BIOMETRIC ANALYSIS OF YIELD AND CERTAIN YIELD ATTRIBUTES IN THE PARA RUBBER TREE:

Hevea Brasiliensis Muell. Arg.

By

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THESIS
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DECLARATION

I hereby declare that this thesis entitled "Biometric analysis of yield and certain yield attributes in the para rubber tree : *Hevea brasiliensis* Muell. Arg." is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled "Biometric analysis of yield and certain yield attributes in the para rubber tree : *Hevea brasiliensis* Muell. Arg." is a record of research work done independently by Shri. V.C. Markose, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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CHAPTER 1

INTRODUCTION

Natural rubber is one of the most versatile industrial raw materials which has multifarious uses in daily life of man. The name rubber is derived from the quality of the material in rubbing black lead pencil marks. The bark of the tree exudes a white viscous liquid on injury. This liquid is called latex and it contains 30 to 50 per cent rubber. Over 90 per cent of the world production of natural rubber comes from the para rubber tree - *Hevea brasiliensis* Muell. Arg.

Hevea brasiliensis is a wild forest tree which has been domesticated only a century back. Currently the tree is grown on a plantation scale in Indonesia, Malaysia, Thailand, China, India, Sri Lanka, Liberia, Nigeria, Indochina, Zaire, Ivory Coast, Cameroon, Philippines, Burma, etc. The total area under this crop is about 75 lakh ha with the current annual production of 34.5 lakh m. tonnes (International Rubber Study Group, 1984). After its introduction from Brazil to the eastern hemisphere, the average yield per hectare increased from less than 300 kg to about 850 kg per ha per annum. This significant increase in yield was mainly due to the genetic improvement made in the planting material.

In India cultivation of Hevea brasiliensis started in 1902. The area under the crop at the end of 1982 was 2.91 lakh hectares of which Kerala State accounted for 2.56 lakh hectares (1982-83). Tamil Nadu, Karnataka and Andaman and Nicobar islands shared the major part of the rest of the area The other States in which rubber is grown are Tripura, Goa, Assam and Meghalaya. The annual production of natural rubber in India was 1,66,000 tonnes during 1982 (Rubber Board, 1984). According to the projections prepared by the Planning Commission, in 1980, the total consumption of rubber by 1989-90 would be 4,05,000 tonnes consisting of 3,42,000 tonnes of natural rubber and the balance synthetic rubber. It is also estimated that by AD 2010, the demand for natural rubber would be around 7 lakh tonnes (Mukundan Menon, 1983). Thus the future of natural rubber industry should be considered very bright. To meet this demand, the area will have to be extended also at the same time enhancing the productivity considerably. It would appear that both are to be considered at equal level of importance to achieve the targets.

Systematic breeding approaches were not done in the past mainly due to the perennial nature of this tree crop. The production of rubber within the tree is a peculiar phenomenon, the exploitation technique more so, which also hinder the studies. Genetic studies have been initiated only recently to elucidate the characters which govern the yield.

The characters of economic importance are, in general, quantitatively inherited, the difference between the individuals being of degree rather than of kind. Such metric variations perhaps depend on gene differences at several loci, the effect of which may or may not be individually distinguishable. The observations in connection with a metric character in a population are means, variances and covariances. The variances can be partitioned into their components which provide basis for measurement of the degree of resemblance between different materials. From such studies the influence of genes concerned, and that of various non-genetic factors, in the expression of characters can be ascertained.

The differences among the individuals of a clone are mostly environmental while that between clones are genetical as well as environmental. The variance and covariance analysis can also elucidate the resemblance between different cultivars.

Exploitation of heterosis holds tremendous scope in this tree crop. Promising hybrid progenies can be multiplied vegetatively in a short span of time and supplied as clones.

A basic knowledge of the cause and effect relationships of various yield attributes and yield is essential for adopting effective selection procedures. An understanding of the nature of genetic control of these characters is also necessary to make a rational choice among various methods of breeding.

In *Hevea* attempts have been made to correlate certain characters with yield. However, much of the required basic information are still lacking. The present investigation was taken up with the objective of collecting certain basic information on the above aspects especially the nature of rubber production, its variability, cause and effect relationships of certain characters on dry rubber yield and genetic diversity in the material.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

The genus Hevea, a native of the humid tropic region of the Amazon Valley in Brazil, belongs to the family Euphorbiaceae. There are nine species belonging to this genus and they are H. brasiliensis, H. benthamiana, H. spruciana, H. guianensis, H. pauciflora, H. rigidifolia, H. camphorum, H. nitida and H. microphylla (Schultez, 1977 and 1980). Of these nine species, only Hevea brasiliensis Muell. Arg. is of commercial importance. This crop species was introduced to the eastern hemisphere by Sir Henry Wickham in 1876 through Kew Botanical Gardens in England (Dijkman, 1951).

H. brasiliensis is a tall, sturdy, perennial tree. It attains a height of 25 to 30 m when mature. When young, the shoot shows alternating periods of rapid elongation and consolidation (Polhamus, 1962). The immature trees also produce several leaf stories which are widely separated on the shoot axis. The tree is deciduous and the leaves fall off once a year, usually in December to February in South India (Radhakrishna Pillai, 1980).

Hevea brasiliensis is monoeceous. Flowers are produced along with the production of new flushes of leaves during January-February. Generally, the flowers are produced from the fifth year of age. Both male and female flowers occur on the same inflorescence. Cross pollination occurs freely and the fruits ripe after about five months. Seeds are characteristic to a clone with regard to size, shape and markings on the seed coat (Dijkman, 1951).

The product of economic importance from the tree is rubber, which is contained in latex. Latex is synthesised by and contained in the latex vessels, which occur in almost all parts except the pith and wood (Bobilioff, 1918, 1923; Aggelen Bot, 1948; Schweizer, 1949). The tree is exploited by controlled wounding of the bark. The anatomical structure of the virgin and renewed bark was reviewed by Panikkar (1974). The bark is delimited from the wood by a layer of cambium which by repeated divisions adds up new tissues towards both the wood and the bark. The mature bark has an outer most corky zone, an inner most soft zone and an intermediate hard zone. The outer most zone comprises of the periderm. The intermediate hard zone comprises of groups of stone cells in addition to latex vessels and other secondary phloic tissues.

Towards the outer portion of this hard zone, however, the latex vessels, sieve tubes etc. become discontinuous due to senescence. The inner most soft bark contains most of the functional tissues of the secondary phloem like sieve tubes, companion cells, phloic rays, latex vessels, etc. The latex vessels are generally oriented in an anti-clockwise direction, the angle of inclination varying from three to five degrees. They are produced in discrete rows and the vessels belonging to the same ring are tangentially inter-connected. The laticifers, therefore, appear as straight tubes in radial longitudinal sections, whereas they have an expanded mesh work appearance in tangential longitudinal sections (Bobilioff, 1918; Panikkar, 1974; Gomez, 1975).

Hevea latex is a hydrosol and rubber occurs as dispersed discrete particles (Bonner and Galston, 1947). Besides rubber, latex of *Hevea brasiliensis* contains various substances like carbohydrates, proteins, resins, inorganic salts, etc. (Archer *et al.*, 1963, 1967; Archer 1980). Milanez (1946) and Andrews and Dickenson (1960) considered latex, as a whole, of cytoplasmic origin in the form of specialised cytoplasm. Heusser (1930) reported the rubber particles in latex to be ovoid and spherical in shape while Andrews and Dikenson (1960) found them always spherical atleast in young plants. The rubber particles measure 50 A^{o} to 3.00 μm in diameter with the majority around 0.5 μm (Gomez and Moir, 1979). These particles are protected in suspension by a film of adsorbed proteins and phospholipids (Archer et al., 1963) It has a molecular weight of one lakh to several millions (Schultez and Mula, 1960).

The trees are brought under exploitation for latex, when they attain sufficient girth. The standard of girth now generally accepted is 50 cm at a height of 125 cm from the bud union for all bud grafted materials (Radhakrishna Pillai, 1980). Tapping is done on half the circumference of the tree. The angle of inclination of the tapping cut of bud grafted trees is 30°. Tapping is generally done on alternate days (Dijkman, 1951; Edgar, 1958; Radhakrishna Pillai, 1980). To obtain maximum crop the tapping cut should be sufficiently deep (Dijkman, 1951; Dejong and Warrier, 1965). During the process of tapping thin shavings of the bark are removed simultaneously opening the latex vessels (Ridley, 1897). As a result, the latex contained in the laticifers exudes which in turn is collected and processed. Field latex usually contains 30 to 40 per cent rubber (Radhakrishna Pillai, 1980).

While latex synthesis occurs within the laticifers, its free movement within them is not normal. The flow of latex starts only after injuring the bark and thereby opening the latex vessels. The formation of latex and the rubber particles within it, is a normal process in Hevea brasiliensis, as long as the laticifers are active. There is no evidence for the biological stoppage of rubber production within active laticifers or chemical transformation of rubber particles. The rubber content of latex remains relatively static until there is an injury resulting in latex exudation. The rapid removal of latex on tapping constitutes an abnormal function and thereby induces a tapped tree to produce many times as much rubber as it would have produced,had it not been tapped at all (Polhamus, 1962).

During the initial years of cultivation, the rubber tree was propagated only through seeds. Subsequently selection was practiced to a limited scale, since its introduction as a commercial crop, but this practice was restricted to collection of seeds from areas supporting healthy and well grown trees. However, the large variation in the yield capacity of seedling population was realised during the latter part of the first quarter of this century. Whitby (1919) found that in a population of 1000 trees raised from ordinary seeds in Malaysia Peninsula, 28 per cent of the total yield was contributed by ten per cent of the trees. Cramer also recognised this type of variation and carried out variance analysis of the 33 Penang seedlings belonging to the Wickham collection in 1924 (Dijkman, 1951).

The wide variation in yield between individual seedling trees within a stand attracted some attention. This opened up the possibility of improving yield by appropriate choice of known high yielding trees with a view to raising a population which would, when mature, has less variable individual yield and higher yield per unit area.

In 1915 Van Helton was able to propagate Hevea vegetatively. By the following year Van Helton, Boddle and Tan improved this technique so that it could be adopted commercially. Mother parents were chosen mainly based on yield considerations (Dijkman, 1951). However, only a small percentage of plants showed high yielding characteristics transmitted to the vegetative progeny (Edgar, 1958). Subsequently a long period of experimentation followed. It required considerable field area for the study to which commercial plantations cooperated. Further the studies also needed several years for observations. The work however, was very much rewarding and consequently a large number of vegetative populations were evolved which within the respective groups showed more or less uniform behaviour. By 1934 many of the clones thus established recorded a four fold increase in productivity compared to the unselected seedling populations (Dijkman, 1951).

In Malaysia, Morris made a series of crosses during 1928-1931 using selected clones as parents (RRIM, 1938). The progenies were vegetatively multiplied and tested in different stages. By 1948, the Rubber Research Institute of Malaysia released the first series of clones, christened as RRIM 500 series. From 1937 onwards, the promising clones developed in Malaysia, Java and Sumatra were used as parents for breeding. Here again the progenies were multiplied and tested and it was found that the selections from this series (RRIM 600 series) were superior than those from the earlier ones. The selections thus developed were capable of yielding five times as much as ordinary unselected seedlings. Further, the RRIM 600 series clones as well as the clones evolved earlier were used in a series of pollinations to produce the RRIM 700, 800 and 900 series of modern clones some of which are still in the experimental stage (Subramaniam, 1980).

Hevea breeding was initiated in Sumatra by Heusser (Heusser, 1921, 1930) with AVROS selections. Dijkman (1938; 1939) reported the breeding work, carried out in Java, during the early years. Dijkman (1939), Dijkman and Ostendorf (1941) and Schweizer (1941) concluded from their work that (a) crossing between pre-selected parent seedlings and clones gave better progenies in yield than those of unselected seedlings, (b) the yield variation of these progenies was intermediate between the parents, (c) certain characters like brown bark and wind susceptibility were dominant, and that (d) the number of latex vessels in the bark was more than that of the unselected seedlings.

Mother tree selection, vegetative multiplication and testing them were carried out in other rubber producing countries which produced a good number of clones for planting in each country. Selection for Dothidella resistant clones by the Ford Rubber Plantation established in 1928 at Fordlandia in Brazil resulted in screening a few clones. These selections were crossed with eastern clones to improve the yield (Baptiste, 1960). In the Rubber Research Institute, Sri Lanka, similar works were carried out (De Silva, 1960).

In India ortet selection was done and is being continued (Joseph *et al*., 1980). Cross pollination between clones was started in 1954 with the available clones introduced earlier into the country (Bhaskaran Nair and Panikkar, 1966). This resulted in the production of RRII 100 series of clones (Bhaskaran Nair and George, 1969). From the subsequent crosses 200 and 300 series of clones are now under experimentation (Saraswathy Amma *et al*., 1980 and Premakumari *et al*., 1982).

The success in *Hevea* breeding has thus been achieved through a combination of generative and vegetative methods of selection in a complementary manner. The early selection of good trees and their propagation by bud grafting, was followed by controlled breeding between selected clones. From the progenies so obtained further selection of the best enabled the evolution of the new modern clones of high promise.

In *Hevea* the yield is the quantum of dry rubber realised from the tree and is expressed as kg per hectare per annum, in commercial practice. In experimental practice, however, the yield of individual trees are usually determined by coagulating the latex on selected tapping days, collecting the individual coagula and ascertaining the dry weight. This is usually expressed as gram per tree per tap. Rubber yield depends on the volume of latex obtained and its dry rubber content which in turn depend on the yield potential, growth vigour, age, girthing on tapping, exploitation procedures, disease incidence and environmental constraints.

Growth vigour in tree species is generally recorded by measurements of girth and in *Hevea* also girth is considered as the parameter of growth vigour. The normal growth pattern of a free growing *Hevea* tree follows an S curve (Vollema and Dijkman, 1939). The increase in girth during the first three years is relatively small but is greatly accelerated, once the tree branches and crown takes shape (Dijkman, 1951; RRIM, 1973). Girthing becomes relatively slow when the trees are opened for tapping (Wycherley, 1976). Ramaer (1929) indicated that growth vigour is genetically controlled and Ferwerda (1940) and De Jong (1941) confirmed this. The genotypic control of growth vigour is evident from the fact that different clones planted in the same locality show differences in qirth (Ostendorf, 1932; Maas, 1937; Dijkman, 1939 and Ferwerda, 1940). There exists apparent difference among clones in the productive structure of trees (Hu, 1980). The genetic build up of the stock, however, influences the vigour of the scion (Dijkman, 1951 and Buttery, 1961). Root stock was the main determinant of scion growth during immaturity and thereafter the scion was the main determinant (Ng and Yoon, 1982). Frey Wyssling (1932) reported that an equilibrium exists between nutrients, growth and formation of latex. Tapping affects this equilibrium which ultimately retards girthing (Russel, 1941 and Spangler and Mac Indoc, 1949). On tapping, the tree looses much of the nutrients in the bark along with latex (Frey Wyssling, 1932; Schweizer, 1949), and leads to a competition for nutrients between growth and rubber regeneration. Blackman (1964) indicated that girth increment on tapping varied between low and high yielding cultivars. Schweizer also found decreased starch reserve near tapping region. Templeton (1969) reported that at the age of six years the dry matter produced was around 35.5 tonnes per hectare per annum and that the effect of tapping on root growth is fairly small. Andrews and Dikenson (1960) reported that extraction of rubber to the tune of 4 kg per annum per tree decreased the growth by one third. Ho (1975b) found little influence of girth on yield in early production period and considered high girth increase on tapping as ideal. Good girth increment on tapping is a desirable attribute of a clone and is genetically governed.

Ng _et al_. (1965, 1969) found that reducing the frequency of tapping at a constant length of cut did not appreciably affect girth increment and that low frequency systems resulted in higher yields per tapping. Rooth (1961) reported better girth increment with a period of tapping rest, whereas De Jong (1969) showed that for a given length of tapping cut girth is related to the yield and not necessarily to the frequency. _Hevea brasiliensis_ often shows a physiological disorder of the panel ultimately leading to stoppage of yield. This is termed 'brown bast'. High frequency tapping was found related to this disorder (Schweizer, 1949; Ng _et al_., 1969 and Paranjothy _et al_., 1975). Vollema and Dijkman (1939) observed that high yielding clones are more susceptible to this disease at early years of tapping. Recently

Sivakumaran and Pak.anathan (1982) was able to induce dryness by puncturing the bark at zero or five points along vertical strips on the panel and sealing with drawing pins. It is reported (Heusser, 1930; Dijkman, 1939 and Ostendorf, 1941) that progenies of brown bast susceptible trees inherit this character to a great extent.

Latex vessel rings are more concentrated in the bark near the cambium (Bobilioff, 1923; Dijkman, 1951; De Jong and Warrier, 1965) and for maximum yields as much latex vessels as possible may be severed without injuring the cambium, as this may lead to the production of nodules and burrs. De Jong (1969) found out that girth increment on tapping is also affected by the tapping depth. Yield increase, however, was not found to commensurate with rate of bark consumption (Maas, 1926). In healthy trees the flow of latex ceases in about two to three hours after tapping. Frey Wyssling (1932) found that soon after tapping, latex flow follows an exponential law while it follows a parabolic law afterwards. This has been ascribed to a contraction of the latex vessels in the beginning and a capillary flow subsequently (Pyke, 1941; Ferrand, 1941; Gooding, 1952). Boatman (1966) indicated that latex flow cease due to some factor located near the cut end of the latex vessels.

Southorn and Yip (1968) and Southern (1969) showed that apparently a clotting mechanism works within the latex vessels. It is now presumed that latex destabilising substancesare segregated inside lutoid particles which are ruptured during latex flow, thus releasing the destabilising substances (Radhakrishna Pillai, 1980). Southorn and Yip (1968) demonstrated breakage of lutoids due to shear stress.

Incidence of diseases and environmental constraints are also factors affecting productivity. Abnormal leaf fall disease caused by Phytophthora spp. is the most devastating disease of H. brasiliensis in India. The disease incidence causes heavy defoliation.. Ramakrishnan and Radhakrishna Pillai,(1961) demonstrated 30 per cent yield drop with 75 per cent defoliation in a clone. Evers et al. (1961) studied the interaction between climate, morphology and production of rubber. Ninane (1967) reported variation in yield at different hours of the day due to the changes in water status of the trees. Yield also follows seasonal variations (Paardekooper and Samosorn, 1969) and soil moisture below a particular level apparently affects the pattern (Sethuraj, 1977). Senanayake (1978) found a non-significant positive correlation between yield and rainfall while Sethuraj (1977) found a positive influence of soil temperature and relative humidity on yield.

The factors affecting yield, in all crops, are the components of yield and also the factors limiting yield (Mayo, 1980). The rubber yield in Hevea brasiliensis is a manifestation of various morphological, anatomical, physiological and biochemical characters of the tree (Pollinere, 1966). Visibly these factors are ultimately manifested in the volume of latex yield on tapping and the quantum of rubber it contains (Sethuraj, 1977). The volume of latex is dependent on the rate and duration of flow. Arisz (1928), Zimmerman (1949) and Sethuraj (19. 7) concluded that latex flow is closely linked with periodicity and that it is a predominant factor during wintering period. Lee and Tan (1979) found a close association between daily latex volume and yield of rubber and suggested that latex volume was a dominant factor determining yield. The dry rubber content of latex (drc) varies in different clonal latices (Ng et al. 1970). Generally the drc is highest at the time of first opening and gradually reaches a stable condition. Wiltshire (1934) reviewed the earlier work on drc variations. Grantham (1925) and Heusser and Holder (1931) found a negative correlation between yield and drc. Schweizer (1936) noted a decrease in drc during wintering which rapidly regained normalcy. Rebaillier (1972) also reported seasonal variations in drc. It was reported that drc vary with clone, age, length of the tapping cut, frequency and time of tapping (RRIM, 1982).

Attempts have been made to correlate productivity with morphological characteristics of the planting materials (Whitby, 1919; Sanderson and Sutcliffe, 1929; Dijkman and Ostendorf, 1929; Gilbert et al., 1973; Narayanan et al., 1973; Lee and Tan, 1979; Liang et al., 1980; Liu et al., 1980; Pavia et al 1982; Hamazah and Gomez, 1982 and Filho, et al., 1982). Rubber yield was found to have positive correlation with girth, number of latex vessels and bark thickness (Dijkman and Ostendorf, 1929; Gilbert et al., 1973; Lee and Tan, 1979; Liang et al., 1980; Liu et al., 1980 and Hamazah and Gomez, 1982).

Genetic studies in *Hevea brasiliensis* are only in the initial stage and probably the perennial habit of the tree hindered detailed biometrical analysis. Analysing the data of Ross and Brookson (1966), Simmonds (1969) found that most of the differences between family yields could be accounted for by additive gene effect. Data on the yield and girth of seedling progenies resultant of earlier hand pollinations had been attempted by Gilbert, Dodds and Subramaniam (1973), Nga and Subramaniam (1974), Tan et al. (1975), Ho (1975a), Tan (1975), Alika (1980) and Liang et al. (1980) for variance analysis. Markose and George (1980) and Liu (1980) also analysed the data of clones. The studies in general indicate additive genetic variance, inbreeding depression and unpredictable interaction when related parents are used for breeding.

It may, however, be remembered in this context that most of the studies had been on the seedling populations resultant of breeding programmes and not on the clonal populations subsequently established by vegetative multiplication. Similarly only very limited attempts had been made to study the progenies of different clonal populations.

