INVESTIGATIONS ON TREE SIZE CONTROL IN MANGO

(Mangifera indica L.)

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CERTIFICATE

This is to certify that the thesis entitled "INVESTIGATIONS ON TREE SIZE CONTROL IN MANGO (*Mangifera indica* L.)" submitted by Mr. REJU M. KURIAN in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY IN HORTICULTURE to the University of Agricultural Sciences, Bangalore is a record of research work done by him during the period of his study in this University under my guidance and supervision and that no part of the thesis has previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

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4. — (Dr. SYAMA SUNDER JOSHI)

Dedicated

to

My beloved parents

Dr. K. MATHEN

and

Mrs ANNIE MATHEN

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INTRODUCTION

CHAPTER I

INTRODUCTION

The realisation of importance of dwarf trees has increased tremendously in the recent past with the concept of high density planting systems (HDPS) for fruit trees. The continuing decline of availability of suitable orchard lands, as well as rising energy costs and labour problems together with the mounting demand for fruits to fortify the precarious diet of our ever increasing population have given thrust to the establishment of high density and ultra high density orchards in the past few decades in many parts of the world.

Trees having dwarf frame work that can be fitted in a HDPS offer many advantages. The use of dwarf fruit trees in HDPS is known to increase the fruit bearing surface per unit land area by way of accommodating more plants and checking excessive vegetative growth as well as to facilitate early economic returns. Dwarfism in trees lessens the competition between the developing fruits on the one hand and the requirement for the growth of other organs on the other. Therefore, much of the plant's energy is stored in the fruits which ultimately increases the harvest index. There is increased tolerance to light intensities by increasing population and a better utilization of incident solar radiation resulting in a low light extinction coefficient. This increase in light utilization efficiency

enhances the net assimilation rates. It is observed that the proportion of assimilates translocated to economic product may be increased through a reduction in the size of alternative sinks such as trunk, branches and other supporting structures. There is also a reduction in the distance, the assimilates have to be translocted from source to sink resulting in quick translocation of assimilates to fruits. All these lead to higher productivity (Tyagi, 1986). The dwarf fruit trees also facilitate easy horticultural operations such as pruning, plant protection etc. and thereby save labour cost in addition to their increased effectiveness. Fruits can be easily harvested from such trees with lesser injury resulting in better postharvest life of fruits. Also, the fruits produced will be of better quality due to better exposure to sunlight. HDPS are better suited to modern input saving horticultural techniques such as drip irrigation, fertigation, mechanical harvest etc. (Tukey, 1970). Thus the benefits of growing dwarf fruit trees at close spacing are many with only few disadvantage such as high establishment cost and need for a more professional and scientific approach (Hugard, 1981).

Among the various approaches to control tree size, pruning and grafting genetically vigorous cultivars on size-controlling rootstocks were the earliest practised

methods. Subsequently, the use of growth retardants was employed. Recently, interest started in evolving scion varieties which have dwarf frame work, by genetic manipulation.

Using these techniques, high density orchards are being established in many countries. In Italy, Switzerland, Austria and Yugoslavia, the first high density apple orchards with 1200 to 2800 trees per hectare were established by the end of nineteen-sixties, but the main increase came in the early seventies (Hugard, 1981). In England, HDPS of apple were established by 1962 with a better knowledge of tree size control and with the development of proper rootstocks and by 1977 its proportion in total apple acreage increased to about 3 per cent (Walker, 1981). HDPS with 1250 to 5000 apple trees per hectare and 1500 to 2500 pear trees per hectare are also being established in countries like Netherlands, Belgium and West Germany (Wertheim, 1981).

Though some headway has been made in transforming the concept of high density orcharding into a practical reality in the case of temperate fruit crops particularly apple and pear, the progress made in tropical fruit crops, especially mango which is regarded as the 'king of fruits' is little. Mango (*Mangifera indica* L.), the most important fruit

crop of India, is cultivated in an area of 942,560 ha in the country which constitutes 42.6% of total area under fruits with an annual production of 8,516,000 metric tonnes accounting for 47.08% of the total production of fruits in India and 63.3% of the world production of mango.

However, the productivity of mango in the country is very low with a national average of only 8.67 tonnes per hectare (Majumder et al., 1982). As already stated, establishment of HDPS is one of the most important approaches to increase the per unit area production of fruit crops. The need for standardising methods for tree size control in mango has been elaborated by Iyer (1985). With the demand for mango fruits and products shooting up, both for internal consumption and export in the recent past and with the known limitations for extensive horticulture in the country, the need for developing HDPS for mango in India was very much stressed during the second International Symposium on Mango held at Bangalore in 1985 (Iyer, 1985). But for some very few reports of works undertaken to identify dwarfing rootstocks (Kohli and Reddy, 1985), control of tree size using traditional growth retardants like cycocel(Vijayan et al., 1985) and to screen rootstocks for vigour at nursery stage (Mukherjee and Das, 1976; 1980; Majumder et al., 1972; Srivastava et al., 1980; Singh

et al., 1986) and an attempt to accommodate 1600 trees per hectare using the new variety Amrapali (Majumder et al., 1982), there have been no systematic and sustained studies in this line in India. A major hurdle that stands in the way of much wanted progress in this new field of horticulture is the lack of proper understanding of the basic aspects that go into the determination of tree stature, in mango. Hence as an attempt to throw somelight into the basic factors governing tree size in mango and to devise suitable means to control tree size, this study was planned in 1986 with the following broad objectives;

(i) to identify the various components of growth that ultimately contribute to tree size in mango;

(ii) to investigate the effects of certain rootstocks raised from open pollinated seeds from parents of varying tree size on the early (nursery) growth of vigorous and dwarf mango scions;

(iii) to explore the possibilities of chemical control of mango tree size; and

(iv) to understand some of the physiological, biochemical and anatomical bases of vigour in mango.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Since tree size control in mango is relatively a new field of research, efforts have been made in this Chapter to review information on various aspects of tree size regulation in different fruit crops. In an attempt to understand and manipulate to our advantage the tree size controlling factors, the literature on tree size control in its totality has been reviewed in this chapter though some of the aspects do not find any direct or apparent implications to the present study.

2.1. COMPONENTS OF GROWTH EFFECTING FRUIT TREE SIZE

For any study relating to tree size and its manipulation, a basic understanding of the components of growth that ultimately contribute to the overall tree size is necessary. The literature available on these is briefly reviewed below.

2.1.1. Expansion growth

Difference in expansion growth may result from either differential rate of cell division or cell elongation or both. The commercial fruit tree cultivars of non-spur-type in most fruit trees differ in their vigour in the range of 20 to 30 per cent (Faust and Zagaja, 1984). Similar

differences in tree vigour has also been found in spur-type cultivars and selections by Lapins (1965). Hansche and Beres (1980) have reported a range of 60 per cent variation in tree vigour in genetically dwarf peach progenies.

In the case of tropical and sub-tropical fruit trees like mango, citrus etc., the number of flushes the tree produces each year as well as the length of the flushes may be very important in determining the overall tree vigour. Subbaiah (1985) found that the number of flushes produced per year ranged from two in the case of 'Amini', 'Langra', etc. to five in the case of 'Pacharisi' among mango genotypes; and that there was also considerable variation in the length of flush among them. A minimun flush length of 9.1 cm was observed in the case of 'Bennet Alphonso' and the maximum length of 24.7 cm in the case of 'Chandrakkaran'.

2.1.2. Internodal length

Until very recently, it was generally accepted that shortening of internodes in fruit trees invariably led to reduction in vigour. However, the studies by Zagaja and Faust (1983) revealed that although short internodes were more frequent in low vigour seedlings, the opposite types, viz., low vigour with long internodes and high vigour with short internodes were also present, in a sibcross population

of apple. This has been confirmed in pear also (Zagaja et al., unpublished, in Faust and Zagaja, 1984). In mango, internodal length as reported by Subbaiah (1985) varied from 0.99 cm in the case of 'Bennet Alphonso' and 'Mulgoa' cultivars to 1.53 cm in the case of 'Raspuri'. Though Langra produced two flushes a year and Mulgoa three, the latter remained distinctly dwarfer than the former, probably because of the shorter internodal length of the flushes. From these studies one can conclude that both expansion growth and internodal length affect tree stature but each of these characteristics act independently.

2.1.3. Side branching and spurriness

It has been observed that shortening of internodes in pome-fruits is usually accompanied by limited side branching, with most of the side branches developing into spurs (Brown, 1975; Lapins, 1976). However Zagaja et al. (unpublished, in Faust and Zagaja, 1984) found no correlation between internodal length and the degree of spurriness and the correlation between spurriness and tree vigour to be erratic in pear. Consequently, they have concluded that spurriness, per se might not be affecting tree vigour.

2.1.4. Crotch angle

Wide crotch angle has been found associated with

small tree size in apple (Zagaja and Faust, 1983) and in some other fruit species (Faust, unpulished, in Faust and Zagaja, 1984). In an apple sibcross F_2 population, wide crotch angled trees consisted of about 12 per cent of the population in the medium vigour class and 34 per cent of the population in low vigour class, indicating the genetic control. More research is needed however, before a conclusive opinion could be expressed on the eventual genetic implication of wide crotch angles on tree vigour.

2.1.5. Precocity

A precocious variety generally tends to be dwarfer compared to a less precocious one as the former diverts its photosynthates and other metabolites to reproductive structures earlier, thus restricting vegetative growth (Tukey, 1970).

2.1.6. Productivity

It is widely accepted that cropping influences tree vigour in that very heavy cropping is usually accompanied by very decreased vegetative growth in the same year with reduced dry weight increments of leaves, trunks, stems and roots, whereas failure to crop leads to excess vigour (Jackson, 1984).

2.2. PHYSIOLOGICAL BASIS OF DWARFING

A lack of proper understanding of the various physiological mechanisms underlying the determination of tree stature has been limiting a much wanted progress in the development of dwarf fruit trees suited to high density orcharding. Hence, an attempt is made to review the available information on physiological basis of dwarfing in fruit trees.

2.2.1. Hormonal basis of dwarfing

The literature available on various plant hormones in relation to vigour of fruit trees is discussed in detail below.

2.2.1.a. Abscisic acid

Abscisic acid is classified as growth inhibitor and the literature of the early 1970's suggested that elevated ABA levels might explain the dwarfism in fruit trees.

Yadav and Dayton (1972) at University of Illinois, conducted experiments to determine whether certain apple rootstock clones differing in their size controlling ability varied in levels of endogenous ABA. Extracts of EM IX contained the highest level of an inhibitor presumed to be ABA and progressively lower levels were found in the extracts of EM VII and I. These clones represent three

It was reported by Lee and Looney (1977a) that free Cis-ABA content per shoot tip was higher in normal seedling than dwarf or compact seedlings in apple. They have also opined that the higher inhibitor levels reported by Jindal et al. (1974) might probably due to the fact that their bioassay techniques were sensitive to inhibitors other than ABA.

In another experiment also, Lee and Looney (1977b) got similar results for endogenous ABA content in compact and normal phenotypes of apple. Free Cis-ABA levels were higher in shoot tips and subapical shoot section of normal seedlings than compact seedlings and on a fresh weight basis, the shoot tips were higher in free ABA than the subapical sections. This study also confirmed that ABA levels were higher in normal plants while other acidic inhibitors might be higher in compact plants.

Looney and Lane (1984) have concluded that it is unlikely that differing ABA levels explain variations in tree size of fruit crops.

2.2.1.b. Gibberellins

While no endogenous growth substance is easy to measure and interpret, the gibberellins are especially problematic. Reliable extraction and definitive identification procedures have until very recently, been lacking. Futhermore the significance of the several gibberellins found in each plant tissue remains an enigma. Nonetheless,

levels of dwarfing capability, decreasing in the above order. Since no treatment was given to remove possible bound ABA from its attached glucoside, they also suggested that the less dwarfing rootstock could contain total ABA equivalent to more dwarfing clones, but with much lower proportion in the free form. The authors also suggested this method as a possible means of predicting the vigour of rootstocks.

Robitaille (1970) found higher ABA activity in the centrifuged sap of grafts on dwarfing than on vigorous apple rootstocks.

Jindal et al. (1974) investigated the endogenous growth inhibitory substances in the defoliated shoots of dwarf mutants of some apple cultivars and concluded that the large amounts of ABA-like compounds found in the shoot extracts of dwarf mutants were responsible for their reduced tree size.

However, in later experiments by other workers employing more sophisticated methods for extraction and quantification of ABA such as spectropolarimetry and gas chromatography, the indications are that this inhibitory substance present in dwarf phenotypes is not ABA. Feucht et al. (1974) could not find any correlation between levels of ABA in the tissue and dwarfing in *Prunus* trees.

it is clear that gibberellins do influence elongation growth in plants and one must suspect a role with regard to the stature of fruit trees also.

Using procedures from the early days of plant endocrinology, Lee and Looney (1977b) reported that the levels of gibberellin like growth promotors appeared to be higher in both the shoot tips and in the subapical stem and leaves of normal seedlings than in the compact seedlings.

In later experiments, actively growing shoot-tips from four spur type strains of Mc Intosh were examined for polar and non-polar gibberellins. Mac spur, Morspur Mac and standard Mc Intosh displayed comparable levels of gibberellins, but the Mc Intosh Wijcik showed lower levels. All the four strains displyed similar non-polar GA levels. These results suggest to us that the dwarfing component of the compact habit, very evident with the Wijcik mutant, but less striking with other strains is probably under gibberellin control particularly under polar gibberellins (Looney and Lane, 1984). The practical control of tree size using inhibitors of gibberellin biosynthesis such as cycocel(Bliek, 1985), Alar (Kolbe, 1983), paclobutrazol (Quinlan, 1981)etc. also lend support to the role of lower gibberellin levels in determining the dwarf tree stature.

Yadava and Lockard (1977) proposed a hypothesis to explain the mechanism of dwarfing in apple rootstock clones, where GA to ABA ratio is stressed. In vigorous rootstocks, there is a relatively low concentration of ABA like hormone and high concentration of GA like compounds and under such conditions, the low concentration of ABA produces a synergistic effect with GA. This type of synergism on GA action by low concentration of ABA has previously been demonstrated by Yadava (1973) in wheat coleoptile straight growth bioassay and by Aspinall et al. (1967) in the promotion of cucumber hypocotyl growth. In apple, GA_4 and GA_7 have been reported to be physiologically more effective than GA_3 and therefore, plants with a promotive combination of high GA_{4+7} and low ABA would tend to be vigorous even if the content of GA_3 in roots is low. In the dwarfing rootstocks, the situation is just the reverse, i.e. they have high levels of ABA-like compound and low levels of GA_{4+7} like substances and the higher concentration of ABA will have an inhibitory effect on gibberellin activity which would reduce the vigour as in M.9 rootstocks.

2.2.1.c. Auxins

Jindal et al. (1974) found that there was significantly higher growth promoting activity in the extracts of normal Cortland and Golden Delicious plants than their

respective dwarf mutants at various growth stages. The significant zones of growth promotion corresponded to Rf value of acidic and neutral auxins, respectively.

Martin and Stathly, as early as 1967 had found that the growth promoting activity in the bark extracts of vigorous EM XVI apple rootstock was higher than that of the dwarfing EM IX at all stages of growth, due to higher chlorogenic acid and lower P-coumaric acid contents of former, which protected IAA from losses.

Lee and Looney (1977b) employed the use of TIBA, an inhibitor of auxin synthesis and transport to study the involvement of auxin in the determination of compact or normal growth type in apple, but could not draw any valid conclusions.

Gorochowska et al. (1984) are of the opinion that the relative proportion of phytohormones, particularly auxin and gibberellin and the unidentified inhibitor is more important in determining the vigour of fruit trees and the imbalance in the ratio of these compounds could possibly be responsible for the dwarf growth characteristics of certain apple phenotypes.

2.2.1.d. Cytokinins

The rationale for examining cytokinins in relation to dwarfing parallels that developed for the auxin analyses.

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An important characteristic feature of compact growth habit is a strong tendency for axillary buds to break dormancy and grow into short shoots or spurs and it has also long been known that the axillary bud break is related to the higher endogenous cytokinin levels. Therefore, it is tempting to predict that cytokinins play a key role in defining the dwarf stature of fruit trees.

Lane et al. (1982) tried to examine the validity of this speculation by growing the meristem tip cultures of compact and standard strains of apple in vitro on Murashige and Skoog medium containing a range of concentrations of Benzyladenine. Their findings indicated the contention that higher cytokinin level plays a key role in determining the compact growth habit to be bit premature. However, at higher concentrations of BA, only Mc Intosh Wijcik tissue continued to proliferate whereas the growth and development of other two strains in terms of the dry weight increment and number of shoots produced were completely suppressed. In another recent experiment, Taylor et al. (unpublished, in Looney and Lane, 1984) examined shoot tips of four Mc Intosh strains for zeatin like growth substances. There were no significant differences among Morspur Mac, Macspur and Standard Mc Intosh, but the Mc Intosh Wijcik had significantly higher level of zeatin like substances.

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The higher endogenous levels of Mc Intosh Wijcik and the higher tolerance of its tissue to BA in the culture medium suggest enhanced ability to metabolize the cytokinin excessive to their growth and development requirements, particularly the sprouting of lateral buds to spurs which in turn results in the compact growth habit. Alternatively, this may simply reflect differences in other growth substances in these phenotypes.

2.2.2. Leaf area and stomatal index

In general, it appears that the vigorous rootstocks had greater leaf area than that of the dwarfing ones in citrus (Mandge, 1978; Shinde, 1982). Agarwal (1986) found significant positive correlation between leaf area and vigour of *Poncirus trifoliata* strains.

Stomatal density or the number of stomata per unit leaf area is known to have a close relationship with plant vigour in many fruit crops. Beakbane and Majumder (1975) found that there was a positive linear relation between stomatal density and the known effect of apple rootstocks on scion vigour. Pathak et al. (1976) concluded that stomatal density can be successfully adopted as a quick and economical method for predicting the vigour of apple rootstock clones. In apple, it was also noted that the

performance of rootstock was related to the original plant vigour, i.e. a vigorous plant will also behave as a vigorous rootstock and a dwarf one as dwarfing rootstock (Beakbane and Thompson, 1939). So it appears that stomatal density can be successfully employed for predicting the vigour of new hybrids also at a very early stages in apple.

Pathak et al. (1977) found that such positive correlation between rootstock vigour and stomatal density exist in plum also. Similar studies were conducted in mango by Srivastava et al. (1980). They concluded that most optimal portion to be sampled for stomatal count is the top to middle leaves of the second flush i.e. neither too old, nor too new. Based on stomatal density, they classified the rootstocks under their study into dwarf, vigorous and very vigorous categories. These workers gave only this arbitrary classification and did not attempt to confirm its validty based on the actual performance of scions grafted on to them. However, later results of some long range field rootstock trails gave indications that this classification is not consistent for prediction of vigour. For example, Valli Columban and Olour produced least vigorous trees when

Alphonso and Dushehari scions respectively were grafted onto them (Reddy, 1986; Srivastava and Sinha, 1986), but these have been classified as vigorous and very vigorous respectively by Srivastava et al. (1980) based on stomatal density. Agarwal (1986) could not obtain any definite relationship between stomatal density and vigour characters in citrus rootstocks. However, Bang (1970) observed that vigorous citrus rootstocks had more stomata on the leaves than dwarfing ones.

A good correlation between the frequency of stomatal distribution and vigour of mango plants was reported by Chakladar (1967) and this character has been suggested for selection and classification of mango rootstocks in the nursery stage by Majumder et al. (1972). However, these findings also lack support from actual long range field trails.

2.2.3. Other characters

Some other physiological characters found associated with low vigour of trees and rootstocks include low water content of roots and leaves (Rameshwar, 1965), low transpiration rate (Mendel, 1951) and lower electrical resistance of stem sap (Taper and Ling, 1961) in Citrus; low respiration rate in Citrus (Phillips, 1969) and apple

(Miller et al., 1961); low content of chlorophyll in Citrus (Tayde, 1981), and mango (Pal et al., 1981), higher top:root ratio in Citrus (Shinde, 1982) etc.

2.3. ANATOMICAL BASIS OF DWARFING

Anatomical investigations of dwarf phenotypes, dwarfing rootstocks and trees dwarfed by growth retardents suggest a possible role of high phloem to xylem ratio in dwarfing of fruit trees. These findings are reviewed below.

The differences in the stem anatomy of vigorous, medium and dwarf phenotypes of apple in an F_2 population of Delicious X Golden Delicious were studied by Jumein and Faust (1984). The differences occurred mainly in the width and the structure of xylem layer. Xylem conducting elements of terminal shoot axes of low vigour trees were sparsely placed in the parenchymatous tissue compared to high vigour trees. Also the xylem vessels in low vigour trees had narrower lumen (14.5 μm) than those of high vigour trees (21.3 μm) with the lumen size of medium vigour trees intermediate (18.4 μm). These resulted in higher phloem to xylem ratio in dwarf phenotypes.

Such recording of higher phloem to xylem ratio with lesser number of xylem vessels and narrower lumen for xylem vessels associated with dwarfing were also made in apple

rootstocks (Beakbane and Thompson, 1939; Beakbane, 1941) and citrus rootstocks (Bang, 1970; Shinde, 1982). Singh et al. (1986) obtained significant negative correlations between bark percentage of stem, root and petiole of one year old rootstock seedlings and the height and volume of trees grafted on to them in long range mango rootstock trials at Lucknow. Anatomical screening of mango seedlings for use as dwarfing rootstocks was also attempted by Mukherjee and Das (1980). Their findings indicated Vallaikolamban showed the least and Dashehari the most vigorous growth potential.

Halfacre and Barden as early as 1968 reported that in apple, spraying of increasing concentrations of Alar progressively decreased the radial diameter of xylem vessels and the number of xylem cells accompanied by considerable dwarfing of sprayed shoots. Jumein (1981) studied anatomical changes induced by 5000 ppm chloromequat on the terminal shoots of Pear Cv.Doyenne-du-comice, and obtained similar results. It was observed that in sprayed shoots the vessels were less numerous and had markedly narrower lumens than in the untreated shoots. Thus higher bark to wood ratios resulting from the poor development of xylem seems to be the main anatomical basis for dwarfing in fruit trees. Based on the works reported above, it has also been proposed that these characters can be used to predict the

vigour of fruit trees and rootstocks at nursery stage itself in apple (Beakbane, 1941), Citrus (Shinde, 1982), mango (Singh et al. 1986) etc.

2.4. BIOCHEMICAL BASIS OF DWARFING

Several workers have tried to give a biochemical basis for tree size control in terms of endogenous phenol contents.

2.4.1. Mechanism of growth inhibition by phenols

The higher concentrations of phenols appear to inhibit extension growth by inhibiting cell division and cell elongation. The former effect seems to be by a direct influence on mitosis and latter effect through altering the auxin levels in the tissue. These are briefly discussed below.

2.4.1.1. Effect on cell division and enlargement

Swensson(1971) found that increasing concentration of coumarin drastically reduced both cell division and cell elongation. The reduction in cell devision was due to a direct inhibitory effect of the phenol on mitosis as proposed by Avers and Goodwin (1956). Phenols inhibit cell elongation by influencing the stretchability and orientation of the cellulose, microfibrils of the cell wall (Swenssson,

1971; 1972). In these experiments, phenols were found to act primarily as sulfhydryl inhibitors in limiting cell wall elongation. A similar mechanism wherein the phenolics retard the formation and stretchability of microtubules of spindle fibres has also been proposed to explain its inhibitory effect on mitosis (Swensson, 1971).

2.4.1.2. Effect on auxin

A primary effect of phenols on plant and tissue growth to through its effect on the level of auxin in the plant tissues (Letham, 1978). There are reports that phenols promote as well as retard the action of auxins and Lockard and Schneidar (1981a) has extensively reviewed these aspects in apple. Ferulic acid appears to be both an IAA synergist and an antagonist. These differences may be due to the use of different concentrations or possibly due to different type of tissue used in the experiments. Gortner et al. (1958) reported that at low levels ferulic acid can stimulate IAA oxidase activity but at higher levels it is a powerful enzyme inhibitor.

Zenk and Muller (1963) using ^{14}C labelled IAA and measuring the quantity of labelled CO_2 evolved at two hour intervals proved that auxin synergists such as caffeic,

sinapic and chlorogenic acids inhibited the oxidative decarboxylation of IAA by IAA oxidase enzyme and thereby the inactivation of IAA; whereas auxin antagonists such as P-hydroxybenzoic and phloretic acids caused an enhancement of IAA destruction by the enzyme.

This differential influence of different phenols on oxidative decarboxylation of IAA is difficult to explain. Intially, it was hypothesised by many workers that monophenols contain a single hydroxyl group and act as cofactors of IAA oxidase enzyme and thereby inhibit growth whereas the polyphenols with two or more hydroxyl groups inhibit IAA oxidase and tend to enhance growth (Grochowska, 1967; Stafford, 1974 etc.).

However, there is evidence in the literature conflicting this hypothesis also. It has been already stated that ferulic acid a monophenol can stimulate IAA oxidase activity at low concentrations and at the same time act as an enzyme inhibitor at higher level (Gortner et al., 1958). Also Lockard and Schneider (1981a) has listed a number of mono and poly-phenols which either promoted or retarded growth in apple. Further, Lee and Skoog (1965) found that the effect of phenols on IAA degradation is not related to number of hydroxyl groups. In their experiment it was also noted that the phenols which

inhibited the growth of callus promoted the differentiation of buds in the callus in the same order, and that the latter response was evident only when the tissue contained higher levels of kinetin suggesting that phenols inhibit growth by lowering IAA levels in the tissue. This lowering of IAA levels could be by promoting its oxidative decarboxylation by IAA oxidase enzyme as suggested by Zenk and Muller (1963).

2.4.1.3. Non - specific effects of phenols

Apart from the two major ways suggested, some non-specific effects of phenols are also known. Kafeli (1978) reported that P-coumaric acid retarded the synthesis of tryptophan from ^{14}C-labelled anthranilic acid resulting in reduction of IAA synthesis, as tryptophan is a precurssor for auxin.

Phloretin and Phloridizin apparently inhibited transport of sugars in phloem (Van Sumare et al., 1975) and some phenols influenced amylase activity and presumably starch synthesis (Datta and Nanda, 1978) which could probably account for the accumulation of starch in the dwarfing rootstocks.

Coumarin is reported to decrease cell wall permeability (Swensson, 1971) but most phenolic acids increase cell wall permeability according to Kafeli (1978). Stenlid (1976) found that ferulic acid increased the polarity of transport of IAA and stimulated basipetal transport in the phloem, whereas according to Basler McBride (1977), Coumarin enhanced acropetal translocation of auxin.

2.4.2. Phenols in the dwarfing of fruit trees

Enough evidence is available in the literature to suggest that phenols might play a major role in tree size control in fruit crops particularly apple, citrus and mango. The papers relating to this aspect are briefed here.

2.4.2.1. Apple.

Messer and Lavae (1969) studied the phenolic content in the callus of a dwarfing apple rootstock viz. M IX and a vigorous one viz. M XIII using paper chromatography of tissue extracts and found that the dwarfing M IX contained greater amounts of those phenolic substances which were also present in the vigorous M XIII and contained at least one additional compound with an Rf of 0.69 in the butanol: acetic acid: water (4:1:3) solvent system. At that time, they did not try to identify or accurately quantify these compounds, but hypothesised that the higher phenol content of M IX tissues might explain its dwarfing behaviour.

In another interesting experiment, Schneider et al. (1978) grew calli from different apple clones, adjacent to one another; and the results of this experiment clearly indicated that stock-scion growth effects on the field could occur even when the physical aspects of graft union were not a barrier and that some freely mobile inhibitory compounds are involved in the dwarfing mechanism. In a later experiment, Chaing et al. (1979) extracted the inhibitors from agar medium which were used to grow stem calli of apple clones of varying vigour, which gave indication that these inhibitory compounds could be phenolics.

Lockard and Schneider (1981b) found the levels of benzoic,caffeic, chlorogenic, ferulic and protocatechnic acids to be higher in the bark of semidwarfing M.26 apple rootstock than in the bark of vigorous MM.111 which had higher livels of P-coumaric acid, phloretic acid, phloridzin and phloretin.

2.4.2.2. Citrus

Mendel and Cohen (1966) as well as Mendal (1969) reported that higher total phenolic compunds (TPC) in Citrus buds and branches were inhibitory to growth and were responsible for the size regulation in citrus. They opined that the level of TPC in the bark of young seedlings

is a fairly reliable indicator of future tree size or rootstock vigour.

2.4.2.3. Mango

The total phenolic content in the bark of non-flowering terminals, in relation to tree vigour was studied in seven varieties of mango by Babu et al. (1985) at TNAU, Coimbatore. The total phenols expressed in catechol equivalents indiacted definite inverse relationship with growth vigour of mango. The correlation coefficient of phenolic content with tree height, N-S spread and E-W spread were respectively -0.7617,-0.7690 and -0.8598. From this study it thus appears that phenolic content has a major role in the determination of tree size in mango also and perhaps it could be a useful method to predict the vigour of trees too.

2.5. CHEMICAL DWARFING OF FRUIT TREES

Though dwarfing rootstocks are very effective in controlling tree size and there has been an overdependence on such size controlling rootstocks for H.D.P.S in the past few years, it restricts the choice of rootstocks to overcome specific problems such as soil and environmental problems and in most cases dwarfing rootstocks have poor

soil anchorage. In this context chemical control of tree size appears promising. Some of the recently developed chemical methods of growth regulation which can modify the form and growth of fruit tree to suit high density orcharding have been discussed below.

2.5.1. Mode of action of growth retardants

An understanding of the mode of action of growth retardants will help in the selection of correct chemicals for specific purpose. There were atleast three basic methods by which plant height is controlled by these chemicals. They are

(a) **by killing the terminal buds of branches or severly inhibiting apical meristematic activity**

The most important chemicals of this group include Maleic hydrazide (Greulach and Haesloop, 1954), fluorenols (Schneider, 1970) and in some cases ethylene and ethylene releasing compounds (Luckwill, 1978). These chemicals however, are of not much use in controlling tree size as they also inhibit normal leaf and flower initiation and development at the concentrations required to bring about growth inhibition (Sachs et al., 1967).

(b) by reduced apical control

Reduction of tree height may also result from

simultaneous growth of many shoot axes which owing to competition for limited nutrients reduce the elongation of one or more axes on the same root system (Sachs and Hackett, 1972). Promising substances for inducing axillary bud growth are TIBA which is an inhibitor of auxin synthesis and translocation (Zimmermann, 1942), cytokinins particularly, benzyl adenine, which promotes the growth of axillary buds (Sachs and Thimann, 1964) and some new chemicals like M&B 25-105 (Quinlan, 1979), dikegulac (Arzee et al., 1977) etc. Unlike those of the previous group, these chemicals are not translocated to the meristems of the new lateral branches and hence do not interfere with leaf and flower development.

(c) by inhibiting internode elongation without disrupting apical meristematic functions

Near specific inhibition of internode elongation without concomitant disruption of apical meristematic function and loss of apical dominance is caused by certain growth retardants like SADH, CCC, Amo-1618 and paclobutrazol. These growth retardants reduce gibberellin synthesis (Dennis et al., 1965) though different retardants probably act at different steps (Wiley et al., 1970). Amo-1618 and Alar prevent the conversion of Trans-geranyl geranyl pyrophosphate to Kaurene and CCC blocks Kaurenoic

acid from getting converted to GA_{12} (Wiley et al., 1970) whereas Paclobutrazol retards the formation of Kaurene-19-01 from Kaurene (Anon., 1984). In addition they may also interfere with auxin synthesis (Cathey, 1964), alter CO_2 assimilation in young and old leaves (Halfacre and Barden, 1968), increase the permeability of cytoplasmic membranes (Underraga and Ryugo, 1970) such that the apoplastic transport of glucose is greatly increased and also interfere with other metabolic processes (Lang, 1970) that may account for some of the effects observed. SADH and CCC are known to cause a substantial increase in ethylene production (Abdel-Gammand et al., 1971). Some of the recent chemicals like paclobutrazol promote early and profuse cropping and thereby restrict vegetative growth (Krieken and Lindenbergh, 1984).

2.5.2. Recent trends in chemical regulation of fruit tree size and form

Quinlan (1981) has outlined three disinct phases during the development of fruit trees at which attempts should be made to regulate tree form and vigour for successful high density orcharding. These stages are (i) the nursery tree, (ii) the young orchard tree and (iii) the cropping tree. The objectives and approaches of chemical

growth control are distinctly different during these three phases. In the nursery stage, the objectives are to produce sufficient branches suitably spaced to form the initial frame work and to remove the unwanted branches which are produced very close to the ground. Recently a new chemical, M&B 25-105 has proved to be very effective for improving branching in apple and pear cultivars at nursery stage (Quinlan, 1978; 1979). This chemical temporarily checks apical dominance by inhibiting the basipetal movement of auxin in the treated shoots (Duckworth et al., 1979) inducing the production of lateral shoots from axillary buds at nodes immediately below the shoot apex. For chemical removal of unwanted low branches from the nursery tree, 'Butralin' seems to be potentially useful (Quinlan, 1978).

As far as a young orchard tree is concerned, the chemical control should be aimed at increasing the branching and inducing early cropping. Increased branching reduces apical growth and early cropping restricts vegetative growth (Quinlan, 1981). Arnold et al. (1983) found that Dikegulac at 1000 ppm was effective in increasing lateral branching as well as reducing the tree height and spread in peach. The beneficial effects of dikegulac in limiting the tree size was also reported by Sachs et al. (1975) in a number of woody perennials. Arzee et al. (1977) using ^{14}C

labelled dikegulae found that the chemical when applied to the leaves is readily translocated through phloem to the apical meristem where it inhibited DNA synthesis resulting in a temporory check in apical growth and thereby sprouting of axillary buds and reduction in internodal elongation. For inducing early cropping pre-bearing orchard trees, chemical growth regulators such as daminozide and ethephon have been tried initially (Luckwill, 1978) but these chemicals were found to have certain disadvantages in that they might reduce fruit size or in the case of ethephon cause flower and fruitlet abscission. More recently, two branching agents M&B 25-105 and PP 528 have been tested on young orchard trees. When applied to run off to whole apple trees in the second and third orchard years both chemicals resulted in the production of more flowers and much heavier crops in the fourth year (Quinlan, 1981).

In the bearing phase, reducing tree vigour, increasing cropping and supplementation or replacement of hand pruning should be the main objectives. Till very recently, Alar and to a lesser extent cycocel were widely used to control the size of bearing fruit trees. Alar was found to effectively reduce the vigour of shoot growth and pruning requirement in apple (Kolbe, 1983; Hricovsky and Gajdosechora, 1984; Fanti, 1983; Jaumein, 1983, Castro

et al., 1984; Stan and Cotorobai, 1983), plum (Coman and Stan, 1982), apricot (Bencat et al., 1984) and pear (Tagliani and Cobianchi, 1984). Trearment with cycocel was effective in controlling shoot leangth of pear (Grauslund, 1983; Blick, 1985), apple (Indenko and Smagin, 1984; Agafonov et al., 1984), plum (Coman and Stan, 1982) and apricot (Bencat et al., 1984). Azzouz et al. (1980) reported that CCC at 4000 ppm led to 50% stunted growth in normal mango seedlings. At TNAU, Coimbatore, Vijayan et al. (1985) found that cycocel at 6000 ppm inhibited vegetative growth significantly resulting in reduction in plant height, internodal length and girth of scion and promoted profuse flowering in mango.

More recently, a new chemical viz. Paclobutrazol (PP 333 or Cultar) has been found effective in the tree size regulation during bearing stage. PP 333 controlled shoot growth as effectively as standard daminozide treatment in four year old trees of Bramley's seedling apple, when sprayed to run off, three weeks after full bloom. However, in contrast to daminozide, PP 333 did not significantly reduce fruit size and in the following year when the trees were untreated, shoot growth was least on trees which had received the higher rate (3000 ppm) of PP 333 (Quinlan, 1981).

Stinchcombe et al. (1984) compared the effects of 2000 ppm foliar sprays of daminozide and paclobutrazol in reducing the terminal growth to bush cider apple Cv. Mecheline for two years. Six weeks after application, both foliar appplied daminozide and paclobutrazol had significantly reduced shoot growth compared with the untreated trees. In the second year diminozide treated trees did not differ significantly from untreated trees and only paclobutrazol caused significant reduction in shoot growth. Where growth was markedly controlled by paclobutrazol, the shoots developed thickened ends, shortened internodes and the foliage appeared rosetted. Leaf area was reduced and the lamina became darker in colour too. The chemical also increased fruit set and subsequently reduced fruit size

Williams (1984) found that one soil application of paclobutrazol controlled terminal shoot growth of vigorous Delicious and Golden Delicious apple trees for several seasons. There was little or no effect of the chemical on fruit size and it caused no phytotoxicity. Yield increased on treated trees and fruits coloured earlier becaused of better exposure to sunlight.

The effects of two new growth retardants viz., paclobutrazol and flurprimidol on growth and cropping of

5-year old 'Redhaven' peach trees were studied in detail by Marini (1986). Shoot growth was suppressed progessively by the increasing concentrations of both the chemicals for two years. Yield per tree, number of fruits per tree and fruit size were not influenced by the treatments. Though flower density (flowers per meter of shoot length) increased with concentrations of growth retardants, fruit density (fruits per meter of shoot length prior to hand pruning) decreased and hence total yield per tree was not significantly affected. The suppression in shoot length was not evident in third year and in fact growth was enhanced in the third year of application.

The effectiveness of paclobutrazol in reducing the expansion growth of peach trees without a reduction of node number and fruit size was also reported by Erez (1984) and young (1983). In the case of pear also, pp 333 markedly reduced shoot growth and enhanced flower bud number in Beurre Hardy and Doyenne du Comice cultivars on vigorous Quince A rootstocks and it was found more effective than cycocel(Krieken and Lindenbergh, 1984).

Greene (1986) studied the effects of foliar sprays of paclobutrazol and analogs at full bloom stage on quality of apple fruits. The year after application, paclobutrazol increased fruit set, fruit firmeness and flesh calcium

content, decreased fruit size, soluble solids, length/diameter ratio and retarded ripening as determined by the onset of the ethylene climacteric. The effects of paclobutrazol were found to dessipate two years after application and after three years, all growth control was lost.

In addition to these responses, paclobutrazol is also known to enhance the resistance of apple seedlings to frost (Holubowicz, 1983) and water stress (Swietlik and Miller, 1983), decrease dark respiration rates, and to directly or indirectly reallocate carbohydrate resources resulting in major shifts in the physiology of treated plants (Steffens et al., 1983)

2.5.3. Factors affecting efficiency of growth regulator application

As a general rule, the growth retardents should be sprayed when the new shoots have made some growth. The uptake of the chemicals will be faster by young leaves and if appiled before, the plant uptake and hence response will be poor. Delayed applications are also ineffective as the internodal elongation would have already been completed (Sachs et al., 1967). Thus application time is very important.

