FIESTER

ASEXUAL PROPAGATION OF COFFEE BY CUTTINGS

I. I. C. A.

TESIS

SOME ASPECTS OF THE ASEXUAL PROPAGATION OF COFFEE BY CUTTINGS

by

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Donald Reid Fiester, Jr. was born March 5, 1924 in Los Angeles, California. He attended the Montebello Senior High School in Montebello, California and the California State Polytechnic College in San Luis Obispo, California, receiving a technical degree. In 1947 he joined, as assistant horticulturist, the staff of the Escuela Agricola Panamericana located near Tegucigalpa, Honduras. He received a scholarship to the Inter-American Institute of Agricultural Sciences in 1950 during the course of which the present studies were completed.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Asexual propagation by cuttings affords the most important means of multiplying many species and varieties of plants. As a means of vegetative reproduction, cuttage and graftage have been in common practice since the beginning of agriculture (71). Until recently, because of a lack of experimental work the practice of making cuttings has been chiefly according to habit. When certain methods were used and results were unsatisfactory, another means of multiplying a plant was tried.

With the advent of the well founded belief that all plants can be propagated by cuttings when proper conditions are maintained (90), intensive research has resulted in the determination of many factors that take part in the rooting of cuttings. This information on how to root coffee cuttings more easily may add a valuable tool in the improvement of this plant.

It was estimated by the Inter-American Coffee Board in 1948 (59) that there are approximately five billion coffee trees in the world. The average production of this population varies from 100 to 455 grams of "Café en oro" a year per tree depending on area, type of cultivation practices and the year selected. To make the picture of this variation in yield clearer, an estimate in Guatemala (91) showed that annually 30 per cent of the trees were producing as much as

70 per cent of the crop, and Cowgill (14) has found that yields from trees of coffee in cherry may vary from 1/10 pound to as much as 1½ pounds.

Considering only this one factor of extreme variation in tree production, it is easily seen what the potentialities are for plant improvement in this important crop. The possibility for coffee yield and quality improvement has existed for many years, but it is only during the last few years that increased effort has been realized along this line. In recent years, with demand outstripping supply and labor costs increasing, the need for improved practices and better plant material is greater than ever before.

Since coffee is propagated by seed almost exclusively, numerous factors other than production show considerable variation. In such a heterogeneous population, it is probable that an almost unlimited supply of character combinations (34) can be found for study, selection, and incorporation through breeding. Some of these factors are bean size, specific gravity of bean (35), resistance to disease (16,88), resistance to insects (16), ability to withstand unfavorable environmental conditions (26, 36), superior root system (67), period of fruiting (16), resistance to fruit dropping, and quality factors.

Two methods of raising production and quality are being used in coffee plant improvement programs. One method is

through controlled breeding, selection from the F_1 population and multiplication through vegetative means (14,17,26). The other method, being used at the Inter-American Institute of Agricultural Sciences (20), is by selection of superior lines followed by vegetative multiplication from which seed production blocks and yield trials are started. The latter method has as its objective the distribution of highly homozygous seed from superior producing parent plants while the former method will distribute asexually propagated plants from high producing parents.

It is evident from the review of literature, that our present knowledge of methods of asexual propagation of coffee by cuttings is based to a large extent on empirical trials. Use of improved methods for comparing results has been limited. Rooting of cuttings was often apparently impossible because necessary environmental conditions were not supplied and since these factors were not provided, results of applications of chemicals, use of various media, and treatments with growth substances could not be ascertained. Trials often reported as giving satisfactory or unsatisfactory results from a certain treatment had no controls. With few exceptions statistics were not applied.

Due to the empirical nature of much of the previous work, it has seemed desirable to begin a more systematic study of the factors that influence the rooting of cuttings.

The purpose of this paper is to report the first experiments on the propagation of coffee by cuttings made at the Inter-American Institute of Agricultural Sciences.

REVIEW OF LITERATURE

Trials and extensive propagation by cuttings in coffee have been reported by Arroyo (1) in Nicaragua, Cottington (12) in Kenya, Guiscafré-Arrillaga (44) in Puerto Rico, Naundorf (66) in Venezuela, Portéres (75) from the Gold Coast, Pattabhiraman and Gopalakrishnan (70) in India, Reaño (76) from the Philippine Islands, Roelofsen (78) in Java, and from Tanganyika (32). Although Ferwerda (27) and Cramer (17) showed that grafts had been used in the asexual propagation of Coffea arabica as early as 1889, it was not until 1938 (22) that a field experiment using cuttings was planted.

In general, the principal interest in the use of vegetative propagation has been centered around experimentation and multiplication of Coffea arabica. This has been logical, due to its commercial importance; however, several investigators have grown cuttings of other coffee species. Guiscafré-Arrillaga and Gómez (48) used the Columnaris species in addition to the Puerto Rican types of Coffea arabica. Porteres (75) planted cuttings of several coffee species in open beds and obtained varying results from the several species.

Roelofsen (78) stated that the method of propagating

robusta and conugu coffee in Java by cuttings was similar to that used in Tanganyika.

A review of the majority of articles published to date on the methods of propagating coffee by cuttings revealed that few systematic experiments have been carried out. With few exceptions the information has been in the nature of observations and direct unreplicated comparisons. Omission of complete conditions of the trial was often encountered when high percentages of rooting were obtained. Methods recommended by one investigator, in some instances, showed a complete disagreement with those used by another. Description of the methods considered of importance by the several workers is of value in a general way, but shows that no one superior method has yet been evolved.

Attempts to root coffee cuttings in Puerto Rico (46) gave poor results. It was at first thought that there might be no root initials on the coffee stem. A trial was made to test this hypothesis. From the results, it was shown that root primordia were present along the stems of coffee.

The following is a general review of the literature presented from the standpoint of factors which the various investigators thought important.

Fernie (25), working in Tanganyika, found that it was best to place the selected clones in mother tree nurseries. Comparing the same clones from the mother tree nursery with

regular field plantings, Fernie found that the best rooting was obtained from material taken from the mother tree nursery. It was reported from Tanganyika (24) in 1940 that the mother trees in the nursery should be grown on the multiple stem system, removing all secondary branches and bending the orthotropic stems horizontally. Guiscafré-Arrillaga (45) agreed with this method, pointing out that when the terminal bud is changed from a vertical to a horizontal position it loses its dominance, allowing the orthotropic buds along the stem to begin growth. This appears to be the easiest method of securing a quantity of suitable material from one clone. Fernie (23) thought that 20 plants per clone, placed in the mother tree nursery, would give a wealth of material. Cuttings can be made from the mother nursery after 18 months to two years. Fernie recommended that three stems be left each year to continue production of material.

Few factors in coffee propagation have received as much attention as the size and type of cutting. These factors were considered of prime importance when the cuttings were planted directly to the field. Arroyo (1), describing the Vaugham method used in Nicaragua, stated that cuttings were 27 to 28 inches long while a report from Kenya (39) stated that native growers were employing large cuttings of approximately two feet in length. Porteres (75) in the Gold Coast

observed that natives in some areas there made cuttings one meter long and planted them directly to the field. No reported consistent success in rooting coffee cuttings was found where softwood cuttings were planted directly to the field. Gillet (39) and Cottington (12) report that the Scott Agricultural Laboratory used many different types of cuttings but was never successful in open field planting. Most of the investigators used cuttings of several nodes and up to 10 inches in length when planting in propagating bins or frames (12,24, 39,41,44,49,75). Use of cuttings having one node, leaf-bud cuttings, or only leaves, has been reported by several investigators (40,47,57,70). Van Overbeek (94) was able to root isolated leaves from one-year-old seedlings but could not root leaves from older trees. Gillet (40) failed completely to root leaf and root cuttings. Fernie (23) had success on a small scale using leaf-bud cuttings of Coffea arabica and Coffea canephora var. robusta, and considered this method worthy of further study. Fernie (23) thought that softwood cuttings should have short internodes. Reports from Puerto Rico (45) state that the material for cuttings should be such that the basal wood is brown while the upper portion of the stem is green. Guiscafré-Arrillaga thought that suckers from old trees were unsatisfactory material from which to make cuttings, although in India (95) sucker cuttings were used when ringed previous to removal from the mother plant.

Roelofsen stated (78) that it was immaterial whether the basal cut was made above or below the node. Another investigator (23) recommended that the basal cut should be made at or just below the node. Cottington (12) used an angled basal cut while Arroyo (1) used a flat basal cut. Fernie (25) compared four types of basal treatments: a)an internodal wedge (two sided) cut (top of cut at node); b)internodal slanting cut (one-sided) (top of cut at node); c)nodal horizontal cut, and, d)an internodal horizontal cut. He found in a direct comparison between the nodal positions that treatments a, b, and d were highly significantly better than treatment c.

Several workers have compared the effect of leaf pruning on the process of rooting of coffee cuttings. Reaño (76) in the Philippines found that cuttings whose leaf blades are cut in half 24 hours after planting responded better than those with blades entirely removed or left intact on the cuttings. Fernie (25) also found that he had better rooting of coffee cuttings when the leaves were trimmed than when they were left whole. He also pointed out that spacing and covering of the medium by the leaves appeared to influence these results.

In all these reports, with one exception (66), the material used for propagation was from orthotropic stems. No field experiments to date comparing orthotropic and plagiotropic plants from cuttings have been reported. Polarity in

coffee is discussed by Ferwerda (27) and Cramer (16) and reviewed by Fielden (22). They state that only orthotropic stems will produce a plant equal in form to that found in seedlings. Plagiotropic branches will maintain a lateral growth habit and develop into flattened shrubs with horizontal or pendent branches. Material taken from upward growing plagiotropic stems has a form intermediate between orthotropic and normal plagiotropic branches and is noted for its vigorous growth. Roelofsen (78) states that fan or plagiotropic cuttings grow horizontally and their root spread is also lateral.

Variation in rooting ability has been noted by Van Overbeek (94) in comparing cuttings from one-, six- and 12-year-old trees. The cuttings from one-year-old seedling trees rooted almost 100 per cent, decreasing to about 45 per cent rooting from six-year-old trees. Material taken from 12-year-old trees rooted only sporadically. There were noticeable differences in rooting and growth between clones (34,78). Some rooted and grew rapidly while others rooted slowly and did not subsequently grow as fast (37). Rooting time appeared to vary from several weeks to a year or more (12, 23, 25, 39, 66, 95). Van Overbeek (93) found in preliminary trials that there was no effect of elevation on the process of rooting itself. There was, however, a possible indication that coffee trees grown at 2,000 feet provided better material for making cuttings than those grown at lower

elevations. Roelofsen (78) believed that the rainy season was the most unfavorable time for rooting cuttings, probably because of the lack of sunlight. No information was found in which monthly rooting of cuttings was compared throughout the year nor were any comparisons found correlating rooting to subsequent growth of the coffee plant.

