3. REVIEW OF LITERATURE

Review of literature on propagation of fastgrowing pulp yielding plant species, their related agronomical parameters and paper making characteristics etc. was undertaken and presented as follows:

3.1 VEGETATIVE PROPAGATION

Vegetative propagation of forest trees is potentially very useful for replicating clonal material and for the multiplication of stock, for plantation purposes (Ghosh and Bhatnagar, 1977).

The effect of size of stem cutting on sprouting in Commiphora mukul was studied by Puri and Kaul (1972), who observed that 15 mm diameter and 300 mm length resulted in higher sprouting. The rooting response of Spiraea sorbifolia stem cuttings was up to 52% without any aid of root promoting hormones and irrigation (Chandra and Khushdii, 1977). Somasundaram and Jagadees (1977) observed that the best results were obtained by propagating lateral or side shoots of Casuarina equisetifolia by using rooting hormone Seradix-2. Sprouting was least abundant when carbohydrate reserves were low during summer as compared to the dormant season, when carbohydrate concentration was high (Kramer and Kozlowski, 1979). The promising effect of Parahydroxy benzoic acid and Indole butyric acid on vegetative propagation of Populus gamblei and Cryptomeria japonica was observed by Lahiri (1979). Nanda (1979) studied in detail the vegetative propagation of Populus nigra, Hibiscus rosasinensis and Ficus infectoria and reported that stem cuttings of easily rooted species exhibited rhythmic changes due to seasonal variation. He further observed that the effectiveness of exogenously applied auxins also changed with the season and
higher number of rootings were recorded during January to March, because of higher starch content in stem during November to January and low level in April till September. The effect of auxins on root formation in the vegetative propagation of *Populus alba*, *Populus tremula*, *Picea abies* and *Juniperus communis* was reported by Al-Kinany (1981). The root forming effect of IPA, IBA and IAA on the stem cuttings of *Dalbergia sissoo* was reported by Pain and Roy (1981), who observed that in the summer planted stem cuttings, the best results were obtained with IBA (100%), next in NAA (80%), then in IPA (60%) and last in the control (20%). In the winter planted cuttings, 100% rooting was noted with 1000ppm IPA and 80% with 500ppm IPA. Chauhan and Sehgal (1982) reported the effect of hormones on root formation of forest trees by stem cuttings.

Jain (1982) has observed some physiological aspects of rooting of cuttings in forest trees and reported that auxin in the presence of adequate amount of carbon nutrition increased the fresh production of protein and that the magnitude of rooting is determined by the size of protein pool that is available in the tissue at the time of root initiation. Pal (1982) reported that IAA and IBA treatments increased the number of roots per cutting of *Populus robusta* and mean root length, whereas MH suppressed rooting. Ethral treatment, when given alone, increased the number of roots and enhanced the root promoting effects in combination with IAA and IBA and decreased the inhibitory effect of MH. Parmar and Kumar (1982) reported maximum rooting in the cuttings of *Murraya koenigii* with IBA, while Rootone did not exhibit any effect at all. Higher percentage of roots of *Moringa oleifera* stem cuttings was observed during February to March with 50ppm IBA (Sharma and Raina, 1982).
Regarding the length and thickness of cuttings in Poplar, Mathur et al (1983) concluded that the length of cuttings should not be less than 20 cm and the thickness should preferably be around 1.5 cm. Deol and Khosla (1983) also observed that increase in diameter of cutting resulted in differential shoot growth.

Singh et al (1984) reported the performance of *Populus ciliata* plant cuttings taken from the bottom one-third, middle one-third and top one-third portions and observed that the bottom one-third performed better than those taken from the middle one-third which did better than those taken from the top one-third part of the plants. Sarma and Bordoloi (1986) also reported similar results in *Populus deltoides* G-3.

Ahmed (1987 and 1989) had successfully propagated *Acacia albida* shoot cuttings without any root hormone and reported that better results were obtained in case of plants raised from shoot cuttings than from seeds. In case of bamboo, culm segments are used for propagation (Kumar et al, 1988). Vegetative propagation through macro-proliferation, by using growth promoting substances, adopting various methods of cuttings etc. were reported by several workers (Cabanday, 1957; Seethalakshmi et al, 1983; Surendran et al, 1983 and Kumar et al, 1988).