Regarding dosage, multiple applications of small dosages are more effective than single application of large doses (Sachs and Hackett, 1972). As per these authors, there is probably a gradual decay of the compounds at the active sites either by metabolism or translocation and hence multiple applications may serve to keep the compounds at growth inhibiting levels and it also has the advantage of reducing the phytotoxic effects.

Cathey (1969) has shown that the effectiveness of SADH in foliar sprays might be increased twelve times by reducing the average droplet size from 6000 /u to 25 /u. Abaxial leaf surface absorbs chemicals more readily than the adaxial and so the sprays should be directed to hit the lower surface of leaves for maximum efficiency (Greene and Bukuvac, 1971). It has also been found that surfactants, adjuvents and humigants enhance the efficiency of foliar sprays (Hull, 1970).

As far as the method of application is concerned, growth retardants are mostly applied as foliar sprays, but in case the chemical causes some foliar injury at the concentration required for reduing stem elongation, they can be applied as soil drench. Bark application has the advantages of simplicity and speed of application and elimination of drift, but unfortunately not many tree

species respond to this (Sachs et al., 1967). Trunk injection into vascular system is also possible in the case of paclobutrazol (Sterrett, 1985). It is recommended that under conditions of good soil moisture supply, paclobutrazol elicits better responses when given as soil drench around the trees rather than as foliar spray (Anon., 1984).

2.6. OTHER METHODS FOR DWARFING FRUIT TREES

Other techniques suggested to control tree size include bark inversion, tieing knots in the stem of rootstock seedlings (Sax, 1955), inoculating rootstocks with mild strains of virus and then grafting resistant scions on to them (Duncan et al., 1978), double grafting or use of intermediate stem piece (Tukey and Brase, 1955), induction of mild moistrure stress (Geoll et al., 1982), root pruning (Ferre and Guister, 1984), shoot pruning (Erez, 1984) and twisting, bending, girdling and notching of shoots (Tukey, 1970). Iyer and Subramanyam (1973) suggested judicious pruning as a simple method for dwarfing mango trees. Use of dwarfing rootstocks (Tukey, 1970) and development of dwarf genotypes through breeding approaches such as selection (Hansche and Bres, 1980) mutation breeding (Lapins, 1965), hybridization (Zagaja and Faust, 1983) and inbreeding

(Faust and Zagaja, 1984) have also been suggested. Tyagi (1986) has suggested 'Malaviya Bhog' to be the idiotype for future high density mango cultivation. Iyer and Subramanyam (1986) described the variety 'Creeping' as a promising genotype for introduction of dwarfness in mango.

MATERIAL AND METHODS

CHAPTER III

MATERIALS AND METHODS

The present set of experiments were conducted at the experimental fields and laboratories of the Indian Institute of Horticulture Research, Hessarghatta, Bangalore. The anatomical studies were conducted at the Botany laboratory of the University of Agricultural Sciences, G.K.V.K., Bangalore.

The research station is situated at altitude of 930 m above mean sea level on 12°58' North latitude and 77°35' East longitude. The orchard soil is red sandy loam with a pH of 6.57 (neutral in reaction) and electrical conductivity of 0.07 mmhos/cm^2

The experiments were carried out during the period June 1986 to December 1988. Experimental details pertaining to material used and techniques adopted are given in this Chapter.

3.1. STUDY OF VARIABILITY WITH RESPECT TO VIGOUR CHARACTERISTICS

From the germplasm collection maintained at the Experimental Station of the Institute, eight each of

apparently dwarf, medium and vigorous cultivars were selected. This initial classfication was made on a comparative basis as per visual assessment of tree size in May 1986. It is quite likely that these cultivars may exhibit different growth vigour under other agroclimatic conditions. The twenty four cultivars so selected were grouped as follows:

(a) Least vigorous: Kurd, Mulgoa, Kodur Hybrid (Rumani X Neelum), Dashehari, Kerala Dwarf Creeping, Rumani and Janardhan Pasand.

(b) Medium vigorous: Kesar, Kadari, Ratul, Neelum, Alphonso, Amini, Mundappa Black and Totapuri.

(c) Most vigorous: Hyder Sahebi, Langra, Gola, Maharaj Pasand, Kerala Kalepad, Padari, Chandrakkaran, Pacharisi.

Kerala Kalepad appears to be totally different from the well known Kalepad variety which is known for its poor vigour.

These cultivars were on unspecified rootstocks.

In each variety, a set of three trees were selected for the study. These trees were in the nineth orchard year (1977 plantings) and on each tree twenty healthy and

uniform shoots, covering all the sides of the tree, and which had fruited in 1986 were tagged during June, 1986. These trees were given uniform cultural treatments throughout the course of this study. Following observations were recorded on the tagged shoots.

3.1.1. Number of flushes produced per year.

The number of vegative flushes produced by the tree per year was recorded as and when new flushes were produced. The tree was considered to have flushed only when at least ten per cent of the shoots on it had put forth new extension growth.

3.1.2. Percentage of shoots giving new flushes

When the trees put forth new vegatative flushes, each of the twenty tagged shoots were carefully examined regarding new growth and from this, the percentage of shoots giving new flushes each time was calculated as representative value for the whole tree.

3.1.3 Length of the flush

Length of new flush produced was recorded from the base of the flush to the point upto which the extension growth had ceased.

3.1.4. Number of nodes on the flush

Number of nodes on the new flush was counted from base to apex while recording the length.

3.1.5. Mean internodal length of the flush

This was calculated by dividing the total length of the flush by total number of nodes on each shoot.

3.1.6. Diameter at the base of the flush

The diameter just below the first node from base on the new growth was recorded simultaneously using a Vernier Calipers.

Observations 3.1.1. to 3.1.6. were recorded on the tagged shoots, each time the tree put forth new flush from June 1986 to May 1988 and the averages were worked out.

For the purpose of Statistical analysis and further comparison, average values for each of these characters were worked out as the mean of different flushes in a year. Each tree was considered as a replication and the replication value, was obtained as the average of different tagged shoots on it. Thus there were twenty four varieties (treatments) each replicated thrice. The data was analysed using Randomized Block Design (RBD).

Further observations (3.1.7 onwards) in this experiment were confined to only a few shoots as is described in each case, but the replication value was obtained in the same manner; i.e. the average of different observations on a tree constituted the replication value and there were three replications for each variety. These observations were also analysed using RBD.

3.1.7. Number of leaves per flush

The number of leaves on each flush was counted carefully from base to tip.

3.1.8. Leaf area per flush

All the leaves of a flush were fed slowly one after other to a LI 3000 (AL-COR) Model leaf area meter and total leaf area was recorded in square centimeters corrected to two decimal places.

3.1.9. Leaf area per leaf

Average leaf area per leaf was calculated by dividing the area of all the leaf on a flush by the number of leaves on it.

3.1.10. Stomatal density

Number of stomata per unit leaf area was determined using the procedure described by Beakbane and Majumder (1975). The leaf samples for the purpose were collected following the sampling procedure given by Srivastava et al. (1980). For further uniformity, stomatal density was only determined in the area between eighth and tenth veins from the leaf base on the dorsal side of each leaf. On each leaf, stomatal density was determined in ten random fields and in each replication five leaves were sampled for observation.

3.1.11. Number of stomata per flush

Number of stomata per flush (Sf) was calculated as

$$SF = \frac{S \times LAF}{a}$$

Where, S is the stomatal density under 100 x magnifaction,

a is the area covered by the microscope under the same magnification in cm^2, and

LAF is the average leaf area per flush in cm^2.

For determining the area covered by the microscope, the diameter (d) of the microscope field under 10 x 10 x magnification was measured using a stage micrometer and from

this, the radius r was calculated as $\frac{d}{2}$. This was substituted in the formula $a = \pi r^2$ to get the area (π = 22/7). The area of the microscopic field so calculated was 0.01912 cm^2.

Observations 3.1.7. to 3.1.11. were recorded during September, 1987 on the second oldest flushes. These flushes were produced in most varieties during the previous March-April and in a few varieties during January-February. On each tree (replication), these observations were recorded on five flushes selected at random. For recording the stomatal density, the middle leaf was selected from each of these flushes.

3.1.12. Phenolic content of apical bud

Phenolic content in the terminal bud of shoots was determined adopting the colourimetric procedure described by Giebel (1970) with slight modification. Three samples consisting of one gram each of clean and healthy apical buds (0.5 cm long) were collected from each tree during April-May 1988. Care was taken to select only dormant buds present at the tip of mature shoots which had not put forth new extension growth. The plant material was boiled in 80 per cent ethanol for 2 to 3 minutes, cooled to room temperature and alcohol extract was filtered. The buds were

then ground using a pestle and mortar and reextracted with 80 per cent ethanol for 3 to 4 times. The combined extract was shaken thrice with petroleum ether to remove lipids and pigments. A known aliquot of extract was used for colour development using folinciacalteau reagent in alkaline medium O.D. was recorded at 660 nm after 10 minutes. Phenolic content was expressed as tannic acid equivalent per gram fresh weight of tissue. For calculation of phenolic content from O.D. value, a standard graph was plotted using tannic acid and from the slope of this curve, the following formula was derived: One O.D. value = 112.0 /ug tannic acid.

3.1.13. Anatomical characters

For anatomical studies, the internodal portion of the stem between third and fourth nodes from the base of young, maturing shoots were fixed during first week of April 1988. The fixative used was a mixture of ethanol chloroform and acetic acid in 6:3:1 ratio (V/V). The material was then dehydrated in ethanol-n-butanol series, wax infiltrated and made into blocks. Sections of 14.0 /u thickness were taken from these using a microtome and stained with periodic acid Schiff's reagent (Jensen, 1962) as well as Toluidine blue (Federm and O'Brien, 1968) as per standard techniques and the slides were made permanent. These sections were

observed under a microscope (10 x 10x magnification). The width of half pith (from the center of sections to the inner periphery of vascular budles), primary xylem (from inner edge of vascular bundles to cambial ring), primary phloem (from cambial ring to outer periphery of vascular bundles) and cortex (parenchyma + collenchyma) were measured along radial lines from center to periphery of section using calibrated occular micrometer. These observations were recorded in a number of sections for each replication and averages worked out. The ratio of width of primary phloem to width of primary xylem was also calculated. For these anatomical studies the standard procedures detailed by Johanson(1940) were employed.

3.1.14. Productivity

Productivity of each tree under study was calculated by dividing the average yield of fruits expressed in kilograms by the volume occupied by the tree in 1988, expressed in cubic meters. The average yield of the tree was calculated as the mean value of the fruit yield in 1987 and 1988.

3.1.15. Tree height

Tree height was measured in meters corrected to two

decimal places, from the soil surface to the top of the canopy using a long scale.

3.1.16. Mean tree spread

The spread of the tree in North-South and East-West directions were recorded using a meter scale and the mean value was calculated.

3.1.17. Tree volume

Tree volume was calculated using the formula given by Castle (1983) with slight modification as follows:

$V = \frac{1}{6} \prod \times h \times (2r)^2$ where

V is the volume in cubic meters

h is the height of the tree in meters, and

r is the canopy radius.

2r is obtained as $\frac{\text{(East-West spread + North-South spread)}}{2}$

Observations 3.1.15 to 3.1.17 were recorded in 1986 June and 1988 June.

The correlation coefficients between the most important characters studied here were also worked out. A mathematical model to predict per cent increase in tree volume over two years based on easy to measure morphological

traits was also derived using multiple linear regression analysis.

3.2. EFFECTS OF SOME ROOTSTOCKS ON THE VIGOUR OF DWARF AND VIGOROUS SCIONS

This experiment, aimed to study the effects of some rootstocks on the vigour characteristics of a vigorous and a dwarf scion was started in June, 1986 and continued upto July 1988.

3.2.a. **Treatments:** The following combinations of scions and rootstocks were evaluated in this study.

Scion	Root stock	
1. Langra	1. Hyder Sahebi	(L/H)
	2. Kerala Kalepad	(L/K)
	3. Gola	(L/G)
	4. Panakkalu	(L/P)
	5. Neelum	(L/N)
	6. Creeping	(L/C)
	7. Dwarf Selection	(L/D)
	8. Rumani	(L/R)

Scion	Root stock	
II. Rumani	1. Hyder Sahebi	(R/H)
	2. Kerala Kalepad	(R/K)
	3. Gola	(R/G)
	4. Panakkalu	(R/P)
	5. Neelum	(R/N)
	6. Creeping	(R/C)
	7. Dwarf Selection	(R/D)
	8. Rumani	(R/R)

3.2.b. **Design and lay out**

The sixteen treatments were laid out in Factorial C.R.D. (Completely Randomised Design) with three replica tions and four experimental units (grafts) per replication for each treatment. Thus there were twelve plants of each combination for recording observations.

3.2.c. **Treatment details**

Open pollinated seeds were collected from trees of three distinct vigour groups during May-June, 1988. These varieties were

Dwarf: Creeping, Rumani, Dwarf Selection

Medium: Neelum, Panakkalu

Vigorous: Hyder Sahebi, Kalepad, Gola

Kernals were extracted from these seeds and sown

without delay on sand beds. Rootstocks from each variety were stone grafted after fifteen days of germination with precured scions from a vigorous and dwarf cultivar. The vigorous scion used was Langra and the dwarf scion was Rumani. After grafting, twelve good stions from each combination were transferred to separate pots of 6" diameter filled with 3:2:1 mixture of FYM, red earth and sand taking care not to damage the root system. The pots were irrigated daily.

3.2.d. **Observations recorded:**

The following observations were recorded during the course of the study.

3.2.1. Length, breadth and thickness of stones and kernals of rootstocks

These observations were recorded before sowing on ten seeds and kernals selected at random from each variety using a vernier caliperse and mean values were worked out. The breadth and thickness were taken at the middle portion of stone/kernel.

3.2.2. Average weight of stones and kernals

The same ten stones/kernals were used to find the average weight for each rootstock variety.

3.2.3. Number of days taken for initiation of germination and fifty per cent germination by seeds of rootstock varieties.

3.2.4. Phenolic content of apical bud and stomatal density on the leaves of the mother plants from which scion wood and rootstock seeds were collected.

These parameters were determined at a later stage as detailed under 3.1.12 and 3.1.10 respectively.

3.2.5. Length of new growth from scion

Length of the new growth produced was measured from the upper end of bud wood to the tip of new growth.

3.2.6. Number of nodes of the new growth

The number of nodes on the scion growth produced after grafting was carefully counted.

3.2.7. Mean internodal length of scion growth

This was obtained by dividing length of new growth by number of nodes on it.

3.2.8. Number of flushes produced after grafting.

3.2.9 Girth at collar region and graft union.

The diameter of the stem at collar region and graft union were recorded with the help of a vernier caliperse.

Observations 3.2.5 to 3.2.9 were recorded after six, twelve and twenty four months of grafting.

3.3. CHEMICAL REGULATION OF TREE SIZE

With the aim of controlling tree size in mango during the bearing phase, some growth retardants were tried in this experiment. The chemicals used were (i) Paclobutrazol (ii) Cycocel and (iii) Alar.

3.3.a. Details of chemicals used:

The paclobutrazol formulation used in this experiment was an experimental sample supplied by Indian Explosives Limited, Bangalore. The formulation named 'Cultar' was originally produced by Imperial Chemical Industries, England and had 25% Paclobutrazol as active ingredient in the form of emulsifiable concentrate.

Two cycocel formulations used in the experiment. For first spraying, a liquid formulation named 'Lihocin' (BASF) containing 50% chloremequat chloride was used. For second spraying, soluble powder of chloroethyl ammonium chloride (99.0% ai) was used.

The Alar formulation used in this experiment was soluble powder containing 99.0% ai of SADH.

3.3.b. **Treatments**

The following growth retardant treatments were selected for trial based on review of literature.

Treatment Code	Chemical	No.of applica-tions	Concen-tration	Method of application
T_0	Control	-	-	-
T_1	Paclobutrazol	One	2.5 g ai/tree	Soil drenching
T_2	"	Two	"	"
T_3	"	One	5.0 g ai/tree	"
T_4	"	Two	"	"
T_5	"	One	10.0 g ai/tree	"
T_6	"	Two	"	"
T_7	Cycocel	One	4000 ppm	Foliar spray
T_8	"	Two	"	"
T_9	"	One	8000 ppm	"
T_{10}	"	Two	"	"
T_{11}	Alar	One	1500 ppm	"
T_{12}	"	Two	"	"
T_{13}	"	One	3000 ppm	"
T_{14}	"	Two	"	"

3.3.c. Design and lay out

These fifteen treatments were laid out in Randomized Block Design (RBD) with three replications and one experimental unit (tree) per replication for each treatment. Care was taken to see that the trees selected for this experiment were of uniform size and yield history as far as possible, within each replication. The treatments were alloted randomly to the trees using random numbers. Only alternate trees in either directions were selected for the experiment. These trees were given uniform cultural treatments such as fertilizer application, plant protection sprays etc. throughout the couse of the experiment.

3.3.d. Experimental trees

The experimental units were nine year old (1977 plantings) mango trees of the cultivars Alphonso on unspecified rootstocks planted at 5 m x 5 m spacing.

3.3.e. Treatment details

The first application of growth retardants were given in the first week of November 1986, approximately one month before the expected time of winter flushing in the variety. In the case of treatments involving two successive applications of growth retardants, the second application was done during first week of March, 1987, about a month before expected summer flushing.

Cycocel and Alar were given as foliar sprays. The required quantity of growth retardant was first dissolved in a small quantity of alcohol and then the volume was made upto give the specific concentrations with water. A few drops of teepol were added as spreading agent. For each tree 1.5 l of spray solution was used. Spraying was done with a small hand sprayer carefully, thoroughly wetting both the sides of the leaves.

Paclobutrazol was given as soil drenching. The required quantity of formulation was emulsified in 20.0 l of water, thoroughly stirred and applied to the drip zone of the trees. These trees were irrigated with 50 l of water 48 and 96 hours after the application of the chemical.

3.3.f. Details of observations recorded

For recording observations on vegetative characters, six shoots were selected at random and tagged on each tree. Similarly, for recording details of flowering and fruit-set, five panicle were randomly selected and tagged on each tree.

Though the experiment consisted of fourteen treatments, for observations recorded upto forst week of March 1987 (i.e. before the second application of chemicals), it was considered that there were only eight treatments. It was done like that because till this time there was no difference between trees receiving single or

double application of a given concentration of growth retardant as far as treatment given was concerned. Thus till March 1987, there were two trees receiving the same treatment except control within each replication. The observations on such two trees were averaged to get the replication value for each concentration of chemicals. However, after the second application of growth retardants in March 1987, there were fourteen separate treatments each replicated thrice.

The following observation were recorded as and when required continuously from December 1986 to October 1988.

3.3.1. Vegetative characters

All the components of vigour and other vegetative characters were studied as per the methods described earlier.

3.3.2 Data on flowering and fruiting

3.3.2.1. Percentage of shoots flowered

At the time of flowering, twenty five random shoots covering all sides of tree were examined to have flowered or

not, on each tree and from this the percentage of shoots flowered in each season was determined.

3.3.2.2. Length of the panicle

Lengths of the tagged panicles on each tree was measured using a scale in centimeters corrected to one decimal place and the average worked out.

3.3.2.3. Number of primaries per panicle

Number of primary branches on the panicles were counted carefully.

3.3.2.4. Mean internodal length of the panicle

This was obtained by dividing the length of each panicle by the number of primaries on it.

3.3.2.5. Spread of the panicle

The panicle spread was measured at the broadest point in centimeters corrected to one decimal place using a scale.

3.3.2.6. Length to spread ratio of the panicles

This value was obtained by dividing the length in cm of each panicle by its spread in cm at the broadest point.

3.3.2.7. Sex ratio

An estimate of sex ratio was obtained by observing three hundred flowers on each tagged panicle selected at random, but covering all parts of the panicle when all flowers on it had opened and noting whether each of them is staminate or hermaphrodite. The sex ratio was obtained by dividing the number of staminate flowers by the number of hermaphrodite flowers.

3.3.2.8. Pollen fertility

From each tagged panicle, five hermaphrodite flowers were used to study pollen fertility using acetocarmine staining technique.

3.3.2.9. Number of fruits per panicle

The number of fruits on each tagged panicle were recorded when the fruits had attained pea size, marble size and again at the time of harvest.

3.3.2.10 Fruit retention

Fruit retention percentage was worked out for each of the tagged panicles as

$$\frac{\text{Number of fruits per panicle at harvest}}{\text{Number of fruits per panicle at pea stage}} \times 100$$

3.3.2.11. Fruit yield per tree

The fruits were harvested in two rounds at a gap of ten days (02-06-1987 and 12-06-1987) in the first year after treatment. In the second year, a single round of picking was sufficient to harvest all the fruits (30-05-1988). At the time of each plucking, the total number of fruits harvested per tree and their weight in kilogram was recorded for each tree under study.

3.3.2.12. Average fruit weight

For recording physicochemical characteristics, ten mature fruits were selected from each tree and stored under laboratory conditions till ripening. The total weight of the ten selected fruits was divided by ten to get the average weight of fruits on each tree.

3.3.2.13. Volume of fruit

Fruit volume was determined by water displacement method for each of the ten fruits and averages worked out.

3.3.2.14. Specific gravity of fruits

This was calculated by dividing the average weight of fruits in grams by average fruit volume in cubic centimeters.

3.3.2.15. Skin weight

The skin was carefully peeled off from each ripe fruit, cleaned from any adhering pulp and weighed.

3.3.2.16. Stone weight

The stone of each fruit was thoroughly cleaned from adhering pulp and its weight recorded.

3.3.2.17. Pulp weight

Pulp weight was obtained for each fruit by substracting the weights of skin and stone from its total weight.

3.3.2.18. Total soluble solids

T.S.S. of fruit juice were recorded separately for each fruit using a hand refractometer.

3.3.2.19. Total titrable acidity

Titrable acidity of fruit juice was determined by titrating an aliquot of sample from each fruit with standard NaOH solution using phenophthalein as indicator and was expressed as percentage of maleic acid equivalent (Ranganna, 1977).

3.3.2.20. Sugars

Samples of pulp from each fruit was preserved in absolute alcohol and the content of total and reducing sugars in them were determined at a later stage employing the method of Lane and Eynon (Ranganna, 1977)

3.4. INVESTIGATIONS ON HORMONAL BASIS OF DWARFING IN MANGO

With a view to throw some light on the hormonal factors controlling the tree size in mango, an attempt was made to quantify the abscisic acid (ABA) and cytokinin contents in varieties with differing vigour.

3.4.1. Abscisic acid

3.4.1.a. **Plant material**

Abscisic acid levels were estimated in a comparatively vigorous and comparatively dwarf cultivar. The ABA levels in Alphonso trees chemically dwarfed by paclobutrazol treatment and in untreated control trees were also analysed for comparison with genetically dwarf and vigorous cultivars. The vigorous and dwarf cultivars selected were Langra and Mulgoa, respectively. Results of earlier experiment indicated that soil drenching with paclobutrazol at rate of 2.5 g ai per tree was effective in inducing dwarfing in Alphonso variety (results of experiment

No.3) and so the trees in which the persistent effects of this chemical were evident as a response to the treatment given during November 1986 as well as untreated trees of this cultivar were selected for this study. In the case of Langra and Mulgoa, ABA levels were determined at two stages, during dormant season and duting active growth phase.

3.4.1.b. Sampling

The plant part sampled for ABA estimation was terminal bud of shoots measuring 0.5. cm in length. ABA content in dormant buds was determined from the samples collected during last week of August 1987. Actively growing apical buds were collected during first week of February in the case of Alphonso and during third week of March for Langra and Mulgoa. Each sample consisted of 2.0 g buds selected at random, but covering all the sides of the trees. Each sample was a pooled one from three different trees. These buds were brought in an ice box to the laboratory and processed immediately.

3.4.1.c. Extraction,purification and estimation

These were done following the procedure described by Saunders (1978) as modified by Murti (1988). The plant tissue was homogenized for two minutes in 50.0 ml of 80.0 per cent alkaline methanol (pH 8.0) using a blendor to

maintain a neutral pH in the final aqueous solution. Extraction was done once again after twenty four hours with fresh solvent. The combined methanolic extract was then filtered and the extract brought to aqueous phase in vacuo at 35° c using a rotary flash evaporator.

The aqueous extract was filtered and then partitioned against three equal volumes of diethyl ether after pH adjustment to 3.5. The organic phase containing ABA was then shaken twice with equal volumes of five per cent sodium bicarbonate solution in a separatory funnel to get rid of any non-acidic substances. Acidic substance including ABA were recoverd by adjusting the bicarbonate extract to pH 3.5 and extracting with three equal volumes of diethyl ether. The bulked ether extract was then dried over anhydrous sodium sulphate for one hour, filtered and the solvent was evaporated on a rotary flash evaporator. The residue was taken up in a small quantity of 0.1 M phosphate buffer (pH 6.0) and loaded on to an insoluble polyvinylpyrrolidone (PVP) column for futher purification of ether soluble acidic fraction. Fifteen grams of PVP was packed in a glass column (2 x 26 cm) in phosphate buffer at pH 6.0, sample loaded and ABA was eluted at pH 6.0 using phosphate buffer as a symmetrical peak between 55.0 and 85.0 ml elution volume. Eluant from the column was adjusted

to pH 3.5 and shaken thrice with equal volumes of diethyl ether. The pooled ether fraction was dried over anhydrous sodium sulphate and ether evaporated. The residue was taken up in a small quantity of 80% methanol and then purified by High Performance Liquid Chromatography (HPLC).

The instrument used for HPLC was a Waters Associate Model 244 liquid chromatograph (Waters Associates, Milford, U.S.A.) equipped with 6000 psi pumps, Model 660 Solvent Programmer, Model U6K Universal injector and Model 440 UV detector. A μ bondapak C_{18} column (4 x 300 mm) and an isocratic elution system with 40 per cent methanol at a flow rate of 1 ml per minute were used. Detection of standard ABA was done at 254 nm. The plant sample after clarification was injected in a single lot and the fraction corresponding to trans-and-cis-ABA retention times was collected.

The HPLC purified fraction containing ABA was dried on a nitrogen evaporator and the residue taken up in 100 μl of absolute methanol. ABA was methylated employing diazomethane reaction. One ml of ethreal diazomethane was added to the vial containing the extract and the reaction was allowed to proceed for five minutes. The solvent was then evaporated on a nitrogen evaporator and the residue was taken up in known quantity of methanol for gas liquid chromatography (GLC).

GLC was carried out on a Hewlett Packard 5840 A gas chromatograph equipped with a ^{63}Ni electron capture detector. A 2.0 m x 0.2 cm column 0f 2.0 per cent EPON1001 loaded on a 80/100 mesh support of WAW-DMCS chromosorb with nitrogen as a carrier gas at a flow rate of 80.0 ml per minute was employed. The temperatures of column, injection port and detector were maintained at 200, 250 and 300° C respectively. One /ul of the extract equivalent to 0.05 or 0.025 g fresh weight of tissue was injected. Quantification was done from the peak area of ABA with the help of a standard curve plotted using authentic ABA methylated in the same manner. The ABA recoveries were estimated by adding a known quantity of standard trans-ABA at the time of homogenization of tissue and comparing its peak area with that of the same quantity trans-ABA directly methylated.

The entire procedure was carried out under diffused light in an air conditioned room.

3.4.2. Cytokinins

3.4.2.a. **Plant material**

Mango trees of Cv. Alphonso which were given soil drenching with paclobutrazol @ 2.5 g ai/tree showed continuous suppression in vegetative flushing, length of shoots, internodal length etc. for two years (refer results of experiment No.3). Trees eliciting these responses as a result of the treatment given in November 1987 as well as

control trees of the same cultivar were selected for the present study. Cytokinin levels were determined during the active growth phase.

3.4.2.b. Sampling

Young leaves which were just turning green from bronze colour on the new flushes produced during January-February 1988, were collected separately from treated and untreated trees during first week of February. 225.0 g leaves were collected from different parts of the trees for each sample and brought immediately to the laboratory in an ice box.

3.4.2.c. Extraction, purification and estimation

The leaves were macerated with 80 per cent methanol in a Blender and the tissue was re-extracted three times each for 24 hours at 3 to 5° c with fresh solvent. The extract was evaporated to the aqueous phase in vacuo at 35° c in a rotary flash evaporator, adjusted to pH 3.5 and passed through an insoluble PVP column similar to the one described earlier. Packing of the column and elution were done with 200 ml distilled water. This step was to get rid of the phenolics. The entire eluent was collected, condensed to 100 ml, pH adjusted to 3.5 and shaken twice with equal volumes of diethyl ether. The aqueous fraction was then adjusted to pH 8.0 and shaken three times with eqaul volumes of water saturated n-butanol. The butanol

soluble and insoluble fractions were purified separately by ion exchange chromatography.

The procedures described by Letham (1966 a,b) were adopted for ion-exchange column chromatography. The butanol soluble fraction was evaporated to dryness *in vacuo*, the residue taken up in water, adjusted to pH 3.5 and passed through Dowex-50 column (NH_4^+ form, 8 per cent cross linked 100-200 mesh) equilibriated at pH 3.5. The column was washed with 2.0 litres of water acidified to pH 3.5, eluted with 250 ml of 70 per cent ethanol at pH 3.5, and 500 ml of 4.0 N NH_4OH. The ammonium hydroxide eluate was evaporated to dryness and the residue was taken up in 35 per cent methanol (fraction B).

Aqueous solution of butanol insoluble fraction was adjusted to pH 10.5 and passed through Dowex 1 column (formate form, 8 per cent cross linked, 200-400 mesh) equilibriated at pH 10.5 and eluted with 500 ml of 1.5 N acetic acid 4 N formic acid. The formic acid eluate was evaporated to dryness and the residue was taken up in 35 per cent methanol (fraction A).

Fractions A and B were further purified by Sephadex column chromatography. The method described by Armstrong *et al*. (1969) was employed using 35 per cent methanol in palce of ethanol. The column was 23 X 1000 mm. Eluates

were collected in 40.0 ml fractions and aliquots equivalent to 25.0 g fresh weight of tissue were bioassayed after solvent evaporation.

Cytokinin activity was detected by the soyabean cotyledon callus test (Miller, 1965) and the soyabean hypocotyl test (Newton et al., 1980) using the cultivar Acme. The medium described by Miller (1967) was used in both bioassays. The bioassays were conducted in 100 ml Erlenmeyer flasks using 20.0 ml of medium and the number of explants per flask was three.

3.5. EFFECT OF PACLOBUTRAZOL TREATMENTS ON PHENOLIC CONTENT OF APICAL BUD AND STEM ANATOMICAL CHARACTERISTICS

In order to study the effect of paclobutrazol treatment on the phenolic content of apical bud and stem anatomical characters, samples were obtained and processed as described under 3.1.12. and 3. 1.13, respectively except that the sampling was done about a fortnight later. In the case of anatomical characters, two more additional parameters - average diameter of the outer most metaxylem vessels and average number of xylem vessels per vascular bundle were also recorded in this case.

3.6. STATISTICAL ANALYSIS AND INTERPRETATION OF RESULTS

For the first three experimetns, Fisher's method of analysis of variance (ANOVA) and 't' tests were applied for analysis of data and interpretation of results. Results were discused at P = o.01 wherever relevant. Correlation studies and multiple linear regression analysis were also done in the frist experiment. These statistical procedures were done as described by Snedecor and Cochran (1967) and Sundararaj *et al*. (1972). For other experiments only means and standard deviations were employed to present the results.

CHAPTER IV

RESULTS

The present studies were undertaken during 1986 to 1988 with a view to understand factors governing the determination of tree size and vigour in mango and to manipulate them to our advantage, as well as to find out some simple and reliable methods to predict the vigour or tree size at an early stage. These studies were carried out at the Indian Institute of Horticultural Research and University of Agricultural Sciences, Bangalore. The results obtained in different experiments are presented in this Chapter.

4.1. STUDY OF VARIABILITY IN VIGOUR CHARACTERISTICS AMONG MANGO CULTIVARS

In order to understand the components of growth that contribute to tree size in mango, characters such as number of flushes produced by different cultivars and the length, number of nodes, internodal length and basal diameter of each flush was recorded. The data are presented in Table 1.1.

For the purpose of comparison and interpretation on statistical grounds, the mean values of these characters (except number of flushes) for whole tree (worked out as

average of different flushes produced per year) were subjected to statistical analysis employing R.B.D. Some physiological anatomical and biochemical characters of the cultivars were also studied. The results of these studies are presented in Tables 1.2 to 1.5 and described below in brief.

4.1.1. Number of flushes produced per year

In various mango cultivars studied, the number of flushes varied from one to five per year (Table 1.1). It was maximum in the case of Pacharisi, belonging to most vigorous group. This character, however, was not consistently related to tree size. A higher number of four flushes per year was produced by most vigorous cultivars like Maharaj Pasand and Kerala Kalepad, medium vigorous cultivars like Mundappa Black as well as least vigorous cultivars like Kurd and Janardhan Pasand. So also the least number of flushes per year (two) was produced by least vigorous cultivars like Kodur Hybrid, medium vigorous cultivars such as Amini and Alphonso as well as by most vigorous cultivars such as Langra. Most cultivars produced three flushes in a year. This data was not subjected to any statistical analysis as there was absolutely no variation between replications.

Table 1.1. Particulars of different vegetative flushings produced in a year (June to May) in twenty four mango cultivars of varying vigour and tree size (each value is the mean of observations on sixty taged shoots)

Cultivar	No.of vegetative flushes produced in a year	First flush (July)					Second flush (October-November)					Third flush (January-February)					Fouth flush (March-April)					Fith flush (May-June)				
		% age of shoot giving new flush	Length of flush cm	No.of nodes on the flush	Mean inter-nodal length of flush cm	Basal girth of flush cm	% age of shoots giving new flush	Length of flush cm	No.of nodes on the flush	Mean inter-nodal length of flush cm	Basal girth of flush cm	% age of shoot giving new flush	Length of flush (cm	No.of nodes on the flush	Mean inter-nodal length of flush cm	Basal girth of flush cm	% age of shoot giving new flush	Length of flush cm	No.of nodes on the flush	Mean inter-nodal length of flush cm	Basal girth of flush cm	% age of shoot giving new flush	Length of flush cm	No.of nodes on the flush	Mean inter-nodal length of flush cm	Basal girth of flush cm
1. Kurd	4	25.0	14.7	9.9	1.485	0.543	12.0	11.0	11.7	0.940	0.441	18.0	13.0	9.1	1.516	0.400	30.0	15.5	12.0	1.292	0.550	-	-	-	-	-
2. Mulgoa	3	17.0	15.3	12.7	1.205	0.555	-	-	-	-	-	19.0	7.1	9.7	0.732	0.329	21.0	8.3	10.0	0.830	0.311	-	-	-	-	-
3. Rumani x Neelum	2	-	-	-	-	-	-	-	-	-	-	27.0	13.0	12.3	1.057	0.492	36.0	9.9	11.2	0.884	0.440	-	-	-	-	-
4. Deshehari	3	17.0	15.7	13.2	1.189	0.602	-	-	-	-	-	13.0	13.9	13.1	1.061	0.399	29.0	12.9	11.6	1.112	0.372	-	-	-	-	-
5. Kerala Dwarf	3	15.0	12.3	10.5	1.171	0.450	-	-	-	-	-	10.0	5.9	7.2	0.819	0.283	11.0	6.1	8.7	0.701	0.277	-	-	-	-	-
6. Creeping	4	20.0	13.3	12.8	1.039	0.398	15.0	12.7	10.9	1.165	0.389	15.0	11.0	8.4	1.310	0.380	21.0	16.1	11.1	1.450	0.580	-	-	-	-	-
7. Rumani	4	13.0	14.9	14.2	1.049	0.547	16.0	11.0	7.9	1.132	0.401	15.0	12.3	8.3	1.482	0.370	19.0	8.5	7.9	1.067	0.330	-	-	-	-	-
8. Janardhan Pasand	3	13.0	15.6	15.0	1.040	0.575	-	-	-	-	-	18.0	13.7	12.1	1.132	0.401	20.0	10.7	9.2	1.163	0.449	-	-	-	-	-
9. Kesar	3	23.0	16.4	12.9	1.271	0.585	-	-	-	-	-	23.0	16.6	12.7	1.307	0.600	29.0	15.2	12.8	1.188	0.532	-	-	-	-	-
10. Kadari	3	25.0	17.1	11.1	1.541	0.620	23.0	11.4	10.0	1.140	0.450	21.0	16.8	10.9	1.541	0.570	-	-	-	-	-	-	-	-	-	-
11. Ratul	3	19.0	18.9	17.9	1.056	0.623	-	-	-	-	-	23.0	19.8	12.8	1.547	0.660	27.0	16.0	12.5	1.280	0.599	-	-	-	-	-
12. Neelum	3	22.0	16.8	13.6	1.235	0.600	-	-	-	-	-	33.0	14.9	11.2	1.330	0.599	27.0	14.0	12.0	1.167	0.587	-	-	-	-	-
13. Alphonso	2	-	-	-	-	-	-	-	-	-	-	38.0	26.0	17.7	1.469	0.886	37.0	29.0	16.9	1.716	0.903	-	-	-	-	-
14. Amini	2	47.0	25.2	16.0	1.575	0.873	-	-	-	-	-	41.0	23.7	16.4	1.445	0.810	-	-	-	-	-	-	-	-	-	-
15. Mundappa Black	4	21.0	16.6	13.4	1.239	0.667	30.0	9.0	10.0	0.900	0.407	27.0	13.3	11.4	1.167	0.503	29.0	14.7	10.8	1.361	0.544	-	-	-	-	-
16. Thotapuri	2	42.0	22.2	17.9	1.240	0.800	-	-	-	-	-	-	-	-	-	-	45.0	22.6	19.4	1.165	0.835	-	-	-	-	-
17. Hyder Saheb	3	50.0	18.7	13.6	1.375	0.620	-	-	-	-	-	39.0	15.6	11.0	1.418	0.576	30.0	23.2	18.0	1.289	0.808	-	-	-	-	-
18. Langra	2	60.0	28.4	19.8	1.434	0.900	-	-	-	-	-	-	-	-	-	-	67.0	32.1	22.6	1.420	1.107	-	-	-	-	-
19. Gola	3	40.0	22.8	17.5	1.307	0.786	-	-	-	-	-	42.0	23.6	16.8	1.405	0.799	33.0	14.8	10.1	1.465	0.550	-	-	-	-	-
20. Maharaj Pasand	4	63.0	21.0	15.1	1.391	0.776	37.0	28.1	18.0	1.561	0.999	55.0	19.9	14.2	1.401	0.645	29.0	14.7	10.0	1.470	0.552	-	-	-	-	-
21. Kalepad	4	59.0	24.1	18.0	1.339	0.850	41.0	17.3	12.0	1.442	0.660	53.0	14.0	11.5	1.217	0.587	23.0	16.0	13.0	1.231	0.657	-	-	-	-	-
22. Padari	3	33.0	16.3	15.3	1.065	0.588	-	-	-	-	-	37.0	26.5	16.6	1.596	0.596	42.0	20.9	14.0	1.493	0.543	-	-	-	-	-
23. Chandrakkaran	3	51.0	29.8	17.1	1.743	1.000	-	-	-	-	-	51.0	23.2	16.0	1.450	0.800	70.0	21.0	16.0	1.313	0.747	-	-	-	-	-
24. Pacharisi	5	25.0	14.9	12.8	1.164	0.566	28.0	11.3	12.0	0.942	0.458	23.0	14.5	12.0	1.208	0.560	30.0	16.3	13.0	1.226	0.590	19.0	12.0	10.0	1.200	0.5

4.1.2. Mean percentage of shoots giving new flushes

The mean percentage of shoots giving new flushes during a flushing season was calculated as the average of different flushes in a year and is presented in Table 1.2. There was highly significant variation in this character among the cultivars. The minimum value was recorded for Kerala Dwarf (12.0%) which was on par with Rumani (15.75%) but differed from all other cultivars. The maximum value for this character was noticed for Langra (63.42%) which was on par with Chandrakkaran (57.33%) and differed from all others. Cultivars like Janardhan Pasand (17.0%), Creeping (17.83%) and Mulgoa (19.0%) showed very less and those like Amini (47.0%), Maharaj Pasand (46.0%) and Kerala Kalepad (44.17%) showed very high percentage of flushing. Mean percentage of flushing ranged from 12.00 to 21.25 (Kurd) in the case of least vigorous cultivars, from 23.00 (Ratul) to 47.00 in the case of medium vigorous cultivars and from 38.42 (Gola) to 63.42 in the case of most vigorous cultivars. Thus it appeared that percentage of shoots giving new flushes at a time is an important factor contributing to tree vigour.

