CHAPTER- IV

EXPERIMENTAL FINDINGS
A research work entitled "Effect of Nitrogen and Sulphur on Growth, Flowering, Fruiting and Metabolic Drift in Indian Mustard (Brassica juncea Linn.) cultivar Varuna" was conducted through field experimentation during rabi in the year 2003-2004 and 2004-2005 respectively at Agricultural Research Farm.

Observations on several preharvest characters such as plant height, number of green leaves/plant, size and area of leaf, fresh weight of leaf, days to flower initiation, average height of plant at flower initiation, green leaves/plant at flower initiation, fresh weight of green leaves at flower initiation, fresh weight of stem/plant at flower initiation, fresh weight of shoot and root/plant at flower initiation were taken.

At flower initiation, the % total nitrogen, % total protein, % reducing sugar content and total free amino acids (mg/g dry weight), in leaf and shoot apices were also estimated.

At flowering and harvest stages, 50 % flowering and 95 %
maturity of crop, number of branches/plant at harvest, length of siliqua at harvest, number of siliquae/plant, number of seeds/siliqua, number of seeds/plant, seed yield/plant, biological yield/plant, harvest index, seed yield q/ha were also observed.

The oil content (%) in seed was also estimated by Soxhlet's Extraction Method using Petroleum ether (40-60 B.P.) as solvent.

All the quantitative and qualitative characters studied in this research work are described stepwise on the basis of average value of the data taken in the year 2003-2004 and 2004-2005 respectively as follows:

1. **Height of Plant**:

At 30 days after sowing, the height of mustard plant, on an average, in untreated control ($N_0$) was 23.30 cm. It was increased upto 24.53 and 26.37 cm in $N_{80}$ and $N_{100}$ treated mustard plant (Table-1, Fig. 1, Photograph-1A). In case of $S_0$ treatment, the average height of plant was 23.22 cm where it reached to 23.97 cm in $S_0$ and 25.04 cm in $S_{40}$ treated plants (Table-1, Fig.1, Photograph-1A). The mustard plants of $N_0S_0$ treatment attended the average height as 23.22 cm whereas it reached to 27.67 cm in $N_{80}S_{20}$, 28.87 cm in $N_{80}S_{40}$, 30.45 cm in $N_{100}S_{20}$ and 31.45 cm in $N_{100}S_{40}$ respectively at 30 days after sowing (Table-1, Fig.1, Photograph-1-A, 1-B, 1-C).
Fig. 1. Average height of plant as influenced by different levels of nitrogen and sulphur at different stages of growth of *Brassica juncea* L. cv. Varuna.
At 60 days after sowing, the average height of mustard plant in $N_0$ treatment was 129.95 cm. It was found to increase up to 138.20 cm and 141.82 cm in $N_{80}$ and $N_{100}$ treated plants respectively (Table-1, Fig. 1). In $S_0$ treatment the average height of plant was 130.07 cm whereas it reached to 137.45 cm and 139.67 cm in $S_{20}$ and $S_{40}$ treated plants respectively (Table-1, Fig. 1). The average height of $N_0S_0$ treated plants at 60 days after sowing was 130.00 cm. The average height of mustard plant cultivar Varuna was 145.65 cm in $N_{80}S_{20}$, 148.12 cm in $N_{80}S_{40}$, 151.50 cm in $N_{100}S_{20}$ and 153.65 cm in $N_{100}S_{40}$ respectively (Table-1, Fig. 1).

At 90 days after sowing, the $N_0$ treatment was found to attend the average height of plant 145.82 cm whereas it was 154.30 cm in $N_{80}S_{20}$, 157.87 cm in $N_{80}S_{40}$, 161.80 cm in $N_{100}S_{20}$ and 164.67 in $N_{100}S_{40}$ treated plants respectively (Table-1, Fig. 1).

In all the treatments, the interaction effect on average height of mustard cultivar Varuna plants was significantly better than other doses at all the stages of growth.

2. **Green Leaves/Plant:**

After one month of sowing i.e. 30 days after sowing, the mustard plants of $N_0$ treatment were found to contain 16.52 leaves/plant. It increased to 18.34 in $N_{80}$ and 19.29 in $N_{100}$ treated...
plants respectively (Table-2, Fig. 2). Similarly, $S_0$ treatment contained 16.47 leaves/plant at 30 days after sowing while $S_{20}$ and $S_{40}$ treated plants were found to contain 17.41 and 18.40 leaves/plant respectively (Table-2, Fig. 2). In case of $N_0S_0$, the number of leaves/plant was 16.52. The plants treated with $N_{80}S_{20}$, $N_{80}S_{40}$, $N_{100}S_{20}$ and $N_{100}S_{40}$ were found to have 20.69, 21.45, 22.60 and 23.70 leaves/plant respectively (Table-2, Fig. 2).

At 60 days after sowing, the $N_0$ plants were found to have 35.32 leaves/plant. The average number of leaves was 38.75 in $N_{80}$ and 42.86 in $N_{100}$ treated plants. (Table-2, Fig.2). Similarly, $S_0$ plants were found to contain 35.62 leaves/plant. It reached to 37.50 in $S_{20}$ and 39.92 in $S_{40}$ treated plants (Table-2, Fig. 2). In case of $N_0S_0$, the average number of green leaves was 35.27 whereas it was 46.47 in $N_{80}S_{20}$, 48.50 in $N_{80}S_{40}$, 50.00 in $N_{100}S_{20}$ and 51.17 in $N_{100}S_{40}$ treated plants respectively (Table-2, Fig. 2).

At 90 days after sowing, the number of green leaves/plant was 46.32 whereas it increased significantly and reached to 49.57 in $N_{80}$ and 52.72 leaves/plant in $N_{100}$ treated plants respectively (Table-2, Fig. 2). The treatment $S_0$ was also found to contain 45.80 green leaves/plant at 90 days after sowing. In plants treated with $S_{20}$ and $S_{40}$ the number of green leaves was 47.55 and 51.32/plant respectively (Table-2, Fig.2).
Fig. 2. Green leaves/plant as influenced by different levels of nitrogen and sulphur at different stages of growth of *Brassica juncea* L. cv. Varuna.
The interaction effect was found significantly better than remaining treatments. The number of green leaves/plant in N₀S₀ was 45.57 whereas the treatment N₈₀S₂₀ and N₈₀S₄₀ were found to contain 50.82 and 53.97 leaves/plant respectively. Similarly the plants treated with N₁₀₀S₂₀ and N₁₀₀S₄₀ were found to produce 56.55 and 58.72 green leaves/plant respectively (Table-2, Fig. 2).

In all the treatments, the interaction affect was found significantly better than other remaining doses.