### 3.2 PLANTING/SOWING TIME

In case of Kenaf, late planting followed by dryness contributes to low yields. On the other hand, early planting may result in slow emergence and slow growth if cool, moist conditions prevail (Anon, 1970). Dutta et al (1979) reported that the ideal time of sowing Kenaf seeds...
in the first fortnight of June in the plains and foothills of north-western India. Wood (1981) established that with irrigation, year round growth of Kenaf was possible in Tropical Australia. Muchow (1981) reported that maximum stem yield of Kenaf occurred in case of crops sown prior to the onset of the wet season i.e. December to March, in Australia. The effect of sowing date on the stem growth of Kenaf was reported by Wood (1981) and according to him, in Australia, sowing in June and July gave peak yields of 23-25t/ha, whereas later sowings led to lesser yield and the extreme case was seen in April with only 8t/ha yield.

Propagation of bamboo in north-eastern region of India is generally done before the onset of monsoon i.e. mid of April to mid of May. The most common method for propagating bamboo is by planting offsets just before the rainy season (Bhatnagar, 1974). Ghosh and Bhatnagar (1977) studied the rooting response of branch cutting in case of Populus gamblei and observed differences in rooting response due to seasonal variation. Nanda (1979) reported that stem cuttings of even "easy-to-root" species like Populus nigra, Hibiscus rosasinensis and Ficus infectoria exhibited rhythmic changes in rooting response during the annual growth cycle. Even after application of auxins like IAA, IBA, NAA, 2-4-D etc. in stem cuttings of the above plants, the number of roots increased from January to March and gradually decreased up to September. It was reported by Sharma and Raina (1982) that pretreatment of stem cuttings for 24 hours during February to March with 50ppm IBA induced higher percentage of roots in Moringa oleifera. It was also reported by Deb Roy (1986) that establishment of tree seedlings of Acacia tortilis, Albizzia amara, Albizzia lebbek, Leucaena
leucocephala and Hardwickia binata was higher during September/October which gradually reduced reaching its minimum level during June. Sarma and Bordoloi (1987) studied the effect of different seasons on sprouting and survival of Poplar (*Populus deltoides* G-3) cuttings and reported the highest percentage of sprouting (96.25%) and survival (75.50%) of cuttings during the months from December to February.

### 3.3 POPULATION DENSITY

Clark and Wolff (1969) reported in case of Kenaf that at population densities of 17,800 to 1,49,000 plants/acre and maturities of 90-138 days after seeding, the stalk solids increased with population density upto 57,500 plants/acre. The desired row width and plant population improves the yield and the trials of row spacings of Kenaf at 12, 24 and 36 inches indicated the highest dry matter yield per acre at 24 inches row spacing (Anon, 1970). Bagby *et al* (1975) reported maximum yield of dry matter in Kenaf as 11.6 and 12.2 t/ha from plant densities of 1,00,000 and 2,00,000 plants/ha respectively. At the lowest level of plant competition, all the components of vegetative yield of Kenaf increased as density increased from 1,30,000 to 9,20,000 plants/ha, with complete plant survival at all densities, while the yield remained constant over the entire range of plant population between 1,00,000 and 9,00,000 plants/ha (Muchow, 1981). Muchow further recorded that high plant population of Kenaf should be used for dry season crops, as no advantage would accrue from such populations in wet season crops. Seeding rates should be planned to give a population of about 5,00,000 plants/ha. Sarma *et al* (1986) reported higher yield of dry biomass (15.18 t/ha) in
Kenaf under 40 cm row spacing in a trial of row spacings at 30, 40, 50 and 60 centimeters.