The manifestation of a multiplicity of factors of the tree and their interactions among themselves as well as with environmental regimes ultimately tell upon the productivity of a given planting material. The same planting material may behave differently in different situations and, naturally, planting materials of different origins may have varying performance under a given set of conditions.

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

3.1. Location

The experiment was conducted at the Central Experiment Station of the Rubber Research Institute of India located at Chethackal in Pathanamthitta District of Kerala State. The area was virgin forest before the planting of rubber. The soil is mostly laterite and lateritic, fairly deep, well drained and acidic. The terrain is generally hilly and undulating. The area receives a mean precipitation of 3556.5 mm per annum, based on the rainfall data from 1979 to 1983.

3.2. Experimental materials

The study was made on twenty clones of *Hevea brasiliensis* planted in the Station during 1971, by the Botany Division of the Rubber Research Institute of India. The clones were of different geographic and genetic origin, having varying potentials with regard to yield and other secondary characters. The country of origin, parentage and brief description of the clones studied are given in Table 1.

Scion buds of the clones were grafted on to ordinary stock seedlings of about nine months' growth in 1971 and planted in the field as budded stumps.

Table 1 : Brief description of the experimental materials

Sl. No.	Clone	Country of origin	Brief description
1.	RRII 3	India	A clone developed through ortet selection from among seedling population at Kollamkulam Estate in Mundakayam. The mother tree was high yielding and preliminary clone trial indicated its high yielding ability.
2.	RRII 4	India	Another clone developed through ortet selection from the same seedling population as that of RRII 3. This clone has also shown satisfactory yield performance in the preliminary clone trial.
3.	RRII 5	India	This clone was developed from a seedling tree showing high yield at Malankara Estate in Thodupuzha. Preliminary studies indicated that the clone is a good yielder.
4.	RRII 6	India	Another ortet selection from Malankara Estate, Thodupuzha. The tree is tall with light secondary branches and shows high yield in preliminary clone trial.
5.	RRII 17	India	It is a clone developed from a seedling tree reported to be tolerant to *Phytophthora* leaf fall disease from a smallholding in Poonjar. Preliminary studies indicated that this clone sets only a few fruits and showed meiotic abnormalities. The seedling tree was a high yielder but clonal population showed poor yield in preliminary trials.

Contd....2/-

Sl. No.	Clone	Country of origin	Brief description
6.	RRII 18	India	The mother tree was selected from a seedling population in Wynad based on high yield and tolerance to Oidium disease.
7.	RRII 37	India	The mother tree was selected based on high yield from Yendayar Estate in Mundakayam.
8.	RRII 38	India	Another selection from the same location as that of RRII 37 based on yield.
9.	RRII 43	India	A clone developed from PBIG seedling trees, raised from the seeds obtained from Prang Besar isolation gardens (Malaysia) and grown at RRII Experiment Station. Selection based on yield performance.
10.	RRIM 600	Malaysia	A clone developed by the Rubber Research Institute of Malaysia from the progenies of the cross between $Tjir_1$ and PB 86. It is high yielding and has been recommended for large scale planting in Malaysia and India based on its yield and other secondary characters. However, the clone is susceptible to Phytophthora leaf fall disease.
11.	RRIM 701	Malaysia	Developed by the Rubber Research Institute of Malaysia, the parents are clone 44/553 and RRIM 501. This is also reported to be a high yielder.

Contd...23/-

Sl. No.	Clone	Country of origin	Brief description
12.	RRIM 703	Malaysia	This is a hybrid between RRIM 600 and RRIM 500. It is also a high yielding clone selected by the RRIM.
13.	PB 5/51	Malaysia	The parents of this clone are PB 56 and PB 24, two primary clones selected by the Prang Besar Estates in Malaysia. The clone is high yielding and wind tolerant.
14.	GT_1	Indonesia	A primary clone developed from the Estate Gondang Tapan in Indonesia. It is a slow starter with rising yield trend. The clone is wind tolerant.
15.	PR 107	Indonesia	This is also a primary clone developed in Java and previously known as LCB 510. It can withstand full spiral tapping. Susceptible to abnormal leaf fall disease caused by *Phytophthora* spp.
16.	Ch 153	Malaysia	It is a vigorous clone developed by Chemera Plantations in Malaysia through hybridisation between $Tjir_1$ and Ch 5. The clone is reported to be high yielding.
17.	IAN 713	Brazil	This clone is developed through hand pollination of PB 86 and F 409. F 409 is a *H. benthamiana* selection. The clone is tolerant to South American leaf blight caused by *Dothidella ulei*.

Contd...24/-

Sl. No.	Clone	Country of origin	Brief description
18.	IAN 873	Brazil	Another hybrid clone developed by hand pollination between PB 86 and FA 1717. A high yielding clone, resistant to *Dothidella ulei*.
19.	Harbel 1	Liberia	A clone developed from a mother tree selection from the Firestone Plantations in Liberia. Reported to be high yielding and tolerant to abnormal leaf fall disease.
20.	Wagga 6278	Sri Lanka	A primary clone developed in Sri Lanka based on yield.

The spacing adopted was 4.9 x 4.9 m. There were 64 plants in a plot with 36 recording plants. The design of planting adopted was RBD with three replications. All cultural operations during immature and mature phases were carried out uniformly as recommended by the Rubber Board.

The trees attained tappable girth seven years after planting and exploitation was started in 1978. The tapping panels were opened at 125 cm height from the bud union. The tapping system was half spiral, alternate daily (S/2 d/2). The volume of latex was measured twice a month, for all the available recording trees in each plot during October, November and December 1980. Based on the volume yield of latex during the three months, six trees from each plot showing almost uniform latex yield were selected. These trees were paint marked and numbered serially. All observations were recorded from the six trees thus selected from each plot.

Observations were carried out from January 1981 onwards at which time the trees were on the third year of tapping. S/2 d/2 system of tapping was continued. The trees were under tapping through out the year without any rest except for national holidays and sundays. The trees were provided with rain guards for exploitation during the rainy months. However, tapping was not possible on certain days when there was heavy downpour during morning hours. The number of tapping days, rainy days and total quantity of rain fall during each month of 1981 and 1982 are furnished in Table 2.

3.3. Observations

The following data were recorded from the trees selected for the study, during the course of investigations.

(a) Girth:-

Girth was recorded at 150 cm height from the bud union at the commencement of the experiment. Recordings were also carried out at quarterly intervals for a period of two years.

(b) Panel length:-

The length of the tapping cut was measured in January 1981 and 1982.

(c) Panel height:-

The height of the tapping panel was measured from the bud union to the bottom of the tapping cut during 1981 and 1982 (January).

Table 2 : Monthly rain fall, rainy days and number of tapping days

Month/Year	1981			1982		
	Rainfall in mm	Number of rainy days	No. of tapping days	Rainfall in mm	Number of rainy days	No. of tapping days
January	46	4	13	0	0	12
February	161	2	12	4	1	12
March	251	15	13	175	9	13
April	194	14	12	169	9	13
May	301	12	12	350	15	11
June	1006	28	6	627	28	13
July	684	23	14	442	24	14
August	595	23	13	404	22	13
September	689	22	12	92	6	13
October	442	18	13	500	14	13
November	374	13	13	252	12	13
December	24	1	12	18	1	12
Total	4767	175	145	3033	141	152

(d) Bark studies:-

Bark samples were collected at 150 cm height from the bud union using a specially designed chisel in January 1981 and in January 1982 and preserved in formalin for subsequent observations. Radial longitudinal sections of 40-60 μm thickness were taken and stained in Sudan IV overnight. Total thickness of bark, thickness of the hard and the soft bark and the number of latex vessel rows (functional and non-functional) were observed from three sections of each sample.

(e) Wintering behaviour:-

The annual leaf fall behaviour was noted at weekly intervals and visual grading was done during 1980, 1981 and 1982.

(f) Branching height:-

The crotch height of the experimental trees were recorded during the commencement of the study.

(g) Bark consumption:-

The consumption of bark through tapping was measured and recorded at quarterly intervals.

(h) Volume of latex:-

The volume of latex on a normal tapping day was measured once every fortnight. The volume was recorded, using a measuring cylinder, after complete cessation of latex flow. The recordings were continued till the termination of the experiment.

(i) Dry rubber yield:-

The latex, after measurement of the volume, was poured back into the collection cup and coagulated using one per cent acetic acid. The individual coagula were collected separately on numbered metal hooks and were hung in shade for about a week for dripping of water and partial drying. The cup lumps were then transferred to the smoke house and dried for twenty to thirty days. After complete drying they were taken out and weight of each lump was recorded on a pan balance.

(j) Dry rubber content:-

The dry rubber content of the latex was ascertained from the volume of latex and actual weight of dry rubber and were summarised monthwise.

(k) Progeny testing:-

During 1981 seedfall season, seeds resultant of open pollination from clones RRIM 600, GT_1, PB 5/51, RRII 3, RRII 37, Harbel 1 and IAN 873 were collected. The seeds were germinated on beds of river sand and 96 sprouted ones were planted in the nursery in three replicates of 32 each. Planting was carried out in eight rows with four sprouted seeds in each. Normal cultural practices were adopted and the seedlings were maintained for a period of ten months. Observations on height, diameter at 15 cm height from the collar, total number of leaves and number of leaves on the topmost whorl were recorded from the twelve inner seedlings, leaving the border ones.

3.4. Computations.

(a) Yield:-

The fortnightly dry rubber yield per tree per tap was added for each quarter of the year beginning from January 1981 to December 1982. As the lumps retain moisture even after prolonged drying, a deduction of 10 per cent was made from the recorded weight to compensate the moisture present in the cup lumps. The average of each plot periodwise was calculated as yield per tree per tap for further computations. The average annual yield per tree per tap during 1981 and 1982 was also calculated. The pooled average for the years 1981 and 1982 was then ascertained.

(b) Volume of latex:-

The procedure followed for dry rubber yield was adopted for the computation of the volume of latex.

(c) Dry rubber content:-

The dry rubber content of the latex was estimated from the volume of latex and the dry weight of rubber, after deducting ten per cent weight to account for the moisture still present in the dried cup lump. The clonewise average was calculated quarterly and also annually. Pooled average for the two years was also calculated.

(d) Girth:-

The girth of the trees recorded during January 1981 and the quarterly measurements thereafter were used to calculate the average girth of the tree in each plot.

(e) Girth increment:-

The girth recorded in 1981, 1982 and 1983 was used to calculate the average annual girth increment.

(f) Bark thickness:-

Bark thickness measured from bark samples collected during 1981 and 1982 were averaged separately for each clone and used for statistical analysis.

(g) Latex vessel rows:-

The number of latex vessel rows, functional and non-functional, were averaged for each clone to calculate the number of vessels per tree during both the years.

(h) Wintering behaviour:-

The wintering behaviour recorded during 1980, 1981 and 1982 were used in grading the clones as early (1), medium (2) and late/partial (3) wintering types.

The average of all other characters recorded were calculated clonewise and used for analysis.

3.5. Statistical techniques

(a) Analysis of variance:-

The data on all metric characters were analysed by using standard statistical techniques. The analyses of variance of the data collected from experiments laid out on randomised block design were performed. With regard to dry rubber yield, volume yield of latex and dry rubber content, the data on quarterly periods were analysed separately. The pooled data were analysed as suggested by Pearce (1953). The manifestation of genotypic (G) and environmental (E) effects on the observed total value of a character was partitioned by the method of analysis (Kempthrone, 1975):

$$V(X) = V(G) + V(E) \quad \text{or}$$

$$\sigma^2 P(X) = \sigma^2 g(X) + \sigma^2 e(X)$$

where $\sigma^2 P(X)$ is the phenotypic variance of character X,

$\sigma^2 g$ (X) is the genotypic variance of X, and $\sigma^2 e$ (X) is the variance due to environment.

The extent of covariance between x and y, due to genetic and environmental factor, was partitioned using the formula:

$$\text{Cov (xy)} = \text{Cov G (xy)} + \text{Cov E (xy)} \quad \text{or}$$

$$\sigma P\ (xy) = \sigma g\ (xy) + \sigma E\ (xy)$$

where g (xy) is the covariance between x and y attributable to genotypes and E (xy) that due to environment.

(b) correlation:-

The phenotypic correlation coefficients were estimated as:

$$r\hat{p}\ (xy) = \frac{\sigma \hat{p}\ (xy)}{\sigma \hat{p}\ (x).\ \sigma \hat{p}\ (y)}$$

where $\sigma \hat{p}$ (x) and $\sigma \hat{p}$ (y) are the estimated phenotypic standard deviations of x and y.

(c) Co-efficient of variation:-

The co-efficient of variation for phenotypic and genotypic traits were estimated as below:

Phenotypic coefficient of variation:

$$\text{C.V.p (x)} = \frac{\sigma p\ (x) \times 100}{\bar{x}}$$

and genotypic coefficient of variation:

$$\text{C.V.g (x)} = \frac{\sigma g\ (x) \times 100}{\bar{x}}$$

(d) Heritability:-

Heritability, the fraction of the total variance which is heritable, was estimated in the broad sense as:

$$H^2 = \frac{\sigma^2 g}{\sigma^2 p}$$

Since the population is a non-segregating one, the method suggested by Burton and Devane (1957) was followed in estimating the heritability of each character.

(e) Path-coefficient analysis:-

The correlation coefficients of different characters with dry rubber yield were partitioned into direct and indirect effects.

To determine the cause and effect relationship the important characters were only considered. The characters taken were volume yield of latex, bark thickness, latex vessel rows, girth, annual girth increment and height of branching. Many factors might influence yield, the factors considered express their influence through volume of latex.

The estimates of direct and indirect effects were calculated as suggested by Wright (1921) and elaborated by Dewey and Lu (1959). The Path-coefficients were obtained by simultaneous solution of the equations:

$$r_{1y} = p_{1y} + r_{12}p_{2y} + r_{13}p_{3y} + \ldots\ldots$$

$$r_{2y} = p_{2y} + r_{21}p_{1y} + r_{23}p_{3y} + \ldots\ldots$$

$$r_{ky} = p_{ky} + r_{k1}p_{1y} + r_{k2}p_{2y} + r_{k3}p_{3y} + \ldots$$

where

r_{1y} to r_{ky} denote coefficient of correlation between causal factors 1 to k and the dependent character y.

r_{12} to $r_{k-1,k}$ denote coefficient of correlation among all possible combinations of casual factors.

and p_{1y} to p_{ky} denote direct effects of characters 1 to k on the character y.

(f) D^2 analysis:-

Mahalanobis' D^2 statistic was used for assessing the genetic divergence between populations (Rao, 1952). The data were analysed with computor adopting the programme suggested by Murthy and Arunachalam (1967) with suitable modifications.

The method involved was to construct a set of uncorrelated linear combinations (y's) which was obtained by pivotal condensation of the common dispersion matrix (Rao, 1952) of a set of correlated variables (x's). The mean values of different clones for different characters were transformed into the mean values of a set of uncorrelated linear combinations (y's). The D^2 between the ith and jth variety for k characters was calculated as follows:

$$D^2_{ij} = \sum_{t=1}^{k} (Y_{it} - Y_{jt})^2$$

where Y_{it} is the mean value of the tth linear combination for the ith clone and Y_{jt} is the mean value of the tth linear combination for the jth clone. The k component D-squares were calculated separately and added to get D^2_{ij}.

Two populations having smallest distance from each other were considered first to which a third population having the smallest average D^2 value from the first two populations was added. Similarly the fourth is chosen to have a small average D^2 value from the first three and so on. The stage at which the average D^2 among the populations added is high, then the last population does not fit in the cluster and hence removed from the cluster. The process is continued till all the populations are included in one or the other cluster.

After the formation of clusters, inter and intra group distances were calculated. The intra cluster distances were computed by adding up the D^2 values for all possible comparisons among the clones in that cluster, two at a time and dividing the D^2 so obtained by the number of D^2's. Similarly the inter cluster average D^2 was obtained by summing up the D^2 values in all possible combinations between each clone of two clusters compared and dividing the total by the numbers of D^2s.

For evaluating the relative contribution of each character towards divergence, the D^2 values of the transformed variate between pairs of varieties were considered. The components of the D^2 for each comparison were allotted rank 1 to 9 (as there are 9 characters) on the basis of relative magnitude. The contribution of the 9 transformed variates towards divergence was worked out as the percentage of rank totals for each of the 9 transformed variates from all comparisons.

RESULTS

CHAPTER 4

RESULTS

4.1. Dry rubber yield.

The dry rubber yield, determined during 1981 and 1982, were analysed for variance separately for the different quarterly periods. The analysis of variance showed significant difference for clones. The pooled analysis showed significant variation for clones, periods and clone period interaction during both the years (Appendix I and II). The mean yields obtained during the different periods for each clone during 1981 and 1982 are given in Tables 3 and 4 respectively. The order of performance of the clones during 1981 and 1982 was more or less the same. The highest yielding clones were RRIM 703, RRII 6, RRIM 600 and RRII 5 in the descending order, whose mean yield per tree per tap ranged from 51.01 g to 56.65 g during 1981. During 1982 the yield of these clones ranged between 50.98 g and 56.21 g per tree per tap. Clones RRII 4 and RRII 43 which recorded slightly less than 50 g per tree per tap during 1981, however, yielded 53.94 g and 54.90 g per tree per tap respectively during 1982. The lowest yielding clones during both 1981 and 1982 were RRII 38 and RRII 17. All the

Table 3 : Mean dry rubber yield (g/tree/tap) during different periods of the year 1981

Sl. No.	Clone	Periods/Yield in g Jan-Mar (1)	Apr-Jun (2)	Jul-Sep (3)	Oct-Dec (4)	Annual average S.E:2.10 C.D:5.82
1.	RRII 3	26.14	28.32	42.33	52.83	37.41
2.	RRII 4	44.63	34.24	62.75	55.18	49.20
3.	RRII 5	39.80	27.44	62.87	73.93	51.01
4.	RRII 6	41.46	39.57	61.65	67.96	55.16
5.	RRII 17	9.95	13.08	27.75	20.97	17.94
6.	RRII 18	23.65	26.40	43.33	39.41	33.20
7.	RRII 37	9.66	15.14	37.42	37.40	24.91
8.	RRII 38	7.45	12.43	19.57	16.54	14.08
9.	RRII 43	13.59	20.34	72.13	71.00	44.27
10.	RRIM 600	33.85	43.39	75.19	64.20	54.16
11.	RRIM 701	30.24	25.95	39.11	49.47	36.20
12.	RRIM 703	46.96	35.84	64.78	79.00	56.65
13.	PB 5/51	35.86	21.34	37.48	52.03	36.68
14.	GT_1	40.99	25.38	46.33	41.99	38.71
15.	PR 107	33.16	29.84	33.15	53.45	37.40
16.	Ch 153	18.12	22.28	43.62	44.18	32.05
17.	IAN 713	19.13	26.26	34.06	32.12	28.09
18.	IAN 873	25.75	29.64	34.41	35.47	31.32
19.	Harbel 1	18.03	27.52	42.36	43.78	32.93
20.	Wagga 6278	22.02	23.39	33.36	40.35	29.78
	Mean	27.08	26.89	45.68	48.56	37.06
	S.E: 0.94					
	C.D: 2.60					

For means in the body of the table : S.E: 4.20
C.D:11.64

Table 4 : Mean dry ·ubber yield (g/tree/tap) during different periods of the year 1982

Sl. No.	Clone	Periods/Yield in g				Annual average S.E:2.01 C.D:5.57
		Jan-Mar (1)	Apr-Jun (2)	Jul-Sep (3)	Oct-Dec (4)	
1.	RRII 3	33.53	49.77	46.27	47.71	44.32
2.	RRII 4	51.05	64.22	54.23	46.24	53.94
3.	RRII 5	41.20	50.85	60.99	50.87	50.98
4.	RRII 6	46.98	55.86	61.18	60.81	56.21
5.	RRII 17	17.29	31.05	24.79	28.27	25.36
6.	RRII 18	36.27	39.16	43.80	47.09	41.58
7.	RRII 37	17.32	26.79	35.97	32.22	28.08
8.	RRII 38	13.19	19.69	19.61	30.75	18.32
9.	RRII 43	22.02	61.72	67.54	68.30	54.90
10.	RRIM 600	46.70	53.05	62.06	62.46	56.07
11.	RRIM 701	34.16	42.81	42.61	50.28	42.47
12.	RRIM 703	47.22	52.08	60.68	59.22	54.81
13.	PB 5/51	34.57	40.10	39.75	44.89	39.83
14.	GT_1	32.92	32.17	35.32	31.03	32.87
15.	PR 107	31.28	34.48	45.15	48.85	39.94
16.	Ch 153	18.83	33.88	45.33	37.82	33.97
17.	IAN 713	20.42	32.53	39.28	32.00	31.06
18.	IAN 873	22.04	35.71	37.45	40.05	33.82
19.	Harbel 1	25.01	44.56	44.68	42.60	39.22
20.	Wagga 6278	23.42	35.73	41.61	42.98	35.94
	Mean	30.77	41.81	45.41	44.72	40.68

S.E: 10.90
C.D: 2.49

For means in the body of the table : S.E: 4.02
C.D:11.13

others were medium yielding clones. The mean annual increase in yield from 1981 to 1982 was 3.60 g per tree per tap.

The pooled data of dry rubber yield during the quarterly periods for the two years were analysed and the results are given in Appendix III. The mean yield during the different quarterly periods as well as the mean annual yield per tree per tap is given in Table 5. Clones RRIM 703, RRIM 600, RRII 6, RRII 4 and RRII 5 yielded above 50 g per tree per tap, the range being 51.00 g to 55.73 g, among which there was no significant difference. Among the clones studied, the lowest yielding were RRII 38 and RRII 17 with 16.20 g and 21.65 g of dry rubber yield per tree per tap respectively.