3. Size and Area of Leaf:

At 45 days after sowing, the average length x width (mean value) of leaf in N₀ treatment was 28.05 x 11.95 cm. In plants treated with N₈₀ and N₁₀₀ it was 31.10 x 12.95 and 33.05 x 13.50 cm respectively. Similarly, in S₀ treatment the length and width of leaf was 28.15 x 11.90 cm whereas the plants treated with S₂₀ and S₄₀ increased the length and width of leaf i.e. 30.05 x 12.45 cm and 32.15 x 12.95 cm respectively. In case of N₀S₀ the length and width of leaf was 28.00 x 12.00 cm. The plant treated with N₈₀S₂₀, N₈₀S₄₀, N₁₀₀S₂₀ and N₁₀₀S₄₀ attended the leaf size 34.25 x 13.45 cm, 35.05 x 14.45 cm, 36.15 x 14.65 cm and 37.00 x 15.05 cm respectively (Table-3. Fig. 3. Photograph- 2-A, 2-B, 2-C).

Similarly, at the same time (45 days after sowing) the average
Fig. 3. Average Size of leaf - cm² at 45 Days After Sowing as influenced by different levels of nitrogen and sulphur in Indian mustard *Brassica juncea* L. cv. Varuna.
Photograph 2-A, 2-B: Showing average size of leaf as influenced by different levels of nitrogen and sulphur at 45 days after sowing in *Brassica juncea* L. cv. Varuna.
Photograph- 2-C: Showing average size of leaf as influenced by different levels of N x S at 45 days after sowing in Brassica juncea L. cv. Varuna.
area of leaf in \( N_0 \) was 335.19 cm\(^2\). It increased to 402.74 cm\(^2\) in \( N_{30} \) and 446.17 cm\(^2\) in \( N_{100} \) treated plants. The treatment \( S_0 \) also contained 334.98 cm\(^2\) of average leaf area whereas it reached to 374.12 cm\(^2\) in \( S_{20} \) and 416.34 cm\(^2\) in \( S_{40} \) treated plants respectively. The area of leaf (average) in \( N_0 S_0 \) was 336.00 cm\(^2\) and at the same time it was found to reach up to 460.66, 495.95, 529.59 and 556.85 cm\(^2\) in \( N_{80} S_{20}, N_{30} S_{40}, N_{100} S_{20}, \) and \( N_{100} S_{40} \) treated plants (Table-3, Fig. 3). The interaction effect was found superior to \( N \) or \( S \) application of different doses alone.

4. **Fresh Weight of Leaf:**

The fresh weight of leaf, on an average, at 45 days after sowing of *Brassica juncea* Linn. cultivar Varuna was 28.30 g in \( N_0 \) treatment. The plants treated with \( N_{30} \) and \( N_{100} \) contained 31.15 and 35.25 g of fresh weight at 45 days after sowing. The average fresh weight of leaf at the same time was 28.69 g in \( S_0 \), 30.15 g in \( S_{20} \) and 33.30 g in \( S_{40} \) treated plants respectively.

In case of \( N_0 S_0 \), treated plants, the average fresh weight of leaf at 45 days after sowing was 28.50 g whereas it was 37.30 g in \( N_{80} S_{20} \), 39.70 g in \( N_{80} S_{40} \), 41.20 g in \( N_{100} S_{20} \) and 42.60 in \( N_{100} S_{40} \) treated plants respectively (Table-4, Fig. 4).
Fig. 4. Fresh weight of leaf at 45 Days After Sowing as influenced by different levels of nitrogen and sulphur in Indian mustard *Brassica juncea* L. cv. Varuna.
5. Days to Flower Initiation:

The flower initiation in mustard plants was significantly delayed in comparison to control with treatments i.e. $N_{100}$, $S_{20}$, $S_{40}$, $N_{80}S_{20}$, $N_{80}S_{40}$, $N_{100}S_{20}$ and $N_{100}S_{40}$ respectively.

From date of sowing, the $N_0$ plants had taken 30.02 days for flower-bud initiation whereas plants treated with $N_{80}$ and $N_{100}$ had taken 31.57 and 34.25 days for flower-bud initiation. In case of $S_0$, the plants required 30.07 days for their flower-bud initiation. The $S_{20}$ and $S_{40}$ treated plants required 32.72 and 33.27 days for their flower-bud initiation respectively (Table-5, Fig. 5).

In case of interaction effect, the flower-bud initiation was found delayed in comparison to remaining treatments. The $N_0S_0$ plants needed 30.18 days for flower-bud initiation while 35.36 days for $N_{80}S_{20}$, 36.67 days for $N_{80}S_{40}$, 37.77 days for $N_{100}S_{20}$ and 38.02 days for $N_{100}S_{40}$ were required respectively for flower-bud initiation in mustard cultivar Varuna (Table-5 Fig. 5).

6. Height of Plant-cm at Flower Initiation:

The average height of mustard plant cultivar Varuna at flower-bud initiation was 29.20 cm. At flower-bud initiation, the average height of plant was 32.45 cm in $N_{80}$ and 35.54 cm in $N_{100}$ treated plants respectively. Similarly, $S_0$ plants also attended the
Treatments

\[ T_1 = N_0, T_2 = N_{80}, T_3 = N_{100}, \]
\[ T_4 = S_0, T_5 = S_{20}, T_6 = S_{40}, \]
\[ T_7 = N_0S_0, T_8 = N_{80}S_{20}, T_9 = N_{80}S_{40}, T_{10} = N_{100}S_{20}, T_{11} = N_{100}S_{40} \]

Fig. 5. Days to Flower initiation as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.
average height of plant 29.15 cm at flower-bud initiation. It increased to 32.00 cm in S_{20} and 34.82 cm in S_{40} treated plants.

At flower-bud initiation, the N_{0}S_{0} treatment also contained the average height 29.32 cm of mustard plant at flower-bud initiation, but it reached to 36.12 cm in N_{80}S_{20}, 37.90 cm in N_{80}S_{40}, 37.87 cm in N_{100}S_{20} and 39.82 cm in N_{100}S_{40} respectively at flower-bud initiation (Table-6, Fig. 6).

The interaction was found more effective in increasing the average height of plant significantly at flower-bud initiation.

7. Green Leaves/Plant at Flower Initiation:

The number of green leaves/plant at flower-bud initiation in N_{0} treatment was 16.61 whereas it increased to 19.05 in N_{30} and 20.17 in N_{100} treated plants respectively.

The treatment S_{0} also contained 16.57 green leaves/plant at flower-bud initiation. It reached to 18.87 in S_{20} and 19.80 in S_{40} treated plants at flower-bud initiation.

The interaction effect was more beneficial than N or S treatment alone. The N_{0}S_{0} treatment contained 16.56 green leaves/plant at flower-bud initiation. The plants treated with N_{80}S_{20}, N_{80}S_{40}, N_{100}S_{20} and N_{100}S_{40} were found to increase significantly the number of green leaves/plant. It was 23.12 in N_{80}S_{20}, 24.75 in N_{80}S_{40},
Treatments

\[ T_1 = N_0, T_2 = N_{80}, T_3 = N_{100}, \]
\[ T_4 = S_0, T_5 = S_{20}, T_6 = S_{40}, \]
\[ T_7 = N_0 S_0, T_8 = N_{80} S_{20}, T_9 = N_{80} S_{40}, T_{10} = N_{100} S_{20}, T_{11} = N_{100} S_{40} \]

**Fig. 6.** Height/plant-cm at flower initiation as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.
25.22 in $N_{100}S_{20}$ and 27.44 in $N_{100}S_{40}$ treated plants at flower-bud initiation (Table-7, Fig. 7).

