were found with comparatively higher values in natural forest.

Appreciably higher frequency and density value of *C. collinus* was found in plantation. In natural forest however, *A. latifolia* and *I. tomentosa* were found to have higher values.

III. Dominance

Total basal area covered by tree species was found to be 12.63 sqm/ha in plantation and 5.96 sqm/ha in the natural forest.

In plantation, 64.80% of the total basal area was found to be contributed by teak alone and remaining 35.20% by non-teak species.

Amongst various common species, 10 species were found to have comparatively higher basal area in plantation than that of natural forest. Of these species, *C. collinus*, *I. arborea*, *I. parviflora*, *S. oleosa*, *S. anacardium* and *I. grandis* were observed to have considerably higher basal area. In natural forest as compared to plantation 12 species were found with higher basal area; of which *A. latifolia*, *C. swietenia*, *P. officinalis*, *P. fabrifuga* and *L. xylopyrus* were found to be most prominent.

IV. Importance Value Index (IVI):

In plantation 5 tree species having maximum IVI values in descending orders were *I. grandis* (95.14), *D. melanoxylon* (43.60), *C. collinus* (23.27), *P. arborea* (16.26) and *A. cordifolia* (13.90). Whereas in natural forest these species
were *D. melanoxyylon* (41.31), *I. grandis* (36.45), *A. latifolia* (35.79), *I. tomentosa* (22.82) and *S. robusta* (12.91).

Critical examination of the IVI values of exclusive species of plantation and natural forest, it was observed that these species were having very low IVI values, and thus these species can be recognised as of minor importance.

On comparing the IVI values of 22 common species, 9 were found to have comparatively higher values in plantation and 13 species were found with higher values in natural forest. Considerably higher IVI values were found in *C. collinus*, *S. oleosa* and *I. grandis* in plantation and *A. latifolia*, *E. officinalis* and *I. tomentosa* in natural forest.

On the basis of first 3 dominant species plantation and natural forest can be categorised as *I. grandis* - *D. melanoxyylon* - *C. collinus* type and *D. melanoxyylon* - *I. grandis* - *A. latifolia* type, respectively.

V. Community Co-efficients :

Similarity co-efficients determined on the basis of (1) presence/absence relationship and (2) IVI values of various species were found to be 62.30% and 55.50%, respectively between plantation and natural forest.

