EXPERIMENTAL RESULTS
EXPERIMENTAL RESULTS

The present investigation "Studies on the performance of provenances and plus trees, floral biology and geographical variation in neem in Bundelkhand region" was carried out to understand the geographical variation, floral biology and performance of provenances and plus trees of neem growing in Bundelkhand region. The details of results are described here:

4.1 Geographical Variations

4.1.1 Range

A set of 200 trees of neem from 40 tehsils of 12 districts of Bundelkhand region were evaluated for assessing morphological and genetic variation in respect of six characters. The study revealed the presence of wide genetic diversity among the materials (Table 3a,b,c).

Widest range in variability for tree height growth was observed in marked trees from Jatara Tehsil of Tikamgarh district (10.18 - 19.39 m with mean value of 13.88 ± 1.76m), followed by that among those collected from Jhansi Tehsil of Jhansi district (range 10.10 - 19.39m and mean 12.50 ± 1.57m). For diameter at breast height (DBH), highest range was observed in trees of Chhattarpur Tehsil of Chhattarpur district (57.96 - 138.53 cm with mean of 89.16 ± 13.24 cm) followed by Lalitpur Tehsil of Lalitpur district (41.40 - 130.57 cm with mean of 80.25 ± 12.87 cm).

For clean bole height (CBH), widest range was observed in Kalpi Tehsil of Jalaun district (283.00 - 810.00 cm with mean of 399.20± 92.02cm), followed by Jalaun Tehsil of Jalaun district (225.00 - 540.00 cm with mean of 377 ± 46.12 cm). Canopy area showed widest range in Konch Tehsil of Jalaun district (619.83 - 1498.91 m² with mean of 891.17 ± 147.69 m²), followed by Lahar Tehsil of Datia district (619.83 - 1498.72 m² with mean of 825.76 ± 151.71 m²). For number of primary branches, highest range was observed in Rath Tehsil of Hamirpur district.
PLUS TREES OF NEEM

Open canopy

Traditional
(3.00 - 8.00 with mean of 5.20 ± 1.03) followed by Banda Tehsil of Banda district
(3.00 - 7.00 with mean of 3.80). The maximum range for taper of tree was
observed in Jhansi Tehsil of Jhansi district (16.80 - 44.80 with mean of 23.23
± 4.84), followed by Datia Tehsil of Datia district (15.31 - 37.20 with mean of

For tree height in Orai Tehsil of Jalaun district, for DBH in Jhansi Tehsil of
Jhansi district, for clean bole height (CBH) in Bhande of Datia district, for canopy
area in Maudha Tehsil of Hamir district, for number of primary branches in Gulganj
Tehsil of Tikamgarh district, for Taper of Tree in Rehli Tehsil of sagar district
minimum range was observed.

4.1.2 Coefficient of Variation

Coefficient of variation was highest (60.96) and lowest (6.69) for plant
height in Baberu Tehsil of Banda district and Konch Tehsil of Jalaun district,
respectively. Similarly, it was highest for DBH, in Jhansi Tehsil of Jhansi district
(48.65) and lowest in Konch Tehsil of Jalaun district (3.45). Highest (51.54) and
lowest (7.41) coefficient of variation for clean bole height in Chhatarpur Tehsil of
Chhatarpur district and Mau Tehsil of Banda district was highest and lowest,
respectively. The highest C.V. for canopy diameter (60.71) in Hatta Tehsil of Damoh
district and lowest (11.04) in Pawai Tehsil of Panna district was recorded. The
highest (44.50) and coefficient of variation for number of primary branches in
Hamirpur Tehsil of Hamirpur district and lowest (00.00) in Gulganj Tehsil of
Teekamgarh district was observed. For highest coefficient of variation (46.57) at
taper of tree in Jhansi Tehsil of Jhansi district and lowest (7.43) in Rehli Tehsil of
Sagar district was recorded.

4.2 Floral Biology

4.2.1 Duration and Habit of Flowering

Flowering in neem started in the 2nd week of March with new flush of
leaves, immediately before or after the abscission of old leaves. It continued up to
second week of May with peak in the first fortnight of April. However, relatively
longer flowering period i.e., from 2nd week of February to May was observed in old
trees grown on nearby fields and road side.
The inflorescence is a long and axillary panicle on old branches with many flowers. Flowers were greenish white in colour and turned white with age. They possessed characteristic sweet aroma which could be sensed at night.

4.2.2 Panicle Development

The number of days taken to initiate opening of flowers in all the tagged panicles were recorded (Table 4). It is clear from the Table-4 that 20-26 days (mean 23.20 ± 1.13) were required for panicle development. Out of 100 panicles, as many as 91 developed. The floral parts arise in acropetal succession. The new emerging panicles were dull green in colour which gradually increase in length. After five days of emergence of panicle, two branches at the base were observed which gradually increased in the number as well as length. The length of panicle increased rapidly upto 15 - 18 days. The emerging flower buds were greenish in colour. A greenish white spot appeared on tip of the bud after 7 - 8 days which gradually increased in size. After about 21 days, flower buds turned greenish white and finally white or pale yellow in colour. Fully developed panicle was long, slender, very lax and branched. The flower buds were arranged on very small sub branches of panicle. At a particular developmental stage of a panicle, flower buds at various developmental stages were observed.