8. Fresh Weight of Leaves-g/Plant at Flower Initiation:

The fresh weight of leaves in $N_0$ treatment was 58.55 g/plant at flower-bud initiation. An increase in fresh weight of leaves/plant was noted in plants treated with $N_{80}$ and $N_{100}$. It was 62.28 g in $N_{80}$ and 63.35 g in $N_{100}$ treated plants. In case of $S_0$, the fresh weight of leaves at flower-bud initiation was 57.87 g/plant. In plants treated with $S_{20}$ and $S_{40}$, the fresh weight of leaves was found to increase over $S_0$ treated plants i.e. 59.80 g in $S_{20}$ and 61.71 g in $S_{40}$ treated plants respectively (Table-8, Fig. 8).

The $N_0S_0$ treatment contained 57.82 g fresh weight of leaves/plant at flower-bud initiation whereas the fresh weight of leaves was 64.42 g in $N_{80}S_{20}$, 65.12 g in $N_{80}S_{40}$, 68.25 g in $N_{100}S_{20}$ and 70.88 g/plant in $N_{100}S_{40}$ respectively (Table-8, Fig. 8).

9. Fresh Weight of Stem-g/Plant at Flower Initiation:

At flower-bud initiation, the fresh weight of stem/plant in $N_0$ treatment was 18.97 g. The plants treated with $N_{80}$ and $N_{100}$ increased the fresh weight of stem/plant but the significant increase in fresh weight of stem/plant was recorded only in $N_{100}$ treated plants.
Fig. 7. Green leaves/plant at flower initiation as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.
Fig. 8. Fresh Weight of green leaves-g/plant at flower initiation as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.
It was 24.17 g/plant.

The fresh weight of stem was 18.98 g/plant in $S_0$ while it was found to increase significantly in $S_{40}$ treated plants. The fresh weight of stem in $S_{40}$ treated plants was 23.30 g/plant.

The treatment $N_0S_0$ had the 18.98 g of fresh weight of stem/plant at flower-bud initiation. All the interaction treatments like $N_{80}S_{20}$, $N_{80}S_{40}$, $N_{100}S_{20}$ and $N_{100}S_{40}$ showed significantly more fresh weight of stem at flower-bud initiation. The fresh weight was 28.67 g in $N_{80}S_{20}$, 30.61 g in $N_{80}S_{40}$, 31.40 g in $N_{100}S_{20}$ and 32.40 g/plant in $N_{100}S_{40}$ treated plants at flower-bud initiation respectively (Table-9, Fig. 9). The interaction effect of N and S was found better than N or S alone.

10 a. Fresh Weight of Shoot-g/Plant at Flower Initiation:

The fresh weight of shoot (stem + leaves/plant at flower-bud initiation in $N_0$ treatment was 77.52 g/plant. It increased significantly with the application of $N_{80}$ and $N_{100}$ i.e. 84.25 g in $N_{80}$ and 87.52 g in $N_{100}$ treated plants. The plants without sulphur ($S_0$) also contained 76.85 g of fresh weight of shoot/plant at flower-bud initiation. It reached to 80.92 g in $S_{20}$ and 85.02 g in $S_{40}$ treated plants. The significant increase was obtained only in $S_{40}$ treated plants (Table-10, Fig. 10).
Fig. 9. Fresh Weight of Stem-g/plant at flower initiation as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.
Fig. 10. Fresh Weight of Shoot and Root-g/plant at flower initiation as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.
The plants without sulphur and Nitrogen (N₀S₀) were found to produce 76.81 g/plant of fresh weight of shoot at flower-bud initiation in mustard cultivar Varuna. All the interactions had significantly enhancing effect on fresh weight of shoot/plant. It was 93.10 g in N₈₀S₂₀, 95.74 g in N₈₀S₄₀, 99.65 g in N₁₀₀S₂₀ and 103.13 g in N₁₀₀S₄₀ treated plants at flower-bud initiation respectively. The combined effect of Nitrogen and sulphur was found significantly better than nitrogen and sulphur applied alone.

10 b. Fresh Weight of Root-g/Plant at Flower Initiation:

At flower-bud initiation, the fresh weight of root in N₀ treatment was 4.07 g/plant. The fresh weight of root was 4.40 g in N₈₀, 4.82 g/plant in N₁₀₀ treated plant. The plants without sulphur application (S₀) also contained the same value of fresh weight of root ie. 4.07 g/plant while it was 4.17 g in S₂₀ and 4.46 g/plant in S₄₀ treated plants. In above all these treatments, the significant increase in fresh weight of root/plant was recorded only in N₁₀₀ and S₄₀ treated plants at flower-bud initiation (Table-10, Fig. 10).

The plants without nitrogen and sulphur (N₀S₀) also produced 4.04 g of fresh weight of root/plant at flower-bud initiation. All the interaction treatments were found to increase the fresh weight of root/plant significantly at flower-bud initiation. It was 5.24 g in
N\textsubscript{80}S\textsubscript{20}, 5.61 g in N\textsubscript{80}S\textsubscript{40}, 5.99 g in N\textsubscript{100}S\textsubscript{20} and 6.39 g in N\textsubscript{100}S\textsubscript{40} treated plants respectively. The higher dose was found better than their lower doses but still better than nitrogen and sulphur applied alone.

In this way it is obvious that the application of nitrogen (N\textsubscript{80}, N\textsubscript{100}) and sulphur (S\textsubscript{20}, S\textsubscript{40}) applied alone in better than control ie. the plants grown without nitrogen (N\textsubscript{0}) or sulphur (S\textsubscript{0}) and combined effect of nitrogen and sulphur (N\textsubscript{80}S\textsubscript{20}, N\textsubscript{80}S\textsubscript{40}, N\textsubscript{100}S\textsubscript{20}, N\textsubscript{100}S\textsubscript{40}) was found better than nitrogen and sulphur applied alone as well as the treatments without nitrogen and sulphur (N\textsubscript{0}S\textsubscript{0}) in respect of height, number of green leaves, size (length and width) of leaf and area of leaf, fresh weight of leaves/plant at different stages of plant growth, height and green leaves/plant, fresh weight of leaves, stem, shoot and root/plant at flower-bud initiation respectively.