The quarterly yields showed significant difference between clones, years, periods within years and their interactions. The mean yields are given in Table 5 and the percentage contribution of quarterly yield to the annual, in Table 6 for comparative purpose. The pooled mean yield of clones is represented in Fig.1. In general, the periods three (July to September) and four (October to December) together contributed 60 per cent of the total annual yield, the contribution being comparable (29.54 per cent and 30.07 per cent respectively).

Table 5 : Pooled mean dry rubber yield (g/tree/tap) during quarterly periods

Sl. No.	Clone	Periods/Yield in g Jan-Mar (1)	Apr-Jun (2)	Jul-Sep (3)	Oct-Dec (4)	Annual average S.E:1.45 C.D:4.03
1.	RRII 3	29.84	39.05	44.30	50.27	40.86
2.	RRII 4	47.84	49.23	58.49	50.72	51.57
3.	RRII 5	40.50	39.15	61.94	62.40	51.00
4.	RRII 6	44.22	52.72	61.42	64.39	55.69
5.	RRII 17	13.62	22.07	26.27	24.63	21.65
6.	RRII 18	29.96	32.78	43.57	43.25	37.39
7.	RRII 37	13.50	20.97	36.70	34.82	26.49
8.	RRII 38	10.49	10.06	19.59	18.65	16.20
9.	RRII 43	17.81	41.03	69.84	69.66	49.58
10.	RRIM 600	40.28	48.23	68.63	63.33	55.12
11.	RRIM 701	32.20	34.38	40.86	49.88	39.33
12.	RRIM 703	47.09	43.96	62.74	69.11	55.73
13.	PB 5/51	35.22	30.72	38.62	48.46	38.26
14.	GT_1	36.96	28.84	40.83	36.52	35.79
15.	PR 107	32.22	32.16	39.15	51.15	38.67
16.	Ch 153	18.48	28.09	44.48	41.01	33.01
17.	IAN 713	20.18	29.40	36.67	32.06	29.58
18.	IAN 873	23.90	32.68	35.94	37.77	32.57
19.	Harbel 1	21.52	36.04	43.52	43.20	36.07
20.	Wagga 6278	22.72	29.56	37.49	41.67	32.86
	Mean	28.93	34.49	45.55	46.65	38.87

S.E: 0.50
C.D: 3.04

For means in the body of the table : S.E: 2.05
C.D: 5.69

Table 6 Percentage contribution of dry rubber yield during quarterly periods

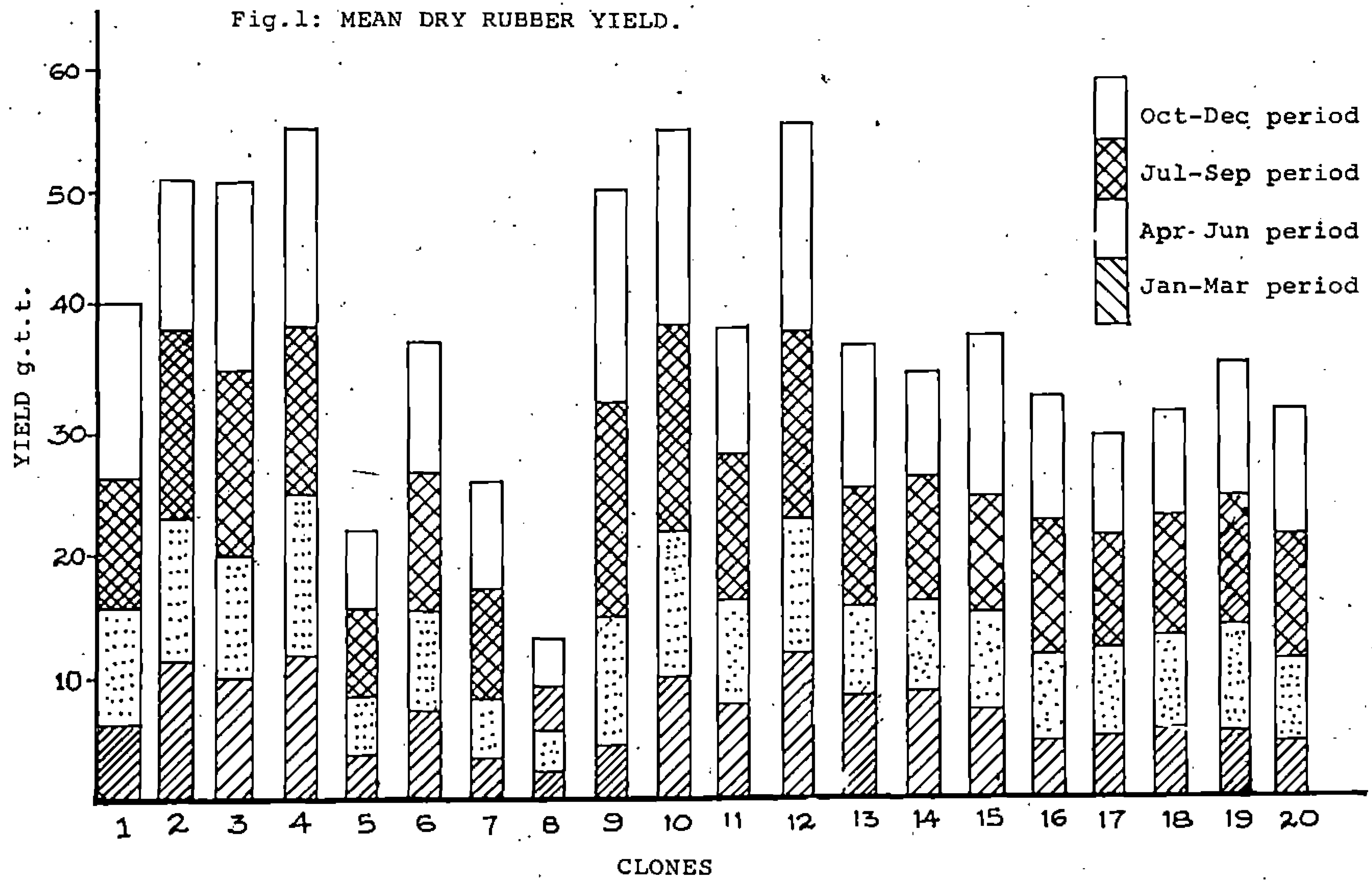
Sl. No.	Clone	Mean annual yield g.t.t	Percentage yield during Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Wintering*
1.	RRII 3	40.86	18.26	23.89	27.10	30.76	2
2.	RRII 4	51.57	23.19	23.87	28.35	24.59	3
3.	RRII 5	51.00	19.85	19.19	30.36	30.59	3
4.	RRII 6	55.69	19.85	23.67	27.57	28.91	3
5.	RRII 17	21.65	15.73	25.49	30.33	28.44	2
6.	RRII 18	37.39	20.03	21.92	29.13	28.92	2
7.	RRII 37	26.49	12.74	19.79	34.64	32.[illegible]	1
8.	RRII 38	16.20	16.19	24.78	30.23	28.78	2
9.	RRII 43	49.58	8.98	20.69	35.22	35.13	2
10.	RRIM 600	55.12	18.27	21.88	31.13	28.72	2
11.	RRIM 701	39.33	20.47	21.85	25.99	31.71	3
12.	RRIM 703	55.73	21.12	19.72	28.14	31.00	2
13.	PB 5/51	38.26	23.01	20.07	25.24	31.66	3
14.	GT_1	35.79	25.82	20.15	28.52	25.51	2
15.	PR 107	38.67	20.83	20.79	25.31	33.07	2
16.	Ch 153	33.01	14.00	21.27	33.69	31.05	2
17.	IAN 713	29.58	17.06	24.85	30.99	27.10	2
18.	IAN 873	32.57	18.35	25.08	27.59	28.99	1
19.	Harbel	36.07	14.92	24.98	30.16	29.94	1
20.	Wagga 6278	32.86	17.27	22.47	28.50	31.68	2
	Mean	38.87	18.61	21.81	29.54	30.07	

* 1 - Early

2 - Medium

3 - Late/Partial

Fig.1: MEAN DRY RUBBER YIELD.



The yield during the first quarter (January to March) was only 18.61 per cent of the total annual production. The yield performance of the individual clones showed much difference during the first quarter. Certain clones showed very low yield during this period while others showed less fluctuation compared to the other periods. The clone GT_1 had very low depression which was followed by clones RRII 4 and PB 5/51 in order. The highest yield depression was noted for clone RRII 43 for which the first quarter period contributed only less than 10 per cent of the total yield. During the periods three and four the clone RRII 43 gave the highest contribution makingup themean annual yield by over 70 per cent. The yield contribution during the second period did not show much fluctuation among the clones. However, among the high yielding clones, RRII 5 and RRIM 703 showed less than 20 per cent contribution during this period. Table 6 also reveals that the yield variation during the different periods was not related to the wintering behaviour of clones.

4.2. Volume of latex.

The volume of latex recorded at fortnightly intervals was averaged for the respective quarters as ml per tree per tap. The data on individual periods were analysed separately for variance. The analysis showed significant difference between clones. The data on mean quarterly volume of latex for the years 1981 and 1982 were analysed separately and they are given in Appendix IV and V. During both the years, significant difference was obtained for clones, periods and clone period interaction. The mean volume of latex during different periods of the year 1981 and 1982 is given in Tables 7 and 8 respectively. The highest volume of latex (157.95 ml) was for clone RRIM 703 during 1981 which was significantly superior to all other clones studied. However, during 1982 RRIM 600 gave the highest volume of latex (158.20 ml) followed by clones RRII 4, RRII 6 and RRIM 703. Among these four clones there was no significant difference. The clones which gave low latex yield by volume were RRII 38 and RRII 17 during both the years, the volume of latex being 36.39 ml and 46.35 ml in 1981 and 47.98 ml and 67.50 ml in 1982 respectively.

The mean volume of latex during the quarterly periods also showed significant difference. The highest yielding quarter was the fourth (125.67 ml) in 1981 and the third (123.07 ml) in 1982. The lowest mean volume yield (63.79 ml) was obtained during the second quarter in 1981 and the first quarter (86.07 ml) in 1982. The clones showed much variation among each

Table 7 : Mean volume of latex (ml/tree/tap) during different periods of the year 1981

Sl. No.	Clone	Periods/Volume in ml Jan-Mar (1)	Apr-Jun (2)	Jul-Sep (3)	Oct-Dec (4)	Annual average S.E: 5.55 C.D:15.35
1.	RRII 3	64.25	71.25	97.16	137.87	92.63
2.	RRII 4	108.30	83.34	162.60	153.02	130.99
3.	RRII 5	106.29	68.46	142.94	165.06	120.69
4.	RRII 6	105.09	110.37	132.62	164.12	128.05
5.	RRII 17	27.26	33.41	70.63	54.09	46.35
6.	RRII 18	80.26	63.61	103.27	111.84	89.75
7.	RRII 37	24.71	37.78	38.12	94.72	61.33
8.	RRII 38	17.46	31.05	49.91	47.14	36.39
9.	RRII 43	36.35	42.91	156.39	172.12	101.95
10.	RRIM 600	92.36	79.02	183.06	169.25	130.92
11.	RRIM 701	99.41	64.12	105.12	119.23	96.97
12.	RRIM 703	151.44	92.19	171.68	216.48	157.95
13.	PB 5/51	99.70	51.33	86.63	130.67	92.09
14.	GT_1	131.03	69.22	111.07	110.05	105.29
15.	PR 107	94.01	66.28	81.40	129.61	92.83
16.	Ch 153	49.28	53.20	110.32	112.64	81.36
17.	IAN 713	61.63	62.63	92.18	100.45	79.22
18.	IAN 873	82.97	76.86	96.44	115.85	93.03
19.	Harbel 1	53.06	64.96	108.70	109.54	84.07
20.	Wagga 6278	57.82	53.99	79.11	99.70	72.66
	Mean	77.97	63.79	111.47	125.67	94.73

S.E: 2.48
C.D: 6.87

For means in the body of the table : S.E: 11.08
C.D: 30.71

Table 8 : Mean volume of latex (ml/tree/tap) during different periods of the year 1982

Slo No.	Clone	Periods/Volume in ml				Mean ml S.E: 5.70 C.D:15.80
		Jan-Mar (1)	Apr-Jun (2)	Jul-Sep (3)	Oct-Dec (4)	
1.	RRII 3	82.59	122.66	118.99	120.41	111.17
2.	RRII 4	148.70	166.85	159.11	126.29	150.24
3.	RRII 5	115.80	128.77	167.43	124.22	134.06
4.	RRII 6	126.38	143.94	162.50	148.92	145.44
5.	RRII 17	45.98	79.52	69.98	74.49	67.50
6.	RRII 18	114.15	98.28	123.01	142.01	119.37
7.	RRII 37	43.47	63.32	93.99	76.40	69.80
8.	RRII 38	32.68	49.37	56.89	52.95	47.98
9.	RRII 43	52.58	138.91	172.73	170.02	133.57
10.	RRIM 600	130.49	142.41	188.23	171.66	158.20
11.	RRIM 701	105.47	106.44	120.27	117.01	112.38
12.	RRIM 703	146.62	137.20	154.71	142.26	145.20
13.	PB 5/51	96.10	113.65	102.89	106.30	104.74
14.	GT_1	98.78	81.91	92.20	76.97	87.47
15.	PR 107	86.45	81.27	113.42	120.82	100.50
16.	Ch 153	48.23	84.27	152.55	94.49	86.56
17.	IAN 713	56.06	76.80	102.14	86.92	80.48
18.	IAN 873	63.07	98.74	110.31	118.92	97.76
19.	Harbel 1	67.80	110.73	125.57	106.48	102.65
20.	Wagga 6278	60.04	86.68	107.48	106.81	90.26
	Mean	86.07	105.68	123.07	114.22	107.27

S.E: 2.55
C.D: 7.07

For means in the body of the table : S.E: 11.40
C.D: 31.60

other and also during the different periods of the year. The pooled data for the two years was analysed and the analysis of variance is given in Appendix VI. It may be seen that variances for clones, periods, years and their interactions were significant. The pooled mean quarterly volume of latex for the clones is given in Table 9. The mean volume of latex is also represented histographically in Fig.2. The pooled mean volume of latex did not show much variation between first and second and also between third and fourth quarterly periods. But significant difference was noted between second and third periods. The highest mean volume of latex was recorded during the fourth period followed by the third.

The clones showed significant difference within the period and between periods. The pooled mean among the clones varied from 42.18 ml to 151.58 ml per tree per tap for clones RRII 38 and RRIM 703 respectively. The clones RRIM 703, RRIM 600 and RRII 4 were at par for this character. The lowest yielding clones with regard to this character were RRII 38 and RRII 17. All the other clones were medium yielders in terms of volume of latex.

4.3. The dry rubber content (drc).

The dry rubber content of latex was determined

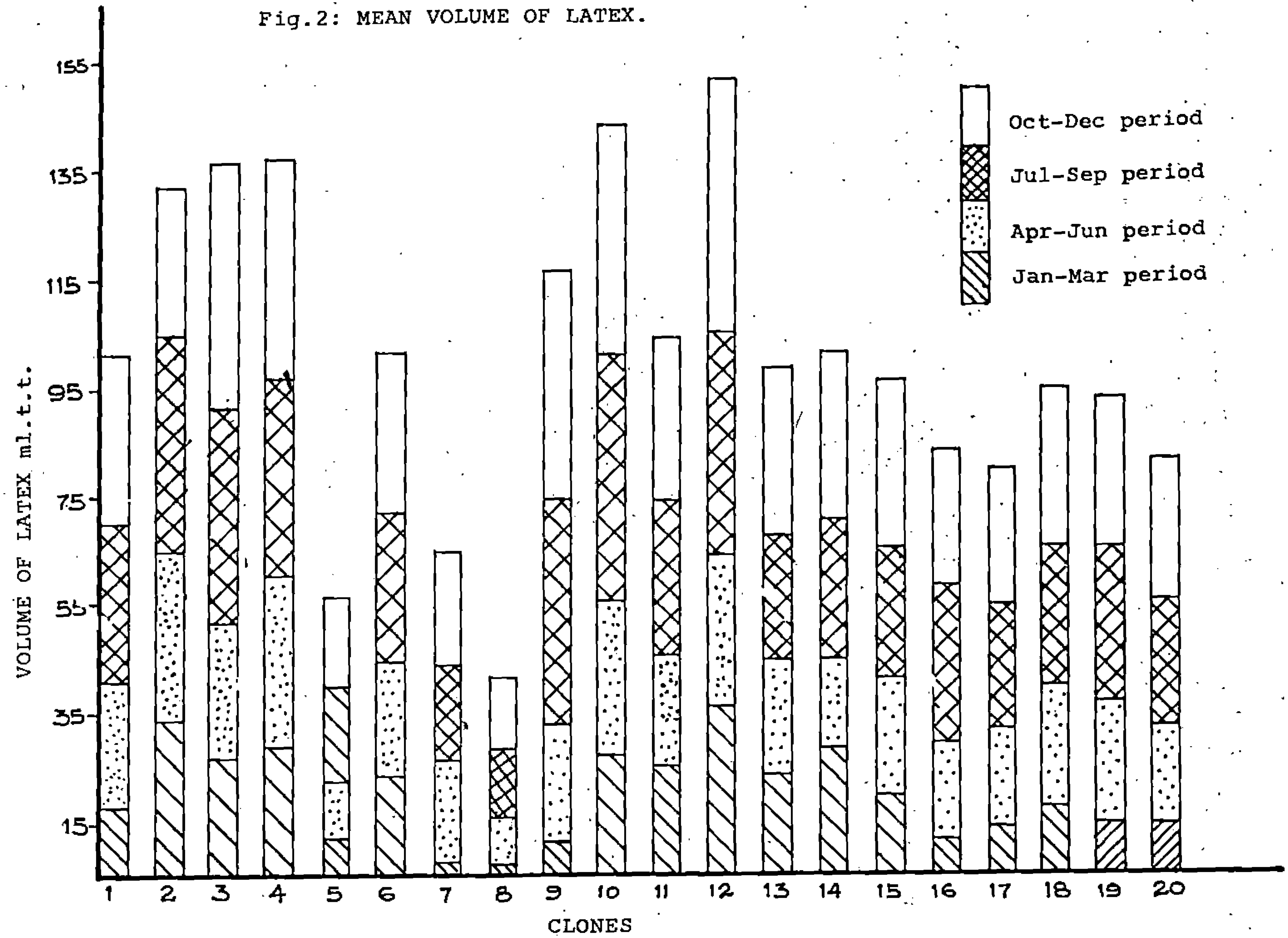
Table 9 : Pooled mean volume of latex (ml/tree/tap) during the quarterly periods

Sl. No.	Clone	Periods/Volume in ml				Mean ml S.E: 3.97 C.D:11.02
		Jan-Mar (1)	Apr-Jun (2)	Jul-Sep (3)	Oct-Dec (4)	
1.	RRII 3	73.42	96.96	108.08	129.14	101.90
2.	RRII 4	136.84	125.10	160.86	139.66	140.61
3.	RRII 5	111.05	98.62	155.19	144.65	127.38
4.	RRII 6	115.74	127.16	147.56	156.52	136.75
5.	RRII 17	36.63	56.47	70.31	64.30	56.92
6.	RRII 18	97.21	80.95	113.14	126.93	104.56
7.	RRII 37	34.09	51.56	91.06	85.56	65.57
8.	RRII 38	25.07	40.21	53.41	50.05	42.18
9.	RRII 43	44.47	90.91	164.58	171.07	117.76
10.	RRIM 600	111.41	110.72	185.65	170.46	144.56
11.	RRIM 701	102.44	85.28	112.86	118.12	104.68
12.	RRIM 703	149.03	114.70	163.20	179.37	151.58
13.	PB 5/51	97.91	82.49	94.76	118.49	98.41
14.	GT_1	114.91	75.47	101.64	93.51	96.38
15.	PR 107	90.23	73.78	97.42	125.22	96.66
16.	Ch 153	48.76	68.74	114.77	103.57	83.96
17.	IAN 713	58.85	69.72	97.17	93.69	79.85
18.	IAN 873	73.03	87.80	103.38	117.39	95.40
19.	Harbel 1	60.44	87.85	117.14	108.01	93.36
20.	Wagga 6278	58.94	70.34	93.30	103.26	81.46
	Mean	82.02	84.74	117.27	119.95	101.00

S.E: 1.26
C.D: 3.48

For means in the body of the table : S.E: 5.62
C.D:15.58

Fig.2: MEAN VOLUME OF LATEX.



from the volume of latex and actual weight of rubber contained in it, as percentage. The percentage dry rubber content of clones for the various periods was analysed for variance. Significant differences were found for clones during the first, third and fourth quarters in 1981 and during first and second quarters in 1982. The analysis of the data for the years 1981 and 1982 showed significant variance for periods and clones. The analysis of variance is given in Appendix VII and VIII. The pooled data of both the years were analysed and they are given in Appendix IX. It was found that the variances between years, periods, clones and the interactions were significantly different.