Reaño (76) studied the histological factors of the rooting process in coffee cuttings both with and without use of hormones. He found that cell suberization of treated cuttings took place 22 hours after treatment. The epidermis was the first cortical tissue to show activity followed by the cortical parenchyma near it. There were no structural changes in the epidermis of either hormone-treated or control cuttings. The most active tissues were the phloem and cambium, while the wood and pericycle were not active at all. The initiation of root primordia was associated with the phloem and cambium. Fernie (23) found that callus formation took place after three weeks.

When propagating the more tender coffee cutting types, workers have usually found that, in order to secure consistent success, some type of structure for at least partial environmental control is needed (39). Cheeseman and Spencer (9) gave a basic approach to what is required in a propagator. Their experience suggested that if any species is kept alive long enough it will ultimately root. The most important

problem is one of water-balance. To fulfill this requirement, they recommended and described the so-called I.C.T.A. (Imperial College of Tropical Agriculture) propagator. This basic propagator design has been the one used in the majority of installations where it was desired to root soft-wood cuttings (23, 45, 49, 93, 95). Several changes under certain conditions gave improved rooting. Guiscafré-Arrillaga (45) found the I.C.T.A. propagator unpredictable, due to variable moisture supply. He secured improved rooting by the addition of ordinary spray nozzles inside the propagators to provide a continuous mist over the cuttings from 9 A.M. to 3 P.M. The same author further noted that a combination of continuous drip of water over the glass cover of the propagator and an overhead lath frame admitting 50 per cent light kept daily temperature low and relative humidity high. Roelofsen (78) stated that they placed a white material resembling muslin over the glass covers, keeping it wet by leakage of water through perforated bamboo tubes. In this way, with a lattice-work roof admitting 25 per cent light, they were able to reduce the temperature from 95°F. (35.0°C.) to 84°F. (28.9°C.). The white cloth cover was used only on sunny days from 8 A.M. to 3 P.M.

Gillet (39) in Kenya claimed that he had good success with a closed propagator in which hurricane lamps were placed for additional heat. No carefully conducted experiments on

the effect of temperature on coffee rooting have been reported, although Fernie (23) does recommend a temperature of from 20°C. (68°F.) to 23°C. (75°F.). Guiscafré-Arrillaga (47) in one trial maintained a temperature as high as 85°F. (30°C.). He also found (44, 46) that a bottom heat of 5°C (9°F.) to 7°C. (12.5°F.) above the air temperature had no effect on inducing root formation but that a bottom heat of 95°F. (35°C.) later proved highly beneficial.

Considering that moisture may be taken up only to a limited extent through the cut stem, it would seem that in order to keep the cutting alive an almost saturated atmosphere is necessary. Fernie (23) was able to maintain a relative humidity of 90 per cent with two daily sprinklings of water in the propagator. Van Overbeek (93) using an I.C.T.A. propagator, was able to keep leaves on cuttings for seven months without their dying. Some cuttings flowered, produced fruit, or made new flushes under the conditions maintained.

In many trials mention was made of numerous media and their effect on rooting of cuttings. Cottington (12) obtained good results with a medium composed of 50 per cent coffee hullings and 50 per cent clean sand. Fernie (23) proved in statistically analyzed trials that peat moss was the most efficient medium he had used. Coconut fiber had possibilities but cuttings required longer to root. Leaf mold was recommended

only when other materials were unavailable. In 1948, Fernie (25) stated that in a recent comparison peat moss was again the best medium; coffee parchment was inferior to peat moss and coconut fiber, while sand in absence of organic material gave the poorest rooting of all. Guiscafré-Arrillaga (44) in 1936 found that sterilized sand was a better medium than unsterilized sand or garden soil. In 1937, he and Gómez (46) mentioned that after trying different types (unnamed) of media they were unable to root coffee. In 1939, these investigators stated that three other media had been tried (47). Of these they believed the best medium was pulverized wood and roots of a local giant fern (probably <u>Cyathea portoricensis</u>). Silty river sand was considered undesirable because of moisture retention as it caused decay after rooting. In 1945, this same worker (49), using the I.C.T.A. propagator considered ordinary beach sand a satisfactory rooting medium. Neundorf (66) in Venezuela, rooted coffee cuttings in sand with good results. Regardless of the fact that in Tanganyika (35) the fungus Rhizoctonia was more prevalent in a medium containing peat moss, it was stated that coffee cuttings rooted quicker in this medium. Well rotted leafmold was tried also in Tanganyika (33) but was found to pack rapidly, preventing sufficient air passage through the medium and causing it to become easily water-logged. In 1938 the Tanganyika (24) investigators wrote that they thought the best medium was peat moss and coarse river sand in a ratio of 2 to 1.

Fernie (25) compared the effect of spacing on the rooting response of coffee cuttings. Spacing of cuttings in the propagation bin allowing 12.80 square inches per cutting (several node cuttings) was significantly better than 6.40 square inches per cutting on the basis of number of cuttings rooted. The amount of time necessary for rooting was not significantly reduced.

Because the asexual propagation of _Coffea arabica_ by cuttings has been such a difficult problem, many investigators have attempted to improve rooting by applications of chemicals or hormones. Gillet (39), in Kenya, reported no positive results with carbon monoxide gas treatments. Guiscafré-Arrillaga (44) reported application of paraffin and collodion to part and to all of cut surfaces, sterilization of cut surfaces by rapid immersion in 1:1000 solution of corrosive sublimate, immersion in a one per cent solution of urea, and protecting cuttings by applying coal tar to all wounds. His results, in preliminary trials, showed that collodion killed the cuttings, paraffin protected the cuttings several weeks from injury by fungi, coal tar preserved the cuttings in good condition, and sterilization with corrosive sublimate protected the cuttings for a long time. Though several of these materials appeared beneficial, he Gómez later reported (46) almost complete failure to obtain roots on cuttings. Possibly this early failure was caused by a lack of proper environment for the cuttings rather than

from the treatments mentioned. Portéres (75) mentions protection of cuttings by the use of paraffin on the upper cut surface of the cuttings, but gave no results of its effectiveness.

Several workers have used plant extracts to test their effect on the rooting of coffee by cuttings. Guiscafré-Arrillaga reports (44, 46) having applied a coffee embryo extract, but he gave no result of this preliminary trial. In India (95) bamboo bud extract in three concentrations was compared with Indolebutyric acid. The rooting of the cuttings treated with bamboo extract in the three concentrations was inferior to the Indolebutyric acid treated cuttings. In another trial, Coffea arabica cuttings were treated with various substances: Indolebutyric acid, Indoleacetic acid, bamboo bud extract, and cows urine extract. None of the treated cuttings rooted as well as the untreated control after about four months. Pottabhiraman and Gopalakrishnan (70) described the preparation and use of a cow's urine extract which they reported gave very good results for rooting coffee cuttings. They pointed out that they had no results with cow's urine extract when it was deodorized with paddy husk charcoal, but when diluted with 95 per cent alcohol excellent results were obtained. In a comparison of natural and synthetic growth substances Pottabhiraman and Gopalakrishnan, using single node, two-leaf cuttings in a

covered propagator with sand medium reported rooting 87.6% of the cuttings in urine extract, 62.9% in indolebutyric acid (2,000 ppm quick dip), 77.1% in phenylacetic acid (2,000 ppm quick dip), 62.9% in Hortamone "A" and 61.0% in the untreated control. From the results obtained it appeared that cow's urine extract stimulated the rooting response of coffee cuttings. Later other workers in India reported (56) that cow's urine extract and a synthetic hormone Seradix (the grade recommended for soft-wood cuttings) produced the best results. Ragi coleoptile extract and indolebutyric acid were satisfactory while indoleacetic acid, bamboo bud extract, and two other concentrations of Seradix powder were not satisfactory. No data from this latter trial were given.

The time necessary for the rooting of coffee cuttings, as well as the percentage rooted, has undoubtedly been one of the major reasons against use of this method of asexual propagation. Fernie (25) found that the longer it required for cuttings to root the higher was the percentage of dead cuttings. In order to overcome this problem and attempt to secure quicker rooting many workers (24, 56, 57) have examined the possibilities of various natural and synthetic growth substances. Little or no work has compared various concentrations of these compounds, although Gillet (41), using Hortamone "A", asserted that an increase in rooting of coffee cuttings was correlated with increase in hormone strength.

In a 1940 report from Tangenyika (24) it was believed that probably the solution concentration must be regulated according to the type and size of cutting used. Leafless hardwood cuttings of large diameter required a higher concentration than smaller, semi-hardwood cuttings. Puerto Rican investigators reported (2) that the largest and most vigorous cuttings responded to growth substances better than weak ones.

The effects of growth substances on the rooting of coffee cuttings have not been consistent. Poor results have been indicated by some workers (2, 46, 78) while others have noted good results (41, 70, 78, 93). Often the method of application apparently influenced the results (48, 78). Growth substances have been applied in lanolin (2, 66, 78), talc (2, 12, 45, 47, 48, 56, 57, 76, 78), and in liquid solutions (1, 41, 46, 70, 76, 95). Guiscafré-Arrillaga (44) applied Hormodin "A" in Analic oil but gave no results of the effect of the combination on the rooting response. The type of response to growth substances discussed by the various investigators appeared to take two general trends: a)decreased rooting time (45, 93), and, b)increased number of roots (45, 49, 93). Guiscafré-Arrillaga (48) made the interesting observation that the columnaris type of coffee was more favorably affected by growth-inducing substances than the Puerto Rican type of Coffea arabica.

The rooting response of coffee cuttings to some 33 com-

pounds or commercial preparations has been studied and reported in the literature. A list of the chemicals and the commercial preparations are:

Chemical Growth Substances:

Indoleacetic acid (46, 48)

Indole-3-acetic acid (76)

Indoleacetamide (47)

Indolebutyric acid (3, 45, 46, 49, 56, 70, 93, 94)

v-(Indole-3)-n-butyric acid (70)

Naphthaleneacetic acid (48)

Naphthylacetimide (3, 47, 48)

Phenylacetic acid (70)

Dichlorophenoxyacetic acid (2)

Dichlorophenoxyacetic propionic acid (2)

Dichlorophenoxyacetic butyric acid (2)

Phenoxy compounds (3)

Amides of naphthaleneacetic acid (48)

Amide of Indolebutyric acid (48)

Tetralyl-6-Naphthylacetamide (48)

Indole propionic acid (46)

Indoleacetic acid (41)

Indolebutyric acid plus Niacin (3)

Alpha naphthil acid (66)

Commercially Prepared Growth Substances:

Hormodin "A" (44, 46, 76)

Hormodin No. 1 (47)

Hormodin No. 2 (2, 47)

Hormodin No. 3 (2, 49)

Rootone (76)

Auxilin (46)

Seradix "B" (12, 56)

Seradix (grade for softwood cuttings) (56)

Seradix No. 1 (1, 41, 70)

Seradix No. 2 (57)

Seradix No. 3 (57)

Seradix "A" (57)

Hortamone "A" (57)

Hortamone "B" (41)

No attempt will be made at this point to review fully the results of the application of the aforementioned compounds. It should be pointed out, however, that in many cases cited, poor rooting after growth substance application is poor criteria upon which to base a conclusion as to its effect. Often when it was reported that a treatment gave poor results the other factors necessary for rooting were not supplied.

