CHAPTER 5
DISCUSSION
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DISCUSSION

Normally, the soil in which a plant grows has all the essential elements which influence its growth and development. However, continuous cropping may deplete the soil of its available nutrients. Such soils can not furnish adequate essential nutrients to subsequent crops without their timely application in sufficient quantities. Often a single basal application (or even split application by basal and top dressing) fails in the exploitation of the full genetic potential of a crop due to non-availability of the added nutrients at critical growth stages (Russell, 1950; Anonymous, 1971). This has been repeatedly demonstrated for mustard at Aligarh and elsewhere by Lahiri and De (1971), Naqvi et al. (1977), Saran and De (1979), Parvaiz et al. (1982a), Afridi et al. (1983) and Mohammad et al. (1986a,1987), among others.

The alternative technique of supplementing basal application with foliar sprays of the required nutrients has proved advantageous, particularly under poor soil conditions (Boynton, 1954; Wittwer and Teubner, 1959; Wittwer and Bukovac, 1969; De. 1971; Afridi and Wasiuddin, 1979; Kannan, 1986). However, this technique has not received due attention in our country and remains to be fully exploited.
This was the motivation behind the field experiments undertaken by the present author, as no work has been done so far on the efficacy of supplemental foliar application of nutrients on the newly introduced varieties of mustard. Of the three high yielding cultivars selected for this study, two (namely Rohini and Vaibhav) belong to this category. The third (Varuna), on which some research has been done (mainly in our laboratory), was included for comparison. The criteria selected to assess the response of the crop included: (i) growth characteristics, (ii) leaf N, P and K contents and (iii) yield and (iv) quality characteristics. For the sake of convenience, the salient data of the first two trials (Experiments 1 and 2), laid out according to a factorial randomised block design, and those of the last three (Experiment 3, 4 and 5), conducted according to a simple randomised block design, are discussed separately under the above headings (i-iv).

5.1 EXPERIMENTS 1 AND 2

In these two field trials, the response of Rohini, Vaibhav and Varuna to nutrients, particularly nitrogen, applied basally or partly basally and partly by supplemental top dressing/foliar spray, was investigated.

The data of Experiment 1 (Tables 7-19) established clearly that, of the two sets of treatments (a) and (b), the
latter, comprising a total of 90 kg N and 30 kg P/ha, proved superior on the basis of growth and yield response as well as the capacity to accumulate N, P and K. Of the various treatments given, $B_{N60P30} + F_{N30}$ resulted in maximum response, which surpassed not only the control ($B_{N60P30} + F_{W}$) but also supplemental top dressing ($B_{N60P30} + T_{N30}$), although the same total amount of nitrogen and phosphorus was applied in all three treatments, thus confirming the earlier data on the efficacy of foliar nitrogen for mustard published from this laboratory Afridi et al. 1983. Mohammadet al. 1987.

The aim of Experiment 2 was to determine whether or not supplemental spray of less than 30 kg N/ha would elicit the same or better response in Rohini, Vaibhav and Varuna (Table 3). If so, fertiliser economy could be effected without sacrificing growth and yield. The data not only confirmed once again the superiority of supplemental foliar spray of nitrogen over basal application (control, i.e. $B_{N90P30} + F_{W}$) but also established $B_{N60P30} + F_{N20}$ as the optimal dose (Tables 23-38).

The salient significant data of Experiments 1 and 2 are discussed below:

5.1.1 Growth characteristics

The growth of a plant organ is the manifestation of cell division, cell expansion and differentiation. These
process depend among other factors on the proper supply of mineral nutrients, growth substances and the genetic makeup of the plants (Sokolov, 1959; Moorby and Besford, 1983).

The data of Experiment 1, presented in Tables 7-10, reveal that the full dose \((B_{N90P30} + F_w')\), applied at sowing in Set (b), brought about a much better growth response, culminating, on an average, in 39.5 per cent higher dry matter production than the lower dose \((B_{N60P20} + F_w')\) of Set (a), at 80 days sampling (Table 10).

More strikingly, the results also establish that various growth parameters, e.g. shoot length (Table 7), leaf number (Table 8) and leaf area (Table 9), were favourably affected by supplementing the initial (sub-optimal) basal doses \((B_{N40P20} \text{ or } B_{N60P30})\) with application of nitrogen through top dressing \((T_{N20} \text{ or } T_{N30})\)/foliar spray \((F_{N20} \text{ or } F_{N30})\) in two equal splits (at 50 and 70 days after sowing). This culminated in about 27.0 per cent increase in dry weight (noted at 80 days) in \(B_{N40P20} + F_{N20}\) and 11.5 per cent, in \(B_{N40P20} + T_{N20}\) over their control \((B_{N60P20} + F_w')\) and in about 17.0 per cent higher dry weight in Treatments \(B_{N60P30} + T_{N30}\) and \(B_{N60P30} + F_{N30}\) (which were at par in their effect) over \(B_{N90P30} + F_w'\) (Table 10).

Confirmation of the positive contribution of significantly enhanced shoot length, leaf number and leaf
area towards more dry matter production is provided by correlation studies (Table 51) wherein significant positive associations \( r = +0.924, +0.953 \) and \(+0.933\) respectively) were noted.

It is likely that the starter sub-optimal doses (applied at sowing) in both Set (a) i.e. \( B_{N40P20} \) and (b) i.e. \( B_{N60P30} \) furnished adequate initial amount of nitrogen that sufficed for early growth of plants (upto 50 days). Supplemental application of 10 or 15 kg N/ha at 50 days and another 10 or 15 kg N/ha at 70 days through foliar/top application boosted the growth processes further (Tables 7-10). It is noteworthy that these two stages are critical in the life of mustard because vigorous growth and branching occur at the first and flowering, at the second. As these physiological activities are highly demanding with respect to nutrients (particularly nitrogen), the plants grown with suboptimal starter doses of nitrogen would have suffered severely but for the timely supplemental application of nitrogen.