Penfold and Willis (1961) indicated that maximum pulp-wood in Eucalyptus was recorded when spacing was maintained at 2.1 x 2.1m or 2.5 x 2.5m. However, in very arid areas, where sand and dunes are prevailing like Tripolitania, the recommended spacings for Eucalyptus were 7 x 7m and 8 x 8m. Bhatia (1980) reported that if spacing is not proper, it will create an intense competition between seedlings for moisture and nutrients in same soil horizon leading to intense mortality and stunted growth in *Eucalyptus hybrid*. He also recorded significantly better height and diameter growth with the wider spacing of 3 x 3m over 2.5 x 2.5m and 1.5 x 1.5m. Malthani and Sharma (1987) reporting on initial spacing in Eucalyptus plantation, stressed on the population density per hectare for realising optimum production. Kapur and Dogra (1989) reported the highest biomass of 48.11 ODT/ha in spacing 0.5 x 1.0m out of 14 spacings tried at the age of 3 years.

In case of Pine plantations, recommendations on initial spacing were made by many workers. Cook (1963) suggested a spacing of 6'x10'. Harms and Collins (1965) tried spacings of 6'x6' to 15'x15' for slash pine and reported that though the merchantable cubic volume did not show any clear relationship to spacing at the age of 12 years, 6'x8' spacing had the highest merchantable volume per acre. Maeglin (1967) reported that the suitable spacing in pine may be 8'x6'. Wakeley (1970) and Bella and DeFranceschi (1974) found out that suitable spacing in pine was 8'x8'. Owens (1974) tried different spacings for loblolly pine and reported that maximum volume occurred at 6'x6' and 8'x8' spacings in
10 years of age. Shepard (1974) found that out of four spacings tried in loblolly pine, 8'x8' spacing gave the highest volume of wood per acre. Balmer et al (1975) also reported the same spacing as suitable for pine plantation. In case of Chir pine plantations, Singh (1977) opined the optimum spacing as 2.5x2.5m, on the basis of crown diameter - d:b.h. relationship and minimum crop diameter for commercial thinnings. Kaul and Sharma (1982) reported that in Pinus caribaea var. bahamensis, the best spacing might lie between 2m² and 2.5m². Ponnuswamy (1982) tried a good number of pine species in Tamil Nadu and achieved higher mean annual increment at a spacing of 2x2m.

Growth parameters and yields are effected by spacing, in case of big trees like Tectona grandis, where higher volume was obtained under the spacing 2.74 x 1.83m for seven years old plants (Adegbeijn, 1982). Singh and Lal (1982) reported that the closest spacing of 1.83 x 1.83m gave the highest yield as compared to that of the widest spacing of 3.66 x 3.66m, which resulted in lowest yield in Anthrocephalus chinensis. Mathur and Sharma (1983) worked on many clones of Poplar and reported higher dry yield under the spacings of 1.0x1.5m (30.2 t/ha), 1.0x1.5m (20.6 t/ha) and 1.0x1.0m (17.4 t/ha) for Populus deltoides "G-3", "67/26" and "IC" respectively. Leucaena leucocephala plantation at 2x2m and 3x3m spacing gave maximum mean annual increment of 11.3 tonnes and 5.6 tonnes respectively (Chaturvedi, 1983). Khullar and Hussain (1986) reported the mean annual increments of 12 years old Acacia tortalis under spacings 6x6m, 4.5x4.5m and 3x3m as 57.7 t/ha, 61.0 t/ha and 76.4 t/ha respectively. However, the green weight per tree was higher (208.0 kg) with the higher spacing.
3.4 FERTILIZER REQUIREMENTS

The vital role played by the nutrients like nitrogen, phosphorus and potash in plant growth have been exhaustively elucidated by Arnon (1933), Wadleigh and Ayers (1945), Bonner (1950) and Vishniac (1955). Nitrogen, in the form of proteins, is present in the protoplasm of every cell. In addition, nitrogen is present in many other compounds, which are of great physiological importance in metabolism, such as chlorophyll, nucleotides, phosphatides and alkaloids; as well as in many enzymes, hormones and vitamins. Nitrogen, therefore, makes plants dark green and more succulent, in addition to make cells larger with thinner cell walls. Nitrogen also increases the proportion of water and decreases the percentage of calcium in plant tissues. Nitrogen promotes vegetative growth and encourages the formation of good quality foliage by promoting the production of carbohydrates, and encouraging succulence. Many crops when fertilised with nitrogen acquires an increased ability to absorb not only more nitrogen but also more phosphorus, potash and calcium. Nitrogen fertilization increases the cation exchange capacity of plant roots and thus makes them more efficient in absorbing other nutrient ions (Tamhane et al, 1970). Black (1957) also recognised nitrogen supply in soil as the largest single factor causing variations in the crop yields. The production of vegetative shoots doubled in Red pine on using nitrogen as ammonium nitrate (Giertych and Forward, 1966).

