OBSERVATIONS

Experiment No. 1A (Germination sheet) - Laboratory data:

Weight of 100 large seeds is equivalent to 4.008 g, while that of small is 2.288 g. Percentage of germination is more or less same. Untreated controls large (LC), small (SC) gave 100% while pretreatments with distilled water - large (LDM) resulted in 96% and small (SDM) 98%; large seeds with GA - 0.1 ppm (LG) and small seeds with KIO₃ - 1 ppm (SK) gave 98% germination in both the cases (Table 1).

Root and shoot length increase with the advancement of germination. Total seedling length is slightly more in small seeds compared to the large seeds. GA increases seedling length as compared to large control (LC), while there are no much significant differences in the case of small seeds (Fig. 6).

Fresh weight of the embryo (Fig. 7) increases with the advancement of germination and fresh weight is generally higher in the large seeds. GA is very effective in increasing fresh weight and it is generally higher in the large seeds. GA is very effective in increasing fresh weight while KIO₃ is not very effective. Pretreatment with distilled water of small seeds is not effective, while in large seeds even pretreatment with distilled water leads to increase in fresh
### Table 1

Germination data - wheat cv. N.P. 718

<table>
<thead>
<tr>
<th>Treatments</th>
<th>No. of seeds kept for germination</th>
<th>No. of seeds germinated</th>
<th>% germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>LDW</td>
<td>50</td>
<td>48</td>
<td>96</td>
</tr>
<tr>
<td>LG</td>
<td>50</td>
<td>49</td>
<td>98</td>
</tr>
<tr>
<td>SC</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>SDW</td>
<td>50</td>
<td>49</td>
<td>98</td>
</tr>
<tr>
<td>SK</td>
<td>50</td>
<td>49</td>
<td>98</td>
</tr>
</tbody>
</table>

LC = Large untreated control  
LDW = Large pretreated with distilled water  
LG = Large pretreated with GA  
SC = Small untreated control  
SDW = Small pretreated with distilled water  
SK = Small pretreated with KIN
Table - 1 (Contd.)

Mean values ± standard deviation and standard error of seedling length wheat cv. N.P.718

<table>
<thead>
<tr>
<th>Treatment</th>
<th>24 Root</th>
<th>48 Root</th>
<th>72 Root</th>
<th>96 Root</th>
<th>120 Root</th>
</tr>
</thead>
<tbody>
<tr>
<td>LG</td>
<td>1.1±</td>
<td>1.7±</td>
<td>3.5±</td>
<td>3.8±</td>
<td>3.6±</td>
</tr>
<tr>
<td>SD</td>
<td>0.16</td>
<td>0.31</td>
<td>0.15</td>
<td>0.37</td>
<td>0.37</td>
</tr>
<tr>
<td>SE</td>
<td>0.07</td>
<td>0.14</td>
<td>0.07</td>
<td>0.16</td>
<td>0.16</td>
</tr>
<tr>
<td>LDW</td>
<td>1.0±</td>
<td>1.7±</td>
<td>3.2±</td>
<td>3.8±</td>
<td>3.9±</td>
</tr>
<tr>
<td>SD</td>
<td>0.19</td>
<td>0.57</td>
<td>0.23</td>
<td>0.39</td>
<td>0.31</td>
</tr>
<tr>
<td>SE</td>
<td>0.08</td>
<td>0.25</td>
<td>0.10</td>
<td>0.17</td>
<td>0.13</td>
</tr>
<tr>
<td>LG</td>
<td>1.2±</td>
<td>1.9±</td>
<td>3.7±</td>
<td>4.0±</td>
<td>4.2±</td>
</tr>
<tr>
<td>SD</td>
<td>0.2</td>
<td>0.38</td>
<td>0.38</td>
<td>0.43</td>
<td>0.58</td>
</tr>
<tr>
<td>SE</td>
<td>0.09</td>
<td>0.17</td>
<td>0.17</td>
<td>0.19</td>
<td>0.26</td>
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<tr>
<td>SC</td>
<td>1.4±</td>
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<tr>
<td>SD</td>
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<td>0.2</td>
<td>0.31</td>
<td>0.34</td>
</tr>
<tr>
<td>SE</td>
<td>0.13</td>
<td>0.17</td>
<td>0.09</td>
<td>0.14</td>
<td>0.15</td>
</tr>
<tr>
<td>SDW</td>
<td>1.0±</td>
<td>2.1±</td>
<td>3.0±</td>
<td>4.0±</td>
<td>4.0±</td>
</tr>
<tr>
<td>SD</td>
<td>0.19</td>
<td>0.16</td>
<td>0.30</td>
<td>0.74</td>
<td>0.55</td>
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<tr>
<td>SE</td>
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<td>0.07</td>
<td>0.13</td>
<td>0.24</td>
<td>0.24</td>
</tr>
<tr>
<td>SK</td>
<td>1.3±</td>
<td>2.0±</td>
<td>3.3±</td>
<td>4.0±</td>
<td>4.2±</td>
</tr>
<tr>
<td>SD</td>
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<td>0.47</td>
<td>0.37</td>
<td>0.38</td>
</tr>
<tr>
<td>SE</td>
<td>0.09</td>
<td>0.07</td>
<td>0.11</td>
<td>0.17</td>
<td>0.17</td>
</tr>
</tbody>
</table>