The data also confirm the desirability of split application of nitrogen for good growth of mustard as is the practice in cereals. This is clearly borne out by the inferior growth response to single basal application of full recommended dose in Set (b) (Treatment \( B_{N90P30+F_W} \)) compared
with $B_{N60P30+T_{N30}}/F_{N30}$. The same picture was repeated when the effect of the lower basal dose in Set (a), i.e. $B_{N60P20+F_W}$ was compared with that of its starter dose ($B_{N40P20}$) supplemented with $T_{N20}/F_{N20}$. Evidently, some loss of basal nitrogen takes place from the soil as the crop grows (Anonymous, 1971) and this requires to be replenished adequately at crucial growth stages to ensure continued vigorous growth and development.

This observation has been repeatedly confirmed during the present study. For example, in Experiment 2, all growth parameters of mustard were more favourably affected by split application of nitrogen than by the one-time basal application. Even those treatments in which a little lower quantity of total nitrogen (70 or 80 kg N/ha) was supplied partly through the soil and partly by spray ($B_{N60P30+F_N10}$ and $B_{N60P30+F_N20}$) proved superior to $B_{N90P30+F_W}$, applied basally. Comparing the treatments comprising equivalent quantity (90 kg N/ha) of nitrogen, $B_{N60P30+F_N30}$ produced 19.24 per cent more dry matter (Table 26) than the control ($B_{N90P30+F_W}$) as a result of better response of the other growth contributing parameters (Tables 23-25).

A more noteworthy observation made in this trial, however, was the superiority of Treatment $B_{N60P30+F_N20}$ (comprising only 80 kg total N/ha) which gave significant
maximum values for all growth characteristics (Table 23-26). It even surpassed the performance of the treatment with higher total nitrogen \( \left( B_{N60P30+F_N30} \right) \) and thus proved optimal for the growth of the crop. Let us take the example of dry weight again, as it reflects the cumulative effect of the other growth characteristics. Thus, \( B_{N60P30+F_N20} \), supplying a total of only 80 kg N/ha, produced 28.8 per cent more dry matter than the control \( B_{N90P30+F_P} \) and even 8.0 per cent more than \( B_{N60P30+F_N30} \).

That the growth characteristics did contribute to the production of dry matter in this trial also, is borne out by Table 51 which reveals that dry weight was positively correlated with the other three parameters, namely shoot length \( (r=+0.897) \), leaf number \( (r=+0.955) \) and leaf area \( (r=+0.823) \).

5.1.2 Leaf N, P and K contents

Data regarding the growth response of mustard to basal and split application of nitrogen in Experiments 1 and 2 discussed above are further supported by leaf NPK analysis undertaken at 80 days (Tables 11-13 and 27-29). For example, in Experiment 1, considering both sets of treatments (Set a and b), the contents of leaf nitrogen (Table 11), phosphorus (Table 12) and potassium (Table 13) were found to be maximum in split applications. Thus, in set (a), \( B_{N40P20+F_N20} \)
Table 51: Correlation of growth parameters with dry weight (Experiments 1-5)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Experiment 3</th>
<th>Experiment 4 &amp; 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoot length</td>
<td>0.924*</td>
<td>0.897*</td>
<td>0.915*</td>
<td>0.981*</td>
</tr>
<tr>
<td>Leaf number</td>
<td>0.953*</td>
<td>0.955*</td>
<td>0.964*</td>
<td>0.992*</td>
</tr>
<tr>
<td>Leaf area</td>
<td>0.933*</td>
<td>0.823*</td>
<td>0.954*</td>
<td>0.972*</td>
</tr>
</tbody>
</table>

*Significant at 5%
resulted in 15.5 per cent higher leaf-N, 12.8 per cent higher leaf-P and 5.7 per cent higher leaf-K content than $B_{N60P20}+F_W$. Similarly, in Set (b), leaf-N was 13.8 per cent, leaf-P, 9.1 per cent and leaf-K, 5.6 per cent higher in the Treatment $B_{N60P30}+F_{N30}$ than in the basal nitrogen application (Treatment $B_{N90P30}+F_W$).

Similarly, in Experiment 2, leaf nitrogen (Table 27), phosphorus (Table 28) and potassium (Table 29) contents were found to be higher due to split application (foliar treatments) than basal application (control). The maximum NPK contents, like growth characteristics, were noted in $B_{N60P30}+F_{N20}$. This treatment resulted in 10.6 per cent higher leaf-N, 8.1 per cent higher leaf-P and 9.0 per cent higher leaf-K content than $B_{N90P30}+F_W$, which received the full nitrogen dose basally.

The reason for the superior performance of split application of nitrogen is not far to seek. The ready availability of the nutrient assured not only its own uptake and accumulation but also those of phosphorus and potassium at the two critical stages (50 and 70 days) in the life of the crop at which supplemental nitrogen was applied. The author has failed in his attempt to trace similar findings of other workers on mustard. He, therefore, feels justified to claim priority for this observation.
Lastly, the practical use of these data on the response of the crop to supplemental nitrogen application with regard to dry weight per plant and leaf nutrient content may be mentioned. These parameters can be utilised as a reliable tool to diagnose "hidden hunger" in mustard before flowering and fruit set. The deficiency, if detected, could then be corrected by taking timely ameliorative measures to ensure good harvest through foliar spray of nitrogen. In case facilities for spray are not available to the farmer, even top dressing of nitrogen, though slightly less effective (Tables 10-13), could be employed for this purpose.

5.1.3 Yield characteristics

Yield is the final manifestation of several complex morphological and physiological traits of a crop. According to Yoshida (1972) "high yield of any crop can be achieved only when a proper combination of variety, environment and agronomic practices is obtained. Understanding the physiological processes involved in seed production such as vegetative growth, formation of storage organs and seed filling helps determine the best combinations of the above three factors".