Dutta (1966) emphasised the role of nitrogen on plant growth as it is a constituent of all proteins and, hence, of protoplasm. He further indicated that nitrogen is a constituent of photosynthetic pigment -
chlorophyll and respiration energy carrier - adenosine triphosphate, both of which are vital for the physiological functions in plants and therefore, its application stimulates leaf growth, resulting in increased photosynthetic surface.

Marked response of nitrogen on the dry matter yield of Kenaf was reported and higher yield was found while administering 200-50-50 pound per acre N, P and K respectively (Anon, 1970). Higher yield of dry Kenaf stalk (217.19 Q/ha) was reported by Dutta et al (1979), while applying 200 kg/ha nitrogen. Muchow (1981) reported the best results in respect of banded applications of 250 kg/ha of super-phosphate and around 200 kg/ha of nitrogen as urea prior to sowing of Kenaf seeds. Sarma et al (1986) studied the effect of nitrogen on the biomass yield of Kenaf varieties and reported a linear trend in the increase of biomass upto the nitrogen level of 200 kg/ha, after which the yield was not proportionate to the nitrogen applied.

Quite striking response of nitrogenous fertilizers was reported even in higher plants like Eucalyptus. Addition of nitrogen would definitely prove beneficial to Eucalyptus, while the addition of phosphatic fertilizers is of doubtful value (Penfold and Willis, 1961). Prasad et al (1984) reported that nitrogen and phosphorus application increased biomass in Eucalyptus grandis.

Brar and Katoch (1982) reported the effect of different levels of nitrogen on growth characteristics of Populus deltoides. It was reported by Deol and Khosla (1983) that growth parameters and yield
significantly increased upto the application of 60 kg nitrogen per hectare in *Populus ciliata*.

Nimbkar *et al* (1986) observed that *Leucaena leucocephala* attained significantly greater height than *Melia azedarach* with no difference in basal stem diameter, while applying a fertilizer dose of N\textsubscript{50}P\textsubscript{50}K\textsubscript{50} kg/ha. Effect of nutrients like nitrogen and phosphorus was observed by Raina *et al* (1988) in *Bambusa tulda* and Totey *et al* (1988) in *Dendrocalamus strictus* on their growth behaviours in seedling stage.

### 3.5 HARVESTING TIME

In case of Kenaf, arithmetic averages, for length and width of bast and woody fibres, decreased between 90 and 120 days after planting, while no significant change was observed after 120 days. Little change in yield of screened sulphate pulp or in pulping quality occurred in the processing of green Kenaf stalks, which were harvested after 120 days from planting (Clark *et al*, 1967). It was also reported by Clark and Wolff (1969) that proportion of stalk solids of Kenaf increased with maturity. Harvesting time is unimportant for pulp preparation if the Kenaf crop is harvested after about 120 days of planting. The time of harvests becomes largely a matter of yield economics as regards to biomass production (Anon, 1970). Wood (1981) was of the opinion that Kenaf should be allowed to continue to grow for maximum production, until declining soil moisture led to a cessation of growth and then only harvesting should be done.

In case of perennial plants, the time of harvest is not fixed as that of the annual plants. Generally, trees are cut at the age of
maximum production. The curves of current annual increment and mean annual increment cross each other at the maxima of mean annual increment curve. The age at which they cut, is the age of maximum production and optimum time of harvest (Chaturvedi and Khanna, 1982).