LC = Large untreated control; LDW = Large pretreated with distilled water; LG = Large pretreated with GA; SC = Small untreated control; SDW = Small pretreated with distilled water; SD = Small pretreated with NaN
weight. Dry weight of the embryo is likewise higher in the larger seeds as compared to small ones. GA helps in more dry matter production of the embryo axis. Distilled water presoaking is also beneficial while KIN presoaking is slightly beneficial whereas distilled water is not very effective. Fresh weight of the endosperm shows a decline with the advancement of germination. Fresh weight of the endosperm is on the whole higher in larger seeds at every given stage of germination as compared to small seeds. Effect of hormones (GA and KIN) is comparable with the other seeds. While the endosperm dry weight decreases with the increase of germination. Large seeds show higher levels of dry matter throughout the period of germination. There is less dry matter in the case of LG indicating better mobilization as a result of GA. KIN influence is not very different (Fig. 7).

Catalase - activity is quite high initially and especially it is higher in the embryo axis during the early stages of germination. Catalase is generally higher or equal in small seeds as compared to large seeds. Similarly one notices higher levels of catalase in the endosperm of small seeds during the later stages of germination (Fig. 8).

Peroxidase activity (Fig. 8) increases with the advancement of germination in embryo axis and levels are manifold higher in the embryo axis as compared to endosperm. Levels are slightly higher in small seeds during the initial stages of
The diagram illustrates the changes in catalase activity (ml O₂ evolved/minute/mg protein) over time (0 to 120 hours) for different wheat endosperm samples. The x-axis represents germination hours ranging from 0 to 120, and the y-axis represents catalase activity from 0 to 120.

Key points:
- **Catalase Activity**: The catalysts for catalase activity are indicated for different samples labeled as SEED, EMBRYO, and ENDOSPERM.
- ** Peroxidase Activity**: The peroxidase activity is shown using different symbols and is measured in O.D. 420 nm/2'/mg protein.
- **Amylase Activity**: The amylase activity is measured in mg starch hydrolysed/5'/mg protein.

The graph shows a decrease in catalase activity over time for all samples, with a peak at around 24 hours. Peroxidase activity remains relatively constant, while amylase activity shows a significant increase over time, particularly in the endosperm samples.
germination, but these differences are wiped out during the course of germination, while in the endosperm one generally notices higher levels of peroxidase.

Amylase activity (Fig. 8) is appreciably higher in the small seeds in their embryo axis. It is very interesting to note that starch contents are very low in the embryo axis, but amylase activity is quite high initially. This activity increases with the advancement of germination and it is generally higher during the early stages in small seeds.

Protein - Protein levels are quite higher at 24 and 48 hours in embryo axis. Protein level decreases with the advancement of germination in embryo axis in both the cases. In endosperm protein levels are quite higher at 48 and 72 hours. Protein level is higher in large seeds as compared to small seeds at all stages (Fig. 9).