4.1.3. Mean basal diameter of the flush

The least diameter at the base of the flushes was in the case of Kerala Dwarf (0.337) followed by Kurd (0.348 cm)

Table 1.2. Variation in morphological characters of tree vigour among different mango genotypes

	Cultivars	Mean percentage of shoots giving new flush each time	Mean basal diameter of flush (cm)	Average length of flush (cm)	Average number of nodes per flush	Mean internodal length of the flush (cm)
1.	Kurd	21.25 (27.41)	0.348	13.75	10.68	1.308
2.	Mulgoa	19.00 (25.81)	0.398	10.23	10.80	0.922
3.	Rumani X Neelum	21.00 (27.28)	0.469	11.45	11.75	0.971
4.	Deshehari	19.67 (26.26)	0.458	14.17	12.63	1.121
5.	Mulgoa (Kerala) (Kerala Dwarf)	12.00 (20.20)	0.337	8.10	8.80	1.230
6.	Creeping	17.83 (24.90)	0.437	13.28	10.80	1.241
7.	Rumani	15.75 (23.34)	0.418	11.68	9.58	1.340
8.	Janardhan Pasand	17.00 (24.30)	0.475	13.33	12.10	1.112
9.	Kesar	25.00 (29.99)	0.572	16.07	12.80	1.256
10.	Kadari	26.33 (30.87)	0.553	15.11	10.67	1.408
11.	Ratul	23.00 (28.65)	0.627	18.23	14.40	1.295
12.	Neelum	27.33 (31.51)	0.596	15.23	12.27	1.244
13.	Alphonso	37.50 (37.76)	0.895	27.50	17.30	1.593
14.	Amini	47.00 (41.55)	0.842	24.45	16.20	1.510
15.	Mundappa Black	26.76 (31.07)	0.530	13.40	11.40	1.180
16.	Totapuri	43.52 (41.27)	0.817	22.40	18.67	1.445
17.	Hyder Saheb	39.67 (39.01)	0.668	19.17	14.20	1.361
18.	Langra	63.42 (52.79)	1.004	30.25	21.20	1.427
19.	Gola	38.41 (38.28)	0.713	20.40	14.80	1.391
20.	Maharaj Pasand	46.00 (42.70)	0.743	20.93	14.42	1.456
21.	Kalepad	44.17 (41.64)	0.689	17.85	13.63	1.307
22.	Padari	37.33 (37.66)	0.575	21.23	15.30	1.385
23.	Chandrakkaran	57.33 (49.22)	0.850	24.67	16.36	1.502
24.	Pacharisi	25.00 (29.95)	0.545	13.80	11.96	1.148
	F Test	**	**	**	**	**
	C.D. 5%	2.66	0.064	2.96	2.69	0.286
	C.D. 1%	3.56	0.086	3.95	3.60	0.382
	S.Em±	0.94	0.023	1.04	0.95	0.101
	CV %	4.84	6.458	10.38	12.19	13.424

(Transformed values are given within parentheses)

and Mulgoa (0.398 cm) whereas the maximum diameter was in the case of Langra (1.004 cm). In the case of least vigorous cultivars, the maximum basal diameter was observed in the case of Janardhan Pasand (0.475 cm) and in the case of most vigorous cultivars the minimum value was noted for Pacharisi (0.545 cm). The basal diameter of flushes varied from 0.530 cm in the case of Mundappa Black to 0.895 cm in the case of Alphonso among medium vigorous cultivars. The variation among cultivars was highly significant as is evident from the data presented in Table 1.2.

4.1.4. Average length of the flush

The flushes were shortest on Kerala Dwarf (8.1 cm), Mulgoa (10.23 cm), Kodur Hybrid (11.45 cm) and Rumani (11.68 cm) and longest on Langra (30.25 cm) and Alphonso (27.50 cm). The longest flushes among least vigorous cultivars was produced by Deshehari (14.17 cm) and the shortest flush among medium and most vigorous cultivars were produced by Kadari (15.11 cm) and Pacharisi (13.80 cm). Highly significant differences with reference to this character occurred between most varieties (Table 1.2).

4.1.5. Average number of nodes per flush

There was highly significant variation among genotypes as far as the average number of nodes per flush was concerned. Among least vigorous cultivars it varied from 8.8 in the case of Kerala Dwarf to 12.63 in the case of Deshehari; among medium vigorous cultivars from 10.67 in the case of Kadari to 18.67 in the case of Totapuri, and among most vigorous cultivars from 11.96 in the case of Pacharisi to 21.20 in the case of Langra.

4.1.6. Mean Internodal length of the flush

Mean internodal length showed highly significant varaition among the mango cultivars under study. Though minimum internodal length of 0.922 cm was shown by Mulgoa a comparatively dwarf cultivar, the internodal length did not follow any distinct pattern in line with the tree vigour of the cultivars. Less vigorous cultivars with longer internodes such as Rumani (1.340 cm) and Kurd (1.308 cm) and more vigorous cultivars with shorter internodes such as Pacharisi (1.148 cm) were also present. The maximum internodal length was in the case of Alphonso (1.593 cm) and Amini (1.510 cm), which were medium vigorous. Maximum internodal length among the most vigorous cultivars was in the case of Chandrakkaran (1.502 cm) and minimum internodal length in the case of medium vigorous cultivars

was in the case of Mundappa Black (1.18 cm) followed by Neelum (1.244 cm). Further details regarding this character are available from Table 1.2.

4.1.7. Average number of leaves per flush

The data pertaining to this character are presented in Table 1.3. Least number of leaves per flush was in the case of Kerala Dwarf (8.0) followed by Mulgoa (9.0) and Kurd (11.0). Highest number of leaves per flush was recorded in the case of Amini (20.67) followed by Deshehari (20.33), Ratul (20.00) and Kadari (19.67). The minimum number of leaves among medium vigorous cultivars was in the case of Kesar and Neelum which produced 12.33 leaves per flush. Among most vigorous cultivars, the leaf number varied from 12.00 in the case of Hyder Saheb to 19.33 in the case of Langra. Thus at a glance it appeared that average number of leaves per flush had little direct correlation with tree vigour.

4.1.8. Average area of leaf

Smaller leaves were produced by cultivars like Kerala Dwarf, Rumani and Kurd (17.71, 19.60 and 21.96 cm^2 1.96am respectively) and larger leaves by cultivars such as

Table 1.3. Variation in leaf number and area, stomatal density and phenolic content of apical bud among different mango genotypes

Cultivar	Average number of leaves per flush	Average leaf area per leaf cm^2	Average leaf area per flush cm^2	Number of stomata per 10 x 10x field	Number of stomata per flush (x 1000)	Phenolic content of apical bud (tannic acid eq. mg/g fr.wt.)
1. Kurd	11.00	21.96	240.7	9.60	121.1	48.67
2. Malgoa	9.00	36.76	327.3	12.37	212.9	45.01
3. Rumani x Neelum	14.00	21.99	307.0	7.70	123.6	43.60
4. Deshehari	20.33	37.55	763.5	13.53	541.1	44.03
5. Malgoa (Kerala) (Kerala Dwarf)	8.00	17.71	141.7	8.90	91.0	56.00
6. Creeping	13.67	36.26	493.2	20.63	525.4	45.35
7. Rumani	14.67	19.60	286.5	14.5	216.6	42.10
8. Janardhan Pasand	15.33	40.88	626.7	14.50	476.5	49.39
9. Kesar	12.33	43.44	534.9	12.07	308.7	30.63
10. Kadari	19.67	27.56	538.8	10.47	295.4	30.32
11. Ratul	20.00	28.39	565.5	11.73	345.6	31.32
12. Neelum	12.33	49.54	598.1	13.50	422.4	39.10
13. Alphonso	14.33	48.14	673.0	8.27	290.1	37.99
14. Amini	20.67	33.37	673.8	11.20	394.2	40.87
15. Mundappa Black	17.33	37.63	648.2	10.73	365.8	23.90
16. Totapuri	17.67	54.34	945.3	11.17	552.4	21.58
17. Hyder Saheb	12.00	67.99	799.9	13.57	567.7	24.80
18. Langra	19.33	74.47	1424.5	9.20	685.9	20.88
19. Gola	12.33	47.03	559.5	9.70	283.8	27.12
20. Maharaj Pasand	16.33	49.83	752.5	13.63	536.6	21.38
21. Kalepad	16.33	67.55	1098.4	5.17	288.1	19.70
22. Padari	15.00	58.96	877.3	13.23	605.2	23.23
23. Chandrakkaran	12.33	35.32	411.7	6.73	144.0	22.37
24. Pacharisi	17.67	36.05	636.4	17.23	572.1	19.33
F-Test	**	**	**	**	**	**
C.D. 5%	3.56	13.21	114.0	3.17	82.20	2.48
C.D. 1%	4.76	17.64	152.3	4.24	109.79	3.31
S.Em±	1.25	4.64	40.1	1.11	28.89	0.87
C.V. %	14.40	19.44	11.2	16.65	13.40	4.48

Langra, Hyder Saheb and Kerala Kalepad (74.67, 67.99 and 67.55 cm^2 respectivily). The average area of single leaf varied from 27.56 cm^2 in the case of Kadari to 54.34 cm^2 in the case of Totapuri among the medium vigorous group. Thus it appeared that dwarfer cultivars generally produced smaller leaves and vigorous cultivars generally produced larger leaves (Table 1.3).

4.1.9. Average leaf area per flush

From the data presented in Table 1.3. it can be stated with a fair degree of confidence that in general, leaf area per flush is comparatively high in more vigorous cultivars and low in less vigorous cultivars with medium vigour cultivars, showing intermediate values. However, exceptions such as Chandrakkaran, a comparatively vigorous variety with less leaf area per flush (411.7 cm^2) and Deshehari and Totapuri, a comparatively dwarf and a comparatively medium sized cultivar respectively, with more leaf area (763.5 and 945.3 cm^2 respectively) were also present. The minimum leaf area per flush was in the case of Kerala Dwarf (141.7 cm^2) and maximum in the case of Langra (1424.5 cm^2). Among medium vigorous trees, the leaf area per flush was least in the case of Kesar (534.9 cm^2).

4.1.10. Number of stomata per unit leaf area

Data on number of stomata per microscopic field of 100 x magnification on the leaves of different cultivars are presented in Table 1.3. Its value ranged from 5.17 in Kerala Kalepad, belonging to the most vigorous category to 20.63 in Creeping, belonging to least vigorous group. No distinct pattern of stomatal density in relation to tree vigour was evident from this data. Some least vigorous cultivars like Kodur Hybrid recorded low values whereas others like Creeping recorded high. So also, most vigorous cultivars, Kerala Kalepad and Pacharisi, recorded low and high values respectively. The differences between many of the cultivars were highly significant.

4.1.11. Number of stomata per flush

Number of stomata per flush ranged from 91.0 thousand in Kerala Dwarf to 685.9 thousand in Langra. The variation among cultivars in this regard was highly significant. Among least vigorous groups, the highest value was recorded for Deshehari (541.1. thousand stomata per flush) and among most vigorous ones, the minimum was in the case of Chandrakkaran (144 thousand stomata per flush). In medium vigour cultivars, stomatal number per flush varied from 290.1 thousand in Alphonso to 552.4 thousand in Totapuri (Table 1.3).

4.1.12. Phenolic content of apical bud

Since there are reports that phenolic content is inversely related to tree vigour in many fruit crops like apple and citrus, the total phenolic content of apical bud expressed as tannic acid equivalent was studied and the data is presented in Table 1.3. It was observed that total phenolics was distinctly higher in less vigorous cultivars and lower in more vigorous cultivars with medium vigorous cultivars showing intermediate value (Table 1.3). It ranged from 42.10 mg/g (Rumani) to 56.0 mg/g (Kerala Dwarf) among least vigorous cultivars; from 21.5 mg/g (Totapuri) to 40.87 mg/g (Amini) among medium vigorous cultivars; and from 19.33 mg/g (Pacharisi) to 27.12 mg/g (Gola) among most vigorous cultivars. Least vigorous cultivars like Janardhan Pasand (49.39 mg/g) and Kurd (48.67 mg/g) ranked high in phenolic level of terminal bud next to Kerala Dwarf most vigorous cultivars like Kerala Kalepad (19.7 mg/g) and Langra (20.88 mg/g) ranked low in phenolic content next to Pacharisi. So it appears that phenolic content has a direct bearing on vigour of mango trees.

4.1.13. Anatomical characters

Various stem anatomical characters of the twenty four

cultivars studied such as width of half pith, cortex, xylem and phloem tissues are presented in Table 1.4 and detailed below.

(a) **Radial width of half pith**

The variation in this character was highly significant. Least width was noted in Kurd (35.00 /u) and maximum in Creeping (105.67 /u). There was no clear cut trend in this character in relation to tree vigour.

(b) **Radial width of cortex**

Radial width of cortex which included parenchyma and collenchyma ranged from 17.00 /u in the case of Kurd and Kerala Dwarf to 37.33 /u in the case of Mundappa Black and the variation was highly significant. The data did not show any relation with tree vigour <u>per se</u>.

(c) **Radial width of primary xylem tissue**

The radial width of primary xylem tissue ranged from 11.67 /u in the case of Kurd, Kerala Dwarf and Janardhan Pasand to 46.0 /u in the case of Chandrakkaran, the variation being highly significant. Pacharisi (41.33 /u), Mundappa Black (43.33 /u), and Totapuri (40.33 /u) and also

Table 1.4. Variation in stem anatomical characters and productivity among different mango genotypes

Cultivar	Radial width of half pith (/u)	Radial width of cortex (/u)	Radial width of primary xylem tissue (/u)	Radial width of primary phloem tissue (/u)	Phloem to xylem ratio	Productivity (fruit yield per unit volume occupied by tree. Av. of 2 years (kg/m³)
1. Kurd	35.00	17.00	11.67	17.67	1.518	0.962
2. Mulgoa	38.33	18.67	12.00	18.00	1.500	1.309
3. Rumani x Neelum	50.00	24.67	23.00	24.67	1.073	1.574
4. Deshehari	84.33	32.67	20.33	23.33	1.145	0.778
5. Mulgoa (Kerala) (Kerala Dwarf)	36.33	17.00	11.67	23.33	2.002	1.901
6. Creeping	105.67	29.67	25.67	21.00	0.840	0.358
7. Rumani	48.33	22.67	18.00	21.33	1.188	1.349
8. Janardhan Pasand	38.00	17.67	11.67	21.00	1.814	1.872
9. Kesar	95.33	25.00	26.33	18.67	0.710	0.999
10. Kadari	103.33	31.00	24.33	16.67	0.718	1.392
11. Ratul	47.33	26.67	20.00	19.67	0.986	0.627
12. Neelum	46.00	23.00	26.33	22.33	0.857	0.842
13. Alphonso	86.33	28.33	30.67	24.00	0.776	0.706
14. Amini	97.33	32.67	34.67	21.33	0.618	0.641
15. Mundappa Black	47.33	37.33	43.33	28.00	0.646	0.947
16. Totapuri	94.67	33.33	40.33	24.00	0.595	0.870
17. Hyder Saheb	84.00	32.33	34.67	19.00	0.548	0.522
18. Langra	47.00	31.33	29.00	13.67	0.470	0.052
19. Gola	105.00	32.00	28.00	12.67	0.460	0.258
20. Maharaj Pasand	54.00	24.33	35.00	11.33	0.329	0.244
21. Kalepad	54.67	24.67	33.67	11.67	0.352	0.170
22. Padari	103.00	19.33	37.33	20.67	0.554	0.611
23. Chandrakkaran	85.00	26.33	46.00	19.33	0.422	0.773
24. Pacharisi	95.00	24.67	41.33	21.00	0.512	0.662
F-Test	**	**	**	**	**	**
C.D. 5%	9.76	7.32	9.52	5.47	0.118	0.251
C.D. 1%	13.04	9.77	12.72	7.31	0.158	0.335
S.Em±	3.43	2.57	3.35	1.92	0.042	0.088
C.V. %	8.48	16.91	20.92	16.86	8.360	17.920

broader xylem tissue. Generally, the less vigorous cultivars showed lesser radial width of primary xylem tissue than more vigorous ones. The maximum width among least vigorous cultivars was in Creeping (25.63 /u) and minimum width among most vigorous cultivars was in Gola (28.00 /u). In the case of medium vigour cultivars, it ranged from 20.0 /u in Ratul to 43.33 /u in Mundappa Black.

(d) **Radial width of primary phloem tissue**

The variation in the radial width of primary phloem tissue was highly significant among the cultivars. It ranged from 11.3 /u in the case of Maharaj Pasand to 24.67 /u Kodur Hybrid. Generally speaking, primary phloem tissue had lesser width in more vigorous cultivars, but there were exceptions also.

(e) **Phloem : xylem ratio**

The data on phloem to xylem ratio presented in Table 1.4 indicated that higher value for this ratio was associated with less vigorous nature of trees, perhaps with the sole exception of Creeping, a less vigorous cultivar with lesser phloem to xylem ratio of 3.340. Barring this cultivar, the value ranged from 1.073 in the case of Kodur Hybrid to 2.002 in Kerala Dwarf among least vigorous

cultivars, from 0.595 in Totapuri to 0.986 in Ratul among medium cultivars and from 0.329 in Maharaj Pasand to 0.554 in Padari among most vigorous cultivars. From this study one is led to conclude that phloem to xylem ratio could be a major factor associated with tree size and could possibly be employed for predicting the vigour of mango genotypes.

4.1.14. Productivity

Fruit yield per unit volume of space occupied by tree was comparatively higher for least vigorous and medium vigorous cultivars than most vigorous ones. However, Creeping, a less vigorous genotype had a lower productivity of 0.358 kg/m^3. Productivity was highest in the case of Kerala Dwarf (1.90 kg/m^3) and least in the case of Langra (0.052 kg/m^3). It was higher also in the case of cultivars like Janardhan Pasand (1.872 kg/m^3) and Kodur Hybrid (1.574 kg/m^3) and lower also in the case of varieties like Kerala Kalepad (0.170 kg/m^3) Maharaj Pasand (0.244 kg/m^3) and Gola (0.258 kg/m^3). Among medium vigorous cultivars the productivity ranged from 0.627 kg/m^3 in Ratul to 1.392 kg/m^3 in Kadari. Among least vigorous cultivars, Creeping, Deshahari and Kurd registered comparatively lower productivity and among most vigorous ones Chandrakkaran, Pacharisi and Padari registered comparatively higher productivity. The variation in this character was highly significant among the cultivars (Table 1.4).

4.1.15. Tree height

There was highly significant variation in tree height among the varieties. In 1986 and 1988, the least height was recorded in the case of Kerala Dwarf (1.39 and 1.48 m respectively) and this was followed by Mulgoa, Kurd, Kodur Hybrid and Deshehari in that order. In 1986, the maximum tree height was observed for Kerala Kalepad (4.09 m) followed by Maharaj Pasand, Langra and Hyder Saheb. In 1988, the tallest trees were those of Maharaj Pasand (5.25 m) followed by Kerala Kalepad, Langra and Gola (Table 1.5).

4.1.16. Mean tree spread

The average spread of the trees was minimum in both the years for Kerala Dwarf (1.69 and 1.83 m respectively) followed by Janardhan Pasand, Mulgoa, Kurd and Rumani. Similarly, maximum spread was observed in trees of Maharaj Pasand (5.20 and 7.41 m respectively), and this was followed by Kerala Kalepad and Langra. The variation in tree spread was highly significant (Table 1.5).

4.1.17. Tree volume

Data obtained in various varieties are given in Table 1.5. There was highly significant variation in tree volume among the cultivars. Kerala Dwarf occupied the least volume in both the years (2.11 and 2.63 m^3 respectively) followed by Janardhan Pasand (4.47 and 6.28 m^3

Table 1.5. Variation in tree size and per cent increase in tree size among different mango genotypes

Cultivar	Tree height (m)		Mean tree spread (m)		Tree volume (m^3)		Per cent increase in tree height over 2 years	Per cent increase in tree spread over 2 years	Per cent increase in tree volume over 2 years
	1986	1988	1986	1988	1986	1988			
1. Kurd	2.20	2.50	2.61	2.90	7.85	11.00	13.93	10.99	39.98
2. Mulgoa	2.10	2.45	2.30	2.64	5.86	8.98	16.54	14.79	53.27
3. Rumani x Neelum	2.27	2.66	2.84	3.16	9.59	13.92	17.56	11.64	47.29
4. Deshehari	2.37	2.79	3.28	3.64	13.34	19.39	17.57	11.32	45.95
5. Mulgoa (Kerala) (Kerala Dwarf)	1.39	1.48	1.69	1.83	2.11	2.63	6.51	8.50	25.49
6. Creeping	2.54	3.05	2.91	3.34	11.25	17.76	19.92	14.88	58.29
7. Rumani	2.37	2.79	2.76	3.15	9.47	14.48	18.22	13.95	53.85
8. Janardhan Pasand	2.41	2.78	1.88	2.07	4.47	6.28	15.62	10.06	40.31
9. Kesar	3.02	3.62	3.54	4.17	20.00	32.97	19.89	18.48	69.49
10. Kadari	2.92	3.50	3.34	4.02	17.03	29.77	19.95	20.53	74.33
11. Ratul	2.47	2.93	3.12	3.69	12.62	21.02	18.66	18.25	66.15
12. Neelum	2.74	3.32	3.56	4.19	18.35	31.03	20.72	17.91	68.16
13. Alphonso	2.69	3.24	3.43	4.10	16.58	28.46	20.37	19.27	71.68
14. Amini	2.86	3.44	4.04	4.81	24.47	41.72	20.54	18.79	69.95
15. Mundappa Black	2.72	3.30	3.81	4.67	20.69	37.72	21.43	22.59	93.90
16. Thotapuri	3.01	3.68	3.59	4.26	20.41	35.17	21.39	18.49	71.83
17. Hyder Saheb	3.43	4.25	4.09	5.26	29.98	61.87	23.97	28.80	105.91
18. Langra	3.51	4.42	4.66	5.86	39.87	79.55	25.95	25.96	100.68
19. Gola	3.47	4.24	4.29	5.32	33.77	63.00	22.32	25.21	98.77
20. Maharaj Pasand	4.03	5.25	5.20	7.41	57.39	151.29	30.38	42.70	166.57
21. Kalepad	4.09	5.21	4.71	6.33	47.61	110.06	27.22	33.59	130.40
22. Padari	3.31	4.09	4.23	5.57	31.14	66.54	23.76	31.78	115.28
23. Chandrakkaran	3.26	4.05	3.94	5.23	26.56	58.27	24.38	32.80	119.40
24. Pacharisi	3.25	4.05	4.01	5.26	27.41	58.78	24.62	31.17	114.75
F-Test	**	**	**	**	**	**	**	**	**
C.D. 5%	0.20	0.24	0.32	0.49	5.25	12.49	7.30	12.69	40.48
C.D. 1%	0.27	0.32	0.43	0.65	7.01	16.68	9.75	16.94	54.06
S.Em±	0.07	0.08	0.11	0.17	1.84	4.39	2.57	4.46	14.23
C.V. %	4.24	4.21	5.61	6.92	15.09	18.22	21.71	36.88	31.10

respectively), Mulgoa (5.86 and 8.98 m^3 respectively) and Kurd (7.85 and 11.00 m^3 respectively). Tree volume was maximum in 1986 as well as 1988 in the case of Maharaj Pasand (57.39 and 151.29 m^3 respectively) followed by Kerala Kalepad (47.61 and 110.06 m^3 respectively) and Langra (39.87 and 79.55 m^3 respectively).

4.1.18. Increase in tree height

The data on per cent increase in tree height is presented in Table 1.5. The least value was noted in the case of Kerala Dwarf (6.57%)and this was significantly lower than all other cultivars. All other least and medium vigorous cultivars were on par with each other with reference to per cent increase in tree height at one per cent significance level. The maximum value was noted for Maharaj Pasand (30.38%) which was on par at five per cent level with all other most vigorous cultivars except Gola.

4.1.19. Increase in tree spread

Per cent increase in tree spread over two years was also minimum in the case of Kerala Dwarf (8.5%) which was on par with all other least and medium vigorous cultivars. Maharaj Pasand recorded the maximum increase in tree

spread (42.7%) which was on par with all other most vigorous cultivars except Langra and Gola (Table 1.5).

4.1.20. Increase in tree volume

The maximum increase in tree volume was in the case of Maharaj Pasand (166.57%). Kerala Kalepad, Padari, Chandrakkaran and Pacharisi also showed comparable increases. Kerala Dwarf showed the minimum increase in tree volume over two years (25.49%) and was on par with other least vigorous and medium vigorous cultivars except Mundappa Black. Some other cultivars which recorded very small increases in tree volume were Kurd, Janardhan Pasand, Deshehari, Kodur Hybrid, Mulgoa and Rumani (Table 1.5.).

4.1.21. Correlation studies

Correlation coefficients of important morphological, physiological, anatomical and biochemical characters with tree size and vigour were worked out. The results are presented in the form of intrecorrelation matrix in Table 1.6.

Number of flushes produced per year was correlated negatively with basal girth and length of flush; and positively with number of stomata per unit leaf area. There was highly significant negative correlation of this character with number of nodes per flush.

Table 1.6. Correlation coefficients between various morphological, anatomical, physiological and biochemical characters as related to tree size and vigour in mango

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}
X_1	1.000	-0.324	-0.477*	-0.478*	-0.566**	-0.234	-0.101	-0.181	-0.210	0.425*	0.010	-0.126	-0.025	-0.113	0.147	0.148	0.132	0.271	0.210	0.278
X_2		1.000	0.914**	0.898**	0.869**	0.678**	0.281	0.693**	0.695**	-0.408*	0.344	-0.720**	-0.753**	-0.677**	0.772**	0.745**	0.793**	0.714**	0.718**	0.719**
X_3			1.000	0.954**	0.928**	0.728**	0.402	0.632**	0.683**	-0.354	0.365	-0.636**	-0.715**	-0.622**	0.662**	0.666**	0.677**	0.565**	0.566**	0.569**
X_4				1.000	0.947**	0.791**	0.380	0.625**	0.673**	-0.308	0.397	-0.572**	-0.663**	-0.657**	0.616**	0.619**	0.644**	0.530**	0.522**	0.526**
X_5					1.000	0.617**	0.399	0.679**	0.748**	-0.298	0.478*	-0.576**	-0.599**	-0.604**	0.562**	0.570**	0.574**	0.445*	0.460*	0.449*
X_6						1.000	0.247	0.328	0.355*	-0.244	0.160	-0.422*	-0.541**	-0.487*	0.483*	0.424*	0.520**	0.458*	0.437*	0.437*
X_7							1.000	0.157	0.571**	0.086	0.521**	-0.386*	-0.422*	-0.327	0.328	0.406*	0.356*	0.196	0.240	0.228
X_8								1.000	0.878**	-0.081	0.661**	-0.641**	-0.601**	-0.665**	0.745**	0.692**	0.675**	0.593**	0.642**	0.608**
X_9									1.000	-0.081	0.758**	-0.658**	-0.613**	-0.660**	0.705**	0.683**	0.667**	0.518**	0.608**	0.546**
X_{10}										1.000	0.545**	0.153	0.091	-0.039	-0.106	0.013	-0.137	-0.091	-0.145	-0.086
X_{11}											1.000	-0.457*	-0.439*	-0.521**	0.490**	0.544**	0.470*	0.382	0.405*	0.402*
X_{12}												1.000	0.884**	0.656**	-0.872**	-0.868**	-0.868**	-0.864**	-0.758**	-0.870**
X_{13}													1.000	0.794**	-0.884**	-0.915**	-0.908**	-0.819**	-0.749**	-0.834**
X_{14}														1.000	-0.769**	-0.782**	-0.803**	-0.681**	-0.711**	-0.699**
X_{15}															1.000	0.955**	0.954**	0.914**	0.924**	0.932**
X_{16}																1.000	0.936**	0.894**	0.865**	0.918**
X_{17}																	1.000	0.939**	0.944**	0.953**
X_{18}																		1.000	0.926**	0.994**
X_{19}																			1.000	0.943**
X_{20}																				1.000

X_1 : Number of flushes per year
X_2 : Percentage of shoots giving new flushes
X_3 : Basal girth of the flush
X_4 : Length of flush
X_5 : Number of nodes per flush
X_6 : Internodal length of flush
X_7 : Number of leaves/flush
X_8 : Leaf area/leaf
X_9 : Leaf area/flush
X_{10} : No.of stomata/10 x 10x fld.
X_{11} : No.Of stomata/flush
X_{12} : Chlorophyll content of mid bud
X_{14} : Productivity
X_{15} : Tree height 1988
X_{16} : Per cent increase in tree height over two years
X_{17} : Mean tree spread, 1988
X_{18} : Per cent increase in tree spread over two years
X_{19} : Tree volume, 1988
X_{20} : Per cent increase in tree volume over two years

The mean percentage of shoots giving new flushes during flushing season showed high positive correlation with basal girth of flush, length of flush, number of nodes per flush, internodal length of flush, leaf area per leaf, leaf area per flush, tree height, percent increase in tree height, tree spread, per cent increase in tree spread, tree volume and per cent increase in tree volume. It was correlated negatively with number of stomata per unit leaf area at five per cent level and with phenolic content of apical bud, phloem to xylem ratio, and productivity at one per cent level.

There was highly significant positive correlation between basal girth of the flush and length of flush, number of nodes, internodal length, leaf area per leaf and per flush, tree height, spread, volume as well as per cent increases in the last three characters. Its correlation was highly significant and negative with phenilic content of apical bud, phloem to xylem ratio and productivity.

Length of the flush was correlated in a highly significant positive manner with its number of nodes and internodal length; leaf area per leaf and per flush; height, spread and volume of trees and per cent increases in these characters. Highly significant negative correlation of this character existed with phenolic content of apical bud, phloem to xylem ratio of stem and productivity of trees.

Number of nodes per flush expressed positive , highly significant correlation coefficients with internodal length of flush, leaf area per leaf and flush, tree height, per cent increase in tree height as well as with tree spread and significant positive correlation with number of stomata per flush, per cent increases in tree sperad and volume, as well as tree volume in 1988. It was correlated in a highly significant negative manner with phenolic content of apical bud, phloem to xylem ratio and productivity.

Internodal length of the flush was correlated negatively with phenolic content of apical bud as well as productivity and positively with tree height, tree volume and per cent increases in tree height, volume and spread. At one per cent level, it was correlated negatively with phloem to xylem ratio and positively with mean tree spread in 1988.

Correlation was highly significant and positive between number of leaves per flush and leaf area per flush as well as number of stomata per flush. It was also correlated positively with per cent increase in tree height over two years and negatively with phloem to xylem ratio.

Area of single leaf had high positive correlation with leaf area and number of stomata per flush,height, spread and volume of tree; as well as per cent increases in tree height,

spread and volume. It showed high negative correlation with phenolic content of apical bud, phloem to xylem ratio and productivity. Leaf area per flush also exhibited the very same trends.

There was high positive correlation between number of stomata per unit leaf area and number of stomata per flush. The latter was correlated negatively with phenolic content of apical bud and phloem to xylem ratio at five per cent level and with productivity at one per cent level of significance. It was also correlated positively with tree height, spread and volume and had highly significant positive correlation with per cent increase in tree height.

Phenolic content of apical bud, phloem to xylem ratio and productivity were highly correlated each other positively and these three characters had high negative correlations with height, spread and volume of trees as well as per cent increases in these over two years. Tree height, spread and volume as well as per cent increases in these characters were correlated each other in the positive manner at one per cent level of significance.

The per cent increase in tree volume over a given period of time gives an indication of tree vigour or rate of growth of the tree. Of the various inherent characters of genotypes studied here the maximum correlation with per cent

increase in tree volume was exhibited by phloem to xylem ratio (r = -0.870) followed by phenolic content of apical bud (r = -0.834). Hence these two characters of genotypes could be used to predict their vigour in screening programmes. Those with higher phloem to xylem ratio or phenolic content will tend to have lesser vigour.

The phenolic content and phloem to xylem ratio had high negative correlation with the actual volume of these trees in the eleventh orchard year also (r = -0.758 and r = -0.749 respectively). Tree vigour or tree size could also be predicted with a lesser degree of percision using characters such as percentage of shoots giving new flushes at the time of flushing (r = 0.715 and 0.718 respectively) average area of single leaf (r = 0.608 and 0.642 respectively), basal girth of flushes (r = 0.569 and 0.566 respectively), leaf are per flush (r = 0.546 and 0.608 respectively) and length of flushes (r = o.526 and 0.522 respectively).

In short, to get dwarfer genotypes with lesser vigour, one should look for characters such as higher phenolic content and phloem to xylem ratio and lesser percentage of vegetative flushes with shorter and thinner flushes producing smaller leaves.

Another finding from this correlation study was productivity of trees is inversely related to tree volume

and vigour (r = -0.699 and -0.711 respectively). Higher productivity was associated with lesser percentage of vegetative flushings, shorter and thinner flushes with lesser nodes, internodal length etc.

4.1.22. Regression equation to predict tree volume from morphological growth components

Taking guidance from the results of correlation studies, a multiple linear regression model was fitted with morphological growth characters which are very easy to record to predict the per cent increase in tree volume over two years and thereby to calculate the expected volume of trees after two years. The equation was

$$y = -39.427 + 21.384\ x_1 + 2.328\ x_2 - 0.855\ x_3 - 6.934\ x_4$$

where, y is the per cent increase in tree volume over two years,

x_1 is the number of vegetative flushes produced per year,

x_2 is the mean percentage of shoots giving new flushes during one vegetative flushing,

x_3 is the average length of the flush, and

x_4 is the yield of fruits in kilograms per cubic meter of space occupied by the tree (productivity)

This model had a R^2 value of 0.805. The model indicated a Durbin-Watson statistic of 1.971.

4.2. EFFECT OF ROOTSTOCKS ON THE VIGOUR OF A DWARF AND A VIGOROUS SCION GRAFTED ON TO THEM

The characters of mother plant from which the stones were collected for raising the rootstocks and their seed characters are presented in Tabel 2.1. This table is self explanatory.

Though observations were recorded on length of new growth, number of nodes, mean internodal length, number of flushes and girth of stem at collar region and graft union, at six month intervals, the differences among treatments were not significant except for length of new growth and coller girth. Hence it is not being attempted here to present all these data, but to get an idea of the general trend the parameters recorded at twentyfour months after grafting are presented in Table 2.2 along with data on phenolic content of apical bud and stomatal density.

Rootstocks did not have any influence on any characters other than collar girth. It was minium for Panakkalu followed by Dwarf selection and maximum for Hyder Sahebi followed by Rumani.

There was significant difference among scions with reference to length of new growth which was less for Rumani than Langra. Similar trends were observed during six and twelve months after grafting also.

Table 2.1. Characters of rootstock varieties used in the experiment (mean ± S.D.)

