherent property of less digestibility (Food Policy and food science service FAO 1970, Farrell 1978, Eggum et al., 1981, Thacker et al., 1983). Ikeda and Kusuno (1978) have presented evidence for the occurrence of a trypsin inhibitor in buckwheat seed. There are also some reports indicating the presence of a proteinase inhibitor in buckwheat seed (Laporate and Tremolieres 1962, Pokrousaki et al., 1978 and 1980). The low digestibility has been ascribed to the presence of the trypsin inhibitors in buckwheat grains, by these workers.
Joshi and Paroda (1991) have reported that buckwheat is a short duration crop (3-4 months) and requires moist and cool temperate climate to grow. They have further reported that it is a suitable crop for summer season at higher altitudes. In the present investigation, seeds of Fagopyrum esculentum Moench were sown in the month of July. The crop attained maturity in about 6 weeks time and completed its life cycle in about 9 to 10 weeks. However, because of the indeterminate growth habit the time period of flowering extended from about 4 to 7 weeks after planting (Table 4.7). Among the seven accessions of buckwheat BDS-1354 distinguished itself by possessing determinate growth habit and synchronization of seed maturity. Therefore BDS-1354 can be introduced among the farmers for wider cultivation. The percentage of germination observed with Fagopyrum esculentum Moench was comparable with the 90 percent germination observed by Gohil and Rathar (1981) with different accessions of buckwheat from western Himalayas. Common buckwheat (F. esculentum Moench) is a herbaceous erect annual attaining a height of 60 to 180 cm. (Joshi and Paroda 1991). The stem is hollow, angular with swollen nodes with red, pink and green colour. The leaves are alternate triangular with the blades being hesitate or cordate. The upper leaves were almost sessile, but lower leaves with petiole of considerable length. The in florescence was auxiliary and terminal Cyme with more or less densely clustered flowers (Fig. 4.12).
Table 4.7: Changes in the harvest index, days of appearance of flower, days of appearance of grain and grain weight in common buckwheat (*Fagopyrum esculentum* Moench).

<table>
<thead>
<tr>
<th>Accession</th>
<th>Harvest index (%)</th>
<th>Days of appearance of flower</th>
<th>Days to appearance of first grains</th>
<th>Total grain weight (grams) per plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC-18889</td>
<td>2.006</td>
<td>21</td>
<td>30</td>
<td>2.506</td>
</tr>
<tr>
<td>Kulugangri</td>
<td>2.120</td>
<td>24</td>
<td>30</td>
<td>2.730</td>
</tr>
<tr>
<td>PRB-8901</td>
<td>2.176</td>
<td>22</td>
<td>32</td>
<td>2.800</td>
</tr>
<tr>
<td>IC-13141</td>
<td>2.170</td>
<td>22</td>
<td>29</td>
<td>2.744</td>
</tr>
<tr>
<td>IC-13145</td>
<td>2.220</td>
<td>24</td>
<td>29</td>
<td>2.730</td>
</tr>
<tr>
<td>BDS-1354</td>
<td>2.600</td>
<td>22</td>
<td>30</td>
<td>3.220</td>
</tr>
<tr>
<td>IC-13411</td>
<td>2.080</td>
<td>24</td>
<td>30</td>
<td>2.548</td>
</tr>
</tbody>
</table>
Fig 4. 12 : The plants of 7 accessions of common buckwheat 
(Fagopyrum esculentum Moench) grown in the 
botanical garden of Botany Department of North- 
Eastern Hill University Shillong : A - 7 th day 
after planting ; B - 19th day after planting ; C- 
43rd day after planting.
Joshi and Faroda (1991) have reported 408 accessions of buckwheat in their monograph. Buckwheat Catalogue reported by Joshi and Faroda was prepared by using; plant height, number of branches, number of internodes, colour of stem, number of leaves, petiole length, colour of petiole, length of the leaf, leaf breadth, blade shape, leaf colour at maturity, leaf margin colour, flowering, flower colour, maturity, length of cyme, seeds per cluster, seed colour and seed shape as the descriptors. Taking the above mentioned descriptors as the reference the seven accessions of buckwheat as analysed by us fall under a single category except minor fluctuations in their growth pattern. An analysis of the polygonal diagram in which variables such as dry weight of stem, shoot, leaf, root and leaf area, for the seven accessions at various stages of growth, have been combined into one figure (Fig. 4.13), reveals that the seven accessions did not differ from each other markedly in their growth characters. However, scanning electronic microscopic observation of seed coat of the seven accessions revealed differences in their seed coat pattern and thickness. Based on the pattern and thickness, the seven accessions could be classified into three groups.