The Tree No.5 required highest number of days (26) for panicle development, followed by Tree Nos. 3 and 6 which took 25 and 24 days. However, Tree No.1 took minimum number of days (20) for the panicle development.

4.2.3 Panicle Dimension and Composition

As is evident from the data given in Table-4 panicle length was maximum (26.70 cm) in Tree No. 4, while it was minimum (14.20 cm) in Tree No.7 with general mean of 18.97 ± 1.27 cm.

Tree Nos. 2 and 5 recorded maximum (107.70) and minimum number of buds (40.40) per panicle, respectively. The number of buds per panicle varied between 40.40 - 107.70 with an average of 70.47 ± 6.82.

The maximum average number of axillary branches per panicle was recorded in Tree No. 9 (9.60), followed by (8.90) in Tree No.10. The number of axillary branches varied between 5.4 and 9.6 with a mean of 7.45 ± 0.38.
4.2.4 Flower and Fruit Development

Observation on period from bud initiation to fruit initiation and period of fruit initiation to maturity of fruit were recorded in each of the ten trees. The results obtained are presented in Table 4.

A persual of the data given in Table 4 revealed that period from initiation of bud to opening of flower was maximum (29.00 days) in tree Nos. 2 and 5, while it was minimum (23 days) in tree Nos. 9 and 10 with general mean of 25.55 ± 0.70 days. Thus, the period from bud initiation to opening of flowers varied from 23.0 to 29.0 days.

The period of opening of flowers to fruit initiation was maximum in Tree Nos. 2, 4, 6 and 7 (20 days) followed by (19 days) in tree Nos. 3, 5, 8, 9 and 10 (19 days). Tree No.1 recorded minimum period of opening of flower to fruit initiation (18 days).

Tree Nos. 2 and 6 recorded maximum period of fruit initiation to its maturity (52.00 days), while Tree Nos. 5 and 8 recorded minimum period (49.0 days).

4.2.5 Anthesis

The observation on time of anthesis was recorded for the peak period of flowering and the number of buds opened at different period of the day was noted from 5.00 A.M. to 4.00 A.M. (next day).

It is evident from the table 5 that anthesis starts in the evening from 9.00 P.M. and continues upto 4.00 A.M. next day. The maximum flowers open (88% ) in Treen No.9 followed by 83% in Tree No.10 and minimum (28%) in Tree No.1 between 9 - 10 P.M.

4.2.6 Dehiscence of Anthers

The observation on time of dehiscence were recorded at half an hour interval between 10.00 A.M. to 6.00 P.M. in unopened flowers which were likely to open by evening. The data on dehiscence of Anthers are presented in Table-6.
STAGES OF FLORAL BUD DEVELOPMENT
ANTHESIS PATTERN IN NEEM
The dehiscence of anthers started before anthesis of flowers. It started at 12.00 A.M. and continued upto 3.30 P.M with maximum frequency between 2.00 - 2.30 P.M. in the closed flowers. This process was also affected by the temperature. The dehiscence started late i.e., at 12.30 P.M. when maximum and minimum temperatures were low. Maximum percentage of dehiscence of anthers was recorded between at 2.00 P.M. and 2.30 P.M., ranging between 27.78 (in Tree No.1) to 47.62 percent (in Tree No.8).

4.2.7 Pollen Viability and Pollen Size

Pollen viability was determined by aceto-carmine stainability test. The pollen grains which stained deeply red and looking normal under microscope were counted as viable, while those shrivelled and unstained ones were considered as non-viable. The colour of unstained and non-viable pollen was brownish. From the data presented in Table-7, it is obvious that pollen viability varied from tree to tree in between 83.33 to 100.00 percent with average of 96.27 ± 1.88 and remained constant. The pollen size also varied from tree to tree between 38.00 to 47.50 with a mean of 44.65 ± 0.86.

4.2.8 Pollen Germination

The germination of pollen grains was studied in artificial media viz., sucrose solution at 5, 10, 15, 20, 25 and 30 percent with (0.005 and 0.01 percent) and without boric acid. The data are presented in Table 8.

There was no pollen germination in 5, 10, 15, 20, 25 and 30 percent sucrose solutions alone as well as with boric acid concentration (0.005 and 0.02).

4.2.9 Fruit/Seed Setting Ability

Ten panicles each at top, middle and lower portions of tree were tagged on each of the ten trees, making total of 100. The matured fruits per panicle were recorded and percent fruit set was calculated and presented in Table 9.

It is evident from the Table 9 that percent fruit set was lowest at the lower portion, highest at top and intermediate at the middle of the tree portion. The highest number of panicle (17) which did not had any fruit set were also at the lower portion, followed by middle (7) and the top (4) of the tree.
VIABLE POLLEN GRAINS

Low magnification (10 x objective)

Magnified view (40 x objective)
POLLEN GERMINATION

Pollen tube emergence

Viable pollen tube stained with Acetocarmine
4.2.10 Pollination Studies

Ten panicles in each of the ten trees were tagged and another 10 panicles were bagged with paper bag continuously for six days. The number of mature fruit in both the cases (open and selfed) was recorded and presented in Table-10.