Variety	Length of stone (cm)	Breadth of stone (cm)	Thickness of stone (cm)	Length of kernel (cm)	Breadth of kernel (cm)	Thickness of kernel (cm)	Average weight of stones (g)	Average weight of kernels (g)	No.Of days taken for Initiation of germination	No.Of days taken for 50% germination	Stomatal density (No.of stomata per 10x10 x field	Phenolic content of apical bud (tannic acid eq mg/g fruit weight
Hyder Saheb	5.55± 0.35	2.83± 0.17	1.71± 0.14	5.24± 0.54	2.49± 0.20	1.45± 0.12	16.00± 2.20	14.15± 1.50	14.0	16.0	13.57± 1.81	24.80± 0.43
Kalepad	4.81± 0.46	3.01± 0.26	1.87± 0.14	4.50± 0.32	2.53± 0.19	1.86± 0.21	16.05± 1.65	15.20± 1.25	11.0	14.0	5.17± 1.04	19.70± 0.00
Gola	6.07± 0.76	3.24± 0.43	2.04± 0.20	5.27± 0.73	2.47± 0.25	1.60± 0.22	21.70± 2.60	14.60± 1.65	16.0	19.0	9.70± 1.00	27.12± 1.26
Panakkalu	5.93± 0.41	3.43± 0.34	1.95± 0.14	4.78± 0.47	2.48± 0.28	1.58± 0.20	19.30± 2.60	14.60± 1.27	17.0	20.0	12.39± 1.01	32.31± 1.75
Neelum	6.46± 0.49	3.67± 0.33	1.86± 0.15	5.14± 0.43	2.87± 0.37	1.54± 0.15	23.70± 3.50	17.25± 2.65	14.0	17.0	13.50± 0.20	39.10± 1.65
Creeping	4.81± 0.45	3.15± 0.36	1.90± 0.18	4.11± 0.55	2.32± 0.32	1.55± 0.15	15.05± 1.55	11.05± 1.15	13.0	15.0	20.63± 4.87	45.35± 1.21
Dwarf	7.24± 0.49	4.18± 0.20	2.25± 0.17	6.60± 0.35	3.13± 0.21	1.80± 0.20	31.35± 5.33	26.75± 2.76	11.0	13.0	14.50± 1.63	53.66± 1.56
Rumani	4.99± 0.55	3.41± 0.23	1.76± 0.16	4.67± 0.32	3.06± 0.26	1.60± 0.16	13.90± 2.56	12.95± 2.13	13.0	15.0	15.40± 3.15	42.10± 1.85

Table 2.2. Effect of some rootstocks on the vigour characteristics of a vigorous and a dwarf scion, 24 months after grafting

Treatment	Length of new growth (cm)	No.of nodes on the new growth	Mean internodal length of new growth (cm)	No.of new flushes produced	Collar girth (cm)	Girth at graft union (cm)	Stomatal density (No.of stomata per 10x10x field	Phenolic content of apical buds (tannic acid eq. mg/g fresh wt.
L/H	65.42	76.99	0.85	4.17	2.49	2.27	11.07	23.64
R/H	59.06	75.34	0.79	4.00	2.38	2.20	14.44	48.44
L/K	71.35	78.88	0.91	4.33	2.22	2.25	10.11	23.49
R/K	68.33	75.08	0.91	3.67	2.30	2.13	9.90	48.34
L/G	62.92	68.59	0.92	4.00	2.25	1.80	9.50	23.74
R/G	59.37	66.53	0.89	3.72	2.23	1.98	13.47	48.58
L/P	65.90	77.02	0.86	4.11	2.01	1.71	10.69	23.68
R/P	60.57	72.14	0.84	3.22	2.02	1.80	16.05	48.46
L/N	63.76	74.48	0.87	3.67	2.24	2.19	10.05	23.68
R/N	60.62	69.21	0.88	3.89	2.40	2.30	12.96	48.50
L/C	71.10	76.34	0.93	4.00	2.10	1.91	8.36	23.50
R/C	68.81	73.70	0.94	3.94	2.03	2.00	11.93	48.39
L/D	64.38	71.30	0.91	4.50	2.10	1.97	11.11	23.61
R/D	62.46	69.42	0.90	3.83	2.10	1.80	13.08	48.40
L/R	65.25	75.56	0.86	5.44	2.49	2.02	10.60	23.62
R/R	62.78	69.88	0.91	3.78	2.28	2.21	13.43	48.44
Mean	64.50	73.15	0.89	4.02	2.23	2.04	11.67	36.03
F-Test								
Rootstock	NS	NS	NS	NS	**	NS	NS	NS
Scion	*	NS	NS	NS	-	NS	**	**
Interaction	NS	NS	NS	NS	-	NS	NS	NS
C.D. at 5%								
Rootstock	-	-	-	-	0.24	-	-	-
Scion	3.33	-	-	-	-	-	1.61	0.533
Interaction	-	-	-	-	-	-	-	-
C.D. at 1%								
Rootstock	-	-	-	-	0.32	-	-	-
Scion	-	-	-	-	-	-	2.16	0.717
Interaction	-	-	-	-	-	-	-	-
C.V. %	8.77	9.28	10.98	19.48	9.05	15.96	23.50	2.52

The difference among scions was highly significant for stomatal density and phenolic content. Stomatal density was less for Langra compared to Rumani which had higher content of total phenols in the apical bud than Langra. The phenolic content was about 23.5 mg/g fresh weight in the case of Langra and about 48.5 mg/g fresh weight in the case of Rumani irrespective of the rootstock on which it was growing.

There was no significant interaction between root-stock and scion with reference to any of the parameters studied. These results indicated that the vigour of the scion variety as well as the basic parameters determining vigour were not influenced by rootstocks. Since rootstocks did not have any influence on the growth of the scion, it was not further attempted to find the correlation between the characters of mother trees and vigour parameters of scions grafted on to the rootstocks raised from the open pollinated seeds of these trees.

However, it seems appropriate to conclude from this study that rootstocks do not have much say in the vigour of mango grafts and that the vigour characteristics of the grafted plants are more influenced by the scion used.

4.3. CHEMICAL REGULATION OF TREE SIZE

The results of the experiment carried out to explore the possibility of controlling tree size in mango using chemical growth retardants are given in the following pages. The treatments tried in this experiment except the highest dose of paclobutrazol (10.0 g ai/ tree) did not have any phytotoxic effects. The highest dosage of paclobutrazol resulted in severe phytotxic symptoms such as crinkling and brittle nature of leaves which were overcroweded as in the case of vegetative malformation, weak shoot growth, reduced fruit set, poor development of fruits etc. Then effects of the treatments on various characters are described individually.

4.3.1. Percentage of shoots giving new flush

All the growth retardents tried namely Cycocel, Alar and Paclobutrazol at different doses resulted in highly significant reduction in the percentage of shoots giving new flushes during 1987 January-February season, compared to control (58.67%). Trees receiving paclobutrazol at 10.0, 5.0 and 2.5 g per plant produced only 16.0, 20.67 and 34.0 per cent flushing respectively. Alar 3000 ppm (34.67%) and Cycocel 8000 ppm (38.33%) were next in the order. The differences between different concentrations of individual growth retardants were highly significant in the case of paclobutrazol and Alar and significant in the case of cycocel (Table 3.1).

During March - April of the same year, paclobutrazol 10.0 or 5.0 g per tree applied either once or twice, 2.5 g per tree applied twice and cycocel 8000 ppm and Alar 3000 ppm sprayed twice caused highly significant reductions in the percentage of shoots giving new flush while cycocel 8000 ppm sprayed once produced significant reduction. Among the paclobutrazol treatments which produced highly significant reduction compared to control (45.0%), 10.0 g of the chemical applied twice caused highly significant reduction (20.67%) compared to all others except the same concentration applied once.

In the two flushings of 1988, the differences in this character among trees receiving different treatments were not statistically significant. Still all the treatments registered lesser percentage of flushing than control. During both these flushings, the minimum value was noticed on tree receiving paclobutrazol at 10.0 g per tree twice. A critical examination of Table 3.1 also revealed that the effect of growth retardant treatments slowly dessipated in subsequent flushings, particularly at the lower concentrations of the chemicals. This was evident from the mere fact that the differences in this character among treatments became non-significant and comparable to control by the third flushing after the initial application and by fourth

Table 3.1. Influence of growth retardant treatments on the percentage of shoots giving new flush in mango Cv. Alphonso

Treatment	Percentage of shoots giving new flush			
	JAN-FEB 1987	MAR-APR 1987	JAN-FEB 1988	MAR-APR 1988
Control	58.67 (49.99)	45.00 (42.12)	30.00 (33.16)	31.67 (34.23)
Paclobutrazol 2.5 g once	34.00 (35.67)	38.33 (38.24)	25.00 (30.00)	30.00 (33.07)
Paclobutrazol 2.5 g twice	-	33.00 (35.02)	21.67 (27.52)	25.00 (29.92)
Paclobutrazol 5.0 g once	20.67 (27.04)	31.67 (34.23)	21.67 (27.52)	30.00 (33.03)
Paclobutrazol 5.0 g twice	--	28.67 (32.34)	18.33 (25.19)	30.00 (33.23)
Paclobutrazol 10.0 g once	16.00 (23.52)	25.00 (30.00)	18.33 (25.30)	26.67 (30.78)
Paclobutrazol 10.0 g twice	--	20.67 (26.92)	16.67 (23.85)	28.33 (32.01)
Cycocel 4000 ppm once	43.00 (40.97)	43.33 (41.16)	21.67 (27.71)	31.67 (34.15)
Cycocel 4000 ppm twice	--	38.33 (38.24)	20.00 (25.37)	30.00 (33.16)
Cycocel 8000 ppm once	38.33 (38.25)	36.67 (37.26)	20.00 (25.83)	28.33 (31.93)
Cycocel 8000 ppm twice	--	31.67 (34.23)	20.00 (26.26)	26.67 (30.67)
Alar 1500 ppm once	44.67 (41.93)	45.00 (42.11)	28.33 (32.09)	35.00 (36.23)
Alar 1500 ppm twice	--	41.67 (40.20)	20.00 (26.26)	31.67 (34.02)
Alar 3000 ppm once	34.67 (36.06)	40.00 (39.21)	20.00 (26.15)	26.67 (31.07)
Alar 3000 ppm twice	--	34.33 (35.85)	18.33 (25.30)	23.33 (28.67)
F - Test (Transformed values	**	**	NS	NS
C.D. 5% are given within	2.36	4.15	-	-
C.D. 1% parentheses)	3.27	5.60	-	-
S.Em±	0.78	1.43	3.27	3.05
CV%	3.67	6.80	20.83	16.21

flushing the trees under different growth retardant treatments had almost the same extent of vegetative flushing as control.

4.3.2. Diameter at the base of the flush

The growth retardant treatments reduced basal diameter of flushes compared to control value of 0.883 cm. During 1987 January-February, the reduction was highly significant in the case of all concentrations of paclobutrazol and 4000 ppm cycocel treatment and was significant for the remaining treatments. The minimum girth was recorded for paclobutrazol 10.0 g/plant (0.497 cm). The differences between different levels of paclobutrazol were not significant.

During 1987 March-April, all treatments except Alar 1500 ppm sprayed once produced highly significant reduction in the diameter at the base of the flush, the maximum effect being produced by paclobutrazol 10.0 g applied twice (0.333 cm), which was on par with all treatments other than Alar levels and control (0.640 cm).

During 1988 January-February, all paclobutrazol treatments and cycocel 4000 ppm sprayed twice caused a highly significant reduction in the basal diameter of the flush and all these treatments were on par. The basal diameter of the flush was only 0.427 cm in the case of trees

treated with 10.0 g paclobutrazol twice, as against 0.763 cm in the case of control.

Highly significant reduction in the basal girth of the flush compared to control (0.957 cm) was observed during 1988 March-April also for all treatments except Alar 1500 ppm sprayed once. The different treatments of individual chemicals were on par but paclobutrazol treatments caused more reduction compared to cycocel and Alar (Table 3.2).

4.3.3. Length of the flush

During 1987 January-February, all treatments caused highly significant reduction in the length of the flush compared to control (25.64 cm), the most effective treatment being paclobutrazol 10.0 g per tree (3.88 cm). The differeneces between the different levels of individual chemicals were significant at five per cent level except in the case of two lower concentrations of paclobutrazol.

The reduction in the length of the flush compared to control (20.17 cm) was highly significant during March-April of 1987 for all treatments except cycocel 4000 ppm and Alar 1500 ppm sprayed once, the reduction caused by former being significant and the latter being on par with control. At one per cent level of significance, there was no difference between number of applications for each individual concen-

Table 3.2. Influence of growth retardant treatments on basal girth and length of flushes in mango Cv. Alphonso

Treatment	Diameter at the base of the flush (cm)				Length of the flush (cm)			
	JAN-FEB 1987	MAR-APR 1987	JAN-FEB 1988	MAR-APR 1988	JAN-FEB 1987	MAR-APR 1987	JAN-FEB 1988	MAR-APR 1988
Control	0.883	0.640	0.763	0.957	25.44	20.17	25.47	30.13
Paclobutrazol 2.5 g once	0.567	0.400	0.433	0.510	8.67	9.03	10.70	12.80
Paclobutrazol 2.5 g twice	-	0.350	0.517	0.527	-	5.95	8.93	12.40
Paclobutrazol 5.0 g once	0.573	0.383	0.507	0.527	8.09	7.17	9.53	12.53
Paclobutrazol 5.0 g twice	-	0.370	0.450	0.513	-	4.57	7.93	11.47
Paclobutrazol 10.0 g once	0.497	0.370	0.443	0.440	3.88	3.72	4.77	6.50
Paclobutrazol 10.0 g twice	-	0.333	0.427	0.443	-	1.23	3.50	4.03
Cycocel 4000 ppm once	0.647	0.470	0.637	0.780	14.00	14.73	17.90	24.60
Cycocel 4000 ppm twice	-	0.420	0.593	0.770	-	10.02	16.10	24.50
Cycocel 8000 ppm once	0.720	0.433	0.710	0.703	10.64	12.68	16.43	22.50
Cycocel 8000 ppm twice	-	0.447	0.603	0.710	-	10.03	15.40	22.13
Alar 1500 ppm once	0.680	0.633	0.677	0.850	18.19	22.50	20.77	26.93
Alar 1500 ppm twice	-	0.510	0.603	0.787	-	17.86	17.80	23.77
Alar 3000 ppm once	0.697	0.480	0.713	0.767	13.95	17.85	19.47	21.33
Alar 3000 ppm twice	-	0.463	0.710	0.730	-	12.50	18.87	19.53
F - Test	**	**	**	**	**	**	**	**
C.D. 5%	0.149	0.091	0.124	0.115	3.31	4.31	5.06	4.39
C.D. 1%	0.206	0.123	0.167	0.155	4.59	5.81	6.83	5.92
S.Em±	0.049	0.032	0.043	0.040	1.09	1.49	1.75	1.51
C.V. %	12.884	12.230	12.660	10.300	14.66	22.73	21.26	14.30

tration of the chemical. Among paclobutrazol treatments, the chemical at 10.0 g per tree applied twice recorded lesser length of the flush (1.23 cm) than when applied at 2.5 g per tree once and all others were on par. The differences between different cycocel treatments were significant at one per cent level of significance. Same was the case with Alar treatments but for the lower concentration applied once.

In the case of 1988 January-February flushing, all levels of paclobutrazol and cycocel caused highly significant reduction in this character. Significant reduction was produced by Alar treatments except 1500 ppm sprayed once. Other trends were same as in the case of previous flushing except that all Alar treatments were on par with each other. Paclobutrazol 10.0 g per tree applied twice registered only 3.50 cm length of flush as against 25.47 cm in the case of control.

All levels of paclobutrazol, cycocel at 8000 ppm sprayed either once or twice and Alar treatments except 1500 ppm sprayed once recorded lesser lengths for flushes produced during 1988 March-April also, compared to control. Paclobutrazol at 10.0 g per plant applied either once or twice were on par with each other and the latter caused highly significant reduction compared to all other paclobu-

trazol treatments and the former compared to other paclobutrazol treatments except 5.0 g per tree applied twice (Table 3.2).

It was also obvious from this table that the effectiveness of chemicals decreased gradually with successive flushings. For example, in the case of 2.5 g paclobutrazol per tree, the lengths of the four subsequent flushes were 8.67, 9.03, 10.70 and 12.80 cm respectively.

4.3.4. Number of nodes per flush

Paclobutrazol at all the three concentrations as well as Alar at 1500 ppm caused highly significant reduction in the number of nodes per flush during 1987 January-February and the other treatments were on par with the control (23.45). The miminum number of nodes (13.63) was recorded on trees receiving paclobutrazol at 10.0 g which was on par with other paclobutrazol treatments, but less than that on Alar 1500 ppm treatment at one per cent level of significance.

In the case of 1987 March-April flushing, highly significant reduction in number of nodes was caused by all concentrations of paclobutrazol applied twice, cycocel 8000 ppm sprayed once and Alar 3000 ppm sprayed twice, compared to control (14.22) and all these treatments were on par with each other. Significant reductions were brought

about by remaining treatments except single application of 4000 ppm cycocel and single or double applications of 1500 ppm Alar. The least number of nodes (8.73) was observed when trees were given 1500 ppm Alar twice.

Highly significant reduction in number of nodes per flush compared to control during 1988 January-February flushing was noted only in the case of paclobutrazol 10.0 g per tree applied once, but significant reductions were effected by paclobutrazol 2.5 g once, 5.0 g twice and 10.0 g once also and all these treatments were on par with each other.

Significant and statistically equal reductions in this character during the next flushing was observed for all paclobutrazol treatments as well as cycocel 4000 ppm sprayed once (Table 3.3).

4.3.5. Mean internodal length of flushes

During the first flushing after the imposition of treatments all treatments except 1500 ppm Alar brought about a highly significant reduction in mean internodal length of the flushes compared to control (1.09 cm). Trees receiving 10.0 g paclobutrazol registered the least internodal length (0.28 cm) as compared to all other treatments and the other effective treatments were on par with each other at one per cent level of significance.

In the case of the subsequent flushing, all paclobutrazol treatments resulted in highly significant reduction in internodal length in comparision with the control length of 1.47 cm. The most effective treatment, paclobutrazol 10.0 g per tree applied twice, registered only 0.14 cm internodal length which was lower than other paclobutrazol treatments except that at 5.0 g applied twice and 10.0 g applied once, but others were on par with each other. Significant reduction in this character was produced by cycocel at 8000 ppm when applied twice.

Highly significant reduction in internodal length during 1988 January-February flushing was brought about by all paclobutrazol treatments and 1500 ppm Alar sprayed twice which were on par. Significantly and statistically equal reductions were also effected by single spraying of 3000 ppm Alar and cycocel treatments other than at 4000 ppm given only once. The internodal length was only 0.25 cm in the case of trees which were given two applications of 10.0 g paclobutazol as against 1.46 cm in control trees.

All paclobutrazol treatments resulted in highly significant reductions and Alar 3000 ppm sprayed once resulted in significant reduction in internodal length during 1988 March-April flushing compared to control (1.84 cm). Among the paclobutrazol treatments, 10.0 g

applied twice recorded less internodal length of 0.38 cm than other treatment except the same concentration applied only once and the others were on par with each other (Table 3.3).

A critical study of this table also revealed that the effectiveness of growth retardants, particularly that of Alar and cycocel in controlling the vegetative growth decreased with time. For example, in the case of 4000 ppm cycocel treatment, the internodal lengths were 0.70, 1.13, 1.14 and 1.87 in the four successive flushing after treatment.

4.3.6. Number of leaves per flush

Compared to control (21.89), paclobutrazol and cycocel treatments at various concentrations resulted in highly significant reductions and Alar at 1500 ppm caused significant reduction in number of leaves per flush during Jarnuary-February, 1987. The differences between different concentrations of individual chemicals in this respect were not significant, but number of leaves per flush on trees receiving 10.0 g paclobutrazol (11.88) was lower than that on trees receiving cycocel and Alar treatments. Other treatnments which reduced leaf number were on par with each other at one per cent level.

Table 3.3 Influence of growth retardant treatments on the number of nodes per flush and mean internodal length of flush in mango Cv. Alphonso

Treatment	No.of nodes/flush				Mean internodal length of flush			
	JAN-FEB 1987	MAR-APR 1987	JAN-FEB 1988	MAR-APR 1988	JAN-FEB 1987	MAR-APR 1987	JAN-FEB 1988	MAR-APR 1988
Control	23.45	14.22	17.47	16.80	1.09	1.47	1.46	1.84
Paclobutrazol 2.5 g once	16.61	9.93	13.93	11.73	0.52	0.91	0.77	1.09
Paclobutrazol 2.5 g twice	-	8.35	14.80	12.87	-	0.71	0.61	0.97
Paclobutrazol 5.0 g once	16.34	10.27	14.93	12.07	0.51	0.70	0.65	1.04
Paclobutrazol 5.0 g twice	-	9.33	13.87	11.73	-	0.49	0.57	0.98
Paclobutrazol 10.0 g once	13.63	9.80	13.07	11.13	0.28	0.38	0.37	0.59
Paclobutrazol 10.0 g twice	-	8.87	14.00	10.80	-	0.14	0.25	0.38
Cycocel 4000 ppm once	20.11	13.10	15.80	13.20	0.70	1.13	1.14	1.87
Cycocel 4000 ppm twice	-	9.68	16.27	13.33	-	1.11	1.01	1.87
Cycocel 8000 ppm once	22.50	9.58	15.93	15.73	0.47	1.44	1.03	1.43
Cycocel 8000 ppm twice	-	11.03	16.27	14.27	-	0.93	0.96	1.64
Alar 1500 ppm once	18.44	14.71	18.53	14.40	0.99	1.54	1.13	1.93
Alar 1500 ppm twice	-	13.17	15.40	13.47	-	1.37	1.16	1.78
Alar 3000 ppm once	20.78	11.27	19.07	15.40	0.68	1.59	1.02	1.39
Alar 3000 ppm twice	-	8.73	18.00	11.20	-	1.47	0.70	1.87
F - Test	**	**	**	*	**	**	**	**
C.D. 5%	3.36	3.42	2.70	3.49	0.15	0.41	0.40	0.43
C.D. 1%	4.66	4.61	3.64	-	0.21	0.55	0.54	0.58
S.Em±	1.11	1.18	0.93	1.12	0.05	0.14	0.14	0.15
C.V. %	10.09	18.91	10.21	15.82	13.35	24.19	18.04	18.69

Though all treatments except one spraying of 1500 ppm Alar tended to decrease the number of leaves in the case of 1987 March-Apirl flushings, the differences were not significant. The minimum number of leaves per flush (6.93) was recorded for single application of 5.0 g paclobutrazol per tree whereas on control trees, it was 10.97.

During the first flushing of 1988, single application of paclobutrazol at 2.5 or 5.0 g per tree led to a highly significant reduction in number of leaves per flush while other paclobutrazol treatments except double application of 2.5 g per tree brought about significant reductions. The treatments which caused this response were on par with each other and the minimum number of leaves was noted in the case of 2.5 g paclobutrazol applied once.

Significantly, lower leaf numbers per flush compared to control were observed during 1988 March-April on trees receiving treatments other than single spray of 8000 ppm cycocel as well as single spray of Alar at both concentrations. Untreated trees produced 14.4 leaves per flush while those which were given two soil drenchings of paclobutrazol at 10.0 g per tree produced only 7.53 (Table 3.4).

Since almost similar trends were observed in the case of number of nodes per flush also, it is likely that the reduction in leaf number brought about by the growth retardant treatments is due to reduction in the number of nodes.

4.3.7. Leaf area per flush

Highly significant reduction in leaf area per flush in 1987 March-April was caused by 10.0 g paclobutrazol applied either once or twice and 8000 ppm cycocel applied twice, compared to trees kept untreated which had a leaf area of 706.29 cm^2 per flush. These three treatments were on par with each other. Cycocel at 8000 ppm applied once also resulted in significantly lower leaf area per flush than control. The minimum leaf area of 507.79 cm^2 per flush was recorded in the case of paclobutrazol 10.0 g per tree applied twice (Table 3.4).

4.3.8. Stomatal density

None of the treatments tried influenced the number of stomata per 10 x 10 x microscopic field on leaves of 1987 March-April flushes to a significant level. However the growth retardants showed a general tendency to increase the stomatal number per microscopic field, particularly at higher concentrations.

4.3.9. Time of flowering

Early flowering was brought about by the growth retardant treatments. This data was not subjected to any statistical analysis. In the first year flowering on control trees was restricted to the fourth week of January.

Table 3.4 Influence of growth retardant treatments on the number of leaves and leaf area per flush and stomatal frequency

Treatments	Number of leaves per flush				Leaf area per flush of MAR-APR,1987 cm^2	No.of stomata per 10x10x field in MAR-APR.1987 flush
	JAN-FEB 1987	MAR-APR 1987	JAN-FEB 1988	MAR-APR 1988		
Control	21.89	10.97	13.20	14.40	706.29	8.52
Paclobutrazol 2.5 g once	14.39	7.67	10.60	9.07	701.81	9.27
Paclobutrazol 2.5 g twice	-	7.43	12.00	9.73	698.18	10.45
Paclobutrazol 5.0 g once	13.97	6.93	10.47	10.00	668.71	9.53
Paclobutrazol 5.0 g twice	-	7.20	11.20	9.33	649.60	12.13
Paclobutrazol 10.0 g once	11.88	7.55	10.87	8.33	542.19	9.97
Paclobutrazol 10.0 g twice	-	7.12	10.87	7.53	507.79	11.90
Cycocel 4000 ppm once	16.12	9.70	13.07	10.07	703.17	8.40
Cycocel 4000 ppm twice	-	7.38	13.60	11.13	668.01	8.67
Cycocel 8000 ppm once	16.05	7.33	12.87	12.20	633.63	10.07
Cycocel 8000 ppm twice	-	8.47	11.93	11.00	581.40	10.68
Alar 1500 ppm once	17.83	11.31	15.73	11.40	707.85	8.38
Alar 1500 ppm twice	-	10.67	12.73	9.87	696.91	8.65
Alar 3000 ppm once	18.89	7.63	16.07	12.47	676.43	9.23
Alar 3000 ppm twice	-	7.80	14.93	9.73	653.19	9.50
F - Test	**	NS	**	*	**	NS
C.D. 5%	3.00	-	1.86	3.23	69.38	-
C.D. 1%	4.16	-	2.53	-	93.60	-
S.Em±	0.99	1.12	0.65	1.12	23.95	0.86
C.V. %	10.44	23.28	8.85	18.55	6.35	15.38

In Alar treated trees flowering occurred in the third week of January and in cycocel treated trees flowering spread from middle of second week to middle of third week. The trees receiving lowest concentration of paclobutrazol flowered in the second week of the month. In the case of trees which were given the two higher doses of paclobutrazol flowering was over by the first week of January and some of these trees started to bloom in the last week of December itself.

In the second year, the two higher concentrations of paclobutrazol brought about flowering by third week of January itself while on other trees blooming was mainly during last week of the month.

4.3.10. Extent of flowering

All the three concentrations of paclobutrazol tried brought about highly significant increases in the percentage of shoots flowered during 1986-87 when compared to control (62.00%). The maximum flowering (89.33%) was on trees which were given soil drenching with 10.0 g paclobutrazol and this was even higher than the extent of flowering in trees given soil drenching with 2.5 g per tree.

In 1987-88, highly significant increases in the extent of flowering resulted from double application of

10.0 g paclobutrazol per tree (81.67%) in comparison with control (60.00%). Other paclobutrazol treatments except single application of 2.5 g per tree also brought about significant increase in this respect. All these effective treatments were on par with each other in statistical terms.

4.3.11. Length of the panicle

In the first year after application, highly significant reductions in the length of the panicle were brought about by all treatments. The differences between various concentrations of individual chemicals were also significant in the case of paclobutrazol and cycocel. The least length of 18.17 cm was recorded on trees which received 10.0 g paclobutrazol as against the control value of 41.75 cm.

Except single application of Alar at 1500 or 3000 ppm, all other treatments resulted in shorter panicles during 1987-88 also, the reductions being highly significant from control. For any given concentration of the chemicals, there was no significant difference between number of times it was applied. But there was highly significant difference between different treatments of paclobutrazol. The length of the panicle was only 17.00 cm in the case of 10.0 g paclobutrazol applied two times as against 41.75 cm in the case of check.

4.3.12. Number of primaries per panicle

In 1986-87, all treatments except 4000 ppm cycocel resulted in highly significant increases in the number of primaries per panicle compared to control and were on par with each other. A maximum of 55.0 primary branches were produced on trees treated with 3000 ppm Alar whereas on untreated trees it was only 46.71.

During the second year, the trend was, however just the reverse in comparision with control (53.67), a highly significant reduction in the number of primaries per panicle was brought about by paclobutrazol 2.5 g applied once, 5.0 g applied once or twice, cycocel 4000 ppm applied once and 8000 ppm applied once or twice and Alar 3000 ppm applied twice. Significant reduction in this character was effected by double applications of 2.5 g paclobutrazol or 4000 ppm cycocel as well as single application of 3000 ppm Alar. These reductions were on par with each other. Single application of paclobutrazol at 2.5 g per tree resulted in the minimum number of primary branches, 41.75 (Table 3.5).

4.3.13. Mean internodal length of the panicle

In the flowering season immediately following the first application of growth regulators, the mean internodal

Table 3.5. Influence of growth retardant treatments on the percentage of shoots flowered, length of the panicle and number of primaries per panicle in mango Cv. Alphonso

Treatment	Percentage of shoots flowered		Length of the panicle (cm)		No.of primaries per panicle	
	1986-87	1987-88	1986-87	1987-88	1986-87	1987-88
Control	62.00	60.00 (50.79)	39.14	41.75	46.71	53.67
Paclobutrazol 2.5 g once	76.00	65.00 (53.76)	27.63	26.84	52.92	41.75
Paclobutrazol 2.5 g twice	-	75.00 (60.08)	-	28.79	-	45.92
Paclobutrazol 5.0 g once	77.33	75.00 (60.07)	24.07	26.46	52.25	42.00
Paclobutrazol 5.0 g twice	-	80.00 (63.85)	-	22.84	-	44.42
Paclobutrazol 10.0 g once	89.33	76.67 (61.22)	18.17	18.63	54.67	51.75
Paclobutrazol 10.0 g twice	-	81.67 (64.70)	-	17.00	-	51.42
Cycocel 4000 ppm once	69.33	58.33 (49.92)	32.33	31.54	49.50	44.33
Cycocel 4000 ppm twice	-	63.33 (53.39)	-	32.04	-	47.17
Cycocel 8000 ppm once	73.33	56.67 (48.87)	27.67	31.29	52.58	43.92
Cycocel 8000 ppm twice	-	58.33 (50.00)	-	31.96	-	43.50
Alar 1500 ppm once	68.00	50.00 (45.03)	31.38	38.41	51.58	53.58
Alar 1500 ppm twice	-	60.00 (50.79)	-	36.08	-	48.92
Alar 3000 ppm once	71.33	50.00 (45.33)	32.84	38.63	55.00	46.58
Alar 3000 ppm twice	-	48.33 (44.04)	-	35.84	-	44.75
F - Test	*	**	**	**	**	**
C.D. 5%	12.53	9.01	1.82	3.70	3.83	5.85
C.D. 1%	-	13.24	2.52	5.00	5.31	7.90
S.Em±	4.13	3.39	0.60	1.28	1.26	2.02
C.V. %	9.75	10.98	3.56	7.25	4.21	7.46

(Transformed values are given within parentheses)

length of panicles was reduced to a highly significant level by all treatments compared to trees left untreated (0.839 cm). Paclobutrazol when applied at 10.0 g per tree produced the panicles with least internodal length (0.342cm). The differences between individual concentrations of paclobutrazol and Alar were highly significant. The higher concentrations of Alar and cycocel were on par with the lower concentration of paclobutrazol in this respect.

During 1987-88, there was a highly significant reduction in the internodal length of the panicle in the case of all treatments of paclobutrazol compared to control and significant reduction was observed in the case of cycocel 4000 ppm sprayed twice. Paclobutrazol at 2.5 g per tree given once or twice and 5.0 g per tree given once as well as the cycocel treatments were on par but other effective treatments differed at one per cent level. The internodal length of the panicle was as low as 0.33 cm in the case of double application of paclobutrazol as against 0.779 cm in the control (Table 3.6).

4.3.14. Spread of the panicle

In 1986-87, panicle spread was reduced to a highly significant level by 10.0 g paclobutrazol treatment (19.67 cm) compared to control (27.06 cm) and to a signifi-

Table 3.6. Influence of growth retardant treatments on mean internodal length, spread and length to spread ratio of panicles in mango Cv. Alphonso

Treatment	Mean internodal length of the panicle (cm)		Spread of the panicle at broadest point (cm)		Length to spread ratio of the panicles	
	1986-87	1987-88	1986-87	1987-88	1986-87	1987-88
Control	0.839	0.779	27.06	24.98	1.45 (6.80)	1.73 (7.41)
Paclobutrazol 2.5 g once	0.570	0.645	27.42	18.88	1.01 (5.68)	1.43 (6.78)
Paclobutrazol 2.5 g twice	-	0.629	-	19.92	-	1.44 (6.72)
Paclobutrazol 5.0 g once	0.513	0.634	22.29	16.59	1.08 (5.81)	1.68 (7.27)
Paclobutrazol 5.0 g twice	-	0.514	-	17.33	-	1.31 (6.46)
Paclobutrazol 10.0 g once	0.342	0.360	19.67	17.21	0.92 (5.50)	1.08 (5.74)
Paclobutrazol 10.0 g twice	-	0.330	-	15.21	-	1.12 (5.92)
Cycocel 4000 ppm once	0.641	0.712	26.88	24.67	1.21 (6.20)	1.28 (6.39)
Cycocel 4000 ppm twice	-	0.684	-	21.04	-	1.35 (6.95)
Cycocel 8000 ppm once	0.613	0.713	22.80	21.96	1.24 (6.28)	1.43 (6.80)
Cycocel 8000 ppm twice	-	0.736	-	21.42	-	1.49 (6.88)
Alar 1500 ppm once	0.659	0.717	25.75	26.00	1.22 (6.20)	1.48 (6.87)
Alar 1500 ppm twice	-	0.740	-	23.63	-	1.53 (7.04)
Alar 3000 ppm once	0.610	0.792	23.83	26.00	1.38 (6.63)	1.49 (6.88)
Alar 3000 ppm twice	-	0.803	-	25.38	-	1.42 (6.71)
F - Test	**	**	**	**	**	**
C.D. 5%	0.033	0.075	3.54	2.81	0.45	0.76
C.D. 1%	0.046	0.101	4.91	3.79	0.63	1.02
S.Em±	0.011	0.026	1.17	0.97	0.15	0.26
C.V. %	3.150	6.886	8.25	7.89	4.21	6.76

(Transformed values are given within parentheses)

cant level by 5.0 g paclobutrazol and 8000 ppm cycocel treatments and these three were on par with each other.

In the following year, highly significant reductions in inflorescence spread was observed on trees which received various paclobutrazol treatments and double spraying of 4000 ppm cycocel. Spraying cycocel at 8000 ppm either once or twice brought about significant reductions. There were significant differences between different paclobutrazol treatments also in this regard. Control trees recorded 24.98 cm spread for their panicles whereas on trees which were given double application of 10.0 g paclobutrazol, it was as low as 15.21 cm (Table 3.6).

4.3.15. Length to spread ratio of the panicle

Statiatically equal and highly significant reductions in length: spread ratio of the panical resulted from all three paclobutrazol treatment and equal significant reductions from all others except 3000 ppm Alar, during 1986-87. In the case of control it was 1.45 and in the case of paclobutrazol 10.0 g treatments, it was only 0.92.

In the next year, this ratio was lower than control (1.73) at one per cent level in the case of double and single applications of paclobutrazol at 10.0 g per tree and at five per cent level in the case of double application

of 5.0 paclobutrazol and single spraying of 4000 ppm cycocel. These reductions were on par.

4.3.16. Sex ratio

The ratio of male to hermaphrodite flowers was lowered by 10.0 g paclobutrazol treatment(3.49) in the first year and this was evident at one per cent level of significance compared to control (6.31). At five per cent level, 8000 ppm cycocel lowered this ratio. Other concentrations of these two chemicals also tended to lower the ratio, but the differences were not significant (Table 3.7).

During 1987-88, 5.0 and 10.0 g paclobutrazol per tree applied either once or twice, 4000 and 8000 ppm cycocel applied twice and 3000 ppm Alar applied once or twice, all caused a highly significant decline in sex ratio and the differences between some of them were also highly significant. In this regard, the most effective treatment was double application of 5.0 g paclobutrazol which brought down the ratio to 3.07 from 7.02 in control. Double applications of 2.5 g paclobutrazol and single applications of both concentrations of cycocel also effected significant and equal fall in this ratio. A lesser sex ratio implicates an increased proportion of bisexual flowers.

Table 3.7. Influence of growth retardant treatments on the sex ratio (male:hermaphrodite) and pollen fertility in mango Cv. Alphonso

Treatment	Sex ratio (Male/hermapnrodite		Pollen fertility (%age)	
	1986-87	1987-88	1986-87	1987-88
Control	6.31 (14.50)	7.02 (15.38)	96.19 (77.78)	97.13 (80.45)
Paclobutrazol 2.5 g once	6.17 (14.38)	5.98 (14.06)	93.67 (75.38)	94.66 (76.60)
Paclobutrazol 2.5 g twice	-	5.38 (13.35)	-	92.62 (74.19)
Paclobutrazol 5.0 g once	5.79 (13.85)	4.52 (12.33)	86.32 (68.30)	89.18 (70.83)
Paclobutrazol 5.0 g twice	-	3.07 (10.01)	-	87.89 (69.64)
Paclobutrazol 10.0 g once	3.49 (10.67)	3.31 (10.38)	74.69 (59.76)	80.32 (63.67)
Paclobutrazol 10.0 g twice	-	3.39 (10.44)	-	77.47 (61.68)
Cycocel 4000 ppm once	6.09 (14.22)	5.53 (13.52)	94.56 (76.47)	96.00 (78.52)
Cycocel 4000 ppm twice	-	4.94 (12.83)	-	95.18 (77.18)
Cycocel 8000 ppm once	5.60 (13.65)	5.38 (13.48)	90.33 (71.90)	93.89 (75.53)
Cycocel 8000 ppm twice	-	4.36 (11.97)	-	92.28 (73.88)
Alar 1500 ppm once	6.93 (15.19)	7.60 (15.96)	95.33 (77.54)	97.00 (80.12)
Alar 1500 ppm twice	-	6.91 (15.22)	-	95.20 (77.30)
Alar 3000 ppm once	6.34 (14.49)	5.14 (13.09)	87.21 (69.05)	94.67 (76.56)
Alar 3000 ppm twice	-	4.83 (12.75)	-	90.08 (71.62)
F - Test	**	**	**	**
C.D. 5%	0.77	1.60	3.18	2.77
C.D. 1%	1.06	2.15	4.42	3.74
S.Em±	0.25	0.55	1.05	0.96
C.V. %	3.16	7.36	2.52	2.24

(Transformed values are given within parentheses)

4.3.17. Pollen fertility

Percentage of fertile pollen was brought down to a high level of significance by higher concentrations of all the three chemicals during 1986-87. The two lower concentrations of paclobutrazol caused a significant reduction. The differences between various levels of paclobutrazol were highly significant. Lowest percentage of 74.67 resulted from 10.0 g paclobutrazol treatment and this value was lower than that for all other treatments as well as control (96.19%) at one per cent level of significance.

All paclobutrazol treatments, 8000 ppm cycocel applied once or twice and 3000 ppm Alar sprayed twice resulted in highly significant fall in pollen fertility in the second year of treatment also. Double applications of lower levels of cycocel and Alar brought about significant drops at the same time. The differences between number of times any given concentration was applied were not significant except in the case of 3000 ppm. Alar, but there were significant differences between most of the treatments. Minimum pollen fertility of 77.47 per cent was recorded in the case of double application of 10.0 g paclobutrazol. In untreated trees it was as high as 97.13 per cent (Table 3.7).

