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THE RELATIONSHIP OF ANTS AND OTHER ORGANISMS TO CERTAIN SCALE INSECTS ON COFFEE IN PUERTO RICO

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INTRODUCTION

From July 1935 to early June 1936 the writer was employed by the Bureau of Entomology and Plant Quarantine to study the relationship between ants and scale insects on coffee. Most of the observations were made at or near Mayaguez, Puerto Rico, in an area quite representative of the mountainous coffee-growing sections of the island.

The theories concerning the relationship of ants to honeydew-excreting insects and to the plants on which the latter feed may be summarized as follows: (1) By protecting them from predators and parasites, ants may benefit insects which excrete honeydew; (2) by assiduously attending their hosts, ants may cause them to feed more and thus hasten their development; (3) by moving them from plant to plant as food becomes scarce, ants may make conditions more favorable for their hosts; (4) by removing the excess honeydew from the plant, ants may prevent their hosts from becoming entrapped and killed by their excretions; (5) by transporting their hosts from plant to plant, ants may spread plant diseases; and (6) by removing the honeydew from their hosts or from plants, ants may indirectly aid the latter by keeping the pores from becoming clogged with honeydew and dust accumulation.

[1] Acknowledgment is made to the staff of the Federal Agricultural Experiment Station at Mayaguez for laboratory facilities and helpful suggestions in connection with the work.

[2] The ants referred to were identified by the author; the other insects were identified by various specialists in the Division of Insect Identification of the Bureau of Entomology and Plant Quarantine.

[3] This work was made possible with special funds available to the United States Department of Agriculture for studies of insects in Puerto Rico.

ANTS AND SCALE INSECTS OF COFFEE

A rather intensive survey of coffee groves to determine the ants and scale insects present in the various groves revealed that of the 66 species of ants known to occur on the island of Puerto Rico 31 are commonly encountered, and of this latter number the following 14 species were noted attending the green scale, *Coccus viridis* (Green), and the hemispherical scale, *Saissetia haemispherica* (Targ.):

1. *Solenopsis geminata* (F.) (hormiga brava, or tropical fire ant)
2. *Wasmannia auropunctata* (Rog.) (albayalde, or little fire ant)
3. *Brachymyrmex heeri* Forel
4. *Brachymyrmex heeri* var. *obscurior* Forel
5. *Monomorium carbonarium* subsp. *ebeninum* Forel
6. *Myrmelachista ramulorum* Whlr. (hormiguilla)
7. *Monomorium floricola* (Jerd.)
8. *Iridomyrmex melleus* Whlr.
9. *Paratrechina longicornis* (Latr.) (hormiga loco, or crazy ant)
10. *Tapinoma melanocephalum* (F.) (albaricoque)
11. *Pseudomyrma flavidula* F. Sm.
12. *Crematogaster steinheili* Forel
13. *Pheidole fallax jelskii* var. *antillensis* Forel
14. *Pheidole subarmata* var. *borinquenensis* Whlr.

Detailed observations were made on *Solenopsis geminata* and *Brachymyrmex heeri* var. *obscurior,* and general observations were made on *Wasmannia auropunctata. Solenopsis geminata,* the hormiga brava, or tropical fire ant, is by far the most important because it is a large ant of an aggressive and ferocious disposition, omnivorous in its habits, and has many individuals per colony. It nests mainly in the soil, but occasionally colonies can be found in rotten stumps and logs. Its nests are more commonly found in open, sunny areas such as the edges of coffee groves.

Wasmannia auropunctata, the albayalde, or little fire ant, is a highly adaptable species which nests in soil or in wood, both in open and in shaded situations, and seems to thrive equally well under moist or arid conditions. Its nests, although very populous, are not so easily located as are those of the larger, tropical fire ant. Probably no ant in the island surpasses the albayalde as an attendant of insects which excrete honeydew, regardless of the type.

Although the colonies of *Brachymyrmex heeri* var. *obscurior* are not large, this ant is widely distributed over the island and is a common attendant on honeydew-excreting insects. It is capable of living both in the ground and in rotten wood.