In so far as the kinetics of growth is concerned all the seven accessions showed the same behaviour except minor differences in their growth curves. When tested for significance at 5 percent probability, the differences however, proved to be insignificant. The results of dry
Fig 4. 13: Polygonal diagram representing variations with time in the Stem dry weight (1) Total shoot dry weight (2) Total leaf dry weight (3) Total leaf area (4) and Total root dry weight (5) in 7 accessions of common buckwheat (Fagopyrum esculentum MOench)
matter accumulation, revealed by dry weight data of shoot, stem and root, separately, showed that the plants achieved a maximum rate of dry matter accumulation in about three weeks after planting. However, a declining trend was observable after 40th day after planting. This declining trend could be attributed to dry matter loss from these region of the plant during later stage of growth. While people differ in their views on the fate of the carbohydrate and dry weight lost from the stems, it is generally accepted that during later stage of growth there is a shift in the sink from stem/leaves to the grains. The loss in dry weight has also been reported to be due to actual transportation of dry matter from shoot to the grains during later stage of development. The estimate varying from 2.7 percent of grain yield in wheat (Rawson and Evans 1971) to 70 percent in barley (Gallagher, et al., 1975). It seems probable that there are differences between species, and between genotypes of a species, in the amounts of stem losses which can occur and in the extent to which substances lost are translocated to the grains. Austin et al. (1977) have reported that the dry weight loss from internodes of the stems of six genotypes of wheat as 172 gm cm⁻². They have viewed the loss of materials from stem as a reflection of the balance between the demands exerted by the grains and the supply from the assimilatory organs.

In all the seven accessions of Fagopyrum esculentum Moench the leaf area (cm²) reached its maximum on 43rd day. However, LAᵡ in all the seven accessions reached its peak in
between 7th and 19th day after planting. In the present study direct relationship was observed between leaf area and dry matter accumulation. The increase in dry weight of the shoot corresponded with the changes in the total leaf area of the plant. Leaves being the source of photosynthates, their contribution towards the dry matter accumulation naturally has a significant role. However, opinions on the significance of LA as well as LAR as a growth index in the conventional growth analysis vary.

Watson (1952, 1963) has laid much emphasis on leaf area as an index of growth. According to him, leaf area is a better determinant of crop growth, mainly because, the photosynthetic capacity of the crops depends on leaf area which in turn responsible for dry matter production. Intervarital difference in CGR have been found almost invariably to be positively related to leaf area of the various varieties of pea (Mahon, 1982), wheat (Rewson et al., 1983) and perennial rye (Rhoden, 1972). Correlation between leaf growth and tuber growth in potato have been described by Humphries and Dyson (1967). They found that connection between leaf growth and tuber growth in potato. They found that a growth inhibitor which slowed leaf growth hastened tuber growth for a few weeks. This result suggest that supply of photosynthate controls dry matter accumulation in the potato tubers. However, in the view of Jalliffe et al., (1990) leaf area ratio was the least interesting factor in growth analysis. They have been tempted to make such a suggestion because leaf
area ratio was not strongly affected by population density treatments. Therefore they turned their attention towards soil resources; and suggested that the competition for soil nutrients and/or oxygen may have been the main source of interference during crop growth. In the present investigation though attention was not paid on the interference of soil nutrients and oxygen on growth, all the seven accessions tested were cultured in the same field with similar environmental and edaphic factors.