11. Metabolic Drifts During Flower Initiation :

(a) Total Nitrogen :

(i) Leaf :

The amount of total-N in the control (N\textsubscript{0}) leaves at the time of flower-bud initiation was found to be 2.94%. It increased to 3.10% in N\textsubscript{80} and 3.21% in N\textsubscript{100} treated plants. The plant without sulphur treatment (S\textsubscript{0}) also contained 2.92% total-N at flower-bud initiation while it was 3.00% in S\textsubscript{20} and 3.17% in S\textsubscript{40} treated plants.
The plants without nitrogen and sulphur \((N_0S_0)\) also contain 2.95\% total-N in leaf at flower-bud initiation in mustard cultivar Varuna. The plants of mustard cultivar Varuna treated with \(N_{80}S_{20}\), \(N_{80}S_{40}\) and \(N_{100}S_{20}\) and \(N_{80}S_{40}\) also showed better response than all other treatments. The amount of total-N was 3.30\% in \(N_{80}S_{20}\), 3.37\% in \(N_{80}S_{40}\), 3.60\% in \(N_{100}S_{20}\) and 3.74\% in \(N_{100}S_{40}\) treated plants at flower-bud initiation respectively (Table-11, Fig. 11).

(ii) **Shoot Apex**:

The total-N in shoot apex in control \((N_0)\) was 3.59\% at flower-bud initiation whereas it was 3.95\% in \(N_{80}\) and 4.14\% in \(N_{100}\) treated plants at flower-bud initiation. Also, the plants without sulphur \((S_0)\) contained 3.51\% of total-N in shoot apex. With the application of sulphur, the amount of N increased in shoot apex at flower-bud initiation. It was 3.85 and 4.00\% in \(S_{20}\) and \(S_{40}\) treated plants respectively (Table-11, Fig. 11).

The plants without Nitrogen and Sulphur application \((N_0S_0)\) also contained 3.50\% of total-N in their shoot apices at flower-bud initiation. It was found to increase to 4.25\% in \(N_{80}S_{20}\), 4.46\% in \(N_{80}S_{40}\), 4.65\% in \(N_{100}S_{20}\) and 4.78\% in \(N_{100}S_{40}\) treated plants respectively in mustard plant cultivar Varuna (Table-11, Fig. 11).

The higher value of total-N in shoot apices in different
Fig. 11. Effect of different levels of nitrogen and sulphur on % total-N at flower initiation in *Brassica juncea* L. cv. Varuna.
treatments rather than leaves showed the translocation of total-N from leaves and stem to shoot apices at flower-bud initiation.

(b) **Protein**:

(i) **Leaf**:

At flower-bud initiation, the total protein content in leaf in control ($N_0$) was 14.20%. The plants of mustard cultivar Varuna treated with $N_{80}$ and $N_{100}$ were found to contain 14.60% and 14.77% of total protein in leaf at flower-bud initiation.

Also, the plants without sulphur ($S_0$) treatment contained 14.21% total protein in leaf at flower-bud initiation. It increased to 14.45% and 14.65% in $S_{20}$ and $S_{40}$ treated plants at flower-bud initiation (Table-12, Fig. 12).

The plants without nitrogen and sulphur ($N_0S_0$) were found to have 14.22% total protein in their leaves at flower-bud initiation. The interaction effect of nitrogen and sulphur was found more effective in increasing the amount of total protein in leaf at flower-bud initiation. The total protein content was 15.05% in $N_{80}S_{20}$, 15.15% in $N_{80}S_{40}$, 15.30% in $N_{100}S_{20}$ and 15.65% in $N_{100}S_{40}$ treated plants of mustard cultivar Varuna at flower-bud initiation. In all these treatments, the combined effects of nitrogen and sulphur (interaction effect) was found more effective than nitrogen and sulphur applied
Fig. 12. Effect of different levels of nitrogen and sulphur on % total protein at flower initiation in Brassica juncea L. cv. Varuna.
alone (Table-12, Fig. 12).

(ii) **Shoot Apex**:

At the time of flower-bud initiation, the translocation of metabolites like protein from leaf and stem to shoot apices has taken place as cleared from the more protein content in shoot apices in comparison to leaf at flower-bud initiation in mustard cultivar Varuna.

The plants without nitrogen application ($N_0$) contained 15.65% protein in shoot apex at flower-bud initiation but increased the amount of protein in plants treated with $N_{80}$ and $N_{100}$ respectively. It was 16.15% in $N_{80}$ and 16.61% in $N_{100}$ in shoot apex respectively.

Similarly, the plants without sulphur ($S_0$) also found to contain 15.60% of total protein in shoot apex in comparison to the amount of protein (14.21%) in leaf. It increased to 15.97% in $S_{20}$ and 16.35% in $S_{40}$ treated plants respectively (Table-12, Fig. 12).

The plants of mustard cultivar Varuna without nitrogen and sulphur ($N_0S_0$) also contained 15.63% of total protein in shoot apex at flower-bud initiation. The content of protein increased to 16.77% in $N_{80}S_{20}$, 17.15% in $N_{80}S_{40}$, 17.38% in $N_{100}S_{20}$ and 17.67% in $N_{100}S_{40}$ treated plants at flower initiation respectively. The interaction effect was more positive than nitrogen and sulphur applied alone as well.
as control ($N_0S_0$ and $N_0S_0$) respectively (Table-12, Fig. 12).

(c) Reducing Sugars:

(i) Leaf:

The amount of reducing sugars in leaf of mustard plant at flower-bud initiation was 2.00% in $N_0$ treatment. It increased to 2.21% in $N_{80}$ and 2.35% in $N_{100}$ treated plants. Similarly, the plants having no sulphur treatment ($S_0$) was found to contain 2.00% of reducing sugars in their leaves at flower-bud initiation. The application of 20 kg S/ha and 40 kg S/ha was found to increase the amount of reducing sugars in leaf at flower-bud initiation. It was 2.18% in $S_{20}$ and 2.23% in $S_{40}$ treated plants respectively.

The plants without nitrogen and sulphur ($N_0S_0$) also found to contain 2.00% reducing sugars in their leaves at flower-bud initiation. After the application of nitrogen and sulphur, the amount of reducing sugars was found to increase over $N_0$, $S_0$ and $N_0S_0$ as well as $N_{80}$,$N_{100}$, $S_{20}$ and $S_{40}$ applied alone. The amount of reducing sugars was 2.38% in $N_{80}S_{20}$, 2.52% in $N_{80}S_{40}$, 2.63% in $N_{100}S_{20}$ and 2.78% in $N_{100}S_{40}$ treated plants respectively in leaf at flower-bud initiation (Table-13, Fig. 13).
Fig. 13. Effect of different levels of nitrogen and sulphur on % reducing sugar at flower initiation in *Brassica juncea* L. cv. Varuna.
(ii) **Shoot Apex:**

At flower-bud initiation, the amount of reducing sugars in shoot apex was higher than the amount of reducing sugars present in leaf. In N0 treatment it was 2.53% in shoot apex (2.00% in leaf) at flower-bud initiation. The plants treated with N80 and N100 contained 2.68 and 2.95% of reducing sugars in shoot apex. Also, in S0 treatment the reducing sugars content was 2.54% in shoot apex while it was 2.65% in S20 and 2.87% in S40 treated plants (Table-13, Fig. 13).