The data of Experiments 1 and 2 (Tables 14-17 and 30-33) reveal that most of the yield characteristics,
including seed yield, responded positively to the treatments. Thus, in the first trial, all yield attributes had a much higher value in Set (b) than in Set (a). For example, seed yield was 24 per cent more in the higher basal treatment $B_{N90P30} + F_w$ than in the lower basal Treatment $B_{N60P20} + F_w$. Similar results showing better response to increasing doses of basal nitrogen have been published on high yielding varieties of mustard by Singh et al. (1978a), Antil et al. (1986), Malavia et al. (1988), Khan et al. (1990), Rana et al. (1991), Katole and Sharma (1992), Chaudhary et al. (1992), Mohan and Sharma (1992) and Tomer et al. (1992a).

Considering the effect of split versus basal application of nitrogen on yield characteristics in Experiments 1 and 2, highly convincing data are provided by Tables 14-17 and 30-33 that clearly establish the superiority of split application. This is not unexpected as these traits are dependent upon vegetative growth and availability and proper balance of mineral nutrient (Marschner, 1986). We have already noted (pp 127-132) that growth and leaf NPK contents were maximum in the treatments containing supplemental nitrogen. Thus, in Experiment 1, the enhanced early growth and nutrient uptake, together with significant positive effect on yield attributes, in both Set (a) and (b) taken separately, showed that supplemental
nitrogen application given with minimal starter dose was superior to the application of equal quantity of nitrogen once at sowing. This applies more conspicuously to the data obtained with treatments containing foliar spray. Thus in Set (a), with lower nutrient content, the good effect of \( \text{B}_N\text{40P20} + \text{F}_N\text{20} \) on the morphophysiological attributes contributed to 11.8 per cent higher seed yield than its water-sprayed control \( \text{B}_N\text{60P20} + \text{F}_W \). It is to be noted that \( \text{B}_N\text{40P20} + \text{F}_N\text{20} \) out-yielded the top dressed Treatment \( \text{B}_N\text{40P20} + \text{T}_N\text{20} \) also, by 4.9 per cent. Similarly, in Set (b), \( \text{B}_N\text{60P30} + \text{F}_N\text{30} \) gave 11.1 per cent and 4.1 per cent higher seed yield than \( \text{B}_N\text{90P30} + \text{F}_W \) and \( \text{B}_N\text{60P30} + \text{T}_N\text{30} \) respectively.

Clear-cut confirmation of these findings is provided by the data of Experiment 2. Tables 30-33 show that all yield attributes, including seed yield, were significantly, enhanced by foliar sprays of nitrogen. Thus, the best treatment \( \text{B}_N\text{60P30} + \text{F}_N\text{20} \) gave 15.6 per cent higher seed yield than the basal control sprayed with water \( \text{B}_N\text{90P30} + \text{F}_W \).

It is obvious from the data that the supplemental treatments, interacting favourably with the growth and nutrient status of the crop, helped in proper partitioning of the photosynthates after 70 days and resulted in more pods per plant (Tables 14 and 30) with more seeds per pod (Tables 15 and 31) and higher hecto-litre weight (Tables 16
and 32), which ultimately manifested themselves in enhanced yield (Tables 17 and 33, Fig. 6 and 7), thus broadly satisfying the results of Mohammad et al. (1987) on Varuna.

Further confirmation of the above assumption is provided by the correlation studies (Table 52). It may be noted that seed yield was significantly and positively correlated in both Experiments 1 and 2 with shoot length per plant ($r=+0.951$ and 0.938), leaf number per plant ($r=+0.962$ and $+0.906$), area per leaf ($r=+0.936$ and $+0.905$) and dry weight per plant ($r=+0.657$ and $+0.960$), among the growth characteristics as well as leaf-N, ($r=+0.975$ and $+0.883$), leaf-P ($r=+0.924$ and $+0.634$) and pods per plant ($r=+0.992$ and $+0.985$), seeds per pod ($r=+0.982$ and $+0.972$) and hecto-litre weight ($r=+0.693$ and $+0.782$), among the yield attributes.

Similarly beneficial effect of foliar application of nitrogen on the yield performance of varieties of mustard, other than Rohini and Vaibhav, has been reported by a few workers, (mainly from the author's laboratory). These include De (1971), Parvaiz et al. (1982a), Afridi et al. (1983), Samiullah et al. (1985) Mohammad et al. (1987) and Mohammad (1992).

5.1.4 Oil content and oil yield

(i) Oil content

Contrary to the better effect of the application of full recommended dose of nitrogen on the growth and yield
Figure 6: Effect of selected combinations of soil-applied nitrogen and phosphorus with top-dressed and leaf-applied nitrogen on seed yield (kg/ha) of three varieties of mustard.
Figure 7: Effect of graded levels of supplemental leaf-applied nitrogen on seed yield (kg/ha) of three varieties of mustard.
Table 52: Correlation of various parameters with seed yield (Experiments 1-5)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Experiment 3</th>
<th>Experiment 4 &amp; 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoot length</td>
<td>0.951*</td>
<td>0.938*</td>
<td>0.971*</td>
<td>0.978*</td>
</tr>
<tr>
<td>Leaf number</td>
<td>0.962*</td>
<td>0.906*</td>
<td>0.977*</td>
<td>0.993*</td>
</tr>
<tr>
<td>Leaf area</td>
<td>0.936*</td>
<td>0.905*</td>
<td>0.981*</td>
<td>0.970*</td>
</tr>
<tr>
<td>Dry weight</td>
<td>0.657*</td>
<td>0.960*</td>
<td>0.980*</td>
<td>0.999*</td>
</tr>
<tr>
<td>Nitrogen-content</td>
<td>0.975*</td>
<td>0.883*</td>
<td>0.885*</td>
<td>0.946*</td>
</tr>
<tr>
<td>Phosphorus content</td>
<td>0.924*</td>
<td>0.634*</td>
<td>0.819*</td>
<td>0.871*</td>
</tr>
<tr>
<td>Potassium content</td>
<td>N.S.</td>
<td>0.771*</td>
<td>0.826*</td>
<td>0.965*</td>
</tr>
<tr>
<td>Pods per plant</td>
<td>0.992*</td>
<td>0.985*</td>
<td>0.970*</td>
<td>0.985*</td>
</tr>
<tr>
<td>Seeds per pod</td>
<td>0.982*</td>
<td>0.972*</td>
<td>0.997*</td>
<td>0.992*</td>
</tr>
<tr>
<td>Hecto-litre weight</td>
<td>0.693*</td>
<td>0.782*</td>
<td>0.890*</td>
<td>0.995*</td>
</tr>
</tbody>
</table>

*Significant at 5%
N.S. = Non-significant
characteristics considered above, in Experiment 1, the oil content in Set (b) was found to be slightly lower than that in Set (a) that received the deficient dose (Table 18). The average oil content in Set (b) was 38.7 per cent and that in Set (a), 39.3 per cent.

