Results and Discussion

1. Survey, collection and conservation of important medicinal plants in South India

During the course of the investigation on medicinal plants, 432 plants were collected and identified (Table-1). All except a few plants were conserved in the herbal garden of KAPL at Nedumbassery, Cochin. A tabulated statement of these plants with scientific and vernacular names, places of collection and official parts used in indigenous system of medicine is given in table 7.

All plants could be established in the herbal garden except *Aconitum heterophyllum* Wall, *Cedrus deodara* (Roxb) Loud, *Drosera burmanni* Vahl, *Ephedra sp.*, *Glycyrrhiza glabra* Linn, *Saussurea lappa* C.B.Clarke. Collected plants were critically examined in the laboratory and identified with the help of relevant literature (Gamble, 1915-1936, Mathew, 1981, 84 and 91). Species not covered in the flora were got identified by the good services of Botanical survey of India, Howrah; Agharkar Institute, Poona; Kerala Forest Research Institute, Peechi; Tropical Botanical Garden and Research Institute, Palode, Trivandrum and Department of Botany, U.C.College, Aluva. Herbaria of these plants were prepared and preserved at the R&D division of KAPL.

The plants collected belong to 98 families of angiosperms and gymnosperms and are arranged according to Benthem and Hookers system of classification. It includes about 60 highly potent medicinal plants collected from other states (table 7). Names of few important ones are given below.

*Operculina turpethum* (Linn) Silva  
*Manso*

*Withania somnifera* Dunal

*Tribulus terrestris* Linn.

*Psoralea corylifolia* Linn.

*Berberis aristata* DC

*Terminalia arjuna* (Roxb) ex D

*Acacia catechu* (Linn.) Wild.

*Celastrus paniculata* Wild.

These plants include all major life forms i.e. herbs, climbers, shrubs and trees. Of these 176 plants are regularly use in classical ayurvedic formulations (Vagbhatta, 1966). Various parts of these plants such as root, root bark, rhizome, bulb, stem, stem bark, heart wood, leaf, fruit, fruit pericarp, flower, seed or the whole plant are used as crude drugs in Ayurveda. Most of them are used in dry form whereas a few are used in classical ayurvedic formulations as fresh or green.

The study also enlists some important families of medicinal plants having ten or more plant species used in ayurvedic preparations.

<table>
<thead>
<tr>
<th>Family</th>
<th>Number</th>
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<tbody>
<tr>
<td>Malvaceae</td>
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</tr>
<tr>
<td>Rubiaceae</td>
<td>14 Nos</td>
</tr>
<tr>
<td>Fabaceae</td>
<td>33 Nos</td>
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<tr>
<td>Asteraceae</td>
<td>16 Nos</td>
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<tr>
<td>Caesalpiniaceae</td>
<td>13 Nos</td>
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<tr>
<td>Aselepiadaceae</td>
<td>14 Nos</td>
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</table>
This study also resulted in the collection of a few controversial plants. One such plant is *Vallippala, which* is used as single drug in tribal medicine for bronchial asthma. *Tylophora indica* (Burm.f) Merrill is generally used as the source drug. But *Cynanchum callialata* Ham ex Wight and *Cryptolepis buchanani* Roem & Schult are also referred and used as *Vallippala*. Another plant whose identity is in dispute is *Somalata*. Different plant species are used in different regions of the country as the source of *Somalata*. Of these, 2 plants namely *Ceropegia tuberosa* Roxb and *Sarcostemma acidum* (Voight) Voight were collected and conserved in the herbal garden. Commercial cultivation of these plants was undertaken to ensure an uninterrupted supply of raw materials for the manufacture of *Manasamitra vatakam*, a classical ayurvedic preparation. The Himalayan plant *Ephedra gerardiana* Wall ex Stapf. though collected from Agharkar Institute, Poona, didn’t establish in the herbal garden at KAPL. Similarly *Coscinium fenestratum* (Gaertn) Colebr., an accepted plant source of ayurvedic drug *daruharidra* is a threatened medicinal plant found in Western ghats. Another plant used as *daruharidra* is *Berberis aristata* DC, which is collected from Dodapetta, Tamil Nadu. Conservation of these controversial plants in the herbal garden provides a better chance for their identification. The report also enlists some important ethno-medicinal plants like

- *Alstonia venenata* R.Br. - anti poisonous
- *Argemone mexicana* Linn. - anti allergic
- *Antiaris toxicaria* Leschen - anti rheumatic

**Table of Plant Families and Numbers:***

<table>
<thead>
<tr>
<th>Plant Family</th>
<th>Number of Species</th>
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<tbody>
<tr>
<td>Apocynaceae</td>
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<tr>
<td>Solanaceae</td>
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<td>Acanthaceae</td>
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<td>Lamiaceae</td>
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<tr>
<td>Euphorbiaceae</td>
<td>14 Nos</td>
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<tr>
<td>Zingiberaceae</td>
<td>14 ,,</td>
</tr>
<tr>
<td>Poaceae</td>
<td>13 ,,</td>
</tr>
</tbody>
</table>
Blepharis boerhaavifolia Pers. - anti septic

Geodorum densiflorum Schlechter - antidote

Gloriosa superba Linn. - abortive

Gymnema sylvestre R.Br. - anti diabetic

Trichopus zeylanicus Gaertn - (used by the kani tribals of Agasthya hills as rejuvenator and immunomodulator).

The entries consist of the fascinating insectivorous plant Nepenthes khasiana Hook.f. and a few exotic plants like

Mentha arvensis Linn.       Pimenta officinalis Lindl
Mentha piperita Linn.       Ruta chalepensis Linn. and
Melaleuca leucadendron Linn. Pogostemon patchouli Pellet

It is interesting to note that among the herbals collected and conserved in the herbal garden, a few are medicinal orchids employed for a variety of medicinal use in traditional system of medicine. They are

Nervilia aragoane Gaudich (the single leaf orchid) - Leaf juice is used as eye drops in case of eye infection.

Geodorum deniflourm Schlechter - antidote

Malaxis accuminata D.Don - Rejuvenative tonic

Malaxis musifera (Lindley) Kuntze – Rejuvenative tonic

Ministry of Environment and Forest, Govt. of India (under the Wild Life Protection Act, 1972-No.53/1972) has included 27 plants in the banned list (A). Export of any part of these plants is strictly prohibited. At the same time, Govt. also insisted for legal procurement certificate (LPC) for another 114 plants (B). It is worth observing
that, among the collected plants, the following are included in the list A and B respectively.

**A.**

1) *Nepanthes khasiana* Hook.f  
2) *Coscinium fenestratum* (Gaertn) Colebr.  
3) *Rauwolfia serpentina* Benth ex Kurz.  
4) *Ceropegia spp.*  
5) *Euphorbia spp.*

6) *Orchidaceae family*  
7) *Pterocarpus santalinus* Linn.  
8) *Kaempferia galanga* Linn.  
9) *Cycas spp.*  
10) *Gnetum spp.*

**B.**

1) *Aristolochia sp.*  
2) *Berberis aristate* DC  
3) *Acorus calamus* Linn  
4) *Artemisia sp.*  
5) *Costus speciosus* (Koen) Sn.  
6) *Trichopus zeylanicus* Gaern  
7) *Adhatoda beddomei* C.B.Clarke  
8) *Gymnema spp.*  
9) *Heliotropium spp.*  
10) *Nervilea aragoane* Gaudich  
11) *Niligirianthus ciliatus* (Nees) Breme
The herbal garden and herbaria serve as a reference for important medicinal plants in South India, especially in Kerala. The facility is being utilised by students, researchers, ayurvedic physicians and drug manufacturers. Besides it promotes interest in conservation and cultivation of medicinal plants. Most of the plants were multiplied and genuine seeds/seedlings are being supplied to those interested in the cultivation of these high value plants. Further, these collections provided the nucleus materials for the subjective studies in this project.