The six species of scale insects commonly noted on coffee plants in Puerto Rico are:

1. *Saissetia haemispherica* (Targ.) (the hemispherical scale)
2. *Coccus viridis* (Green) (the green scale)
3. *Cryptostigma inquilina* (Newstead)
4. *Pulvinaria psidii* Maskell (the green shield scale)
5. *Selenaspidus articulatus* (Morgan) (the rufous scale)
6. *Ischnaspis longirostris* (Signoret) (the black thread scale)

Of these the two most important are the hemispherical scale and the green scale. They are the commonest scales in coffee groves throughout the island and are of special interest because they are attended constantly by ants. Although these scales are usually of secondary economic importance, they can become of real significance under conditions particularly favorable for their development. Either of these scales can be found on almost any part of the coffee plant, but they are usually most abundant and noticeable on the smaller and more tender twigs of the terminal branches; and the base of the fruit, or even entire berries, may be incrusted with them. It is almost impossible to find coffee plants that do not support a few individuals of one or both these species.

Both scales are of the soft, unarmored type. The hemispherical scale is more convex and larger than the green scale and is easily recognized by its dark-brownish color. The green scale is flatter and pale green in color. Both give off a great amount of honeydew, and for that reason are eagerly visited by various species of ants. The hemispherical scale was selected for study in the scale-ant relationship because of its greater availability.

RELATIONSHIP OF THE ANTS *Solenopsis geminata* AND *Brachymyrmex heeri* VAR. *obscurior* TO THE HEMISPHERICAL SCALE

Many hours were spent in watching *Solenopsis geminata* and *Brachymyrmex heeri* var. *obscurior* as they visited the hemispherical scale for honeydew. To obtain honeydew from a scale, a worker ant stood to the rear of the insect and dragged the tips of its antennae back and forth over the caudal end of the scale until the scale responded or until

the ant ceased its attentions and moved away. Not every solicitation resulted in the production of honeydew, for on many occasions the ants left the scales after stroking them for some time unsuccessfully, but usually the ants were rewarded for their efforts. When a scale responded, the worker ant eagerly seized the droplet of honeydew with her mandibles and allowed it to remain suspended from the lower part of her mouth where it hung while being gradually sucked up, a process requiring from 1 to 2 minutes. The solicitation of the scales by the ants appears to be aimless. For instance, a worker ant was seen to obtain a droplet of honeydew from a certain scale, walk off, and return immediately to the same scale and solicit it again. On one occasion a worker ant was seen trying to obtain food from the caudal end of a ladybird beetle larva which happened to be in the midst of a group of scales. Ants also have been seen trying to "milk" dead scales or scales too immature to excrete honeydew.

An attempt was made to learn if the presence of ants stimulated the scales to produce more honeydew and thereby speed up metabolism, thus causing them to become more abundant. Detailed observations indicated, however, that the scales did not void quite so often in the presence of the ants as when no ants were near, but there was not a pronounced difference. Although it was not practical to measure the size of the droplets of honeydew obtained by the soliciting ants, these appeared to be generally larger in the presence of the ants than otherwise.

The visits of the *Solenopsis* to the scales seemed to be influenced to a large extent by both temperature and wind. Workers were not seen in large numbers attending scales on plants until well along in the day when the temperature was high. The ants also did not seem inclined to visit scales during strong winds.

On no occasion during the studies were workers of either *Solenopsis geminata* or *Brachymyrmex heeri* var. *obscurior* observed to show any evidence of interest in transporting, guarding, or fostering the scale insects in any way. No cartonlike coverings were made over the scales by workers of *Brachymyrmex*, but the tropical fire ant has been observed to make these coverings over the hemispherical scales, especially where the latter were very near the soil level on coffee plants in nurseries.