RNA (Fig. 9) is very high initially in the embryo axis followed by decline. Contents are either equal or slightly higher in the small seeds. RNA content decreases after 48 hours in the endosperm of both the types of seeds.

DNA content (Fig. 9) increases up to 48 hours in the embryo axis both in small and large seeds. Generally DNA content is higher in the embryo axis of small seeds. DNA in the endosperm shows active turnover and one finds net synthesis of DNA at 120 hours. Small seeds generally show higher DNA. Generally DNA is higher in the embryo axis than endosperm.
WHEAT CV. N.P. 718
ENDOSPERM

REDUCING SUGARS - mg/g dry wt
WHEAT CV. N.R 718
ENDOSPERM

NON REDUCING SUGARS
TOTAL SUGARS - g/dry wt.

GERMINATION - HOURS

FIG. 10 24 48 72 96 120

SEED

EMBRYO

REDUCING SUGARS - mg/g dry wt

LARGE CONTROL (LC)
SMALL CONTROL (SC)
Total sugars (Fig. 10) are generally higher or equal in small seeds when compared with the large seeds. Contents increase up to 96 hours followed by a decline in the embryo axis, while in the endosperm content increases up to 96 hours. Total sugars are generally higher in the endosperm of large seeds. Reducing sugars (Fig. 10) increase up to 72 hours in the embryo axis of both the seed sizes. Contents tend to be slightly higher in embryo axis of small seeds, while in the endosperm one notices a fluctuating trend and contents are always higher in large seeds. Trend of the non-reducing sugars is rhythmic one in the embryo axis, while it increases up to 96 hours in the endosperm. Contents are generally higher in the large seeds especially in the embryo axis (Fig. 10).
Weight of 100 large seeds is equivalent to 3.490 g while that of small is 2.587 g. Large seeds show slightly higher percentage of germination and there is no effect of GA and KIN on the final germination (Table 2).

GA and KIN generally increase root length during the early stages of germination. Small seeds grow faster and total length of seedling is generally higher in small controls (SC). Distilled water and KIN slightly reduce the final seedling length while seedling length of large seeds is significantly lesser than the small seeds. GA enhances seedling growth. Finally at 120 hours of germination GA increases growth comparable only with small controls, though it is slightly lower. Small and large seeds produce longer roots. Distilled water, GA and KIN increase length of hypocotyl. Though the length of small seeds is higher than compared with the large seeds. Length of the epicotyl is slightly increased by GA only (Fig. 11).

Fresh weight of the embryo axis increase with the advancement of germination. Fresh weight is generally higher in large seeds. GA exhibits more fresh weight; even DW is quite effective in both the cases. KIN is effective when compared with the small controls (SC) (Fig. 12).

Dry matter (Fig. 12) of embryo axis increases with the advancement of germination and seed size and hormonal effects.
Table - 2

Germination data - *Vigna mungo* cv. *S-g*

<table>
<thead>
<tr>
<th>Treatments</th>
<th>No. of seeds kept for germination</th>
<th>No. of seeds germinated</th>
<th>% germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>LDW</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>LG</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>SC</td>
<td>50</td>
<td>49</td>
<td>98</td>
</tr>
<tr>
<td>SDW</td>
<td>50</td>
<td>48</td>
<td>96</td>
</tr>
<tr>
<td>SK</td>
<td>50</td>
<td>49</td>
<td>98</td>
</tr>
</tbody>
</table>

LG = Large untreated control
LDW = Large pretreated with distilled water
LG = Large pretreated with GA
SC = Small untreated control
SDW = Small pretreated with distilled water
SK = Small pretreated with KIN
SD = Standard deviation
SE = Standard error
### Table 2 (Contd.)