2. Performance appraisal of selected medicinal plants under Kerala conditions

2.1. Aloe barbedensis Mill. (PLATE - I. b)

The plants of *Aloe barbadensis* established within 20 – 25 days. The dimensions of the leaves recorded at the age of 12 months are given in table 8. Leaves recorded an average length of 53.2cm and breadth of 5.36cm.

*Aloe* plants reached the age of harvest in 6 months, when the leaves attained maximum turgidity. Subsequent harvests were undertaken at the 8th, 10th, 14th and 18th months of age. Thereafter, there was a considerable decrease in yield and the plants were uprooted at the 24th month. Plants in the experimental plots never blossomed during the trial period, probably due to continuous severe pruning of the leaves.

Data on the yield of leaves in different harvests obtained in 3 experiments conducted are given in table 9. *Aloe barbadensis* gave an average yield of 672.6t/ha for two years.(annual yield of 336.34 t/ha ). At an average cost of Rs.8/kg, the gross return is estimated as Rs.26,90,700/ha/annum. This study demonstrates that *A. barbadensis* is well adapted for commercial cultivation in Kerala.
\[2.2 \textit{Alpinia calcarata} \textbf{Rosc.} \text{(PLATE - I.c)}\]

\textit{Alpinia calcarata} plants blossomed at an age of 10 to 12 months. Inflorescence is a terminal panicle with 16 flowers in each panicle. Flowers are white with red lip. Labellum is coloured yellow and red with fimbriated margin. The crop was found to be resistant to diseases and pests and could thrive well in the hot summer season without irrigation. (PLATE-IV.c).

Data on the growth and yield characteristics of \(A.\ \text{calcarata}\) recorded from five randomly selected plants at an age of 12 months in 1998-planted crop are given in Table 10. Plants recorded an average height of 132.8cm. Leaves showed an average length of 46.4cm and breadth of 5.6cm. Diameter of rhizome ranged from 1.9 – 2.1 cm with a mean of 2.02 cm. The crop recorded an average rhizome yield of 6.1 kg/plant on fresh weight basis equivalent to 1.9 kg dry rhizomes. The average drying was 31.1%.

Data on the fresh rhizome yield of the crops planted in 1995, 1996, 1997 and 1998 are presented in Table 11. The rhizome yield of \(A.\ \text{calcarata}\) ranged from 159 t/ha to 183 t/ha with an average of 170.2t/ha. The phytochemical analysis done in this project in experiment 4. has shown that the quality of \(A.\ \text{calcarata}\) is on par with that of \(A.\ \text{officinarum}\) which is at present used in ayurvedic formulations such as \textit{Ashtavargam kwath, Rasnasapthakam kwath, Rasnerandadi kwath} etc. The quality of \(A.\ \text{calcarata}\) being comparable with that of \(A.\ \text{officinarum}\), the former can be substituted for the later in ayurvedic preparations. This being the case, there is a great demand for \(A.\ \text{calcarata}\) for ayurvedic drug manufacturers. The present market price of \(A.\ \text{officinarum}\) is about Rs.140/kg of dried rhizome. If comparable price is
obtained for *A. calcarata* rhizome, a very high annual returns can be expected by the cultivator. This study has revealed that *A. calcarata* can be successfully and economically cultivated under Kerala conditions.

2.3 *Anisomeles malabarica* (Linn.) R.Br.ex.Sims (PLATES-II.a & IV.d)

The crop established within 20 days time. The plants were robust and comparatively free of diseases and pests. They blossomed at an age of 90 days. The growth characteristics of *A. malabarica* recorded from five randomly selected plants is given in table 12 and yield characteristics during 1996,97 and 98 in table 13. Plants recorded an average height of 133cm. Great variation was observed in leaf dimension. Leaf recorded an average length of 13.8 cm where as its breadth ranged from 1.5cm to 4.5cm recording a mean of 2.98cm.

The dynamics of leaf yield of *A. malabarica* is shown in figure 1. Leaf yield increased steadily with age and it was maximum in the harvest taken during the 10th month. Thereafter the yield decreased abruptly. The observation was consistent over different years of the trial. This suggests that from the commercial point of view, it is better to replant the crop after 10 to 12 months of age. On an average, a one-year crop yields about 527.6 tons/ha. At an average cost of Rs.10/kg fresh leaves, the gross return of *A. malabarica* fetches Rs.52,76,000/ha.
2.4 *Bacopa monnieri* (L.) Pennell. (PLATE-II. b)

Observation on leaf yield of crop planted in 1997, 1998 and 1999 are given in Table 14. *B. monnieri* gave an average annual yield 135.43 t/ha. At an average cost of Rs.8, the gross return of *B. monnieri* is estimated as Rs.10,83,440/ha/annum. These trials clearly show that *B. monnieri* can be successfully cultivated in Kerala especially in the marshy wastelands and paddy fields.

2.5 *Holostemma adakodien* Schultes. (PLATE-II.c)

Data on growth characteristics of *Holostemma adakodien* at vining stage is presented in Table 15. The plants attained an average height of 22.4cm and produced on an average 13 to 14 vines. The leaves were cordate measuring on an average 5.38 x 4.75 cm. The plants blossomed in September, i.e. about 123 days after planting. The inflorescence was an umbel of few flowered cymes.

The plants exhibited leaf fall during the winter season (December – January). Fresh leaves were put up during February. Mite infestation on the under side of the leaves was noticed during October-November months. Feeding by the pest resulted in the appearance of dark spots on the leaves. In the advanced stage, the spots became rusty and spread throughout the leaf surface. Later on the leaves turned black and got dried up. Spraying of neem oil emulsion plus tobacco decoction was effective in checking the damage. Sun scorching symptoms were observed on the leaves during September–November. Sufficient shade was provided as remedial measure. During the first week of December, in addition to the leaf fall, die back of vines was noticed. The diseased portions were cut off and the plants rejuvenated and grew normally.
One to two fruits ripened from each inflorescence producing on an average 16 mature fruits per plant. Fruits are follicles with the tip tapering to a blunt point. It measured on an average 10.3 cm in length and 6.6 cm in breadth. Fruit characteristics of *Holostemma adakodien* is presented in Table 16.

There were two mericarps out of which one was suppressed. Seeds were very thin, ovoid, flattened, winged with silky white coma. Plants shed their leaves at the time of fruit ripening. On maturity, the fruits dehisced and the seeds were dispersed by wind.

The tubers were yellowish white in colour with smooth surface, root scars and several rootlets. Data on the average yield of five plants harvested at different stages is given in Table 17 and depicted graphically in figure 2.

In general, tuber yield of *H. adakodien* exhibited a steep increase up to the 11\textsuperscript{th} month and showed a gradual increase thereafter up to the 24\textsuperscript{th} month. The maximum yield of 488 g fresh tubers per plant was recorded at this stage. Driage manifested a gradual rise from 40\% in the 8\textsuperscript{th} month to 43\% in the 24\textsuperscript{th} month.

The root characteristics of *H. adakodien* at harvest is presented in Table 18. The plant produced on an average 11 roots. Out of these, only 3 to 4 underwent tuberisation. An interesting observation was made on the growth pattern of this tuber crop. After attaining a length of about 39-45 cm, the main root branched into two or three along the horizontal plain. Later, the main root and the branches started thickening and developed into root tubers. The tubers recorded an average length of 161.8 cm and diameter of 2.4 cm. It is noticed that the size of the tubers observed in
this study is much greater than that reported by Iyer and Kolam mal (1979) in *H. adakodien* plants collected from the wild.

2.6 *Indigofera tinctoria* Linn. (PLATE-II.d)

Height of *Indigofera tinctoria* at branching stage and growth characteristics at the age of 3 months are given in table 19. Plants recorded an average height of 88.4 cm. Average number of branches at this age was 23. Plants started branching at an average height of 23 cm.