The results of Experiment 2 are more explicit in this regard. Table 34 clearly shows that supplemental application of only 10 kg N/ha ($B_{N60P30} + F_{N10}$) through foliar spray resulted in significantly higher oil content than that of 20 or 30 kg N/ha (Treatments $B_{N60P30} + F_{N20}$ and $B_{N60P30} + F_{N30}$ respectively). The most apparent explanation for this adverse effect of high doses of nitrogen, applied through foliar spray and/or through soil seems to be the preferential utilisation of carbon skeletons, at the time of seed filling, towards protein synthesis rather than oil formation. This is well documented for mustard grown with high foliar and/or basal nitrogen doses (Arora and Bhatia, 1970; Dasgupta and Friend, 1975; Vir and Verma, 1979; Parvaiz et al., 1982a,b; Mohammad et al., 1985; Singh and Rathi, 1985; Khan et al., 1990; Rana et al., 1991; Singh et al., 1991; Mohammad, 1992; Tomer et al., 1992a).

(ii) Oil yield

The depressing effect on oil content noted above notwithstanding, Table 19 clearly shows that higher nitrogen
doses in Set (b) of Experiment 1 conspicuously enhanced the computed values for total oil yield over those obtained for Set (a). Thus, the average oil yield in Set (b) was 22.1 per cent higher than that in Set (a). This is explicitly established by comparing the control of one set with the other. In Set (b), $B_{N90P30} + F_W$ produced 22.5 per cent more oil than $B_{N60P20} + F_W$ of Set (a). Further, taking the effect of the treatments of each set separately into consideration, it is to be noted that, in Set (a), $B_{N40P20} + T_{N20}$ produced 7.2 per cent more oil and $B_{N40P20} + F_{N20}$, 13.5 per cent more oil than their control ($B_{N60P20} + F_W$). Similarly, in Set (b) $B_{N60P30} + T_{N30}$ enhanced oil yield by 7.6 per cent and $B_{N60P30} + F_{N30}$, by 12.1 per cent over $B_{N90P30} + F_W$ (control). This comparison establishes beyond doubt that, considering the effect of equal amount of nitrogen, application of supplemental foliar sprays not only proved more effective than basal application but also out-yielded top dressing in oil productivity (Table 19) in the same manner as it affected seed yield (Table 17) considered earlier.

The superiority of foliar application over soil application with regard to oil yield is brought out more clearly in Table 35 of Experiment 2. Here the effect of the control in which the entire quantity of nitrogen was applied through the soil at sowing ($B_{N90P30} + F_w$) was far inferior
not only to that of the same quantity of nitrogen applied partly as starter dose and partly by spray \((B_{N60P30} + F_{N30})\) but also to that of \(B_{N60P30} + F_{N10}\) as well as \(B_{N60P30} + F_{N20}\) in which less than the recommended total quantity of nitrogen was applied. In fact, as in the case of seed yield (Table 33), \(B_{N60P30} + F_{N20}\) comprising a total of 80 kg N/ha, proved optimum for seed and oil yields in this experiment, thus establishing a saving of 10 kg N/ha.

The explanation for these observations is not far to seek. The overall improvement in growth (Tables 7-13 and 23-26) and yield attributes (Tables 14-16 and 30-32) due to availability of sufficient nitrogen when it was required most culminated in superior seed yields (Tables 17 and 33), which more than compensated for the lower oil content (Tables 18 and 34) to give higher oil yields in Experiment 1 and 2.

### 5.1.5 Quality characteristics

In Experiment 1, the acid value (Table 20) of the oil (which denotes its keeping quality) was, slightly more in Set (b) than in Set (a). This implies that the application of higher amount of nitrogen in the former treatment and the higher content of this nutrient in leaves (Table 11) might be the reason for the higher acid value. The data presented in Table 36 (Experiment 2) further confirm that application of higher nitrogen doses
increased the acid value more than the lower dose ($B_{N60P30 + F_{N10}}$). Similar results have been published by other workers on basal application of nitrogen to mustard (Bishnoi and Singh, 1979b; Mohammad et al., 1985). It may be admitted that high acid values are an indication of poor keeping quality of oil. However, it may be emphasised that: (i) the acid values for high nitrogen treatments in Set (b), that promoted seed and oil yields most, were not alarmingly high and (ii) the demand of mustard oil in our country is so large that it is hardly stored for a few months, if at all.

In contrast to acid value, iodine value, (which denotes the presence of unsaturated fatty acids in the oil) was lower in Set (b) than in Set (a) in Experiment 1. In fact, the lowest value was noted in Treatment $B_{N60P30 + F_{N30}}$ in both Experiments 1 and 2 (Table 21 and 37). It may be noted that low iodine value is considered better for hydrogenation. A similar decrease in iodine value of mustard oil with increasing doses of nitrogen has been noted by several workers, using basal application (Arora and Bhatia, 1970; Bishnoi and Singh, 1979b; Mohammad et al., 1985).

Saponification value of the oil, determined to know its worth for the soap industry and also denoting digestibility, decreased marginally in high nitrogen treatments (Set b of Experiment 1 and $B_{N60P30 + F_{N30}}$ and
$B_{N60P30} + F_{N20}$ of Experiment 2) compared with low nitrogen treatments e.g. Set (a) of Experiment 1 and Treatment $B_{N60P30} + F_{N10}$ of Experiment 2 (Tables 22 and 38). This observation confirms the findings of Mohammad et al. (1985). However, mustard oil, being in short supply in our country, is not normally used for the manufacture of soaps. Moreover, with regard to digestibility, the difference was so small that the rather undesirable effect on this trait could be ignored in view of the enormous increase in yields by the application of higher nitrogen doses.