Mean values ± standard deviation and standard error of seedling length of mung cv. S-8

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Length</th>
<th>24h</th>
<th>48h</th>
<th>72h</th>
<th>96h</th>
<th>120h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large untreated control (LC)</td>
<td>1.2 ± 0.2</td>
<td>3.0 ± 0.4</td>
<td>5.2 ± 0.4</td>
<td>7.8 ± 0.4</td>
<td>10.0 ± 0.4</td>
<td>12.0 ± 0.4</td>
</tr>
<tr>
<td>Large pretreated with distilled water (LDW)</td>
<td>1.8 ± 0.2</td>
<td>3.3 ± 0.4</td>
<td>5.8 ± 0.4</td>
<td>6.3 ± 0.4</td>
<td>7.0 ± 0.4</td>
<td>8.7 ± 0.4</td>
</tr>
<tr>
<td>Large untreated control (LG)</td>
<td>3.4 ± 0.2</td>
<td>3.8 ± 0.4</td>
<td>5.4 ± 0.4</td>
<td>7.7 ± 0.4</td>
<td>8.7 ± 0.4</td>
<td>9.3 ± 0.4</td>
</tr>
<tr>
<td>Small untreated control (SC)</td>
<td>0.9 ± 0.2</td>
<td>4.2 ± 0.4</td>
<td>9.2 ± 0.4</td>
<td>11.7 ± 0.4</td>
<td>8.3 ± 0.4</td>
<td>5.1 ± 0.4</td>
</tr>
<tr>
<td>Small pretreated with distilled water (SDW)</td>
<td>1.6 ± 0.2</td>
<td>3.0 ± 0.4</td>
<td>5.0 ± 0.4</td>
<td>5.6 ± 0.4</td>
<td>4.0 ± 0.4</td>
<td>9.0 ± 0.4</td>
</tr>
<tr>
<td>Small untreated control (SK)</td>
<td>1.8 ± 0.2</td>
<td>2.9 ± 0.4</td>
<td>7.1 ± 0.4</td>
<td>13.2 ± 0.4</td>
<td>8.6 ± 0.4</td>
<td>6.0 ± 0.4</td>
</tr>
</tbody>
</table>

**Legend:**
- **LC**: Large untreated control
- **LDW**: Large pretreated with distilled water
- **LG**: Large pretreated
- **SC**: Small untreated control
- **SDW**: Small pretreated with distilled water
- **SK**: Small pretreated
- **GA**: γ-glutamyltransferase
- **SD**: Standard deviation
- **SE**: Standard error
MUNG CV S-8

FIG. 11  GERMINATION-HOURS

SEEDLING LENGTH - Cm

EPICOTYL

HYPOCHOTYL

ROOT

1 2 3 4 5 6 1 2 3 4 5 6 1 2 3 4 5 6 1 2 3 4 5 6

24 48 72 96 120
are more or less same. Fresh and dry weights of the cotyledons decreases with the advancement of germination. Fresh weight of the cotyledon is generally at a higher level in the case of large seeds. GA is effective in increasing fresh weight. Same is the case with KIN in small seeds. Distilled water is not very effective. Dry weight of the cotyledons decreases with the advancement of germination and one can find lower dry weight of the cotyledon under the influence of GA indicating faster mobilization. KIN is not that effective.

Catalase activity (Fig. 13) of the seed is quite high initially but the activity increases upto 48 hours and then again at 120 hours in the embryo axis, while in the cotyledons the activity slowly increases upto 120 hours. Activity is slightly higher during the earlier stages in small seeds while at later stages it is taken over by the large seeds in the embryo axis. In the cotyledons higher catalase activity is generally seen in the large seeds.

Peroxidase (Fig. 13) increases upto 48 hours in the embryo axis in both the cases. Peroxidase activity is likewise higher in the small seeds during the early stages of germination, while in the cotyledons the activity slowly increases. Seed size effect is not much pronounced.

Embryo axis (where there is very little starch) shows very high amylase activity (Fig. 13). Activity is generally
higher in the large seeds, while in the cotyledons the trend is reversed. Cotyledons of the small seeds exhibit higher amylase activity throughout. Amylase activity generally increases with the advancement of germination.

Protein (Fig. 14) levels show rhythmic pattern and levels are quite higher at 24, 72 and 96 hours. Protein levels are higher at later stages in the small seeds. Protein level decreases with the advancement of germination in the cotyledons and the levels are generally higher in the large seeds.

RNA content (Fig. 14) increases up to 72 hours in large seeds and 96 hours in small seeds in the embryo axis. During the later stages appreciable amount of RNA is seen in the cotyledons in both the cases. Net synthesis of RNA can also be traced at 120 hours.

