INTRODUCTION

Trees being the chief components of the forest, form a green mantle over the forest areas of the earth. They not only form an upper stratum of an ecosystem, but also have an upper hand to fulfill the needs of day-to-day life of the man. Trees provide ecological security by protecting mountains against pollution in addition to their multiple application such as producer of wide range of economically important products viz., timber, paper pulp, fertilizer, food and fuel. They are the part and parcel of various programs like reforestation and social forestry. It is imperative, therefore, that their biology is well studied.

The tree has a complex living system. The need to study the functioning of the tree requires consideration of its structure. In a sense, tree can be considered as a multiple plant, because in every growing season a completely new set of tissues envelop/replace the older ones. In trees, height growth also called extension growth is due to divisions and elongation of the cells at the tip of the stem. Once they attain definite height, trees face primarily the problem of gravity. To overcome this major hurdle, trees apply a method of increasing its diameter with an interesting lateral meristem the "vascular cambium".

Much information is available on micro-morphological and physiological aspects of Cambium of fossil plants (Progymnosper-matophyta) to the much advanced monocotyledons (Iqbal, 1990). Cambium, a thin layer of cells, comprises of two kinds of meris-tematic cells - fusiform and ray cambial cells. The presence of

cambium can be assessed from the circumferential continuity with the cells arranged in radial files. Fusiform cambial cells are picket-shaped, vertically elongated and cambial ray cells are short. These two cambial cells are responsible for the formation of axial and ray systems of the stem and root.

The structure and activity of cambium are not uniform, but show great variations according to the differing genetic constituents of plants and differences in internal conditions and the external environment (Philipson et al., 1971). The changes in the temperate environment are closely associated with a regular sequence of growth and dormancy in most plants. The onset of cold period usually terminates growth and brings about dormancy in the temperate trees. Trees growing in temperate regions show distinct growth rings. In tropical climate the cambial cells usually divide and develop at more or less uniform rate throughout the year and, thus no obvious growth rings are visible in the wood. However, the formation of growth rings in some tropical deciduous and evergreen trees has been studied (Chowdhary, 1969; Paliwal and Prasad, 1970).

Studies on cambium of tropical trees are rather insufficient compared to those of temperate species. However, since last two decades, due consideration has been given for the studies on structure and seasonal activity of cambium in tropical trees (Paliwal et al., 1970, 1975, 1976; Amobi, 1974; Ghouse and Hashmi, 1979, 1983; Rao and Dave, 1981, 1983a, b; Dave and Rao, 1982a, b; Krishnamurthy and Venugopal, 1983; Ajmal and Iqbal, 1987 a, b; Silva et al., 1990).

The cambial periodicity is controlled by various environmental and physiological factors (Paliwal and Paliwal, 1990; Kitin-Pet, 1992). Temperature, light, rainfall, relative humidity, gravity, geographic location, photosynthesis, water deficiency, endogenous hormones, leaf fall, fruit bearing pattern and age of the plant are known to influence the behavior of cambium (Kozlowski, 1962). As to the environmental factors controlling the cambial activity, the effect of temperature is considered as a limiting factor (Lu and Chiang, 1975; Brett, 1983; Antonova et al., 1988; Badola et al., 1989). Cambial activity is also dependent on the availability of water. In tropical environment it is thought to be onset of dry season which brings about dormancy (Fahn, 1990). Cambial activity is rather dependent upon the amount of water available (Catesson, 1974) and rainfall is considered as an important factor controlling the cambial activity (Waisel et al., 1970; Kozlowski, 1982; Silva et al., 1990). The relationship between bud break and the onset of cambial activity has been recognized since long (Priestly, 1930; Wareing, 1951; Denne and Atkinson, 1987). The initiation of cambial activity and radial expansion of xylem cells is an auxin related phenomenon originating from developing buds. Studies on cambial activity in relation to hormones both in-vivo and in-vitro have also been carried out (Little and Wareing, 1981; Savidge and Wareing, 1984; Little and Savidge, 1987; Savidge, 1989; Sundberg et al., 1987, 1990, 1991; Gersani and Sachs, 1990).