Results indicated that fruit setting in selfed flowers was 3.06 percent, while in open pollinated ones it was 4.15 percent. There was a wide variation in fruit set from tree to tree.

Growth attributes (Plant height and collar diameter) and leaf characters recorded in self and open pollinated progenies at the age of 21 months. Plant height and collar diameter of selfed progeny were 231.25 cm and 5.15 cm while, in open pollinated progeny these measurements were 196.25 cm and 3.86 cm, respectively. Results indicated that there was no difference between progenies of self and open pollinated seedlings for growth and leaf characters (Table 11). Hence inbreeding depression was absent in self pollinated tree species.

4.3 Provenances and Plus Trees Performance

4.3.1 Seed Physical Parameters

For this study, the measurement and weight of seeds were recorded and the results are presented in Tables 12 and 13. From the Table 12 and 13, it is observed that a good amount of variability existed among different provenances and plus trees in respect of seed characters.

Maximum variability in seed length was observed among three provenances, which are from Kalpi (0.95-1.80cm with mean of 1.150 ± 0.022 cm), Hamipur (0.90 - 1.65 cm with mean of 1.203 ± 0.022cm) and Tikkamgarh (0.85 - 1.60 cm with mean of 1.145 ± 0.024cm) sites. For seed diameter, maximum variability was observed in provenances Moth (0.45 - 0.95 cm with mean of 0.593 ± 0.011), Hamipur (0.50 - 0.95 cm with mean of 0.630 ± 0.012cm) and Satana provenances (0.45 - 0.85 cm with mean of 0.587 ± 0.012). The maximum mean for 100- seed weight was observed in Ghattampur provenances (22.58g), followed by Maudha (21.48g) and Jhansi provenances (20.90g).
Maximum range of variability in seed length was observed in plus tree, PT-27 (0.85 - 1.50 cm with mean of $1.020 \pm 0.015$ cm), PT-22 (1.10 - 1.70 cm with mean of $1.437 \pm 0.017$ cm) and PT-21 (1.20 - 1.85 cm with mean of $1.440 \pm 0.024$ cm). For seed diameter, maximum range was observed in PT-28 (0.45 - 0.85 cm with mean of $0.658 \pm 0.011$ cm) followed by PT-4 (0.40 - 0.40 cm with mean of $0.584 \pm 0.010$ cm). The maximum 100-seed weight in PT-21 (20.28 g) followed by PT-8 (19.30 g) was recorded.

### 4.3.2 Nursery Studies

The results on seedling characters of the nursery studies, variation among provenances and plus trees are presented in table 14 and 15.

Maximum seedling height of three provenances, Katani provenances (83.57 ± 3.23 cm), Damoh provenances, 75.50 ± 2.77 cm) and Rajgarh provenance (71.37 ± 3.12 cm) was noted Fig. 3. The maximum mean value of basal diameter (cm) of provenances Katani (0.70 ± 0.02 cm), Tikkamgarh (0.68 ± 0.04 cm) and Jhansi (0.67 ± 0.70 cm). The maximum leaf length in provenance of Bhopal (6.40 ± 0.13 cm), Rajgarh (6.37 ± 0.22 cm) and Damoh (6.10 ± 0.23 cm), whereas maximum leaf width of provenance of Bhopal (2.40 ± 0.16 cm), Jabalpur and Damoh (2.15 ± 0.12 cm) and Rajgarh (2.12 ± 0.14 cm) were recorded.

The maximum seedling height in plus tree PT-8 (72.30 ± 3.15 cm) followed by PT-20 (65.83 ± 3.20 cm) was observed (Fig. 4). Maximum basal diameter was observed in PT-24 (0.68 ± 0.04 cm), followed by PT-7 (0.66 ± 0.066 cm). Maximum leaf length in PT-10 (6.75 ± 0.25 cm) followed by PT-8 (6.50 ± 0.15 cm) was noted. On the other hand, the maximum leaf width (cm) in PT-12 (3.28 ± 0.10 cm) followed by PT-27 (2.35 ± 0.14 cm) was observed.

### 4.3.3 Field Observations

Plant height and collar diameter at the age of 21 months after plantation in provenances trial ranged from 147 - 229 cm and 3.0 - 4.90 cm, with 195.49 ± 3.73 and 3.98 ± 0.11, respectively. At 14 months magnitude of plant height, collar diameter, length of primary branches, canopy diameter, number of primary branches, leaf area index and leaf area ratio varied from 144-205 cm, 2.7-4.5cm, 106-159cm, 1.6-5.9cm, 3.1-6.9, 9.94-15.07 and 2.52-3.03 with mean of 167.99 cm
NEEM NURSERY