In embryo axis DNA content (Fig. 14) increases up to 48 hours followed by decline. Contents are slightly higher in the small seeds during the earlier stages. In the cotyledons also the DNA levels increase up to 48 hours followed by decline. One can also notice net synthesis of DNA at 120 hours.

Total sugars (Fig. 15) show rhythmic pattern showing higher values at 24, 72 and 120 hours in the embryo axis in both the seeds. Level of total sugars is generally higher in the large seeds during the early stages while small seeds takeover during the later stages of germination. Total sugars
FIG. 15 GERMINATION - HOURS

MUNG CV S-8
COTYLEDON

SEED EMBRYO

REDUCING SUGARS mg/g dry wt.
TOTAL SUGARS mg/g dry wt.
NON REDUCING SUGARS mg/g dry wt.
increase up to 48 hours followed by a decline, again at 120 hours very high levels of total sugars are observed. On the whole one notices higher levels of total sugars in the embryo axis as compared to the cotyledons.

Reducing sugars increase (except 48 hours) up to 72 hours followed by a decline in the embryo axis. Contents are generally higher at 24 and 72 hours in large seeds, while in the cotyledons the trend declines at 48 hours but then increases right up to 120 hours (Fig. 15).

Non-reducing sugars also show rhythmic pattern and contents are generally higher in small seeds while in the cotyledon also one notices active phases of synthesis and degradation and contents are generally higher in the small seeds (Fig. 15).
Experiment No. 1

DISCUSSION

Percentage germination is not affected by GA and KIN as untreated seeds themselves give almost 100% germination (Table 1 and 2). The initial seed lot consists of seeds of very high viability both in wheat and mung.

Root and shoot length increase with advancement of germination both in wheat and mung (Fig. 6 and 11). Total seedling length is slightly more in small seeds both in wheat and mung and GA increases seedling length as compared to large controls in wheat, while GA and KIN generally increase root length initially in mung. KIN is not very effective. In mung, GA increases slightly the length of the epicotyl. It is an interesting finding as Abdul Qahi and Anderson (1973) proved inferiority of small seeded soyabean due to lower rate of respiration, which in turn, was associated with low vigour. Austin and Longden (1967); Saeed (1977); Burris et al. (1977); Gelmond, (1972); Bremer et al. (1973); Verma and Gupta (1975) also had shown superiority of large seeds in producing more vigorous and better plants. However, Dhillon et al. (1976,c) showed that it was proved in many cases that large seeds take more time to emerge as calculated according to Fick's second law of
diffusion. It was further shown by them that small seeds had the highest and the large seeds the lowest emergence capacity even though the differences were not significant. Edward and Hartwig (1971) studied the seedling vigour reported that small seeded isogenic lines had more seedling vigour than the large seeded isogenic lines. On the other hand Johnson and Lendders (1974) concluded that seeds of different size did not exhibit significant differences on emergence in soyabeans.

Woodstock (1969) advocates the use of shoot length as a measure of vigour of seeds. Saxena et al. (1974), Saxena (1978, 1978a), Saxena and Sarula (1973, 1979), Gang (1981) have shown in case of soyabean, maize, gram, wheat, mung and berseem seedling length is generally more in small seeds. Saxena et al. (1974) have suggested that small seeds grew longer like the dark grown seedlings under the influence of GA while large seeds showed kinetin type of growth comparable to light grown growth (see: Laloraya, 1970). It appears to be further substantiated that GA could not significantly increase seedling growth in small seeds over the untreated controls possibly because of optimal utilization endogenous gibberellins for enhanced seedling length. This point was confirmed in another way when small seeds were presoaked in KI6 and large seeds with GA and one can notice that these exogenous hormones could modify seedling length to great extent. The small seeds
shown higher activity of hydrolytic enzymes as compared to large seeds (Saxena et al., 1974). It means that small seeds utilize their reserves faster and it also confirms indirectly once more the viewpoint that GA's dominate small seeds and once reserve nutrients are exhausted, the seedlings may not grow well. On the other hand, if small seeds are sown in the field, they show earlier emergence and reserves do not become limiting factors as soil supports this aspect in these seeds and thus they grow well and catch up and sometimes even surpass large seeds in terms of growth and final yields (Ldje and Burris, 1971; Singh et al., 1972; Edward and Hartwig, 1970; Dhillon, 1973; Dhillon and Kler, 1976). Lang (1965) also stressed the importance of reserve nutrients as well as environmental conditions influencing the accumulation of reserve nutrients as these have potentialities for influencing seedling vigour in the following generation.