5.1.6 Varietal response

Considering the comparative performance of mustard varieties (Rohini, Vaibhav and Varuna) with regard to growth parameters, leaf NPK contents and yield attributes, Rohini proved best for most of parameters studied in both experiments and was invariably followed by Varuna (Tables 7-38). Thus, seed yield, which is the deciding criterion of performance, was 14.3 per cent and 6.6 per cent higher in Rohini than in Vaibhav and Varuna respectively. Not only this, it out-yielded the other two varieties in total oil production also by 14.5 per cent and 6.5 per cent respectively. Data of Experiment 2 confirm this observation (Tables 23-35). For example, seed yield (Table 33) of Rohini was 16.9 per cent and 6.6 per cent higher than that of
Vaibhav and Varuna respectively, while the oil yield (Table 35) was 17.6 per cent and 6.7 per cent higher than that of the two varieties respectively. This is a welcome improvement in the right direction and Rohini seems capable of replacing Varuna that has been the most popular mustard variety in this region for more than a decade. Its adoption for large scale cultivation would ensure higher productivity and returns for the farmer and enhanced availability for the consumers which effectively means substantial reduction in the import bill of the nation.

The superior yield performance of Rohini is not surprising if we compare its growth characteristics (Tables 7-10 and 23-26) with those of the other two varieties. Thus, its shoot dry weight at 80 days was 23.0 per cent and 7.1 per cent higher than that of Vaibhav and Varuna respectively in Experiment 1 and 18.3 per cent and 5.2 per cent higher, respectively in Experiment 2. It was also better adapted for absorbing and accumulating nitrogen, phosphorus and potassium (Tables 11-13 and 27-29). This reflected itself in maximum pod and seed production and hecto-litre weight (Tables 14-16 and 30-32), culminating in highest seed and oil yields (Tables 17, 19, 33 and 35) noted above.

It is also noteworthy that Rohini performed the other varieties in its iodine and saponification values
(Tables 21, 22, 37 and 38), thus establishing it as the most suitable variety from all angles, including yield and quality.

5.1.7 Interaction effect

Considering the overall treatment x variety interaction effect in Experiment 1 on growth attributes (Tables 7-10), leaf N, P and K concentrations (Tables 11-13) and yield parameters (Tables 14-17), $B_{N60P30} + F_{N30}$ x Rohini proved the most outstanding. Thus, it out-yielded all other interactions in both seed and oil production, which, for example, were each 60 per cent higher than those in the interaction $B_{N60P20} + F_w$ x Vaibhav, that gave the lowest value for these two most important characteristics.

It may also be noted that, in both Set (a) and (b), each of the three varieties interacted better with the treatment containing foliar nitrogen than the one in which the nutrient was applied as top dressing, although the latter (Treatments $B_{N40P20} + T_{N20}$ and $B_{N60P30} + T_{N30}$) also interacted with each variety better than the full basal treatments ($B_{N60P20} + F_w$ and $B_{N90P30} + F_w$) in the two sets.

Considering the data of Experiment 2, the overall treatment x variety interaction effect on growth attributes (Tables 23-26), leaf N, P and K contents (Tables 27-29) and
yield parameters (Tables 30-35), Treatment $B_{N60P30 + F_{N20}}$ x Rohini proved the most outstanding. Due to this excellent performance, it even out-yielded $B_{N60P30 + F_{N30}}$ x Rohini that proved the best interaction in Experiment 1, but was at par with $B_{N60P30 + F_{N20}}$ x Varuna in the present trial. Thus, the seed (Table 33) and oil (Table 35) yield in this combination ($B_{N60P30 + F_{N20}}$ x Rohini) was 5.4 per cent and 6.9 per cent higher than those in $B_{N60P30 + F_{N30}}$ x Rohini respectively. This implies that it would be profitable to cultivate Rohini rather than Varuna with the dose $B_{N60P30 + F_{N20}}$ in view of higher productivity of the former. Also, it is preferable to spray 20 (instead of 30) kg N/ha on Rohini to attain maximum productivity coupled with saving of nitrogenous fertiliser. Tables 33 and 35 make another conspicuous revelation. Treatment $B_{N60P30 + F_{N20}}$ x Rohini gave 15.5 per cent higher seed yield and 18.1 per cent more oil than $B_{N90P30 + F_{W}}$ x Rohini. The latter, however, proved far superior to $B_{N90P30 + F_{W}}$ applied to Varuna and Vaibhav, as these combinations proved the least effective.

It is therefore concluded, on the basis of the entire data of Experiments 1 and 2, that $B_{N60P30 + F_{N20}}$ x Rohini is to be preferred to ensure maximum productivity where facilities for spray are available. Even in the absence of these facilities, variety Rohini commends itself for adoption as the other two varieties responded far more
poorly with the recommended basal dose $B_{N90P30}$ in both experiments and to top-dressing in Experiment 1. These conclusions may be claimed by the author as a very modest but original contribution towards solving the perpetual problem of edible oil crisis in the country.

5.2 EXPERIMENTS 3, 4 AND 5

These simple randomised field trials were planned to study the effect of supplemental foliar spray of phosphorus and/or sulphur, in combination with nitrogen, on growth characters, leaf N, P and K contents and yield and quality characters of mustard variety Rohini, that proved best in Experiment 1. It may be recalled that the treatments in Experiment 3 (carried out simultaneously with Experiment 2) were based on the results of Experiment 1 and those of Experiment 4, on the data of Experiment 2. Further, Experiment 5 was a repetition of Experiment 4 for final confirmation of the data. These are, therefore, discussed in the form of mean of two-year results.