RELATIONSHIP OF ANTS TO THE PARASITE *Encyrtus infelix* (Embleton)

One of the objects of the study was to ascertain what relationship ants bear to parasites of the scale insects of coffee. It is claimed com-

monly that ants help scales increase in number by protecting them from parasites which, if unmolested, would diminish their numbers. The parasite most commonly seen attacking the hemispherical scale, and for that reason chosen for specific observations, was *Encyrtus infelix,* which was noted in coffee groves, in nurseries, and in experimental plots. This species is about 2 mm. long, of a dark-brown color, and of the general form of workers of the acrobatic ants (*Crematogaster* spp.), closely resembling the latter superficially. It was noted that the female wasp, while apparently preparing to oviposit, would often stroke the scale with her antennae, thus causing the scale to void honeydew. The wasp would then eagerly lap up the excreted honeydew. Similar observations have been made by Cendaña [4] in the case of *Coccophagus scutellaris* (Dalm.), a parasite of the black scale, *Saissetia oleae* (Bern.). This author states that the adult parasites were often seen to "massage" the posterior portion of the body of the host with the antennae and forelegs, thus inducing the excretion of a drop of honeydew, which was immediately consumed. In this instance there is apparently no direct relationship between this habit and oviposition.

All data secured showed that the ants exerted little if any effect in reducing parasitization of the hemispherical scale by *Encyrtus infelix.* The wasps were on the plant hour after hour, and day after day, parasitizing the scales as they chose, unmolested by the ants. If a wasp, while running over a plant in search of a suitable host for parasitization, encountered an ant unexpectedly, it moved to the right or left and avoided the ant. Often the ant and parasite passed within a fraction of an inch of each other without either taking notice of the other. Sometimes a wasp met an ant face to face, whereupon it showed its disturbance by dashing somewhat excitedly to the side and away from the ant. On some occasions the ant attempted to avoid the wasp. An ant was never seen to capture a wasp, and it is doubted that this would be possible, considering the agility of the latter. Although the fire ant is more vicious and aggressive than *Brachymyrmex,* its relation to the parasite was not noticeably different from that of *Brachymyrmex.* However, on a number of occasions twigs heavily infested with the hemispherical scale and attended by tropical fire ants at the time of collection were brought to the laboratory and placed in cages. A large number of *Encyrtus infelix* emerged from the scales on the twigs, further suggest-

[4] Cendaña, S. M. 1937. Studies on the Biology of *Coccophagus* (Hymenoptera) A Genus Parasitic on Nondiaspidine Coccidae. *Univ. Calif. Publ. Ent.* 6: 383.

ing that the ants exerted no appreciable effect in preventing parasitization of the hemispherical scales by the wasps.

RELATIONSHIP OF ANTS TO THE PREDATORS OF SCALE INSECTS

The scales on which detailed observations were made had very few predators; hence, there was little opportunity for a study of the relationship of ants to the predators of scales. Occasionally adults of coccinellids, thrips, or the hemipteron *Asthenidea picta* (Uhler) were seen on the plants, but no ants were seen pursuing, attacking, or killing these insects. In a survey of coffee groves, larvae of the syrphid fly *Baccha capitata* (Loew) were often observed destroying scales, but none of the fly larvae appeared to be attacked by ants although there were many species of ants in their vicinity besides *Solenopsis geminata* (F.) and *Brachymyrmex heeri* var. *obscurior*.

EFFECT OF ENTOMOGENOUS FUNGI ON THE ABUNDANCE OF THE HEMISPHERICAL SCALE

The fact that tropical fire ants prefer to nest and work in sunny areas may have caused observers to believe that the ants are responsible for the increase of the scale in those areas. The observations made by the writer, however, indicate that the scale becomes more abundant in sunny locations because conditions there are unfavorable to entomogenous fungi, which in more humid situations keep the scale well in check.

The importance of entomogenous fungi in controlling scale insects was forcibly impressed on the writer when he was attempting to run some experiments to determine the relationships between ants and the hemispherical scale. A number of coffee plants infested with scales, but with no apparent entomogenous fungi on them, were placed on tables in a well-shaded coffee grove. Within a period of two months the fungi had increased so rapidly as to wipe out the scales completely, and as a result the experiments had to be discontinued. The worst infestation of scale the writer saw on the island was that in a grove of the thick-leaved Excelsior variety of coffee. This coffee does not require shade like *Coffeea arabica* (L.), the common Puerto Rican coffee, and conditions were ideal for the development of the scale. That certain ecological conditions apparently are responsible for the increase of the scale is brought out by the observation that (1) plants in exposed places, such as ridges and edges of fields, usually are more heavily infested than those