NEEM (ANACARDIUM OCCIDENTALE)
GERmplasm OF CENTRAL INDIA
PROVENANCES: 36
PLUS TREES: 18
ICAR CESS FUND SCHEME
VARIATION IN LEAFLET PATTERN
FIG. 3: SEEDLING HEIGHT OF PROMISING PROVENANCES OF NEEM (AGE - 12 MONTHS)
FIG. 4: SEEDLING HEIGHT OF PROMISING PLUS TREES OF NEEM (AGE - 12 MONTHS)
FIG. 5 : PLANT HEIGHT OF PROMISING PROVENANCES OF NEEM AT DIFFERENT AGE
FIG. 6: PLANT HEIGHT OF PROMISING PLUS TREES NEEM AT DIFFERENT AGE
FIG. 7: COLLAR DIAMETER OF PROMISING PROVENANCES OF NEEM AT DIFFERENT AGE
Fig. 8: Collar diameter of promising plus trees of Neem at different age.
± 3.60, 3.56 cm ± 0.08, 139.45 cm ± 3.22, 3.23 cm ± 0.31, 4.37 ± 0.14, 11.55 ± 0.26 and 2.80 ± 0.04, respectively. These results showed that there was wide range of variability exist between the provenances (Table 16).

Plant height and collar diameter at the age of 21 months after plantation in plus tree progenies trial ranged from 129-215 cm with mean of 181.37 cm ± 5.83 and from 2.1-3.8 cm with 3.22 cm ± 0.16, respectively. At 14 months, magnitude of plant height, collar diameter, length of primary branches, canopy diameter, number of primary branches, leaf area index and leaf area ratio varied from 107-189 cm, 2.2-4.0 cm, 78-152 cm, 1.1-3.4 cm, 2.10-6.20, 9.88-13.30, 2.55-3.10 with mean of 156.50 cm ± 5.64, 3.18 cm ± 0.11, 112.70 cm ± 4.32, 1.96 cm ± 0.24, 4.51 ± 0.37, 11.68 ± 0.34, 2.86 ± 0.022, respectively. These results indicated that there was wide range of phenotypic variability exist in the collected materials of neem (Table 17).

4.3.4 Analysis of Variance for 10 Characters of Provenances of 33 months old plants

The 'F' test indicated that the variances among the provenances were highly significant for all the characters under study. (Table 18a). This indicated that genetic variability present among provenances was quite appreciable.

4.3.5 Means and Variability of Provenances

As is evident from Table-19a that maximum range of variability in plant height was observed in provenances of Sagar (226.71 - 378.22 cm with mean of 330.57 ± 3.90 cm), Damoh (219.17 - 371.52 cm with mean of 341.22 ± 4.42 cm) and Datia (181.12 - 310.33 cm with mean of 242.77 ± 0.35 cm). The plant height of promising provenances is being shown in Fig. 5.

For collar diameter, maximum variation was observed in provenances of Kota (5.75 - 8.85 cm with mean of 7.88 ± 0.34 cm), Satana (5.24 - 8.05 cm with mean of 6.81 ± 2.43 cm) and Dabra (4.50 - 7.10 cm with mean of 6.63 ± 0.26 cm). The collar diameter of promising provenances at different ages is being shown in Fig. 7.

For diameter at breast height (DBH), the maximum range was observed in provenances Vidisha (2.67 - 3.80 cm with mean of 3.42 ± 0.11 cm), Karera (2.70 - 3.92 cm with mean of 3.61 ± 0.17 cm) and Datia (1.21 - 2.40 cm with mean of 2.09 ± 0.16 cm).
PROVENANCES TRIAL
Maximum variability was observed for number of branches per tree in Charkha (1.80 - 2.94 with mean of 2.71 ± 0.13), Jabalpur (3.50 - 4.52 with mean of 4.00 ± 0.14) and Dabara provenances (3.85 - 4.80 with mean of 4.49 ± 0.13).

For number of leaves per branch, highest range was observed in Murena provenances (35.20 - 61.21 with mean of 48.55 ± 1.47), Jhansi (37.20 - 58.00 with mean of 45.03 ± 2.22) and Moth provenances (33.28 - 52.10 with mean of 43.22 ± 1.94). For total pruned biomass, maximum variability was observed in Jhansi provenances (5.00 - 6.50 kg with mean of 5.67 ± 0.18 kg), Damoh (8.45 - 9.87 kg with mean of 9.22 ± 0.18 kg) and Moth provenances (6.36 - 7.50 kg with mean of 6.79 ± 0.11 kg).

For weight of fresh leaves, maximum range was observed in Sagur provenances (2.05 - 3.05 kg with mean of 2.40 ± 0.11 kg), Moth (2.60 - 3.50 kg with mean of 2.92 ± 0.12 kg) and Mureña provenances (1.15 - 1.96 kg with mean of 1.47 ± 0.06 kg).

For weight of fresh wood, maximum range was observed in Damoh provenance (5.20 - 6.55 kg with mean of 5.90 ± 0.13), Dabra (6.90 - 7.95 kg with mean of 7.50 ± 0.18 kg) and Kalpi provenances (2.89 - 3.75 kg with mean of 3.25 ± 0.11 kg).