In N0S0 plants, the amount of reducing sugars in shoot apex was 2.50%. The combined effect of nitrogen and sulphur was found better in respect of reducing sugar synthesis at flower initiation. It was 3.15% in N80S20, 3.45% in N80S40, 3.57% in N100S20 and 3.85% in N100S40 treated plants respectively (Table-13, Fig. 13).

On the basis of above findings it is clear that at flower-bud initiation, the translocation of reducing sugars from leaf to shoot apex takes place more actively, resulting higher amount of reducing sugars in shoot apex than the amount of reducing sugars present in leaf.

(d) **Total Free Amino Acids:**

(i) **Leaf:**

At flower-bud initiation, the amount of total free amino acids in mustard plant having no application of nitrogen (N0) was
3.30 mg/g dry weight. It increased to 3.84 mg/g in N80 and 4.35 mg/g in N100 treated plants. The mustard plants having no sulphur application (S0) also found to contain 3.31 mg/g of total free amino acids at flower-bud initiation in mustard cultivar Varuna. The plants treated with S20 and S40 were found to increase the amount of total free amino acids in leaf at flower-bud initiation. The amount of total free amino acids was 3.78 mg/g in S20 and 4.10 mg/g in S40 treated plants (Table-14, Fig. 14).

The mustard plants without nitrogen and Sulphur (N0S0) were found to contain 3.31 mg total free amino acids/g of dry weight, in leaf at flower-bud initiation. With the application of nitrogen and sulphur the content of free amino acids was found to increase over the amount of free amino acids found in plants treated with nitrogen or sulphur alone.

In case of interaction, the amount of total free amino acids at flower-bud initiation in mustard cultivar Varuna was 4.68 mg/g dry weight in N80S20, 5.65 mg/g in N80S40, 6.32 mg/g in N100S20 and 6.78 mg/g dry weight in N100S40 treated plants (Table-14, Fig. 14).

Thus it is clear from the above findings that the combined effect of nitrogen and sulphur is better than the effect of nitrogen or sulphur applied alone in respect of increasing the amount of total free amino acids in leaf of mustard plant cultivar Varuna at flower-
Fig. 14. Effect of different levels of nitrogen and sulphur on total free amino acids-mg/g dry weight at flower initiation in *Brassica juncea* L. cv. Varuna.
bud initiation.

(ii) **Shoot Apex:**

The mustard plant cultivar Varuna in $N_0$ treatment (without application of nitrogen) was found to contain free amino acids 5.85 mg/g dry weight of shoot apex at flower-bud initiation. Application of nitrogen increased the amino acid content in shoot apex at flower-bud initiation. The total free amino acids content in $N_{80}$ and $N_{100}$ treated plant was 6.30 and 6.78 mg/g dry weight respectively.

Similarly the mustard plant cultivar Varuna contained 5.80 mg total free amino acids/g of dry weight in shoot apex, whereas it increased to 6.15 and 6.35 mg/g dry weight in $S_{20}$ and $S_{40}$ treated plants.

The plants without nitrogen and sulphur application ($N_0S_0$) also contained 5.84 mg total free amino acids/g dry weight, while the amount of free amino acids was 6.95 mg in $N_{80}S_{20}$, 7.32 mg in $N_{80}S_{40}$, 7.52 mg in $N_{100}S_{20}$ and 7.85 mg in $N_{100}S_{40}$ treated plant/g dry weight of shoot apex (Table-14, Fig. 14).

At the time of flower initiation, the amount of total free amino acids in leaf was less than the amount of total free amino acids present in shoot apex. Thus, it is clear from the findings that mobilization of free amino acids from leaf to the shoot apex at the
time of flower initiation takes place more actively (Table-14, Fig. 14).

(12) Days to 50% Flowering:

The mustard plant cultivar Varuna, without nitrogen application (N₀) attended 50% flowering at 47.05 days after sowing. The application of nitrogen delayed the flowering. The 50% flowering reached at 48.68 days after sowing in N₈₀ and at 49.90 days after sowing in N₁₀₀ treated plants respectively.

Similar to plants having no nitrogen application (N₀), the plants without sulphur application (S₀) also attended 50% flowering at 46.87% days after sowing. As the doses of sulphur increased, the delay in 50% flowering had taken place. The plants treated with S₂₀ and S₄₀ attended 50% flowering at 48.80 and 49.90 days after sowing (Table-15, Fig. 15).

The plant of mustard cultivar Varuna having no application of nitrogen and sulphur (N₀S₀) reached the stage of 50% flowering at 46.90 days after sowing. The days taken for 50% flowering in N₈₀S₂₀, N₈₀S₄₀, N₁₀₀S₂₀ and N₁₀₀S₄₀ treated plant were 50.55, 51.90, 53.30 and 54.62 days after sowing respectively.

In this experiment, as the doses of N, S, and NS increased, the flowering was found delayed (Table-15, Fig. 15, Photograph- 3-A, 3-B, 3-C, 3-D, 3-E, 3-F, 3-G).
Days to 50% flowering as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.

**Treatments**

\[ T_1 = N_0, \quad T_2 = N_{80}, \quad T_3 = N_{100}, \]
\[ T_4 = S_0, \quad T_5 = S_{20}, \quad T_6 = S_{40}, \]
\[ T_7 = N_0S_0, \quad T_8 = N_{80}S_{20}, \quad T_9 = N_{80}S_{40}, \quad T_{10} = N_{100}S_{20}, \quad T_{11} = N_{100}S_{40} \]

**Fig. 15.** Days to 50% flowering as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.
Photograph- 3-A: Showing 50% flowering in untreated control plants of *Brassica juncea* L. cv. Varuna.
Photograph- 3-B: Showing 50% flowering in N80 treated plants of *Brassica juncea* L. cv. Varuna.
Photograph 3-C

$N_{100}$

Treatment

Photograph 3-C: Showing 50% flowering in $N_{100}$ treated plants of *Brassica juncea* L. cv. Varuna.
Photograph- 3-D

S20 Treatment

Photograph- 3-D: Showing 50% flowering in S20 treated plants of *Brassica juncea* L. cv. Varuna.
Photograph- 3-E: Showing 50% flowering in S<sub>40</sub> treated plants of Brassica juncea L. cv. Varuna.
Photograph- 3-F

Photograph- 3-G

Photograph- 3-F, 3-G : Showing 50% flowering in $N_{80}S_{40}$ and $N_{100}S_{40}$ treated plants of *Brassica juncea* L. cv. Varuna.
(13) Days to 95% Maturity:

Normally, the mustard crop cultivar Varuna was found to reach the stage of 95% maturity at 113.04 in N₀ treatment. The application of nitrogen delayed the maturity of crop. In N₈₀ treated plant, the 95% maturity of crop reached at 115.68 days and in N₁₀₀ at 117.36 days after sowing.

The plants without sulphur (S₀) application also reached the stage of 95% maturity at 113.48 days after sowing. The time taken for 95% maturity in S₂₀ and S₄₀ were 116.80 and 118.95 days after sowing (Table-16, Fig. 16).