The NAR for the seven accessions, increased up to 19 days after which it showed a rapid decrease between 19th day and 31st day. Net assimilation rate is the net difference between the amount of dry matter assimilated and respired. According to Shivakumar and Shaw (1978) important in the calculation of NAR by classical methods is the assumption that dry weight is linearly related to leaf area. In their observation with soyabean, they found that there was a linear relationship between leaf area and dry matter accumulation. They further suggest that NAR, like RGR has photosynthetic and respiratory components and the relative importance of respiration increases with plant age. Kollar et al., (1970) has interpreted, the increase in the NAR with progressing time as a response of the photosynthetic apparatus to an increased demand for assimilates. The decline in the NAR after 19 days, as observed in the present study could be attributed to either/or (a) diversion of dry matter towards grains; (b) a lower photosynthetic activity in lower
levels due to mutual shading and (c) increase in the respiratory activity during later stage of growth.

The plants of common buckwheat showed a maximum RGR value of 0.16 mg mg dry weight\(^{-1}\)d\(^{-1}\) and a maximum NAR value of 0.6 mg cm\(^2\) leaf area\(^{-1}\)d\(^{-1}\). These values compare well with the rates of 0.167 and 0.445 for RGR and NAR respectively reported by Blackman and Wilson (1950) in case of *Fagopyrum esculentum* Moench. A large number of workers have reported that relative growth rate change with time (e.g. Blackman, 1961; Eagles, 1969; Evans, 1972). Hunt and Burnett (1973) showed that it only changed slightly over a period of eight weeks in plants of *Lolium perenne*. Unit shoot root resembles unit leaf rate except that the increase in the total weight of the plant is calculated relative to the weight of the shoot rather than leaf area. Unit leaf rate has been reported by a number of workers to show no significant trends with time during the vegetative phase of growth (Heath, 1937; Hammond and Kirkham, 1949; Blackman and Wilson, 1951). Other workers have reported a decline in unit leaf rate with age (Ballard and Petrie, 1936; Eagles, 1971).

Blackman and Wilson (1950) in their comparative studies with *H. annus* and *F. esculentum*, have correlated relative growth rate with light intensity. They found that the maximum relative growth rate was attained by *Fagopyrum esculentum* at higher intensity of light and the magnitude of relative growth rate at any light intensity is dependent on
the net assimilation rate and the leaf area ratio. However, the result obtained from their data showed that higher leaf area ratio of buckwheat more than offset any difference in the assimilation rates in determining the greater relative growth rate of *F. esculentum*.

The low yield of *F. esculentum* Moench grown in the Botany Department field of NEHU could be attributed to climatic and edaphic factors prevailed on the particular period of plant growth of the region. Veremichik (1972) and Gubbels (1978) found that the yield of common buckwheat increased with high soil moisture. Ruszkowski and Zebrowski (1982) have reported that, in the same climatic conditions the productivity of buckwheat is higher on heavier soil than on lighter soil. Krotov (1963) reported that flowering at temperatures above 30°C is accompanied by desiccation of fruit and lowering of yield. Since the temperature in Shillong is on an average lower than 30°C, the possibility of desiccation of fruits due to high temperature can be ruled out. However, lighter soil, less moisture content, late spring and early fall frosts and shading of the field could be the causative factors for low yield.

The present investigation deals with the importance prospects and limitations which are associated with the classification and cultivation of seven accessions of *Fagopyrum esculentum* Moench in the North-Eastern regions. The results of the present investigation clearly reveals that
the criteria used for the classification of accessions are arbitrary and some more physiological features should be taken into consideration for the same purpose. Even though, the seven accessions differ from each other morphologically as supported by SEM photographs of seed coat morphology, they show similar values in their nutritive content and growth pattern.