more centrally located or better shaded; (2) the scale is generally more abundant in dry weather; (3) hurricanes or storms that destroy the shade of coffee seem to cause the scale to increase. The conditions enumerated are those in which entomogenous fungi cannot successfully develop because of the lack of sufficient shade and moisture. The fact that the scale has not become abundant evidently is due to the control exerted over it by entomogenous fungi, one of the most important of these being *Cephalosporium lecanii*. When an extremely dry spell occurs, or when some of the plants become unduly exposed to sunlight, the scale immediately begins to increase in abundance, and its economic significance rises sharply. According to extension workers of Puerto Rico, the truth of this statement was well brought out by the San Felippe hurricane of 1928. Shade trees of coffee were either blown down by this storm or many of the branches stripped from them, thus depriving the coffee of its normal shade. As a result one of the worst outbreaks of scale that the island has experienced took place.

SUMMARY

Of the 14 species of ants attending scale insects of coffee, the three most commonly observed are the tropical fire ant, *Solenopsis geminata* (F.), the little fire ant, *Wasmannia auropunctata* (Rog.), and *Brachymyrmex heeri* var. *obscurior* For. The most important scales are the hemispherical scale, *Saissetia haemispherica* (Targ.), and the green scale, *Coccus viridis* (Green). The commonest parasite is *Encyrtus infelix* (Embleton).

The process of ingestion of honeydew by ants is described. Attendance of the scale insects by ants did not result in more frequent voiding of honeydew but did seem to increase the quantity voided. Little evidence of special care or colonization of the hemispherical scale by ants could be detected, and little discrimination was shown by the ants in soliciting honeydew.

No restraining action of the ants against the parasite *Encyrtus infelix*, or against general predators, was observed. The wasp *Encyrtus infelix*, while apparently preparing to oviposit, often stroked the scale with her antennae, thus causing the scale to void honeydew, which was immediately and eagerly lapped up by the wasp.

The principal factors regulating abundance of coffee scales appeared to be certain entomogenous fungi, especially *Cephalosporium lecanii*. These fungi were favored by shade, coolness, and moisture. Scales were accordingly less abundant in the normal shady locations.

NEW PSYLLIDAE FROM PUERTO RICO WITH NOTES ON OTHERS (HOMOPTERA)

By John S. Caldwell, Circleville, Ohio

The Herbert Osborn Collection and the efforts of my friend Luis F. Martorell have furnished the following data.

Carsidara concolor Crawford

A series of four females; three from Aguirre, 1–18–29, and one from Rio Piedras, February 1929, Herbert Osborn collector.

Heteropsylla puertoricoensis n. sp.

Length of tip of forewing male 1.6 mm., female 1.7 mm.; forewing male 1.3 mm., female 1.4 mm.

Head and thorax yellow, abdomen greenish in female.

Vertex over half as long as broad, concave caudad. Genae slightly swollen. Antennae about one and one-half times as long as width of head.

Proctiger of male short, stout, scarcely longer than forceps; forceps deeply bifurcate, outer fork invert "L" shaped with horizontal part of "L" projecting cephalad and twice as stout as basal portion, inner fork of similar shape but less curved and more slender.

Dorsal valve of female genital segment about as long as rest of abdomen in dried specimens, rather styliform in caudal half; ventral valve half as long as dorsal, stout, blunt.

Male holotype, female allotype, five male and two female paratypes from Rio Piedras, 7–19–16, R. T. Cotton collector. Host: *Samanea saman*. Types are in the University of Puerto Rico Collection at Rio Piedras.

Ceropsylla martorelli n. sp.

Length to tip of forewing male 2.3 mm., female 2.6 mm.; forewing male 1.9 mm., female 2.3 mm.

General color of male red to light orange, female light to dark brown.

Head as broad as thorax, scarcely deflexed. Eyes very prominent. Genal cones three-fourths as long as vertex, contiguous throughout;

apices acute. Antennae one and one-fourth times as long as width of head.

Thorax scarcely arched, rather short, flat. Forewing with short cubital petiole; cubital cell twice size of medial. Metacoxae with posterior spurs; hind tibia with no basal spur, with apical spur ratio of 2–1.

Male genital segment with a basal projection on either side about as long as forceps. Forceps slightly tapered apically, with a very small spur caudad near apex.