Data on the root and leaf yields of *I. tinctoria* is given in tables 20 and 21 respectively. The weight of roots increased gradually from the 8\textsuperscript{th} month and almost doubled by the 24\textsuperscript{th} month. Maximum yield was recorded by plants between 4½ and 7½ months of age. Thereafter, a gradual decrease in herbage yield was observed. The crop gave an average annual yield of 275.8 t/ha. At the present market rate of Rs.40/kg of leaves, the crop gives annual returns of Rs. 11,000/ha which can be considered to be economically attractive.

2.7 *Kaempferia rotunda* Linn. (PLATES-II.e & V.b)

The growth parameters recorded from five randomly selected plants on the 120\textsuperscript{th} day of planting in 1996 planted and 1997 planted crops are presented in table 22. The plants measured on an average 23.7 cm in height. The average length of leaf was 44.2 cm and breadth 6.6 cm.

The rhizome yield characteristics recorded from the 1996, 1997 & 1998 planted crops are given in Table 23. The main rhizome divided on an average into 20 finger rhizomes. Each of this rhizomatous branches produced adventitious roots of
which about 4 to 5 ended in ovoid tubers. (PLATE-VII). On an average, 110 tubers were recorded in a plant.

The rhizome yield of *K. rotunda* obtained from 1996, 1997 and 1998 planted crops is given in Table 24. It is seen that the crop thrives well and produces an annual rhizome yield of about 25 t/ha. This yield is very high when compared to other zingiberaceous crops. At the present market rate of Rs.40/kg fresh rhizome the crop gives an annual returns of Rs.10,00,000/ha. This study demonstrates that the crop is well adapted to the climatic situation in Kerala and can be cultivated in the state on a commercial scale.

2.8 *Operculina turpethum* (Linn.) Silva Manso (PLATE-III.f)

The important growth and yield characteristics of *O. turpethum* are given in table 25. On an average, the plants attained a height of 13.86 cm at vining stage and 6.1m at flowering stage. At the age of about 15 months, growth rate decreased considerably. Severe falling of leaves together with die back of vine was noticed at this stage. Most of the roots decayed by this time. At this stage, the plants were harvested by uprooting cleaned and weighed and recorded an average yield of 141.66 g/plant.

2.9 Yield of *Pogostemon patchouli* Pellet (PLATES-III.c & V.e)

Data on the leaf yield of patchouly during the two years from 1997 to 1998 is presented in table 26 and depicted graphically in fig. 3. In the 1997-98 experiment, patchouli yielded 24.5 tons of fresh leaf per hectare equal to a dry matter of 3.43 tons. The yield of leaves increased to 40.3 t/ha in the third harvest taken 180 days after planting. There after the leaf production showed a gradual decline reaching 17.5 t/ha
during the 5th harvest made at 360 days after planting. The same trend was observed in the experiment conducted during 1998-99 also. On an average, the crop yielded 149.4 tons of green leaf equivalent to 20 tons of dry matter per hectare annually. The results of the study show that patchouli is well adapted for cultivation under Kerala conditions. When cultivated as a pure crop it has a huge potential of producing leaves that can be profitably used in the manufacture of ayurvedic drugs. The findings of the present study show that patchouli leaves are available all the year round, an important pre-requisite for the drug industry. An important observation made was that the yield of patchouli leaves obtained in the study was much more than that reported in literature. According to Guenther (1949), a crop of patchouli yields about 1.3 tons/ha. Similarly Weiss (1997) reported that the leaf yield of patchouli during the first year is in the range of 1 to 3 tons/ha falling to 1 to 2 tons/ha during the 2nd and 3rd years. The average yield of 150 t/ha was far greater than that reported hitherto. This large difference in leaf yield of patchouli obtained in this study can be attributed to the use of Singapore variety, an improved type of patchouli. Also it may be due to the closer spacing of 30x30 cm followed in this field study. According to Weiss (1997), spacing closer than 60-90 x 30-45 cm will tend to increase branching and fresh leaf production in this crop.

However, a characteristic observation was that the plants in the experiment declined and died out after one year. This is contradictory to information available in literature. In the reports of Guenther (1949) and of Weiss (1997), the crop can be grown for 3 years even though there is a gradual decline in the yield during the second and third years. In the study under report, even though the crop yield was many times
higher than that reported earlier, the plant did not survive for the second year. Perhaps this may be due to over exhaustion of the plant resulting from closer spacing and nutrient application.

3. Standardisation of agrotechniques

3.1 Growth and rhizome yield of *Acorus calamus* under different spacings and types of irrigation water (PLATES-I.a & IV.a)

*Spacing*: Average data recorded in 1997 crop is presented and discussed below. Average data on the height of plants and breadth of leaves in different combinations of treatments is presented in Table 27 and 28. Even though spacing did not exert much influence on plant height, the leaf breadth increased by 19.15% when spacing was increased from 30x30 cm to 60x60 cm.

Data on the size of rhizomes dimension as well as yield are presented in table 29 to 31. Notable differences were observed in case of rhizome length and thickness with change in plant spacing. When plant spacing was increased from 30x30 cm to 60x60 cm, the length of rhizome increased by 15.53% with an increase of rhizome diameter by 25.19%. Examination of data on the weight of rhizomes shows that the yield of rhizomes remained unchanged at around 21.5 t/ha irrespective of change of spacing from 30 x 30 cm to 60 x 60 cm. This showed that when the space between plants was increased, the linear growth of the rhizomes got accelerated at the expense of its thickening, so that the biological yield remain unchanged. From the results obtained in the study it can be suggested that since the rhizome yield in both the spacings is same, a wider spacing of 60x60 cm will be more economical, as it requires only less
planting material. However, information of the quality of the produce is to be ascertained before confirming this recommendation.

**Quality of irrigation water**: Swamps and riversides are the natural habitats of *A. calamus*. A wet soil with standing water is best suited for the plant. The crop can be cultivated in low-lying paddy lands of the state. The experiment envisages assessing the performance of the plant under the wetland condition in comparison to flood irrigation with a factory effluent.

Data on the growth and yield characteristics of the crop when grown under irrigation with fresh water or with factory effluent is presented in tables 29 to 31. When the plants were irrigated with the effluent water, its height and breadth showed a substantial increase of 39%. The breadth of the leaf increased tremendously (96.2%). Significant increase was observed in the dimensions of the rhizome as well. When rhizome length showed an increase 21.68%, its breadth increased by 147.05%. The yield of rhizomes obtained from plots that received effluent water irrigation (25.2 t/ha) was substantially higher than that (17.84 t/ha) from plots that received normal irrigation water, recording an increase of about 41%. This indicated the large influence of the treatment on bio-matter accumulation by *A. calamus*.

Usually factory effluent water is as such unsuitable for irrigation. The high concentration of degradable substances depletes oxygen in the water. Such waters will inhibit root respiration. Further, high levels of organic and inorganic substances usually present in factory effluents prove detrimental to plant growth and its quality. The BOD of the effluent water (900 mg/l) was not so high as to affect root respiration. On the contrary, irrigation with effluent water has favoured growth and biomatter
accumulation by the crop. The effect can be attributed to several factors. Some chemical principles present in the effluent would have been stimulatory to the plant. Also the organic and inorganic materials in the water would have contributed plant nutrients. Positive evidence to this argument cannot be provided, as the chemical composition of the effluent water was not studied. Also the plant nutrient status of the soil before and after irrigation was not ascertained. However it is clear from the study that irrigation of *A. calamus* with the factory effluent water has significantly improved growth and yield of the crop. The overall advantage of the practice can be confirmed only after ascertaining the effect of the treatment on the quality as well. Also the physico-chemical changes in the soil as a result of continuous use of this water has to be studied to evaluate the safety of the practice.