Ihseng (1976) showed that protein and oil contents of the cotyledons and seed coats decreased with decreasing seed size. Demirlicakmak et al. (1963), Kaufmann and Guiterd (1967) and Boyd et al. (1977) showed a positive correlations among protein content and vigour and grain yields in barley. This was also supported by Dhillon et al. (1976,b) for sunflower.

If the problem of size is examined more closely, intra-specific seed size may imply differences in weight and/or in
degree of differentiation. If differences in seed size involve differences only in weight and volume but not in stage of development, then relative growth rates are often equal, although absolute rates vary with differences in initial capital (Black, 1957; Rorison, 1961). In optimum competitive situations, individuals from large seeds have therefore a better chance of survival than those from small seeds. If differences in seed size involve varying degrees of differentiation and maturity this may lead not only to different initial growth rates, but also to differences in rate and time of germination and these may blur experimental responses to a prescribed range of conditions (e.g. nutrients) unless taken into account. It is agricultural practice to harvest seeds at one time when the majority are mature but of various weights. The smallest seeds whose embryos are least likely to be completely differentiated are to be discarded. Under natural conditions all seeds do not necessarily leave the parent plant at once. Any process which ensures departure only at maturity has advantages. There is, however, virtually no information in the literature on how long nutrient supply from the parent continues and to what degree competition between seeds in an inflorescence occurs (Rorison, 1973). We shall return to this point later on.
Fresh and dry weight of the embryo axis in wheat (Fig. 7) and mung (Fig. 11) increase with advancement of germination. This is indicative of active growth and increase in fresh weight (hydration of protoplasm) is essential for the activation of preformed enzymes as well as travel of germination agent like GA to the endosperm/cotyledon where de novo synthesis of enzyme is initiated. There is a corresponding decrease in the dry weight of the endosperm/cotyledon in wheat and mung respectively. Fresh weight is generally higher in the large seeds and more so under the influence of GA in both the cases while KIN is not effective (wheat) but effective in mung when compared to small controls. Even presoaking of seeds (large seeds) with distilled water leads to increase in fresh weight. Presoaking (presowing or prehardening) treatments are well known to activate many physiological processes leading to enhanced water uptake and better seedling growth (see: Saxena, 1974, 1979, 1981 and Saxena and Singh, 1980 and 1981, 1981,a). Dry weight of the embryo is like wise higher in large seeds (wheat) but there are no marked differences in mung.

Fresh weight of the endosperm/cotyledons is also higher in large seeds (Fig. 7 and 11) GA and KIII effects are comparable with other seeds (wheat). There is less dry weight in case of LG indicating faster mobilization due to GA (both in wheat and mung) (Fig. 7 and 11). GA and KII increase fresh
weight of the cotyledons as compared to DW and untreated control. These findings are in close agreements with the results of other workers on germination (Ching, 1972; Heydecker, 1973; Mayer and Poljakoff-Mayber, 1975; Reiley and Black, 1978; Khan and Tao, 1978; Saxena, 1981; Saxena and Singh, 1981, 1981a). Another interesting case is the selection of proper plant material and organs. Many a times we study biochemical changes and other physiological parameters in the whole seedling rather different organs (Pollock, 1959) but studies on whole seedling will not reflect the true metabolic manifestations of growth as bulky endosperm/cotyledon marks the real metabolic reflections/status of the tiny embryo axis (hardly 1%) but which is, in fact, associated with the active growth of the seedling as most of the anabolic(synthetic) activities are concentrated in this unit. Endosperm/cotyledon is concerned mainly with the breakdown of reserve nutrients (hydrolysis) and their transport and mobilization to the growing axis (in other words endosperm/cotyledon represent bulk of the catabolic (oxidative) activities for the support of the embryo axis). Thus when one observes different biochemical and physiological parameters in the seedling one fails to get any clear idea. Hence in order to understand the process of germination clearly under the influence of seed size, embryo axis endosperm/cotyledons were separated. Another important point
in understanding biochemical data (especially enzyme activities) is the basis of calculations or expression of data. Calculation of data on fresh or dry weight will not throw much light as in the endosperm/cotyledon the fresh weight may increase with the advancement of germination but without involvement/participation of any active growth as dry weight actually decreases. Increase in fresh weight (moisture) is merely to increase osmotic relations of the system for enzyme activation leading to the hydrolysis of the reserve nutrients. Similarly calculation of the data on dry weight basis is of no meaning as the dry matter in the endosperm/cotyledon (say after 72 hours) is merely the inert material which could not be hydrolysed. Many a times we calculate data on per organ basis this too present the difficulty of true comparison as one organ like embryo axis not comparable to the endosperm/cotyledon in terms of weight and metabolic status in terms of physiological processes. Hence one of the most simple comparable way would be to calculate enzyme activity per mg (unit) protein and metabolite on per dry weight basis.