Little mention is made of the need for elaborate hardening off of rooted cuttings, as is used in cacao. Fernie (23) mentions that after rooting, the cuttings are potted and kept in the shade for three to four mohths. Cottington (12) thought that the process of hardening off is an important one, but did not describe the methods he used.

In Tanganyika (24, 96) the cuttings were potted in a mixture of compost and sand, returned to the propagation bins for four weeks, then removed to a cool atmosphere in the forest for an additional two to three months. After hardening off they were planted in the nursery under shade to await field planting.

Aside from these more generally used methods of propagation, there are several others worthy of mention. In 1948, from India (58, 95), a method of pre-curing of the suckers was used with success. The internodes of suckers, while still attached to the mother plant, were ringed several inches below each node. The bark at the ring was raised and cow's urine extract was smeared upon it. Moss was used to cover the rings. After two weeks the stems were removed and made into cuttings, retreated with cow's urine extract and planted in the propagator. Up to 83 per cent success was obtained. Maundorf (66) described the use of a similar method in which the major changes were the use of two cuts on opposite sides of the stem instead of ringing, and the application of a layer of hormone in paste form. This latter author claimed 90% rooting possible in 28 days. No mention of age of mother plant was made.

MATERIALS AND METHODS

The following materials and methods were used generally throughout the experiments. Of necessity, some materials and/or methods were specific to only one experiment, and these have been described under Experimental Results for the specific experiment involved.

Propagation Equipment

The propagation equipment used in the following experiments was located in an Institute propagation house. The roof of this house was in two sections, one part of glass and the other a slat roof which allowed entrance of about 60% light. The interior consisted of two propagation units and benches around the walls. Each unit was divided into sections separated by cement walls.

Various investigators have used special equipment for the propagation of coffee and other plants (6, 9, 29, 42, 45, 49, 62, 78, 79, 83, 93). Generally these propagators were considered unsatisfactory for Costa Rican conditions due to excessive water or labor requirements.

Several bin arrangements were tried before one considered satisfactory was developed. This method overcame to a large extent the objections encountered in other installations. The construction and arrangement of the equipment has been recently described by Fiester (28).

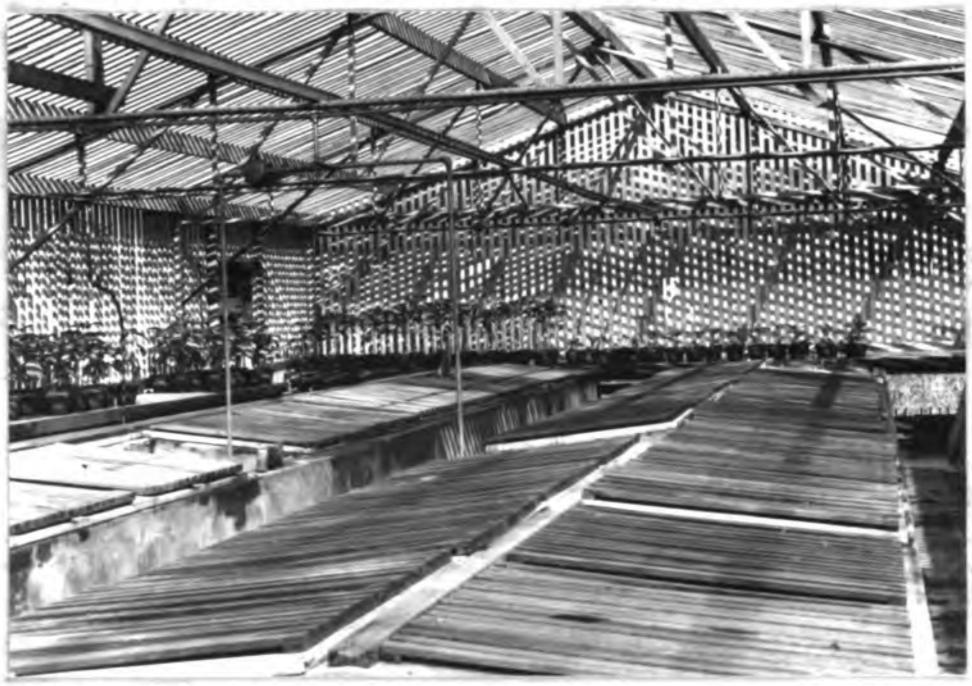

Fig. 1. Interior view of propagation house showing arrangement of the two propagating units.

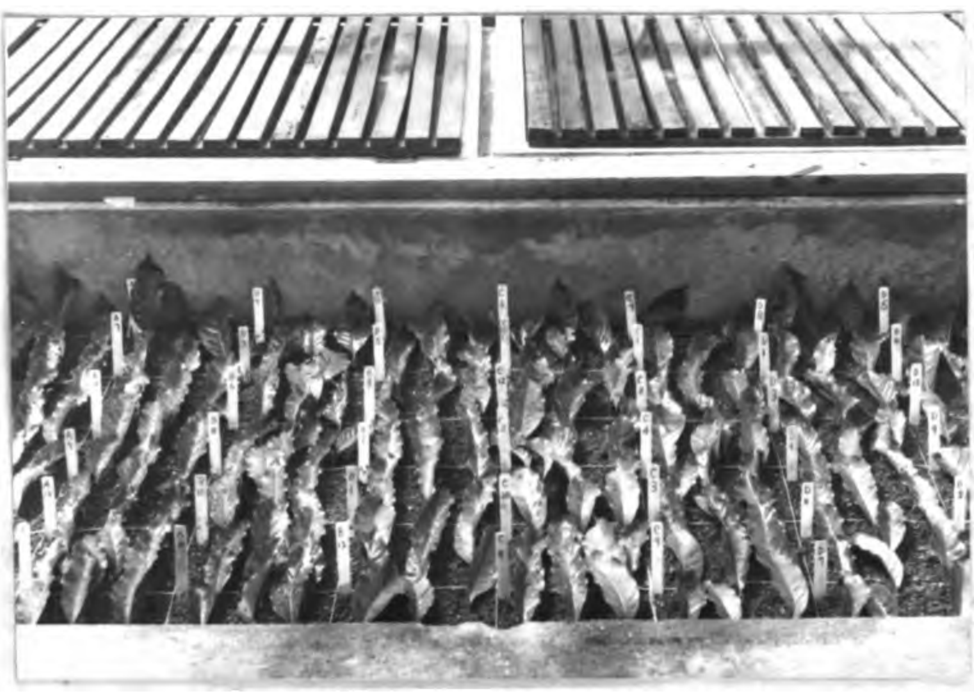

Fig. 2. Interior view of a propagating bin demonstrating the arrangement of plots.

The principle of the method used was to maintain a layer of water under the cutting trays. Evaporation from this layer was sufficient to maintain the required environmental humidity. As it was desired to control all bins in a unit from one reservoir, holes five centimeters in diameter were placed at the base of each interior wall to allow free flow of water from the reservoir. A float valve extending to within 55 centimeters of the bottom was placed in one bin which acted as the central controlling reservoir. An overflow outlet was placed 2.5 centimeters above the normal level of water in the reservoir.

A wooden tray for cuttings, 10 centimeters deep, was placed on a supporting frame in each bin. The bottom of the tray was held five centimeters above the surface of the water level in the bin. The trays were so constructed that they would have approximately 2.5 centimeters clearance on all sides between the tray and the bin wall. Each tray was built with outlets made by separating the boards in the bottom of the tray 1.5 centimeters to allow excess moisture from the medium to drain through. To maintain high humidity, a glass sash was used to cover each bin. It was found that from one half to two thirds shade placed over the glass sash was of considerable aid when bin temperatures were above 28°C. (82°F.). The amount of humidity and temperature within the propagating bins were taken periodically. Hygro-thermograph instruments showed that the relative humidity was maintained

at 100% for approximately 20 hours daily. The relative humidity never went below 85%. The period of lowest relative humidity was found to be during the mid-day period from 12 noon to 2 P.M. No attempt to control the temperature within the bins was made other than use of the previously mentioned wooden shades. The high humidity prevailing in the bins made it necessary to water the cuttings only once every five to eight days. More frequent watering was found detrimental.

A standard water meter placed above the float valve during the period January 24, 1951 to February 6, 1951 showed that approximately $1\frac{1}{4}$ liters of water a day were necessary to maintain the desired humidity in the bin and water level in the reservoir in each unit. This water loss was due mainly to seepage through the cement walls of the propagating bins and escaped water from evaporation when the bins were opened for examination.

Preparation of Cutting Trays

The trays for the experiments were prepared several days in advance. Drainage slots were covered with broken tile. The rooting medium was placed in the trays to a depth of ten centimeters. The proper moisture content of this medium was secured by sprinkling the day previous to planting.

The plots of cutting treatments were divided by waxed string. Each plot was marked with wooden pot labels according

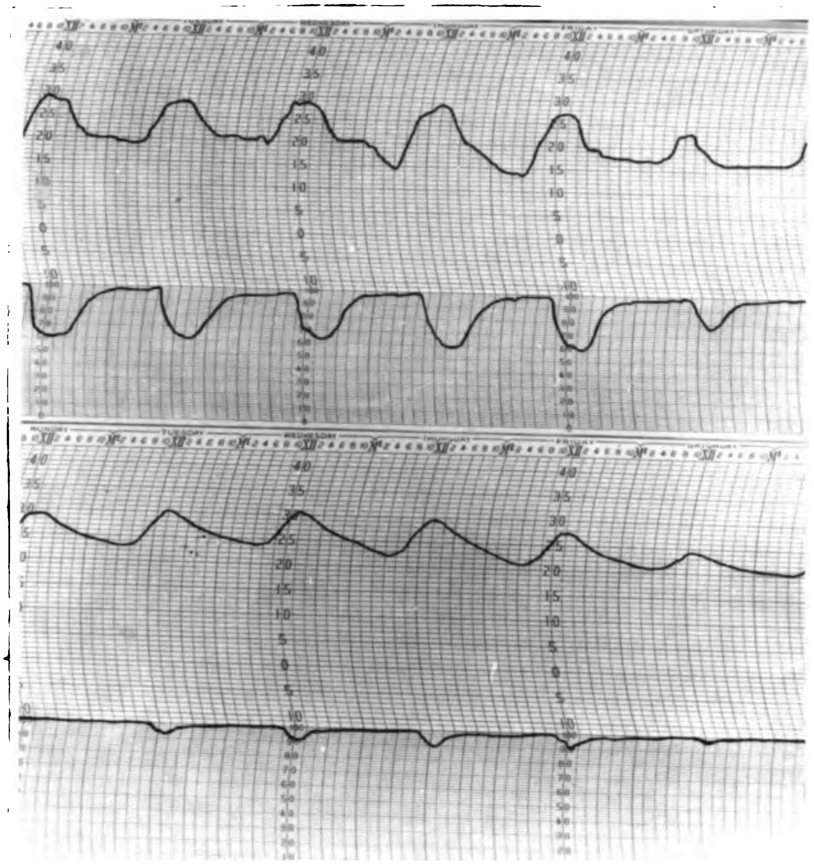

Fig. 3. Comparison of hygro-thermograph charts for the week April 3-10. The upper chart was recorded in the I.I.C.A. weather station while the lower chart was recorded in one of the propagating bins. The temperature in degrees centigrade is shown by the upper curve in each chart and the per cent of relative humidity by the lower curves.

to a predetermined random arrangement. All cuttings were planted according to the predetermined plan replication by replication.