4.52 36 YEAR OLD TEAK PLANTATION AND ADJOINING NATURAL FOREST

Floristic composition and various phyto-sociological parameters were calculated for each species occurring in
<table>
<thead>
<tr>
<th>No.</th>
<th>Species</th>
<th>Frequency</th>
<th>Density Trees/ha</th>
<th>Basal area sq. ha</th>
<th>Importance Value index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>A. coriaria</td>
<td>11.11</td>
<td>11.11</td>
<td>0.110</td>
<td>4.00</td>
</tr>
<tr>
<td>2.</td>
<td>A. excelsa</td>
<td>22.22</td>
<td>22.22</td>
<td>0.222</td>
<td>8.03</td>
</tr>
<tr>
<td>3.</td>
<td>A. latifolia</td>
<td>100.00</td>
<td>777.78</td>
<td>1.363</td>
<td>71.52</td>
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<tr>
<td>4.</td>
<td>A. racemosa</td>
<td>66.67</td>
<td>33.33</td>
<td>0.039</td>
<td>9.40</td>
</tr>
<tr>
<td>5.</td>
<td>E. tomentosa</td>
<td>66.67</td>
<td>33.32</td>
<td>0.101</td>
<td>10.33</td>
</tr>
<tr>
<td>6.</td>
<td>E. latifolia</td>
<td>44.44</td>
<td>33.33</td>
<td>0.092</td>
<td>7.77</td>
</tr>
<tr>
<td>7.</td>
<td>E. racemosa</td>
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<td>66.67</td>
<td>0.039</td>
<td>9.176</td>
</tr>
<tr>
<td>8.</td>
<td>E. tomentosa</td>
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<td>33.33</td>
<td>0.147</td>
<td>5.90</td>
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<tr>
<td>9.</td>
<td>E. latifolia</td>
<td>66.67</td>
<td>44.44</td>
<td>0.018</td>
<td>9.95</td>
</tr>
<tr>
<td>10.</td>
<td>E. spicata</td>
<td>33.33</td>
<td>44.44</td>
<td>0.018</td>
<td>9.95</td>
</tr>
<tr>
<td>11.</td>
<td>E. latifolia</td>
<td>100.00</td>
<td>66.67</td>
<td>0.198</td>
<td>10.52</td>
</tr>
<tr>
<td>12.</td>
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<td>66.67</td>
<td>0.198</td>
<td>10.52</td>
</tr>
<tr>
<td>13.</td>
<td>E. spicata</td>
<td>33.33</td>
<td>33.33</td>
<td>0.259</td>
<td>5.71</td>
</tr>
<tr>
<td>14.</td>
<td>E. pseudocostata</td>
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<td>44.44</td>
<td>0.076</td>
<td>10.76</td>
</tr>
<tr>
<td>15.</td>
<td>E. tomentosa</td>
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<td>66.67</td>
<td>0.062</td>
<td>1.20</td>
</tr>
<tr>
<td>16.</td>
<td>E. racemosa</td>
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<td>44.44</td>
<td>0.218</td>
<td>1.74</td>
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<td>17.</td>
<td>E. racemosa</td>
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<td>33.33</td>
<td>0.051</td>
<td>5.05</td>
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<td>E. racemosa</td>
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<td>211.11</td>
<td>0.148</td>
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</tr>
<tr>
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<td>0.097</td>
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<td>20.</td>
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<td>33.33</td>
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<tr>
<td>21.</td>
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<td>11.11</td>
<td>0.049</td>
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<tr>
<td>22.</td>
<td>E. tomentosa</td>
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<td>0.035</td>
<td>7.24</td>
</tr>
<tr>
<td>23.</td>
<td>E. tomentosa</td>
<td>100.00</td>
<td>77.77</td>
<td>122.22</td>
<td>15.108</td>
</tr>
<tr>
<td>24.</td>
<td>E. tomentosa</td>
<td>22.22</td>
<td>22.22</td>
<td>0.074</td>
<td>3.16</td>
</tr>
<tr>
<td>25.</td>
<td>E. tomentosa</td>
<td>22.22</td>
<td>22.22</td>
<td>0.074</td>
<td>3.16</td>
</tr>
</tbody>
</table>

Total

3705.52 2399.97 20.403 5.087
plantation and in the natural forest. These ecological characteristics are summarised in Table 11. The results have been discussed under various headings in the following paragraphs.

I. Floristic composition and Species diversity :

Number of tree species recorded from plantation were 20 and from natural forest the total species were 19. In all, there were 25 species enumerated from both the sites. Of these 25 species, 14 were common to the plantation as well as to the natural forest. Of the remaining species 6 were found to be exclusive to plantation and 5 species were found to be exclusive to natural forest.

The exclusive species in plantation were *D. latifolia*, *D. paniculata*, *H. excelsum*, *L. parviflora*, *R. ulcinosa* and *T. tomentosa*. In natural forest these were, *A. cordifolia*, *A. marmelos*, *A. latifolia*, *S. anacardium* and *S. febrifuga*.

II. Frequency and Density :

Degree of homogeneity in plantation and in the natural forest was found to be 1.13 and 0.31, respectively.

Total density of tree species in the plantation and in natural forest was found to be 3705 plants/ha and 2400 plants/ha, respectively. In teak plantation proportional density of teak and non-teak species was found to be 14.70% and 85.30%, respectively.
While comparing the frequency and density of 14 species common to plantation and natural forest, it was found that 11 species were having comparatively higher IVI values in plantation and remaining 3 species were found to have higher values in natural forest. In plantation, 3 species, viz., *D. melanoxylon*, *S. oleosa* and *T. grandis* were having considerably higher values of frequency and density than in the natural forest. Similarly, *B. monosperma* was found to have considerably higher value in natural forest than in the plantation.