The N₀S₀ treatment also showed similar results as in N₀ S₀ treatment. The N₀S₀ treatment also reached at the stage of 95% maturity on 114.02 days after sowing of crop. In plant treated with N₈₀S₂₀, N₈₀S₄₀, N₁₀₀S₂₀ and N₁₀₀S₄₀ the 95% maturity of crop reached at 118.05, 118.38, 119.30 and 120.40 days after sowing respectively (Table-16, Fig. 16).

In this way, the application of N, or S or NS delayed the maturity of crop.

(14) Branches/Plant at Harvest:

(i) Primary Branches:

At harvest of crop, the number of primary branches/plant in
Fig. 16. Days to 95% maturity as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.

Treatments

\[ T_1 = N_0, \quad T_2 = N_{80}, \quad T_3 = N_{100}, \]
\[ T_4 = S_0, \quad T_5 = S_{20}, \quad T_6 = S_{40}, \]
\[ T_7 = N_0 S_0, \quad T_8 = N_{80} S_{20}, \quad T_9 = N_{80} S_{40}, \quad T_{10} = N_{100} S_{20}, \quad T_{11} = N_{100} S_{40} \]
N₀ treatment was 4.17. It increased to 5.90 and 6.79 in N₈₀ and N₁₀₀ treated plants respectively. Similarly, the S₀ treatment had 4.19 primary branches/plant at harvest. The plants treated with S₂₀ and S₄₀ had 5.12 and 5.97 branches, on an average, respectively (Table-17, Fig. 17).

The treatment N₀S₀ also had the similar characteristic in producing primary branches/plant as in N₀ and S₀ treatment. The N₀S₀ treatment contained 4.14 branches/plant. It reached to 7.31 in N₈₀S₂₀, 8.75 in N₈₀S₄₀, 9.45 in N₁₀₀S₂₀ and 10.10 in N₁₀₀S₄₀ treated plants respectively at harvest (Table-17, Fig. 17).

The interaction effect was found superior to nitrogen (N) or sulphur (S) applied alone. More number of branches/plant was recorded in N₁₀₀S₄₀ treated plants.

(ii) **Secondary and other Branches:**

At harvest, the secondary and other branches in N₀ was 9.22/plant, whereas it was 11.25 in N₈₀ and 12.27 N₁₀₀ treated plants respectively.

The plants having no sulphur treatment (S₀), had 9.35 branches/plant and increased to 10.75 and 11.57 branches/plant in S₂₀ and S₄₀ treated plants respectively (Table-17, Fig. 17).

The treatment N₀S₀ also found to contain 9.27 branches
Fig. 17. Number of branches/plant at harvest as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.

**Treatments**

- $T_1 = N_0$, $T_2 = N_{80}$, $T_3 = N_{100}$,
- $T_4 = S_0$, $T_5 = S_{20}$, $T_6 = S_{40}$,
- $T_7 = N_0 S_0$, $T_8 = N_{80} S_{20}$, $T_9 = N_{80} S_{40}$, $T_{10} = N_{100} S_{20}$, $T_{11} = N_{100} S_{40}$
per plant at harvest. The application of N and S in combination produced more secondary and other branches/plant. It was 13.05 in N$_{80}$S$_{20}$, 13.97 in N$_{80}$S$_{40}$, 15.10 in N$_{100}$S$_{20}$ and 15.40 branches/plant in N$_{100}$S$_{40}$ treated plants respectively at harvest (Table-17, Fig. 17).

The combined effect of nitrogen and sulphur was found more beneficial than all other treatments including N$_{0}$, S$_{0}$, and N$_{0}$S$_{0}$ in respect of producing more secondary and other branches/plant at harvest.

(iii) Total Branches:

At time of harvesting of mustard crop cultivar Varuna, there were 13.39 branches/plant in N$_{0}$ treatment. The application of nitrogen @ 80 kg N/ha (N$_{80}$) and 100 kg N/ha (N$_{100}$) produced 17.15 and 19.65 branches/plant respectively. The plants without sulphur application (S$_{0}$) was found to produce 13.54 branches/plant whereas S$_{20}$ and S$_{40}$ treated plants produced 15.87 and 17.55 branches/plant at harvest (Table-17, Fig. 17).

The treatment N$_{0}$S$_{0}$ produced 13.42 branches/plant. The plants treated with N$_{80}$S$_{20}$, N$_{80}$S$_{40}$, N$_{100}$S$_{20}$ and N$_{100}$S$_{40}$ produced 20.36, 22.72, 24.55 and 25.50 branches/plant respectively at harvest (Table-17, Fig. 17).

The interaction effect of nitrogen and sulphur was found
Length of siliqua-cm at harvest as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.

**Treatments**

- $T_1 = N_0$, $T_2 = N_{80}$, $T_3 = N_{100}$,
- $T_4 = S_0$, $T_5 = S_{20}$, $T_6 = S_{40}$,
- $T_7 = N_0S_0$, $T_8 = N_{80}S_{20}$, $T_9 = N_{80}S_{40}$, $T_{10} = N_{100}S_{20}$, $T_{11} = N_{100}S_{40}$

**Fig. 18.** Length of siliqua-cm at harvest as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.
Photograph- 4: Showing the size of siliqua as influenced by different levels of N, S and N x S application in *Brassica juncea* L. cv. Varuna.
harvested at maturity. There were 972.5 siliquae/plant in N₈₀ and 980.8 siliquae/plant in N₁₀₀ treated plants. The plants without sulphur application (S₀) also contained 952.8 siliquae/plant at harvest. The plant treated with S₂₀ and S₄₀ produced 968.9 and 971.9 siliquae/plant at harvest.

Similarly, the plants of mustard cultivar Varuna without nitrogen and sulphur application (N₀S₀) were found to produce 954.9 siliquae/plant whereas 1058.3 siliquae/plant in N₈₀S₂₀, 1066.6 siliquae/plant in N₈₀S₄₀, 1075.0 siliquae/plant in N₁₀₀S₂₀ and 1082.8 siliquae/plant in N₁₀₀S₄₀ were harvested at maturity (Table-19, Fig. 19).

In all these treatments, the combined effect of nitrogen and sulphur was found better than remaining treatments including control (Photograph- 5).

All the doses of interaction like N₈₀S₂₀, N₈₀S₄₀, N₁₀₀S₂₀, N₁₀₀S₄₀ were found to have better response in producing more number of siliquae/plant at harvest than remaining treatments (Table-19, Fig. 19, Photograph-6-A, 6-B, 6-C & 7).