The mean dry rubber content for the different periods of the years 1981 and 1982 are given in Table 10 and 11 respectively. In 1981, the highest drc (41.66) was during April to June period followed by July to September period. Among the clones, RRII 43 had the highest (43.36) while IAN 873 had the lowest (34.00) dry rubber content. The clones showed significant difference between periods also. During the year 1982 also highest dry rubber content was during April to June period which was significantly superior to January to March period and July to September period. Among the clones RRII 43 showed significantly higher drc (41.65) than other clones and the lowest dry rubber

Table 10 : Mean dry rubber content (per cent) during different periods of the year 1981

Sl. No.	Clone	Periods/Per cent				Mean per cent S.E: 0.20 C.D: 0.54
		Jan-Mar (1)	Apr-Jun (2)	Jul-Sep (3)	Oct-Dec (4)	
1.	RRII 3	42.52	39.42	43.94	38.22	41.03
2.	RRII 4	36.21	41.24	38.57	36.06	38.02
3.	RRII 5	37.05	39.78	44.04	44.56	41.36
4.	RRII 6	39.73	44.71	46.46	41.63	43.13
5.	RRII 17	36.37	39.12	43.29	38.68	39.37
6.	RRII 18	29.80	41.69	42.29	35.33	37.29
7.	RRII 37	38.59	41.31	43.55	40.04	40.87
8.	RRII 38	42.05	40.05	39.16	34.98	39.06
9.	RRII 43	38.94	46.79	46.13	41.35	43.31
10.	RRIM 600	36.67	45.44	40.98	35.85	39.74
11.	RRIM 701	30.47	40.78	37.21	41.54	37.50
12.	RRIM 703	31.03	38.89	37.78	36.52	36.06
13.	PB 5/51	36.21	41.69	43.22	39.86	40.25
14.	GT_1	31.22	37.17	41.36	38.24	37.00
15.	PR 107	35.29	45.23	40.76	41.14	40.61
16.	Ch 153	37.19	42.06	39.46	39.08	39.45
17.	IAN 713	32.41	42.45	37.07	32.00	35.99
18.	IAN 873	31.03	38.69	35.63	30.64	34.00
19.	Harbel 1	34.26	42.60	38.78	40.11	38.94
20.	Wagga 6278	38.75	43.97	42.24	43.44	42.11
	Mean	35.79	41.65	41.09	38.46	39.25

S.E: 0.88
C.D: 2.43

For means in the body of the table : S.E: 1.76
C.D: 4.87

Table 11 : Mean dry rubber content (per cent) during different periods of the year 1982

Sl. No.	Clone	Periods/Per cent Jan-Mar (1)	Apr-Jun (2)	Jul-Sep (3)	Oct-Dec (4)	Mean per cent S.E:0.19 C.D:0.53
1.	RRII 3	40.50	41.27	38.78	39.59	40.04
2.	RRII 4	34.55	38.88	34.29	37.33	36.26
3.	RRII 5	37.21	39.60	36.43	40.95	38.55
4.	RRII 6	37.10	39.02	37.53	40.74	38.60
5.	RRII 17	37.29	39.69	35.60	37.76	37.59
6.	RRII 18	31.81	39 74	35.83	37.08	36.12
7.	RRII 37	40.50	41.23	38.62	41.64	40.59
8.	RRII 38	40.72	40.31	34.87	39.33	38.81
9.	RRII 43	42.13	44.74	39.12	40.58	41.65
10.	RRIM 600	35.92	37.14	32.87	36.34	35.57
11.	RRIM 701	32.36	40.50	35.49	43.06	37.86
12.	RRIM 703	32.30	38.46	39.38	40.69	37.71
13.	PB 5/51	36.00	36.03	39.18	42.83	38.51
14.	GT_1	33.59	39.26	38.23	40.60	37.92
15.	PR 107	36.24	42.24	39.86	40.64	39.75
16.	Ch 153	39.00	40.93	38.31	39.98	39.56
17.	IAN 713	36.50	42.39	38.42	37.02	38.59
18.	IAN 873	34.92	36.04	38.52	33.93	35.02
19.	Harbel 1	37.00	40.33	38.69	40.04	38.19
20.	Wagga 6278	39.63	41.46	40.14	40.35	40.40
	Mean	36.77	39.96	37.17	39.54	38.36

S.E: 0.85
C.D: 2.36

For means in the body of the table : S.E: 1.70
C.D: 4.72

content was for clone IAN 873. Table 12 gives the mean data for drc during different quarterly periods. The mean dry rubber content of latex of different clones is shown in histogram (Fig.3). It may be seen that the periods July to September and October to December were at par with regard to this character. Period April to June showed the highest (40.81) and January to March the lowest (36 ubber content.

The general mean dry rubber content for clones was 38.81 per cent. The range of dry rubber content variation among clones was from 34.51 to 42.48 per cent. The clones having low dry rubber content were IAN 873, RRII 18, RRIM 703, RRII 4 and IAN 713. The highest dry rubber content was for clone RRII 43 with 42.48 per cent followed by Wagga 6278, RRII 37, RRII 3 and PR 107. Clones showed difference in dry rubber content among periods also. Even though the lowest mean dry rubber content (36.28) was during January to March period, certain clones showed higher values, particularly the clones RRII 3 and RRII 38.

4.4. Bark thickness.

The data on thickness of virgin bark recorded from the samples of bark taken at 1.5 m height from the bud union during January in 1981 and 1982 were subjected to

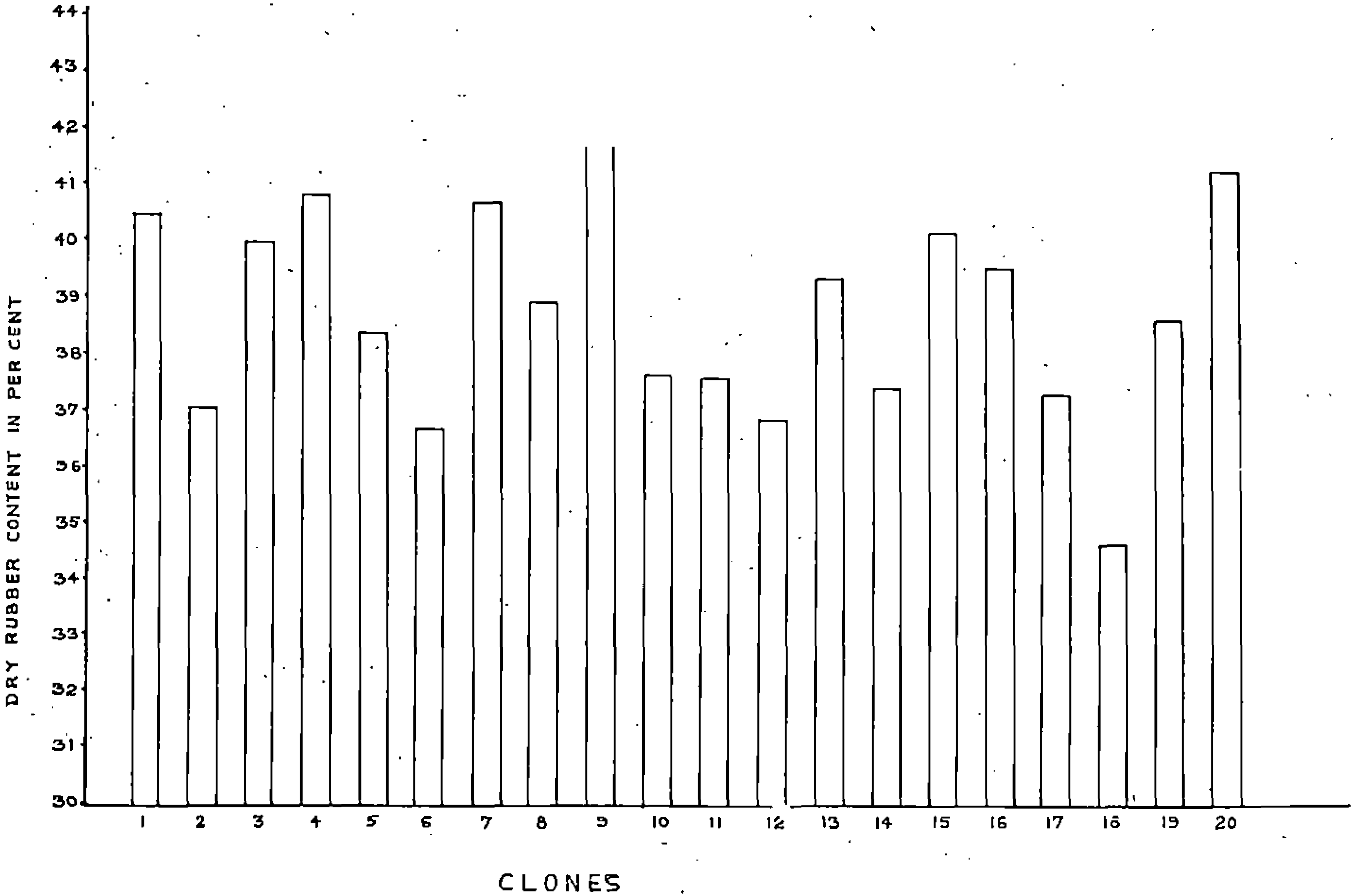
Table 12 : Pooled mean dry rubber content (per cent) during quarterly periods

Sl. No.	Clone	Periods/Per cent				Mean S.E:0.19 C.D:0.54
		Jan-Mar (1)	Apr-Jun (2)	Jul-Sep (3)	Oct-Dec (4)	
1.	RRII 3	41.51	40.35	41.36	38.91	40.53
2.	RRII 4	35.38	40.06	36.42	36.70	37.14
3.	RRII 5	37.13	39.70	40.24	42.76	39.96
4.	RRII 6	38.42	41.87	42.00	41.19	40.87
5.	RRII 17	36.83	39.41	39.45	38.22	38.48
6.	RRII 18	30.81	40.72	39.08	36.22	36.70
7.	RRII 37	39.58	41.26	41.09	41.01	40.73
8.	RRII 38	41.39	40.18	37.02	37.16	38.94
9.	RRII 43	40.54	45.77	42.63	40.97	42.48
10.	RRIM 600	36.30	41.30	36.93	36.10	37.66
11.	RRIM 701	31.42	40.64	36.36	42.30	37.68
12.	RRIM 703	31.67	38.68	38.58	38.61	36.89
13.	PB 5/51	36.11	38.86	41.20	41.35	39.38
14.	GT_1	32.41	38.22	39.80	39.43	37.40
15.	PR 107	35.77	43.74	40.31	40.89	40.18
16.	Ch 153	38.10	41.50	38.89	39.53	39.50
17.	IAN 713	34.46	42.42	37.75	34.51	37.29
18.	IAN 873	32.98	32.37	35.42	32.29	34.51
19.	Harbel 1	35.63	41.47	37.07	40.08	38.56
20.	Wagga 6278	39.20	42.72	41.17	41.90	41.25
	Mean	36.28	40.81	39.14	39.01	38.81

S.E: 0.12
C.D: 0.35

For means in the body of the table : S.E: 0.87
C.D: 2.40

Fig.3 MEAN DRY RUBBER CONTENT %



analysis of variance. Significant difference was observed for clones. The mean thickness of virgin bark for the clones during 1981 and 1982 is given in Table 13. Fig. 4 shows the mean virgin bark thickness for the year 1981. There was, in general, an increase in thickness from 16.10 mm in 1981 to 17.11 mm in 1982. The rate of increase showed difference among the clones. The clone RRIM 703 showed the maximum bark thickness during both the years (19.30 mm and 20.29 mm respectively). The clone RRII 17 had the least thickness (13.33 mm) in 1981, followed by clones RRII 37, RRII 38 and RRII 18, among which there was no significant difference. However, in 1982, RRII 17 and RRII 37 were at par while others showed significant difference in this character.

The hard bark and soft bark were separately measured but they did not show much difference and hence only the total thickness has been taken for further analysis.

4.5. Latex vessel rows.

The number of latex vessel rows, from radial longitudinal sections of the bark stained with Sudan IV, was counted. The vessels showing continuity were considered as functional and broken ones at hard bark region as non-functional. The number of functional

Table 13 : Mean thickness of virgin bark during 1981 & 1982

Sl. No.	Clone	Mean thickness in mm					
		1981			1982		
		Hard bark	Soft bark	Total S.E:0.83 C.D:1.68	Hard bark	Soft bark	Total S.E:0.78 C.D:1.58
1.	RRII 3	10.31	7.39	17.70	12.66	5.71	18.38
2.	RRII 4	9.57	6.19	15.79	9.58	6.63	16.12
3.	RRII 5	10.64	6.12	16.78	12.53	5.56	18.10
4.	RRII 6	10.36	6.55	16.91	12.70	5.76	18.46
5.	RRII 17	8.13	5.13	13.33	9.02	4.85	13.86
6.	RRII 18	9.52	5.41	14.93	10.69	5.17	15.87
7.	RRII 37	8.51	5.23	13.74	10.36	5.08	15.44
8.	RRII 38	9.53	5.20	14.73	10.64	5.08	15.72
9.	RRII 43	9.93	5.91	15.84	11.35	5.05	16.40
10.	RRIM 600	9.09	6.75	15.84	10.92	5.36	16.28
11.	RRIM 701	10.21	6.96	17.17	12.26	5.21	17.47
12.	RRIM 703	11.91	7.39	19.30	13.94	6.32	20.29
13.	PB 5/51	10.02	6.32	16.35	12.11	5.23	17.34
14.	GT_1	11.68	5.31	16.99	12.26	5.82	18.08
15.	PR 107	10.67	6.21	16.84	11.83	5.36	17.19
16.	Ch 153	10.28	5.64	15.92	11.43	5.35	16.78
17.	IAN 713	10.34	5.10	15.44	10.35	5.90	16.25
18.	IAN 873	10.64	5.08	15.72	10.68	6.10	16.78
19.	Harbel 1	11.35	5.05	16.40	13.31	6.18	19.50
20.	Wagga 6278	10.76	5.59	16.35	12.54	5.44	17.98
	Mean	10.19	5.93	16.10	11.56	5.56	17.11

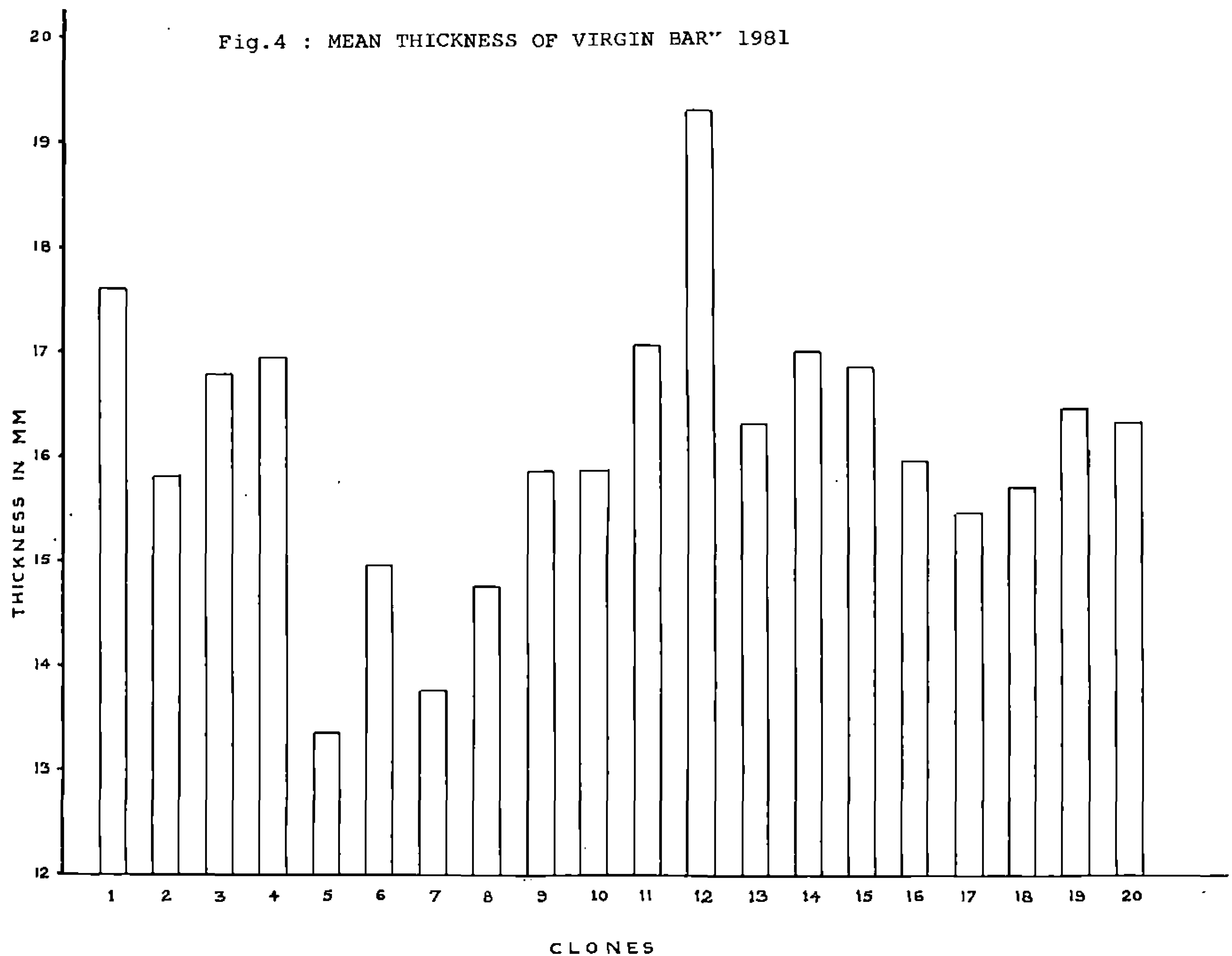


Fig.4 : MEAN THICKNESS OF VIRGIN BAR" 1981
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THICKNESS IN MM
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CLONES

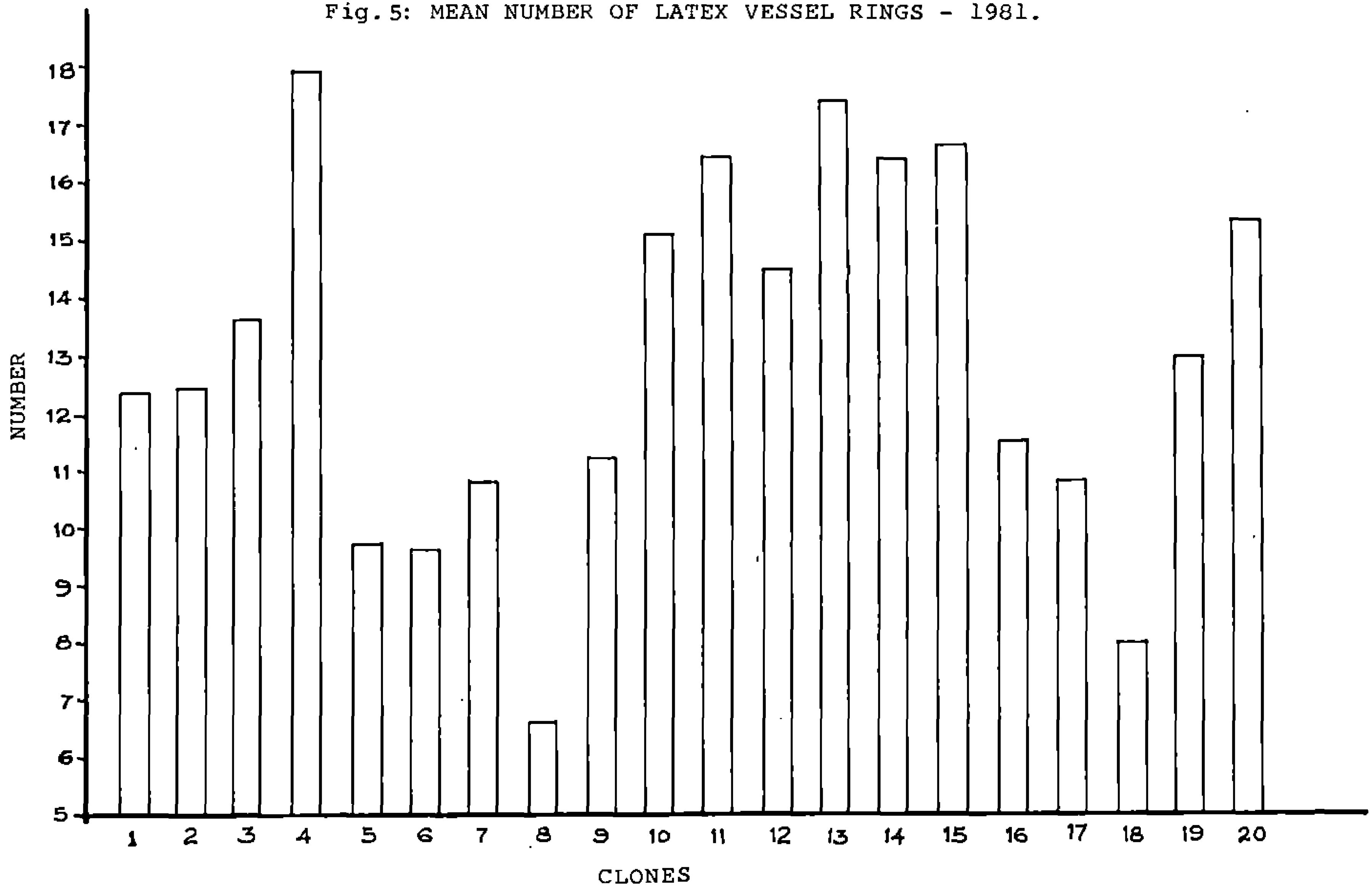
vessels and the total number recorded from the bark samples collected during January 1981 and 1982 were analysed for variance separately. The difference between clones was highly significant during both the years. The mean number of latex vessel rows, both functional and total, during 1981 and 1982 is given in Table 14. The number of functional latex vessel rows of different clones is represented in Fig.5. The clone RRII 6 had the maximum number of functional vessels in 1981 and 1982 with 17.95 and 22.48 respectively. During 1981, clones PB 5/51, RRIM 701, PR 107, GT_1 and Wagga 6278 were at par with clone RRII 6. In the next year, only Wagga 6278 showed comparative increase as that of RRII 6. The number of functional latex vessel rows was the lowest for clone RRII 38 with 6.60 and 8.05 in 1981 and 1982 respectively.