3.6 BIOMASS PRODUCTION

Singh (1982) observed that biomass production in relation to planning in forestry is one of the important aspects. Evaluation of biomass, in general, may be made based on complete measurement of roots, stem and branches (Chaturvedi and Khanna, 1982). Green matter produced by Ipomoea carnea in Tamil Nadu has been reported to the tune of 75,000 lb per annum (Anon, 1959). Dutta and Fotedar (1979) tried seven varieties of Kenaf and got maximum dry stalk yield (154.98 Q/ha) in HC-583 under Jammu conditions. Muchow (1981) reported that the highest stem yield in Kenaf was obtained from the June sowing crops in Australia. Biomass produced by the Kenaf varieties HC-583 and AMC-108 was 16.570 t/ha and 13.830 t/ha respectively under the agro-climatic conditions of Jorhat (Sarma et al, 1986).

In bamboo plantation, the yield of Dendrocalamus strictus is estimated at 3.5 t/ha per annum (Varma and Pant, 1981). Sharma (1988) is of the opinion that sympodial bamboos are low yielding, unless the clumps are clearfelled and the monopodial species - Phyllostachys pubescens forms dense stands containing 2,000 to 6,500 clumps per hectare.

Several workers have made interesting observations on the biomass yield and yield components of higher plants. Biomass yield was
recorded on *Leucaena leucocephala* by Lohani (1979), Pathak *et al* (1981) and Maslekar (1984) and reported that the aerial biomass harvested at 3 and 4 years of age under farm forestry conditions, the mean annual increments showed a rising trend with maximum increment between the 3rd and 4th year and the dry matter of 11.0 tonnes on the 4th year. However, Maslekar's investigation showed the average biomass yield of two and half years old Subabul plantation as 29.42 kg/tree.

Singh (1980) observed in *Shorea robusta* of different ages and reported the growth and yield informations upto the age of 50 years. In *Pinus elliottii*, Kaul *et al* (1982) reported that the total biomass ranges from about 169 tonnes (10 years) to 529 tonnes (40 years) per hectare with 81 to 85% being contributed by the above ground parts and 15 to 19% by the roots. On the other hand, Sharma and Srivastava (1984) observed in *Pinus patula* that the total biomass ranges from 7 tonnes (3 years) to 194 tonnes (9 years) per hectare with 82 to 87% being contributed by the above ground parts and 13 to 18% by roots. The net primary productivity and productive structure in three girth classes of five different aged plantations of *Eucalyptus tereticornis* have been reported by Singh (1982). Observations were recorded by Gupta and Raturi (1984) in *E. hybrid* plantation for a period of 10 years, with a standing biomass of 98052 kg/ha (1120 tree/ha). Biomass in Eucalyptus have been reported to increase with increasing age (Gurumurti *et al*, 1984). Mathur *et al* (1984) reported the increase in the yield of biomass from 2.25 t/ha in one year old plantation to 43.50 t/ha in 3 years old plantation with average spacing of 1.3x1.3m in Eucalyptus. The total biomass of 1600 tree stocking per hectare in
E. camaldulensis was recorded as 43.27 t/ha and 554.16 t/ha for 5 and 15 years old plantation respectively (Prasad et al, 1984). Negi and Sharma (1987) estimated the biomass of Eucalyptus species by regression method.

Kaul and Sharma (1983) and Sarma and Bordoloi (1986) reported the yield of biomass in Populus deltoides upto the age of 10 years (175 t/ha) and 4 years (26.326 kg/tree) respectively. Shetty and Rajagopal (1984) made a critical study on Acacia nilotica and reported the out turn tables for fuelwood, pulpwood, bark, faggotwood and brushwood against independent variables of basal area and height. A thorough study in respect of utilizable and non-utilizable biomass on Eucalyptus hybrid, Albizia lebbeck, Dalbergia sissoo, Acacia nilotica, Cassia siamea, Acacia tortilis and Prosopis juliflora was made by Mathur et al (1984) for different period of growth.