Collection of Plant Material

As no clonal source of plant material for these experiments was available stems of arabica coffee, variety "typica", were collected from trees of bearing age on the Institute's farm. The farm contains coffee trees estimated to be eight or more years of age and care was taken not to include material from young replanted coffee trees.

Actual field collection for the experiments was made the morning of the day previous to planting the cuttings. The orthotropic stems were cut with pruning shears and the plagiotropic branches were carefully removed. All material was shaded in the field until its removal to the propagation house. Upon arrival in the propagation house, the stems were watered and again placed under shade.

Preparation of Cuttings

Cuttings were made from the previously collected plant material. Only coffee stems having healthy leaves were used. A one node cutting having one leaf and two orthotropic buds with two and one half to three and one half centimeters of internode below the leaf was used. All cuts were made with a sharp nurseryman's knife. The superior cut was horizontal, made approximately one centimeter above the node. The basal

cut was a single horizontal cut.

Care of cuttings after planting was minimal, consisting principally of routine watering and removal of diseased cuttings.

Collection of Data

After a predetermined period, cuttings were removed and data taken. The collection of data for most trials was standardized.

In preliminary trials, measurement of the number of cuttings callused was made. These data were found unnecessary on the experiments reported in this paper since no cuttings were found in these reported trials which if alive had not callused before their removal.

The kind of data taken and the procedure for each is as follows:

Number of cuttings alive were counted at the end of the experiment and entered in the results as a plot trial.

Number of cuttings rooted were determined after removing all of the cuttings in a plot.

Number of primary roots were counted for each cutting and entered as a total for the plot.

Number of secondary roots were determined by actual count. Any root of one half centimeter or more attached to a primary root was counted.

Number of vegetative buds sprouted were recorded on a plot basis, grouping together all buds having one half centimeter of new growth. No cuttings that exhibited sprouted buds were planted.

Fresh weight of the roots was determined by weighing after the removal of all of the roots from the cuttings in a plot with a sharp knife. Accuracy with the balance used was possible only to 0.1 gram. Weights of 0.1 gram or less were entered in the data as 0.1 gram.

Fresh weight of the vegetative buds was obtained by removing all new bud growth from the cuttings with a sharp knife and weighing.

Dry weight of roots and vegetative bud development was made after the fresh weights were taken. The plant material was placed in one-pound paper bags and dried to constant weight in a forced draft oven at 75°C. When thoroughly dried the bags were removed, allowed to cool and weighed. Weights of less than 0.1 gram were entered as 0.1 gram.

Analyses of Data

The method of analyzing the accumulated data was by analysis of variance. Minimum significant differences were calculated at the 5% level only for data proving significant in the analysis of variance.

EXPERIMENTAL RESULTS

Experiment I: The effects of the position of the cutting on the orthotropic stem to rooting and vegetative bud growth in Coffea arabica L.

The dimorphic growth habit of coffee is well known (17, 22, 27, 66, 78, 99). Due to the limited amount of orthotropic

material available, care must be taken to secure the greatest benefit possible from this limited supply. As yet, no method of inducing orthotropic growth from plagiotropic branches has been encountered.

The smallest cutting types from which a normal plant could be secured would be by leaf-bud cuttings or single leaves (40, 47, 55, 57, 65, 70, 80, 84, 86, 97, 98, 100). Propagation at the Inter-American Institute of Agricultural Sciences with leaf-bud cuttings shows promise but Colletotrichum disease incidence has up to the present made this method impractical. Leaf cuttings have not been attempted. The next larger cutting size, that of a node with one leaf, having approximately three centimeters of internode was proven practical.

Differences have already been noted (94) in rooting ability of cuttings taken from coffee trees of various ages. No investigator in coffee seems to have determined whether differences in rooting ability could be due to the position of the cutting on the stem, although reports from work in other crops suggest this possibility.

The experiment to be described immediately below was designed to substantiate the results of a former observational trial. This had previously indicated that differences did exist between cuttings taken from different nodes along the orthotropic stem as to their rooting ability.

Coffee shoots, seven nodes in length were collected in

the field. The young tender tip of each stem was discarded. Count of the cuttings was made from the first node below the discarded tip of the stem. This highest and youngest node cutting was called number 1 and each succeeding node cutting was numbered consecutively. The basal cut for each cutting was made in the internode midway between the two nodes. A recut was made above the node at the superior end of the cutting to shorten this internode to within one centimeter of the node. Cuttings were made progressing down the stem until a cutting was completed for the sixth node. Each was made and planted in the sand medium before severing the next.

On September 6, 1950 after 90 days in the propagation bin, the cuttings were removed and data collected as described in Materials and Methods. The data presented in Table I indicate that nodal position did not have a significant effect on the number of cuttings alive after 90 days. Nodal position did have a highly significant effect, however, on number of cuttings rooted, number of primary roots, number of secondary roots, fresh and dry weight of the roots and fresh and dry weight of the vegetative growth of the buds. There were no statistically significant differences in the number of cuttings having vegetative growth from the buds, although the F value for treatments was very close to the significant limit at the 5% value.

Nodal position comparisons indicate that nodes one, two and three were significantly better than the other nodes in

Position below apical tip	Pl
Node 1	
Node 2	
Node 3	
Node 4	
Node 5	
Node 6	
Total	
M.S.D. (5%)	

1/ Mater

2/ Exper

regard to their effect on the number of cuttings rooted, the number of primary roots, number of secondary roots, and the fresh weight of the roots.

The fresh and dry weights of the vegetative growth of the cuttings appear related to the distance of the cutting from the apical tip of the stem. Node six was significantly superior in this respect to all nodes except node five. Node five was significantly superior to nodes three, two and one, and significantly superior to node four in dry weight only.

It is apparent in this study that strong inverse correlations existed between the nodal position and its effect on fresh and dry weight of the vegetative growth. Positive correlations appeared evident between the nodal position and rooting.

Experiment II: The effect of potassium permanganate on the rooting of coffee cuttings.

Potassium permanganate has been used by several investigators to stimulate the rooting of cuttings of a number of species of plants (8, 18, 21). This experiment was designed to test its potentialities as a stimulant for rooting coffee cuttings.

The cuttings used in this experiment were collected from seedling two-year-old trees previously sprayed for six months with Fermate at recommended dosage. The medium used was fine sand. Cuttings from the first three nodes were co

distributed as to have only a limited number from any one stem in the same treatment.

Chemically pure potassium permanganate (C. M. Baker and Company) and distilled water were used. The concentrations employed for the solutions were: 0.005, 0.01, 0.02, 0.05, 0.1, 0,2 and 0.4 mol. sol. Distilled water was applied to the control cuttings.

On October 22, 1950 as each cutting was made it was placed at random in one of the various concentrations to a depth of one and one half centimeters. The controls were placed to the same depth in distilled water. Glass sash was placed over the propagating bin and in turn was covered with a two-thirds slat shade which had an additional cover of a heavy type kraft paper allowing an estimated 5% to 10% of light to enter the bin.

Twenty-four hours after placing the cuttings in the solutions, they were removed. As each cutting was removed from the solution it was carefully washed in a low pressure, moderately fine spray from a garden hose and planted in the proper plot.

While washing the cuttings previous to planting, it was noted that the cuttings from the treatment containing a 0.1 mol. sol. appeared swollen at their base. This swelling of the base increased in severity with each higher concentration. In treatments containing 0.2 and 0.4 mol. sol. of potassium permanganate, swelling was very noticeable. When these cuttings were washed by the spray, the cortex separated from the bark

apparently at the cambium layer and sloughed off to a height of one to one and one half centimeters from the base of the cutting.

The experiment was terminated after two months. Data were collected for all plots and the results are shown in Table II.

In none of the treatments on which data were taken, did any chemical application give improvement in rooting over the untreated cuttings.

Although a wide range of concentrations was applied, results showed that the application of potassium permanganate in this experiment was apparently detrimental to shoot and root development in all concentrations used. There were no definite trends of improvement that would indicate that a lower or higher concentration might be beneficial to coffee cuttings.

Experiment III: The effect of sucrose and Hormodin Number 2 on rooting of coffee cuttings.

The study of the importance of plant reserves in the cutting has given interesting results with regard to successful initiation and elongation of roots and vegetative bud growth.

Starring (82), working with tomatoes and *Tradescantia virginiana*, grew these two species in different light intensities to cause differences in the carbohydrate content. His conclusion was that as such wide differences in root development could not be caused by varying the nitrate content, the

Concentration KMnO applied to				
0.005 mol. sol.	.	.	.	.
0.01 " "	.	.	.	.
0.02 " "	.	.	.	.
0.05 " "	.	.	.	.
0.1	.	.	.	.
0.2	.	.	.	.
0.4	.	.	.	.
No treatment	.	.	.	.
Total	.	.	.	.
M.S.D. (5%)		.	.	.

1/ Cuttings fr
2/ Experiment

production of new roots is probably derived more from carbohydrate than from nitrogenous reserves.

Van Overbeek and Gregory (92), van Overbeek and others (94), and Gregory and Van Overbeek (43) found that some factor or factors other than growth substance application was necessary on a white variety of hibiscus, while such factors did not appear to be lacking in a red hibiscus. By treating defoliated cuttings with sucrose and ammonium sulphate the lacking factors could at least quantitatively be replaced. Calma and Richey (7), working with concord grape cuttings, found that after trials carried on during two succeeding years, with but one exception, the initial rooting was directly associated with the percentage of total carbohydrates in the cutting stems. Pridham (74), working with *Ligustrum ovalifolium* and *Rhododendron catawabiense*, concluded that the previous carbohydrate reserves and maturity of the stock plant were of primary importance to the rooting of cuttings and subsequent growth of the young plant.

This experiment was designed to study the effects of sucrose and hormone applications on the rooting of coffee cuttings. The source of cutting material for this experiment was a Fermate sprayed plot of two-year-old seedling coffee trees. Only the cuttings from the first three nodes were used.

On October 28, 1950, material for the cuttings was collected and brought to the propagation house and immediately made into cuttings.