The mean annual increase in the number of vessels was around two, the rate being different for the various clones. The minimum increase (0.34) was observed for clone RRIM 600, even though the clone was a very high yielder. The increase in the total number of vessels for clone Wagga 6278 was comparatively more (5.47) than that of the other clones. However, the increase in yield was not commensurate with the increase in the number of latex vessel rows for this clone.

Table 14 : Mean number of latex vessel rows during 1981 and 1982 (functional and total)

Sl. No.	Clone	Functional vessels 1981 S.E:1.33 C.D:2.70	Functional vessels 1982 S.E.0.91 C.D:1.85	Total No. of vessels 1981 S.E:1.42 C.D:2.88	Total No. of vessels 1982 S.E:0.97 C.D:1.97
1.	RRII 3	12.44	16.12	14.71	18.56
2.	RRII 4	12.48	16.47	14.68	18.89
3.	RRII 5	13.60	16.11	15.84	18.65
4.	RRII 6	17.95	22.48	21.09	25.36
5.	RRII 17	9.70	10.89	12.20	13.12
6.	RRII 18	9.65	15.83	11.54	18.09
7.	RRII 37	10.83	10.87	13.10	12.79
8.	RRII 38	6.60	8.05	8.92	9.61
9.	RRII 43	11.25	12.99	13.14	14.40
10.	RRIM 600	15.07	15.35	17.29	17.63
11.	RRIM 701	16.40	17.26	18.92	19.17
12.	RRIM 703	14.57	17.89	16.99	19.52
13.	PB 5/51	17.43	19.55	19.61	21.74
14.	GT_1	16.48	19.29	18.39	20.98
15.	PR 107	16.61	17.20	18.60	18.60
16.	Ch 153	11.49	12.44	13.40	14.46
17.	IAN 713	10.86	11.76	12.79	13.77
18.	IAN 873	8.03	9.48	9.58	11.29
19.	Harbel	12.99	16.78	14.39	18.83
20.	Wagga 6278	15.35	21.05	17.77	23.24
	Mean	12.99	15.36	15.13	17.43

Fig. 5: MEAN NUMBER OF LATEX VESSEL RINGS - 1981.



4.6. Girth of the tree.

Data on the girth of the tree recorded at quarterly periods from individual trees at 150 cm height, were analysed for variance. Significant difference was observed for clones at 5 per cent level during certain quarters. The mean girth of clones at the beginning of the experiment i.e. January 1981 and at the end .i.e. December 1982 is given in Table 15. The mean girth of different clones in 1981 January is also represented in Fig.6. The clone RRII 38 showed the highest girth (84.60 cm) and clone IAN 873 had the lowest (66.00 cm) girth during January 1983. The difference in girth between the maximum and the minimum among the clones was 14.21 cm in 1981 and 18.60 cm in 1982. The mean girth of the trees was 66.16 cm in January 1981 and 74.31 cm in January 1983.

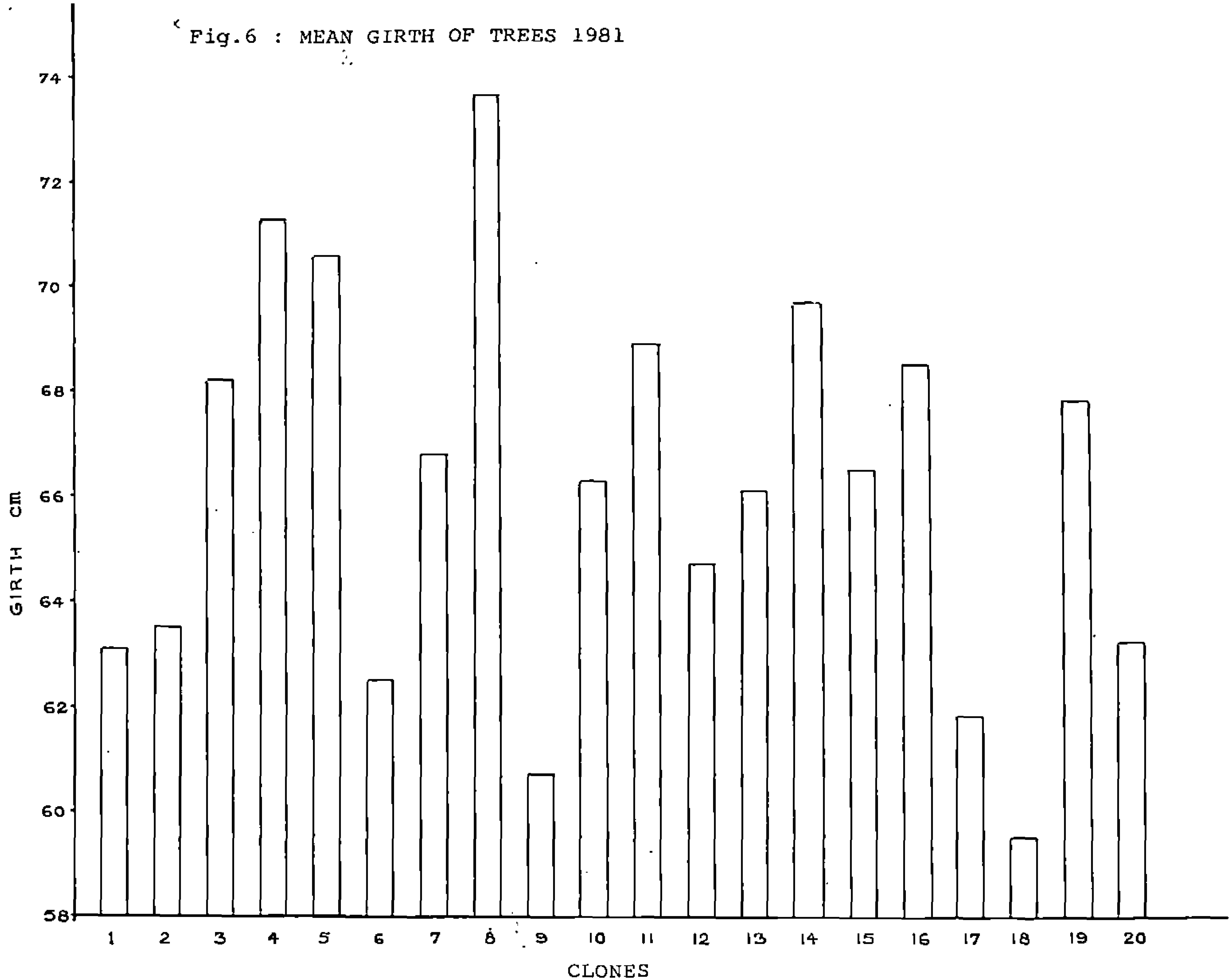
4.7. Annual girth increment.

The rate of increase in girth was computed from the difference in girth during the experimental period. The clonal difference was found to be significant. In Table 15 and Fig.7 the mean annual girth increment of clones is given. During the experimental period RRII 6 showed an annual increment of 5.22 cm followed

Table 15 : Mean girth and annual increment

Sl. No.	Clone	Girth in cm 1981 (Jan) S.E: 3.74 C.D:10.12	Girth in cm 1983 (Jan) S.E: 4.23 C.D:11.42	Mean annual increment S.E:0.917 C.D:2.47
1.	RRII 3	63.19	70.13	3.47
2.	RRII 4	63.55	71.53	3.99
3.	RRII 5	68.38	77.23	4.42
4.	RRII 6	71.32	81.76	5.22
5.	RRII 17	70.60	79.83	4.61
6.	RRII 18	62.55	72.43	4.94
7.	RRII 37	65.80	75.03	4.60
8.	RRII 38	73.72	84.60	5.29
9.	RRII 43	60.74	67.30	3.21
10.	RRIM 600	66.30	74.86	4.28
11.	RRIM 701	68.99	74.20	2.60
12.	RRIM 703	64.69	70.66	2.98
13.	PB 5/51	66.10	72.30	3.09
14.	GT_1	69.83	78.03	4.10
15.	PR 107	66.53	74.03	3.74
16.	Ch 153	68.55	77.26	4.35
17.	IAN 713	61.80	70.00	4.10
18.	IAN 873	59.49	66.00	3.25
19.	Harbel 1	67.83	77.30	4.74
20.	Wagga 6278	63.22	71.73	4.25
	Mean	66.16	74.31	4.07

Fig.6 : MEAN GIRTH OF TREES 1981



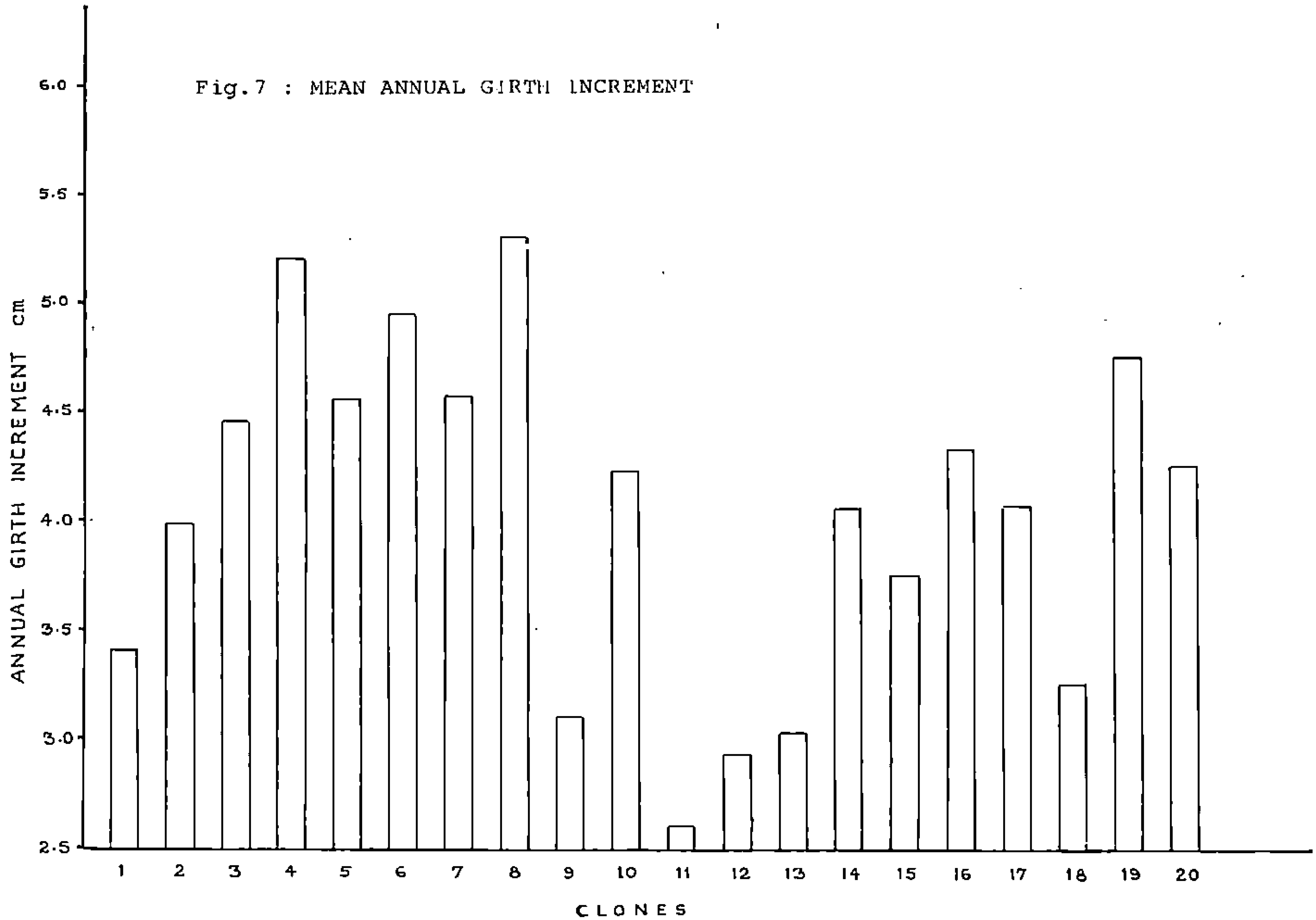


Fig.7 : MEAN ANNUAL GIRTH INCREMENT

by RRII 18. The minimum increment was for RRIM 701 (2.60 cm) followed by RRIM 703 (2.98 cm). The average increment was 4.07 cm. Out of the 20 clones studied, 12 showed above average annual girth increment.

4.8. Height of branching.

The height from the ground of the main trunk of the tree to the region where the branches were observed was measured for the selected trees. The data were analysed for variance and found that the difference between clones was significant. Table 16 and Fig.8 give the mean height at which branching started for the different clones. The clones PB 5/51 and IAN 873 showed highest branching height (4.20 m) of main trunk. Low branching height was observed for clones RRII 38 (2.61 m) and RRII 43 (2.68 m). The difference between the maximum and minimum height of branching was 1.59 m.

4.9. Length of the tapping panel.

The mean length of the tapping panel for each clone recorded in 1981 and 1982 is presented in Table 17. The panel length recorded, showed no significant difference. It may be stated that the length of the panel is dependent on the girth of the tree. The mean panel length was 37.12 cm and it varied from 32.82 cm to 40.80 cm.

Table 16 : Mean height of branching

Sl. No.	Clone	Mean height in m S.E: 0.44 C.D: 1.21
1.	RRII 3	2.91
2.	RRII 4	2.70
3.	RRII 5	3.59
4.	RRII 6	3.85
5.	RRII 17	2.92
6.	RRII 18	3.49
7.	RRII 37	3.24
8.	RRII 38	2.61
9.	RRII 43	2.68
10.	RRIM 600	2.98
11.	RRIM 701	2.99
12.	RRIM 703	3.29
13.	PB 5/51	4.20
14.	GT1	3.80
15.	PR 107	3.04
16.	Ch 153	3.45
17.	IAN 713	2.86
18.	IAN 873	4.20
19.	Harbel 1	3.31
20.	Wagga 6278	2.84
	Mean	3.25

Fig.8: MEAN BRANCHING HEIGHT.

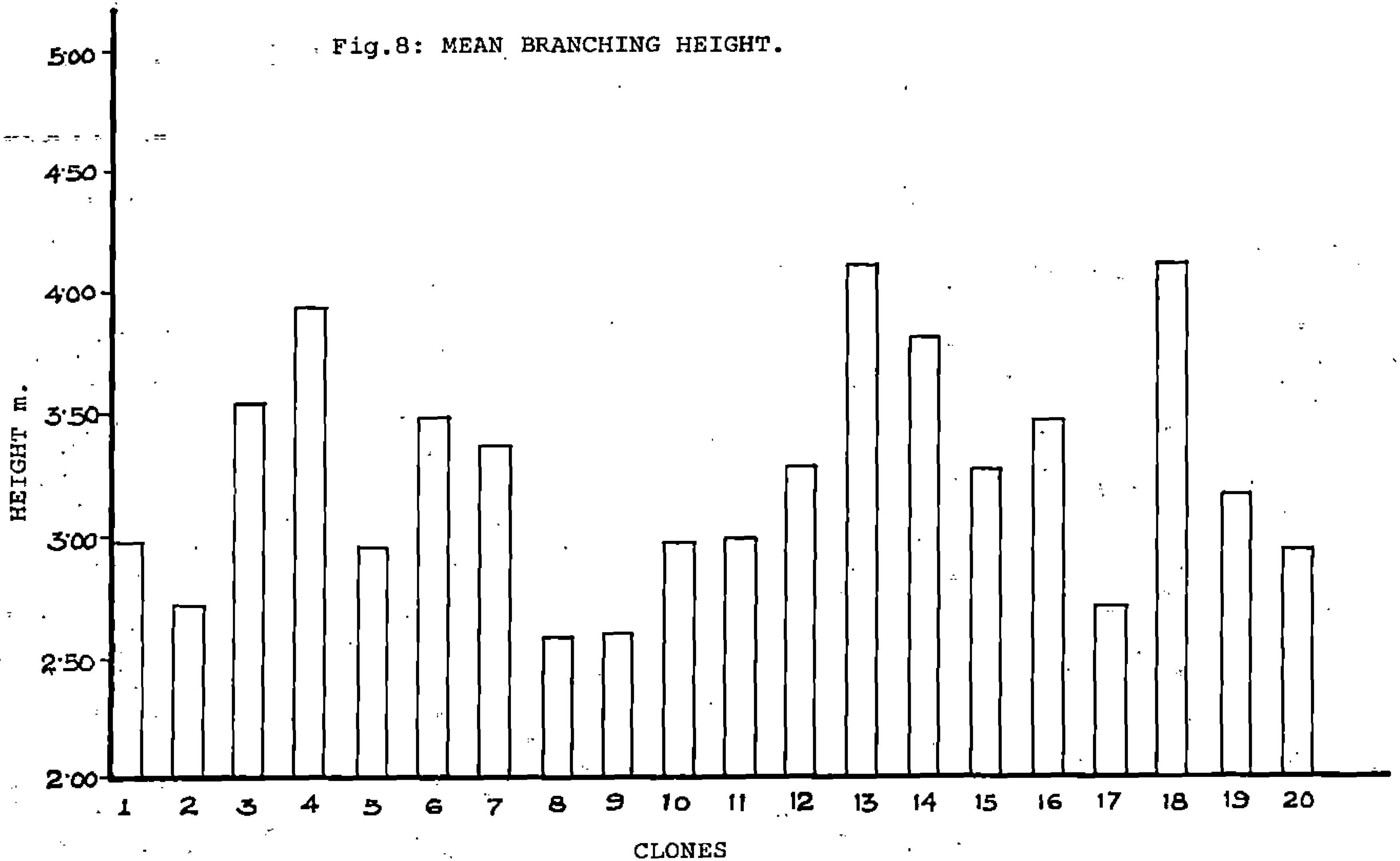


Table 17 : Mean panel length and quarterly bark consumption during 1981 and 1982

Sl. No.	Clone	Panel length cm	Quarterly bark consumption in cm							
			1981				1982			
			1	2	3	4	1	2	3	4
		S.E:2.53 C.D: -	S.E:0.34 C.D:0.69	S.E:1.06 C.D: -	S.E:0.61 C.D:1.23	S.E:0.55 C.D: -	S.E:1.16 C.D:2.34	S.E:1.25 C.D: -	S.E:1.40 C.D: -	S.E:1.31 C.D: -
1.	RRII 3	34.36	6.60	5.22	5.44	4.88	6.33	9.27	9.37	9.83
2.	RRII 4	34.72	5.69	5.25	5.68	5.10	6.11	8.85	10.16	9.73
3.	RRII 5	38.99	5.85	4.91	5.38	4.72	6.22	8.31	9.38	9.82
4.	RRII 6	40.48	6.77	4.85	4.94	4.40	6.05	9.20	11.11	10.25
5.	RRII 17	37.52	5.89	5.05	5.16	4.85	7.27	7.62	9.19	9.74
6.	RRII 18	35.22	6.05	5.00	5.30	4.71	6.16	7.44	8.66	8.78
7.	RRII 37	36.94	5.99	5.08	5.33	4.36	5.91	8.53	9.97	9.73
8.	RRII 38	38.66	6.00	5.55	6.00	4.87	6.05	7.80	8.85	8.66
9.	RRII 43	35.27	5.77	5.16	5.72	4.66	6.25	8.36	9.53	9.23
10.	RRIM 600	35.58	6.10	4.86	5.00	4.83	6.06	8.63	8.83	9.66
11.	RRIM 701	40.72	5.92	5.00	7.55	5.49	6.33	9.33	11.32	10.80
12.	RRIM 703	37.93	6.00	5.01	7.55	6.22	5.88	11.00	11.91	11.26
13.	PB 5/51	36.77	6.33	4.83	7.55	5.77	6.36	8.85	9.01	8.33
14.	GT_1	39.99	6.19	4.85	8.30	5.50	6.55	9.13	9.50	9.38
15.	PR 107	36.35	6.77	5.02	7.68	5.86	6.49	9.09	10.02	8.68
16.	Ch 153	34.99	6.66	5.10	7.55	6.22	5.72	10.24	11.35	10.40
17.	IAN 713	32.82	5.88	4.73	6.44	5.53	5.80	9.00	9.25	9.18
18.	IAN 873	34.91	6.38	4.99	7.55	5.58	5.72	10.86	11.16	10.07
19.	Harbel 1	40.80	6.49	5.02	7.05	6.08	6.02	10.91	11.31	10.25
20.	Wagga 6278	36.08	6.47	4.80	7.55	5.83	5.94	11.25	13.03	10.90
	Mean	37.12	6.19	5.01	6.45	5.27	6.16	9.20	10.14	9.77

4.10. Bark consumption.

The consumption of bark was recorded during each quarterly period and analysed for variance. The extent of bark consumed during each quarter of 1981 and 1982 is summarised in Table 17. The analysis showed significant difference during certain quarters for clones. The mean quarterly consumption of bark was 7.27 cm and maximum consumption was recorded during the third quarter in 1982.