4.3.18. Number of fruits per panicle at pea stage

Highly significant increases in the number of fruits per panicle at pea stage of 1986-87 flowering season was effected by the two lower concentrations of paclobutrazol as well as cycocel treatments. Except the two levels of cycocel, the other treatments differed each other in this respect. At the pea stage, a maximum number of 9.38 fruits per panicle resulted from drenching the trees with 2.5 g paclobutrazol but in the case of control it was only 4.99.

All the paclobutrazol treatments were effective in increasing the fruit number per panicle at this stage in 1987-88 also and the increment over control (4.09) was highly significant. The most effective treatment was 2.5 g paclobutrazol applied twice (8.58) followed by the same concentration applied once (7.42) which were on par with one another but were superior to other four paclobutrazol treatments which in turn were on par with each other. Other treatments except higher concentration of Alar irrespective of number of times it was sprayed tended to reduce fruit set as was evident at this stage, but the reduction was insignificant (Table 3.8).

Table 3.8. Influence of growth retardant treatments on number of fruits per panicle at pea stage, marble stage and at harvest in mango Cv. Alphonso

Treatment	Number of fruits/panicle at					
	Pea stage		Marble stage		Harvest	
	1986-87	1987-88	1986-87	1987-88	1986-87	1987-88
Control	4.99	4.09	1.36	1.13	0.572	0.487
Paclobutrazol 2.5 g once	9.38	7.42	4.92	4.25	1.292	1.070
Paclobutrazol 2.5 g twice	-	8.58	-	4.33	-	1.127
Paclobutrazol 5.0 g once	7.69	6.75	3.36	3.08	0.757	0.747
Paclobutrazol 5.0 g twice	-	6.58	-	3.58	-	0.649
Paclobutrazol 10.0 g once	5.35	6.00	2.40	2.83	0.474	0.466
Paclobutrazol 10.0 g twice	-	5.92	-	2.92	-	0.407
Cycocel 4000 ppm once	5.98	3.83	1.44	1.25	0.563	0.458
Cycocel 4000 ppm twice	-	3.83	-	1.17	-	0.480
Cycocel 8000 ppm once	5.96	3.75	1.52	1.17	0.617	0.488
Cycocel 8000 ppm twice	-	3.83	-	1.25	-	0.517
Alar 1500 ppm once	4.92	3.67	1.88	1.67	0.767	0.511
alar 1500 ppm twice	-	3.75	-	1.58	-	0.540
Alar 3000 ppm once	5.12	4.33	2.17	1.42	0.692	0.627
Alar 3000 ppm twice	-	4.58	-	1.67	-	0.625
F - Test	**	**	**	**	**	**
C.D. 5%	0.49	0.95	0.64	0.46	0.167	0.147
C.D. 1%	0.68	1.28	0.88	0.62	0.232	0.199
S.Em±	0.16	0.33	0.21	0.16	0.055	0.051
C.V. %	4.51	11.07	15.26	12.29	13.506	14.353

4.3.19. Number of fruits per panicle at marble stage

At marble stage of fruits, more fruits were present on the panicle of the trees which wer given paclobutrazol treatments than those on control which retained only 1.36 per panicle, in the first year of treatment. The differences between paclobutrazol treatments were highly significant, as was with the case between control and any of these three. The treatment which produced the best result was 2.5 g of the chemical which recorded 4.92 fruits of marble size per panicle. Alar 3000 ppm spray also was helpful in making a signficant increase in fruit number per panicle at this stage.

In the succeeding year also, all paclobutrazol treatments caused highly significant enhancements in and all Alar treatments other than single spraying of 3000 ppm caused significant enchancements in number of fruits per panicle at marble stage. As in the previous year, best results were produced by the lowest concentration of paclobutrazol when applied either twice (4.33 fruits/panicle) or once (4.25 fruits per panicle) which were on par, but superior to all other treatments at one per cent level. Trees without any treatment recorded 1.13 fruits per panicle at this stage (Table 3.8).

4.3.20. Number of fruits per panicle at harvest

At the time of harvest in the first year, maximum number of fruits per panicle (1.292) was present on trees which recieved soil drenching with 2.5 g paclobutrazol whereas untreated trees produced only 0.572 fruits per panicle, thus difference being highly significant. Next best treatment in this respect was soil drenching with 5.0 g paclobutrazol which recorded significantly higher number (0.757 fruits/panicle) than control.

At the correcponding time in the next season also highly signficant increments in the number of fruits per panicle over control (0.487) resulted from 2.5 g paclobutrazol given once or twice and 5.0 g given once. The most effective treatments were 2.5 g of the chemical applied twice (1.127 fruits/panicle) or once (1.07 fruits/panicle) which were on par but both of them were superior to 5.0 g treatment given once. Significantly higher number of fruits compared to control were retained per panicle at the time of harvest by double application of 5.0 g paclobutrazol per tree.

In both seasons, higher concentration of Alar showed a strong but non-significant tendency to promote the number of fruits per panicle at harvest (Table 3.8).

4.3.21. Fruit retention

None of the treatments affected significantly the percentage of fruits at pea stage carried to maturity per panicle, in comparison with control (11.62%) in 1986-1987. The maximum fruit retention was noticed in the case of 2.5 g paclobutrazol and 1500 ppm Alar treatments Compared to these two, 4000 ppm cycocel 10.0 g paclobutrazol treatments registered lower fruit retention values at one per cent level of significance.

Highly significant and significant reductions in the retention of fruits per panicle compared to control (12.17%) were caused by paclobutrazol at 10.0 g per tree applied twice (6.89%) and once (7.77%) respectively in 1987-88. Other treatments did not differ from the control though most of them showed a trend towards the positive direction. The maximum value (14.56%) was in the case of trees given one foliar spray of 3000 Alar (Table 3.9).

4.3.22. Time of harvest

The fruits on trees treated with the higher levels of paclobutrazol took longer time to mature compared to those on other trees and were ready for harvest only after seven to ten days, in the first year. There were two rounds

of harvest at a gap of ten days. In control trees as well as Alar cycocel treated trees, majority of the fruits were ready for harvest at the time of first round itself and only very few fruits were left for the second round. In the case of trees treated with 2.5 g Paclobutrazol, almost equal proportions of fruits were harvested each time. In trees which were given 5.0 or 10.0 g paclobutrazol only few fruits were ready for harvest at the first round and almost all fruits could be harvested only in the second round. No such striking difference in maturity period was observed in the second year. However, no statistical analysis was employed for this data.

4.3.23. Fruit yield-number of fruits per tree

In both the years under study, number of fruits per tree was enhanced to a highly significant level by paclobutrazol treatments either at 2.5 or 5.0 g per tree applied once or twice. In the second year, these treatments did not differ among themselves in their effectiveness, but in the first year, number of fruits was higher for double drenching with paclobutrazol at 2.5 g per tree compared to other three, which were on par with each other. This was the best treatment in both the years giving 47.00 and 16.67 fruits per tree respectively, as against the respective control values of 21.67 and 8.00 fruits per tree. Number of fruits per tree was

comparatively higher for 3000 ppm Alar applied once or twice in both the years, but they did not differ significantly from the respective control values. The number of fruits per tree recorded low values in both the years for double application of 10.0 g paclobutrazol per tree, but this reduction from control was also not significant (Table 3.9).

4.3.24. Fruit yield - weight of fruits per tree

Two treatments -2.5 g paclobutrazol per tree applied either once or twice - brought about a highly significant enhancement in fruit yield in terms of weight per tree in 1986-87. These gave 8.23 and 9.5 kg per tree respectively against 4.88 kg by untreated trees. The two treatments were equally effective in statistical terms. Single or double applications of 5.0 g paclobutrazol were also effective in bringing about significant increases in this character. However, highly significant and significant reductions in weight of fruits per tree were brought about by double and single applications respectively of 10.0 g paclobutrazol per tree (2.68 and 3.41 kg per tree respectively).

During 1987-88, 2.5 or 5.0 g paclobutrazol per tree applied once or twice resulted in highly significant

Table 3.9. Influence of growth retardant treatments on fruit retention and yield in mango Cv. Alphonso

Treatment	Fruit retention (percentage)		Fruit yield/tree			
			No.of fruits per tree		Wt.of fruits(kg) per tree	
	1986-87	1987-88	1986-87	1987-88	1986-87	1987-88
Control	11.62 (19.83)	12.17 (20.19)	21.67	8.00	4.88	1.98
Paclobutrazol 2.5 g once	13.81 (21.73)	14.48 (22.31)	36.33	15.00	8.23	3.67
Paclobutrazol 2.5 g twice	-	13.40 (21.37)	47.00	16.67	9.50	3.88
Paclobutrazol 5.0 g once	9.90 (18.15)	11.04 (19.34)	32.67	14.53	6.39	3.61
Paclobutrazol 5.0 g twice	-	9.82 (18.21)	34.00	15.33	6.35	3.65
Paclobutrazol 10.0 g once	8.83 (17.12)	7.77 (16.03)	20.00	6.67	3.41	1.27
Paclobutrazol 10.0 g twice	-	6.89 (15.15)	16.67	3.33	2.68	0.55
Cycocel 4000 ppm once	9.38 (17.74)	11.99 (20.14)	20.00	6.67	4.75	1.79
Cycocel 4000 ppm twice	-	12.99 (20.86)	21.67	7.33	4.95	1.94
Cycocel 8000 ppm once	10.40 (18.68)	13.15 (21.23)	21.33	5.00	5.04	1.30
Cycocel 8000 ppm twice	-	13.60 (21.58)	22.00	8.67	5.10	2.27
Alar 1500 ppm once	13.78 (21.73)	14.01 (21.93)	21.00	8.67	5.08	2.22
Alar 1500 ppm twice	-	14.48 (22.31)	21.33	9.33	5.27	2.27
Alar 3000 ppm once	13.50 (21.51)	14.56 (22.37)	27.00	9.67	5.95	2.49
Alar 3000 ppm twice	-	14.33 (22.06)	28.00	10.67	6.17	2.69
F - Test	**	**	**	**	**	**
C.D. 5%	2.73	3.56	6.94	4.83	1.30	0.80
C.D. 1 %	3.79	4.80	9.37	6.52	1.76	1.08
S.Em±	0.90	1.23	2.40	1.67	0.45	0.28
C.V. %	7.96	10.45	15.94	29.83	13.94	20.12

(Transformed values are given within parentheses)

increases in fruit yield over control (1.98 kg/tree). Though the best treatment was double application of 2.5 g per tree, the other three effective treatments also produced comparable yields. This time also double application of 10.0 g paclobutrazol per tree resulted in a highly significant reduction in yield registering only 0.55 kg fruits per tree.

As in the case of number of fruits, weight of fruits per tree also tended to record higher values in the case of single and double applications of 3000 ppm Alar in both the seasons, but the increments were not significant compared to respective control values (Table 3.9).

4.3.25. Average fruit weight

In 1986-87, average weight of fruits on untreated trees was 219.5 g and compared to this, double application of 5.0 g paclobutrazol as well as single or double application of 10.0 g resulted in a highly significant reduction, the last one recording significantly lower weight (170.17 g) than the former two treatments also which were on par. The lower concentrations of cycocel and Alar exhibited a tendency to raise the average fruit weight, but the increments over control were not significant. The maximum fruit weight of 235.0 g resulted

from single spray of 4000 ppm cycocel followed by 233.83 g for single spray of Alar at 1500 ppm.

All paclobutrazol treatments except single application of the lowest concentration caused a highly significant drop in fruit weight compared to control (260.5 g) in the second year. The 10.0 g per tree treatment registered lower weight compared to others and the minimum value of 196.33 g was on trees which received two soil drenchings of this concentration and it differed at a high level of significance from other treatments except the same concentration given only once (Table 3.10).

4.3.26. Volume of fruit

The fruits on control trees had a volume of 207.17 cc in 1986-87 and compared to this, highly significant reductions were observed in the case of double and single applications of 10.0 g and double application of 5.0 g paclobutrazol, the first treatment recording significantly lower volume (159.33 cc) compared to the latter two too. Other treatments did not differ from the control though lower rates cycocel and Alar applications tended to increase the fruit volume (Table 3.10).

4.3.27. Specific gravity of fruits

Specific gravity of fruits was not affected significantly by the treatments. However there was a general tendency exhibited by paclobutrazol and cycocel treatments to slightly boost the specific gravity of fruits. The control value was 1.059 g/cc and in the case of 5.0 g paclobutrazol applied once, it was 1.074 g/cc (Table 3.10).

4.3.28. Weight of fruit skin

There were no significant differences among treatments with reference to the weight of fruit skin, though increasing concentrations of growth retardants, particularly paclobutrazol decreased skin weight progressively. A minimum value of 35.83 g per fruit was recorded for double application of paclobutrazol at 10.0 g as against 48.17 g per fruit in untreated trees (Table 3.10).

4.3.29. Weight of stone

Stone weight remained unaffected by various treatments tried in the experiment though increasingrates of paclobutrazol tended to progressively reduce the stone weight. In the case of 10.0 g paclobutrazol treatment given twice, weight of stone was only 28.50 g whereas in control it was 35.33 g (Table 3.10).

Table 3.10. Influence of growth retardant treatments on physical parameters of fruit in mango Cv. Alphonso

Treatment	Average fruit weight (g/fruit) 1986-87	Average fruit weight (g/fruit) 1987-88	Volume of fruit cc	Specific gravity of fruit g/cc	Skin weight g/fr	Stone weight g/fr	Pulp weight g/fr
Control	219.50	260.50	207.17	1.059	48.17	35.33	136.00
Paclobutrazol 2.5 g once	225.00	240.50	212.00	1.061	48.17	36.17	140.67
Paclobutrazol 2.5 g twice	222.17	229.00	209.00	1.073	46.33	35.94	139.89
Paclobutrazol 5.0 g once	213.83	230.67	199.17	1.074	43.17	35.50	135.17
Paclobutrazol 5.0 g twice	196.33	218.33	182.83	1.073	39.50	34.00	122.83
Paclobutrazol 10.0 g once	191.17	196.33	178.83	1.070	38.00	28.50	122.00
Paclobutrazol 10.0 g twice	170.17	181.17	159.33	1.068	35.83	27.83	106.50
Cycocel 4000 ppm once	235.00	259.83	223.83	1.050	50.17	36.33	148.67
Cycocel 4000 ppm twice	225.83	254.67	210.50	1.072	46.50	38.50	140.67
Cycocel 8000 ppm once	224.17	254.17	210.33	1.065	44.17	37.50	141.83
Cycocel 8000 ppm twice	210.83	249.67	198.67	1.062	44.83	37.00	129.00
Alar 1500 ppm once	233.83	250.17	221.83	1.054	52.33	36.67	144.83
Alar 1500 ppm twice	229.67	262.50	217.83	1.054	47.83	39.67	142.17
Alar 3000 ppm once	227.17	254.00	215.50	1.054	43.83	39.50	143.67
Alar 3000 ppm twice	218.50	246.50	207.67	1.052	44.00	34.83	139.50
F - Test	**	**	**	NS	NS	NS	NS
C.D. 5%	16.64	20.91	17.07	-	-	-	-
C.D. 1%	22.44	28.21	23.04	-	-	-	-
S.Em±	5.74	7.22	5.90	0.008	3.50	3.35	7.89
C.V. %	4.60	5.23	5.01	1.300	13.53	16.31	10.09

4.3.30. Weight of fruit pulp

Pulp weight also did not vary significantly as a result of the treatments tried in this experiment, but in this case also, the same trend as in the case of previous two characters was exhibited by paclobutrazol (Table 3.10).

4.3.31. Pulp : Stone + Skin ratio of fruits

The variations caused by the different treatments in this value were also not significant. However the growth retardant treatments except double application of 8000 ppm cycocel registered slightly higher values than control (1.630), the maximum being 1.805 in the case of double application of Alar 3000 ppm (Table 3.11).

4.3.32. Total soluble solids

Significantly lower values T.S.S. of fruits were noted in the case of double applications of 10.0 g paclobutrazol (15.02°B) and 3000 ppm Alar (14.93°B) compared to control value of 17.0°B and were on par with one another. Lowest concentration of paclobutrazol though showed a strong tendency to elevate the T.S.S. regardless of the number of applications, the increments over control were

non-significant. Compared to these two treatments, the earlier mentioned ones as well as single application of 10.0 g paclobutrazol registered low values at one per cent level of significance (Table 3.11).

4.3.33. Titrable acidity

Although higher rates of paclobutrazol treatment tended to increase the acidity of fruits expressed as maleic acid equivalent, none of the treatments influenced this character to a significant level. Its value was 0.322 per cent in the case of double application of 10.0 g paclobutrazol and 0.302 per cent in the case of untreated trees (Table 3.11).

4.3.34. T.S.S. : Acid ratio

The highest value for this ratio was recorded in the case of fruits from trees which were given soil drenching with 2.5 g paclobutrazol twice (62.34) or once (62.04). Compared to these two, significantly lower values were observed in the case of paclobutrazol at 5.0 g twice (51.60) and at 10.0 g once (48.66) or twice (46.59) as well as 3000 ppm Alar twice (50.26). But none of the treatments led to significant variations

Table 3.11. Influence of growth retardant treatments on pulp : stone+skin ratio, T.S.S., acidity and TSS: acidity ratio of fruits in mango Cv. Alphonso

Treatment	Pulp/ stone+skin ratio	T.S.S. °B	Titrable Acidity (% maleic acid equivalent)	T.S.S./acid ratio
Control	1.630 (7.193)	17.00	0.302	56.26 (48.56)
Paclobutrazol 2.5 g once	1.710 (7.383)	18.50	0.298	62.34 (52.15)
Paclobutrazol 2.5 g twice	1.704 (7.340)	18.50	0.300	62.03 (52.00)
Paclobutrazol 5.0 g once	1.767 (7.437)	17.00	0.304	56.04 (48.46)
Paclobutrazol 5.0 g twice	1.683 (7.320)	16.17	0.313	51.60 (45.87)
paclobutrazol 10.0 g once	1.769 (7.557)	15.36	0.316	48.66 (44.21)
Paclobutrazol 10.0 g twice	1.680 (7.340)	15.02	0.322	46.69 (43.08)
Cycocel 4000 ppm once	1.766 (7.520)	17.97	0.304	57.30 (49.16)
Cycocel 4000 ppm twice	1.690 (7.307)	17.50	0.302	57.91 (49.55)
Cycocel 8000 ppm once	1.757 (7.547)	17.83	0.305	58.70 (50.02)
Cycocel 8000 ppm twice	1.579 (7.187)	17.17	0.305	58.27 (49.74)
Alar 1500 ppm once	1.654 (7.290)	16.67	0.307	54.73 (47.70)
Alar 1500 ppm twice	1.646 (7.250)	16.00	0.306	52.43 (46.37)
Alar 3000 ppm once	1.724 (7.417)	16.83	0.307	54.90 (47.79)
Alar 3000 ppm twice	1.805 (7.603)	14.93	0.297	50.26 (45.12)
F - Test	NS	**	NS	*
C.D. 5%	-	1.96	-	4.73
C.D. 1%	-	2.64	-	-
S.Em±	1.212	0.68	0.007	1.63
C.V. %	27.412	6.95	4.169	5.90

(Transformed values are given within parentheses)

compared to control (56.26) as is evident from Table 3.11.

4.3.35. Total sugars

All treatments were on par with control as for the total sugar content of fruits was concerned, but a tendency to reduce the total sugar level was evident with higher rates of paclobutrazol. In the case of double application of 10.0 g of this chemical, its value was 9.23% and in control it was 12.18% (Table 3.11).

4.3.36. Reducing sugars

The various treatments did not influence the reducing sugar level of fruits significantly (Table 3.11).

4.3.37. Sugau: Acid ratio of fruits

Significantly lower values for sugar to acid ratio was recorded in the case of fruits from trees which were under paclobutrazol 10.0 g treatment irrespective of the number of applications. Compared to control value of 40.29, this concentration resulted in sugar to acid ratios of 32.49 and 28.66 respectively when applied once and twice (Table 3.12).

Table 3.12. Influence of growth retardant treatments on the sugar content and sugar: acid ratio of fruits and time taken by mature fruits to ripen in mango Cv. Alphonso

Treatment	Total sugars %	Reducing sugars %	Sugar/acid ratio	Number of days taken by mature fruits for ripening
Control	12.180	1.529	40.29 (39.37)	6.667
Paclobutrazol 2.5 g once	12.667	1.540	42.55 (40.69)	7.000
Paclobutrazol 2.5 g twice	12.827	1.555	41.18 (39.83)	7.333
Paclobutrazol 5.0 g once	12.153	1.571	40.04 (39.19)	8.333
Paclobutrazol 5.0 g twice	10.953	1.552	33.83 (35.51)	9.667
Paclobutrazol 10.0 g once	10.257	1.485	32.49 (34.71)	11.000
Paclobutrazol 10.0 g twice	9.230	1.388	28.66 (32.32)	13.000
Cycocel 4000 ppm once	12.067	1.530	39.75 (39.05)	6.333
Cycocel 4000 ppm twice	12.287	1.530	40.71 (39.61)	6.667
Cycocel 8000 ppm once	12.227	1.516	39.35 (38.82)	7.000
Cycocel 8000 ppm twice	12.487	1.518	40.97 (39.76)	7.667
Alar 1500 ppm once	11.817	1.566	38.38 (38.25)	6.667
Alar 1500 ppm twice	11.777	1.503	38.57 (38.34)	8.000
Alar 3000 ppm once	12.400	1.535	40.54 (39.46)	8.000
Alar 3000 ppm twice	11.380	1.517	38.32 (38.12)	9.000
F - Test	NS	NS	*	**
C.D. 5%	-	-	4.42	0.928
C.D. 1%	-	-	-	1.252
S.Em±	0.798	0.051	1.52	0.320
C.V. %	11.763	5.759	6.93	6.804

(Transformed values are given within parentheses)

4.3.38. Number of days taken by mature fruits for ripening

Mature harvested fruits from untreated trees took only 6.667 days to attain fifty per cent yellow colouration of the skin under ambient conditions. Highly significant increase over this was observed in the case of 5.0 and 10.0 of paclobutrazol and 3000 ppm Alar treatments irrespective of the number of application and by double spraying of 1500 ppm Alar. Paclobutrazol 5.0 g and Alar treatments were on par, but paclobutrazol 10.0 g treatments differed from them as well as one another at one per cent significence level. Single and double applications of 10.0 g paclobutrazol took 11.0 and 13.0 days respectively for ripening. Significantly longer ripening perid resulted from double application of 8000 ppm cycocel (Table 3.12).

4.3.39. Per cent increase in tree height over two years

Regardless of number of applications, highly significant reductions in per cent increase of tree height was effected by all paclobutrazol and higher concentrations of cycocel and Alar treatments. The most effective one was the double application of 10.0 g paclobutrazol per tree which produced only 3.77 per cent increase in two years for tree height as against 24.28 per cent in untreated trees and was on par with all

paclobutrazol treatments except single application of 2.5 g. Significant reductions in tree height increments were brought about by spraying 1500 ppm Alar twice. Other treatments also resulted in lesser increases, but did not differ from control significantly (Table 3.13).

4.3.40. Per cent increase in tree spread over two years

The data pertaining to this character are presented in Table 3.13. All treatments which caused a highly significant or significant reductions in per cent increase of tree height also resulted in highly significant reductions in per cent increase in tree spread over two years. Highly significant differences between number of applications was observed only in the case of 10.0 g paclobutrazol per tree. However, there were highly significant differences even mong effective treatments. Applications of 10.0 g paclobutrazol two times caused only 2.24 per cent increase in tree spread over a span of two years whereas the corresponding value for untreated trees was 18.37 per cent. Significant reductions in this character were brought about by 8000 ppm cycocel when applied either once or twice.

4.3.41. Per cent increase in tree volume over two years

All growth retardant treatments registered lesser

Table 3.13. Influence of growth retardant treatments on per cent increases in tree height, spread and volume over two years in mango Cv. Alphonso

Treatment	Percent increase in tree height over two years (1986-88)	Per cent increase in tree spread over two years (1986-88)	Per cent increase in tree volume over two years (1986-88)
Control	24.28 (29.11)	18.37 (25.35)	75.59 (60.61)
Paclobutrazol 2.5 g once	10.87 (19.21)	10.13 (18.52)	33.80 (35.51)
Paclobutrazol 2.5 g twice	9.29 (17.63)	9.46 (17.85)	30.94 (33.77)
Paclobutrazol 5.0 g once	8.79 (17.20)	7.64 (16.00)	26.06 (30.66)
Paclobutrazol 5.0 g twice	7.43 (15.59)	6.73 (14.94)	22.43 (28.08)
Paclobutrazol 10.0 g once	5.90 (13.88)	6.51 (14.38)	20.22 (26.36)
Paclobutrazol 10.0 g twice	3.77 (11.08)	2.24 (8.33)	8.46 (16.77)
Cycocel 4000 ppm once	23.25 (28.37)	14.66 (22.46)	59.20 (50.32)
Cycocel 4000 ppm twice	16.65 (24.01)	13.94 (21.91)	51.98 (46.13)
Cycocel 8000 ppm once	13.33 (21.35)	9.94 (18.33)	48.67 (44.31)
Cycocel 8000 ppm twice	9.36 (17.68)	12.92 (20.97)	38.30 (38.19)
Alar 1500 ppm once	17.35 (24.65)	17.04 (24.29)	60.99 (51.42)
Alar 1500 ppm twice	15.72 (23.32)	13.45 (21.47)	48.94 (44.39)
Alar 3000 ppm once	12.47 (20.64)	10.15 (18.50)	47.16 (43.33)
Alar 3000 ppm twice	10.38 (18.66)	11.74 (19.99)	37.82 (37.91)
F - Test	**	**	**
C.D. 5%	5.56	2.68	14.63
C.D. 1%	7.50	3.62	19.73
S.Em±	1.92	0.93	5.05
C.V. %	16.49	8.49	23.27

(Transformed values are given within parentheses)

increase in per cent increase of tree volume than the trees left without any treatment. This reduction compared to control value of 75.59 per cent was highly significant for all paclobutrazol treatments and double applications of higher concentrations of cycocel and Alar; and significant in the case of 8000 ppm cycocel or 3000 ppm Alar applied once as well as 1500 ppm Alar applied twice. The least increase of 8.46 per cent was resultant of double application of 10.0 g paclobutrazol which was on par with all other paclobutrazol treatments at one per cent significance. This treatment virtually arrested the increase in volume of trees for two years. Other paclobutrazol treatments brought about more than fifty per cent reduction in tree volume increase compared to control (Table 3.13).

4.4. INVESTIGATIONS ON HORMONAL BASIS OF DWARFING IN MANGO

The findings of the experiment conducted on hormonal basis of vigour regulation in mango are presented below.

4.4.1. Abscisic acid

ABA levels in the shoot tip of mango cultivars studied are presented in Table 4.1 and demonstrated in figures 1 to 6.

Expressed on a per unit fresh weight basis or per bud basis, the vigorous cultivar, Langra, recorded slightly higher level of ABA in the apical buds than the dwarf cultivar, Mulgoa during both dormancy and active growth phases. In both the cultivars, ABA level was remarkably higher during dormant reason than active growth period.

During active growth phase, Alphonso trees in which the vigour was drastically restricted by paclobutrazol treatment showed a lower ABA level in their terminal buds compared to untreated trees either per unit weight or per bud basis.

From these results it appeared that ABA might not be the inhibitor responsible for restriction of vigour in mango. Its content was in fact higher in the apical buds of more vigorous shoots than that of less vigorous ones, whether the difference in vigour was natural due to genetic make up of cultivars or induced due to growth retardant treatment.

4.4.2. Cytokinins

The cytokinin levels in the young leaves of Alphonso trees treated or untreated with paclobutrazol are presented in Figures 7 to 12.

Table 4.1. Abscisic acid levels in the shoot tip of three mango cultivars

Physiological condition of buds	Variety/ treatment	Date of sampling	Weight of sample (g)	No.of buds per sample	Abscisic acid content µg/g fr.wt of tissue	µg/bud
Dormant	Mulgoa	29-08-87	2.0	25.0	2.290	0.0916
	Langra	29-08-87	2.0	25.0	2.420	0.0968
Active	Mulgoa	16-03-88	2.0	63.0	0.750	0.0119
	Langra	16-03-88	2.0	43.0	0.760	0.0177
Active	Alphonso (a) Control	06-02-88	2.0	24.0	2.800	0.1167
	(b) Treated with paclobutrazol	06-02-88	2.0	38.0	2.275	0.0599

From the butanol-soluble fraction of mango cultivar Alphonso, eight cytokinin like substances (X_1, X_2, X_3, X_4, X_5 , X_6, X_7 and X_8) have been isolated based on the elution patterns on Sephadex LH 20 column chromatography. The detection of the cytokinin activity has been done using bioassay - soybean cotyledon callus test and soybean hypocotyl test. Factors X_3 with elution volume 440 to 520 ml, X_4 with elution volume 560 to 680 ml, X_5 with elution volume 760 to 880 ml and X_7 with elution volume 1000 to 1080 ml, coincided with the elution volumes of the authentic cytokinins Zeatin riboside (ZR), Dihydro Aeatin riboside (DHZR), Zeatin (Z), Dihydro Zeatin (DHZ), Isopentenyl adenine (ipA) and Isopentenyl adenosine (ip) respectively. In Sephadex column chromatography, factors X_1 and X_2 (elution volumes 80 to 200 and 240 to 320 ml respectively) elution in fractions earlier to ZR. Some cytokinins glucosides are reported to elute in this position with 35 per cent ethanol as eluent. The general trend in the activity of these compounds were similar in both bioassays (fig).

The cytokinin activity of the factors X_1 and X_2 which are presumably the glucosides and of the factors X_3 and X_4 which behaved like ZR/DHZR and Z/DHZ were for higher in control plants compared to paclobutrazol treated ones. The differences in ipA and ip - like substances were not striking.

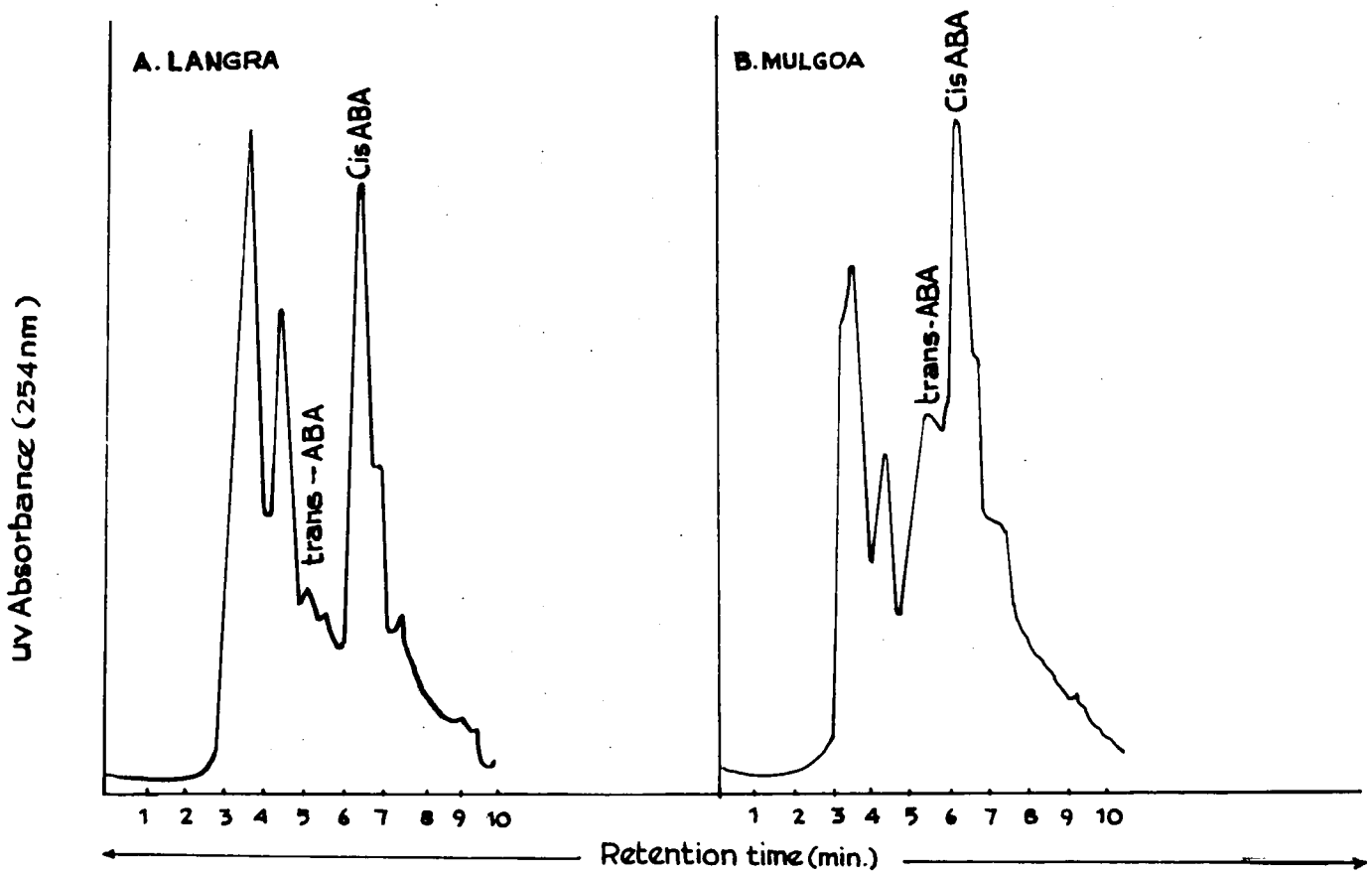


FIG.1 ELUTION PROFILES OF Cis AND Trans-ABA FOLLOWING HPLC IN EXTRACT EQUIVALENT TO 0.04g ACTIVE APICAL BUDS OF MANGO CULTIVARS LANGRA AND MULGOA

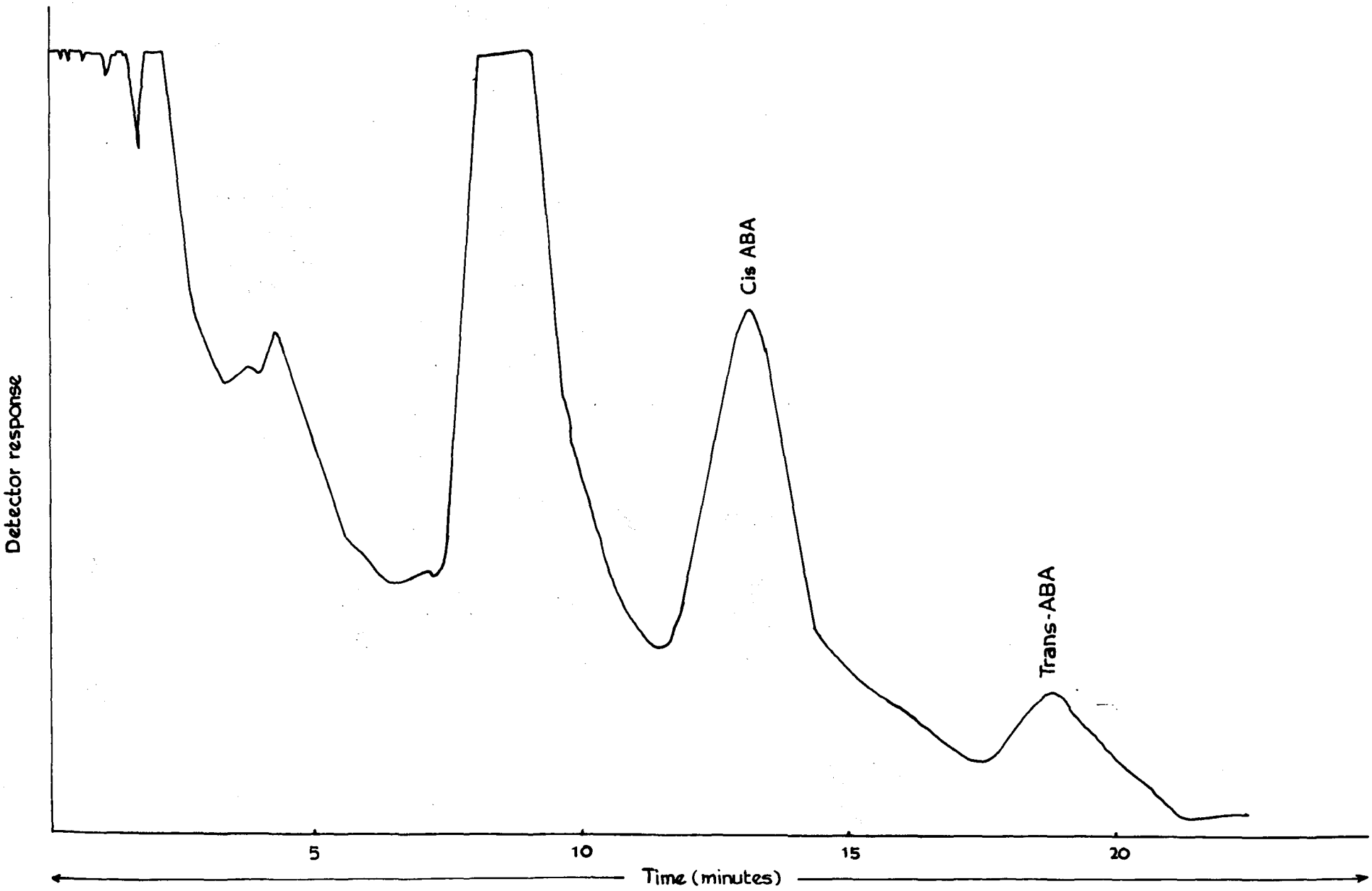


FIG. 2 PEAKS OF ABA IN GLC IN EXTRACTS EQUIVALENT TO 0.05g FRESH WEIGHT OF ACTIVELY GROWING APICAL BUDS OF MANGO Cv. LANGRA