Dorsal valve of female genital segment with basal two-thirds bulbose, apical third short, styliform; circum-anal ring appearing triangular with apex of triangle projecting caudad.

Male holotype, female allotype, five male, and nine female paratypes from Cayey, 5–31–41, collected by L. F. and M. C. Martorell, and one male paratype and several imperfect specimens from Aguas Buenas, June 1940, collected by L. F. Martorell.

The writer takes great pleasure in naming this distinctive species in honor of Mr. Luis F. Martorell.

Fifth stage: Length 1.2 mm., width 1. mm. Broadly oval, head and abdomen slightly narrower than wing pads. Form more like *Triozа* than *Ceropsylla.*

Antennae short, apparently trisegmented with terminal segment black. Derm with no conspicuous plates. Entire margin closely beset with a continuous series of sectasetae resembling those found in other *Ceropsylla.* Circum-anal ring set in from abdominal apex, extremely long, narrow, consisting of a single ring of slit-like pores.

Biologic: This psyllid attacks a lauraceous tree, *Ocotea leucoxylon* (Sw.) Mez., commonly called "black laurel" which is also reported from St. Thomas, Tortola, Cuba, Jamaica, Hispaniola, and from Guadeloupe to Grenada. The tree itself may be identified by the rough appearance of the leaves. The gall is an open pit type with the immature psyllid fully exposed on the under side of the leaf. The adult psyllids are only found during the rainy season when the tree puts out new shoots. Apparently the eggs are laid on the tender foliage and the immatures develop with the leaves.

Arytaina cayeyensis n. sp.

Length to tip of forewing, male 2.7 mm., female 3.2 mm.; forewing male 2.3 mm., female 2.5 mm.

General color straw yellow over all with indications of broad white stripes on the thorax; five terminal antennal segments black.

Head rather declivious, finely pubescent, as broad as thorax. Vertex twice as broad as long, somewhat rounding downward in front. Posterior ocelli strongly elevated. Genal cones half as long as vertex, divergent, broadly rounded. Antennae almost two and one half times as long as width of head.

Thorax not especially arched; pleurites of pronotum appearing subequal in length. Forewing twice as long as broad, broadly rounded apically; membrane yellowish; pterostigma very short, broad; costa with conspicuous fringe of setae. Hind tibiae with basal spur and 4–5 apical spines.

Forceps of male deeply bifurcate; outer branch broadest just before apex which is short, broadly rounded, located caudad; inner branch longer than outer, slender, evenly narrowed to acute, inner projecting apex.

Female genital segment as long as rest of abdomen. Dorsal valve, in lateral aspect, suddenly and greatly lowered from anal opening to styliform apex, caudal half serrate on dorsal surface. Ventral valve much shorter than dorsal, blunt apically.

Male holotype, female allotype, four female and four male paratypes from Cayay, 1–28–29, on *Inga*, collected by Herbert Osborn.

The vertex, forewings, and genitalia of this species are not typical of *Arytaina* and may place it in *Euceropsylla* Boselli[1] with which the writer is not familiar.

Arytaina unga n. sp.

Length to tip of forewing of female 2. mm.; forewing 1.7 mm.

General color dull orange with light stripes on dorsum of thorax and on center of vertex. Antennae annulate with black, two terminal segments black.

Vertex one and one half times as broad as long, foveae very deep. Genal cones half as long as vertex, short, obtuse. Antennae one and one half times as long as width of head.

Prothoracic dorsum strongly descending. Forewing little over twice as long as broad; pterostigma very short, broad.

Female genital segment as long as rest of abdomen. Dorsal valve, in lateral aspect, with dorsum straight except for depression just caudad anal opening; apex acute, abruptly turned up. Ventral valve shorter than dorsal, apex acute.

[1] Boselli, F. B. Studi Sugli Psyllidi: Lab. Zool. Gen. Agr., Portici, *Bull. V*, 24: 70, 1929.

One female collected by Herbert Osborn at Mayagüez, March 3, 1929.