3.2. *Adhatoda spp.*

3.2.1 Histological study of *Adhatoda sp.* (Manjapra ecotype)

*Root*: C.S. of the root of *Adhatoda sp.* (Manjapra ecotype) is given in fig. 4A. The root is circular in cross section with a narrow bark outside the central woody region of 6 – 8 mm diameter. The phellem is made of thin walled rectangular to tangentially elongated cells (300 – 350 μ in thickness). The outer region of the cork is slightly brown in colour. The cortex is parenchymatous with cells containing starch grains. Besides, large, solitary and elongated cystoliths (250 μ long) are found in cortical cells which is similar to *A. beddomei* (Aiyer and Kolammal, 1963). Within the cortex, tangentially elongated, irregular, lysigenously formed lacunae or air spaces occur. Stone cells form a discontinuous annular band towards the inner region of the cortex. Phloem is wide and is associated with acicular fibres. Wood is similar to that
of *A. zeylanica* (Aiyer and Kolammal, 1963), with large number of wood fibres and medullary rays. Vessels are arranged in groups of 2 – 7 in radial rows.

**Leaf:** C.S. of the leaf of *Adhatoda sp.* (Manjapra ecotype) is given in fig. 4B. Anatomy of the leaf shows the structure of a dorsiventral leaf. It is similar to that of *A. zeylanica* with abundant stomata (diacytic type) on the lower epidermis. Stomata are occasionally found in the upper epidermis intermingled with trichomes, a character found in *A. beddomei*. Cystoliths are present in the mesophyll (Aiyer and Kolammal, 1963).

Presence of solitary cystoliths both in the cortex of the root as well as in the mesophyll of the leaf relates the plant to *A. beddomei*. Besides, the occurrence of stomata on the upper epidermis of the leaf also relates it to *A. beddomei*. But presence of lysigenously formed air spaces in the root cortex is a character which is found in *A. zeylanica*. The present ecotype (under study) shows similarities with both *A. zeylanica* and *A. beddomei*. But it differs markedly in its creeping (repent) habit. The taxonomic identity could not be established due to lack of flowering and as such it is treated as an ecotype of *A. zeylanica*. (PLATE-IV.b).
3.2.2 Comparative evaluation of types of *Adhatoda*

Data on the growth characteristics at three months and yield characteristics at harvest of three cultivated types of *Adhatoda* are given in table 32 and presented graphically in figure 5 A-D. *A. zeylanica* and *A. beddomei* are erect in habit, whereas the *Manjapra* ecotype is repent. (PLATE-I. d, e & f).

There is significant difference in the height of the three plant types. *A. zeylanica* recorded an average height of 275 cm which was three times more than that of *A. beddomei* and 6 times more than the *Manjapra* ecotype. *A. beddomei* was intermediate in height (87.5 cm) which was twice that of the *Manjapra* ecotype. The *Manjapra* ecotype was shortest of the three (45cm), was repent in nature, rooting throughout the length of the twigs.

The dimensions of the leaf was in the order *A. zeylanica* > *Manjapra* ecotype > *A. beddomei*. Regarding the number of branches per plant, *A. zeylanica* and *A. beddomei* were more or less on par registering 5.6 and 6.0 branches per plant respectively but the *Manjapra* ecotype produced significantly more number of branches (14.4). As regards the number of leaves per plant, the *Manjapra* ecotype (207.36) was far superior to the other two types (76.16 & 57.78).

The above yield components exerted a cumulative effect on the most important economic trait, the leaf yield per unit area of land. It was maximum (75.55 t/ha) in case of the *Manjapra* ecotype followed by *A. zeylanica* and *A. beddomei*. Based on the above observations it may be inferred that the *Manjapra* ecotype studied is superior in yield to *A. zeylanica* and *A. beddomei*, the two types that are widely used.
in pharmacy at present. If this new plant type is acceptable from the quality point of view as well, it offers great potential for large-scale cultivation.

3.3 *Holostemma adakodien* Schultes

3.3.1. Biochemical changes in *H. adakodien* during growth

The growth of plants was satisfactory and they started flowering at 4-5 months of age. Flowers and young fruits were pruned off to save energy. This method worked well and delayed the shedding of leaves. Since protein and alkaloids are the pharmacologically active part in the dry roots, their level in tuber is very much important in determining the quality of the drug. The percentage of these compounds varies with age and vigour of the tubers. So it was decided to carry out trials for fixing the optimum period of harvest by taking into consideration of the strength of the major constituents viz. protein, carbohydrate and alkaloids.

Chemical composition of *H. adakodien* tubers at different stages of growth are given in table 33 and presented graphically in figure 6. Though the carbohydrate content showed a decrease between 10 and 20 months, the carbohydrate yield remained more or less constant, probably due to increase in the total dry matter production with age. The major quality attributes, viz. protein and alkaloid contents as well as their yields increased from the eighth month onwards and reached maximum at 17th to 18th month and declined thereafter. Since the alkaloids and proteins are considered to be the active constituents in *Holostemma*, the efficacy of the drug is maximum at the 17th to 18th month stage. Therefore it is advisable to harvest the crop at this stage, for better quality.
3.3.2 Comparative yield of seed propagated and vegetatively propagated plants of *Holostemma adakodien* Schultes.

Data on the yield and protein content of tubers harvested at different periods are presented in table 34. Data on the tuber yield establishes definite superiority of clones over seedlings. The clones recorded a mean yield of 281 g/plant, which was almost 52% more than that of the seed propagated crop. Similar superiority was observed in case of quality also. Protein content of tubers produced by clones (9.85%) was almost 25% more than that of tubers (7.09%) produced by crop raised from seeds.

In both the treatments, the yield of tubers exhibited a gradual increase up to 24 months, but the protein content reached a peak at 18 months and declined thereafter. Both types of crops were consistent in this aspect. Reviewing the results of experiment reported under Section 3.3.1, it can be proposed that the optimum stage of harvest of *H. adakodien* shall be 17-18 months irrespective of the method of propagation.

The results available from 3.3.1. and 3.3.2. convincingly show that higher yield of tubers with superior quality could be obtained from clonally propagated plants. Thus it can be claimed that this method of propagation is better suited for commercial cultivation than seed propagation.

3.3.3 Effect of soil tilth on the tuberisation of *Holostemma adakodien* Schultes.

Data on the root characteristics and tuber yield of the plants are given in table 35. The difference in growth and development pattern of tubers in the two treatments is noteworthy. The total length of the root system (184 cm) was more in plants grown in tilled soil (T1) than that (140.8 cm) of plants grown in untilled soil (T2). In case of T1, tuber formation started only at 59.1 cm from the base of the plant whereas in case
of T2, it started at 28.4 cm. When plants in T1 recorded a tuber yield of 233 g/plant, those in T2 produced a significantly higher yield, 420 g/plant, and an increase of about 80%.

The results indicate that the root growth pattern of *H. adakodien* is influenced by the compactness of soil. In the loose soil, the main root grew to a greater depth before tuberisation was initiated. But when the plant was grown in a compact soil, linear growth of the root was restricted and tuberisation started much earlier. As a result of this phenomenon, the plants grown in zero tilled soil out yielded those grown in tilled soil.

The practical significance of the finding is far reaching. It is desirable to select a comparatively hard type of soil like the laterite for the cultivation of this crop. The resistance offered by the soil to the elongation of the root might change the physiology of the plant in favour of root thickening and accumulation of secondary metabolites in it. Much higher yield can be expected in such situations. Although the more compact nature of the soil should make the excavation and recovery of the tubers at the time of harvesting difficult, the limited depth traversed by the tubers in the a compact soil necessitates only less extensive digging.

3.3.4 Effect of time of planting on the performance of *Holostemma adakodien* Schultes.

Data on the field establishment and leaf characteristics of May-planted and August-planted crops of *H. adakodien* are presented in table 36. Almost all the seedlings survived and established well in the field when transplanting was done during May. On the contrary, seedling establishment was poor in the case of August-planted crop. The southwest monsoon rain stopped in July-August and the plants
were severely affected by the scorching sun during the dry spell that followed. Sun scorching was serious in spite of all the care taken for giving adequate shade. The average establishment was only 47.8% after 4 months of planting. Although the plants rejuvenated on receipt of northwest monsoon showers during October-November, their growth was severely affected by the low temperature during the December-January period. The plants showed stunted growth, defoliation and dieback of vines. The net effect was reflected on the field recovery of plants. Only 22.16% of the plants recovered after 10 months of planting.