III. Dominance :

Total basal area contributed by tree species was found to be 20.40 sqm/ha in plantation and 5.09 sqm/ha in natural forest.

In the plantation, 74.40% of the total basal area was found to have been contributed by teak alone and remaining 25.60% by non-teak species.

While comparing the basal area of 14 species, common to plantation as well as to the natural forest, it was found that 2 species were having comparatively higher basal area in the plantation. Of these *B. racemosa*, *C. arborea*, *C. collinua*, *D. melanoxylon*, *I. arborea*, *S. oleosa* and *T. grandis* were most prominent species. In natural forest, however, remaining 3 species were found to have comparatively higher basal area. These were *B. monosperma* and *C. swietenia*, were most prominent.
IV. Importance Value Index (IVI):

In plantation, first 5 dominant species in descending order were *I. grandis* (99.02), *D. melanoxylon* (39.95), *C. collinus* (39.23), *P. retusa* (10.33) and *C. fistula* (10.28). In natural forest however, these were, *A. latifolia* (71.52), *I. grandis* (49.95), *C. collinus* (33.55), *D. monosperma* (20.01) and *M. parviflora* (18.37).

Majority of the exclusive species were of minor importance in both the stands, viz., plantation and natural forest, except *A. latifolia* which was found as first a leading dominant species in natural forest but totally absent in the plantation.

In the plantation *I. grandis* - *D. melanoxylon* - *C. collinus* type and in the natural forest *A. latifolia* - *I. grandis* - *C. collinus* type of associations were recognised.

V. Community Co-efficients:

The similarity co-efficients determined on the basis of presence/absence relationship of various species was found to be 56.00% and $SS_{XY}$ on the basis of IVI values it was 53.70%.
DISCUSSION

4.61 TRENDS IN PLANTATIONS:

Teak plantation at 4 different sites, were found to have 58 tree species (Table 3 to 11). The number of tree species varied from 17 to 32 in plantations of different ages. The mean number of plants in teak plantation thus worked out to be 22.

The species diversity in plantation at a given site may be attributed to the difference in the micro-climatic changes and degree of biotic influences (Troup, 1921). Critical review of the data revealed that at least 11 tree species, viz. A. latifolia, B. racemosa, B. lanza, C. fistula, D. melanoxylon, L. parviflora, E. tomentosa, M. parviflora, S. oleosa, T. grandis and Z. xylopyrus were present in majority of the plantation stands at 4 different sites. Silvicultural characteristics of these species enable them to withstand the sudden disturbances brought about by clear felling before plantations. On account of their good coppicing power and their physiological mechanism to spread from the root-stock makes them adapted to survival under light demanders such as teak (Rao, 1953). The presence of these species in varying edapho-climatic zones from Bijawar in North to Raipur in South confirms their adaptability to various adverse growing conditions. Marballi (1982) through his observations exploded the mystery that clear felling of natural stand followed teak
plantation results in ecological disturbance of site. In fact the ecological balance is restored through adequate adoption of non-teak species on ecological grounds. Regular and close spacing of planted tree species, soil working, cultural operations at regular interval and protection against biotic factors such as fire, promiscuous grazing and illicit felling, etc. help not only to restore the ecological balance but also help in initiating ecological progression.

Species diversity was observed to be increasing from Bijawar to Raipur. While there were 25 tree species recorded from plantation in Bijawar area, there were 28 species in Kalpi, 35 in Nainpur and 36 in Raipur. It is to be seen that Bijawar area has mostly the low level dry deciduous non-teak species. On the other hand Mandla area on account of well drained soils derived from Deccan traps and better distribution of annual rainfall, provides comparatively more favourable site conditions, and as a result, more species diversity is observed. As we go towards Sal zone the species diversity further increases. Infact the teak plantation in Raipur have been raised after felling the non-teak species. One of the plantation in Raipur was 56 years old where the site appears to have developed into self sustainable ecosystem. This is reflected by more homogeneity than other sites.