5.2.1 Growth characteristics

In Experiment 3, comparing the effect of $B_{N60P30} + F_{N30} (T_2)$ and the control, i.e. $B_{N90P30} + F_{W} (T_1)$, on growth parameters, it is evident from Table 39 that the values for growth parameters in Treatment $T_2$ were higher than those in
the control \((T_1)\). Thus, the beneficial effect of supplemental foliar spray of nitrogen over its basal application noted in Experiments 1 and 2 was reconfirmed. For example, dry weight per plant, representing the cumulative effect of other growth parameters, was 9.7 per cent higher in Treatment \(T_2\) than in the control (Table 39).

When phosphorus was added to the nitrogen in the spray with \((T_5\) and \(T_6)\) or without \((T_3)\) sulphur and the effect collated with the remaining treatments higher values were obtained for each growth parameter. To cite the example of dry weight again, \(T_3\), containing \(N+P\) in the spray, (equalled by \(T_5\) and \(T_6\)) produced more than 10 per cent higher dry matter than \(T_2\) (\(N\) alone) and 26.5 per cent and 7.6 per cent more than \(T_1\) (water) and \(T_4\) (\(N+S\)) respectively. Seemingly, the ready availability of phosphorus (with nitrogen) at crucial stages of growth through foliar spray was the reason for better growth as phosphorus is known to influence cell division, cell enlargement and cell differentiation thus enhancing all the parameters selected for the study (Devlin and Witham, 1986; Marschner, 1986; Salisbury and Ross, 1986).

Lastly, the inclusion of sulphur in the supplemental spray of nitrogen as in \(B_{N60P30 + F_{N30S2}}\) \((T_4)\) resulted in higher values for all growth parameters than those of the control \((T_1)\) and proved generally at par with \(T_2\) (spray of
nitrogen only). However, the combination of nitrogen, phosphorus and sulphur in the spray ($T_5$ and $T_6$) proved most beneficial for all growth parameters. Thus, shoot length, leaf number and leaf area were enhanced in $T_5$ by 18.1 per cent, 55.9 per cent and 33.6 per cent over $T_1$ (water), culminating in the highest dry weight which was 26.5 per cent higher than in $T_1$ (Table 39). If the reasoning for the effect of spray phosphorus given above is accepted the argument becomes stronger when data for combined sprays of nitrogen, phosphorus and sulphur are considered. Sulphur, being an essential part of proteins and enzymes, could well be considered to play an important role in growth and dry matter production together with the other two nutrients, through the S-containing amino acids, vitamins and co-enzymes (Hewitt, 1963; Gauch, 1972; Mengel and Kirkby 1978; Devlin and Witham, 1986; Marschner, 1986; Salisbury and Ross, 1986). That the ameliorative effect of the spray treatments on dry matter production was the result of the contribution made by the other growth attributes is clearly borne out by Table 51, showing significant positive correlation of shoot length ($r=+0.915$), leaf number ($r=+0.964$) and leaf area ($r=+0.954$) with dry weight at 80 days.

Before discussing the results of the last two field trials (Experiments 4 and 5), it may be pointed out that the
treatments (based on the data of Experiment 2) differed from those of Experiment 3 in one respect only (20 kg N/ha applied as spray instead of 30 kg N/ha). The total amount of nitrogen applied through spray and/or soil was, therefore, kept as 80 kg N/ha instead of 90 kg N/ha as in Experiment 3.

The pooled results (Tables 43 and 44) of the two-year study reveal that the split application of nitrogen, partly as basal and partly as supplemental foliar spray (B\textsubscript{N60P30} + F\textsubscript{N20}, i.e. Treatment T\textsubscript{2}) proved superior for all growth parameters compared with the basal application of the same quantity of the nutrient (B\textsubscript{N80P30} + F\textsubscript{W}, the control), thus reconfirming the data obtained in Experiments 1-3. For example, dry weight, which represents the cumulative effect of the other growth parameters, was 17.3 per cent higher in Treatment T\textsubscript{2} than in the control (T\textsubscript{1}).

When phosphorus and/or sulphur were added to the nitrogen spray, as in Treatments T\textsubscript{3} (N+P), T\textsubscript{4} (N+S), T\textsubscript{5} (N+P+S) and T\textsubscript{6} (N+P+S) and the effect collated with the remaining treatments, still higher values were obtained for almost all growth parameter. As in Experiment 3, the combination of nitrogen, phosphorus and sulphur (T\textsubscript{5} and T\textsubscript{6}) in the spray proved most beneficial. It is noteworthy, however, that Treatments T\textsubscript{5} and T\textsubscript{6} affected all the growth characteristics equally (Tables 43 and 44), thereby
highlighting the desirability of using commercial grade monocalcium superphosphate ($T_6$) in the spray and confirming the findings of Experiment 3. To give an example, dry weight was 10.8 per cent and 30.1 per cent higher in $T_6$ than in $T_2$ and $T_1$ (control) respectively. That the ameliorative effect of the spray treatments on dry matter production was the results of the contribution made by the other growth attributes is clearly borne out by Table 51, showing significant positive correlation of shoot length ($r=+0.981$), leaf number ($r=+0.992$) and leaf area ($r=+0.972$) with dry weight at 80 days. This implies that the best response of shoot length and leaf number (Table 43) as well as leaf area (Table 44) contributed significantly to dry matter production (Table 44) in mustard variety Rohini due to the application of $B_{N60P20} + F_{N20P2S3.4}$. In view of the silence of available literature regarding the effect of combined supplemental spray of nitrogen, phosphorus and sulphur on growth of mustard, the author may be allowed to claim priority for reporting the above findings.