The effect of time of planting was very much evident on the size of leaves. Leaf size of *H. adakodien* plants planted in the month of May was larger than that planted in August. The leaf length was 39% and leaf breadth 32% more in May-planted than in August-planted crop. The adverse effects of the seasons as described above would have affected the leaf growth as well.

Yield characteristics of May-planted and August-planted *H. adakodien* are presented in table 37. Significant differences were observed in the yield attributes of the crops planted in the two different seasons. The number of tubers was 72% more in May-planted crop than in August-planted crop. A much larger effect was noticed in case of the economic part viz., the tuber. The tuber yield was about 347% more in case of May-planted crop than in the other.

The results of this experiment are of paramount importance as regards the cultivation of *H. adakodien*. Highly significant differences were noticed in the growth and yield of the crop planted in the two seasons. It was observed that the environmental factors at the establishment stage of the plants were very much
detrimental to the performance of the crop. It is to be presumed that the May-planted crop enjoyed a set of favourable weather conditions during the establishment period whereas reverse was true in case of August-planted crop. The net result of this was reflected on all the growth and yield characteristics studied. The significant superiority of the May-planted crop over the other could be doubtlessly established in this study. It can thus be concluded that for getting better yield of *H. adakodien*, the crop has to be planted in the month of May, before the start of monsoon.

### 3.3.5 Variation in the quality of *Holostemma adakodien* Schultes in market

The results of physico-chemical analysis of the market samples of *adapathiyan* are presented in table 38. Large variations were not observed in the physical characteristics of the material like colour, length and breadth of pieces. However the protein content ranged from 4.5 to 7.15% with an average of 5.71%. The alkaloid content was almost constant (1.15 – 1.5%). The consistency in the physico-chemical characteristics of the material collected from different markets indicates that the materials reaching the different markets originate from the same source. As already stated, the material of commerce is extracted from the forests of Palakkad and Malappuram districts and hence consistency in quality can be attributed to the uniqueness of the source. Still, variation can be expected in the raw drug available at different periods of time. However such a study was not undertaken.

Elaborate quality analysis has been done on cultivated samples of *adapathiyan* in Experiment 3.3.1. Protein content varied from 3.94 to 11.5% and alkaloid content between 1.10 to 1.52% depending on the stage of maturity. At the optimum stage of
maturity, the protein content was 11.5% and the alkaloid content was 1.52%. In comparison, the quality of market samples was much inferior to the cultivated sample. This highlights the scope for improving the quality of the crude drug by resorting to cultivation.

3.4 *Indigofera tinctoria* Linn. (PLATE-V.a)

3.4.1 Effect of date of planting on the performance of *Indigofera tinctoria*

Growth characteristics of *Indigofera tinctoria* in January planted and May planted crop are given in Table 39. In general growth of the plant was more vigorous in May planted crop. It recorded a mean plant height of 40.33 cm, which was about 18% higher than that of the January planted crop which recorded only 33 cm on an average.

Similarly the former produced 41% more branches than the latter. It is thus found that the influence of climatic factors on the growth of *Indigofera tinctoria* is very much significant.

In the case of May planted crop, the harvest of leaves started in July i.e., 2 months after planting. The leaf production reached a maximum by September and exhibited a declining trend thereafter when the plants entered the reproductive phase. After flowering, leaf yield diminished drastically and the plants started to perish by January. The quick decline in growth may be due to the intervention of flowering during November – December. However, within this short span of 8 months, a leaf yield of 635 kg/plot could be realised, equivalent to 140 tons/ha.
In case of January planted crop, harvesting of leaves started in March and the peak yield was recorded in June. Thereafter, the leaf yield showed a slow decline till December – January. In this case, the leaf production was more protracted and spread over a period of 10 months. The cumulative yield was only 540 kg/plot (120 tons/ha). It is thus found that planting *Indigofera tinctoria* in May is better and produces about 15% more leaf yield than when planted in January. (Table-40).

However, certain drawbacks have been observed in the case of May planted crop. The incidence of pests was very severe in this case which warranted pest control measures to be undertaken causing problems in crop management. At the time of harvest, the root system of the plants was rotten due to disease infections. Hence, this part of the crop was not available for utilisation. On the contrary, the January-planted crop was free from pests and diseases and created fewer problems in crop management. The crop performance was consistent and the produce was available over a protracted period of time.

### 3.4.2 Effect of maceration of *neelamari* leaves on the extraction of colour by oil

Data on the colour and absorbance of 604 nm light by oil extract of *neelamari* leaves in different treatments are presented in table 41. The colour of the extracts varied from light violet to deep violet. Absorption spectra of the extracts are presented in figure 7.

The leaves of *neelamari* contain the glucoside, indican. When the leaves are crushed, the enzymes in the leaves effect the conversion of indican to an yellow solid, indoxyl. Indoxyl in turn is oxidised by atmospheric air to indigotin, a deep bluish
violet pigment (Dymock et al.1890; Finar, 1975). Since the bluish violet colour of indigotin is the characteristic colour of the extract of neelamari leaves, the absorbance of the extract in the area of 590-61 nm can be used for quantifying the colour of the extract. Thus the intensity of colour of the oil extract of neelamari leaves was measured in terms of absorbance at 604 nm.

It was seen that absorbance in general (fig.7) and specifically at 604 nm (Table-41) was very strong in all the treatments except T1 which was the oil extract of old leaves prepared with intact leaves. The low colour intensity of extract prepared by the extraction of intact old leaves may be because of the subdued activity of hydrolytic enzymes responsible for the conversion of indican to indoxyl. The high activity of these enzymes in young leaves probably would be the reason for the high colour intensity in such leaves even when it is not crushed. The matter to be specifically noted in this connection is that irrespective of the age of the leaf, maximum colour is extracted if the leaf is crushed and juice collected for preparation of the drug.

3.4.3 Effect of maturity of leaf on the oil extractable colour of neelamari

The data on the colour of oil extracts as observed visually and on the absorbance at 604 nm are presented in Table 42. The data shows that the colour intensity of oil extracts prepared from juice of leaves belonging to different age groups did not vary significantly. More or less similar absorbance values at 604 nm further supports this observation. However, when the leaves were crushed to express the juice, and when this juice was extracted with oil, the colour intensity of the
products in different treatments remained almost the same. This indicates that if the leaf tissues are macerated and sufficient time is given for the completion of hydrolytic and oxidative reactions involved the formation of indigotin, the colour of the extract will be the same irrespective of the age of the leaves from which it is prepared. However it is to be noted that the dry matter content of leaves is more in old leaves and vice versa. This being true, it is evident that the chemical factors responsible for oil extractable colour is more in younger leaves than older ones, when considered on dry matter basis.

It has been generally observed that active ingredient of drug plants increases with age. Applying this principle to neelamari, the colour contributing factors will be more in older leaves than younger ones. This is the reason why old and mature leaves are preferred for the preparation of oil. But the results of this study indicate that leaves of all ages contribute equally to the colour of the product, neelabhringadi. Hence leaves of all ages can be used for the preparation of this ayurvedic formulation.