Maximum range of variability for weight of dry leaves in Damoh provenance (0.95 - 1.25 kg with mean of 1.08 ± 0.02 kg), Chhattarpur (0.57 - 0.80 kg with mean of 0.66 ± 0.02 kg) and Karera provenances (0.45 - 0.65 kg with mean of 0.54 ± 0.02 kg) was observed.

For weight of dry wood, maximum range of variability was observed in Bhopal provenances (2.55 - 3.62 kg with mean of 3.12 ± 0.14 kg), Bhognipur (1.65 - 2.70 kg with mean of 2.33 ± 0.11 kg) and Katani provenances (2.05 - 3.00 kg with mean of 2.43 ± 0.10 kg).

Highest coefficient of variance was observed for collar diameter in Guna provenance (13.47), for DBH in Shivpuri (22.10), for number of branches per tree in Ghatampur provenances (16.80), for number of leaves per branch in Dabra (22.23), for weight of fresh wood in Charkha (20.31), for weight of dry leaves in Dabra provenances (10.59), for weight of dry wood in Bhopal provenances (12.99) (Table 19a).
4.3.4 Estimates of Heritability and Genetic Advance

The estimates of heritability (broad sense) and expected genetic advance (%) for 10 characters of provenances are presented in Table 20(a) & Fig. 9. High estimates of heritability were recorded for plant height, collar diameter, DBH, number of branches per tree, number of leaves per branch. Pruned biomass, weight of fresh leaves, weight of fresh wood, weight of dry leaves and weight of dry wood.

The expected genetic advance expressed as percent of mean was high for weight of fresh wood, pruned biomass, weight of dry wood, weight of fresh leaves, weight of dry leaves and DBH and medium for the number of branches per tree, collar diameter, number of leaves per branch and plant height.

The direct selection parameters indicated that the characters DBH, pruned biomass, weight of fresh leaves, weight of fresh wood, weight of dry leaves and weight of dry wood had high heritability with high genetic advance. Plant height, collar diameter, number of branches per tree and number of leaves per branch had high heritability with medium genetic gain.

4.3.7 Variance and Coefficient of Variability

The coefficients of variability for all the ten characters has been given in the Table 21(a) and their graphic representation has been shown in the Fig. 11.

The highest phenotypic coefficient of variance was observed for weight of fresh wood (37.56), weight of dry wood, (37.40), pruned biomass per tree (33.22), weight of fresh leaves (32.69), weight of dry leaves (25.69), number of branches per tree (19.47), DBH (18.89) and collar diameter (15.70). The minimum magnitude of this parameter was observed for plant height (10.25).

The estimates of coefficient of genotypic variance for all 10 characters are presented in Table-21(a) and illustrated in Fig. 11. In general, the values of this parameter were lower than their respective coefficients of phenotypic variance. The maximum amount of coefficient of genotypic variance was observed for weight of fresh wood (36.35) and minimum for plant height (9.60).
Fig. 11: Genotypic & phenotypic coefficients of variation in provenances of neem
4.3.8 Correlation Coefficients for Provenances

The genotypic and phenotypic correlation coefficients were worked out to measure the association among the characters studied. It is obvious from the table 22(a) that the magnitude of genotypic correlation was higher than their respective phenotypic correlation coefficients in most of the cases.

In provenances (Table 22a) plant height was associated positively and significantly with collar diameter and DBH at phenotypic level. Collar diameter was associated positively and significantly with DBH, pruned biomass, weight of fresh leaves, weight of dry leaves and weight of dry wood had negative correlation with number of leaves per branch. DBH was associated positively and significantly with weight of fresh leaves and had weak association with pruned biomass, weight of fresh wood, weight of dry leaves and weight of dry wood. Number of branches per tree had positive association with remaining characters. Number of leaves per branch also had positive association with all other remaining traits. Pruned biomass was positively and significantly associated with weight of fresh leaves, weight of fresh wood, weight of dry leaves and weight of dry wood. Weight of fresh wood was positively and significantly associated with weight of dry leaves and weight of dry wood. Weight of dry leaves was positively and significantly associated with weight of dry wood.

4.3.9 Path Coefficient Analysis of Provenances

To obtain a clear understanding of the genotypic and phenotypic correlation of weight of dry wood with its contributing characters were partitioned into direct and indirect effects through path coefficient analysis. The estimates of direct and indirect effects are presented in table 23(a) and 23(b) and their graphic representation has been shown in Fig. 13.

4.3.9.1 Phenotypic Effects

Plant height had low positive association with dry weight of wood, though the direct effect was positive. The positive indirect effect via number of branches per tree, total pruned biomass per tree, weight of fresh leaves, weight of fresh wood and weight of dry leaves were nullified by negative indirect effect through collar diameter, DBH and number of leaves per branch.
Collar diameter had positive and significant association with dry weight of wood, though the direct effect was negative. The positive indirect effect via number of branches per tree, number of leaves per branch, pruned biomass, weight of fresh leaves, fresh weight of wood and weight of dry leaves were nullified by negative indirect effect through DBH.