4.11. Incidence of Brown bast.

The percentage of trees affected by brown bast during the experimental period is given in Table 18. The percentage of trees affected during the first year and total trees affected at the end of the observations are given separately. The trees of clone RRIM 703 were the most susceptible to the disease. In this clone out of the 18 experimental trees 6 trees have gone out of tapping by the end of second year. The other clones affected by this phenomenon were RRII 3 and RRII 17. None of the trees belonging to clones RRII 38, PR 107, Ch 153, IAN 713, Harbel 1 and Wagga 6278 showed this syndrome.

4.12. Components of variances and heritability.

Table 19 shows the analysis of variance of plot

Table 18 : Percentage of trees affected by brown bast.

Sl. No.	Clone	per cent during 1981	per cent during 1982	Total
1.	RRII 3	5.5	16.7	22.2
2.	RRII 4	5.5	5.5	11.1
3.	RRII 5	5.5	5.5	11.1
4.	RRII 6	11.1	-	11.1
5.	RRII 17	5.5	11.1	16.6
6.	RRII 18	Nil	11.1	11.1
7.	RRII 37	Nil	11.1	11.1
8.	RRII 36	Nil	-	Nil
9.	RRII 43	5.5	5.5	11.1
10.	RRIM 600	Nil	5.5	5.5
11.	RRIM 701	Nil	5.5	5.5
12.	RRIM 703	11.1	22.2	33.3
13.	PB 5/51	Nil	Nil	Nil
14.	GT_1	Nil	11.1	11.1
15.	PR 107	Nil	Nil	Nil
16.	Ch 153	Nil	Nil	Nil
17.	IAN 713	Nil	Nil	Nil
18.	IAN 873	Nil	11.1	11.1
19.	Harbel 1	Nil	Nil	Nil
20.	Wagga 6278	Nil	Nil	Nil

Table 19 : Analysis of variance of plot means for different characters in 20 clones of <u>Hevea brasiliensis</u>

Character	Mean sum of squares Clones (df=19)	Error (df=38)
1. Dry weight of rubber	385.45**	25.69
2. Volume of latex	2543.47**	226.84
3. Dry rubber content	11.05**	3.19
4. Girth 1981 January	42.79*	21.07
5. Girth 1982 December	66.50*	26.84
6. Annual girth increment	3.22*	1.26
7. Bark thickness 1981	21.08**	4.06
8. Bark thickness 1982	36.98**	3.56
9. Latex vessel rows 1981	31.01**	2.68
10. Latex vessel rows1982	45.44**	1.13
11. Panel length	16.08	9.67
12. Branching height	0.69*	0.30

** Significant at 1 per cent.

* Significant at 5 per cent.

means for different characters. It may be noted that the variance of all characters was significant for clones except for panel length. The general mean, components of variance, coefficients of variance and broad sense heritability of the main characters are given in Table 20. Dry weight of rubber had shown the maximum genotypic coefficient of variability (28.34) followed by volume of latex and number of latex vessel rows. Even though the girth increment showed high phenotypic coefficient of variance (36.22), the genotypic coefficient of variance (21.26) was lower than that of the other three characters. Girth showed minimum genotypic coefficient of variance.

The broad sense heritability was very high (0.93) for number of latex vessel rows, dry weight of rubber (0.82), volume of latex (0.77) and bark thickness (0.75). The other characters showed medium to low heritability. The minimum heritability was observed for girth at the beginning of the experiment.

4.13. Correlation and path-coefficients.

The correlation coefficient of dry rubber yield with other characters is given in Table 21. A positive significant correlation (0.9466) was found with volume of latex, bark thickness (0.5404) and number of latex vessel rows (0.5925). The volume of latex was found to be correlated with bark thickness (0.4396) and the

Table 20 : Mean, components of variance and broad sense heritability of characters.

Sl. No.	Character	Mean	Genotypic variance $\sigma^2 g$	Error variance $\sigma^2 e$	Phenotypic variance $\sigma^2 p$	Genotypic CV	Phenotypic CV	Heritability h^2
1.	Dry rubber yield (g/tree/tap)	38.87	119.92	25.69	145.61	28.34	31.25	0.82
2.	Volume of latex (ml/tree/tap)	101.00	772.21	226.84	1009.05	27.46	31.39	0.77
3.	Dry rubber content (percentage)	38.81	2.62	3.19	5.81	4.13	6.19	0.54
4.	Bark thickness (mm)	16.86	11.14	3.56	14.70	19.64	22.98	0.75
5.	Latex vessel rows No.	15.36	14.77	1.12	15.89	25.00	25.98	0.93
6.	Girth 1981 (cm) (January)	66.16	7.24	21.07	28.31	4.07	8.04	0.26
7.	Girth 1982 (cm) (December)	74.31	13.22	26.84	40.06	4.90	8.52	0.33
8.	Girth increment (cm)	4.07	0.65	1.26	1.91	21.26	36.22	0.34
9.	Branching height (m)	3.25	0.13	0.30	0.43	11.08	20.31	0.30

Table 21 : Correlation coefficients

Characters	1	2	3	4	5	6	7	8	9
1. Dry rubber yield.	1.0000	0.9466*	0.5404*	0.5925*	0.1027	-0.2114	-0.2573	-0.2540	0.1118
2. Volume of latex/ tree/tap.		1.0000	0.4396*	0.4566*	0.0835	-0.3186	-0.3800	-0.3739	0 0798
3. Bark thickness			1.0000	0.7300*	0.2746	0.2061	0.1097	-0.1609	0.1605
4. Latex vessel rows				1.0000	0.1976	0.0577	-0.0143	-0.1625	0.3552
5. Dry rubber content					1.0000	0.1813	0.2049	0.1731	-0.2670
6. Girth (1981)						1.0000	0.9577*	0.4712*	0.0129
7. Girth (1982)							1.0000	0.7047*	-0.0202
8. Girth increment								1.0000	0.0762
9. Branching height.									1.0000

* Significant

number of latex vessel rows (0.4566). The annua˘ girth increment on tapping was found to be positively related to the girth of trees. The annual girth increment, however, was found negatively (not significantly) correlated with all other characters except dry rubber content and girth. The height of branching showed a positive but not significant correlation with number of latex vessel rows (0.3552).

The direct and indirect effect of the major six components towards dry rubber yield are given in Table 22. The path-coefficient is represented diagramatically in Fig. 9.

The direct effect towards dry rubber yield was the highest for volume of latex (0.9405) followed by number of latex vessel rows (0.0891). The direct effect of all other characters was negative, though not at high levels. The effect of all other attributes which were not considered in the analysis (residual effect) worked out to be only 0.2032.

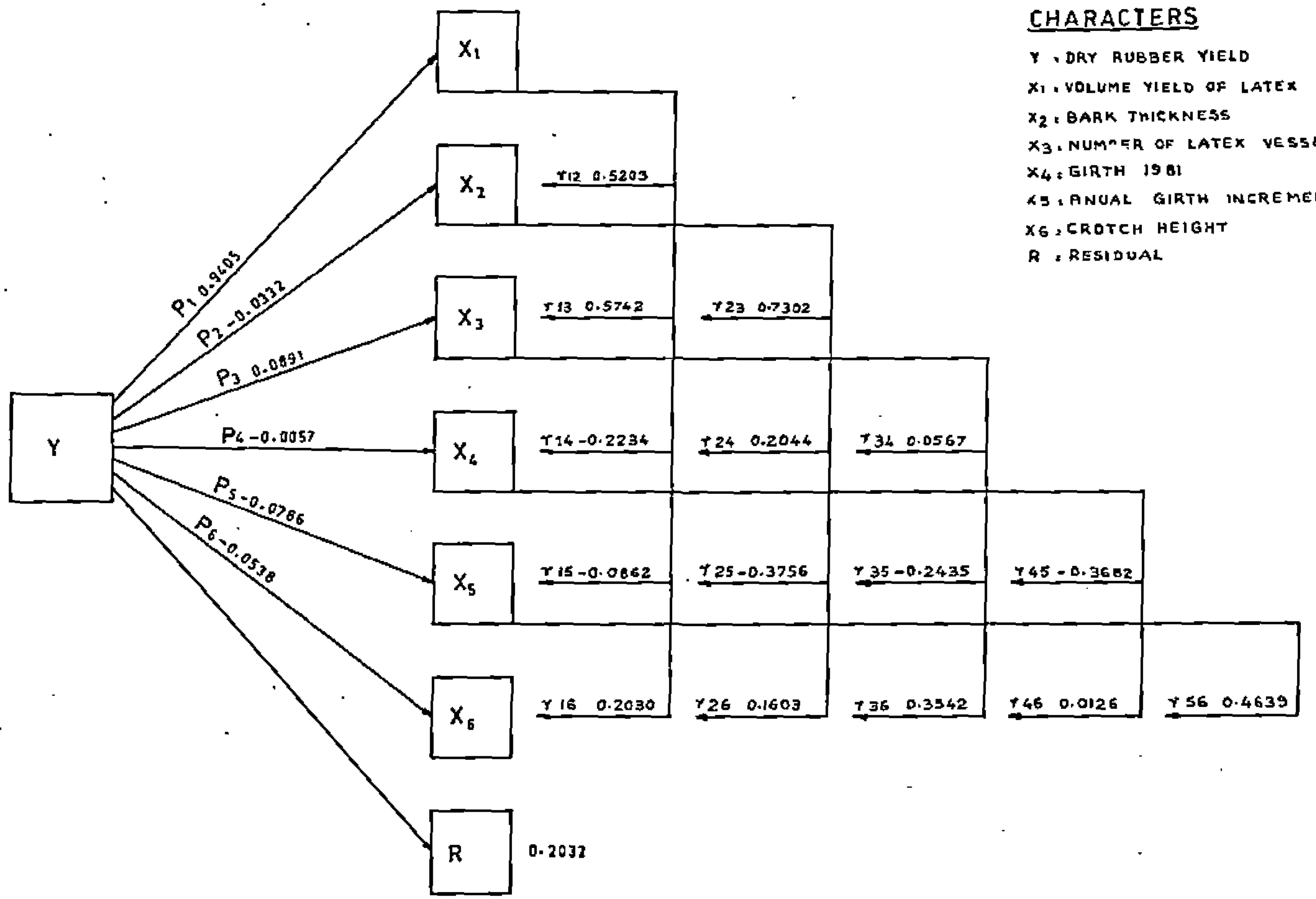
The indirect effects of a few characters are worth considering. Bark thickness showed a positive significant correlation coefficient (0.5406) with dry rubber yield, but it showed negative direct effect (-0.0332). However, the indirect effect through volume of latex was positive (0.4893). Similarly the number

Table 22 : Direct and indirect effect of six major characters on dry rubber yield. (The correlation coefficients of these characters are given in Appendix xi).

Characters	Volume of latex	Bark thickness	Latex vessel rows	Girth	Annual girth increment	Branching height	Correlation with dry rubber yield
Volume of latex	0.9405	-0.0172	0.0511	0.0012	0.0067	-0.0109	0.9713
Bark thickness	0.4893	-0.0332	0.0650	-0.0012	0.0295	-0.0089	0.5406
Latex vessel rows	0.5400	-0.0242	0.0891	-0.0003	0.0191	-0.0191	0.6044
Girth	-0.2105	-0.0067	0.0050	-0.0057	0.0289	-0.0007	-0.1895
Annual girth increment	-0.0810	0.0124	-0.0216	0.0020	-0.0786	-0.0236	-0.1913
Branching height	0.1909	-0.0053	0.0316	-0.0001	-0.0365	-0.0538	0.1267

Residual effect = $\sqrt{1 - 0.9587}$ = 0.2032

FIGURE.9 PATH COEFFICIENT DIAGRAM



CHARACTERS

Y : DRY RUBBER YIELD

X_1 : VOLUME YIELD OF LATEX

X_2 : BARK THICKNESS

X_3 : NUMBER OF LATEX VESSEL ROWS

X_4 : GIRTH 1981

X_5 : ANUAL GIRTH INCREMENT

X_6 : CROTCH HEIGHT

R : RESIDUAL

of latex vessel rows had significant correlation coefficient (0.6044), but the direct effect was negligible (0.0891). However, both these characters showed high indirect effect (0.4893 and 0.5400) through volume of latex on dry rubber yield.

Among the yield attributes studied, volume of latex showed the highest positive correlation and direct effect with dry yield and it also showed positive indirect effect via number of latex vessel rows and bark thickness. The branching height had positive correlation with dry rubber yield (0.1267), and the direct effect was negative but positive indirect effect via volume of latex.

4.14. Genetic divergence among the clones.

Using the values of uncorrelated linear combinations for nine characters in the twenty clones, the squares of the genetic distances (D^2) were obtained. The 190 values of D^2 obtained by taking 20 clones two at a time are given in Appendix X.

The D^2 values ranged from 0.92 to 630.26. The results show that genetic divergence exists in the materials studied. The percentage contribution of characters (in terms of ranks of D^2) towards divergence in descending order is given in Table 23. Maximum

Table 23. Relative contribution of nine uncorrelated variables towards divergence among 20 clones of Hevea brasliensis.

Comparisons	Dry rubber yield	Volume yield of latex	Bark thick-ness	No. of latex vessel rows	Dry rubber content	Girth Jan 1981	Girth Dec 1982	Girth incre-ment Jan 1983	Branching height
A. Between clones									
Rank totals	912	1399	1355	1363	1004	278	1004	709	523
Percentage	10.66	16.36	15.84	15.94	11.74	3.25	11.74	8.29	6.15
Ranks	4	8	6	7	5	1	5	3	2
B. Within clusters									
I. Rank totals	29	47	39	48	40	16	40	29	27
Ranks	3	6	4	7	5	1	5	3	2
II. Rank totals	12	11	11	10	5	8	11	11	11
Ranks	5	4	4	3	1	2	4	4	4

divergence was shown by girth at the start of the experiment. This was followed by branching height, annual girth increment, dry rubber yield and dry rubber content. Bark thickness and number of latex vessel rows contributed equally towards divergence. Minimum divergence was for volume of latex per tree per tap.

Based on the D^2 values the 20 clones were grouped into eight clusters. The intra cluster distance (D^2) within each group was below 11. The clones included in each cluster based on the distances (D^2) are given in Table 24. In cluster one there were eight clones (RRII 3, RRIM 701, PB 5/51, GT_1, PR 107, Ch 153, IAN 713, and Harbel 1) and was the biggest cluster. Three clones (RRIM 600, RRII 5 and RRII 4) were included in cluster two and two clones each in cluster three (RRII 37 and RRII 7), four (RRII 43 and RRII 6) and five (RRII 18 and IAN 873). The other clusters have only one clone each (Wagga 6278 in cluster six, RRIM 703 in cluster seven and RRII 38 in cluster eight). The average of intra and inter cluster distance square are worked out and are given in Table 25. The average intra and inter cluster distance (the square root of the values in Table 25) are given in Table 26. The maximum distance was between clusters 7 and 9 followed by 3 and 7. The average intra cluster distance for cluster one was only 2.71. This cluster showed maximum genetic divergence with clusters seven and eight.

Table 24 : Clones included in each cluster and intra cluster D^2 values

Cluster	Average intra cluster D^2	Sl. No. of clones included
I	7.32	1, 11, 13, 14, 15, 16, 17 and 19.
II	4.68	2, 3 and 10.
III	3.74	5 and 7
IV	4.90	4 and 9
V	5.24	6 and 18
VI	0	20
VII	0	12
VIII	0	8

Table 25 : Average intra and inter cluster D^2 values

Cluster	I	II	III	IV	V	VI	VII	VIII
I	7.32	90.89	60.74	32.09	16.78	25.73	165.91	142.29
II		4.68	243.10	27.17	28.94	190.73	15.62	33.01
III			3.74	166.00	117.12	14.60	449.05	139.20
IV				4.90	24.18	82.80	29.97	292.14
V					5.24	65.58	108.86	221.30
VI						0	320.13	61.02
VII							0	630.26
VIII								0

Table 26 : Average intra and inter cluster distance (D)

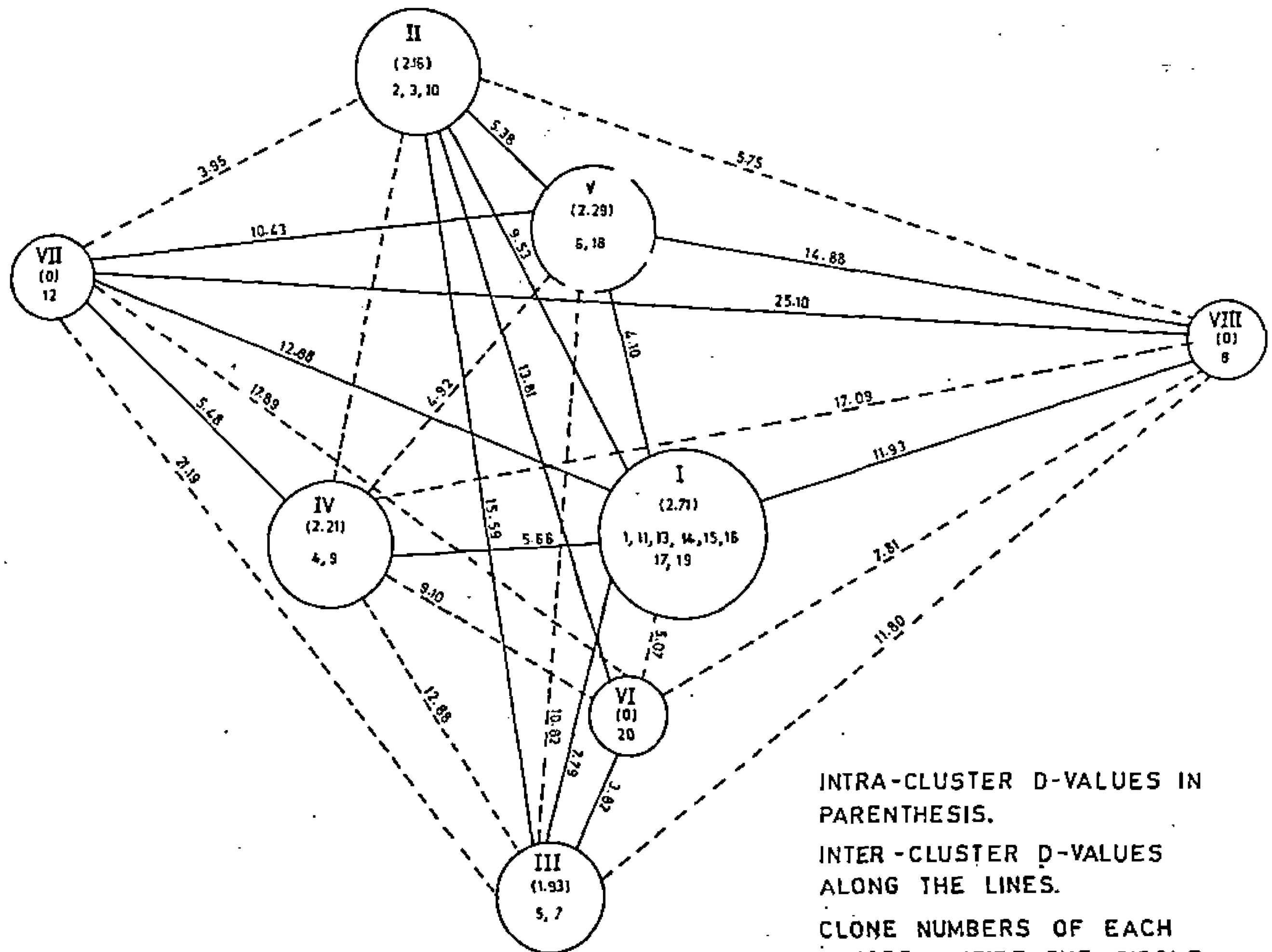
Cluster	I	II	III	IV	V	VI	VII	VIII
I	2.71	9.53	7.79	5.66	4.10	5.07	12.88	11.93
II		2.16	15.59	5.21	5.38	13.81	3.95	5.75
III			1.93	12.88	10.82	3.82	21.19	11.80
IV				2.21	4.92	9.10	5.48	17.09
V					2.29	8.10	10.43	14.88
VI						0	17.89	7.81
VII							0	25.10
VIII								0

The inter cluster D values ranged from 3.82 to 25.10 showing considerable genetic divergence among the clusters. The intra and inter cluster relationships in a two dimensional space are shown diagramatically in Fig.10. As the clusters represent a multi-dimensional space, the relative distance between the clusters could not be shown accurately in the two dimensional diagram.

9.15. Progeny testing.

Growth characters (plant height, diameter, total number of leaves and number of leaves on the top flush) recorded on seedlings raised from seeds resultant of open pollination belonging to seven clones, at 10 months growth, are presented in Table 27. The mean values of characters studied did not show significant difference between the progenies. Basal diameter was found to be numerically superior in seedlings belonging to clone RRII 3, with 12.51 mm followed by those from clones IAN 873 and Harbel 1. The seedlings of clone RRII 37 showed least growth (10.02 mm) in terms of diameter. The range of variation of individual seedlings for diameter was high for IAN 873 (7.15 to 21.00 mm), Harbel 1 (7.00 to 18.85 mm) and PB 5/51 (6.25 to 15.50 mm). The lowest was for seedlings from clone RRII 37 (6.30 to 13.70 mm). Almost the same trend, as that of diameter, was observed for height of seedlings. The number of leaves did not show much variation between the seedlings of different clones.

Fig. 10. GROUP CONSTELLATION AND STATISTICAL DISTANCE AMONG TWENTY CLONES OF *HEVEA BRASILIENSIS*.