3.4.4 Effect of ingredients other than neelamari on the colour of neelabhringadi oil

The colour of the oil extracts prepared in different treatments and the absorbance measured at 670 nm, 600 nm and 580 nm are given in table 43. The absorption spectra of the extracts are given in fig 8. Characteristic colour differences were observed for the oil extract of neelamari leaf juice, combined with the other herbal ingredients. This is further evident from the spectra in fig. 8. The oil extract of neelamari leaves manifested a bluish violet colour. Spectroscopically it was characterised by large absorption peaks at 580 and 600 nm. The oil extract of other
ingredients showed a light greenish yellow colour with high absorption at 670 nm and feeble absorption at 580 and 600 nm. However when neelamari and other ingredients are extracted together, the violet colour of neelamari was decreased with a commensurate increase in the green colour, characteristic of neelabhringadi oil. This was evidenced from the changes in the absorption levels at 580, 600 and 670 nm. This demonstrates that an interaction exists between neelamari and other herbal constituents of neelabhringadi oil in determining the final colour of the neelabhringadi formulation.

3.5 Shade requirement of Mentha arvensis Linn.

Observations on height, leaf length & breadth, number of branches and the internodal length at the age of 40 days recorded on 5 plants selected at random is given in table 44. Plants in shaded plots registered about 38% more height than that (36.6 cm) in unshaded plots (65 cm). It is natural that plants grown in restricted light exhibit more internodal length resulting in a net increase in plant in height. This is evident from the data on internodal length. The internodal length of plants under shaded plots (2 cm) was 33% more than that (1.5 cm) of plants on exposed plots.

Leaf size of M. arvensis was tremendously increased by shading. The length of leaf increased from 4.86 cm in open to 6.84 cm under shade. Similarly leaf breadth increased from 1.58 cm to 2.62 cm. However, there was no effect of the treatment on the number of branches. In general it was observed that the growth parameters of the plant was significantly increased by shade.

Data on the yield of leaves obtained in different harvests of M. arvensis crop is given in Table 45. It was noticed that plants under shaded plots blossomed at an age
of 50-60 days, which was slightly earlier than those in the other treatment. The leaf yield of *M. arvensis* was greatly influenced by shade. Leaf yield in the case of shaded plants increased with age reaching to a maximum (12.5 t/ha) at around 80 days, declining sharply thereafter. The yield of plants grown under open conditions reached a maximum (7.5 t/ha) in 70 days, which declined slowly as time progressed. There was great difference in the total leaf yield with treatment. It was only 25.96 t/ha when the plant was grown in open whereas it was as high as 39.51 t/ha when grown under shade. It is thus seen that the leaf yield increased by about 50% when shade was provided.

The results indicate that *M. arvensis* can be successfully cultivated in Kerala and under 50% shade, a leaf yield of about 40 t/ha can be obtained with good management.
3.6 *Operculina turpethum* (Linn.) Silva Manso

3.6.1 Comparative yield of seed propagated and vegetatively propagated plants of *Operculina turpethum* (Linn.) Silva Manso.

Data on the growth characteristics of vegetatively propagated plants of *O. turpethum* is presented in table 46 and that of seed propagated plants in table 47. It has been observed that the dimensions of leaf were more in vegetatively propagated plants. The mean leaf length of vegetatively propagated plants (10.82 cm) was about 25% more than that (8.22 cm) of seed propagated plants. The effect was much more pronounced in the case of breadth of leaf. Leaf breadth of vegetatively propagated plants (12.02 cm) was about 50% more (8.56 cm) than that of the other. As regards diameter of the stem also, asexually propagated plants were superior (1.46 cm) to the sexually propagated ones (1.29 cm), though the effect was only marginal.

A significant difference could be observed between the two types of plants in the case of time required for flowering. Whereas the vegetatively propagated plants blossomed within about 157 days, it took 306 days for the seed propagated plants to come to flowering. Though early flowering is a basic characteristic of vegetatively propagated plants, the effect is very much pronounced in the case of this plant and has great significance in the cultivation of this crop.

Observations on the yield characteristics of vegetatively propagated plants of *O. turpethum* are tabulated in table 48 and those of seed propagated plants in table 49. The dynamics of root growth parameters with age is depicted graphically in fig.9.
It was observed that root length increased marginally with age from 365 days to 460 days in case of vegetatively propagated plants and up to 520 days in case of seed propagated plants. In both cases, there was a steady decline thereafter. Examination of the root showed that the decrease in root length was attributed to decay of root tips due to ageing. Both the types of plants attained a maximum root length of about 1 m. However, vegetatively propagated plants approached this value earlier (460 days) than seed propagated plants (520 days).

The diameter of the root showed a steady increase up to 460 days in case of vegetatively propagated plants and 490 days in case of the other. This parameter remained steady thereafter.

The change in the fresh and dry weight of roots per plant with age of the plant observed in experiments conducted during 1997 and 1998 is given in table 48 and 49 and shown graphically in fig.10. The root yield in the case of vegetatively propagated plants increased with age reaching a maximum at around 430 days. Thereafter, it showed a sharp decline. Similarly the yield of seed propagated crop reached a maximum by 520 days. It is thus shown that the vegetatively propagated plants produced an early crop that can be harvested after about 14 months and the seed propagated plants produced a late crop that can be harvested only after about 17 months.

A much more significant effect between the two types of propagation was observed regarding the yield of roots, the economic part of *O. turpethum*. Vegetatively propagated plants recorded a maximum dry root yield of 1.424 kg/plant which is about 16% more than that (1.198 kg/plant) obtained in the case of seed propagated plants.
In general, the plants propagated vegetatively through compound layering were more vigorous in growth, they flowered early and produced much more yield of roots in a much shorter period. Hence this method of propagation is found to be more suited for cultivation.

**3.6.2 Nutrient management in *Operculina turpethum* Silva Manso**

Data on the yield of *O. turpethum* under various manurial treatments is given in table 50. Application of manure as well as fertiliser significantly reduced the time taken for flowering of the plant. When plants in control treatment flowered after 220 days, the plants that received farmyard manure flowered in 180 days. This duration was further reduced to 160 days in case of plants treated with chemical fertilisers. Nutrient elements are known to increase the rate of growth of plants and to induce flowering. Naturally, a corresponding decrease in the age of harvest time has also been observed. This justifies the need for nutrient supplementation in cultivation of this plant.

One of the general difficulties experienced in the cultivation of *O. turpethum* was the low recovery of plants at germination. The poor establishment was found to be due to decay of roots. In this experiment, it is found that application of farmyard manure has reduced mortality from 10% in control to 5%. This demonstrates the effect of manure in favouring the establishment of this plant. However under conditions of fertiliser application, the mortality has been high at 20% indicating that the plant do not withstand fertiliser application at rates applied in this treatment.

Examination of data on root yield reveals that the crop responds tremendously to nutrient application. The fresh root yield registered a nine-fold increase from 7.2
t/ha in control to 66.5 t/ha in plots receiving farmyard manure. Similar effect was observed in the case of plants receiving fertiliser treatment, though less pronounced. The root yield in this treatment increased about 6 times. The apparent disadvantage observed in the case of fertiliser treatment when compared to the manure treatment may be because of the probable over dosing of nutrients in the former. This is also indicated by the higher mortality rate in fertiliser applied plots than in the manure applied ones. The study demonstrates that *O. turpethum* responds very well to nutrients. However, detailed studies are required for working out the optimum manure/fertilizer requirement of this crop.

3.6.3 Physical characteristics of market *trivrit*

In order to study the physical characteristics of *trivrit* available in the market, samples of market trivrit were collected from various sources and physical characteristics of the material like colour, length and breadth of pieces were recorded.

Mean of physical characteristics of the samples is presented in table 51. Anatomical observations showed that all the samples studied consisted of stem pieces of *trivrit* 7.0 to 30.0 cm in length. A wide variation in the diameter ranging from 1.3 to 14.9 cm was also observed. This shows that the material consisted of stem at different age. A similar variation was observed in colour which ranged from light brown in thin pieces to brown in thick ones.