The various treatments included were:

1. 0.1% sucrose solution
2. 0.1% sucrose solution plus Hormodin No. 2
3. 1% sucrose solution
4. 1% sucrose solution plus Hormodin No. 2
5. 2% sucrose solution
6. 2% sucrose solution plus Hormodin Nol 2
7. 5% sucrose solution
8. 5% sucrose solution plus Hormodin No. 2
9. Hormodin No. 2 only
10. Distilled water
11. Distilled water plus Hormodin No. 2
12. Control - no treatment

Glass containers were used for these solutions. Cuttings had approximately one and one half centimeters of their basal tip submerged in the solution. Each cutting was placed in the proper solution immediately after being cut. The cuttings placed in distilled water received the same care as those placed in the sucrose solutions. The treatment receiving an application of Hormodin No. 2 (Merck and Company) and non-treated cuttings used as controls were planted to their respective plots immediately. All other cuttings were placed in their appropriate containers.

On October 29, 1950 after 24 hours in the solutions, each cutting was removed and washed in a medium fine stream of water. If hormone application was required, this was applied

and the cutting placed in the proper plot. This experiment was planted in a random plot design.

It had been planned previously that this experiment would be removed in 60 days, but rooting of the controls had advanced so far that it was necessary to remove the cuttings after 50 days.

Results from the data taken December 17, 1950, showed highly significant differences for the number of cuttings rooted, number of primary roots, number of secondary roots, and the fresh weight of roots over the untreated control (see Table III). There were no significant differences for treatments in the number of cuttings that were alive at the end of the experiment, the number having buds with new vegetative growth, dry weight of the roots, or fresh, or dry weight of the new vegetative growth.

From the minimum significant difference calculations for the various types of data calculated at the 5% level only, it is noted that 2% sucrose and the non-treated control were significantly poorer in the number of cuttings rooted than the other treatments. It may be of interest to note that the distilled water treatment stimulated the cuttings sufficiently to produce significant improvement in the number of cuttings rooted over that of the non-treated control. The 2% sucrose, the 5% sucrose, and the non-treated control were significantly poorer than the remaining treatments in the

T
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1

Treatment applied to 3/
0.1% sucrose
0.1% sucrose plus Hormodin No. 2
1.0% sucrose
1.0% sucrose plus Hormodin No. 2
2.0% sucrose
2.0% sucrose plus Hormodin No. 2
5.0% sucrose
5.0% sucrose plus Hormodin No. 2
Hormodin No. 2
Distilled water
Distilled water p Hormodin No. 2
No treatment
Total
M.S.D. (5%)

1/ Materia
2/ Experim
3/ Cutting

number of primary roots. Five treatments averaged four primary roots per cutting or more. Seven treatments were significantly better in the number of secondary roots than the control. There was no significant difference in the number of cuttings having vegetative growth of the latent buds, nor in the fresh or dry weight of this vegetative growth. In five treatments the fresh and dry weights of the roots were significantly less than the other treatments. The correlation of fresh to dry weight of the roots apparently held true in this experiment as might be expected. The same treatments were significantly inferior in both fresh and dry weight. One treatment only, that of 5% sucrose plus Hormodin No. 2, was significantly superior to the non-treated control in fresh weight of the roots and not superior to the non-treated control in dry weight.

Attention was drawn to the fact that, although sucrose stimulated the number of cuttings rooted, the application of Hormodin No. 2 increased this number in every case when applied following sucrose application. Also, the application of Hormodin No. 2 alone produced as many cuttings rooted and more primary and secondary roots than any other treatment. The mean rooting percentage of all treatments obtained in this experiment was 84 per cent. Five treatments rooted 100 per cent in 50 days. The non-treated control had the lowest rooting percentage (42%) of any treatment.

Experiment IV: The effect of the type of cutting and medium on rooting of coffee cuttings.

Probably no two factors in coffee reproduction through cuttings are as important as the type or size of cutting and the medium in which it is planted. By using the proper cutting type and medium, it may be possible to secure more efficient rooting, and considerable reductions in time and cost of rooting.

Use of various types of cuttings have been advocated in coffee propagation by a number of workers (1, 12, 24, 39, 41, 44, 45, 49, 75). Few of these have used small-sized cuttings such as a one node, or a leaf-bud cutting (12, 23, 47, 57, 70). Due to the dimorphic nature of coffee it appears imperative that small sized cuttings be used. Until a method of increasing the amount of vegetative material through use of the plagiotropic stems can be found, the greatest care should be exercised to use the existing orthotropic plant material efficiently.

Recommendations based on the use of various media have been reported by several investigators (12, 23, 25, 33, 46, 49, 66). This information should be used only as a reference of possibilities to be tested under local conditions since in most cases no mention was made of either the watering schedule used or the amount of water applied.

The author is in full agreement with Evans (21) who, while working with cacao found that consideration of the rooting

medium alone was insufficient. The important consideration is the air/water relationship of the rooting medium. The medium giving the most satisfactory results under one set of moisture conditions may be entirely inadequate under slightly different conditions.

This fourth experiment was designed to study the effect on rooting of various types of cuttings and media using a predetermined water schedule.

In previous trials, loss from cuttings was as much as 75% in three weeks due to the attack of the fungus Colletotrichum coffeanum. To avoid this difficulty all material for the leaf-bud cuttings was secured from material collected from sprayed two-year-old seedling trees.

It was understood that cuttings made from young seedling trees might bring about an unfair comparison but interest in this type of cutting was sufficient to cause it to be included. The media used were a commercial grade of vermiculite, screened and washed medium fine local river sand, and screened soil. The soil was a clay loam having an acidity of approximately pH 5.6. This soil was secured from the Institute's coffee farm. The media were separated by four inch wooden partitions placed in the trays. The plant material was collected on November 7, 1950 and cuttings were made and planted the next day. No growth substance or chemical application was used.

The four cutting types used were a single node, one leaf

cutting, identical to the standard cutting used in the other experiments; a leaf-bud cutting having one orthotropic bud; a one node cutting identical to the standard type of cutting but having two leaves; and a three node tip cutting having a minimum of four leaves. As all cuttings were made from the first three nodes, the influence of the position on rooting can be considered minimal. All cuttings, except the leaf-bud type, had the basal cut three to four centimeters below the node. The basal cut for these cuttings was a single horizontal cut. The leaf-bud cuttings were made by two horizontal cuts, one cut one and one half centimeters above and the other the same distance below the node with a third cut splitting the node into two cuttings each with one attached leaf.

The experimental design used was a split plot. The cutting types were considered main treatments and the media were secondary treatments.

Watering of the cuttings was held to a seven day cycle except during one extended overcast period in which watering of the cuttings was held back until nine days had elapsed. The experiment was terminated on February 7, 1951 ninety days after planting.

Analysis of variance indicated that clay loam soil and vermiculite were significantly better than the river sand with regard to the number of cuttings rooted (see Table IV). These two media were also superior to local river sand in number of primary and secondary roots and in the fresh weight of the

Fig. 4. A one node two leaf coffee cutting.

Fig. 5. A one node one leaf coffee cutting.

Fig. 6. A rooted leaf bud cutting made from a seedling tree 60 days after planting in the propagating bin.

roots. The fresh weight of the roots of the cuttings planted in vermiculite was significantly higher than that of the cuttings planted either in sand or in the clay-loam soil. There were no significant differences between the media in their effect on the number of cuttings with new vegetative growth, or on the fresh weight of the new vegetative growth produced.

There were no significant differences between the four types of cuttings in the number alive at the end of the experiment. The three node tip cutting was significantly poorer than the other three types in number that rooted. There was no statistically significant difference between the one node, one-leaf cutting and the leaf-bud cutting in the number of cuttings rooted, although they were both significantly superior to the three node tip cutting. The totals show that there were significant differences for cutting types in the number of primary and secondary roots and the fresh weight of the roots.

As it was impossible in this experiment to determine the amount of new vegetative growth of the three node tip cutting, comparison was made of only three types of cuttings for this factor. The single node one-leaf cuttings and the single node two-leaf cuttings were both significantly superior to the leaf-bud type in the number having new vegetative growth and the fresh weight of vegetative growth. There were no significant differences between the two types of node cuttings in either

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developme

Cutting 1/	
Treatment applied to plant material	Number planted
Medium	
Sand	96
Soil	96
Vermiculite	96
M.S.D. (5%) for medium treatments	
Type of cutting	
1 node-1 leaf	72
Leaf-bud	72
1 node-2 leaves	72
3 node tip	72
M.S.D. (5%) for cutting treatments	

1/ Material for cutting
2/ Experiment planted N
3/ No data taken

number with new vegetative growth or the fresh weight of the vegetative growth.

Experiment V: The effect of naphthaleneacetic acid and two types of basal cuts on the rooting of coffee cuttings.

Considerable advancement has been made in the study of plant growth and its control since the discovery of auxins (10, 11, 43, 51, 52, 80, 85, 101, 103). This has been especially true in the field of rooting cuttings. The results of several investigations using hormones on coffee cuttings are listed in the literature review (22, 72, 89). In general these results have been undependable. There appears to be considerable variation in success with hormone treatment, possibly due to some other uncontrolled factor or factors. In no case was the optimum range of any reported hormone concentration given.

With any hormone concentration used, the basic aim is to have the material absorbed to the maximum for the concentration applied. It is known that hormones are absorbed through the cortex of the stem as well as through the cut surface. Use of different types of basal cuts on coffee cuttings has received no previous attention, especially where hormone application was involved.

This experiment was designed to determine the effect of five concentrations of naphthaleneacetic acid and two basal cut treatments as well as their interactions. The maximum concentration used was determined from a previous observa-

tional trial which indicated phytotoxicity at 3000 ppm of naphthaleneacetic acid.

The cutting material was collected from bearing coffee trees on the Institute farm. Only the first three nodes were used for cuttings.

The naphthaleneacetic acid was applied in concentrations of 1000, 1500, 1750, 2000, and 2500 ppm. After weighing, the dry naphthaleneacetic acid was dissolved in 50% alcohol to make a master solution. From this master solution the several concentrations were prepared by dissolving small amounts into the correct volume of 50% alcohol. Each concentration was placed in 25 cc. covered petri dishes. During the application only one dish was opened at a time and closed immediately after use. Growth substance application was for one second only, by the quick dip method (10).

The two types of basal cuts used were: 1) the standard horizontal basal cut, and, 2) a horizontal basal cut plus the removal of a strip of bark half the circumference of the base of the cutting and approximately one centimeter wide. After making the cutting, it was dipped in the correct naphthaleneacetic acid concentration and planted. This experiment, planted October 16, 1950 was of a split plot design.

After ninety days in the propagating bin the cuttings were removed. A highly significant difference was found for the interaction in the number of cuttings alive. As there was no significant differences for either concentration of hormones

or basal cut treatments, and since the interaction data presented no trend or wide differences, it may be assumed that these differences are possibly due to plot variations and not to the interaction of treatments. Hormone concentrations, basal-cut treatments, and the interaction all had highly significant influence on the number of cuttings rooted (see Table V). From the unadjusted data, naphthaleneacetic acid concentrations were the only highly significant treatments affecting the number of primary roots, number of secondary roots, and the fresh weight of the roots. There were no significant differences in the number of cuttings with new vegetative bud growth or the fresh weight of the vegetative bud growth as a result of the hormonal concentrations or basal-cut treatment applied.