Distributional pattern of various species in plantations of different ages showed that 4 tree species, viz. *A. latifolia, D. melanoxylon, L. parviflora* and *T. grandis* fell in
higher frequency classes ('D' and 'E') in most of the plantations. Their comparative abundance may primarily be due to their good capacity to regenerate through root suckers (Brandis, 1906; Haines, 1916; Rao 1953, Narbwalli, 1982).

Total density of tree species at 4 different sites varied from 3705 plants/ha to 8308 plants/ha.

In different ages of plantations, the proportional density of non-teak species was found to be comparatively higher than teak. The density of teak varied from 14.70% to 35.00%. Whereas that of non-teak species it varied from 65.00% to 85.30%. In general, density of non-teak species was found to be increasing with the increasing age of the plantations. As against this the density of teak was found to be decreasing with increasing age of the plantations. While reduction in the number of teak plants in the older plantations is purely an outcome of management strategies the corresponding abundance of non-teak species with advancing age of plantation appears to be an ecological phenomenon. While for obtaining good quality teak logs, thinning is resorted to congested poles the ultimate openings in the canopy help induce the growth of coppicers such as Alatifolia, D.melanoxylon, L.parviflora etc.(Champion and Seth,1968; Lal, 1961). The minute seeds of most of the non-teak species continue to come at plantation sites. Seeds of other species when brought to the plantation sites by other biological means have a sure chance of germination, survival and growth on account of better production and favourable micro-climatic conditions in the plantations.
As expected the minimum total basal area (1.83 sqm/ha) was found in younger plantation at Bijawar (4-6 year old). Whereas maximum basal area of 20.40 sqm/ha was found in 56 year old plantation at Raipur. While teak continued to put on volume increment with age, there were little indication of any direct correlation between the basal area of age of non-teak species. As discussed earlier, the tending operations in favour of teak helps it to develop higher dimensions. On the other hand the non-teak species have a chance to close up only thinning creates lasting gaps in the canopy. However, this does not happen as teak canopy closes quickly leaving non-teak species to struggle and survive under shade of aggressive teak. This fact is further confirmed by the following observations. While basal area of teak ranged from 59.30% to 86.50%; in case of non-teak species the basal area remained very low (13.50% to 40.70%).

For determining the percent similarity among plantations of different ages, a similarity matrix was made on the basis of IVI values (Table 12). On perusal of community co-efficient figures in Table 12, following facts are brought about:

- Similarity co-efficients among plantations of different ages of Bijawar forest varied from 72.00% to 80.00%.
- Similarity co-efficients among plantations of different ages of Raipui varied from 69.00% to 85.00%.
- Similarity co-efficients among plantations of different ages of Nainpur varied from 55.00% to 78.00%.
<table>
<thead>
<tr>
<th>Age (in years) of teak plantations</th>
<th>0 yr</th>
<th>5-7 yr.</th>
<th>10-17 yr.</th>
<th>15-17 yr.</th>
<th>30-35 yr.</th>
<th>35-39 yr.</th>
<th>40-45 yr.</th>
<th>45-50 yr.</th>
<th>50-55 yr.</th>
<th>55-60 yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species</td>
<td>6-7 yr.</td>
<td>10-17 yr.</td>
<td>15-17 yr.</td>
<td>30-35 yr.</td>
<td>35-39 yr.</td>
<td>40-45 yr.</td>
<td>45-50 yr.</td>
<td>50-55 yr.</td>
<td>55-60 yr.</td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
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<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td><em>Albizia</em></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
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<td>-----------</td>
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<td>-----------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td><em>Tectona</em></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The table above presents the age distribution of teak plantations across different years and species categories.
- Similarity co-efficients among plantations of Raipur forest varied from 53.00% to 70.00%.
- Similarity co-efficients between 6-7 year old plantation of Bijawar forest and 4-6 year old plantation of Nainpur forest was found to be 55.00%.
- Similarity between 16 year old plantation of Bijawar forest and 15-17 year old of Kalpi was found to be 75.50%.
- Similarity between 16 year old plantation of Bijawar forest and 16-17 year old of Nainpur forest was found to be 63.90%.
- Similarity between 20-23 year old plantation of Bijawar forest and 20-23 year old of Kalpi was found to be 70.90%.
- Likewise similarity between 29-35 year old and 56 year old plantation of Raipur forest was found to be 70.40%.
- Highest similarity co-efficients (85.00%) was found between 15-17 year old and 20-23 year old plantation of Kalpi forest.