Catalase activity is considered by many workers (Coleson, 1951; Boca and Onderza, 1953; Verza and Van-Ruystee, 1970) as an index of metabolic activity/status of the system. Catalase activity is quite high initially and especially in the embryo axis in wheat (Fig. 8) and it is higher or equal in
small seeds as compared to large seeds. One can notice higher levels of catalase in the endosperm of small seeds especially at later stages (Fig. 3). In mung also activity, though high initially, increases upto 48 hours and it increases slowly at a lower ebb in the cotyledons right up to 120 hours in mung (Fig. 13). It is higher in the embryos of small seeds during early germination but afterwards embryos of large seeds take over. However it is generally higher in the cotyledons in the large seeds. The maintenance of levels of catalase (oxidative levels) in the endosperm/cotyledon may be necessary for the regulation of active transport and mobilization of the solubilized nutrients as suggested earlier from this laboratory (Chinoy et al. 1972; Saxena et al. 1974; Gosai, 1980; Patel, 1980 and Garg, 1981). Catalase activity can be taken here as a measure of metabolic status of the system and since small seeds grow faster, the catalase activity is also higher in small seeds. The higher initial activity shows the participation of catalase in the germination as major differentiation is also over by 48 hours. Higher catalase activity will mean higher levels of oxygen being made available to the respiratory system. Higher catalase will then mean higher respiration and higher respiration ... is positively correlated with better growth (Bewley and Black, 1978). In wheat (starchy seed) the catalase in the endosperm is higher in small seeds during later stages
of germination while it is generally in the cotyledons of large seeds in mung (proteinous seed). Saxena et al. (1974) and Saxena (1978, 1979) have shown increased levels of catalase in small seeds. The differences may also be due to the calculation of data, as in the our earlier paper we had referred to above data which were calculated on fresh weight basis. In physiological studies much depend on the proper description of the experimental details for the age of the seedling as well as expression of data (as discussed earlier) and thus calculating data on one basis one can support/contradict other's research findings. For a proper and critical valid comparison, data of other laboratories/workers should be converted to comparable basis e.g. Harley (1964) reports effects of GA on catalase on different organs of cucumber seedlings while Galston (1951) records catalase data of plant tissue cultures. Prathapasenan et al. (1969) express catalase activity for the whole seedling of cotton and sorghum. Pollock (1959) has already clarified and warned of misinterpretation of data using whole seedling. Abdul-Baki (1969) has also demonstrated that bulky endosperm/cotyledon marks the activity of the embryo axis and thus one cannot get any idea about the synthetic capabilities of the seedling of one uses whole seedling.