5.2.2 Leaf $N$, $P$ and $K$ contents

The superiority of supplemental sprays containing $P$ and/or $S$ with regard to growth parameters noted above, is further established as leaf nitrogen, phosphorus and potassium contents were mostly found to be higher in these treatments ($T_3, T_4, T_5$ and $T_6$) than in Treatments $T_1$ and $T_2$, respectively.
comprising spray of water and nitrogen respectively. However, it is evident from Tables 40 and 45 that combined supplemental spray of nitrogen, phosphorus and sulphur gave the maximum leaf N, P and K contents. This becomes more evident when the total nitrogen, phosphorus and potassium accumulated in the shoots of plant samples collected at 80 days in Treatments T_5 and T_6, calculated by multiplying their contents (Table 40 and 45) with their respective dry weights (Table 39 and 44), were compared with those in Treatments T_1 and T_2. Thus, in Experiment 3, Treatments T_5 and T_6 (which were at par in their effect) and comprised supplemental spray of nitrogen, phosphorus and sulphur, accumulated more than 27.0 per cent, 22.7 per cent and 21.8 per cent total nitrogen, phosphorus and potassium respectively than Treatment T_2, containing only nitrogen in the spray. Similarly, compared with the control (T_1), in which the total quantity of nitrogen and phosphorus was applied basally and the plants were sprayed with water only, 55.3 per cent, 37.9 per cent and 38.9 per cent more of these nutrients respectively of Treatment T_5 and T_6 were noted in the leaves.

In Experiments 4 and 5 also, the mean computed total quantities of nitrogen, phosphorus and potassium in the leaves sprayed with N+P+S (T_5 and T_6) resulted in the accumulation of more than 24.7 per cent and 61.3 per cent nitrogen, 12.1 per cent and 14.2 per cent phosphorus and
11.2 per cent and 21.0 per cent potassium than those accumulated by the leaves in Treatments \( T_2 \) i.e. spray of nitrogen only and \( T_1 \) (control) respectively.

It seems that the overall good effect of combined spray of nitrogen, phosphorus and sulphur on the growth parameters increased the vigour of the plants which resulted in better accumulation of N, P and K in the leaves. This is for the first time that such an observation has been made in mustard.

5.2.3 Yield characteristics

In general terms, results of Experiment 3, 4 and 5 (Tables 41, 46 and 47) clearly indicate several points regarding the effect of treatments on various yield attributing characteristics and seed yield of Rohini (Figure 8 and 9). First, the supplemental spray application of nitrogen alone (\( T_2 \)) resulted in higher values for pods per plant, seeds per pod as well as seed yield over the water-sprayed control (\( T_1 \)), as was noted for growth attributes and leaf N, P and K contents discussed above. This observation confirms the results of Experiment 1, and establishes the superiority of the application of nitrogen, partly basally and partly by foliar spray. Secondly, inclusion of phosphorus or sulphur in the nitrogenous spray (Treatments \( T_3 \) and \( T_4 \)) proved more efficacious than \( T_2 \) (spray of
Figure 8: Effect of soil + foliar nitrogen and phosphorus, with or without sulphur in the spray, on seed yield (kg/ha) of mustard var. Rohini.
Figure 9: Effect of soil + foliar nitrogen and phosphorus, with or without sulphur in the spray, on seed yield (kg/ha) of mustard var. Rohini.
nitrogen alone). Thirdly, best results were obtained when all three nutrients (nitrogen, phosphorus and sulphur) were sprayed ($T_5$ and $T_6$). These data broadly confirm the findings of Parvaiz et al. (1982a) and Afridi et al. (1983) on mustard variety Laha-101 and of Samiullah et al. (1985) and Mohammad et al. (1987) on Varuna.

Let us now consider these results in detail. In Experiment 3, the highest values for yield attributes were noted in Treatment $T_5$. These were followed closely by $T_6$, which was itself at par with $T_3$ and $T_4$ (but better than $T_2$ and $T_1$) in its effect on most of the attributes, including seed yield (Table 41). Almost similar results were obtained in Experiment 4 and 5 (Tables 46 and 47).

It is thus clear that addition of phosphorus and/or sulphur to the nitrogen spray is beneficial for yield. It may be emphasised that, in addition to their ameliorating effect on yield and yield attributes, treatments $T_3$, $T_4$, $T_5$ and $T_6$ also enhanced the growth characteristics and leaf N, P and K contents more than supplemental spray of nitrogen alone, i.e. $T_2$, in all three trials (pp.145-150, Table 39-40, 43-45). It is, therefore, confirmed that the ensured availability of these mineral nutrients, at growth stages at which the demand of the crop was probably not being met fully by the soil, helped in the fullest realisation of the
genetic potential of Rohini in the Experiments under discussion.

It may be added that detailed correlation studies (Table 52) reveal that shoot length, leaf number, leaf area, dry weight, leaf N, P and K contents, pods per plant, seeds per pod and hecto-litre weight showed significant positive correlation ($r=+0.971$, $+0.977$, $+0.981$, $+0.980$, $+0.885$, $+0.819$, $+0.826$, $+0.970$, $+0.997$ and $+0.890$ respectively) with seed yield in Experiment 3 and thus contributed cumulatively towards seed production. Similar results were obtained in Experiments 4 and 5 where the pooled data showed a positive correlation between shoot length ($r=+0.978$), leaf number ($r=+0.993$), leaf area ($r=+0.990$), dry weight ($r=+0.999$), leaf N, P and K contents ($r=+0.946$, $+0.871$ and $+0.965$ respectively), pods per plants ($r=+0.985$), seeds per pod ($r=+0.992$), hecto-litre weight ($r=+0.995$) and seed yield (Table 52).

This remarkable response, with regard to growth and yield attributes, as well as NPK accumulation, culminated in the maximisation of seed yield. For example, in Experiment 3, Treatment $B_{N60P30} + F_{N28P2S2}$ ($T_5$) gave 18.8 per cent higher seed yield than $B_{N90P30} + F_W$, the control ($T_1$) and 8.3 per cent, than $B_{N60P30} + F_{N30}$ ($T_2$).

However, a noteworthy feature of the data in Table 41 (Experiment 3) is the economic superiority of
Treatment $T_6$ over all other treatments (including $T_3$) on cost-benefit consideration. Treatment $T_6$ comprised the addition to the nitrogenous spray of the easily available and inexpensive commercial grade fertiliser monocalcium superphosphate whereas Treatments $T_3$ and $T_4$ (which were at par with it in their effect on seed production) and Treatment $T_5$, which slightly out-yielded it comprised costly laboratory grade sodium dihydrogen orthophosphate and/or sodium sulphate. This is even more clearly highlighted by Table 47 (Experiments 4 and 5) where $T_6$ proved at par with $T_5$. It may be recalled that in these experiments, 20 kg N/ha was sprayed in place of 30 kg N/ha (Experiment 3). Thus, there was not only a saving of 10 kg N/ha but it was also convincingly established that monocalcium superphosphate could be sprayed with ensured efficacy as well as economy for the cultivation of Rohini.