INTRA-CLUSTER D-VALUES IN PARENTHESIS.

INTER-CLUSTER D-VALUES ALONG THE LINES.

CLONE NUMBERS OF EACH CLUSTER INSIDE THE CIRCLE.

Table 27 : Mean height, diameter and number of leaves present on seedling population

Sl. No.	Clone	Height cm S.E:13.2 C.D: -	Diameter mm S.E:1.14 C.D: -	Total No. of leaves S.E:2.75 C.D: -	No. of leaves on top flush S.E:0.92 C.D: -
1.	RRII 3	139.25	12.51	23.30	7.44
2.	RRII 37	110.16	10.02	16.88	7.24
3.	RRIM 600	124.67	10.18	19.36	6.46
4.	GT_1	112.49	11.21	20.89	6.71
5.	PB 5/51	115.64	10.81	19.53	7.32
6.	IAN 873	142.32	12.19	23.75	7.42
7.	Harbel 1	141.14	12.13	23.80	7.76
	Mean	126.53	11.29	21.07	7.19

DISCUSSION

CHAPTER 5

D I S C U S S I O N

5.1. General.

Since its introduction to the eastern hemispheres in 1876, the Para Rubber tree, *Hevea brasliensis* Muell Arg., has become one of the important industrial crops of the world and the only commercial source of natural rubber, as revealed by the several fold increase in the area under the crop and the total production of natural rubber. Propagation was through unselected seeds in the beginning which resulted in field populationsof trees of low productivity and wide variability. Although seeds picked up from elite individuals of such population produced superior genotypes, variability still existed and it was the perfection of the vegetative propagation method which paved the way for modern rubber culture. This resulted in the evolution of a large number of primary clones developed through ortet selection as well as secondary and tertiary clones through artificial hybridisation. This crop species could however, attract only little attention of geneticists owing mainly to its perennial nature. The earlier works (Whitby, 1919; Maas, 1937; Gilbert *et al.*, 1973; Nga and Subramaniam, 1974; Tan *et al.*, 1975) were mainly to assess the variability of seedling populations from ortet selections and the hybrids. Attention has recently been given to the analysis of the results of hybridisation in the light of known models in other crops. Analysing the results of the work carried out by Ross and Brookson (1966), Simmonds (1969) reported that the expected and observed yields were highly correlated and also that there existed additive gene effects for this character. Nga and Subramaniam (1974) obtained high genetic variance for yield and girth on analysing the data of the same families using the model of Comstock and Robinson (1952). Gilbert et al. (1973) and Tan et al. (1975) also reported high genetic variance for yield.

Productivity or yield of a tree or a population is measured in terms of the dry rubber recovered from the latex collected through tapping. Yield is governed by several factors like genetic nature, volume of latex, dry rubber content of the latex, girth of the tree and bark characteristics, singly and in combination. The expression of yield is further influenced by environmental characteristics. Thus the populationsexhibit considerable variability with regard to productivity. With these in the background, the results of the present work are discussed in the following pages.

5.2. Dry rubber yield.

The mean dry rubber yield per tree per tap for the different clones during the two years (Table 5) show that the productivity of the clones differ widely. The materials studied included thirteen primary clones (ortet selections) and seven secondary clones. While the low yielding clones were RRII 38 (16.2 g) and RRII 17 (21.6 g), twelve clones recorded yield less than the average yield (38.8 g) of all the clones for both the years. Among the primary clones, the yield of five were more than the general mean, whereas the yield of the rest were comparable or significantly less. Out of the seven secondary clones, three were superior yielders whereas the rest were comparatively less productive. This indicates that although the original germplasm introduced, from which all the cultivars had originated either through ortet selection or through hybridisation, was limited in number (Dijkman, 1951), it was fairly rich in genetic variability with regard to productivity. The results indicate that both hybridisation and ortet selection are of much value for tree improvement in *H. brasiliensis*.

The Para Rubber tree is deciduous and wintering takes place during December to February in South India. Soon after wintering the tree refoliates and produces a large number of inflorescences. It had been generally recognised in the past that the productivity of the trees dropped down during this period and exploitation stopped for two to three weeks during February, when the drop in yield would be maximum. Yield decrease during or soon after wintering had been reported by Dijkman (1951), Wimalaratna and Pathiratna (1974) and Sethuraj (1977).

Maas and Bokma (1950), Edgar (1958), Polhamous (1962) and Ninane (1967) also reported that the summer months are lean in terms of crop production. In the location where the experiment was conducted, rainfall was minimum during the period from December to March. The total rainfall during this period (1981 and 1982) was 67.9 cm or only 8.70 per cent of the total annual precipitation. A review of the pattern of rainfall (Table 2) reveals that it is lowest during the first quarter (January to March) when it was 8.16 per cent of the mean annual rainfall. During the second (April to June), third (July to September) and fourth (October to December) quarters the contribution of the quarterly precipitation to the total had been 33.93, 37.25 and 20.64 per cent respectively. In general, there had been a drop in yield during the January to March quarter, coinciding with the rainfall pattern. This observation is in confirmity with the low production reported by the authors cited above. However, there had been clonal differences with regard to this characteristic (Tables 5 and 6) in as much as certain clones showed less depression in yield during the first quarter. In this respect clones GT_1, RRII 4 and PB 5/51 are noteworthy for which the yield during the first quarter was 25.8, 23.1 and 23.0 per cent of the total annual yield respectively. The performance of such clones in areas with extended period of drought would be worth investigating.

The period July to December (quarters three and four) together accounted for about 60 per cent of the annual production. Among the third and the fourth quarters, there had not been much difference. However, the production during the second quarter was comparatively less (21.81 per cent), but more than that of the first quarter. Prakash (1984) had also noted that around 60 per cent of the total yield was realised during July to December period, under commercial practice. While the clones could be categorised into early, medium and late/partial wintering types based on field observations, no relationship between the wintering behaviour and yield pattern was discernible. This is in agreement with earlier reports (Wimalaratna and Pathiratna, 1974; Sethuraj, 1977).

5.3. Volume of latex

The volume yield of latex is a character related to the productivity of the trees and marked variation in this character could be expected while comparing the productivity of different genotypes. The mean volume yield of latex per tree per tap during the two years showed marked variation and ranged from 42.18 ml for clone RRII 38 to 151.58 ml for RRIM 703 (Table 9). The latex yield was more in nine clones, six primary and three secondary, compared to the general mean. The volume of latex extracted through tapping is an indication of the extent of drainage of the bark tissues and ultimately to the tree, during the process of exploitation and depends on the initial flow rate and the total duration of latex flow. When a tree is tapped the flow of latex is rapid at first due to the release of turgor pressure within the tree, gradually diminishes and ultimately ceases. The cessation of latex flow is attributed to the formation of minute plugs of rubber particles which block the cut end of latex vessels (Arisz, 1918; Frey-Wyssling, 1932; Gooding, 1952; Boatman, 1966; Buttery and Boatman, 1966). Milford et al., (1969) suggested an index based on the initial flow rate and the total volume of latex resultant of tapping and this index known as plugging index (PI), is reported to be a clonal characteristic (Sethuraj, 1977).

The mean volume of latex yield per tap recorded an increase in 1982 compared to that in 1981, a trend also reflected in the case of dry rubber yield. This difference is mai.ly due to the difference in age, accumulation of biomass and its reflection on girth of the tree and drainage area (Dijkman, 1951). The volume of latex also showed pronounced seasonal variations. Comparing the volume yield during 1981 and 1982 together, the contribution of each quarter was 20.3, 27.0, 20.0 and 29.7 per cent, in order, of the mean annual volume yield. Seasonal variation in PI had been reported by different workers (Saraswathy Amma and Sethuraj, 1975; and Sethuraj, 1977).

There had also been difference in the pattern of volume yield during 1981 and 1982 when the quarterly volume yield of latex was considered separately. During 1981, the total annual volume yield of latex was contributed by the different quarters to the extent of 20.6, 16.8, 29.4, 33.2 per cent in order. During 1982, the corresponding contributions were 20.1, 24.7, 28.7 and 26.6 per cent. The variation was reflected more in the second and the fourth quarter periods. It may be recalled in this context that there had been a change in the rainfall pattern between the two years. However, it is evident that rainfall influenced the volume yield of latex and also that the distribution of rainfall as seen from the number of rainy days (Table 2) was more important in this context than the total precipitation recorded during the respective quarter periods.

The observation also revealed that there was clonal variation with regard to this character. The genotypes may have varying interaction with the climatic conditions. It is reported (Paardekooper and Sookmark, 1969) that variation in saturation deficit of air is closely and inversely related to volume yield of latex. The present observation also indicated that volume of latex and its seasonal fluctuations are clonal characteristics. This is in confirmity with the reports of Paardekooper and Sookmark (1969), Saraswathy Amma and Sethuraj (1975) and Sethuraj and George (1976).

5.4. Dry rubber content (drc).

Dry rubber content (drc) is the measure of the quantity of rubber contained in latex expressed as percentage. Yield of rubber is dependent on the volume of latex and its dry rubber content. The dry rubber content generally falls in the range of 30 to 40 per cent (Radhakrishna Pillai, 1980). Wiltshire (1934) observed that dry rubber content may vary with time, depth, intensity and height of tapping in addition to climatic or seasonal influences. Clonal difference in dry rubber content has also been reported (RRIM, 1982). Dijkman (1951) reported that the dry rubber content decreased in latices when the tapping cut was higher on the trunk.

clonal differences in the dry rubber content of latices was observed in the present study also. Variation in dry rubber content during different seasons had also been observed. Rebaillier (1972) had also reported seasonal variations in dry rubber content. Dry rubber content was minimum during the first quarter and maximum during the second. The low dry rubber content during the first quarter could be due to wintering and concomitant changes within the tree as indicated by Schweizer (1936) who observed a decrease in the dry rubber content soon after wintering. This however, did not appear to be true for all clones (Table 12). In clones RRII 3 and RRII 38, there was no decrease in dry rubber content percentage during January to March period. It shows that there is genotypic difference in dry rubber content from lowest to highest is about eight per cent. The increase in dry rubber yield by increased dry rubber content is a desirable trait as there will be less loss of water and other constituents from the tree.

5.5. Virgin bark thickness.

Although the thickness of the bark varies in a seedling tree depending on the height along the trunk, in the case of mature budgrafted trees the bark has almost the same thickness from the union upto over 150 cm height (Vollema and Dijkman, 1939).

The bark samples for the present study from different trees were collected at a uniform height of 150 cm from the bud union. In 1981, when the trees were of ten years age, there was significant variation among clones for bark thickness. During the second year of observation also this variation was continued. Bark thickness is reported to be a clonal characteristic (Tan *et al*., 1975) with which the observations are in agreement. Of the 20 clones, 10 clones recorded above average thickness during both the years. It was further observed that while the thickness of bark increased from 1981 to 1982 in all the clones the rate of increase was different among the clones. It is therefore, apparent that the rate of increase in bark thickness is also a clonal characteristic as indicated by Vollema and Dijkman (1939). Virgin bark thickness is also an indication of growth vigour of a clone. It was also of interest to note that the lowest yielding clones had below average virgin bark thickness. The results however, reveal that bark thickness alone did not govern the production potential of a clonal population. An increase in bark thickness accompanied with increase in the number of latex vessel rows is a desirable trait in *Hevea brasiliensis*.

5.6. Latex vessel rows.

Schweizer (1949) reported that the formation of latex vessels in *Hevea brasiliensis* is dependent on the genotype and it varies with age. Han and Wu (1982) reported that the number of latex vessel rows are more in trees under tapping compared to untapped ones of the same clone. Significant difference was observed in the number of functional latex vessel rows among clones during both the years of observation (Table 14). As growth proceeds the formation of new latex vessels as well as senescence of the oldest ones take place within the tree and from the point of view of productivity, the functional latex vessels are more important. The observations (Table 14) indicated that significant variation existed among clones during both the years in the number of functional latex vessels. The response on tapping towards formation of newer latex vessels was also found to be a clonal characteristic as the rate of increase in the number of functional vessels formed varied widely. In this regard, it may be noted that newer vessels are formed towards the inner side as growth proceeds and older ones towards the outer bark become non-functional. It appears that the rate of formation is more compared to that of senescence. It was generally observed that the clones with low dry rubber yield had lesser number of functional latex vessels.

5.7. Girth and girth increment.

The girth of the tree is a measure of growth vigour and is an important attribute in the case of

Para Rubber tree in which the criterion for exploitation is girth rather than the age. In mature buddings girth is more or less uniform from the region of bud union to over 150 cm height (Vollema and Dijkman, 1939). The mean values for girth recorded at the commencement (January 1981) of the observations and at the end (December 1982) showed significant difference for clones. The observations are in confirmity that growth vigour is a genetically controlled character as earlier reported (Ostendorf, 1932, Maas, 1937; Vollema and Dijkman, 1939; Schmole, 1939; and Ferwerda, 1940). The mean annual girth increment from January 1981 to December 1982 (Table 15) is an indication reflecting the clonal characteristics. The clones behaved differently and it was indicated that trees with high vigour continued to maintain good girth. However, a true comparison of girth increment on tapping in trees within different girth groups was not possible as all the trees were under tapping and criterion for opening was already based on specified girth standards. Comparing the rate of girth increment in tapped and untapped trees Vollema (1941a) found that the rate is reduced by about one third on extraction of 3 to 4 kg of dry rubber per annum. Vollema (1941a) and Schweizer (1949) proved conclusively that tapping retard the rate of girth increment and that different clonal populations reacted differently on tapping. Decrease in dry weight on tapping was reported by Templeton (1969) and Wycherly (1976). The experimental trees were opened for tapping in 1979 and the girth recorded in January 1981 already reflected the influence of exploitation on girth increment. High yielding clones like RRIM 703, RRIM 600, RRII 4, RRII 5 and RRII 6 recorded a mean girth of 64.6, 66.3, 63.5, 68.3 and 71.3 cm respectively. The general mean girth for all the clones was 66.1 cm. However, all the clones with more girth were not highly productive. The rate of annual girth increment showed clonal variation and the highest increment was recorded by clone RRII 6 (5.22 cm). Of the five high yielding clones mentioned above, clones RRIM 600 and RRII 5 also showed above average annual girth increment. However, for the other two clones (RRIM 703 and RRII 4) the girth increment was below average (Table 15). Most of the low yielding clones, had above average girth increment on tapping which is in agreement with the reports of Schweizer (1949) and Blackman (1964). This observation is indicative that the partitioning of assimilates is less efficient in these clones. Clones like RRIM 600, which showed high rate of girth increment on tapping in spite of average initial girth are desirable.

5.8. Length of tapping panel and rate of bark consumption

The length of the tapping panel did not show any significant difference during the experimental period. The trees were tapped on half the circumference at an inclination of 30^{o} under commercial exploitation system. As the trees were on continuous exploitation from year to year without rest on the same side, no change in the length of panel was measurable, although there was an increase in girth. It may be pointed out that maximum care is taken to renew and extend the front chanel on the tapping side only, to facilitate unhindered flow of latex and its collection.

The mean quarterly consumption of bark was 7.27 cm and the analysis of the data on bark consumption showed significant difference during certain quarter periods. This was due to the difference in the number of tapping days (Table 2), particularly during the second quarter in 1981. It may however, be mentioned that the trees in different tasks were being tapped by different tappers and a slight variation depending on difference in the skill of tapping due to human factor cannot be ruled out.

5.9. Branching height.

Bud grafted trees under plantation practices generally put out branches two to three years after planting out in the field. The rate of girthing is more after the formation of branches and development of crown (Dijkman, 1951). In commercial plantations very low branches are not desirable as it will affect the exploitation system and as a practice branches arising from below 2.5 m are pruned as and when they arise (Radhakrishna Pillai, 1980). The height of branching was recorded at the commencement of the experiment. The results showed that there was significant difference between clones with regard to this character. Clones PB 5/51 and TAN 873 showed more branching height (4.20 m) than the other clones. Further these two clones showed continuity of the leader with comparatively smaller laterals which showed self pruning. In most of the other clones, however, two or more branches became heavy and as such were of more or less equal dimensions. Low branching and lesser tree height are desirable secondary attributes in *Hevea* (RRIM, 1973).

5.10. Incidence of brown bast.

Brown bast (brown bark) is a physiological disorder associated with excessive drainage of latex due to over exploitation. The affected trees may show partial or complete drying up of the panels and associated discolouration of the bark. The affected bark ultimately become unproductive. The observations on the incidence of brown bast (Table 18) revealed that the extent of its occurrence is a clonal characteristic. While trees belonging to six of the clones did not have any symptoms of brown bast during the period of observation, the others showed varying degrees of occurrence ranging from 5.5 (RRIM 600 and RRIM 701) to 33.3 (RRIM 703) per cent. The disease was found to affect both high yielding and low yielding cultivars. Latex is synthesized within the laticiferous tissues which are alive (Bobilioff, 1918 and Gomez, 1975) and it would appear from the observations that different clones may have varying capacity for latex regeneration and hence the optimum level of exploitation a clone can withstand may vary. However, high yielding clones are more prone to this disorder. Clone PR 107 reported to withstand high intensity of exploitation (RRIM, 1971) did not show any symptoms of the disease. Occurrence of brown bast is of importance in plantation management and may often warrant change in intensity of exploitation if the extent is high (Dijkman, 1951).

5.11. Components of variance.

The mean values of all characters studied showed considerable variation among the clones. The variance for girth, girth increment and branching height were significant at 5 per cent level. Hamazah and Gomez (1982) found low variance for height of branching and girth in clonal population which is supported by present observation. The variance exceeded one per cent level of significance with respect to dry rubber yield, volume of latex, bark thickness and latex vessel rows.

High phenotypic and genotypic coefficients of variance was observed for yield of dry rubber, volume of latex and number of latex vessel rows. The comparatively higher phenotypic coefficient of variation for the characters dry rubber content of latex, girth and branching height indicate that environmental influence is more in the expression of these traits. The high degree of genotypic coefficient of variation observed for rubber yield is in agreement with Whitby (1919), Simmonds (1969), Gilber et al. (1973), Nga and Subramaniam (1974), Markose and George (1980) and Hamazah and Gomez (1982). Though girth is a clonal characteristic, its manifestation is reported to differ during different phases of growth (Wycherley, 1969 and Ho, 1975b). Girth increment on tapping is also a clonal characteristic and may vary depending on the response of the clonal population to wounding (Markose and George, 1980).

5.12. Heritability.

High degree of heritability of a character is an indication of the effectiveness of selection based on phenotypic performance. The broad sense heritability was high for the characters dry rubber yield, volume of latex, number of latex vessel rows and bark thickness and was medium for the other characters (Table 19).

The dry rubber yield showed 0.82 heritability in the broad sense. This value was higher than that observed for half sib clonal populations (Markose & George, 1980). Analysing the observations of Ross and Brookson (1966), Simmonds (1969) found that general combining ability accounts for most of the differences between family yields in Hevea. The heritability estimated from progeny data were lower than that observed in the present studies. Analysing the results of 1947 to 1958 breeding programme of the Rubber Research Institute of Malaysia, Tan et al. (1975) observed a heritability of 0.27 and 0.35 for yield over five years in two groups of progenies respectively and suggested that studies on clonal population and seedling families would be useful. Liang et al. (1980) observed a heritability of 0.42 in seedling progenies involving eight cross combinations. Alika (1982) observed only 0.21 for yield over four years from ten biparental Hevea families. Liu et al. (1980) also obtained low broad sense heritability for yield. Latex vessel rings showed very high heritability compared to the other characters (Table 19) which show the possibility of effective selection based on this character. Virgin bark thickness was another character showing high heritability which also could aid clonal selection. The heritability for girth however, was only medium and may be due to the fact that the observations were confined to the third and fourth year of exploitation. Similar observations were reported by Liang et al. (1980) and Alika (1982) for girth.

5.13. Correlation.

The association of important tree characteristics revealed significant positive correlation of the dry rubber yield with volume yield of latex, latex vessel rows and virgin bark thickness (Table 20). The results are in agreement with the findings of Dijkman and Ostendorf (1929), Wycherley (1969), Narayanan et al. (1973), Tan et al. (1975), Hamazah and Gomez (1982) and Filha (1982b). Several workers like Narayanan et al. (1974), Tan and Subramaniam (1975) and Liu (1980) reported positive correlation of yield with girth of the tree. In the present study, however, a negative correlation with girth and yield (-0.2114) was obtained. Wycherley (1969) found that at opening of the tree for tapping the mean yield per tree and mean girth were positively correlated between clones, but as tapping proceeded this relationship disappeared and eventually a negative correlation with concurrent girth emerged between clones. Negative correlation with yield and girth was reported by Narayanan et al. (1973). Ho et al. (1973) and Ho (1975) found yield to be correlated with girth during the initial years of tapping, but during early maturity, girth assumed lesser importance in determining yield.

They presumed that plant assimilates are partitioned in favour of latex formation rather than growth, particularly in the case of high yielding clones, leading to a negative association of girth and girth increment with rubber yield. However, the girth recorded at the commencement and completion of the observation showed a positive correlation (0.9577). The volume of latex also showed the same relationship as that of dry rubber yield with the other characters. The number of latex vessel rows showed a very strong relationship with yield of the tree which is in agreement with many earlier reports like Bobiliof (1919), Gunnery (1935), Narayanan et al. (1974), etc. The correlation of yield of dry rubber and volume yield of latex showed only a small relation with dry rubber content. However, it had been reported that at the nursery stage yield is positively correlated with dry rubber content (Narayanan et al., 1974). It therefore, appears that under normal exploitation procedure the effect of dry rubber content may not reflect much on dry rubber yield. This may possibly be due to selection of clones based on yield of dry rubber. It is however, interesting to note a negative relationship with branching height and dry rubber content. The correlation of branching height with other characters were all small and agrees with the findings of Hamazah and Gomez (1982).