Peroxidase activity (Fig. 8) increases with the advancement of germination in the embryo axis and levels are
manifold higher in the embryo axis as compared to endosperm in wheat (Fig. 8). Levels are slightly higher in small seeds during early germination. Endosperm also shows higher levels of peroxidase. In mung (Fig. 13) it increases up to 48 hours and it is higher in small seeds during early growth. The activity slowly increases in the cotyledons and seed size effects are not much pronounced. Positive correlations between growth and peroxidase activity have been shown various workers (Altman et al. 1966; Chinoy et al. 1972; Paul and Mukherji, 1972; Laloraya, 1973; Saxena, 1973, 1980; Saxena et al. 1973; Garg, 1981). Amylase activity (Fig. 8) is appreciably higher in the embryo axis of small seeds (wheat) while it is higher in the embryos of large seeds of mung (Fig. 13). The activity increases more so, in small seeds in the endosperm (wheat) and cotyledon (mung) with the advancement of germination. It is very interesting to note that there is hardly any starch in the embryo axis of wheat and mung but appreciable amylase activity is noticed. Small seeds exhibit higher amylase activity. This in again in conformity with our earlier findings (Saxena et al. 1974) on increased amylase levels in small seeds and thus small seeds by better mobilization and utilization of their reserves (starch) make available to the growing axis solublized nutrients at a faster rate (which is also supported by decrease in greater dry weight and more so under the influence of CA
and higher catalase and peroxidase activities in small seeds). Protein (Fig. 9) levels are higher during the first 48 hours in wheat followed by a decline. Proteins levels are generally higher in the endosperm of large seeds throughout. In mung (Fig. 14) however levels are higher in small seeds except 48 hours and these decrease with advancement of germination and these are generally higher in large seeds. RNA and DNA are higher initially in the embryo axis of wheat (Fig. 9). Seed size effect is not pronounced rather it is slightly higher in small seeds while RNA decreases after 48 hours (wheat), while DNA shows active turnover and small seeds show higher DNA (wheat) (Fig. 9). In mung (Fig. 14) RNA contents increase up to 72 hours in large and 96 hours in small seeds while DNA is higher only up to 48 hours in embryo and cotyledon in mung. DNA content is slightly higher in small seeds initially. DNA synthesis can be seen at 120 hours. Protein, RNA and DNA levels are either same or slightly higher in embryos of small seeds as compared to large seeds and thus these metabolites are generally higher initially especially up to 48 hours when critical stages of germination are completed. This is in line with one thinking that small seeds exhibit increased metabolic activities. Another interesting point is the net synthesis of RNA and DNA in the endosperm (wheat)/cotyledon (mung), the tissue which is not concerned with active growth. Similar findings were also
reported earlier in the literature (Bewley and Black, 1973). Total sugars and reducing sugars are generally higher or equal in embryo axis of small seeds as compared to large seeds. Contents increase upto 96 hours both in embryo and endosperm of wheat (Fig. 10). Large seeds exhibit more reducing and total sugars. Nonreducing sugars show active turnover and contents are higher in large seeds (wheat) (Fig. 20). In mung (Fig. 15) total sugars exhibit rhythmic patterns and higher seeds initially. Reducing sugars increase upto 72 hours (except 48 hours) and are higher in large seeds. Non-reducing sugars exhibiting fluctuations are generally higher both in embryo and cotyledons of small seeds of mung (Fig. 15).

An active group on seed size under the guidance of Dr. Hartwig (Hartwig, unpublished data) have shown that small seed germinates more rapidly and with less soil moisture than large seed. They have also shown that some varieties have more sugars in the seed coat and with excess moisture after planting, these sugars become available and stimulate growth of phythium. Germination is then low and finally it is opined that one can develop small-seeded lines having excellent seed quality than it is to develop large-seeded types. In the present studies reducing and total sugars are generally more in the embryo axis of wheat. These are utilized at a faster rate in small seeds for enhanced seedling growth.
Reducing and total sugars are generally more in the endosperm of large seeds. This is explainable on two counts, firstly because of initial higher reserves and secondly less translocation. In mung the trend is reversed in the embryo axis, possibly that proteins are main reserves while carbohydrates are secondary. More over sugar metabolism, on the whole, shows active turnover as synthesis and utilization of different fractions shows the direct participation in germination.

On the whole it appears that small seeds are more active metabolically as revealed by the increased levels of various metabolites and enzymic activities, which in turn leads to increased seedling growth and thus small seeds exhibit better vigour during the early germination both in wheat and mung and these findings support the data of other workers (Dhillon and Klev, 1976). Minor differences in their metabolism are related with the initial reserves of the seeds (wheat-starchy and mung-proteineous seed).