DBH had positive and significant association with weight of dry wood through the direct effect was negative. The positive indirect effect via number of branches per tree, pruned biomass, weight of fresh leaves, weight of fresh wood and weight of dry leaves were nullified by negative indirect effect through collar diameter and number of leaves per branch.

Number of branches per tree had positive direct effect. The indirect effect via plant height, pruned biomass, weight of fresh leaves, fresh weight of wood and weight of dry leaves were nullified by negative indirect effect through collar diameter, DBH and number of leaves per branch.

Number of leaves per branch had low positive association with dry weight of wood, the direct effect was negative. The positive indirect effect via plant height, collar diameter, number of branches per tree, pruned biomass, weight of fresh leaves, weight of fresh wood and weight of dry leaves had negative indirect effect via DBH.

Pruned biomass had positive and significant association with dry weight of wood, though the direct effect was positive. The positive indirect effect via plant height, number of branches per tree, fresh weight of leaves, weight of fresh wood and weight of dry leaves were nullified by negative indirect effect via collar diameter, DBH and number of leaves per branch.

Weight of fresh leaves had positive direct effect on dry weight of wood. The positive indirect effect via number of branches per tree, pruned biomass and weight of fresh leaves had negative indirect effect via collar diameter, DBH and number of leaves per branch.

Weight of fresh wood had positive and significant association with weight of dry wood though the direct effect was positive. The positive indirect effect via number of branches per tree, pruned biomass, fresh weight of leaves weight of dry leaves and had negative indirect effect via collar diameter, DBH and number of leaves per branch.
FIG. 13: PATH DIAGRAM OF PROVENANCES OF NEEM SHOWING CAUSE AND EFFECT RELATIONSHIP
Weight of dry leaves had positive and significant association with weight of dry wood, though the direct effect was positive. The positive and indirect effect via plant height, number of branches per tree, pruned biomass, weight of fresh leaves and weight of fresh wood had indirect and negative effect via collar diameter, DBH and number of leaves per branch.

4.3.9.2 Genotypic Effect

Plant height had negative direct genotypic effect on weight of dry wood. The positive indirect effect via DBH, number of leaves per branch and weight of fresh wood were nullified by the negative indirect effect via collar diameter, number of branches per tree and fresh and weight of dry leaves.

Collar diameter also had negative direct effect. The positive indirect effect via DBH, pruned biomass, number of branches per tree, number of leaves per branch and fresh and weight of dry leaves.

DBH had positive and direct genotypic effect on weight of dry wood. The positive indirect effect via number of leaves per branch, pruned biomass per tree and weight of fresh wood had negative indirect effect via plant height, collar diameter, number of branches per tree and fresh and dry weight of leaves.

Number of branches per tree had negative direct effect. The positive direct effect via DBH, number of leaves per branch, pruned biomass and weight of fresh wood had the negative indirect effect via plant height, collar diameter and fresh and dry weight leaves.

Number of leaves per branch had direct positive effect. The positive indirect effect via collar diameter, DBH, pruned biomass and weight of fresh wood had negative indirect effect via plant height, number of branches per tree and fresh and dry weight of leaves.

Pruned biomass per tree had positive association with weight of dry wood, though had direct effect. The indirect positive effect with DBH, number of leaves per branch and weight of fresh wood had negative indirect effect via plant height, collar diameter, number of branches per tree and fresh and weight of dry leaves.

Weight of fresh leaves had negative direct effect. The positive indirect effect by DBH, number of leaves per branch, pruned biomass via fresh weight of
wood and negative indirect effect via plant height, collar diameter, number of branches per tree and via weight of dry leaves.

Weight of fresh wood had positive association with weight of dry wood, though the direct effect was positive. The positive indirect effect via DBH, number of leaves per branch and total pruned biomass were nullified with negative indirect effect via plant height, collar diameter, number of branches per tree and fresh and weight of dry leaves.

Weight of dry leaves had negative direct effect. The positive indirect effect via DBH, number of leaves per branch, pruned biomass, fresh weight of wood, and negative indirect effect were via plant height, collar diameter, number of branches per tree and weight of fresh leaves.

4.3.10 Analysis of Variance for Plus Trees of 33 Month Old Plants

The analysis of variance for 10 characters was carried out for testing the significance of differences among plus trees. The mean sum of squares for all the characters are presented in Table 18(b). The F-test indicated that the variances among the plus trees were highly significant for all the characters except dry weight of leaves.

4.3.11 Mean and Variability of Plus Trees

The result of statistical analysis of ten characters of 20 plus trees are presented in Table-19(b). Maximum range of variability in plant height was observed in PT-10 (276.16 - 295.00 cm with mean of 285.58 ± 2.43 cm), PT-27 (274.00 - 291.53 cm with mean of 282.77 ± 2.26 cm) and PT-15 (253.75 - 270.50 cm with mean of 262.12 ± 2.37 cm). The plant height of promising plus trees at different ages is being shown in Fig. 6.

For collar diameter, maximum range was observed in PT-12 (4.48 - 6.75 cm with mean of 5.13 ± 0.39 cm), PT- 8 (3.25 - 5.12 cm with mean of 4.08 ± 0.24 cm) and PT-15 (3.80 - 5.50 cm with mean of 5.12 ± 0.26 cm). The Collar diameter of promising plus trees at different ages is being shown in Fig. 8.