No significant differences were found between the 1750, 2,000, and the 2500 ppm. treatments of naphthaleneacetic acid in number of cuttings rooted, although all three treatments were significantly better than the control. The cuttings dipped in the 2500 ppm. treatment were not significantly superior to the 1,000 ppm. concentration.

Since the 1750 ppm. and 2000 ppm. treatments were both significantly superior in number of cuttings rooted to the 1000 ppm. treatment, it may be assumed that the latter two treatments were the best concentrations used in this experiment. No significant differences for basal cut treatments were found at these concentrations.

The basal cut treatments in themselves showed the effect

Concentra applied
1000 ppm
1000 ppm
1500 ppm
1500 ppm
1750 ppm
1750 ppm
2000 ppm
2000 ppm
2500 ppm
2500 ppm
No treatm
No treatm
Total
M.S.D.(5
M.S.D. (5

1/
2/
3/
4/

of this type of cutting most clearly in the controls. Interestingly enough there was significant improvement in the number of cuttings rooted by removal of the bark over the normal basal cut when no hormone application was made.

<u>Experiment VI: The effect of various concentrations of five hormones on the rooting of coffee cuttings.</u>

Since the discovery of auxins and their ability to stimulate rooting of cuttings, a number of other organic chemicals have been found with root stimulating ability. Among the earlier discoveries were Indolebutyric acid and naphthaleneacetic acid. More recently two new hormones showing promise in stimulating the rooting of cuttings have been investigated (50, 53). These new substances are 2,4,5-trichlorophenoxyacetic acid and 2,4,5-trichlorophenoxypropionic acid.

Variation of the activity of hormones on the rooting of cuttings has been noted by Hitchcock and Zimmerman (51). These authors claim that the highest concentration of a hormone not producing toxic symptoms should be the optimum concentration for the stimulation of rooting in cuttings.

Different rooting results have been reported not only for the concentration of a hormone but even for a hormone itself (89). Indolebutyric acid and naphthaleneacetic acid are both generally considered more active than indoleacetic acid. The two mentioned phenoxy acids are very active in promoting root growth, although their non-toxic range is

extremely narrow (4).

This study was designed as a factorial experiment to compare the rooting of coffee cuttings in various concentrations of five hormones. The optimum range below toxicity as well as the effect of the hormone in a group of concentrations were studied.

Cutting material was collected from the Institute farm. Only the first three nodes from orthotropic stems were used. This experiment was planted starting on January 4, 1951, in three replications. One group of treatments selected at random from each replication was planted in each of five adjoining propagating bins. Due to the size of the experiment, one replication was planted daily during three consecutive days. The initial watering of the cuttings in each replication was made 24 hours after planting.

The hormones used in this experiment were 2,4,5-trichlorophenoxypropionic acid (Dow Chemical Co.), 2,4,5-trichlorophenoxyacetic acid (Dow Chemical Co.), Indolebutyric acid (Eastman Kodak Co.), Indoleacetic acid (Eastman Kodak Co.) and naphthaleneacetic acid (Eastman Kodak Co.).

The range of concentrations used was determined by previous trials. Cuttings in the previous trials were subjected to applications of each hormone in wide steps in concentration. After this they were planted in sand. When treated cuttings had been planted for 30 days they were removed and toxicity

effects determined by visual inspection. The toxic limit was considered exceeded when the cuttings showed swelling at the base, cracking of bark, or blistering of the stem of the cutting. Symptoms of toxicity were noted for Indolebutyric acid at 5000 ppm., 2,4,5-trichlorophenoxyacetic acid at 100 ppm., and naphthaleneacetic acid at 2500 ppm. No symptoms of toxicity were noted at even 2500 ppm. for 2,4,5-trichlorophenoxypropionic acid; the hormone stock of this substance was old and it was thought this might have influenced the results. The actual concentrations used for 2,4,5-trichlorophenoxypropionic acid in this experiment were the same as those used for 2,4,5-trichlorophenoxyacetic acid and the old hormone source was replaced by a fresh supply. Fungus damage of cuttings in the indoleacetic acid trial did not permit a careful comparison to be made, thus the same concentration range used for Indolebutyric acid was used for indoleacetic acid. The concentrations found in these preliminary trials to be the toxic limit were placed approximately in the center of the range of concentrations used in this experiment.

At the completion of 60 days, March 3, 1951, the cuttings were removed and data taken. Each replication was taken out in the same order as planted. One replication was examined daily.

Notes taken on March 4, 1951 of the visual symptoms of toxicity in replication "B" show that 2,4,5-trichlorophenoxyacetic acid is apparently toxic to softwood cuttings of coffee

in concentrations as low as 60 to 140 ppm. Indolebutyric acid showed no marked uniform symptoms of toxicity throughout the concentrations used, although in no case were the symptoms as clearly defined as when 2,4,5-trichlorophenoxyacetic acid was used. No visual toxic symptoms were displayed by any cuttings treated with Indoleacetic acid or 2,4,5-trichlorophenoxypropionic acid in the concentrations used in this study. Possibly the optimum concentration for neither of these two chemicals was reached. The visual symptoms of hormone toxicity for naphthaleneacetic acid can possibly be concluded to be between 2500 to 3200 ppm. although initiation of roots above the base of the cutting was found in one case at a concentration of 1500 ppm.

From the analysis of variance of the unadjusted data, it was found that the treatments were highly significant in number of cuttings rooted, number of primary roots, fresh weight of the roots, and number of vegetative buds sprouted (see Table VI), Hormones and the interaction of hormones and concentrations were both highly significant with respect to the number of cuttings rooted, number of primary roots developed and the fresh weight of the roots. Hormones without regard to concentrations had effect on the number of secondary roots only. The interaction was highly significant for the number of buds sprouted but as neither hormones nor concentrations had any effect on the number of vegetative buds sprouted, this interaction effect may be due to a wide plot variation or due to certain concentrations of specific hormones. The concentrations

The effect of
naphthaleneace
root developme

Cuttir	
Treatment 3/	Pl
2,4,5-trichlorophen-oxyacetic acid at:	
20 ppm	
30 "	
40 "	
50 "	
60 "	
70 "	
80 "	
90 "	
100 "	
110 "	
120 "	
130 "	
140 "	
Total	1
Indolebutyric acid	
3000 ppm	
3200 "	
3400 "	
3600 "	
3800 "	
4000 "	
4200 "	
4400 "	
4600 "	
4800 "	
5000 "	
5200 "	
5400 "	
5600 "	
Total	2
Indoleacetic acid	
3000 "	
3200 "	
3400 "	
3600 "	
3800 "	
4000 "	
4200 "	
4400 "	
4600 "	

Cutt

Treatment 3/		
Indoleacetic acid (cor		
4800 ppm		
5000 "		
5200 "		
5400 "		
5600 "		
Total		
2,4,5-trichlorophen-oxypropionic acid		
50 ppm		
70 "		
90 "		
110 "		
130 "		
150 "		
170 "		
190 "		
210 "		
230 "		
250 "		
270 "		
290 "		
310 "		
Total		
Naphthaleneacetic aci		
1100 ppm		
1300 "		
1500 "		
1700 "		
1900 "		
2100 "		
2300 "		
2500 "		
2700 "		
2900 "		
3100 "		
3300 "		
3500 "		
Total		
Control - No treatment		
M.S.D. (5%)		

1/ Material f
2/ Experiment
3/ Solutions

Fig. 7. A young coffee tree grown from a leaf bud cutting. This tree is fifteen months old from planting the cutting. Picking of the first light crop of fruit was begun twenty-three months after planting.

were significant only as regards the fresh weight of the vegetative growth, again possibly an effect of the plot variation.

In only one case was a concentration of 2,4,5-trichlorophenoxyacetic acid (70 ppm.) significantly superior to the control in the number of cuttings rooted. The 100 ppm. and 140 ppm. treatments were both significantly poorer than the controls in number of vegetative buds sprouted, although there were no significant differences in the fresh weight of the vegetative growth produced.

The effect of Indolebutyric acid on the number of cuttings rooted was significantly better than the controls in concentrations of 3600, 3800, 4000, 4400, 4600, and 5400 ppm. The treatments of 3600, 4200, 4400, 4600, and 5400 ppm. were all significantly better than the control in the number of primary roots. There were no significant differences in the number of secondary roots. The fresh weight of the roots was significantly superior to the control in only one concentration, 4200 ppm., of indolebutyric acid. With one exception, 5000 ppm. indolebutyric acid, there were no significant differences in the number of vegetative buds sprouted in the treatments over the control. No significant differences were found in the fresh weight of the vegetative growth as compared with the control.

No significant improvement over the control was found in any factor studied when applications of indoleacetic acid were made.

When 2,4,5-trichlorophenoxypropionic acid was applied in concentrations of 190, 230, and 250 ppm., significant improvement in the number of cuttings rooted were found over the controls. Only the 250 ppm. concentration was significantly better than the control in the number of primary roots. The 130 ppm. treatment of 2,4,5-trichlorophenoxypropionic acid was significantly poorer than the controls in the number of vegetative buds sprouted. No significant differences over the control were found for the fresh weight of either the new vegetative growth or the roots.

The effect of naphthaleneacetic acid on the number of cuttings rooted was significantly better than the control in concentrations of 1100, 1500, 2300, 2700, 2900, 3100, 3300, and 3500 ppm. There were significant increases in the number of primary roots over the control in the 1500, 2700 and 2900 ppm. concentrations. Only one treatment, 1500 ppm., of naphthaleneacetic acid, was significantly better than the control in the number of secondary roots. Concentrations of 1500 and 2700 ppm. produced root systems in which fresh weight was significantly superior to that of the control. No effect of the naphthaleneacetic acid hormone concentrations used was found on the number of vegetative buds sprouted or the fresh weight of the new vegetative growth.

<u>Experiment VII: The effect of chemical, hormonal and cultural treatments on the rooting of stem cuttings made from the fifth and sixth nodes of orthotropic coffee stems.</u>

Due to the dimorphic growth habit of the coffee plant, only the orthotropic stems when asexually propagated may be expected to produce plants similar in form to plants from seed. This apparent fact greatly reduces the material suitable for asexual propagation. Results from Experiment I show considerable reduction in the rooting ability of cuttings made from the lower nodes of the orthotropic coffee stems. This problem presents a serious handicap to the general use of cuttings for coffee propagation.

In Experiment I, no chemical, hormonal, or cultural treatments were used to improve rooting of the cuttings. The following experiment was designed to study the effects of various treatments upon cuttings made from the fifth and sixth nodes.