From the above conclusions it is apparent that the diversity of the species in plantation is not a mere coincidence of topography, soil or any other factor but it is mostly on account of the adaptability of the species to grow under teak monoculture. It also confirms that species diversity also has stability as most of the species are found from one site to another and continue to grow even in older plantations. 

Direct relations between diversity and stability in plantations
have also been shown by Fretwell (1975) and Whitehead (1982). Their dominance was (higher frequency, density and basal area), therefore, found pronounced at all sites. Exceptionally high values of co-efficient of similarity in 15-20 year old plantations indicate that at this stage most of the species which were found before clear felling get themselves established.

4.62 PLANTATIONS AND NATURAL FORESTS:

There were 60 tree species enumerated from all the plantations and natural forest stands. Of these total species, 51 were common to plantations and natural forests. There were 7 species, viz., *A. leucophaea*, *D. latifolia*, *E. glomerata*, *H. excelsum*, *L. monopetala*, *Terminalia* sp. and *Z. rucosa* were found to be exclusive to plantations. As compared to this only 2 species, viz., *Albizia* sp. and *N. fructicosa* were found to be exclusive to the natural forest. Of the 51 species which were present in plantations as well as in natural forest, 10 species, viz. *A. latifolia*, *B. lanzan*, *C. fistula*, *D. melanoxylon*, *L. parviflora*, *N. tomentosa*, *M. parviflora*, *Q. dalbergioides*, *Sw. T. grandis* and *Z. xylopyrus* were found to be common in majority of the plantations as well as in the natural forests. Most of these are the characteristics associates of teak and non-teak mixed miscellaneous forests in tropical and dry deciduous forest ecosystem (Champion and Seth, 1968). Their presence in plantations in varying edapho-climatic regions also indicates that the species which are good coppicers
and which have inherent power of regeneration after the
sites are protected, are not effected by temporary environ-
mental disturbances brought about by clear felling. In fact
after clear felling the stools of existing trees are left
intact and they act as barriers to restrain the flow of
rain water and thus help to check accelerated erosion which
is likely to take place during the short period of a month
or two, when the ground is rendered bare by clear felling
till it is finally planted. Soon after the commencement
of the rain the land gets covered by profuse natural growth
of grasses, weeds, shrubs and coppice growth from the stools
which together with the antierosion works carried out, etc.
help to reduce erosion (Darballi, 1982).

Number of tree species in different natural stands
at 4 varying sites varied from 14-30 as compared to 15-32
in different plantations located at different sites (Fig.6).
These facts indicate that species diversity at plantation
sites is more than the natural stands presumably on account
of better protection in plantations. Soil working and weedings
in plantation helps in moisture conservation. The litter
accumulation also helps in moisture conservation and fertility
build up in plantation more than the natural forest, the
latter being subjected to biotic pressures. The cumulative
effects of all the measures in plantation, therefore, help
to create more hospitable conditions (Hakeem, 1985; Prasad, 1985).
Fig. 5 SHOWING NUMBER OF TREE SPECIES IN T.P. AND N.F.

Fig. 6 SHOWING DENSITY OF TREES IN T.P. & N.F.

Fig. 7 SHOWING BASAL AREA (SQM/HA.) OF TREES OF T.P. & N.F.

INDEX
- T.P. - TEAK PLANTATION
- N.F. - NATURAL FOREST
- B - BIJAWAR
- N - NAINPUR
- K - KALPI
- P - RAIPUR
On comparing the degree of homogeneity among various plantations and in natural forests it was found that except juvenile plantations (4-7 year old), all other plantations showed comparatively higher degree of homogeneity than their adjoining natural forests.