(17) Number of Seeds/Siliqua:

After harvesting, the seeds/siliqua were counted in each treatment. The N₀ treatment had 11.00 seeds/siliqua whereas N₈₀ and
Fig. 19. Number of siliquae/plant at harvest as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.

\[ T_1 = N_0, T_2 = N_80, T_3 = N_{100}, \]
\[ T_4 = S_0, T_5 = S_{20}, T_6 = S_{40}, \]
\[ T_7 = N_0 S_0, T_8 = N_{80} S_{20}, T_9 = N_{80} S_{40}, T_{10} = N_{100} S_{20}, T_{11} = N_{100} S_{40} \]
Photograph- 5: Showing fruiting behaviour (Siliqueae/plant) of $N_{100}^qS_{40}^q$ treated plants of *Brassica juncea* L. cv. Varuna.
Photograph- 6-A, 6-B, 6-C: Showing fruiting behaviour of a twig of *Brassica juncea* L. cv. Varuna as influenced by N, S and N x S treated plants.
Photograph 7: Showing fruiting behaviour of untreated (control) and $N_{100S_{40}}$ treated plants of *Brassica juncea* cv. Varuna.
N$_{100}$ treated plants produced 11.40 and 11.81 seeds/siliqua respectively. Similarly S$_0$ treatment produced 11.00 seeds/siliqua at harvest. The number of seeds/siliqua was found to increase over untreated control. There were 11.40 seeds/siliqua in S$_{20}$ and 11.61 seeds/siliqua in S$_{40}$ treated plants respectively (Table-20, Fig. 20).

The mustard plant, without nitrogen and sulphur (N$_0$S$_0$) produced 11.00 seeds/siliqua. There were 12.00 seeds/siliqua in N$_{80}$S$_{20}$, 12.25 seeds/siliqua in N$_{80}$S$_{40}$, 12.82 seeds/siliqua in N$_{100}$S$_{20}$ and 13.20 seeds/siliqua in N$_{100}$S$_{40}$ treated plants at harvest (Table-20, Fig. 20).

In all these treatments, combined effect of nitrogen and sulphur was found better than remaining treatments. The treatment N$_{100}$S$_{40}$ was found superior to remaining treatments in respect of producing more seeds/siliqua at harvest.

(18) Number of Seeds/Plant:

The plants of without nitrogen application (N$_0$) were found to produce 10482.5 seeds/plant at harvest. The plants treated with N$_{80}$ and N$_{100}$ produced 11086.5 and 11582.0 seeds/plant respectively (Table-21, Fig. 21).

The mustard plant cultivar Varuna without sulphur application (S$_0$) also produced 10477.5 seeds/plant whereas it was
Fig. 20. Number of seeds/siliqua at harvest as influenced by different levels of nitrogen and sulphur in Brassica juncea L. cv. Varuna.

Treatments

$T_1 = N_0$, $T_2 = N_{80}$, $T_3 = N_{100}$,
$T_4 = S_0$, $T_5 = S_{20}$, $T_6 = S_{40}$,
$T_7 = N_0S_0$, $T_8 = N_{80}S_{20}$, $T_9 = N_{80}S_{40}$, $T_{10} = N_{100}S_{20}$, $T_{11} = N_{100}S_{40}$
Seeds/Plant at harvest

16000.
14000 I 
12000-
;
100G0J
8000 J 
6000- 
4000- 
2000- 
0!
T1 T2 T3 T4 T5 T6 T7 T8 T9 T10 T11

Treatments

\[ T_1 = N_0, T_2 = N_{80}, T_3 = N_{100}, \]
\[ T_4 = S_0, T_5 = S_{20}, T_6 = S_{40}, \]
\[ T_7 = N_0S_0, T_8 = N_{80}S_{20}, T_9 = N_{80}S_{40}, T_{10} = N_{100}S_{20}, T_{11} = N_{100}S_{40} \]

Fig. 21. Number of seeds/plant at harvest as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.
11046.0 seeds/plant in $S_{20}$ and 11260.8 seeds/plant in $S_{40}$ treated plants respectively (Table-21, Fig. 21).

Also, the plants without nitrogen and sulphur application ($N_0S_0$) produced 10503.9 seeds/plant. The plants treated with nitrogen and sulphur produced more seeds/plant than remaining treatments. There were 12700.2 seeds/plant in $N_{80}S_{20}$, 13029.6 seeds/plant in $N_{80}S_{40}$, 13786.8 seeds/plant in $N_{100}S_{20}$ and 14293.6 seeds/plant in $N_{100}S_{40}$ treated plants respectively at harvest (Table-21, Fig. 21).

(19) **Seed Yield-g/Plant:**

The seed yield in mustard plant cultivar Varuna, without nitrogen application ($N_0$) was 68.61 g/plant. It increased to 75.82 g/plant in $N_{80}$ and 81.82 g/plant in $N_{100}$ treated plants respectively.

The plants without sulphur ($S_0$) also yielded 68.61 g of seeds per plant whereas the plants treated with $S_{20}$ and $S_{40}$ yielded 74.33 and 78.53 g of seeds/plant at maturity (Table-22, Fig. 22).

The plants having no nitrogen and sulphur supply ($N_0S_0$) produced 68.64 g of seeds/plant. The plants treated with $N_{80}S_{20}$, $N_{80}S_{40}$, $N_{100}S_{20}$ and $N_{100}S_{40}$ produced significantly more seeds yield/plant. It was 85.17 g in $N_{80}S_{20}$, 88.17 g in $N_{80}S_{40}$, 91.23 g in $N_{100}S_{20}$ and 94.58 g of seeds/plant respectively at harvest (Table-22,
Fig. 22. Seed yield-g/plant at harvest as influenced by different levels of nitrogen and sulphur in Brassica juncea L. cv. Varuna.
The combined effect of nitrogen and sulphur was found more effective in increasing the seed yield/plant in mustard. The higher dose $N_{100}S_{40}$ was better than all other remaining treatment in this respect.

**Biological Yield-g/Plant:**

The biological yield in $N_0$ treatment was 234.56 g/plant whereas the plant treated with $N_{80}$ and $N_{100}$ showed 242.23 and 244.60 g of biological yield/plant respectively.

Also, the plants without sulphur application ($S_0$) had 234.16 g biological yield/plant. It was 242.51 g in $S_{20}$ and 243.27 g/plant in $S_{40}$ treated plants at harvest (Table-23, Fig. 23).

The plants without nitrogen and sulphur application ($N_0S_0$) contained 234.18 g/plant of biological yield, whereas it reached to 247.68 g in $N_{80}S_{20}$, 248.71 g in $N_{80}S_{40}$, 250.81 g in $N_{100}S_{20}$ and 252.21 g/plant in $N_{100}S_{40}$ treated plant respectively (Table-23, Fig. 23).

In all these treatments, all the interactions were found better than other treatments in respect of having more biological yield/plant. The treatment $N_{100}S_{40}$ was superior to all other treatments (Table-23, Fig. 23).
Fig. 23. Biological yield g/Plant at harvest as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.