5.2.4. Oil content and oil yield

(i) Oil content

Tables 41 and 48 establish one point unequivocally. Treatment $T_1$ containing rather high basal nitrogen doses (80 or 90 kg N/ha) and $T_2$ in which the same quantities of nitrogen were applied partly through soil and partly by foliar spray, gave the lowest values for the oil content of
seed. This observation confirms not only the results of Experiments 1 and 2 but also those of other workers on mustard mentioned earlier (pp. 135-136).

Further, it is noteworthy that the inclusion of small quantities of phosphorus and sulphur (preferably combined together) in the spray of nitrogen offsets the depressing effect of the latter (Tables 41 and 43). This finding gives support to the data of earlier experiments performed at Aligarh (Parvaiz et al., 1982a and Afridi et al., 1983 on mustard variety Laha-101; Samiullah et al., 1985 and Mohammad et al., 1987 on Varuna).

(ii) Oil yield

Another noteworthy feature of Table 41 (Experiment 3) is that, although the percentage of oil in Treatment $T_4$ was significantly higher than in all other Treatments, $T_5$ surpassed $T_4$ (as well as $T_6$ and $T_3$, which equalled it) in the production of oil due to its higher seed yield. In the other two trials (Experiments 4 and 5), the picture was more well defined. Treatments $T_5$ and $T_6$ out-yielded all other treatments in oil productivity (Table 48) apparently due to their higher seed productivity (Table 47) as well as oil content (Table 48) broadly confirming the data of Parvaiz et al. (1982a) and Afridi et al. (1983) on mustard variety Laha-101 and of Samiullah et al. (1985) and Mohammad et al.
(1987) on Varuna. However, considering the cost-benefit ratio, Treatments $T_6$ (based on commercial grade monocalcium superphosphate) proved much more economical than Treatment $T_5$ in all three experiments as well as $T_3$ and $T_4$ in Experiment 3 as these contained laboratory grade sodium dihydrogen orthophosphate and/or sodium sulphate.

5.2.5 Quality characteristics

Regarding the effect of the treatments on acid, iodine and saponification values, Tables 42 and 49 present a slightly disturbing picture. In all three experiments, oil quality was found to be affected slightly adversely by Treatments $T_5$ and $T_6$. However, this could be ignored as by and large the values were within the permissible range for mustard oil (Anonymous, 1970). Moreover, in view of the fact that Treatments $T_5$ and $T_6$ far out-yielded all other treatments in seed and oil productivity, which is highly desirable due to the chronic oil crisis of our country, the slightly marginal lowering of oil quality by these treatments is only of academic importance.

5.2.5.1 Fatty acid composition

As explained earlier (p 78), the fatty acid composition of the oil produced as a result of various treatments was studied in Experiment 5 only. The data
(Table 50) reveal that the effect of the treatments on the percentage of palmitic, stearic, oleic and linoleic acid in the oil was non-significant. This implies: (i) that the effect of basal application of nitrogen (T\textsubscript{1}) was not different from that of nitrogen applied partly at sowing and partly through spray (T\textsubscript{2}) and (ii) addition of phosphorus and/or sulphur (T\textsubscript{3}-T\textsubscript{6}) to the nitrogenous spray also did not affect the content of these four acids in the oil.

Let us now consider the effect of the treatments on the remaining three acids affected significantly by the treatments (Table 50). Among these, linolenic acid (18:3) content was lowest in the control (T\textsubscript{1}), receiving the entire quantity of nitrogen basally. On the other hand, this treatment promoted eicosenoic acid (20:1) content most. The third component, i.e. erucic acid (22:1), was predominant in the oil obtained in Treatment T\textsubscript{1} which was at par in this respect with Treatment T\textsubscript{2}, containing supplemental spray of nitrogen only. However, its content was lowest in all treatments containing supplemental spray of sulphur applied either with nitrogen (T\textsubscript{4}) or with nitrogen and phosphorus (T\textsubscript{5} and T\textsubscript{6}). As high amounts of this acid are detrimental for human consumption (Jorgansen, 1972), the observation that spray of small quantities of phosphorus and sulphur together with nitrogen (T\textsubscript{5} and T\textsubscript{6}) played a part in reducing
the erucic acid content of the oil (in addition to increasing the seed and oil yield noted earlier) is very heartening. Incidentally, such a finding has not been reported so far, although there are reports that increasing doses of basally applied nitrogen may increase the erucic acid content of rape-seed oil (Appelqvist, 1968). On the other hand, Bachmann (1964), Dembinski et al. (1967) and Lammerink and Morice (1970) failed to note significant effect of basal application of nitrogen on the fatty acid composition (including erucic acid content) of rape-seed oil. In view of these controversial findings, the present author is tempted to suggest that it would be worthwhile to explore if manipulation of the concentration of phosphorus and sulphur in the nitrogenous spray would help bring down the erucic acid content of the oil further without lowering the seed and oil yields.

5.3 **Proposals for future work**

As the present investigation progressed, it was realised that much work remains to be done for achieving the national objective of increased oilseed productivity. A few suggestions are summarised below:

Agronomic studies consisting of optimum date of sowing, plant density and number of irrigations should also be undertaken for the presently available high yielding mustard varieties.
Effort should be made to enhance the quality of oil while ensuring maximum yields by manipulating nutritional and other practices.

The technique of foliar application should also be extended to high yielding varieties of other important edible oil producing crops, like sunflower, ground nut, soybean, linseed and sesame.

Lastly, it would be interesting to use isotopic nitrogen, phosphorus and sulphur to trace the uptake, translocation and subsequent metabolisation of these nutrients.