3.7 PLANT CONSTITUENTS VARIATION AT DIFFERENT GROWTH STAGES

Variations in cellulose content of Kenaf at different maturities were studied by Clark et al (1967). Clark and Wolff (1969) reported that alpha-cellulose (24-28%), lignin (7-10%) and pentosan (9-15%) contents in Kenaf stalk increased with maturity. Agarwal et al (1987) studied the characteristics variations of chemical composition by aging of Leucaena leucocephala and noted that "Wood of 4 years of age is seen to be the most suitable for pulp manufacture because of its low basic density. Density increases with the age subsequently necessitating higher concentration of chemicals and longer time for proper penetration".
and cooking. Paper made from pulp of 150 day-old was stronger by about 12% than that from 120 day-old mesta plant (Ray et al, 1988). Composition and content of important chemical constituents like cellulose, lignin, pentosan, sugar etc. varies from plant to plant. Quantitative differences of such constituents were observed in the same plant at different stages of growth (Immergut, 1963). In mature wood tissue, the amount of lignin varies between 18 and 38% (Sarkanen, 1963). Rao et al (1983) and Sarma et al (1986) analysed the plant constituents in different varieties of Kenaf. The characteristics variations of chemical composition by ageing in *Leucaena leucocephala* was determined by Agarwal et al (1987).

### 3.8 PULPING QUALITY

Pulps from Kenaf was studied by Bagby et al (1975), who reported that the strength characteristics were comparable to commercial coniferous wood pulps. Bagby (1977) also found that Kenaf pulps have the properties generally equal or superior to most wood pulps. Jeyasingam (1983) studied a good number of non-wood plants in Sri Lanka for pulping and put forward his conclusion as "The use of Kenaf as a long fibre substitute has proved to be a success and there is a need to promote the growing of Kenaf on a commercial scale with the active participation of the rice farmer". Because of its good pulping quality, the Phoenix Pulp and Paper Co Ltd; Khou Kaen, Thalland, has produced for the first time in the world, pulp from Kenaf commercially with an annual capacity of 70,000 MT (Leekha and Thapar, 1983). The possibility of using Kenaf as a new source for manufacture of pulp and paper was evaluated.

Pulping characteristics of many other annual plants were also studied by Manavalan et al (1979) on Crotalaria juncea and C. retusa; Markila (1979) on Sesbania aculeata and Sharma et al (1983) and Banerjee et al (1985) on Roselle.

Utilization of soft and hard wood in paper industry is also increasing day by day. Pulps from Eucalyptus species were evaluated by Sharma et al (1975), Bhandari et al (1982) and Chauhan and Bist (1987), who observed that the material could be used for manufacture of standard hardboard, pulp, paper, etc. Studies were made by Moorthy et al (1977) and Rao et al (1978) on Cupressus lusitanica, Pinus radiata, Pinus caribaea and Pinus patula and reported that the pulp yield was satisfactory with good strength properties. Melia azedarach is a very promising raw material for production of wrapping, writing and printing paper, provided the trees are grown slowly to gain higher specific gravity for good strength properties (Singh et al, 1977). In case of Poplar, Chakravarty et al (1979) found that the pulp confirmed to TAPPI standards for its suitability and opens avenues for preparation of viscose and
other cellulosic derivatives. Pilot plant trials for production of chemical, mechanical and semi-chemical pulps from *Populus deltoides* showed the suitability of pulp for producing wrapping papers (Singh *et al.*, 1981). Similar studies were also made on Poplar species by Rai and Sharma (1983), Shukla *et al.* (1985) and Sarma and Bordoloi (1986) and it was established that the pulp was suitable as regards to its physical and mechanical properties.

Guha and Karira (1981) studied the chemical pulps derived from *Albizia moluccana* and found to be promising for paper making. Kraft pulping of *Leucaena leucocephala* was investigated by Bhola and Sharma (1982) who found that it has high holocellulose, low ash and solubilities with unbleach pulps (48-56%) suitable for writing and printing papers. Shukla *et al.* (1985) also found *L. leucocephala* suitable for hard boards. Pulping qualities of Acacia species were evaluated by many workers like Bhandari *et al.* (1983) and Kumar *et al.* (1987). The chemical nature of pulp sheet properties of Indian bamboos and various aspects of pulping and paper making qualities were investigated by Singh and Bhola (1978) and Singh *et al.* (1988).