Plant material for the pruning and ringing treatments was prepared on January 16 and 17, 1951. A check was made of the rings on January 28 to assure that cambium had not reunited the two sides of the ring. Each stem was numbered and labelled. The treatments were as follows: a)orthotropic stems were ringed at the internode between the seventh and eighth node, b)orthotropic stems were ringed at the internode between the seventh and eighth node, the apical tip to the first node was removed,

and all plagiotropic branches were removed, and c)orthotropic stems were ringed at the internode between the seventh and eighth nodes and the apical tip including the first node was removed. These selected and pruned stems were all on bearing coffee trees. The trees were beginning to show elongation of the floral organs, with some nodes having a few fruits that had begun to enlarge. After two weeks this material, which had previously been ringed and pruned, was removed from the parent plant. Flowers were still present on the stems and fruit setting was more general. Some fruit had developed to as large as 3/4 cm. in diameter. At the same time cutting material was collected for the chemical and hormonal treatments, but without previous pruning or ringing of stems. This material was of the same approximate age as the pruned material and was selected to be as identical as possible in physiological condition in blooming and fruit set. The next day, cuttings were made of the stems from prepared or ringed and unprepared or unringed materials. The fifth and sixth nodes were counted, secondaries removed and oversized cuttings made, using pruning shears. As each group of material was prepared, it was immediately recut at the base with a sharp knife and then placed either in the proper plot or into solutions for treating in accordance with the previously planned experimental design.

The chemical substances used were: a) trans-cinnimic acid

at a concentration of 1000 ppm., b) ammonium sulphate applied at a concentration of 2000 ppm., c) sucrose used at a concentration of 1%. This concentration was selected because of its effectiveness in Experiment III, and d) the hormone source was Hormodin No. 2 (Merck and Co.). This substance is reported (89) to contain indolebutyric acid at a concentration of 4000 ppm. in a talc carrier. The chemicals, dissolved in distilled water, were placed in glass dishes to a depth of two centimeters. Cuttings were placed upright in the different solutions after the basal cuts had been remade.

Four different amounts of leaf surfaces were used: a) no leaves, b) one leaf, c) two leaves, and d) two leaves cut in half. These were prepared before the cuttings were placed in the chemical solutions. Cuttings were left in ammonium sulphate and sucrose solutions for 24 hours.

After this period the cuttings were removed, washed in a gentle spray of water and either planted in the appropriate plot or treated with hormone and planted, or returned to glass containers holding a second chemical for treatment during the succeeding 24 hours. After the second chemical treatment, the cuttings were again washed, treated with hormone or not, and planted according to plan.

The cuttings were removed after 90 days in the propagating bins. Data were taken on all plots and treatments at this time.

In the analysis of variance for this experiment the data

were separated into two groups, one analysis included treatments one through seven and 16 (control), the other analysis included treatments 16 through 39. Analysis was not possible on the cuttings planted without leaves in treatments 9 to 15. Of the 115 cuttings planted in these treatments, only 13 survived. Of these 13 surviving cuttings, five were untreated, seven were treated with Hormodin Number 2, and one was treated for 24 hours in a 1% sucrose solution.

Results of the analysis of the first group of treatments (1-7 and 16) show that there were significant differences in number of cuttings rooted (see Table VII). Highly significant differences were found in the number of secondary roots. No other factor studied apparently resulted in any significant variation.

The analysis of variance made on the remaining treatment (Table VIII) shows that highly significant differences existed in the number of cuttings rooted, and fresh and dry weight of the new vegetative growth.

From the minimum significant differences for the pruning and ringing treatments, significant improvement over the control in numbers of cuttings rooted in treatment numbers 3, 5 and 6 was obtained. The hormone-treated and non-treated cuttings previously ringed and tipped, and the non-treated cuttings receiving a previous treatment of basal ringing and removal of the plagiotropic branches and orthotropic apical

Treatme number
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
Total
M.S.D.

Footnotes (Table VIII)

1/ Material for cuttings from trees 12 years old or more

2/ Experiment planted June 9, 1951

3/ The two leaves on each cutting were cut in half, midway between apex and base, just before planting

4/ Chemical treatments applied as follows:

D. Hormodin No. 2 (Merck and Co.) applied to the base of the cutting before planting

E. Transcinnimic acid (Shell Exp. Lab.) 1000 ppm in 50% alcohol applied to base of cutting before planting as a one second "quick dip"

F. Ammonium sulphate 2000 ppm dissolved in distilled water. Applied to base of cuttings by immersing base of cutting in solution for 24 hours, removing, washing in stream of water from hose and planting.

G. Sucrose 190 solution applied by immersing base of cutting in solution for 24 hours, removing, washing, in stream from hose and planting.

G-D, G-F, F-D and G-F-D combination treatments applied as described above. Letters indicate order of treatment. Cuttings washed in stream from hose before application of second or third treatment.

tip, were significantly better than the non-treated controls in number of cuttings rooted. Significant improvement in the number of secondary roots over the control was found in treatments 2, 3, 5 and 7.

In the number of cuttings rooted, significant improvement was found in treatments 18, 22, 25, and 33 over the control treatment. Significantly lower fresh weight of the vegetative growth was found in treatments 25, 28, 30 and 31 than the control. Dry weight of the cuttings in treatments 25 and 30 was significantly less than the control cuttings.

SUMMARY AND DISCUSSION

The process of rooting cuttings of Coffea arabica L. has been shown in the preceding experiments to be possible under various conditions. Significant improvement of the rooting of cuttings over controls has been attained by different methods. Although rooting of cuttings has been found successful, a thorough study of the subsequent growth of the cuttings is necessary before recommendations of propagation by this means can be made.

After coffee cuttings are made, there appears to be two main types of conditions influencing their subsequent rooting. These factors can be considered as internal and external in nature. The effects of each of these factors may be better considered separately.

External Factors

Previous investigators have found that some method of environmental control is necessary for the rooting of softwood cuttings of coffee. The propagating equipment described by Fiester (28) proved to be very satisfactory under conditions existing at Turrialba, Costa Rica.

In this propagating equipment, single leaf cuttings have remained in a healthy although non-rooted condition for as long as five months. A number of plagiotropic cuttings collected between December 1, 1950 and May 30, 1951 bloomed and bore fruit as large as 1 1/2 centimeters in diameter while the cuttings did not show any evidence of rooting.

Although no data were obtained on the effect of temperature, relative humidity and light intensity upon rooting of coffee cuttings, observations made in the course of this investigation seem to indicate the following environmental conditions as optimum for the process:

Temperature: The best range of temperature for rooting coffee cuttings appears to be between 26°C. and 30°C. Temperatures of 32°C. or over for periods of one hour or more often killed the cuttings.

Humidity: The relative humidity maintained in the propagating bins never fell below 85%. The optimum appears to be slightly above this or within the range of 90% to 100% relative humidity.

Sunlight: The intensity of sunlight used in these experiments

was controlled only when it caused the temperature within the propagating bin to raise above a 29°C. to 30°C. maximum. On days of full sunlight additional shade was used over the bins allowing approximately 25% of the sunlight to enter.

Watering schedule-media relationship: As previously stated the watering schedule is dependent on the media and relative humidity maintained in the propagating bins. By observation, with the sand media a schedule of watering once every five to six days was found best. However, as can be seen in the media trial, when watering every eight days the best media were soil and vermiculite. The effect of these different media on the rooting of coffee cuttings appears to vary with the watering schedule used. Under conditions of existing high humidity, too frequent watering of a given medium often produced rotting of the base of the cutting while too infrequent watering either retarded rooting or killed the tissue of the base of the cutting. This watering schedule-media relationship appears to affect the rooting of coffee cuttings significantly when the proper watering schedule for a given medium, under one group of environmental conditions, is used.

In Table IV there is a significant effect of the media upon rooting of coffee cuttings. This significant increase in rooting by the soil and vermiculite media appears to be due to maintenance of better humidity or moisture of the base of the cuttings which in turn may have some effect on breaking of root initials into growth.

As can be seen from these data, it seems that no noticeable differences in either length or weight of roots can be attributed to the absorption of nutrients by the cutting from the medium within the first three months after planting. The greater length and weight of roots planted in the vermiculite medium may be given as evidence. Vermiculite is considered as a relatively sterile medium in plant nutrients yet cuttings planted in it produced roots which were longer and weighed more than roots from cuttings planted in garden soil. It has been observed that cuttings requiring three months to root start to elongate primary roots after approximately two months and generally do not start to produce fine secondary roots until almost two weeks later. Therefore, the effect of nutrient absorption by the cutting appears to be so small during the first three months that it has little influence upon the length or weight of the roots produced. This would indicate that the rooting of cuttings is probably dependent upon the internal reserve existing in the cutting at the time of planting and is not significantly augmented through the absorption of nutrients by the newly produced roots while in the propagating medium.

Internal Factors

At present it is a general belief that cuttings of any plant will root when grown under proper conditions. This assumes that all cuttings without any special treatment have a predetermined natural potential for rooting which must be

above zero. This potential is manifested by length of time needed for rooting, number of primary roots, length of secondary roots, diameter and weight of roots, etc.

The natural rooting potential seems to be established for a cutting some time before it is made. Apparently the rooting is regulated not by any one factor or even any group of factors but rather by the whole complex entering into growth and development of the plant from which the cutting was taken. Any factor that affects the growth and development of part or all of the mother plant may also affect the initiation and development of roots on cuttings made from that plant.

Variation in the natural rooting of other crops has shown that there is considerable variation between clones of the same species as to ease of rooting and the root system produced. This may also become apparent in coffee. Although no studies have been started on a clonal basis, studies comparing nodal variation of the natural rooting potential have been made.

On the coffee plant, it appears that the normal rooting potential is at least partly a localized effect. Differences found as a result of making cuttings from various nodes along the orthotropic stem seems to indicate that this localized effect may be so restricted as to show variation even from node to node.

The variation in the natural rooting ability obtained

does not appear to be directly due to a hormonal influence. If such were the case the variation from node to node when placed on a graph might be expected to exhibit a normal curve. The data for number of cuttings rooted in Experiment I demonstrate too great a difference between nodes 3 and 4 to fit such a pattern. The explanation for these striking results seems to be related to other physiological differences between the two nodes. The most obvious factor varying between these nodes is the relative maturity of the tissue below the fourth node compared to the relatively vigorous juvenile state of the first two or three nodes. This influence of active growing tissue in cuttings, possibly combined with an optimum hormone concentration as a secondary factor, most likely explains these wide variations in the natural rooting potential of cuttings from the third and fourth nodes along the orthotropic stem.

Use of material still juvenile is one method of securing cuttings having a higher natural rooting potential. A greater number of cuttings rooted, greater number of primary roots, greater number of secondary roots, as well as a greater total wet and dry weight of roots resulted when material from the first three nodes were used.

It does not seem likely that any one internal factor will prove all important to maximum rooting response of coffee cuttings although the big increases in rooting appears to be possible when limiting internal factors are supplied. Augmenting any of the limiting factors may be a means of adjusting to an

internal balance more favorable to root initiation and elongation. Consequently, new and often better rooting may be obtained.