Studies on various aspects of cambial activity have drawn much attention because, the answers for what controls the dura-

tion of cambial activity and the rate of xylem differentiation are still incomplete and yet they are of critical importance for wood production and wood quality. Wood is a highly ordered arrangement of living, dying and dead cells that have walls mostly of cellulose and lignin. Wood has four integrated functions within a tree: transport, storage, protection and mechanical support. Much of the research on the variability of wood anatomy and morphology of trees has been carried out by silviculturists, plant breeders, forest geneticists and botanists. For many reasons studies on general structure and amount and quality of wood have been concentrated in temperate regions and there is an urgent need for similar information in tropical and developing countries. Therefore, it is obvious to study the structure and quality of cambium so as to understand the wood structure and its development.

Third world countries are currently facing a major threat of "the pollution" from rapid industrialization and urbanization. Pollution is an undesirable change in the environment by excessive accumulation of unwanted compounds or matter, thus deteriorating the quality of air, water and land disturbing the biogeochemical cycles and affecting adversely the biotic organisms (Odum, 1971). Spreading of major pollutants in the biosphere has its origin from fast growing industrialization and urbanization, resulting from the dramatic increase in human population. Lack of judicious utilisation of fossil fuels in transport, thermal power stations and industries causes this defilement of the once clean atmosphere of the pre-industrial age.

The classification of pollutants lies under three major groups; water, soil and air pollutants. Water is regarded as polluted when it is changed in its quality or composition directly or indirectly as a result of man's activity, so it becomes less suitable for drinking, domestic, agricultural, fisheries and recreational purposes (Kumar, 1981). The various toxic chemical pollutants found in water are heavy metals like cadmium, mercury, selenium etc., nitrates, biocides and chlorinated hydrocarbons. Important soil pollutants are methylated mercury from insecticides, copper compounds resulting from fungicides, organic compounds like DDT from pesticides and heavy metals like strontium, aluminium, etc. Pollutants in air includes oxides of sulfur, oxides of nitrogen, carbon monoxide, carbon dioxide, ozone and chloroflourine, etc.

Industries like fertilizer complexes, oil refineries, cement factories, various chemical industries and brick kilns and auto exhaust are the main source of air pollutants. Sulfur is found in oil and coal as sulfides, complexed with organic molecules and when roasted or burned escapes as sulphur dioxide. Similarly, oxides of nitrogen results as an end product of burning fuels. Ammonia is the reduced form of nitrogen formed in the fertilizer manufacturing and part of it escapes into the atmosphere as a pollutant.

Mixed air pollutants contaminated all the three spheres (air, soil and water) of earth, at a rate sufficient for the concentrations to reach levels considered adverse to the vegetation and public welfare. Among the gaseous pollutants sulfur

dioxide and ozone cause more injury to plants than all the other pollutants combined. Sulfur dioxide injury to vegetation near a smelter was described as early as 65 A.D. by a bygone biologist Pliny (Kozlowski and Constantinidou, 1986).

Responses of plants have been studied for morphological, physiological, biochemical and anatomical variations brought about by different gaseous pollutants either under natural or experimental conditions (Mudd and Kozlowski, 1975). For two important physiological processes, photosynthesis and transpiration, leaf is positioned as a cynosure of pollution studies. Extensive literature is available on effect of pollution on leaf morphology (Inamdar and Choudhary, 1984; Patel and Devi, 1985; Isakov, 1987; Glavac, 1988; Sharma, 1989; Haseman and Wild, 1990; Guenthardt et al., 1993), leaf injury (Bialbok, 1989; Fiedler et al , 1990; Amundson, 1990), leaf fall (Yoshitake and Masuda, 1986; Keller, 1988; Amundson et al., 1990; Kocon, 1991), physiological and biochemical aspects of leaf and plants (Jager et al., 1986; Saxe and Murali, 1989; Rao and Dube, 1990; Schulz et al., 1990; Thornton et al., 1990; Petitte and Ormrod, 1992; Sanders et al., 1992), anatomical studies of plant (Danilova et al., 1987; Niedzielska, 1987; Krishnayya and Bedi, 1989), pollen germination (Mejnartonicz and Andrzej, 1985; Krishnayya and Bedi, 1986; Renzoni et al., 1990) and on plant growth (Suwannapinunt and Kozlowski, 1979; Biggs and Davis, 1981; Jensenk, 1985; Fulford and Murray, 1990).