The maximum range was observed for diameter at breast height (DBH) in PT-21 (1.15 - 3.00 cm with mean of 2.19 ± 0.22 cm), PT-20 (0.85 - 2.50 cm with mean of 1.75 ± 0.21 cm) and PT-8 (1.15 - 2.5 cm with mean of 1.38 ± 0.22).
For number of branches per tree it was maximum in PT-6 (1.15 - 3.15 with mean of 2.25 ± 0.23), PT-18 (1.10 - 3.00 with mean of 1.75 ± 0.24) and PT-17 (1.00 - 2.66 with mean of 1.66 ± 0.22).

For number of leaves per branch, maximum range was observed in PT-13 (42.15 with mean of 31.42 ± 3.08), PT-27 (18.00 - 34.50 with mean of 22.15 ± 2.47) and PT-21 (18.00 - 38.00 with mean of 26.92 ± 1.72).

Maximum range of variability of was observed for total pruned biomass in PT-12 (0.80 - 3.50 kg with mean of 2.34 ± 0.28 kg), PT-5 (0.80 - 3.25 kg with mean of 2.38 ± 0.14 kg) and PT-22 (2.10 - 4.50 kg with mean of 3.81 ± 0.32 kg.).

For weight of fresh leaves, maximum range was observed in PT-14 (0.75 - 1.80 kg with mean of 1.47 ± 0.15 kg), PT-21 (0.70 - 1.70 kg with mean of 1.02 ± 0.14 kg) and PT-8 (0.43 - 1.25 kg with mean of 0.93 ± 0.10 kg). For fresh weight, it was maximum in PT-22 (0.85 - 3.80 kg with mean of 2.65 ± 0.42 kg), PT-27 (0.95 - 3.52 kg with mean of 2.67 ± 0.37 kg) and PT-10 (0.85 - 3.30 kg with mean of 2.75 ± 0.39 kg).

Highest range of variability was observed for weight of dry leaves in PT-21 (0.22 - 0.59 kg with mean of 0.47 ± 0.05 kg), PT-24 (0.14 - 0.44 kg with mean of 0.32 ± 0.04 kg.) and PT-28 (0.20 - 0.48 kg with mean of 0.30 ± 0.04 kg.).

For weight of dry wood, maximum range of variability in PT-15 (1.05 - 3.10 kg with mean of 2.32 ± 0.28 kg), PT-22 (0.85 - 2.75 kg with mean of 2.75 kg with mean of 2.07 ± 0.27 kg) and PT-27 and (0.65 - 2.10 kg with mean of 1.38 ± 0.23 kg) was observed.

The highest coefficient of variance was observed for collar diameter of PT-12 (18.78), for DBH in PT-8 (32.80), for number of branches per tree in PT-17 (33.30), for number of leaves per branch in PT-27 (27.33), and for pruned biomass in PT-12 (30.39), for fresh weight of leaves in PT-1 (36.27), for weight of fresh wood in PT-17 (38.05), for weight of dry leaves in PT-13 (40.88) and for weight of dry wood in PT-27 (40.83).

4.3.12 Estimates of Heritability and Genetic Advance

The estimate of heritability (broad sense) and expected genetic advance (%) for 10 characters of plus trees are presented in Table-20(b) and Fig. 10.
FIG. 10: HERITABILITY & GENETIC ADVANCE
IN PERCENTAGE OF MEAN IN PLUS
TREES OF NEEM
High estimates of heritability were recorded for plant height, collar diameter, DBH, number of branches per tree, number of leaves per branch, pruned biomass, weight of fresh leaves, weight of fresh wood and weight of dry wood.

The expected genetic advance expressed as percent mean was high for all characters except weight of dry leaves (low genetic advance).

The study of direct selection parameters indicated that the characters DBH, number of branches per tree, number of leaves per branch, pruned biomass, weight of fresh wood and weight of dry wood had high heritability with high genetic advance. Plant height, collar diameter and weight of fresh leaves had high heritability with medium genetic advance. Weight of dry leaves had low heritability with low genetic advance.

4.3.13 Variance and Coefficient of Variability

The coefficient of variability for all the characters have been given in the Table-21(b) and their graphic representation has been shown in the Fig. 12.

The highest phenotypic coefficient of variance was observed for weight of dry leaves (119.99), weight of dry wood (43.00), pruned biomass per tree (27.85), weight of fresh leaves (27.24), DBH (23.14), number of leaves per branch (18.59) and collar diameter (14.04). The minimum coefficient of phenotypic variance was observed for plant height (12.71).

The estimates of coefficient of genotypic variance for all 10 characters are presented in Table-21(b) and illustrated in Fig. 12. In general, the values of coefficient of genotypic variance were lower than their respective coefficients of phenotypic variance. The maximum amount of coefficient of genotypic variance was observed for weight of dry wood and minimum for weight of dry leaves.