In Ayurveda treatises, *trivrit* root is recommended for formulations such as *Avipathi choornam, Manibhadram, Kalyanagulam, Bahusalagulam, Aragwadharishtam* etc. There is no authentic substitution of root with stem in such formulae. According to classics, if the official part of a plant is not specified, root
should be used and that too in specific cases root bark should be used (Achutha Warrier, 1955). However, the crude drug trivrit available in market consisted mainly of stem pieces. The physical observation has revealed that the material consisted of pieces varying widely in age. No information is available on the dynamics of pharmacologically active ingredients in stem with age. Raghunathan (1982) reported that glycosidic resin having the specific therapeutic action is concentrated mostly in the root bark. Hence the root should be used in ayurvedic formulations to assure maximum efficacy.

3.6.4 **Biochemical analysis of *Operculina turpethum* Silva Manso.**

Biochemical analysis of *Operculina turpethum* the ayurvedic drug and *Marsdenia tenacissima*, its adulterant was undertaken to characterise the materials and to develop chemical methods for their identification. Results of analysis of representative samples are given in table 52 and shown in figure 11.

The content of crude fibre exhibited a large variation in the samples studied. It was smallest in sample 1 and highest in sample 4. In general, the crude fibre content of market samples of *Operculina* (23.58% to 33.39%) was lower than those in cultivated samples (63.42 to 79.23%). This difference may be due to the genetic difference between the material collected from the market and the cultivated type. Comparison of the results in the case of samples 4 and 5 shows that the crude fibre content increases with age. It was 63.42% in immature plant sample whereas the value was 79.23% in mature sample. It is well established that the synthesis of cellulose, hemicellulose, lignins etc. that constitute plant fibre increases as the plant ages.
Chloroform extractable matter was comparatively less in cultivated samples. The result was similar in the case of acetone extractables too. The content of water-soluble matter in the samples were in a narrow range of 20.44% and 21.72% except in the case of cultivated sample (mature) which contained only 9.41% water solubles.

RP-18 thin layer chromatogram of the water extract of the samples is presented in Fig.12. A lot of variation is observed between samples in this study. In the case of sample 2, almost all of the extract was retained at the origin (spot A). In the case of sample 3, B was the major spot with small amounts of spots C and D. No spot developed in the TLC in the case of samples 1.

Characteristic difference was noticed in the crude fibre content of Operculina studied. It varied from 23.58% to 33.39% in market samples whereas in the case of the cultivated sample, it was as high as 79.23%. The chemical make up of the solvent extract of the samples did not show any significant variation. However, characteristic differences existed in the chemical constitution of the water extract of the samples. The results indicate that significant differences exhibited by Operculina turpethum root, stem and Marsdenia stem on reversed phase TLC. Hence this method can be used for distinguishing unknown samples of these materials.

3.7 *Piper* spp. (PLATES-III a,b & VI.a,b)

**Comparative evaluation of *Piper* spp.**

Data on leaf dimensions recorded at 150 days after planting and on fruit characteristics at the time of harvest are presented in table 53. Noticeable differences were observed in the leaf dimensions of the leaves of the two species. The mean leaf length of *P. chaba* (15.8cm) is about 127% more than in *P. longum* (6.96cm).
However as regards leaf breadth, *P. chaba* recorded values 8.5% less than that of *P. longum*. Significant differences existed between the two plants in the case of fruit length and diameter. In *P. chaba*, the mean fruit length was 5.6 whereas in *P. longum* it was only 2.6 cm. Similarly fruits of *P. chaba* registered a diameter of 1.1 cm whereas in *P. longum*, it was only 0.5 cm, about 76% less than the other.

Data on the yield of *P. chaba* and *P. longum* are presented in table 54. *P. chaba* produced 1123.1 t/ha of fresh fruits during 1996-98 and 1163.1 t/ha during 1997-99 with an average of 1143.1 t/ha during the two-year cropping period. During the corresponding period, *P. longum* produced 896.0 and 902.8 t/ha of fresh fruits with a mean of 899.4 t/ha. Thus *P. chaba* produced about 20% more yield of fresh fruits than *P. longum*. The drainage of spikes in the two cases is note-worthy. When *P. chaba* yielded 30.3% of dry matter whereas *P. longum* gave a recovery of only 16.47%. Hence the recovery of dry drug from the former is almost double that from the latter. It is observed that on dry matter basis, the yield per unit area of *P. chaba* is almost 40% greater than that of *P. longum*. Although a slight variation in therapeutic value is attributed to *P. longum* and *P. chaba* in classical literature (Pandya, 1985) in the Sanskrit names *upakulya* and *ephagana* both the species are widely used in classical ayurvedic preparations. The present study highlights the superiority of *P. chaba* over *P. longum* on the basis of dry matter yield.
3.8 *Pogostemon patchouli* Pellet

**Performance of patchouli seedlings under shaded and unshaded conditions.**

Data on the establishment of patchouli seedlings under open and shaded conditions are given in table 55. Only 41.3% of the cuttings established in the open condition. However the establishment percentage was as high as 84.7 when the nursery was provided a shade of about 75%. Extreme necessity of shade for the establishment of patchouli cuttings is demonstrated in this experiment. Patchouli is a tender herb by itself and the planting material consisted of soft wood cutting comprising of stem with 4-6 tender leaves and growing tip. Since tender plant parts were used for propagation, during summer months, transpiration loss of water exceeds absorption from soil. This results in the drying up of the material. It is revealed from the results of the study that in spite of copious irrigation, more than half of the cuttings perished under open situations. However when 75% shade was provided, the establishment percentage could be enhanced to around 85%. Possibility of increasing the establishment rate further by increasing the shade has to be studied.
3.9 Ruta chalepensis Linn. (PLATE-III.d)

Response of Ruta chalepensis Linn. to shade

Observation on the establishment of plants on the 45th day of transplanting showed that when 90% of plants established in shaded plot, it was only 50% in unshaded plot.

Data on the growth characteristics of Ruta chalepensis plant recorded at the three-months stage are given in table 56 and fig.13. Plants in unshaded plots exhibited severe stunting of growth. When plants grown under shade registered a height of 75.76 cm, it was only 34.85 cm in case of plants grown in open. Thus plant growth was found to be retarded to an extent of around 54% by direct sunlight. On the contrary, the number of branches/plant (7.2) was more in case of unshaded plants when compared to that (5.1) in shaded plants.

A significant observation made in case of this plant is that it did not blossom even after a growth period of 1½ years. It may be inferred that the plant does not flower under the climatic conditions in Kerala.

Data on yield characteristics of shaded and unshaded R. chalapensis is given in table 57. Significant differences in yield were observed between R. chalapensis planted under shade and unshaded condition. In open condition, an average yield of only 103.30 kg/ha was obtained. But in shaded condition it increased to 265.58, recording an increase of around 157%.

Changes in the cumulative yield of R.chalapensis with progress of time is shown in fig.13. In case of both shaded and unshaded treatments, the cumulative yield of plant tops increased up to about 300-350 days and remained stagnant.
thereafter. Based on this data it can be concluded that when the plant is grown on a commercial scale, the plots may be replanted after one year for getting consistently higher yields.

3.10 Wedelia chinensis (Osbeck) Merrill (PLATES-III.e & VI.c)

**Performance of Wedelia chinensis (Osbeck) Merrill under different spacings.**

Data on the yield of plant tops recorded up to 420 days after planting of the crop is given in table 58 and depicted graphically in fig. 14. Under a spacing of 25x25 cm, the plants spread well between the inter space and reached the stage of harvest within 60 days. Subsequent harvests were undertaken at bimonthly interval. The yield increased gradually up to 300 days and declined sharply thereafter, probably due to over crowding of plants. When grown under a spacing of 50x50 cm, the crop came to harvest only in 120 days. But the yield at first harvest was very high. Throughout the growth period, higher yields were recorded by plants grown at wider spacing. The total yield in a period of 420 days was 1037.7 t/ha in case of wider spacing and this was almost 93.8% more than that (535.5 t/ha) in case of closer spacing.

The result of the study shows that higher yields of up to 1000 t/ha can be realised from *W. chinensis* when cultivated at a spacing of 50 x 50 cm.