The effects of pollutant mixtures on woody plants are complex and not well understood (Kozlowski and Constantinidou,

1986). Much work has been carried out to assess the role of air pollutants on forest decline. Studies on amount of wood production, structure, density, moisture content of wood and width of growth rings of affected trees of temperate regions are amply reported (Keller, 1980; Bauch, 1986; Fengel and Schulz, 1986; Fink, 1986; Fox et al., 1986; Fruhwald, 1986; Ingrid de Kort, 1986; Jakucs and Babos, 1988; Frelich et al., 1989; Roberts, and Cannon, 1989; Kagamimori et al., 1990; Shyamal et al., 1991). But similar studies on tropical trees are very rare (Ghouse et al., 1984a, b). However, recently few attempts have been made to study the affect of air pollution on structural and functional aspects of phloem (Ahmad and Kalimullah, 1986; Kalimullah and Ahmad, 1987; Ahmad and Kalimullah, 1988; Gould, et al., 1988; Mauroussset et al., 1992). Moreover pH values of bark can also be used as indicators of pollution (Ljudevit et al., 1989; Cha and Lee, 1991).

Any variation in the activity of cambium leads to size variations in the ring width of wood. However, such tree ring analysis is not possible with tropical trees as many of them do not exhibit distinct growth rings, especially the evergreen species. Therefore, a study on seasonal dynamics of cambial anatomy is essential to evaluate the effect of air pollutants on radial growth rate of trees. Cambial activity is also considered as one of the best parameters to investigate the adaptation of plants to their surrounding environment. The relationship between pollution stress and cambial anatomy has been studied recently. Apart from the work of Fink (1986), Ingrid de Kort (1986),

Shortle and Bauch (1986), Irena et al., (1989), Masuch et al., (1989) Torelli et al., (1992), little information has been published on the effects of air pollutants on structure and activity of vascular cambium. There is virtually no information on their effects on the cambium of tropical tree species.

On the other hand much work has been carried out on the effects of air pollutants on the accumulation of reserve food materials like carbohydrates, proteins and lipids in various tissues of temperate trees (Evans and Miller, 1972; Percy and Riding, 1981; Wiebe and Blashke, 1988; Alscher et al., 1989; Balsberg, 1989; Forschner et al., 1989; Leuthy Krausse and Landolt , 1990; Sudachkova et al., 1993). However, little is known about the influence of air pollutants on reserve materials in various tissues of tropical species.

The studies described in this thesis were carried out in an attempt to define the influence of combined air pollutants on the anatomy and histochemistry of cambium and its derivative tissues. Baroda is a fast growing city with many industrial complexes around it, situated in the central region of Gujarat State in western India and lies between 21° - 23° North latitudes and 73° - 74° 10' East longitude. Gujarat State Fertilizer Complex (G.S.F.C.), situated in the north of city emits oxides of sulfur, oxides of nitrogen, ammonia and particulate matter. The surrounding vegetation is exposed continuously to those air pollutants all through the year. The trees planted on National Highway-8 are exposed to auto exhaust along with the air emission from the same industrial complex. Responses (injury and biochemical analy-

sis) of woody vegetation exposed by mixed air pollutants up to 0.5 K. M. from the source were already studied (Vijayan, 1987; Krishnayya, 1989; Krishnamurthy et al., 1994). Based on their economic importance two deciduous species, Dalbergia sisoo Roxb., Holoptelea integrifolia (Roxb.) Planch. and an evergreen species Syzygium cumini (Linn.) Skeels, growing in the areas relatively free from pollution and also growing under the influence of the complex air pollutants in the vicinity of GSFC were selected to investigate the following aspects:-

(1) Structure and seasonal behavior of vascular cambium in different tree species growing in the polluted and relatively unpolluted air zone.
(2) Variations in rate and duration of cambial growth.
(3) The relation between cambial activity and phenology.
(4) The relation between cambial activity and climatic conditions.
(5) Structural and dimensional changes that occur in cambial cells and secondary xylem elements.
(6) Differentiation of secondary vascular tissues from cambial zone.
(7) Accumulation and seasonal distribution of reserve materials in cambium and its derivatives.

The trees from relatively less polluted areas are considered as "normal trees" and those from pollution zone are considered as "affected trees".