Under local conditions, application of hormones appears to be one method of adjusting to a higher rooting potential in coffee. In the previously described experiments, indolebutyric, naphthaleneacetic, and 2,4,5-trichlorophenoxypropionic acids seem to be more effective than 2,4,5-trichlorophenoxyacetic acid. Indolebutyric acetic acid appears to have no effect upon raising the rooting potential in the concentrations applied.

The response to hormones is not uniform in raising the rooting potential and appears to depend not only upon the hormone used but also its concentration. Indolebutyric acid was effective in raising the rooting potential (number of cuttings rooted) over a broad range of from 3600 to 5400 ppm. Naphthaleneacetic acid was effective in increasing the number of cuttings rooted at concentrations of from 2300 to 3500 ppm. 2,4,5-trichlorophenoxypropionic acid was effective at 190 to 250 ppm. and 2,4,5-trichlorophenoxyacetic acids seems to be effective only near 70 ppm.

By increasing the hormone content of the cuttings, the rooting of coffee cuttings was increased. While control treatments rooted from 25% to 30%, the cuttings receiving hormone treatments in the optimum range rooted from approximately 65% to 100%.

Application of sucrose to coffee cuttings appears to be another method of adjusting the internal balance to a more

favorable rooting potential. Under conditions where cuttings are made from plants whose carbohydrate reserve has been depleted through fruit production, rapid growth or loss of leaves, sucrose application may be beneficial in raising the rooting potential.

Sucrose treatment significantly increased the rooting potential of cuttings made from young vigorous growing two-year-old coffee trees. However, when sucrose was applied to cuttings made from nodes five and six of old coffee trees (Experiment VII), in only one case was an increase obtained in the rooting potential.

The improvement over control of the rooting potential of cuttings made from the first three nodes of young coffee trees after application of sucrose seems to indicate that a low internal carbohydrate reserve may exist. This low reserve may be due to rapid growth of the tree from which the cuttings were made causing the carbohydrate reserve to be used soon after it becomes available.

As improvement of the rooting potential over controls by the sucrose treatments was found in only one case on cuttings made from the fifth and sixth nodes of twelve-year-old coffee trees, lack of sufficient carbohydrate reserve in cuttings made from this type of material may be considered as a limiting factor of minor importance.

Improvement of the rooting potential of cuttings after treatment by sucrose application seems to indicate that this

method may be used for augmenting the reserve of coffee cuttings. From the various concentrations of sucrose applied, a treatment of one per cent, in which the basal 1-1½ centimeters of the cuttings are placed for 24 hours appears best.

Another method used to increase the rooting of cuttings has been by application of potassium permanganate. Curtis (18) concluded that the action of the manganese deposited on and in the base of the cutting probably causes an increase in the rate of respiration in the treated cuttings or causes more complete oxidation.

A wide range of concentrations of potassium permanganate was applied to coffee cuttings. The application of a .05 molecular solution appeared to be the highest non-toxic concentration applicable. Concentrations in excess of a .05 molecular solution, when applied to the base of the cuttings for 24 hours, resulted in toxic symptoms. The .05 mol. concentration was near the center of the range of concentrations applied. Therefore as there were no definite trends of improved rooting with higher or lower concentrations applied, it may be concluded that there were no indications of other possible concentrations that might give beneficial effects. The application of potassium permanganate for the purpose of improving the rooting of coffee cuttings under the conditions used does not seem advantageous.

The type of cutting used seems to have a marked influence upon the rooting of coffee cuttings. This can be clearly seen

in Experiment IV. Although similar plant material was used for these cuttings with the exception of the leaf-bud type, there was considerable variation in number of cuttings rooted, number of primary and secondary roots as an effect of the type of cutting used.

These data seem to substantiate the results obtained by previous investigators (12, 24, 39, 41, 44, 45, 49, 75) when a large sized cutting is used. The three node cutting, when compared with the other types, seems to show a tendency toward lower or slower rooting. Possibly this effect of slow rooting can best be explained as a result of apical inhibition caused by the growing tip or due to an inability of the latent root initials to compete for food with the elongating apical point.

Taking into consideration that the material used for the leaf bud cuttings was made from seedlings, which van Overbeek (94) found had a higher rooting potential than cuttings made from older trees, this type of cutting is probably inferior to a one-node one-leaf and one-node two-leaf cutting. The explanation for the poor results obtained from leaf-bud cutting possibly can be due to lack of sufficient reserves and/or low potential for hormone production.

The one node two-leaf cutting made from the first three nodes of the orthotropic stem was found to be better than the other three cutting types studied. The reason for this is not clearly understood.

When cuttings are made from the nodes down the orthotropic stem and receive no treatment before planting, the sprouting of the orthotropic end appears to be uniformly high at the end of three months in the propagating bin. However, the time of sprouting and subsequent growth follow a definite trend. Bud sprouting occurs earlier in the case of cuttings made from the lower nodes and later in those coming from more apical nodes. The fresh and dry weights of bud growth after three mohths are strongly correlated with the former positions in which they were found along the stem. These correlations as well as the order of bud sprouting can probably be explained on an apical dominance basis.

There seems to be no effect of the number of primary and secondary roots on the number of buds sprouted since no similar or inverse trends were noted.

In the media-type of cutting trials no trend or effect of a specific medium on any specific type of cutting was found. The effect of any of the three media used on the number or weight of roots, appeared to be in approximately the same proportion for all of the four cutting types compared.

The influence of hormones appears to be more of a direct effect on the number of cuttings rooted and number of primary roots than on the number of cuttings alive, or the number of secondary roots.

It was observed but not proven that a higher hormone concentration may be needed in order to be effective on cuttings made from the lower nodes of the coffee tree than when the cuttings are made from material taken from nearer the apical tip.

Different treatments applied to the fifth and sixth nodes of orthotropic coffee stems have produced inconclusive results as to the needs of this type of material. No well defined improvement as a result of the application of any one treatment was noted throughout the trial. However, certain materials under rather specific conditions did give statistically significant improvement in rooting. Further experimentation is necessary before any recommendations for the use of this type of cutting material can be made.

Although no direct experiment was possible comparing the age of the mother tree upon the rooting response the present data seem to confirm the findings of van Overbeek (94), insofar as time necessary for rooting is concerned. Where cuttings were made from seedling coffee trees only 50 days were needed for rooting. By contrast, where material from bearing coffee trees was used, the time needed for rooting was approximately 75 to 90 days. It appears that there is some correlation between the age of the mother tree from which the cuttings are made and the time necessary for rooting.

A difference is evident between the results of van Overbeek (94) and those of the author as to the rooting responses obtainable from cuttings made from coffee trees twelve years old or

older. Van Overbeek concluded that rooting of cuttings made from coffee trees twelve years old was "sporadic". Undoubtedly, these differences found between the two studies can be traced to the use of different types of cuttings, the treatments applied, and possibly the number of cuttings involved in the two trials. Van Overbeek made no statement of the number of cuttings used in his comparison.

CONCLUSIONS

Some factors affecting the propagation of coffee by cuttings have been studied at the Inter-American Institute of Agricultural Sciences. Results of these experiments indicate that successful rooting of coffee cuttings is possible with a high degree of success if certain precautions are observed.

The following conclusions may be made as a result of the experimentation presented:

1. The propagating equipment described gave satisfactory control of environmental conditions for the rooting of coffee cuttings.

2. The environmental conditions which appear satisfactory for rooting coffee cuttings are:

a. Temperature - 26°C. to 30°C.

b. Humidity - 90% to 100% relative humidity

c. Sunlight - control only in relation to excessive temperature in the propagating bins

d. Media - sand, soil and vermiculite are satisfactory media when each is used at its optimum watering schedule.

3. The first three nodes from orthotropic coffee stems seem to be the most satisfactory material for making coffee cuttings.

4. The one-node two-leaves cuttings appear to be the best type of cutting under Turrialba conditions.

5. The application of indolebutyric acid at a range of from 3600 to 5400 ppm, naphthaleneacetic acid from 2300 to 3500 ppm, and 2,4,5-trichlorophenoxypropionic acid from 190 to 250 ppm in solutions of 50% alcohol applied for one second to the base of the cutting stimulates rooting of coffee cuttings.

6. A one per cent solution of sucrose aids the rooting of coffee cuttings made from seedling trees.

7. Potassium permanganate does not appear to stimulate the rooting of coffee cuttings and at some concentrations appears to be even harmful.

RESUMEN

Se ha diseñado y construído un propagador para enraizamiento de esquejes de cafeto que ha dado control satisfactorio de las condiciones ambientales. Los esquejes propagados en esta unidad dieron un porcentaje de enraizamiento de 75 a 100 en 90 días.

Se encontró una variación considerable, disminuyendo en orden descendente, en el poder de enraizamiento de los esquejes obtenidos de cada uno de los seis nudos del tallo ortotrópico. El enraizamiento de los esquejes obtenidos de los tres nudos próximos a la yema apical, no mostró diferencia estadística entre ellos, pero indicó superioridad en poder de enraizamiento con respecto a los esquejes provenientes de partes inferiores del tallo.

El mejor tipo de esqueje es el de un nudo con dos hojas y con 2.5 a 4 cm. de entrenudo bajo el pecíolo foliar.

De los medios de enraizamiento usados vermiculita y suelo franco arcilloso fueron superiores al de arena, con riegos cada ocho días.

El permanganato de potasio resultó inefectivo para elevar el poder de enraizamiento de los esquejes de cafeto.

Los ácidos indol-butírico, naftaleno-acético, 2,4,5-triclorofenoxi-acético y el 2,4,5-triclorofenoxi-propiónico elevaron el poder de enraizamiento de los esquejes. Cuando fueron aplicadas por el método de inmersión rápido estas hormonas fueron efectivas sólo con un grado específico de concentraciones, que varían para cada hormona. El ácido

indol-acético no elevó el poder de enraizamiento de los esquejes de cafeto.

Ninguno de los tratamientos químicos aplicados a los esquejes provenientes del quinto y sexto nudo de los tallos ortotrópicos, asi como tampoco los sistemas de podar y anillar el tallo del cafeto un mes antes de obtener los esquejes, dieron resultados favorables en el enraizamiento de éstos.

La aplicación de sucrosa fué efectiva en el poder de enraizamiento de esquejes provenientes de cafetos jóvenes.

Existe una correlación muy marcada entre la posición del nudo sobre el tallo ortotrópico y el desarrollo de nuevo brote durante el proceso de enraizamiento. Los brotes de nudos ubicados en partes más bajas del tallo tendieron a iniciar el crecimiento primero que los nudos provenientes de secciones más proximas a la yema apical.

Se encontró una marcada correlación entre el peso fresco y seco de las raíces.

Se encontró asimismo una marcada correlación entre el peso fresco y seco del brote.

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Fiester, Donald Ried
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