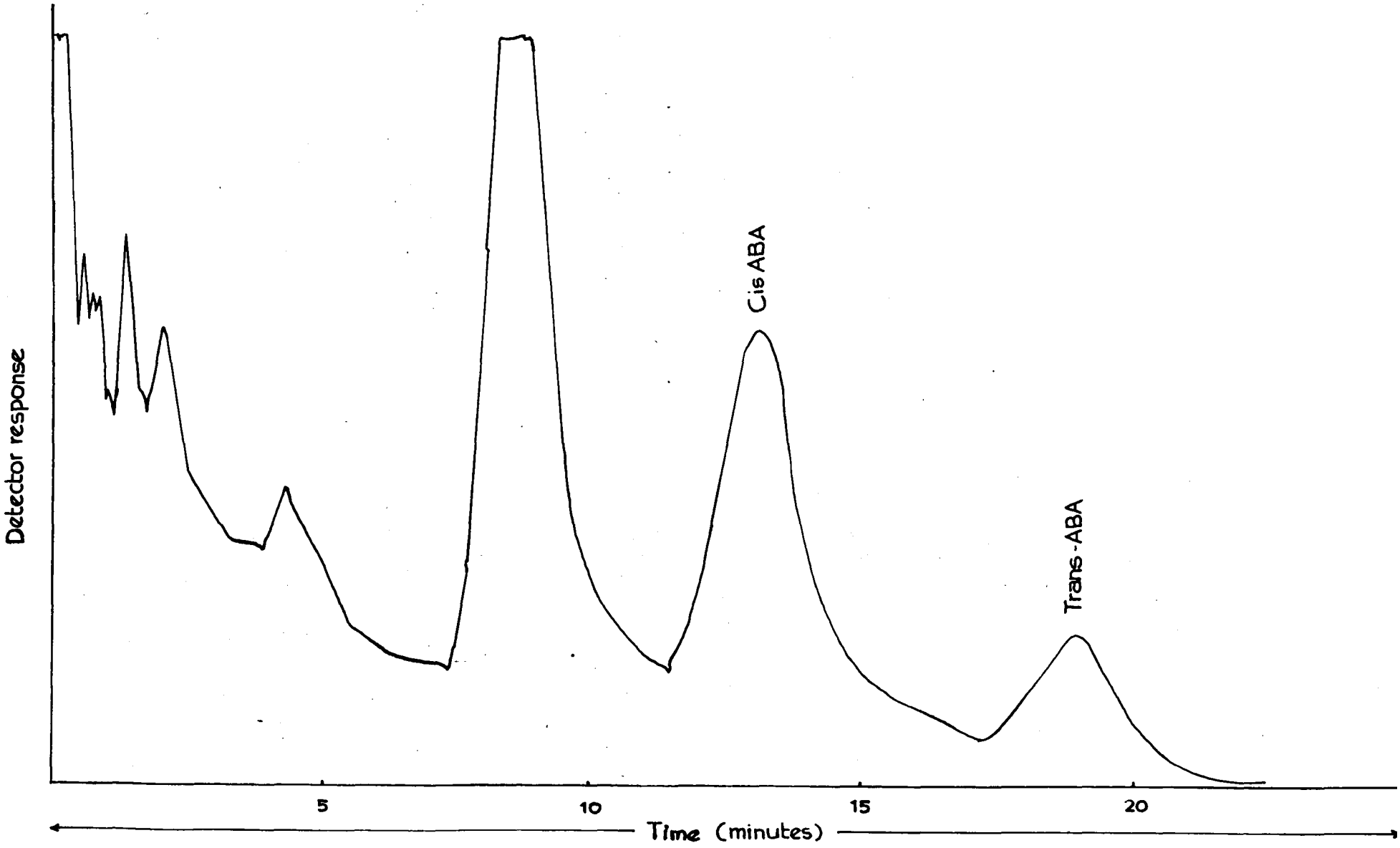


FIG.3 PEAKS OF ABA IN GLC IN EXTRACTS EQUIVALENT TO 0.05g FRESH WEIGHT OF ACTIVELY GROWING APICAL BUDS OF MANGO Cv. MULGOA

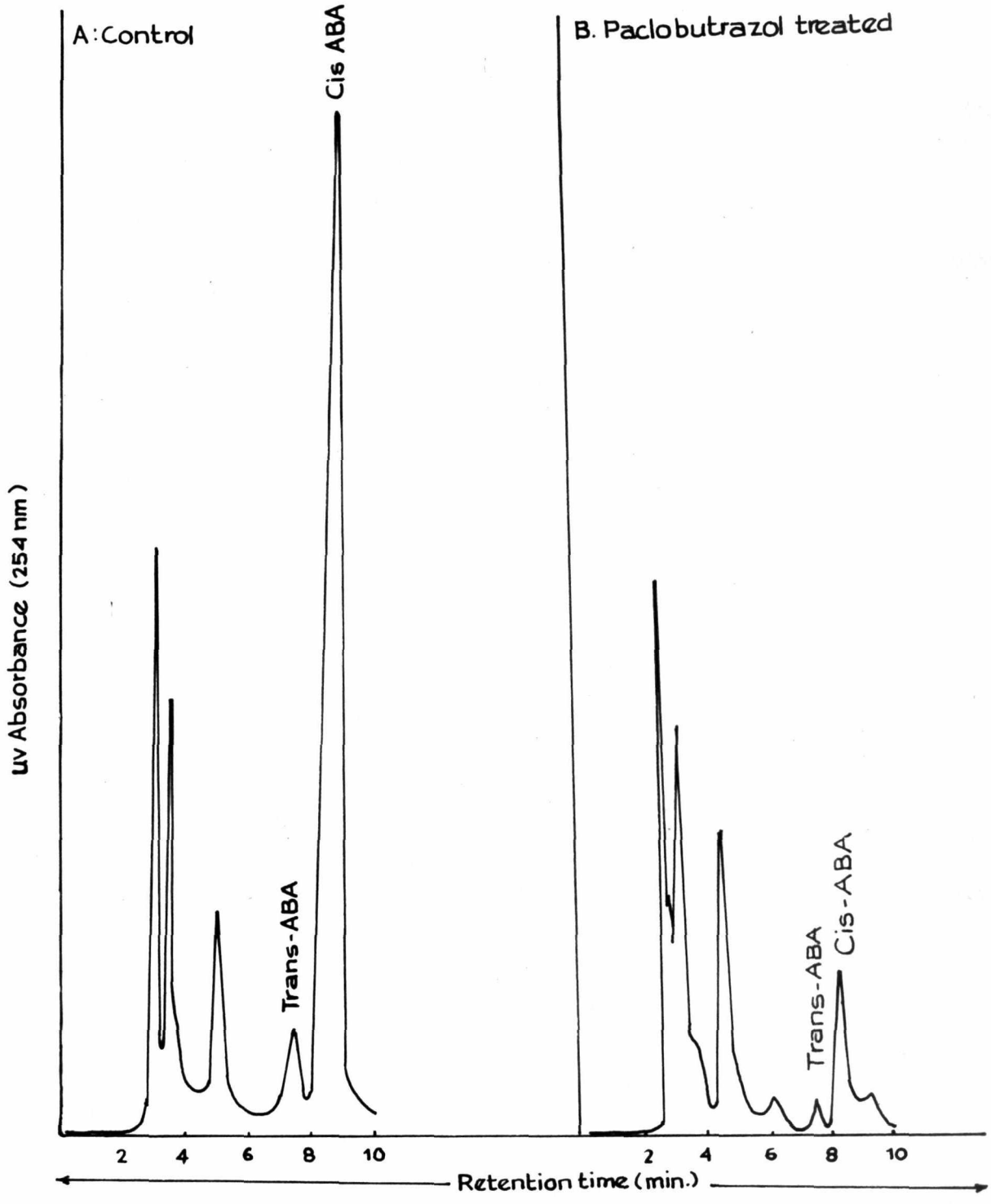


FIG. 4 ELUTION PROFILE OF Cis AND Trans-ABA FOLLOWING HPLC IN EXTRACTS EQUIVALENT TO 0.07g ACTIVE APICAL BUDS OF MANGO Cv. ALPHONSO

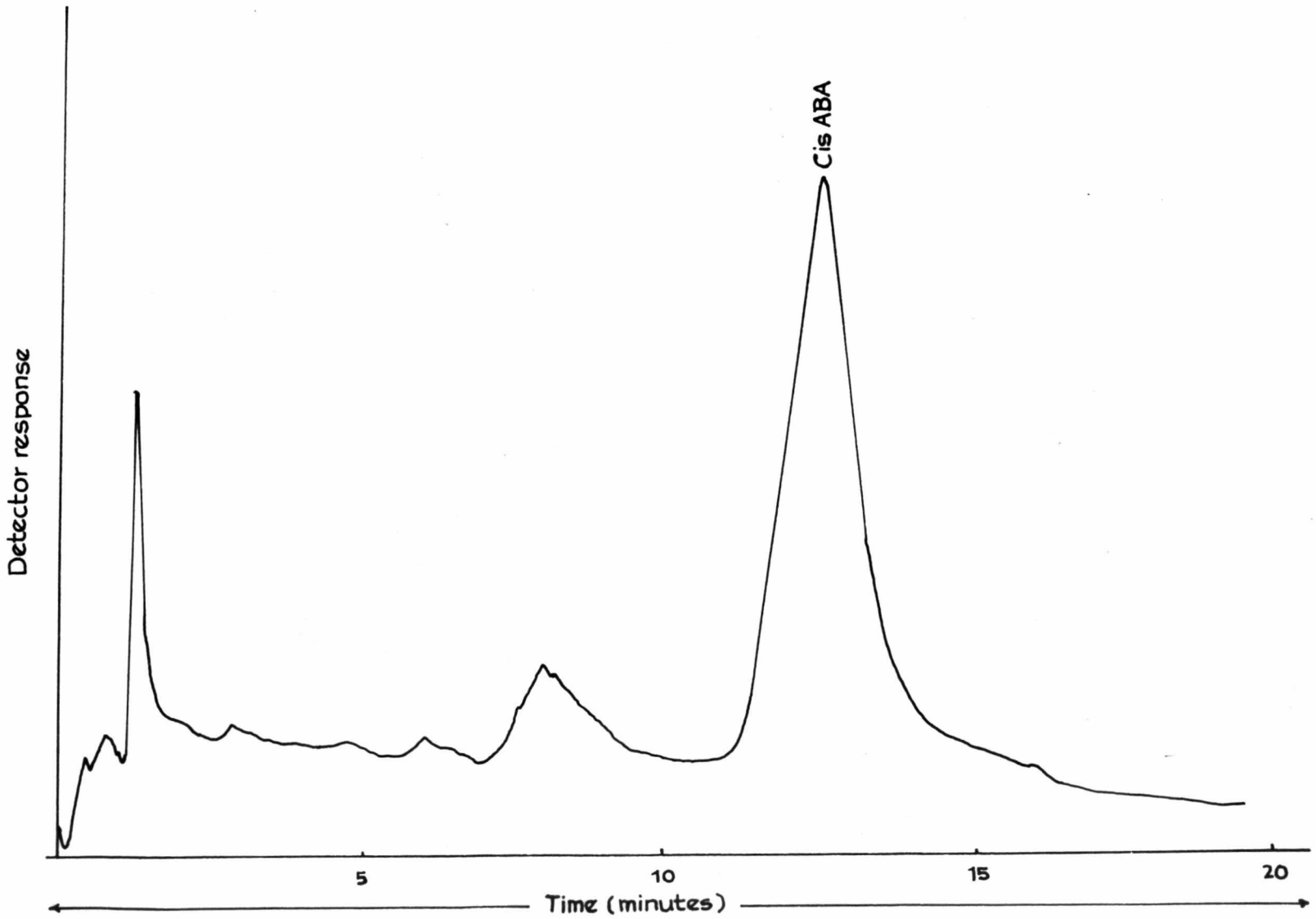


FIG.5 PEAKS OF ABA IN GLC IN EXTRACTS EQUIVALENT TO 0.02g FRESH WEIGHT OF ACTIVELY GROWING APICAL BUDS OF MANGO Cv. ALPHONSO TREATED WITH PACLOBUTRAZOL

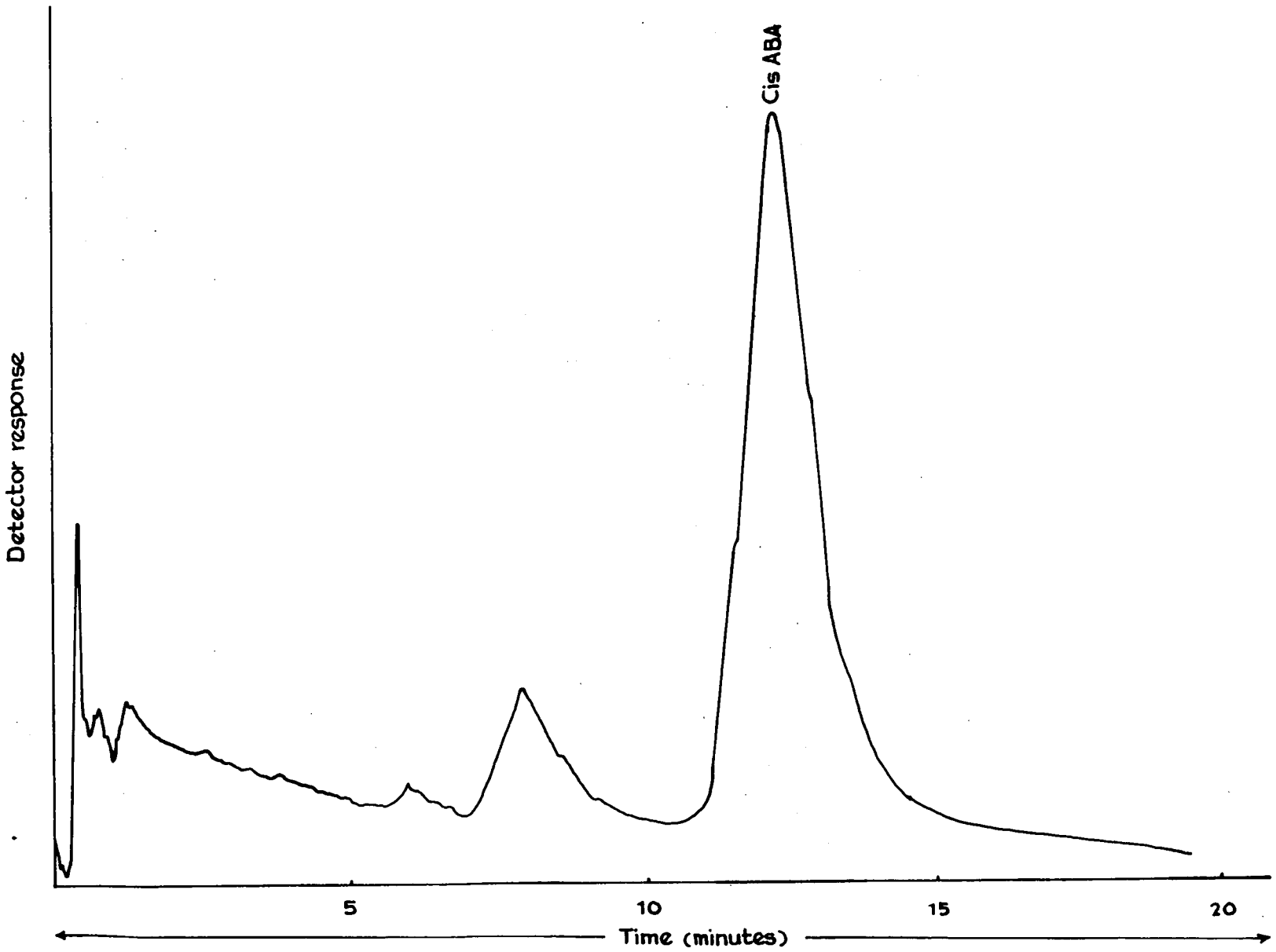


FIG. 6 PEAKS OF ABA IN GLC IN EXTRACTS EQUIVALENT TO 0.02g FRESH WEIGHT OF ACTIVELY GROWING APICAL BUDS OF MANGO Cv. ALPHONSO NOT TREATED WITH PACLOBUTRAZOL (CONTROL)

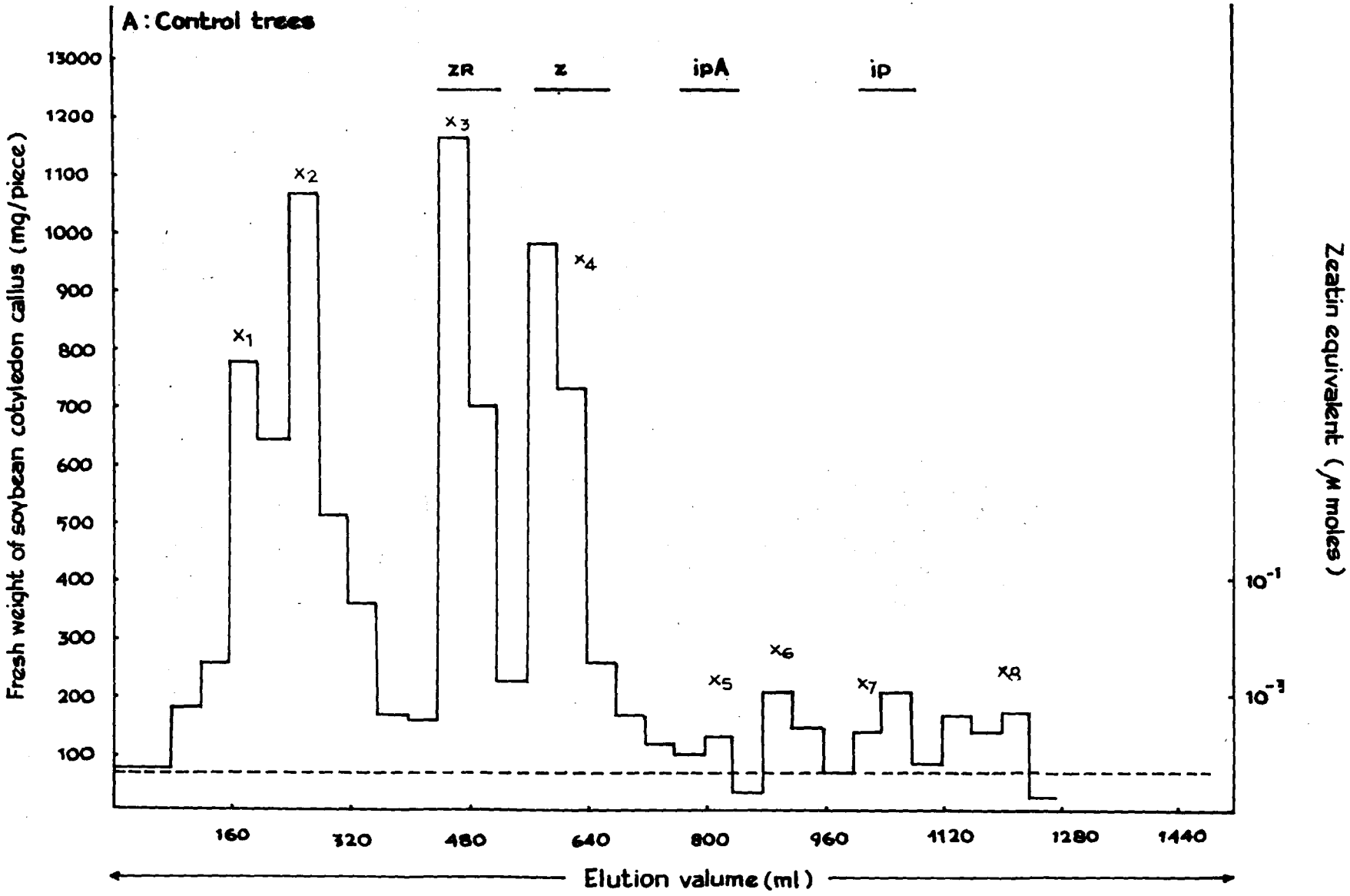


FIG.7 HISTOGRAM SHOWING BIOLOGICAL ACTIVITY OF BUTANOL SOLUBLE CYTOKININS IN MANGO LEAF EXTRACT EQUIVALENT TO 25.0g FRESH WEIGHT (SOYBEAN COTYLEDON CALLUS TEST)

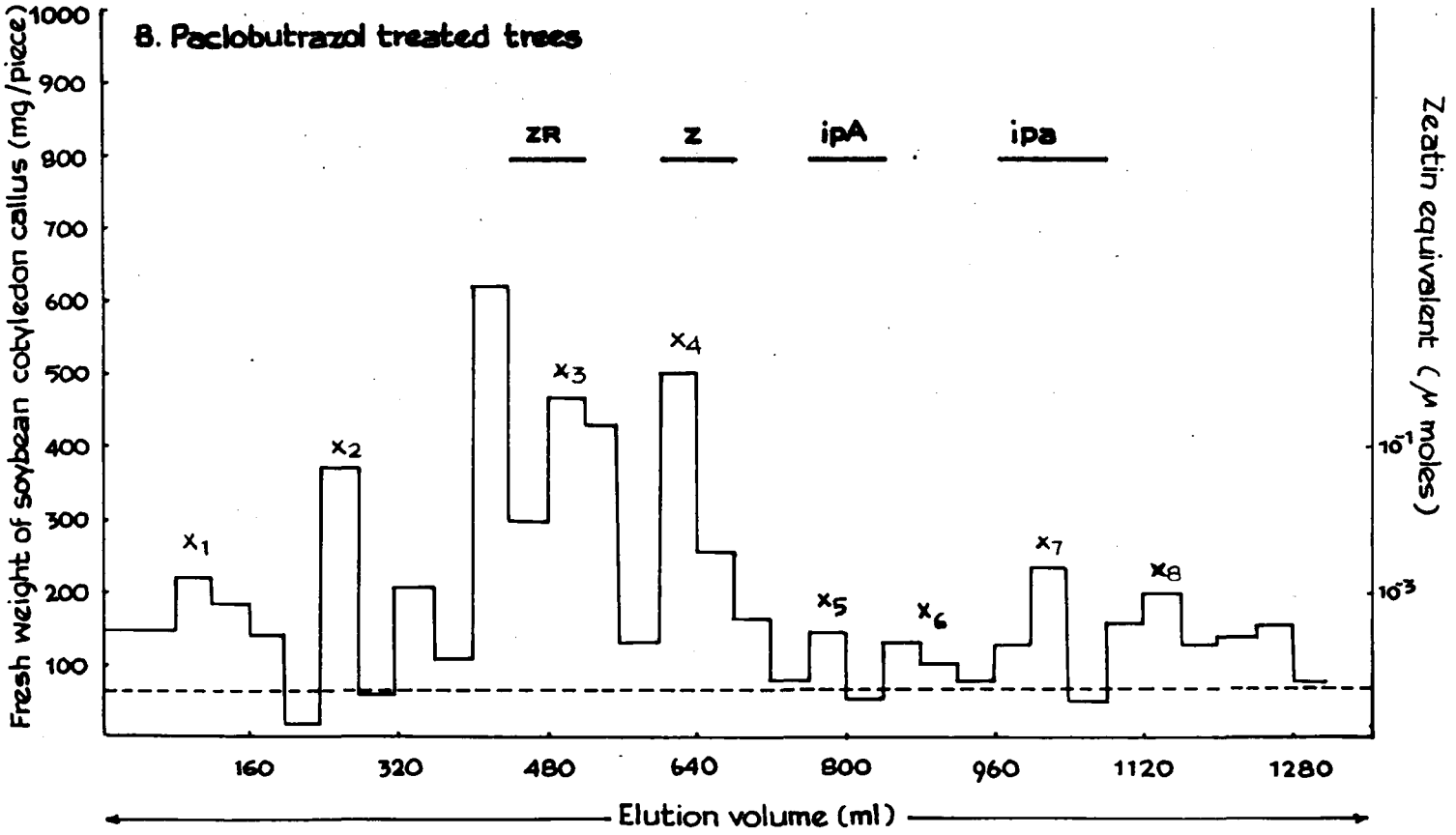


FIG.8 HISTOGRAM SHOWING BIOLOGICAL ACTIVITY OF BUTANOL SOLUBLE CYTOKININS IN MANGO LEAF EXTRACT EQUIVALENT TO 25.0 g FRESH WEIGHT (SOYBEAN COTYLEDON CALLUS TEST)

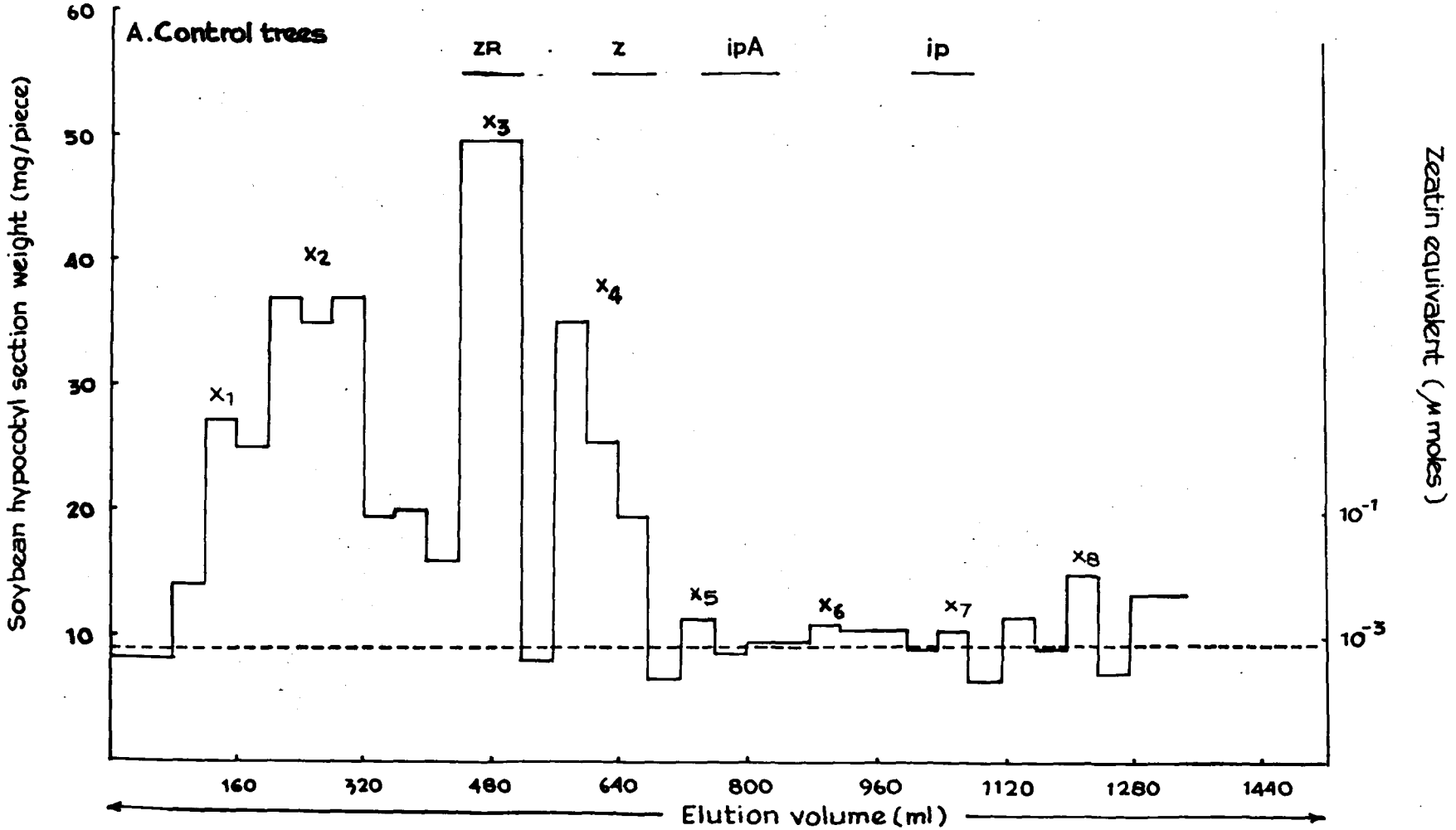


FIG.9 HISTOGRAM SHOWING BIOLOGICAL ACTIVITY OF BUTANOL SOLUBLE CYTOKININS IN MANGO LEAF EXTRACT EQUIVALENT TO 25.0g FRESH WEIGHT (SOYBEAN HYPOCOTYL TEST)

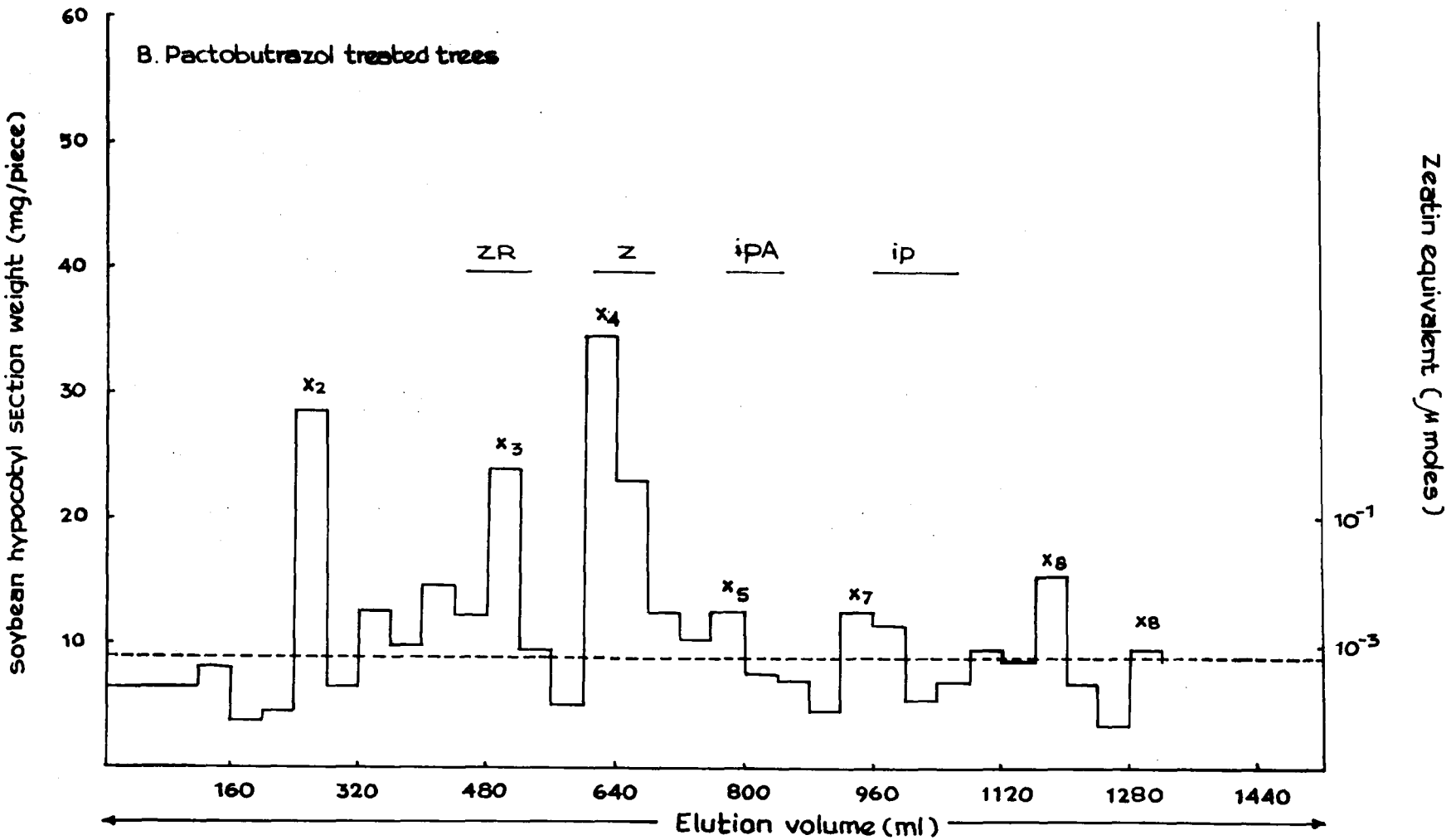


FIG.10 HISTOGRAM SHOWING BIOLOGICAL ACTIVITY OF BUTANOL SOLUBLE CYTOKININS IN MANGO LEAF EXTRACT EQUIVALENT TO 25.0g FRESH WEIGHT (SOYBEAN HYPOCOTYL TEST)

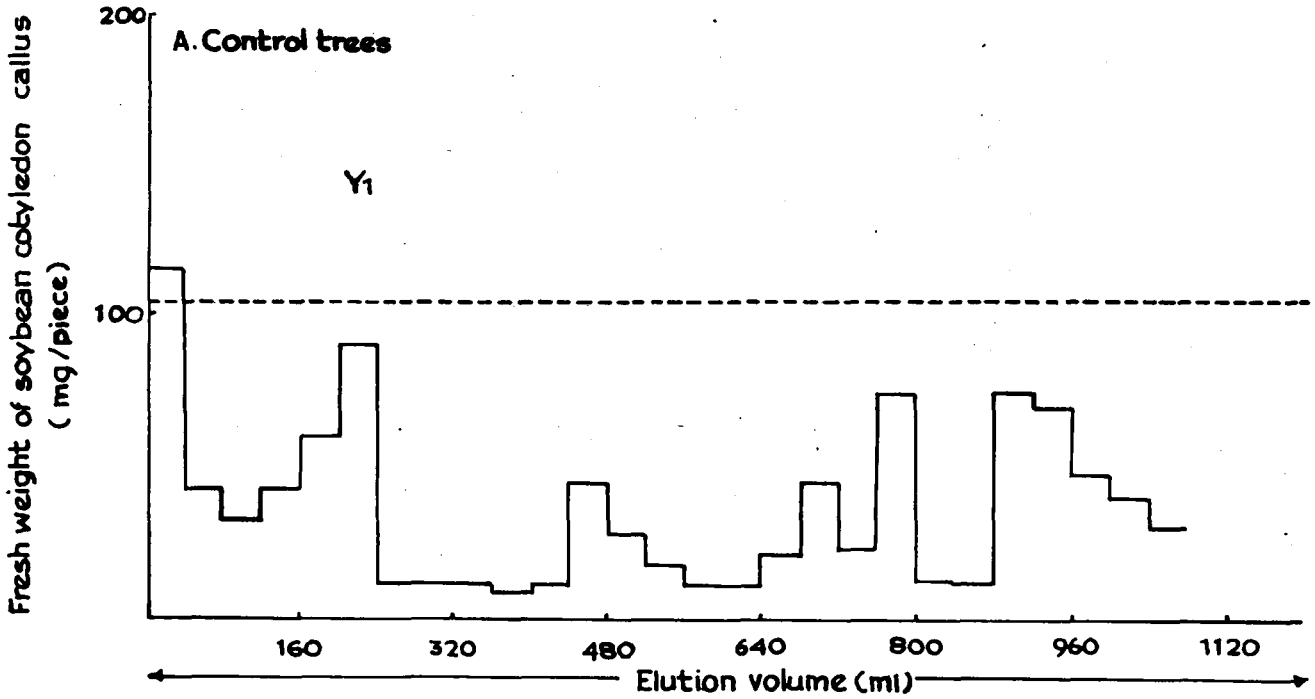


FIG.11 HISTOGRAM SHOWING BIOLOGICAL ACTIVITY OF BUTANOL INSOLUBLE CYTOKININS IN MANGO LEAF EXTRACT EQUIVALENT TO 25.0g FRESH WEIGHT (SOYBEAN COTYLEDON CALLUS TEST)

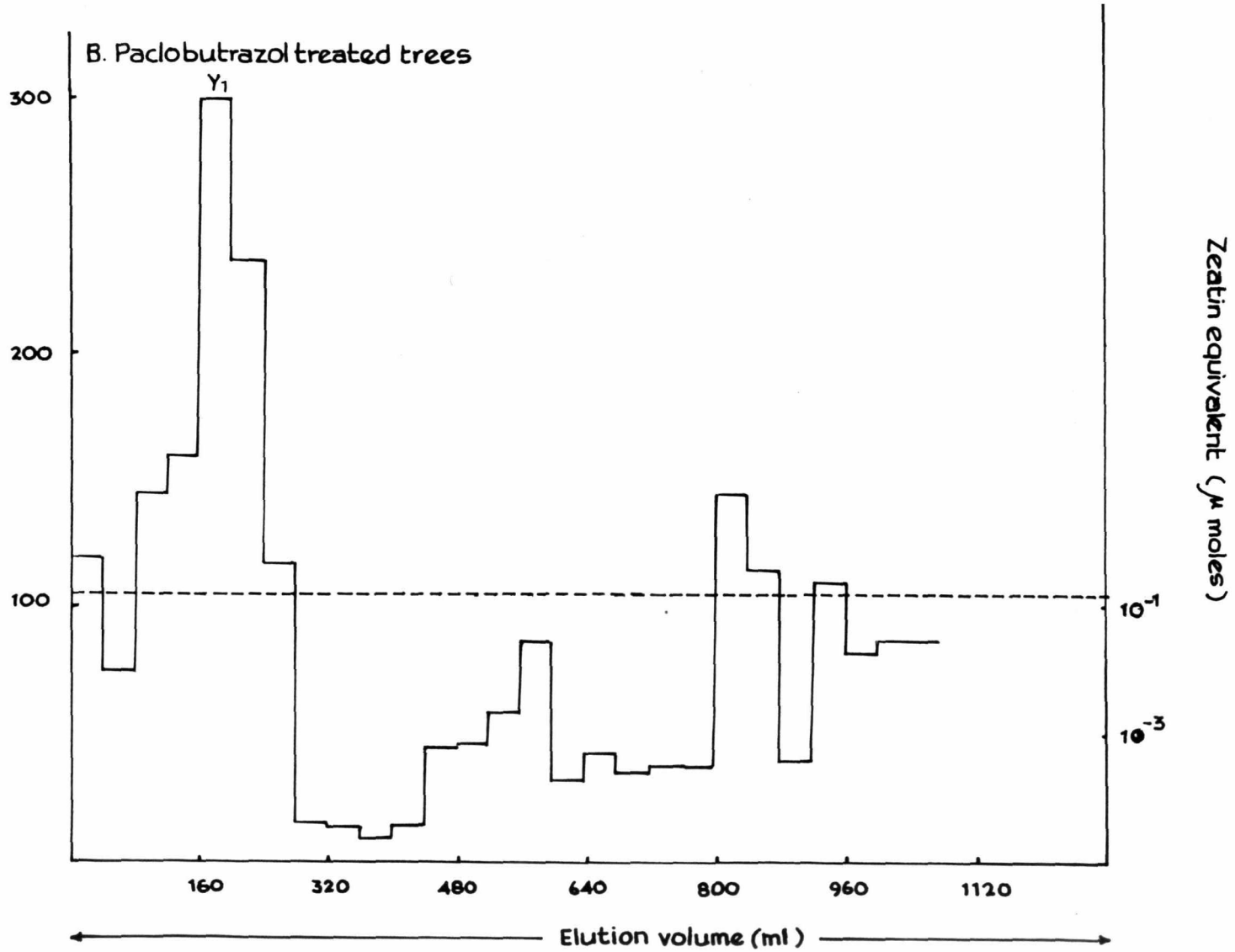


FIG.12 HISTOGRAM SHOWING BIOLOGICAL ACTIVITY OF BUTANOL INSOLUBLE CYTOKININS IN MANGO LEAF EXTRACT EQUIVALENT TO 25.0g FRESH WEIGHT (SOYBEAN CALLUS TEST)

In the aqueous fraction (butanol insoluble fraction) one major zone of activity (factor Y) was detected at elution volume 120 to 240 ml after Sephadex LH 20 column chromatography and soybean cotyledon callus bioassay. This compound is possibly a cytokinin nucleotide or an amino acid conjugate of cytokinin. This compound did not partition into butanol at pH 8.0 and when chromatographed on Dowex-1 column (formate form) equilibriated at pH 10.5 was retained on the column and was released by the formate ion. The activity of butanol insoluble cytokinins was found to be higher in paclobutrazol treated trees than the untreated ones. This fraction possibly ineludes nucleotides and/or an amino acid conjugate of cytokinin, lupinic acid.