4. Phytochemical studies in Rasna

The rhizomes/stem bits of a wide variety of plants primarily possessing anti rheumatic property are being used as *rasna* in a number of anti-rheumatic preparations namely *Rasnerandadi kwath, Ashtavargam kwath, Rasnasapthakam kwath, Rasnadi choornam, Gandha thailam, Balaswagandhadi thailam*. These plants include *Alpinia galanga, A.officinarum, Pleuchea lanceolata, Vanda tessellata* and *Rheum emodi.*
They possess one or more of the properties of *rasna* described in classical literature namely tongue like leaf, fragrant root, anti-rheumatic property, resemblance to cardamom, high pungency etc. Scientific documentation of the anti-rheumatic principles of these plants are not available as such. This study is intended to make a comparative evaluation of their physicochemical characteristics and to rank them in the order of efficacy as drug, based on the content of anti-rheumatic principles analysed chemically.

The fluorescence characteristics of five *rasna* selected for the study are given in table 59. Finely powdered drugs of *A. officinarum, A. calcarata* and *A. galanga* when exposed to ultra violet source of light exhibited greenish yellow colour where as the colours were much different in *R. emodi* (ash) and *V. tessellata* (brown). When viewed after impregnation of the powders with alcoholic alkali, *A. officinarum, A. calcarata* and *A. galanga* exhibited similar colour (reddish brown). Differences were observed in the colour of *R. emodi* (dark brown) and *V. tessellata* (dirty green).

The drug materials exhibited wide variations on presentation of alkali-impregnated powder in nitrocellulose to uv light. Here also the observations were one and the same as in powder as such, except in *V. tessellata* were the colour was dirty green with violet tinge.

The physico chemical properties of five *rasna* drugs selected for the study are given in table 60. Where as rhizomes of *Alpinia* spp. and *Rheum emodi* comprised the drug material, it was the stem bits of *V. tessellata* that was used for drug preparation. There was a lot of variation in the dimension of the drug materials studied. The rhizome bits of *R. emodi* were small, the
length ranging from 1.5 – 3.3 cm and thickness from 1.3 – 3.1 cm. The other crude
drugs were larger with length, in the range of 5-9 cm as well as thickness 3-6cm. The
drug materials also exhibited characteristic variations in their colour.

Odour was one of the characteristics by which these materials would be
differentiated. While *A. officinarum* and *A. calcarata* were strong in their aromatic
smell, *A. galanga* and *V. tessellata* possessed only a feeble odour. On the other hand
*R. emodi* didn’t possess any distinct odour. Differences were also observed in the taste
of the drug material. Whereas *A. officinarum* and *A. calcarata* possessed strong
aromatic and pungent taste, *A. galanga* was less pungent. On the other hand *R. emodi*
didn’t have any distinct taste. Contrastingly *V. tessllata* was bitter in taste.

Representative chromatographs of extracts of *A. officinarum* and *R. emodi* are
presented as figure 15 and 16. Methyl cinnamate chromatographed at 4.24 min. Data
on the methyl cinnamate content of different *rasna* drugs is given in table 60. A large
variation was observed in the methyl cinnamate content of different *rasna* drugs. The
two species of *Alpinia* namely *A. officinarum* and *A. calcarata* topped the list with
2.12 to 2.135 % respectively. This was closely followed by *A. galanga* with 1.9% methyl cinnamate. *V. tessellata* analysed far less content of methyl cinnamate (0.5%) where as *R. emodi* did not contain any cinnamate at all. Methyl cinnamate, a cinnamic acid derivative is well known for its anti-rheumatic,
anti-arthritis and anti-inflammatory properties. Chatterjee (1996) found that methyl
cinnamate manifested high level of anti-rheumatic property in albino rats similar to
β-methasone. Hence methyl cinnamate was selected as a “marker compound” to compare the anti-rheumatic and anti arthritic property of the rasna drugs.

The analytical results show that among the 5 sources studied, the three plants of the family Zingiberaceae are rich sources of methyl cinnamate. Hence *A. officinarum* and *A. calcarata* can be considered as the best anti-rheumatic drugs to be followed by *A. galanga*. In a similar study Sharma & Sharma (1977) made a comparative evaluation of the anti-inflammatory activity of five rasna plants against formalin arthritic, carrageenin and formaldehyde induced acute rat paw oedema. They found that anti-inflammatory effects were maximum for *Alpinia galanga* followed by *Pleuchea lanceolata*. Their study also proved *Vanda tessellata* to be least effective.

Though *A. galanga* is seen growing in wild, its availability is too meager to be a good source for commercial drug manufacture. Most of the drug manufacturers in Kerala use *A. officinarum*, the source of which is China and the sub Himalayan states. Due to the long distance over which this material has to be transported, its market price is always very high. *A. calcarata* is a related species, which is equally high in quality and seen cultivated in isolated places in Kerala. If this plant is popularised and cultivated on commercial scale, it can very well substitute the present requirement of *A. officinarum*.

*V. tessella* is the widely used rasna drug second to *P. lanceolata* by North Indian drug manufacturers. The present study has revealed that this is a poor source of the anti-rheumatic factor, methyl cinnamate. The introduction of *A. calcarata* to North India and popularisation of its cultivation will help in increasing the availability
of this drug in the North Indian market. In that case *A. calcarata* will be an ideal substitute to *V. tessellata*.

*R. emodi* is being used by several drug manufacturers in South India as a cheap alternative to *Alpinia spp*. The results of the study showed that *R. emodi* does not contain the anti-rheumatic factor, methyl cinnamate. In other physical and organoleptic characteristics also, *R. emodi* differed significantly from the other *rasna* plants. The absence of methyl cinnamate strongly suggests that the use of *R. emodi* as *rasna* in anti-rheumatic drugs should be discontinued.

No information is available on the possible changes in the physico-chemical properties of drugs during their processing into formulations. Methyl cinnamate being the principle compound in *rasna* drugs, it is important to study the possible changes in the content of this principle during drug manufacture. It can be anticipated that this aromatic compound may be lost by volatilisation during the process of cutting and powdering done during preparation of the *kwath* powder. Further, volatilisation of these compounds may take place during preparation of the *kwath*, which involves concentration by prolonged heating. An effort was made to quantify the loss of methyl cinnamate during preparation of *kwath* powder and *kwath*. From the quantity of methyl cinnamate in the *rasna* drugs used for *kwath* powder making and from the quantity of methyl cinnamate in the *kwath* powder made, the recovery of methyl cinnamate after the process of *kwath* powder preparation was worked out and presented in table 61. Similarly the recovery of methyl cinnamate during the process of *kwath* preparation was also worked out. The data showed that the necessary of methyl cinnamate in *Rasnerandadi kwath* powder, *Ashtavargam kwath* powder and
Rasnasapthakam kwath powder was in the range of 89.62% – 103.4%. Except Ashtavargam kwath powder prepared using A.officinarum as rasna, the recovery of methyl cinnamate from the formulation was almost total. The results shows that practically no loss of the methyl cinnamate occurs during disintegration and machine powdering of Alpinia spp. during the manufacture of Rasnerandadi kwath powder, Ashtavargam kwath powder and Rasnasapthakam kwath powder. This indicates that compounds like methyl cinnamate with boiling point as high as 127°C at 10 mm mercury do not succumb to loss when plant materials containing them are powdered using hammer mill.

Data in table-61 shows that almost all methyl cinnamate in the drug powder taken for kwath preparation was recovered in the product. In spite of concentration of the extract to ⅛ th of the original volume by prolonged heating for a period of 8 hrs, the methyl cinnamate in the extract did not suffer any loss. This shows that less volatile principles in crude drugs like methyl cinnamate is conserved during the process of preparation of kwath, inspite of long hours of wet heat treatment prescribed in the manufacturing process of kwath.
SUMMARY AND CONCLUSION