4.3.14 Correlation coefficient for Plus Trees

The genotypic and phenotypic correlation coefficients were worked out to measure the association among the 10 characters studied and presented in Table-22(b). It is obvious from the table that the magnitude of genotypic correlation was higher than their respective phenotypic correlation in most of the cases.
FIG. 12: PHENOTYPIC & GENOTYPIC COEFFICIENTS OF VARIATION IN PLUS TREES OF NEEM
Plant height was associated positively and significantly with collar diameter and DBH, but it had negative and non-significant association with weight of fresh leaves. Collar diameter had positive and significant association with DBH and had weak association with number of leaves per branch, but it had negative association with weight of fresh leaves and weight of fresh wood. DBH had positive and significant association with collar diameter, it had negative association with fresh weight of leaves and weight of fresh wood. Number of branches per tree had negative association with weight of fresh leaves and weight of dry wood. Number of leaves per branch had negative association with fresh wood. Pruned biomass had negative association with dry weight of leaves. Weight of fresh leaves had negative association with dry weight of leaves and had positive association with fresh weight of wood and weight of dry wood and weight of fresh leaves. Weight of dry leaves had negative association with weight of dry wood.

4.3.15 Path Coefficient Analysis of Plus Trees

To obtain a clear understanding of the association the phenotypic and genotypic correlation coefficients of dry weight of wood with contributing characters were partitioned into direct and indirect effects through path coefficient analysis. The estimates of direct and indirect effects are presented in Tables 24(a) and 24(b) and their graphic representation has been shown in Fig. 14.

4.3.15.1 Phenotypic Effect

Plant height had positive association with weight of dry wood, though the direct effect was positive. The positive indirect effect via number of leaves per branch, pruned biomass, and weight of fresh leaves were nullified by negative effect through collar diameter, DBH number of branches per tree and weight of fresh wood.

Collar diameter had negative direct effect. The positive indirect effect on weight of dry wood via plant height, number of leaves per branch, pruned biomass, weight of fresh leaves and had negative indirect effect through DBH and number of branches per tree.

DBH had negative direct effect as well as indirect effect via collar diameter, number of branches per tree and positive indirect effect through plant height, number of leaves per branch, pruned biomass and weight of fresh wood.
FIG. 14: PATH DIAGRAM OF PLUS TREES OF NEEM SHOWING CAUSE AND EFFECT RELATIONSHIP
Number of branches per tree had negative direct association with dry weight of wood and had negative indirect effect via collar diameter and DBH, and positive indirect effect through plant height, number of leaves per branch, pruned biomass and weight of fresh leaves.

Number of leaves per branch had positive association with dry weight of wood, though direct effect was positive. The positive indirect effect via plant height and pruned biomass per tree were nullified by negative indirect effect through collar diameter, DBH, number of branches per tree and weight of fresh leaves.

Weight of fresh leaves had negative direct effect on dry weight of wood with negative indirect effect via plant height and fresh weight of wood. The positive indirect effect, collar diameter, DBH, number of branches per tree, number of leaves per branch and pruned biomass.

Weight of fresh wood had negative direct effect and had negative indirect effect through collar diameter, number of branches per tree, number of leaves per branch and weight of fresh leaves. The positive indirect effect was through plant height, DBH and pruned biomass.

4.3.15.2 Genotypic Effect

Plant height had positive genotypic association with weight of dry wood, though the direct effect was positive. The positive indirect effect via number of leaves/branch, pruned biomass and weight of fresh leaves were nullified by negative indirect effect through collar diameter, DBH, number of branches per tree and weight of fresh wood.

Collar diameter had negative direct effect on weight of dry wood. The positive indirect effect by plant height, number of leaves per branch, pruned biomass, weight of fresh leaves with negative indirect effect through DBH, number of branches per tree and weight of fresh wood was observed.

DBH had negative direct effect on weight of dry wood and had negative indirect effect via collar diameter, number of branches per tree. The positive indirect effect through plant height, number of leaves per branch, pruned biomass and weight of fresh leaves and wood.

Number of branches per tree had negative direct effect on weight of dry wood. The positive effect indirect effect via plant height, number of leaves per
branch, weight of fresh wood and negative indirect effect through collar diameter, DBH and weight of fresh leaves was observed.

Number of leaves per branch had positive association with weight of dry wood, though the direct effect was positive. The positive indirect effect via plant height, pruned biomass, weight of fresh wood. The negative indirect effect through collar diameter, DBH, number of branches per tree and weight of fresh leaves was also observed.

Pruned biomass had positive direct effect. The positive indirect effect was via plant height and number of leaves per branch and negative indirect effect was via collar diameter, DBH, number of branches per tree and weight of fresh leaves and wood.

Weight of fresh leaves had negative direct effect with weight of dry wood and the negative indirect effect via plant height, weight of fresh wood. The positive indirect effect through collar diameter, DBH, number of branches per tree, number of leaves per branch and pruned biomass was also observed.

Weight of fresh wood had negative direct effect. The positive indirect effect was via plant height, DBH and pruned biomass and it was negative via collar diameter, number of branches per tree, number of leaves per branch and weight of fresh leaves.