The total cytokinin activity in terms of callus weight in the butanol soluble fraction was 8526.9 and 4962.1 mg for control and paclobutrazol treated samples respectivily in soybean cotyledon callus test. In soybean hypocotyl test, the corresponding values were 297.9 and 112.8 mg respectivily.

4.5. EFFECT OF PACLOBUTRAZOL TREATMENTS ON PHENOLIC CONTENT OF APICAL BUD AND STEM ANATOMICAL CHARACTERISTICS

The results of this study are presented in Table 5.1.

4.5.1. Phenolic content of apical bud

Since phenolic content was found to vary in different cultivars depending on their vigour, it was thought useful to study the phenolic content in various chemical treatments to find any correlation between induced size control and phenolic content.

Increasing content of total phenols in the apical bud concurrent with the reduction in vigour was a major response to increasing concentrations of paclobutrazol given to the tree. Trees which were given soil drenching with paclobutrazol @ 10.0 g per tree showed 50.65% increase in phenol content of apical buds compared to control. The phenolic content expressed as tannic acid equivalent was 37.17 mg/g fresh weight in the case of control trees whereas its value was 40.28, 49.50 and 56.00 mg/g fresh weight in the case of trees receiving 2.5, 5.0 and 10.0 g paclobutrazol, in that order.

4.5.2. Stem anatomical characters

It was obsereved in earlier study that dwarfer genotypes have higher phloem to xylem ratio than vigorous ones. To see whether this holds good in trees dwarfed by chemical treatments, similar anatomical studies were conducted in the case of trees dwarfed by paclobutrazol.

Table 5.1. Influence of paclobutrazol treatments on stem anatomical characters and phenolic content of apical buds in mango Cv. Alphonso (Mean ± Standard deviation)

Paclobutrazol concentration g/tree	Phenolic content of apical bud (tannic acid eq.mg/g fr.wt)	Radial width (μ) of				Phloem to xylem ratio	Number of vascular bundles per cross section	Number of xylem bessels per vascular bundle	Mean diameter of metaxylem vessels μ
		Half pith	Primary xylem	Primary phloem	Cortex				
0.0	37.17± 1.92	83.7± 8.3	33.1± 6.8	24.4± 6.8	27.0± 2.8	0.736± 0.129	20.17± 2.17	6.00± 2.04	6.3± 0.67
2.5	40.28± 1.59	54.3± 5.7	24.7± 5.5	22.5± 3.4	25.2± 4.4	0.936± 0.172	22.34± 4.32	5.33± 2.00	5.4± 0.52
5.0	49.50± 1.53	49.7± 3.2	22.9± 4.5	27.1± 3.9	26.1± 7.3	1.221± 0.285	19.69± 1.96	3.80± 1.82	4.0± 0.67
10.0	56.0± 1.98	49.3± 1.9	15.0± 3.5	24.9± 3.4	26.7± 2.7	1.749± 0.379	18.91± 2.89	2.20± 1.28	3.1± 0.74

The radial width of half pith and primary xylem tissue were drastically reduced by paclobutrazol treatments. The higher concentration of paclobutrazol brought about 41.1% reduction in the radial width of half pith over control. The width of primary xylem was progressively reduced by increasing concentrations of paclobutrazol and at the highest level of the chemical, the width of xylem tissue was only 15.0 /u as against 33.1 /u in untreated trees. This reduction was more than fifty per cent of the control. The radial width of primary phloem and cortex remained almost unaltered by the paclobutrazol treatments. It is interesting to note here that the suppression of growth in response of paclobutrazol occured only for the tissues which are inner to cambial ring with the tissues outside the cambial ring remaining uneffected.

The phloem to xylem ratio as a consequence was very much enhanced by paclobutrazol treatments. The increase was linear with the concentration of the chemical.

The treatment did not have any striking influence on the number of vascular bundles per stem section. But the number of xylem vessels per vascular bundle and the size of metaxylem vessels were drastically reduced by higher concentrations of the chemical. On an average there were six vessels per vascular bundle with mean diameter of 6.3 /u

Plate 1. Variation in the proportion of xylem and phloem tissues in the stem sections of mango cultivars with different vigour

1.	Mulgoa	Least vigorous
2.	Kerala Dwarf	
3.	Neelum	Medium vigorous
4.	Ratul	
5.	Langra	Most vigorous
6.	Hyder Sahebi	

Plate 2. Influence of paclobutrazol treatments on the relative proportion of xylem and phloem tissues in stem sections of mango Cv. Alhonso

1. Control
2. 2.5 g paclobutrazol per tree
3. 5.0 g paclobutrazol per tree
4. 10.0 g paclobutrazol per tree

X - xylem
P - phloem

PLATE 1

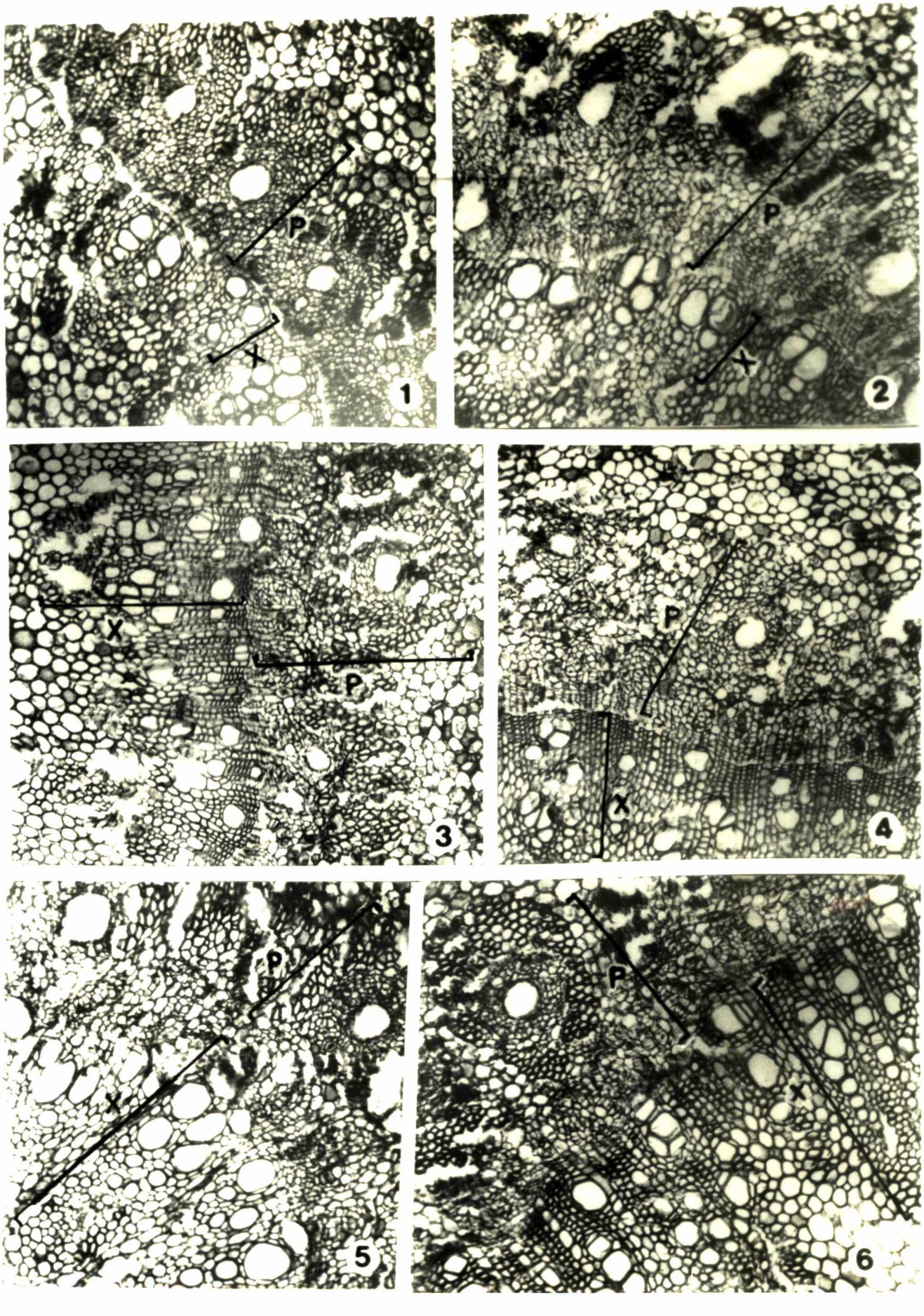


Plate 3. Effects of paclobutrazol treatments on the extent of flowering and earliness in flowering in mango Cv. Alphonso

A. Tree which was given paclobutrazol @ 2.5 g ai

B. control tree (left) and tree which was given paclobutrazol @ 5.0 g ai (right)

C. Tree which was given paclobutrazol @ 10.0 g ai (left) and control tree (right)

PLATE 2

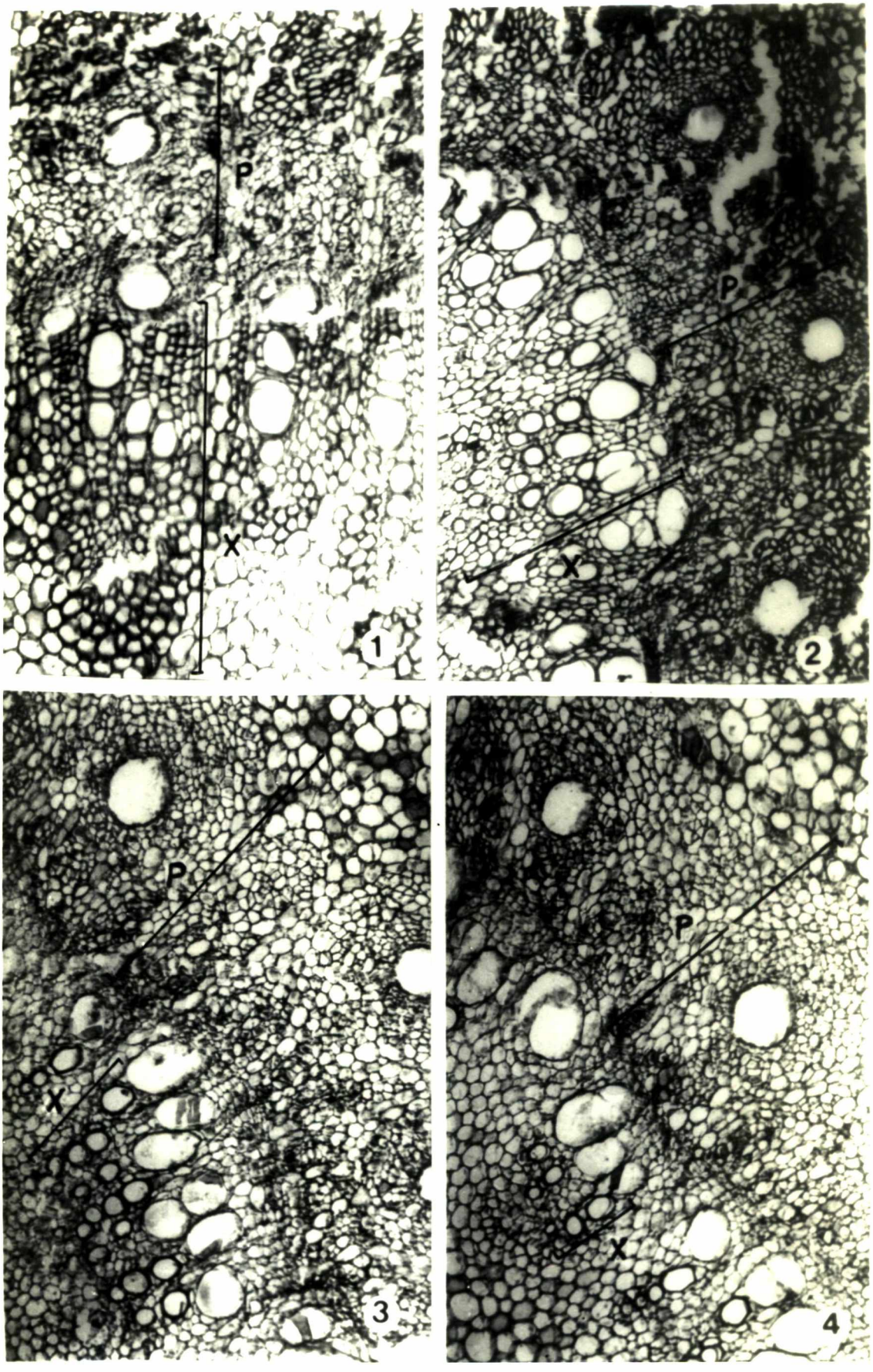


Plate 6. Effects of paclobutrazol treatments on the length and spread of inflorescence and on the length and internodal length of successive flushes in mango Cv. Alphonso (close up)

A. Effect on inflorescence

1. 10.0 g ai/tree
2. 5.0 g ai/tree
3. 2.5 g ai/tree
4. Control

B. Influence on successive flushes

1. 10.0 g ai/tree
2. 5.0 g ai/tree
3. 2.5 g ai/tree

(White arrows are used to demarkate different flushes. Please note that the effect of paclobutrazol in limiting length and internodal length of flushes is very marked for the first two flushes and slowly dessipates thereafter)

Plate 4. Influence of growth retardant treatments on the length and internodal length of new flushes in mango Cv. Alphonso

A. Influence of Alar treatments

1. 3000 ppm spray
2. 1500 ppm spray
3. Control

B. Influence of cycocel treatments

1. 8000 ppm spray
2. 4000 ppm spray
3. Control

C. Influence of paclobutrazol treatments

1. 10.0 g ai/tree
2. 5.0 g ai/tree
3. 2.5 g ai/tree
4. Control






1
2
3


1
2
3


1
2
3
4

Plate 5. Influence of growth retardant treatments on the length of successive flushes in mango Cv. Alphonso

A. Influence of 3000 ppm Alar treatments

1. Control
2. Single application
3. Double application

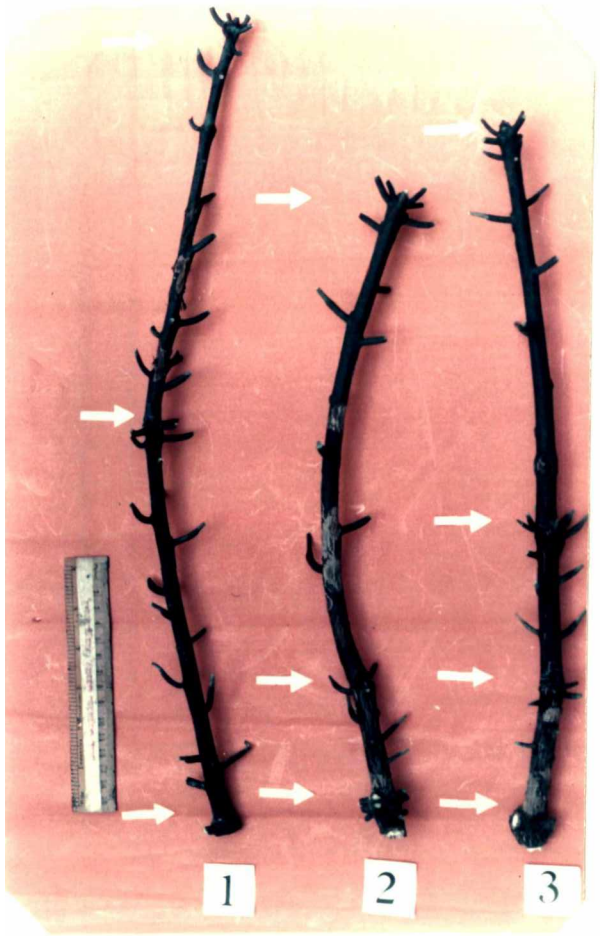
B. Influence of 8000 ppm cycocel treatment

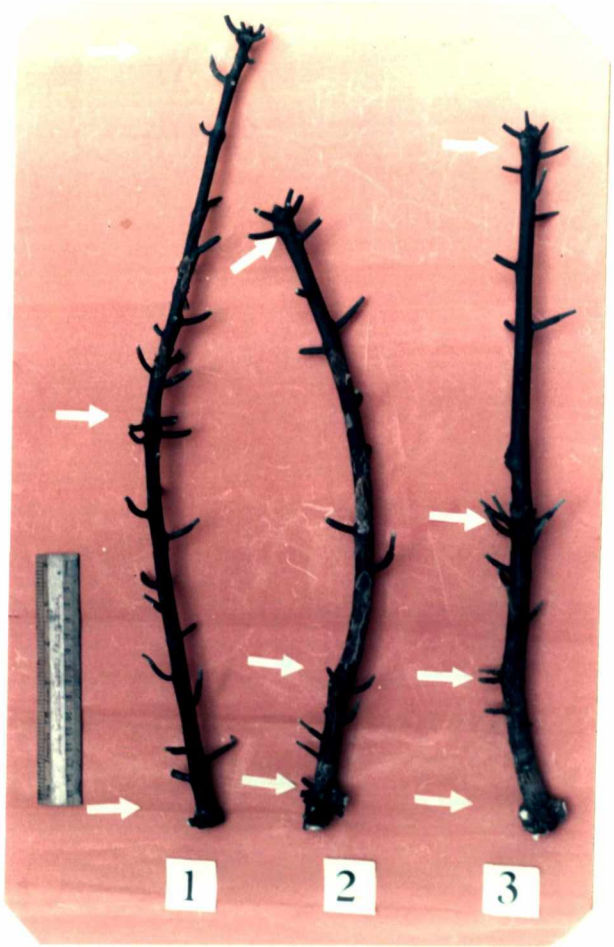
1. Control
2. Single application
3. Double application

C. Influence of single application of paclobutrazol

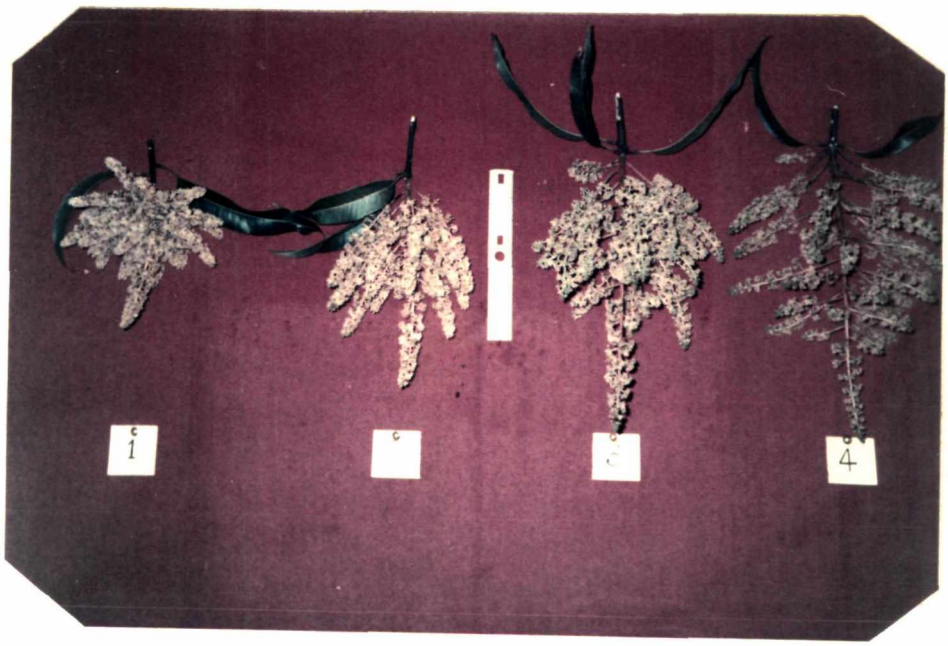
1. 10.0 g ai/tree
2. 5.0 g ai/tree
3. 2.5 g ai/tree
4. Control

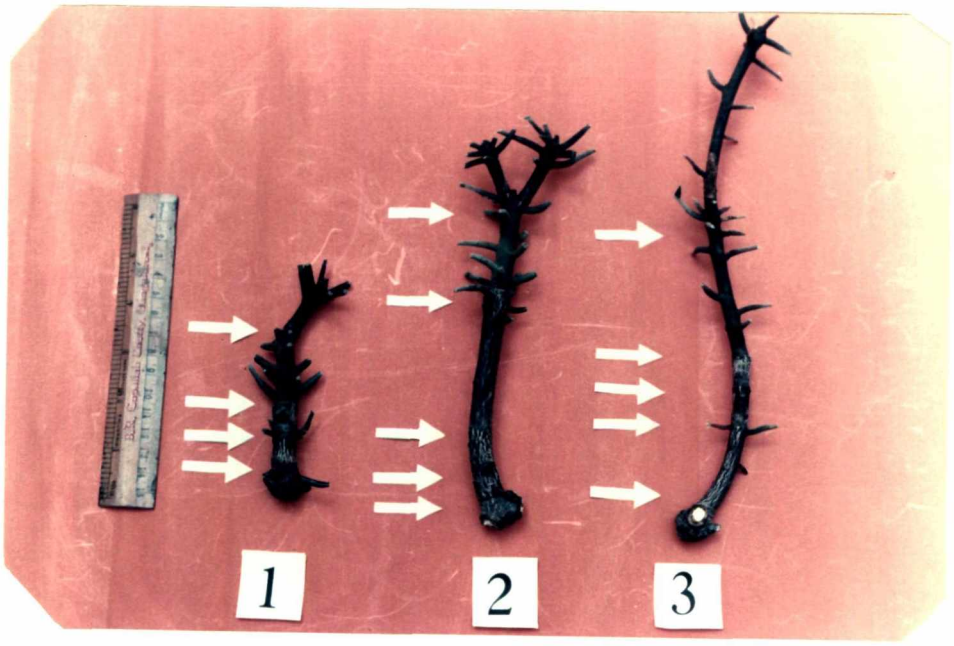
(White arrows are used to demarkate the different flushes. Please note that in the case of Alar and cycocel, the reduction in length and internodal length of flushes were evident only for one season after application whereas in the case of paclobutrazol the effects were persistent)


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2
3

for the outer most vessel in untreated trees. In trees which were given 10.0 g paclobutrazol treatment, these values were only 2.2 and 3.1 respectively. Some air space, probably formed by rupture of metaxylem, was also observed in the case of sections from paclobutrazol treated trees and this was more evident at higher concentrations of the chemical (Plate 2). Such differences in the number and size of xylem vessels were not all that striking in genotypes of varying vigour (data not presented).

Thus the trees dwarfed by the application of paclobutrazol exhibited similar biochemical and anatomical characteristics as that of genetically dwarf cultivars.

DISCUSSION

CHAPTER V

DISCUSSION

5.1. MORPHOLOGICAL GROWTH COMPONENTS IN RELATION TO TREE VIGOUR IN MANGO

There are reports that various morphological growth characteristics such as expansion growth (Faust and Zagaja, 1984), internodal length, crotch angle (Zagaja and Faust, 1983), side branching and spurriness (Brown, 1975; Lapins, 1976) influence tree vigour and size in temperate fruit crops. Any study designed to understand the basis of tree size or attempts to induce size control in mango necessitates information on the various components of the growth and their relative contribution to the ultimate tree size. Hence an attempt was made in the present study to assess the variations in some of these morphological traits associated with growth in mango cultivars of varying vigour.

The data collected revealed considerable variation with reference to characters such as number of flushes produced per year, percentage of shoots giving new flushes each time, basal diameter of flushes, length of the flushes, number of nodes per flush and mean internodal length of the flushes.

No single character can be pointed out as the main growth factor responsible for the determination of tree size in mango. In fact it is a function of various characters

particularly that of percentage of shoots giving new flushes and length of these flushes. Among these characters, the maximum correlation with tree volume and per cent increase in tree volume was obtained for the mean percentage of shoots giving new flushes during each flushing season ($r = 0.718$ and 0.715 respectively).

In tropical crops like mango where growth is cyclic, expansion growth occurs in different flushes. Though the number of flushes produced by mango cultivars varied from two to five per year, it was observed that it did not have a pronounced influence on the ultimate tree size. Its correlation coefficients with tree volume and per cent increase in tree volume were only 0.210 and 0.278 respectively. Langra produced only two flushes per year whereas Kerala Dwarf produced three, though the latter was distinctly dwarfer compared to the former. The percentage flushing and the average length of flushes were two important characters in the determination of tree size. The latter revealed correlation coefficients of 0.522 and 0.526 respectively with tree volume and tree volume increase.

Diameter at the base of the flushes showed good correlation with tree size and tree size increase probably because it was highly correlated ($r = 0.954$) with the length of flushes. Number of leaves per flush was not related to tree size.

Number of nodes per flush and mean internodal length were found to have no significant influence on tree vigour and size. Until very recently, it was generally ably led that shortening of intermodes in fruit trees invariably led to reduction in vigour. However, the studies of Zagaja and Faust (1983) revealed that although short internodes were more frequent in low vigour seedlings, the opposite types - low vigour with long internodes and high vigour with short internodes were also present in a sibcross population of apple. Similar trends were observed in the present study also. Some dwarf cultivars like Rumani and Kurd had comparatively longer internodes while vigorous cultivars like Pacharisi had shorter internodes.

The reduction in tree vigour as a result of exogenous application of growth retardants, particularly paclobutrazol was accompanied by suppressions in percentage of shoots giving new flushes, length of flushes and internodal length. The number of flushes produced per year remained unaltered. The various rootstocks tried in this study did not affect the vigour of scion varieties to any considerable extent.

Though the variations in morphological growth characters and their impact on tree vigour and size have

been understood to some extent on the present study, it is not easy to explain why different genotypes show variations in these vigour components. The physiological mechanism for the vigour controlling genome action remains obscure. Some attempts are made to probe into the probable explanations for this in the subsequent pages of this chapter, on the basis of the results obtained in the present set of experiments.

5.2 PHYSIOLOGICAL BASIS OF TREE VIGOUR IN MANGO

A proper understanding of the physiological processes underlying the determination of tree vigour is essential to manipulate it to our advantage.

5.2.1 Hormonal basis

Plant hormones are extremely difficult to be quantified accurately and interpreted logically. Reliable extraction and definitive identification procedures have until very recently, been lacking. The role of plant hormones in the determination of tree vigour has not been understood properly and no work in this line has been done in the case of mango. Hence it was attempted to study the abscisic acid and cytokinin levels in relation to vigour in mango.

5.2.1.1. Abscisic acid

The mere fact that ABA is classified as a plant growth inhibitor (Milborrow, 1974) would tempt any one to suspect a role for it in the dwarfing of trees. Some early works reported lend credence to this presumption also (Yadava and Dayton, 1972; Robitaille, 1970; Jindal et al., 1974).

The results of the present experiment, however, do not support this. A vigorous cultivar, Langra, was found to have slightly higher ABA levels in its apical buds than Mulgoa, a dwarfer cultivar, during both dormant and active growth phases. The average length of the flushes in these cultivars were 30.25 and 10.23 cm respectively. Similarly, trees of the Cv. Alphonso which were given soil drenching with paclobutrazol recorded lesser shoot length and ABA content of active terminal buds compared to untreated trees of the same cultivar. So it appears that ABA is not the inhibitor responsible for vigour restriction in mango. Though these results are contradictory to the earlier findings mentioned above in the case of apple, it gains support from some recent experiments conducted elsewhere using more refined techniques for purification and quantification of ABA. Feuch et al. (1974) could not find any correlation between levels of ABA in the tissue

and dwarfing in *Prunus* trees. In apple, free Cis-ABA content in shoot tips was found to be higher in normal plants than dwarf types (Lee and Looney, 1977a, b). They have also opined that the higher inhibitor levels reported by Jindal et al. (1974) might probably be due to the fact that their bioassay techniques were sensitive to inhibitors other than ABA. Based on the current results one is inclined to agree with Looney and Lane (1984) in concluding that it is not likely that differing ABA levels could explain variations in tree size of fruit crops, particularly mango.

The two cultivars Langra and Mulgoa recorded higher ABA levels in their shoot tips during dormant season. They showed 21.03 and 14.74 times fall in ABA content respectively during active growth. Hence it appears likely that changes in ABA levels might explain the variations in the number of extension growths or vegetative flushes produced by mango cultivars per year and there are several reports confirming higher ABA levels associated with dormancy of buds in woody perennials (Milborrow, 1974; Walton, 1980). So it might be useful to study the changes in ABA levels in relation to the flushing habit of mango cultivars and hence its impact on ultimate tree vigour.

5.2.1.2. Cytokinins

In the butanol soluble fraction of mango leaf extracts, eight factors (X_1 to X_8) with cytokinin like activity were detected in both the bioassays, at elution volumes shown in Figures 7 to 10, following Sephadex L.H.20 column chromatography. The elution profiles of factors X_3, X_4, X_5 and X_7 corresponded to those of authentic Zeatinriboside, Zeatin, Isopentenyl adenosine and Isopentenyl ladenine, respectively. Factors X_1 and X_2 could be glucosides of cytokinins as these are known to elute earlier than Zeatin riboside with 35 per cent methanol as the eluent (Rao et al., 1983). The chemical nature of X_6 and X_8 are unknown.

In the butanol insoluble fraction, one zone with cytokinin like activity (Y_1) was detected in soybean cotyledon callus test with elution profiles as shown in figures 11 and 12. Rao et al. (1983) had proposed that such factors which did not partition into butanol at pH 8.0 and which were retained on Dowex-1 column equilibriated at pH 10.5 and later released by formate ion could be cytokinin nucleotide or a zeatin-amino acid conjugate viz., lupinic acid.

The role of cytokinins in the determination of tree vigour has been little explored though it has been

suggested by Lane et al. (1982) that a dwarf apple mutant probably had enhanced ability to metabolize the cytokinin excessive to its growth and developmental requirements. Response of endogenous cytokinins to exogenous application of paclobutrazol has never been studied earlier. In the present experiment, it was found that the activities of zeatin-zeatin riboside-and zeatin glucosides-like substances were considerably lower and the activity of cytokinin nucleotide and/or lupinic acid-like substances were comparatively higher in paclobutrazol treated trees than control. Letham and Palni (1983) have opined that nucleotides of cytokinins are of special significance in cytokinin metabolism-they appear to be the initial products of cytokinin biosynthesis and, in many tissues, the first metabolites formed in appreciable amounts from exogenous cytokinin bases, The incorporations of readioactive zeatin nucleotide into zeatin has been demonstrated by Stuchbury et al. (1979). Lupinic acid is an unusual cytokinin metabolite - a conjugate of zeatin with alanine (Letham and Palni, 1983). From the results of the present study, it appears that paclobutrazol treatment possibly prevent the conversion of zeatin necleotide to zeatin. This might account for the lower levels of zeatin - zeatin riboside- and zeatin glucosides - like compounds in the paclobutrazol treated trees and also the higher level of cytokinin nucleotide in the same.

It is a well established fact that cytokinins promote cell division in plants (Skoog and Armstrong, 1970). The reduced rate of cell division resultant of lower cytokinin levels can be one of the causes for the suppressed vegetative growth in response to paclobutrazol treatment.

However, while discussing phytohormones in relation to any growth and development process, the relative proportion of various hormones should be kept in mind more than absolute quantities of individual ones. Lee and Looney (1977b) and Gorochowska et al. (1984) have pointed out the need for such an approach in relation to tree vigour also. Paclobutrazol is known to be an inhibitor of Gibberellin biosynthesis also (Anon., 1984) and the reduced extension growth observed in paclobutrazol treated trees could be due to reduced gibberellin levels also. Or it may be even due to the imbalance in the ratio of these various hormones. More elaborate studies are needed to specifically pinpoint the physiological effects of paclobutrazol.

5.2.2. Leaf area and stomatal density

Leaves are the organs associated with photosysthesis and stomata are the pores through which carbondioxide enters the leaf mesophyll cells for photoreduction. Hence it is natural to expect that an

increase in leaf area and stomatal density would result in an increased rate of photosynthesis and hence tree vigour in mango cultivars. Vigorous rootstocks were found to have greater leaf area than that of the dwarfing ones in citrus (Mandge, 1978; Shinde, 1982; Agarwal, 1986). Positive linear relationship between stomatal density and known effect of rootstocks on scion vigour was identified in the case of apple (Beakbane and Majumder, 1975) and Plum (Pathak et al., 1977).

Attempts were made in the present investigation to see whether these parameters are associated with the vigour of mango scion varieties also. It was found that in general, leaf area per leaf as well as per flush were comparatively more in more vigorous cultivars and less in less vigorous ones. However, exceptions to this were also noted. These parameters showed highly significant positive correlations with vigour characteristics such as percentage of shoots giving new flushes, length of flush, number of nodes per flush, tree height, tree spread, tree volume and per cent increases in last three characters.. The correlation coefficients of these two parameters with per cent increase in tree volume were respectively 0.608 and 0.546. Growth retardant treatments which brought about a decrease in tree vigour, particularly paclobutrazol treatments, also brought about a parallel reduction in leaf area per flush.

Leaf area is very easy to determine compared to other characters like phloem to xylem ratio, phenolic content, stomatal density etc., and the time and efforts required is also considerably less. But since their correlation with vigour and tree size are not very strong, error of prediction could be high while employing these characters for the forecast of tree vigour. However, it may serve as a simple tool for making first assessment of tree vigour to enable the fruit breeders to select relatively few genotypes from very large population in the shortest practicalbe time or to eliminate rapidly the most unwanted types.

No positive linear relation between stomatal density and tree vigour characteristics were evident in this study. On the contrary, stomatal density exhibited non-significant negative correlations with the vigour characteristics of mango cultivars. Its value was least in Kerala Kalepad, a very vigorous cultivar and maximum in Creeping, a less vigorous cultivars. Also, it was found that treatment with growth retardants, particularly paclobutrazol, resulted in an increase in stomatal density, though statistically non-significant, along with reduction in vigour of trees. A probable reason for this could be the reduction in leaf expansion as a result of these treatment. It may be noted that these treatments brought about a reduction in leaf area too.

Hence it was thought that it would be more meaningful to calculate the number of stomata per flush, and this showed significant positive correlations with vigour components like number of nodes per flush and height spread and volume of trees. It had highly significant positive correlation only with per cent increase in tree height. Hence from the present study, stomatal distribution does not appear to be a useful criterion to predict the vigour of mango genotypes.

Srivastava et al. (1980) had studied the stomatal density in mango varieties. In their studies also,stomatal density was minimum (8.93/field) in Kalepad and maximum (17.68/field) in Dashehari. Based on stomatal density, they classified the rootstocks under their study in to three vigour groups, but the results of some long range rootstock trials in the field (Reddy, 1986; Srivastava and Sinha, 1986) are not in confirmity with that classification. Frequency of stomatal distribution has been suggested for selection and classification of mango rootstocks in the nursery stage by Chakladev (1967) and Majumder et al. (1972) also but this too lack backing up from actual field trials. Though Bang (1970) observed that vigorous citrus rootstocks had more stomata on their leaves than dwarfing ones, Agarwal (1986) could not obtain any definite relationship between stomatal density and vigour in citrus rootstocks. Slack (1974) found that there

was considerable variation in stomatal distribution over the surface of single leaf as well as between leaves of the same variety and also between seasons and orchard types; and that these variations did not show any systematic pattern in apple. Salisbury (1927) showed that in woodland flora, the stomatal densities were highest near leaftips and lowest near the petioles and increased from midrib to leaf margin. He concluded that stomatal density was mainly a function of humidity, high values being associated with dry conditions and low with humid conditions.

From the foregoing discussion, it could be concluded that stomatal density is not a very reliable or consistent character to be employed in the prediction of vigour in the case of mango.

5.3 BIOCHEMICAL BASIS OF TREE VIGOUR IN MANGO

The finding in this investigation that ABA might not be the inhibitor responsible for vigour regulation in mango as has already been discussed, prompted a study of the role of phenols in this respect. A number of phenolic compounds are known to inhibit plant growth (Thimann, (1977) and phenols are known to inhibit growth of hypocotyls, roots and stems (Lockard and Schneider, 1981).

The total phenolic content of apical bud was distinctly higher in less vigorous cultivars and low

in more vigorous cultivars with medium vigorous cultivars showing intermediate values. It ranged from 19.33 mg per g fresh weight in Pacharisi to 56.00 mg per g fresh weight in Kerala Dwarf. Phenolic content of shoot tip revealed highly significant negative correlations with tree vigour characteristics like percentage of shoots giving new flushes, length of the flush, number of nodes per flush leaf area, height, spread and volume of tree as well as per cent increases in last three. Increasing concentrations of Paclobutrazol caused a marked linear increase in phenolic content in the terminal buds of Alphonso variety concurrent to the reduction in vigour of the trees. It was also found that the various rootstocks tried did not affect the vigour and phenolic level of scion varieties considerably.

These results indicate that higher total phenolic content of apical buds is associated with reduction in vigour and dwarfing in mango. This finding is in agreement with other reports. There is evidence to suggest that higher phenolic levels are inhibitory to growth and is related to dwarfing in fruit crops like apple (Messer and Lavae, 1969; Chiang et al. 1979) and citrus (Mendeland Cohen, 1966; Mendel, 1969). In mango, the total phenolic content in the bark of non-flowering terminals indicated a definite inverse relationship with growth vigour, showing

correlation coefficients of -0.7617, -0.7690 and -0.8598 with tree height, N-S spread and E-W spread respectively (Babu et al., 1985). It has been proposed that phenolic content could be employed to predict the vigour in citrus (Mendel, 1969) and mango (Babu et al., 1985). In the current study, total phenolic content of apical bud had very strong correlation coefficients of -0.872, -0.868 and -0.758 with tree height, spread and volume respectively and -0.868, -0.864 and -0.870 respectively with per cent increases in these. Hence total phenolic content of apical bud seems to be a very good tool for prediction of vigour in mango genotypes.