8.14. Path coefficient analysis.

The cause and effect relationships of the important characters (Table 21) showed that volume yield of latex had the highest positive direct effect on dry rubber yield. The number of latex vessel rows showed a very low positive effect on dry rubber yield eventhough the correlation (0.6044) was very high. The direct effect of all other characters showed negative direct effect, though not at high levels. The significant positive correlation of yie'd with number of latex vessel rows and virgin bark thickness was manifested through volume of latex.

Napitapulu (1973) found correlation between individual yield and girth within clones but not between clones. The correlation of yield and girth needs further elucidation as the effect of tree girth on dry rubber yield varies with the growth phase as well as the stage of exploitation as already discussed.

The volume of latex is the major factor governing the dry rubber yield of a clone. As such the factors influencing the volume yield of latex also assume importance. Sethuraj (1977) found that the soil temperature in the morning hour was the most important single factor influencing day to day variation in the volume yield of latex, the direct effect on dry rubber yield being -1.08 and correlation -0.551. The yield of dry rubber was found to be positively correlated with bark thickness and number of latex vessel rows. However, the direct effect of these characters on dry rubber yield was small indicating that the influence was mainly through volume yield of latex. Use of such characters as parameters for selection would therefore be reliable (Singh and Choudhary, 1977). The undefined factors (residual effect) contributed only 0.2032.

5.15. Genetic divergence.

The genotypes introduced from the centre of origin of the species, which became available as nucleus material for commercial cultivation, was limited in the case of *Hevea brasiliensis*. The tree is cross pollinated and in the early history of commercial cultivation, propagation was only through seeds. Subsequent selection procedures using generative and vegetative modes of propagation had resulted in a large number of genotypes exhibiting wide variation in different characters. However, mainly the variability in respect of dry rubber yield has been exploited for the improvement of this crop species. No attempt has been so far made in estimating the genetic divergence of the genotypes. It is, however, reported that combination of genetically divergent parents could result in better heterosis.

An attempt has been made in the present studies to estimate the genetic divergence, through Mahalanobis' D^2 analysis, with respect to the 20 clones employing nine quantitative characters. The clones were grouped into eight clusters keeping the intra cluster distances as small as possible. The intra cluster D values ranged from 0 to 2.71 whereas the inter cluster D values ranged from 3.82 to 25.10. This revealed the existance of considerable genetic divergence between the clusters. The number of genotypes in each cluster varied from one to eight. It was found that the combinations of different set of parameters accounted for the observed genetic divergence. Among the characters, maximum divergence was shown for girth (January 1981) which was followed in order by branching height, annual girth increment, girth (December 1982), dry rubber content,bark thickness, number of latex vessel rows, volume of latex and dry rubber yield. Eight clones were represented in cluster I and interestingly these clones belong to different geographic, primary and secondary origin. Clones evolved in different countries as well as clones in different stages of experimentation could be appropriately placed in this cluster. The next biggest cluster was the second, having three clones, two evolved in India and the other in Malaysia. The third, fourth and fifth clusters had only two clones in each. The three remaining clusters had only one clone each.

The existance of genetic divergence among clones as revealed in the present study and the observations that genetically divergent parents give rise to progenies with more variability (Liu, 1980; Ho and Ong, 1981) and that yield is polygenically controlled (Simmonds (1969) will aid tree improvement in the species in a more sound footing. It may be possible to exploit heterosis for different characters based on the genetic divergence.

5.16. Progeny testing.

Seedling progenies raised from open pollinated seeds belonging to seven clones of varying dry rubber yield and other parameters did not reveal any significant difference in seedling height, basal diameter, total number of leaves and number of leaves on the top flush, at ten months growth in spite of the fact that they belonged to different clusters. Numerical differences were, however, noticeable with respect to all the characters studied. Out of the seven clones, four belong to cluster one and one clone each from cluster two, three and five. In this connection it may be pointed out that the diameter of the seedlings above collar region showed variation within each progeny population (Table 27). It would therefore appear possible to utilise seedlings belonging to diameter classes higher than the mean as stocks for propagation. The lack of significant difference in the parameters observed when the seedlings were 10 months old, indicate that for full expression of traits the population would be rared for longer duration preferably in the field with appropriate spacing allowing proper development of a root system and crown in this perennial crop species. However, an indication of growth parameters of seedlings of different clones could be assessed. It was observed that seedlings belonging to clone RRII 37 showed numerically low diameter and height.

5.17. Conclusion.

The results of the study confirm that there is considerable genetic variation in the production potential of the different clonal populations. Further, the production of dry rubber yield vary with periods and environmental interaction is indicated. The choice of planting materials for a particular location needs a clear understanding of the climatic condition prevailing in that area as well as the clonal characteristics.

The characters that influence the production of rubber vary with the growth phase. Plant vigour, in terms of girth, is important at the early years of exploitation and later the partitioning of nutrients is more important. Among the characters, volume yield of latex is the most important factor governing the yield of dry rubber. Virgin bark thickness and number of functional latex vessel rows are also important characters governing yield, though their influence is indicated through the volume yield of latex. It is also of importance that the trees may exhibit brown bast when more latex is extracted, particularly in the case of high yielding clones. A rational approach towards exploitation is therefore needed in commercial practice. The study of correlation and path analysis has shown that in a selection programme for improvement in yield appropriate emphasis must be given for the different characters involved.

The assessment of genetic divergence in the materials using D^2 analysis, has revealed that there exist considerable genetic diversity within the species, Hevea brasiliensis. The genetic divergence among the different genotypes is not due to the divergence in a particular character or the same set of characters, but a combination of different characters. Hybridisation between widely diverse genotypes may result in greater range of variability, especially in view of the heterozygous nature of the species, coupled with cross pollination under natural conditions. The resultant hybrid progenies will offer ample scope for selection of superior genotypes, which can be multiplied vegetatively without impairing the genetic make up. A systematic approach in this direction is yet to be attempted in Hevea breeding.

SUMMARY

CHAPTER 6

SUMMARY

Biometrical analysis of yield and certain yield attributes in *Hevea brasiliensis* was undertaken with respect to twenty clones. The studies made were on (1) productivity, (2) seasonal fluctuations in productivity, (3) variability of yield and certain yield attributes, (4) correlations, (5) cause effect relationship, (6) genetic divergence and grouping, and (7) early growth vigour of seedlings belonging to seven clones. The observations were carried out on trees planted in 1971 at the Central Experiment Station of the Rubber Research Institute of India, Chethackal (Pathanamthitta District) during 1981 and 1982.

The mean dry rubber yield showed variation among clones during the two years of observation. The maximum mean yield was obtained for the clone RRIM 703 (55.73 g.t.t) and the minimum for RRII 38 (16.20 g.t.t). The mean annual increase from the first to the second year of observation was only 3.60 g.t.t. Sixty per cent of the annual dry rubber yield was contributed by the July to September (third) and October to December (fourth) quarter periods. The yield during the period

January to March showed maximum variation among clones. The clone GT_1 showed minimum fluctuation in yield during the different quarter periods.

Significant difference was noted in volume yield of latex for clones, periods and clone period interaction. The trend was comparable to that for dry rubber yield. The dry rubber content of latex showed significant difference for clones. Highest dry rubber content was noted for the latex of clone R. II 43 (42.48 per cent) and the lowest for IAN 873 (34.51 per cent). Difference between years, periods and interactions were also significant.

Thickness of the virgin bark at 150 cm height from the bud union showed significant difference among clones. The range was 13.86 to 20.29 mm. The average annual increase in thickness of bark was 1.01 mm. Significant difference was noted for the number of latex vessel rows among clones during both the years. The number of functional latex vessels was maximum for clone RRII 6 during 1981 (17.95) and 1982 (22.48). The minimum was observed for RRII 38, the number being 6.60 and 8.05 during 1981 and 1982 respectively. Clones also showed difference in the rate of increase in the number of latex vessel rings. The rate was comparatively high for clone Wagga 6278.

Crotch height also showed clonal difference. The girth of the trees at 150 cm height from the bud union showed significant difference at certain quarters only. However, the mean annual girth increment showed significant difference among clones. Highest increment was noted for the low yielding clone RRII 38 (5.29 cm) and lowest for the clone RRIM 701 (2.60 cm). The high yielding clone RRIM 703 had only 2.98 cm annual girth increment. The clones RRII 6 and RRII 5, two high yielding clones, showed comparatively good girth increment (5.22 and 4.42 cm respectively). It appears that partitioning of nutrients is quite efficient in these clones towards latex production as well as growth. The length of the tapping panel did not show significant difference. The mean quarterly consumption of bark on tapping was 7.27 cm. The rate of incidence of brown bast was more in high yielding clones although its occurrence was noted in some of the low yielding clones also.

Genotypic coefficient variance and broad sense heritability was high for dry rubber yield, volume yield of latex, bark thickness and number of latex vessel rows. Dry rubber content showed comparatively low genotypic coefficient of variance. Yield was positively and significantly correlated with latex volume, bark thickness and number of latex vessel rows. Positive direct effect of volume of latex and number of latex vessel rows on dry rubber yield was revealed in path coefficient analysis. The correlation of bark thickness and latex vessel rows with yield was found mediated through volume yield of latex.

Estimation of D^2 values of nine characters showed that girth, crotch height, girth increment, dry rubber yield, dry rubber content, bark thickness, number of latex vessel rows and volume yield of latex contribute for the genetic divergence. The cultivars studied were grouped into eight clusters based on intra and inter cluster distances. Among the different clusters the divergence (D values) varied between 3.82 and 25.10.

No significant difference was noted in early growth behaviour of seven clonal seedling progenies, raised from seeds resultant of open pollination, at ten months' growth in the nursery. It appears that for expression of clonal characters in seedlings needs further growth in the field.

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APPENDIX

Appendix I : Analysis of variance : Dry rubber yield during different periods of 1981

Source	df	SS	MSS	VR	F 5%	F 1%
Periods	3	24577.67	8192.56	154.96**	2.67	3.91
Within periods	6	408.56	68.09	1.29	2.16	2.92
Clones	19	31995.75	1683.99	31.85**	1.66	2.03
Periods x clones	57	11124.60	195.17	3.69**	1.42	1.63
Pooled error	152	8036.62	52.87			

** Significant at 1%

Appendix II : Analysis of variance : Dry rubber yield during different periods of 1982

Source	df	SS	MSS	VR	F 5%	F 1%
Periods	3	8293.09	2764.36	57.15**	2.67	3.91
Within periods	6	333.64	55.61	1.15	2.16	2.92
Clones	19	28131.63	1480.61	30.61**	1.66	2.03
Periods x clones	57	5194.45	91.13	1.88**	1.42	1.63
Pooled error	152	7352.62	48.37			

** Significant at 1%

Appendix III : Analysis of variance : Dry rubber yield. Pooled data for 1981 and 1982

Source	df	SS	MSS	VR	F 5%	F 1%
Between years	1	1577.25	1577.25	31.16**	3.88	6.73
Periods within years	6	32870.75	5478.46	108.23**	2.11	2.88
Clones	19	58521.04	3080.05	60.85**	1.63	1.98
Year x clones	19	1606.35	84.54	1.67*	1.63	1.98
Periods x clones	114	16348.45	143.41	2.83**	1.25	1.37
Pooled error	304	15388.48	50.62			

* Significant at 5%
** Significant at 1%

Appendix IV : Analaysis of variance : Volume of latex during different periods of 1981

Source	df	SS	MSS	VR	F 5%	F 1%
Periods	3	148555.80	49518.60	134.50**	2.67	3.91
Within periods	6	2458.90	409.82	1.11	2.16	2.92
Clones	19	197950.72	10418.46	28.30**	1.66	2.03
Periods x clones	57	68995.41	1210.45	3.29**	1.42	1.63
Pooled error	152	55963.74	368.18			

** Significant at 1%

Appendix V : Analysis of variance : Volume of latex during different periods of 1982

Source	df	SS	MSS	VR	F 5%	F 1%
Periods	3	44990.37	14996.79	38.46**	2.67	3.91
Within periods	6	2629.10	438.18	1.12	2.16	2.92
Clones	19	209117.53	11006.19	28.23**	1.66	2.03
Periods x clones	57	44854.70	786.92	2.02**	1.42	1.63
Pooled error	152	59269.74	389.93			

** Significant at 1%

Appendix VI : Analysis of variance : Volume of latex : Pooled data for 1981 and 1982

Source	df	SS	MSS	VR	F	
					5%	1%
Between years	1	18864.35	18864.35	49.77**	3.88	6.73
Periods	6	193546.33	32257.72	85.10**	2.11	2.88
Clones	19	389262.68	20487.51	54.05**	1.63	1.98
Year x clones	19	17805.73	937.14	2.47**	1.63	1.98
Periods x clones	114	113793.55	998.19	2.63**	1.25	1.37
Pooled error	304	115232.72	379.06			

** Significant at 1%

Appendix VII : Analysis of variance : Dry rubber content for 1981

Source	df	SS	MSS	VR	F 5%	F 1%
Periods	3	1307.14	435.71	47.10 **	2.67	3.91
Within periods	6	14.64	2.44	<1	2.16	2.92
Clones	19	1380.28	72.65	7.85 **	1.66	2.02
Periods x clones	57	1097.80	19.26	2.08**	1.42	1.63
Pooled error	152	1405.35	9.25			

** Significant at 1%

Appendix VIII : Analysis of variance : Dry rubber content for 1982

Source	df	SS	MSS	VR	F 5%	F 1%
Periods	3	474.25	158.08	18.15**	2.67	3.91
Within periods	6	85.02	14.17	1.63	2.16	2.92
Clones	19	675.90	35.57	4.08**	1.66	2.02
Periods x clones	57	646.20	11.34	1.30	1.42	1.62
Pooled error	152	1323.81	8.71			

* Significant at 5%
** Significant at 1%

Appendix IX : Analysis of variance : Dry rubber content : Pooled data for 1981 and 1982

Source	df	SS	MSS	VR	F 5%	F 1%
Between years	1	95.23	95.23	10.60**	3.88	6.73
Periods	6	1781.37	296.90	33.06**	2.11	2.88
Clones	19	1694.73	89.20	9.93**	1.63	1.98
Year x clones	19	361.43	19.02	2.12**	1.63	1.98
Periods x clones	114	1744.08	15.30	1.70**	1.25	1.37
Pooled error	304	2729.16	8.98			

* Significant at 5%
** Significant at 1%

Appendix X : D^2 values among 20 lones of <u>Hevea brasiliensis</u>

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	52.24	54.65	25.93	94.35	4.81	61.79	169.95	12.05	96.21	7.87	150.81	1.44	4.73	2.88	15.83	10.17	16.87	5.06	32.17
2	0	0.92	1[illegible].17	285.26	36.31	226.56	407.75	18.46	6.93	37.10	26.72	68.18	53.01	79.53	123.82	100.39	33.88	86.53	164.94
3		0	20.47	287.32	35.90	229.20	409.18	22.26	6.21	35.61	24.44	70.33	51.81	82.21	125.50	100.72	30.63	87.79	169.10
4			0	210.57	24.90	159.25	317.07	4.90	39.45	30.98	76.85	37.57	37.64	43.38	79.31	67.80	38.64	51.71	103.84
5				0	122.79	3.74	11.19	169.84	376.75	127.66	476.52	76.26	99.57	64.81	33.25	48.83	149.33	58.46	21.15
6.					0	86.37	205.56	11.90	71.52	2.72	117.65	8.39	2.39	12.44	29.42	17.62	5.24	12.59	52.64
7.						0	27.19	124.37	309.43	92.35	401.58	47.96	68.49	38.45	15.58	27.57	111.80	33.98	8.05
8.							0	267.22	515.03	211.73	630.26	145.49	174.74	129.46	82.37	104.97	239.28	119.62	61.02
9.								0	47.25	15.37	88.75	21.20	21.00	25.85	53.75	42.12	21.30	32.37	79.92
10									0	70.60	6.80	117.10	93.53	132.13	186.48	155.97	61.99	140.02	238.16
11										0	113.42	10.34	2.54	15.95	33.02	20.12	2.81	16.48	59.75
12											0	175.39	143.45	194.79	259.16	221.69	100.08	203.58	320.13
13												0	4.84	0.79	9.50	5.99	21.09	2.01	22.31
14													0	8.26	15.92	10.57	7.29	7.20	40.27
15														0	5.68	4.28	27.97	0.98	16.08
16															0	2.49	46.42	3.97	6.10
17																0	28.79	2.18	14.85
18																	0	27.00	78.53
19																		0	14.32
20																			0

Appendix xi. Genotypic Correlation coefficients of six major characters on dry rubber yield.

Characters	Dry rubber yield	Volume of latex	Bark thickness	Latex vessel rows	Girth	Girth increment	Branching height
Dry rubber yield	1.0000	0.9713*	0.5406*	0.6044*	-0.1895	-0.1913	0.1267
Volume of latex		1.0000	0.5203*	0.5742*	-0.2234	-0.0862	0.2030
Bark thickness			1.0000	0.7802*	0.2044	-0.3756	0.1684
Latex vessel rows				1.0000	0.0567	-0.2436	0.0543
Girth (1981)					1.0000	-0.3687	0.0126
Girth increment						1.0000	0.4659*
Branching height							1.0000

* Significant 5%

P L A T E S 1 - 4

Hevea brasiliensis Muell. Arg.

Plate 1

Fig.1. Sowing of rubber seeds in germination bed.

Fig.2. Nursery with stock seedlings of approximately six months' growth.

Plate 1

Fig.1. Sowing of rubber seeds in germination bed.

Fig.2. Nursery with stock seedlings of approximately six months' growth.

Plate 2

Fig.3. Source bush nursery for collection of budwood.

Fig.4. Young rubber plantation, four years after planting.

Plate 3

Fig.5. Mature rubber plantation under regular exploitation.

Fig.6. Mature rubber plantation with polythene rain guards provided on the trees to facilitate exploitation during rainy season.

Plate 4

Fig.7. A rubber tree under tapping showing tapping panel, collection cup, etc.

Fig.8. Radial longitudinal section of the Hevea bark (x 11) showing latex vessel rows, soft bark, hard bark, etc.

Fig.9. Tangential longitudinal section showing the anastamose between laticifers (x 250).

BIOMETRIC ANALYSIS OF YIELD AND CERTAIN YIELD ATTRIBUTES IN THE PARA RUBBER TREE:

Hevea Brasiliensis Muell. Arg.

By

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ABSTRACT OF A THESIS
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ABSTRACT

The para rubber tree, Hevea brasiliensis, is the commercial source of natural rubber. Introduced into the Far East in 1876, from Brazil, commercial cultivation started in India during 1902.

The tree has a gestation period of six to seven years. A large number of clones have been evolved through ortet selection and through hybridisation, which show variability for different characters.

The present study was undertatken to estimate (1) productivity, (2) yield pattern, (3) variability, (4) correlations, (5) effect of yield attributes, (6) genetic diversity of twenty clones, and (7) early growth vigour of open pollinated seedlings of selected clones.

The investigations were carried out on twenty clones, planted in 1971 on RBD and opened for tapping (S/2 d/2 system) in 1978 at the Central Experiment Station of the Rubber Research Institute of India for a period of two years, beginning January 1981. Observations were recorded on dry rubber yield, volume yield of latex, dry rubber content of latex, girth, bark thickness, number of latex vessel rows and branching height. Vigour of seedlings belonging to seven clones was studied at ten months' growth.

The mean dry rubber yield showed significant variation among clones during both the years. The order of performance of the clone was more or less the same during both the years. Yield recorded during different quarterly periods showed significant difference among clones, periods and clone period interaction. In general 60 per cent of the total yield was obtained during June to December. The volume of latex showed almost a similar trend as that of dry rubber yield. The volume of latex was more during the last quarter of the year. The dry rubber content of latex showed significant variation for periods and clones. Significant clonal difference was also noted for virgin bark thickness. Clonal differences in number of functional latex vessel rings was highly significant during both the years. Tree girth showed significant difference for clones only during certain quarters, at 5 per cent level, while annual girth increment showed significant clonal difference. Clonal difference was observed for crotch height. The mean quarterly consumption of bark was 7.27 cm. The incidence of brown bast was found to be more in high yielding clones.

The genotypic variance and thereby broad sense heritability was high for dry rubber yield, volume yield of latex, bark thickness and latex vessel rows.

The dry rubber yield was positively and significantly correlated with latex yield, bark thickness and number of latex vessel rows. Path coefficient analysis showed positive direct effect of latex volume and latex vessel rows on dry rubber yield. The correlation of bark thickness and latex vessel rows on dry rubber yield was mediated through volume yield of latex.

The D^2 values on nine characters showed that the divergence occurred on girth, branching height, girth increment, dry rubber yield, dry rubber content, bark thickness, number of latex vessel rows and volume yield of latex, in order. The clones were grouped into eight clusters based on genetic distance. The divergence was found to vary between 3.82 to 25.10 among the different clusters.

Seedlings of seven clones, raised from open pollinated seeds, at 10 months' growth, did not show significant differences in plant height, basal diameter, total number of leaves and number of leaves on top flush.

The high broad sense heritability for volume yield of latex, number of latex vessel rows and thickness of virgin bark indicate effectiveness of phenotypic selection towards productivity. The results are of practical adaptability in formulating breeding strategies with a view to maximising desirable attributes in <u>Hevea brasiliensis</u>.