Treatments

\[ T_1 = N_0, \quad T_2 = N_{80}, \quad T_3 = N_{100}, \]
\[ T_4 = S_0, \quad T_5 = S_{20}, \quad T_6 = S_{40}, \]
\[ T_7 = N_0S_0, \quad T_8 = N_{80}S_{20}, \quad T_9 = N_{80}S_{40}, \quad T_{10} = N_{100}S_{20}, \quad T_{11} = N_{100}S_{40} \]
(21) Harvest Index (HI) :

The harvest index of plants, without nitrogen application (N₀) was 29.24. It reached to 31.20 in N₈₀ and 32.21 in N₁₀₀ treated plant respectively.

In the same way the plants without sulphur application (S₀) were found to have 29.19 harvest index while S₂₀ and S₄₀ were found to have 30.52 and 32.22 harvest index respectively (Table-24, Fig. 24).

The mustard plants cultivar Varuna having no supply of nitrogen and sulphur (N₀S₀) had 29.41 harvest index but in plants treated with different doses of nitrogen and sulphur had more harvest index than all the other doses. The harvest index was 34.35 in N₈₀S₂₀, 35.44 in N₈₀S₄₀, 36.36 in N₁₀₀S₂₀ and 37.50 in N₁₀₀S₄₀ treated plants respectively (Table-24, Fig. 24).

(22) Seed Yield q/ha :

The seed yield was 8.05 q/ha each in N₀, S₀, and N₀S₀ treatment. As the doses of nitrogen increased the seed yield q/ha was found to increase over N₀, S₀, and N₀S₀ respectively. The seed yield was 9.03 q/ha in N₈₀ and 10.71 q/ha in N₁₀₀ treated plants respectively.

Similarly, the treatments S₂₀ and S₄₀ also produced 9.05 and 10.20 q/ha of seeds respectively.
Fig. 24. Harvest Index % as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.

Treatments

\[ T_1 = N_0, T_2 = N_{80}, T_3 = N_{100}, \]
\[ T_4 = S_0, T_5 = S_{20}, T_6 = S_{40}, \]
\[ T_7 = N_0 S_0, T_8 = N_{80} S_{20}, T_9 = N_{80} S_{40}, T_{10} = N_{100} S_{20}, T_{11} = N_{100} S_{40} \]
The plants having nitrogen and sulphur application \((N_{80}S_{20})\) had 11.30 q/ha of seed yield whereas the plants treated with \(N_{80}S_{40}\), \(N_{100}S_{20}\), and \(N_{100}S_{40}\) were found to produce 11.30, 12.80, 14.40 and 15.89 q/ha of mustard seeds respectively (Table-25, Fig. 25).

In all these treatments all the interaction treatments were found better than others in respect of producing more seeds q/ha. The higher dose \(N_{100}S_{40}\) was significantly superior to their lower doses as well as remaining doses of nitrogen or sulphur and control respectively (Table-25, Fig. 25).

(23) Test weight (1000-grain weight)-g :

The 1000-grain weight in untreated control \(N_{0}, S_{0}\), and \(N_{0}S_{0}\) was 6.08, 6.09 and 6.10 g respectively.

The plants treated with \(N_{80}\) and \(N_{100}\) were found to have more test weight ie. 6.14 g in \(N_{80}\) and 6.18 g in \(N_{100}\) respectively.

Similarly, the plants treated with sulphur also increased the test weight. It was 6.13 and 6.16 g in \(S_{20}\) and \(S_{40}\) treated plants respectively (Table-26, Fig. 26).

The interaction effect of nitrogen and sulphur was found more effective in increasing the test weight of mustard seeds. It was 6.21 g in \(N_{80}S_{20}\), 6.35 g in \(N_{80}S_{40}\), 6.45 g in \(N_{100}S_{20}\), and 6.53 g in \(N_{100}S_{40}\) treated plants respectively. (Table 26, Fig. 26).
T1 = N0, T2 = N80, T3 = N100,
T4 = S0, T5 = S20, T6 = S40,
T7 = N0S0, T8 = N80S20, T9 = N80S40, T10 = N100S20, T11 = N100S40

Fig. 25. Seed Yield (q/ha) as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.
Fig. 26. Test weight (1000-grain weight) of seeds-g as influenced by different levels of nitrogen and sulphur in *Brassica juncea* L. cv. Varuna.

Treatments

\[ T_1 = N_0, \ T_2 = N_{80}, \ T_3 = N_{100}, \]
\[ T_4 = S_0, \ T_5 = S_{20}, \ T_6 = S_{40}, \]
\[ T_7 = N_0S_0, \ T_8 = N_{80}S_{20}, \ T_9 = N_{80}S_{40}, \ T_{10} = N_{100}S_{20}, \ T_{11} = N_{100}S_{40} \]
In all these treatments, the interaction effect was found superior to N or S application. The $N_{100}S_{40}$ treatment had the maximum test weight (6.53 g) than other interactions as well as N or S and untreated control.

(24) Oil Content (%): 

The oil content in $N_0$ treatment was 40.60% while it increased to 40.75 and 40.91 in $N_{80}$ and $N_{100}$ treated plants respectively.

The $S_0$ treatment was also found to contain 40.60% of oil in seeds. It reached to 40.66 and 40.84% in $S_{20}$ and $S_{40}$ treated plants respectively (Table-27, Fig. 27)

The plant having no application of nitrogen and sulphur ($N_0S_0$) yielded 40.61% of oil in seeds at harvest. The plants treated with $N_{80}S_{20}$, $N_{80}S_{40}$, $N_{100}S_{20}$ and $N_{100}S_{40}$ were found to have more oil content% in seeds than all other treatments.

The oil content was 41.17% in $N_{80}S_{20}$, 41.32% in $N_{80}S_{40}$, 41.71% in $N_{100}S_{20}$ and 41.92% in $N_{100}S_{40}$ respectively, but the difference in oil content % was not significant (Table-27, Fig. 27).

The Plants of mustard Brassica juncea L. cultivar Varuna treated with nitrogen or sulphur or nitrogen + sulphur were found to increase the height of plant, number of green leaves/plant, primary,
Treatments

$T_1 = N_0, T_2 = N_{80}, T_3 = N_{100},$
$T_4 = S_0, T_5 = S_{20}, T_6 = S_{40},$
$T_7 = N_0S_0, T_8 = N_{80}S_{20}, T_9 = N_{80}S_{40}, T_{10} = N_{100}S_{20}, T_{11} = N_{100}S_{40}$

Fig. 27. Oil content (%) in seeds as influenced by different levels of nitrogen and sulphur in Brassica juncea L. cv. Varuna.
secondary and total branches/plant as well as the total-N, total Protein, amino acids and reducing sugar content in leaf and shoot apices resulting the formation of more flowers, more siliquae/plant, more seeds per siliqua, more seeds/plant, seed yield/plant and seed yield q/ha resulting the production of more oil but not the increase in oil per cent significantly.

Thus, it is obvious that the oil content per cent is not increased significantly but due to higher production of seed, the amount of oil produced/ha is more with the application nitrogen or sulphur or nitrogen + sulphur respectively. The treatment N$_{100}$S$_{40}$ is more useful in respect of seed and oil production in Indian mustard Brassica juncea Linn. cultivar Varuna.