Total density of the tree species was also found to be higher in each of the plantations of different ages than their adjoining natural forests. In different aged plantations total density of tree species varied from 3706 plants/ha to 8308 plants/ha as compared to 2356 plants/ha to 6178 plants/ha in natural forest (depicted graphically in Fig.6).

Total basal area per hectare occupied by tree species in plantations of different ages was also found to be higher than the natural forest, except 2 juvenile plantations (4-6 year old plantation) of Nainpur Project and 6-7 year old plantation of Bijawar forest). In plantations, values varied from 1.83 sqm/ha to 20.40 sqm/ha as compared to 2.91 sqm/ha to 10.62 sqm/ha in different natural forests (Fig.7).

While comparing the basal area of various species common to plantations and adjoining natural forest it was found that mostly those species which had higher frequency and density in plantations than the natural forest also had comparatively higher basal area. In majority of the plantations, as compared to natural forest, considerably higher basal area was noted in B.racemosa, B.lanzen, D.melanoxylon, L.parviflora,
<table>
<thead>
<tr>
<th>Age (in year)</th>
<th>Site</th>
<th>Shade type</th>
<th>Soil type</th>
<th>Forest type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 6-7 yr.</td>
<td>Bijapur</td>
<td><em>I. robusta</em></td>
<td><em>P. planipes</em></td>
<td><em>L. latifolia</em></td>
</tr>
<tr>
<td>2. 16 yr.</td>
<td>Bijapur</td>
<td><em>I. robusta</em></td>
<td><em>L. latifolia</em></td>
<td><em>P. planipes</em></td>
</tr>
<tr>
<td>3. 20-23 yr.</td>
<td>Bijapur</td>
<td><em>I. robusta</em></td>
<td><em>P. planipes</em></td>
<td><em>L. latifolia</em></td>
</tr>
<tr>
<td>4. 18-17 yr.</td>
<td>Kolpi</td>
<td><em>I. robusta</em></td>
<td><em>P. planipes</em></td>
<td><em>L. latifolia</em></td>
</tr>
<tr>
<td>5. 30-33 yr.</td>
<td>Kolpi</td>
<td><em>I. robusta</em></td>
<td><em>P. planipes</em></td>
<td><em>L. latifolia</em></td>
</tr>
<tr>
<td>6. 4-5 yr.</td>
<td>Sapat</td>
<td><em>I. robusta</em></td>
<td><em>P. planipes</em></td>
<td><em>L. latifolia</em></td>
</tr>
<tr>
<td>7. 16-17 yr.</td>
<td>Sapat</td>
<td><em>I. robusta</em></td>
<td><em>P. planipes</em></td>
<td><em>L. latifolia</em></td>
</tr>
<tr>
<td>8. 20-35 yr.</td>
<td>Sapat</td>
<td><em>I. robusta</em></td>
<td><em>P. planipes</em></td>
<td><em>L. latifolia</em></td>
</tr>
<tr>
<td>9. 55 yr.</td>
<td>Sapat</td>
<td><em>I. robusta</em></td>
<td><em>P. planipes</em></td>
<td><em>L. latifolia</em></td>
</tr>
</tbody>
</table>
M. tomentosa, S. oleosa and T. grandis. Though, some species like B. retusa, C. arborea, C. tomentosa, C. collinus, E. glaucum and I. arborea were not recorded from all the 4 study sites but wherever found, these species showed higher basal area in the plantations than the natural forests.

Table 13 incorporates the type of associations found in plantations of different ages and their adjoining natural forests.

From the various ecological parameters discussed above, it is brought out that the clear felling before plantation does not result in eliminating the species present in the natural forests. In fact, at a number of locations the plantations have been found with more species diversity and stability than their adjoining natural forests. Only the social status of certain plants changes in the plantations. Tree species such as A. latifolia, D. melanoxylon, D. latifolia, L. parviflora, etc. which are found as co-dominant, in the natural stand are relegated to the position of dominated or suppressed. These findings are in conformity with those of Whitehead (1982) who observed that plantations in many cases are comparable to natural stands in terms of species diversity, stability, maturity and productivity. Whittaker (1974) and May (1974) indicated the adaptation strategy of many species in pure crops.