It is premature to pinpoint the mechanism by which higher levels of phenols bring about a dwarfening effect in mango. The higher concentrations of phenols appear to inhibit extension growth by inhibiting cell division and cell elongation as proposed by Swensson (1971). The reduction in cell division is due to a direct inhibitory effect on mitosis, probably retarding the formation and stretchability of microtubules of spindle fibres; and reduction in cell elongation is due to its action as sulfhydryl inhibitors, altering the stretchability and orientation of the cellulose microfibrils of cell wall

(Swensson, 1971; 1972). It has been also postulated that reduction in cell elongation brought about by phenols could be through lowering endogenous auxin levels (Lee and Skoog, 1965; Letham, 1978) by promoting its oxidative carboxylation by IAA oxidase enzyme (Zenk and Muller, 1963).

Even in the absence of a sound physiological explanation, it can be concluded with a fair degree of confidence, from the foregoing discussion that higher phenolic content of apical buds do have a definite role in the dwarfing of mango trees and that this character can be employed in the rapid screening of genotypes for the vigour. In addition, it is also necessary to find out means by which phenols levels could be raised in plants to bring about size control. Further research on phenolics in relation to growth habit of mango and indentification of predominant phenolic compounds in mango would be of fundamental and applied interests.

5.4 ANATOMICAL BASIS OF TREE VIGOUR IN MANGO

Anatomical studies conducted in the present study on genotypes of varying tree vigour as well as trees dwarfed by paclobutrazol treatment revealed a possible role of high phloem to xylem ratio of stem in dwarfing of mango trees.

Among the genotypes studied, the radial width of half pith or radial width of cortex did not show any direct relationship with tree vigour. However, striking differences were observed in the case of primary xylem and primary phloem tissues. Generally speaking, the less vigorous cultivars showed lesser radial width of primary xylem tissue and more radial width of primary phloem tissue; and in the case of more vigorous cultivars the situation was just the reverse. This resulted in a higher phloem to xylem ratio in dwarf cultivars and a lower ratio in vigorous ones. Medium vigour cultivars showed intermediate values. The only exception to this general trend was in the case of Creeping. The minimum phloem to xylem ratio (0.329) was observed in the case of Maharaj Pasand and maximum (2.002) in the case of Kerala Dwarf. This parameter showed highly significant negative correlations with vigour characteristics such as percentage of shoots giving new flushes; length, number of nodes and internodal lenght of flushes; leaf area; height, spread and volume of trees; and per cent increases in tree height spread and volume. Its correlation coefficients with the last six characters mentioned were found to be -0.884, -0.908, -0.749, -0.915, -0.819 and -0.834 respectively. So determining the phloem to xylem ratio of stem can be a good technique for predicting the vigour

of mango genotypes. Results in accordance with this finding were reported by Jumein and Faust (1984). They found that higher phloem to xylem ratio was associated with dwarf phenotypes of apple in an F_2 population of Delicious x Golden Delicious. They also reported fewer xylem vessels and narrower lumen for xylem vessels in dwarf phenotypes but there was no striking difference in number and size of xylem vessels in association with tree vigour evident in the present study. Recording of higher phloem to xylem ratio in association with dwarfing potential of rootstock was also made in apple (Beakbane and Thompson, 1939; Beakbane 1941) citrus (Bang, 1970) and mango (Singh et al., 1986).

It was also noted in the present study that paclobutrazol treatments which resulted in reduced vigour of Alphonso trees also brought about a parallel enhancement in phloem to xylem ratio. The number of xylem vessels per vascular bundle and lumen size of metaxylem vessels were progressively reduced by increase sing concentrations of this chemical leading to a decrease in the width of the premary xylem tissue. At the same time, width of the primary phloem tissue was found to increase. All these resulted in a higher phloem to xylem ratio in response to soil drenching with paclobutrazol. Halfacre and Barden

(1968) reported that in apple, spraying of increasing concentrations of Alar progressively decreased the radial diameter of xylem vessels and number of xylem cells accompanied by considerable dwarfing of sprayed shoots. jumein (1981) obtained similar results by spraying 5000 ppm chloromequat on the terminal shoots of Pear. Thus all these inhibitors of gibberellin biosynthesis seem to have a common mode of action in limiting extension growth in fruit trees.

In this study, it was observed that the width of pith also showed a reduction as the concentration of paclobutrazol increased. Interestingly, only the tissues which were radially inner to the cambial ring showed suppression of growth while the growth of tissues outer to the cambial ring was either enhaced or unaffected. It is a well established fact that xylem and phloem tissues are differentiated from the vascular cambium (Wodzicki and Brown 1973). The differential effect of paclobutrazol on the development of these two conducting tissues from the same meristematic cells is difficult to explain. It is known that movement of paclobutrazol within the plant is acropetal through xylem and there is no phloem mobility for the chemical (Anon, 1984). So it is likely that higher concentration of paclobutrazol within the stem, after uptake,

occurs on the xylem side of cambial zone and this may inhibit the division of xylem mother cells towards that side, probably by enhacing the level of phenols or by lowering the level of active cytokinins as already discussed, while phloem mother cells on outer side of cambial zone multiply normally or even at a faster rate. The enlargement of parenchymatous cells of the pith could also be inhibited due to the same reason. The statement of Holl (1975) that ray parenchyma cells transport nutrients and water really between phloem and xylem might appear to be a serious objection to this explanation. But it is known that the differentiation of rays generally occur at a later stage of ontogeny after the differentiation of primary xylem and phloem (see Wodzicki and Brown, 1973) and hence this objection can be overruled.

The poorly developed xylem in the new flushes may restrict the nurtient supply for these flushes thereby limitimg their growth. At the same time the better developed phloem in these shoots may permit more efficient translocation of metabolites to panicles and developing fruits which could be one of the reasons for higher productivity and restricted vegetative growth in response to paclobutrazol treatment as well as in the case of less vigorous cultivars. It is known that paclobutrazol causes reduction in vegetative growth by altering relative sink strengths

within the plant, allowing a greater partitioning of assimilates to reproductive growth, flower bud differentiation, fruit formation and fruit growth (Anon., 1984).

The present finding that a higher phloem to xylem ratio has a definite role in the dwarfing of mango trees could be used for the prediction of vigour also. It would be interesting to study how exactly higher phloem to xylem ratio results in dwarfing of trees.

5.5. YIELD IN RELATION TO TREE VIGOUR IN MANGO

Precocity and preductivity as known to affect tree size in fruit crop (Tukey, 1970; Jackson, 1984). In the present study it was observed that productivity expressed as yield per unit space occupied by trees (kilograms of fruit per cubic meter) was higher for least vigorous and medium vigorous cultivars compared to most vigorous ones. In a very vigorous cultivar, Langra, it was as low as 0.052 kg/m^3, while a maximum productivity of 1.901 kg/ m^3 was recorded for Kerala Dwarf. Productivity of cultivars had highly significant negative correlations with vigour components like percentage of shoots giving new flushes, length of the flush, number of nodes per flush, leaf area, tree size, per cent increase in tree size etc. In experiments with paclobutrazol also, coulped with a drastic suppression of vegetative growth a marked increase

in fruit yield was observed in the case of Alphonso trees. The suppression in vegetative growth was evident in terms of percentage flushing, and length and internodal length of flushes mainly. Increased yield was resultant of more flowering, higher proporation of hermaphrodite flowers and higher fruit set and retention. It is reported that paclobutrazol limits vegetative growth through altering relative sink strengths within the plant so that the assimilate partitioning to the reproductive structures is enhanced (Anon., 1984). Thus it is quite likely that paclobutrazol enhanced flowering and fruit yield indirectly by checking the vegetative vigour. Pacolbutrazol has been reported to have the same effect on vegetative growth and yield in other fruit crops like apple (Williams, 1984) pear (Kruken and Lindemberg, 1984) and many temperate crops (Anon., 1984).

The finding that productivity of trees is inversely related to tree volume and vigour would lead one to conculde that (i) higher yield per unit space can be obtained by planting dwarf or medium sized cultivars of mango, and (ii) The higher productivity itself act as a check on further vegetative growth leading to dwarfing in the case of mango.

It is widely accepted in the case of pereninal fruit crops that cropping influences tree vigour to that very

heavy cropping is usually accompanied by very decreased vegetative growth in the same year with reduced dry weight increments of leaves, trunks, stems and roots whereas failure to crop leads to excess vigour (Jackson, 1984). Tyagi (1986) reported that dwarfism in fruit trees as such leads to higher productivity due to lesser competition between developing fruits on the one hand and other alternative sinks such as trunk, branches and other supporting-stuctures on the other, better utilization of incident soalr radiation and more efficient translocation of assimilates from source to sink. Tukey (1970) has consolidated the works on these lines in the case of apple and has stated that dwarfed fruit trees will outbear standard sized fruit tree as former produced more fruits with a lower leaf/fruit ratio; as well as that fruiting as such is a dwarfing process and bearing of fruits itself is responsible for smaller tree size. Thus there is evidence in the literature supporting both the above conclusions.

5.6. PREDICTION OF TREE VIGOUR IN MANGO AND SIGNIFICANCE IN MANGO BREEDING

Till very recently mango breeders had no appreciation of low vigour scion varieties and attempts made to develop such varieties are scarce barring the example of the release of the dwarf variety Amrapalli (Majumder *et al.*,

1982). Though interest in the ornamental value of dwarf fruit trees dates back to medieval ages (Hugard, 198o), scientific interest started to develop in dwarf cultivars of fruit crops only after the realisation of the various advantages of high density planting systems in the Nineteen sixties. The need for developing dwarf scion varieties of mango was very much stressed by Iyer (1985) particularly in light of our inability to identify a commercially acceptable polyembryonic dwarfing rootstock so far.

A major hurdle faced in the hybridization programmes for developing hybrids with dwarf tree stature is the large size of hybrid population that has to be raised and evaluated. The tree vigour components in fruit crops are generally polygenically controlled and the proportion of very dwarfed seedlings in the hybrid progeny do not exceed 20 per cent in apple and 10 per cent in pear (Zagaja and Faust, 1983). Faust and Zagaja (1984) suggested that for producing sufficient number of low vigour trees with commercially acceptable fruit in the hybrid progeny, the population size would have to be 5 to 15 times larger than when tree vigour is not a consideration. So it would be very much advantageous for fruit breeders to develop methods to predict tree vigour which would enable rapid screening of the progeny at an early stage. Attempts were made in

the present study to find the correlations of various morphological, physiological, biochemical and anatomaical characters with tree size and vigour, with a view to identify some means to enable the rapid screening of genotypes. These have been discussed in detail under the respective headings earlier in this chapter. So it is intented here only to outline the selecton procedure that could be employed profitably.

If the population is very large, initial screening can be done based on leaf area to eliminate the most unlikey types. Genotypes with lesser leaf area generally tend to be dwarf. However, since the correlation coefficient of this character with tree size or vigour is not very high, it is very much likely that some desirable genotypes might also get discarded and so it will be advisable to skip this step if the population is manageably small enough to employ other more precise techniques. From the genotypes so selected, a second round of screening can be done based on phenolic content of apical bud and phloem to xylem ratio of stem. These two characters are highly correlated with tree size and vigour and so either or both of them may be employed at this stage. The error of prediction can be considerably reduced by employing both of them simultaneously. Genotypes with very high content of total phenols and high phloem to xylem ratio would most probably prove to

be dwarf in stature. Based on the variability of these characters in the genotypes of varying vigour, the following classification seems appropriate for prediction purpose.

Character	Range	Vigour group
a) Phenolic content of apical bud	40 mg/g	Least vigorous
	25-40 mg/g	Medium vigorous
	25 mg/g	Most vigorous
b) Phloem to xylem ratio of stem	1.0	Least vigorous
	0.6 - 1.0	Medium vigorous
	0.6	Most vigorous

Thus a small proportion of the whole population depending on land area and other facilities available can be selected for actual field evaluation studies.

The genotypes selected for field evaluation should be carefully assessed in the early years of their growth for their morphological characters such as number of flushes produced per year, percentage of shoots giving new flushes each time, length of flushes etc. as well as yield character such as precocity and productivity. Trees with excessive

vegetative growth, long juvenile phase and lower productivity can be discarded if needed. After maintaining these genotypes for a few years in the field, their future tree volume can also be predicted based on a mathematical model derived based on regression analysis on this study. This model is demonstrated in the case of representative cultivars from each of the three vigour groups below.

(a) Kerala Dwarf

$$Y = -39.427 + (21.384 \times 3) + (2.328 \times 12) - 12) -$$

$$(0.855 \times 8.1) - (6.934 \times 1.901) = 32.55\%$$

Tree volume in 1986 = 2.11 m^3

$\therefore$ Expected tree volume in 1988 $= 2.11 + \frac{(2.11 \times 32.55)}{100}$

$= 2.797\ m^3$.

Actual measured tree volume in 1988 = 2.63 m^3.

(b) Neelum

$$Y = -39.427 + (21.384 \times 3) + (2.328 \times 27.33) -$$

$$(0.855 \times 15.23) - (6.934 \times 0.842) = 69.61\% \quad 61\%$$

Tree volume in 1986 = 18.35 m^3

$\therefore$ Expected tree volume in 1988 $= 18.35 + \frac{(18.35 \times 69.61)}{100}$

$= 31.12\ m^3$

Actual measured tree volume in 1988 = 31.03 m^3.

(c) Kerala Kalepad

$$Y = -39.427 + (21.384 \times 4) + (2.328 \times 44.17) - (0.855 \times 17.85) - (6.934 \times 0.170) = 132.5\%$$

Tree volume in 1986 = 47.61 m^3

$$\therefore \text{ Expected tree volume in 1988} = 47.61 + \frac{(47.61 \times 132.5)}{100}$$

$$= 110.69 \ m^3$$

Actual measured tree volume in 1988 = 110.06 m^3.

The coefficient of non-determination ($1-R^2$) is 0.195 for this model indicating 19.5 per cent of the variability in Y is not explained by the model and hence the predictions can go wrong in a few cases as is with Kurd in this study. Still this regression equation may be employed if it is felt that it would be advantageous to loose a few desirable genotypes rather than to incur the additional expenditure of maintaining a large number of undesirable types in the field, which requires space, labour and other inputs.

This model had been developed based on morphological characters which are simple to record and may find application also in rootstock evaluation programmes, developing tendative spacing recommendations for newly developed

hybrids in HDPS etc. It would be of great practical utility to see whether the predictions of tree size and vigour made on the basis of these different characters hold good under varying agroclimatic conditions.

Since the vigour components in fruit trees are mostly quantitative in nature, it is also hoped that the chances of getting more proportion of dwarf seedlings in the hybrid progeny may be enhanced by selecting parents with higher phenolic content, productivity and phloem to xylem ratio and lesser leaf area, percentage flushing and length of flush.

5.7. INFLUENCE OF ROOTSTOCKS ON THE VIGOUR OF A DWARF AND A VIGOROUS SCION

Several mechanisms for dwarfing by rootstocks such as poorly developed root system (Tukey, 1970), higher phloem to xylem ratio (Beakbane, 1941), reduced size of xylem vessels (Jumein, 1981), physiological mechanisms involving leaf size, hormonal signal between scion and stock (Lockard and Schneider, 1981a) etc. have been proposed in the case of temperate and subtropical fruit crops. More recent approaches of explanation give stress to the phenolic content of rootstocks in apple (Lockard and Schneider, 1981a; Chiang et al., 1979) and Citrus (Mendel and Cohen, 1966; Mendel, 1969). With a view to test whether these

findings hold good in the case of mango also, the effects of some open pollinated seedlings from trees of known vigour on the vigour of a dwarf and vigorous cultivar (Mulgoa and Langra respectively) were studied. These open pollinated seeds were collected from mother plants showing clear-cut variations in phenolic content, phloem to xylem ratio, morphological vigour characteristics, leaf area and stomatal density and these trees were of different tree size. Another objective of this experiment was to see whether any of the characters of mother tree could be used to predict the vigour of rootstocks obtained as open pollinated seedlings from them. With the same intention the characteristics of these seeds such as size and weight and growth vigour of seedlings were also recorded. However the rootstocks tried in the present experiment did not have any marked influence on the vigour of the scions and hence these objectives could not be satisfactorily met with. The total phenolic content of apical bud, stomatal density and vegetative vigour parameters of the scions were not affected by the various rootstocks tried. The interaction between scion and rootstock was also not significant for these characters. Hence the only valid conclusion that can be drawn from this experiment is that the vigour characteristics of grafted mango plants is mainly governed by the scion

variety and the rootstocks do not influence the scion vigour considerably. Hence more attention may be paid for developing scion varieties with restricted vigour rather than developing dwarfing rootstocks in the case of mango.

5.8. EFFECTS OF GROWTH RETARDANTS ON GROWTH AND YIELD OF MANGO Cv. ALPHONSO

The effects of soil drenching with paclobutrazol and foliar sprays of cycocel and Alar at different doses on the vegetative growth, flowering and yield of mango were studied in the present experiment. The time of application of growth retardants was selected as about three weeks before the expected flushing, so that the chemical is properly taken up and equilibriated within the plant at the time new extension growths are initiated. These chemicals were administered at the concentrations and by the applications methods proved effective in the case of temperate fruit crops like apple and pear, as no reports expect one by Vijayan *et al*. (1985) in a parellel line were found in the case of mango or other tropical crops

5.8.1. Effects on vegetative growth

All the growth retardant treatments tried in the current experiment, cycocel, Alar and Paclobutrazol brought about considerable suppression in vegetative growth in terms

of percentage flushing, length of flush, mean internodal length of flush, basal diameter of flush,number of nodes per flush, number of leaves and leaf area.

The most effective chemical in limiting vegetative growth was paclobutrazol. This chemical at all the concentrations (10.0, 5.0 and 2.5 g/tree) resulted in a drastic reduction in vegetative growth continuously for two years; the maximum reduction being effected by 10.0 g ai per tree applied twice, which parctically arrested tree growth. The per cent increase in tree volume over two years was only 8.46 in the case of trees given this treatment as against 75.89 per cent in the case of control. This concentration of the chemical irrespective of the number of applications, however, revealed some phytotoxic symptoms such as drying and die back of a few shoots, highly brittle nature of leaves and stems and crinkling of leaves in the second year of treatment. Other paclobutrazol treatment brought about more than fifty per cent reduction in the per cent increase in tree volume over two years compared to control, without any evident phytotoxicity and were on par with each other. Paclobutrazol was found more effective than stardard Alar treatments in the tree size regulation of bearing apple tree (Quinlan, 1981; Stinchcombe et al., 1984). Williams (1984) found that one soil application of paclobutrazol controlled terminal shoot growth of apple cultivars for several

seasons; and Marini (1984) reported that shoot growth of peach trees was suppressed progressively by increasing concentrations of paclobutrazol for two years. Reports regarding reduction of leaf size (Greene and Murray,1983) and leaf area (Wieland and Wample, 1985) as a response to paclobutrazol treatment can also be found in the literature. Similar trends were observed in the persent study too.

Alar and cycocel have been extensively used to control the vigour of fruit trees in bearing stage in temperate fruit crops (Kolbe, 1983; Jaumein, 1983; Indenko and Smagin, 1984; Bliek, 1985; Coman and Stan, 1982; Bencat et al., 1984 etc.). In the present study, the effectiveness of cycocel and Alar in checking vegetative growth lasted only for one season after application especially at at lower concentrations. The effects of these chemicals slowly dessipated in the subsequent flushings. Hence repeated application was found to be needed to maintain the reduction in vigour. The highest concentrations of these two chemicals brought about nearly fifty per cent reduction in per cent increase in tree volume compared to control, when applied twice.

From the present study it can be concluded that soil drenching with paclobutrazol at the rate of 2.5 g ai

per tree once in November and again in March can control vegetative growth and tree size for two years.

5.8.2. Effects on flowering and fruit set

In the first year of treatment, all paclobutrazol treatments resulted in an increase in the extent of flowering in terms of percentage of shoots producing panicles. In the second year also, these treatments except single applications of 2.5 ai per tree led to enchanced flowering. The increase in the extent of flowering caused by single application of paclobutrazol at 2.5 g ai per tree was not significant.

Cycocel and Alar treatments also resulted in a non-significant increase in the extent of flowering in the first year, but in the following year led to reduced flowering compared to control. These chemicals, particularly paclobutrazol, slightly advanced the flowering time also. The panicles were shorter on trees which were given growth retardant treatments which also increased the number of primary branches per panicle in the first year but decreased it during the second year. Internodal length of the panicle was reduced in the first season by all growth retardant tretments and in the second year by all paclobutrazol treatments as well as double application of 4000 ppm cycocel. The latter group of

treatments reduced the panicle spread also. All treatments except lower concentration of Alar showed a general tendency to boost the proportion of hermaphrodite flowers, and higher rates of the chemicals, especially paclobutrazol, tended to reduce the pollen fertility in both the years. However, mango being a cross pollinated crop (Singh, 1978) this slight reduction in pollen fertility have not adversly affected the fruit set. In fact, fruit set was generally higher on the treated trees in the first year, both at pea stage and at marble stage. All paclobutrazol treatment and higher doses of Alar exhibited the same tendency in second year also. The best treatment as far as increased fruit set was concerned proved to be the lowest concentration of paclobutrazol. Paclobutrazol at 10.0 g, ai/tree resulted in decreased fruit retention whereas Alar and lowest concentration of paclobutrazol tended to increase fruit retention. As a consequence, the number of fruits per panicle at the time of harvest were more on trees which received lower doses of paclobutrazol treatment in both the years. The higher concentration of Alar showed a strong but non-significant tendency to promote the number of fruits per panicle at harvest in both the seasons.

Fortes (1984) found no effect of Alar on flowering and fruit drop in apple trees. As per Castro et al. (1984) Alar applications reduced fruit drop in apple. Ramirez and Hoad (1984) found that spraying apple trees 2000 ppm Alar increased flowering in the following year; and Kashyap et al. (1983) reported that Alar induced early flowering in apple. Alar was not as effective as cycocel in inducing early flowering in pear cultivars (Grasuland, 1983) and the latter chemical was found effective in enhancing flowering in ringed branches of mango cv. Langra (Rath et al., 1982). Cycocel at 6000 ppm promoted profuse flowering in mango cv. Neelum (Vijayan et al., 1985) also.

According to Church et al. (1984) paclobutrazol sprayed at bud burst or at petal fall reduced fruit set in apple. However, Greene and Murray (1983) observed that post bloom application of 1500 or 3000 ppm paclobutrazol increased fruit set without affecting flowering in the following season. Krieken and Lindenbergh (1984) found that Paclobutrazol but not cycocel enhanced flower bud numbers in pear. Increased flower density (number of flowers per m. shoot length) resulted from an early spring spray of 0.2 per cent paclobutrazol in peach trees, but in spite of this, higher concentrations of the chemical brought about a decrease in fruit density (number of fruits per m

shoot length) due to a decrease in fruit set and retention, as per a report by Marini (1986). Thus there are several conflicting reports regarding the influence of growth retardants on flowering and fruit set on fruit crops.

However, in this experiment, some distinct trends were evident in both the years. Soil drenching with paclobutrazol resulted in early and profuse flowering, the effect showing a linear trend with concentration. Fruit set and fruit retention were higher in trees which were given soil drenching with paclobutrazol at 2.5 g ai/tree, probably due to the higher proporation of hermaphrodite floweres resulting from the treatment. The higher concentration of this chemical however had a detrimental influence on fruit retention. The growth of the inflorescence was also suppressed as a result of paclobutrazol treatment. Alar and cycocel also showed similar trends but were not as effective as paclobutrazol. The former chemical also had a strong tendency to increase flowering and fruit set, especially in the first year after treatment. The effects of Alar and cycocel on flowering and fruit set were not very much evident on the second year and infact cycocel revealed some adverse effects during the second year, as far as extent of flowering and fruit set were concerned.

5.8.3. Effects on yield and quality of fruits

Yield in terms of number or weight of fruits per tree was enhanced in both the years by single or double application of paclobutrazol at 2.5 or 5.0 g ai/tree, the best treatment being double application of the lower concentration. It brought about 94.67 per cent and 95.96 per cent increase in fruit weight per tree over control in the first and second year respectively. Single or double application of Alar at 3000 ppm also tended to increase fruit yield, but the increment over control were not significant. However the highest concentration of paclobutrazol i.e. 10.0 g ai/tree resulted in a considerable decline in yield in both the years probably due to the reduced leaf area and phytotoxic effects. Cycocel treatments did not influence fruit yields.

Alar or cycocel at 3000, 4000 and 5000 ppm did not increae yield (Hricovsky and Gajdosechova, 1984), but Alar at 6000 ppm increased yield (Kashyap et al. 1983) in apple. Alar but not cycocel increased yield in plum (Coman and Stan, 1982). Spraying cycocel at 3 l per hectare increased yield in pear (Monin and Paques, 1984) and at 0.6 per cent twice in apple (Agafonov et al., 1984). Cycocel was ineffective in increasing yield of pear when applied at 0.25 per cent (Bliek, 1985) and caused a decline

in fruit yield at 1000 or 2000 ppm in the same crop (Grasuland, 1983). There are several reports that paclobutrazol enhanced yield in several temperate fruit crops (Anon., 1984) like apple (Williams, 1984), pear (Krieken and Lindenberg, 1984) etc.

As far as the fruit quality was concerned, higher doses of paclobutrazol resulted in a considerable decline in fruit size in terms of average weight and volume of fruits. The lower rates of cycocel and Alar tended to increase these two physical parameters, but the influence was not significant. Other physical characters like specific gravity, weights of stone, skin and pulp as well as pulp to stone + skin ratio remained unaltered by the treatments. There are reports that growth retardent treatments like that of Alar (Fortes, 1984) and paclobutrazol (Greene and Murray, 1983; Greene, 1986) reduce fruit size in apple. But at lower concentrations fruit size was found to be reduced by Alar but not paclobutrazol (Quinlan, 1981; Williams, 1984).

Highest doses of paclobutrazol and Alar treatments adversely affected T.S.S. of fruits while lowest concentration of paclobutrazol brought about a non-significant increase in T.S.S. In comparision with control, the growth retardant treatments did not affect the chemical parameters

like titrable acidity, T.S.S. to acid ratio and sugar content of fruits. The sugar to acid ratio was however drastically reduced by paclobutrazol at 10.0 g ai/tree. Higher doses of paclobutrazol and Alar also delayed the ripening of harvested fruits. Greene (1986) also observed that paclobutrazol retarded ripening in apple fruits as measured by the onset of ethylene climateric due to increased flesh calcium content and fruit firmness; and decreased soluble solids of fruits. Reduction in soluble solids of fruits in response to paclobutrazol treatment was recorded by Greene and Murray (1983) too. Fortes (1984) reported that Alar at 3000 ppm delayed ripening and reduced sugar content in apple, but acidity remained unaffected.

5.9. MECHANISM OF ACTION OF PACLOBUTRAZOL

Paclobutrazol as well as Alar and cycocel are reported to be inhibitors of gibberellin biosynthesis (Wiley *et al.*, 1970; Anon., 1984). Paclobutrazol retards the formation of Kaurene - 19 - of from Kaurene.

In the present set of experiments, it was found that paclobutrazol also reduces the level of butanol soluble cytokinins, possibly by inhibiting the conversion of zeatin nucleotides to zeatin riboside. The ABA levels in the shoot tips of paclobutrazol treated trees was found to be lower than that of control trees. The reduced content of these plants

hormones may also be the ways by which the chemical brings about growth retardation or can merely be due to the reduced growth vigour of trees particularly that of roots and leaves, we are not able to specify. Treatment with paclobutrazol resulted in a considerable enhancement in the total phenolic content of terminal buds and higher phenolic levels are known to be inhibitory to plant growth (Lockard and Schneider, 1981a). The growth reduction brought about by paclobutrazol could be due to the altered proportion between these endogenous growth promotors and inhibitors.

The chemical was also found to modify the phloem to xylem ratio of stem, probably by inhibiting the division and enlargement of xylem mother cells. These alterations in the proportion of xylem and pholem tissues may also have a major role in restricting vegetative growth and enhancing flowering and yield by altering the patterns of nutrient supply for new growth and assimilate partitioning.

Gibberellins have been shown to be powerful modifiers of sex expression, particularly in cucurbits and their effect is to favour the production of staminate flowers. By careful manipulation of GA level either by application of GA or by addition of inhibitors of GA biosynthesis sex ratio can be changed (Jones, 1973). The reduced

endogenous GA levels as a result of paclobutrazol can be the possible explanation of higher proporation of hermaphrodite flowers observed on treated plants. This in turn may result in higher fruit set and thereby higher yield. However, higher concentrations of paclobutrazol have a detrimental effect on yield due to phytotoxicity and severe growth inhibition.

5.10. CONCLUDING REMARKS

In the present set of experiments, it was found that higher total phenolic content of apical buds, higher phloem to xylem ratio of stems and smaller leaves were associated with dwarfing in mango; and hence it is proposed that these characters can be used to perdict vigour and there by enable the screening of genotypes for tree vigour and size at an early stage. Morphological growth characteristics like percentage of shoots giving new flushes and length of flushes were also related positively, with tree vigour and size; and a mathematical model to perdict tree volume based on easy to record morphological traits has been projected. Productivity was found to be inversely related to tree size and vigour in mango cultivars.

Results of the present study indicated that rootstocks may not have much influence on the vigour of grafted

plants in the case of mango which appears to be mainly governed by thescion variety. Soil drenching with paclobutrazol at the rate of 2.5 g ai per tree once in November and again in March checked vegetative growth continuously for two years and resulted in higher yields without any adverse effects on fruit quality. Though a higher dosage of 10.0 g ai per tree was more effective in restricting tree size, it had some phytotoxic effects and resulted in lower yields. The growth controlling effects of lower concentrations of paclobutrazol (2.5 and 5.0 g ai/tree) completely dessipated by third year and the shoots produced during January - February flushing of 1989 were almost as long as those on control trees. The inflorescence and shoots produced on trees which were given this chemical treatment at the rate of 10.0 g ai per tree were somewhat condensed in the third year also (data not presented). Paclobutrazol had multifacial influence on the physiology of the trees. From the persent study, soil drenching with paclobutrazol at the rate of 2.5 g ai/tree during November and March every alternate year seems to be recommendable for chemical regulation of tree size in young, bearing mango trees. However the effectiveness of annual application of this concentration once during November as well as that of some lower concentrations may also be studied before making the final recommendation.

SUMMARY

CHAPTER VI

SUMMARY

The present study was designed to obtain information on various morphological growth components contributing to tree vigour, understanding the physiological biochemical and anatomical bases of tree size control in mango and possibilities of chemical modification of tree vigour and size. The results of this investigation carried out at the Indian Institute of Horticultural Research, Bangalore, are summarised in this Chapter.

6.1. Several morphological, physiological anatomical and biochemical characters were assessed in relation to tree vigour and size in twenty four mango cultivars, eight each from dwarf, medium and vigorous categories. The data revealed considerable variation in these characters among the genotypes.

6.1.1. Among the morphological growth characters, the mean percentage of shoots giving new vegetative flushes and the average length of flushes were highly correlated with tree size and vigour. This indicated the need to give emphasis on these characters in programmes designed to modify the tree size in mango. Number of flushes per year and number of nodes and mean internodal length of flushes did not influence tree size or vigour considerably.

6.1.2. It was observed that dwarfer cultivars generally produced smaller leaves than vigorous ones. Leaf area per

flush and per leaf showed good correlation with tree size and vigour. No relationship between stomatal density and tree vigour characteristics were evident in this study.

6.1.3 Results of the present study indicated that higher total phenolic content of apical buds was associated with reduction in vigour and dwarfing in mango. It exhibited a strong negative correlation with tree size and vigour.

6.1.4. Anatomical studies conducted revealed that higher phloem to xylem ratio is one of the main factors associated with dwarfing in mango. This character exhibited strong inverse relation with tree size and vigour.

6.1.5. Productivity was found to be inversely related to tree size and vigour indicating that higher productivity leads to dwarfing and/or dwarfer genotypes tend to be more productive.

6.1.6 It has been suggested that characters such as leaf size, total phenolic content of apical bud and phloem to xylem ratio could be employed for prediction of vigour and hence screening of mango genotypes for dwarfness at an early stage.

6.1.7. A linear regression model to predict the tree volume based on easy to record morphological traits has also been proposed.

6.2. Results of experiments conducted using certain rootstocks gave some indications that the vigour of grafted mango plants was governed mainly by the scion cultivar and that it was not much influenced by rootstock. Though the experiment was conducted only for two years, strong evidence to support this comes from the fact that in addition to lack of differences among morphological vegetative parameters, no differences were found in the phenolic content among various treatments, though significant variation was found between the scion varieties.

6.3. To study the possibilities of chemical regulation of tree size in mango during the early bearing phase, three chemicals namely cycocel, Alar and paclobutrazol were tried at various doses. Of these former two were given as foliar spray and paclobutrazol as soil drech. The effects of these treatments on the vegetative grwoth, flowering, yield and fruit quality were studied for two continuous years.

6.3.1. All the growth retardant treatments tried in this experiment brought about a considerable decrease in vegetative growth. The most effective chemical in this regard was paclobutrazol which @ 10.0 g ai/tree almost arrested expansion growth, but had some phytotoxic effects. The two lower concentrations of paclobutrazol (i.e. 2.5 and 5.0 g

ai/tree) brought about more than fifty per cent reduction in tree vigour as compared to the control and checked the tree size for two years. The higher doses of cycocel and Alar (i.e. double applications of 8000 and 3000 ppm respectively) also checked increase in tree volume effectively. All chemicals mediated tree size control through reducing percentage of shoots giving new flushes and length and internodal length of flushes. There were differences among the chemicals with regard to the persistence of their effects. While the effect of paclobutrazol lasted for two years, in the case of Alar and Cycocel it was only for one season indicating the need for repeated application every season.

6.3.2. Flowering was enhanced by all paclobutrazol treatments in the first year of application. In the second year also, these treatments except single application of lowest concentration (2.5 g/tree) brought about significant increases in extent of flowering. Cycocel and Alar treatments resulted in non-significant increases in extent of flowering in the first year but led to reduced flowering during second year. These treatments, especially paclobutrazol slightly advanced the time of flowering, and resulted in condensed panicles. All growth retardant treatments except lower concentration of Alar in general enhanced the proportion of hermaphrodite flowers.

paclobutrazol at higher concentrations decreased pollen fertility.

6.3.3. Fruit set and retention during both years was promoted by 2.5 g paclobutrazol per tree. Alar treatments also showed a tendency to boost fruit set and retention. The highest concentration of Paclobutrazol however had a detrimental influence on fruit set and retention wheras cycocel treatments did not influence these parameters considerably.

6.3.4. Fruit yield was considerably enhanced by single or double applications of paclobutrazol at 2.5 or 5.0 g ai/tree. The lower concentration incresed fruit yield by 94.67 and 95.96 per cent respectively in the first and second years, when applied twice. Application of the chemical at 10.0 g ai/tree led to decline in fruit yield in both the years. Alar at 3000 ppm also showed a slight but non-significant tendency to enhance fruit yeild.

6.3.5. Higher doses of paclobutrazol application reduced fruit size and adversely affected T.S.S. of fruit juice while the lowest concentration of the chemical resulted in non-significant increase in T.S.S. Higher dose of Alar also led to a decline in T.S.S. Other physico-chemical characters of fruits were not much affected by the growth retardant treatments.

6.3.6. From the results of this study, soil drenching with paclobutrazol @ 2.5 g ai/tree during November and March every alternate year seems to be recommendable for regulating tree size and enhancing yield in young, bearing mango trees.

6.4 Paclobutrazol had manifold effects on the physiology of mango trees. It enhanced total phenolic content of apical bud, phloem to xylem ratio of stem and reduced endogenous ABA and cytokinin levels as well as leaf area. There was similarity with regard to phenolic contents and phloem / xylem ratio in genetic dwarfs and induced dwarfs indicating the mode of tree size control in mango.

6.5. The results also indicated that ABA might not be theinhibitor responsible for reduction of vigour in mango, since a less vigorous cultivars as well as trees dwarfed by paclobutrazol treatments recorded lesser ABA content in their apical bud, than vigorous ones.

6.6 The present studies in addition to unravilling the various basic aspects of tree size control in mango and identifying suitable means to control tree size chemically, also are beneficial for developing preselection methods for vigour in mango.

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CHAPTER VII

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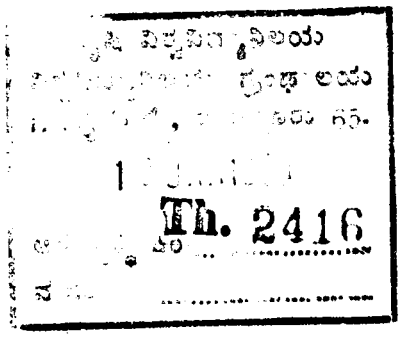
A P P E N D I X

APPENDIX 1. Common and Chemical names of chemicals used to regulate tree-size and vigour in various fruit crops

	COMMON NAME/COMMERCIAL NAME	CHEMICAL NAME
1.	MALEIC HYDRAZIDE (M.H.)	6-Hydroxy-3-(2H)-Pyridazinone
2.	MORPHACTINS (Chloroflurenol methyl esters)	Methyl 2-chloro-9-hydroxy flourene-9-carboxylic acid
3.	ETHREL, ETHEPHON	(2-chloroethyl) phosphonic acid
4.	TIBA	2,3,5-Triiodobenzoic acid
5.	EMGARD 2077	Methyl nanoate
6.	OFFSHOOT-O (0.50)	Methyl decanoate
7.	CHLORMEQUAT, CYCOCEL, CCC	(2-Chloroethyl) trimethyl ammonium chloride
8.	SADH, ALAR, B-9	Succinic acid-2, 2-dimethyl hydrazide
9.	PHOSPHON-D, CBBP	2,4-dichlorobenzyl-tributyl phosphonium chloride
10.	ANCYMIDOL, E-53	L-Cyclopropyl, L-4-methory propyl, L-5-pyrimidine methanol
11.	AMO-1618	2'isoprophyl-4'- (trimethyl ammonium chloride)-5'-methyl phenyl pyperidine-1-carboxylate
12.	M & B 25-105	n-propyl-3-t-butyl phenoxy acetate
13.	AMEX A-820, BUTRALIN	n-Secondary butyl-4-tertiary-butyl -2, 6-dinitroaniline
14.	DIKEGULAC	2,3: 4,6-di-O-Isopropylidene-2-keto-L-gulinate
15.	PP.528	Ethyl-5-(4 Chlorophenyl + -2H tetrazol-2-yl acetate.
16.	PACLOBUTRAZOL, PP.333	B /(4-Chlorophenyl) methyl/ 2-(1,1,dimethyl)- 1-11-1,2,4-triazol-i.ethanol
17.	FLURPRIMIDOL	/4-(trifluoroemthoxy) phenyl/ -5-pyrimidine-methanol.

Th. 2416




Th. 2416