Psylla minuticona Crawford

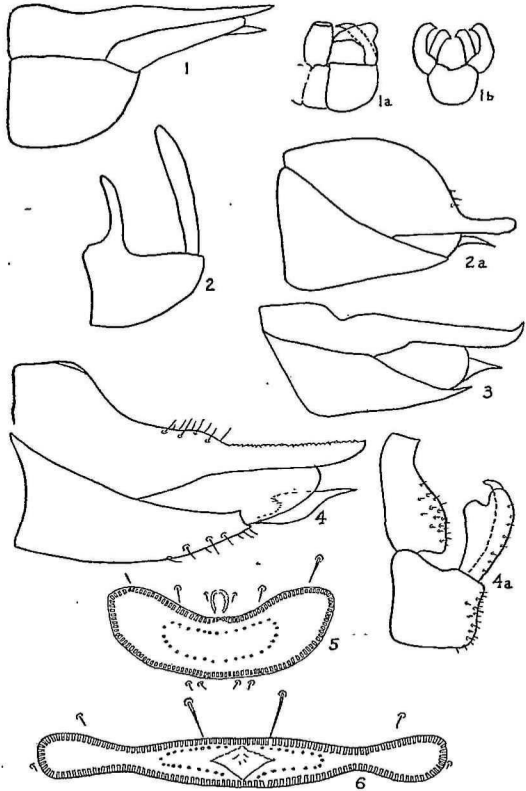
Fifth stage immature: Length 1.9 mm. Antennae almost as long as entire insect, nine segmented, last four segments imbricate.

Dorsum of entire insect beset with long capitate setae as follows: head with a scattered group of six to eight, fore wingpads with five to seven each, hind wingpads with two each, each abdominal segment with six to eight and the terminal plate bearing three rows of six to eight.

Circum-anal ring small, kidney shaped, located at abdominal apex, ventrad; composed of a single ring of slit-like pores.

EXPLANATION OF PLATE

1. *Heteropsylla puertoricoensis,* profile of female genitalia.
1*a*. Profile of male genitalia.
1*b*. Caudal view of male genitalia.
2. *Ceropsylla martorelli,* profile of male genitalia.
2*a*. Profile of female genitalia.
3. *Arytaina unga,* profile of female genitalia.
4. *Arytaina cayeyensis,* profile of female genitalia.
4*a*. Profile of male genitalia.
5. *Psylla minuticona* Crawford, circum-anal ring of immature.
6. *Ceropsylla martorelli,* circum-anal ring of immature.



NEW PSYLLIDAE FROM PUERTO RICO WITH NOTES ON OTHERS.

STUDIES OF THE ROOT SYSTEM OF *COFFEA ARABICA* L.

Part III. Growth and Distribution of Roots of 21-year-old Trees in Catalina Clay Soil

By J. Guiscafré-Arrillaga and Luis A. Gómez

The study hereby presented gives information on the growth characteristics of the root systems of old coffee (*Coffea arabica* L.) trees growing in Catalina Clay soil. It completes previous studies (I, II) of young trees grown on Coloso and Catalina Clay soils.

Materials and Methods

Six 21-year-old trees of coffee, variety Puerto Rico, set at 8 ft. apart and averaging 348 centimeters in height, 323 centimeters in lateral spread and 8.08 centimeters in trunk diameter were used. (Figure 1.)

The trees were growing on level land under mixed natural shade of "guaba" (*Inga Inga* (L.) Britton) and "guamá" (*Inga laurina* (Sw.) Willd.).

Catalina clay is a compact soil. It is one of the most extensive lateritic soil types of Puerto Rico, and coffee is one of the principal crops which are grown on it.

TABLE I. *Distribution of roots of 21-year-old coffee trees in Catalina clay soil*

LAYER DEPTH	TREE NUMBER						MEAN WEIGHT ROOTS PER LAYER	
	1	2	3	4	5	6		
Inches	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Percent*
0–12	2102.97	2461.03	2094.95	1769.58	2399.92	2379.87	2201.39	93.75
12–24	67.91	79.50	115.21	74.96	150.36	126.37	102.38	4.36
24–36	11.32	10.34	27.65	24.45	40.95	32.97	24.61	1.05
36–48	6.64	0.70	9.25	11.96	26.97	11.23	11.12	0.47
48–60	4.68	0.01	5.08	5.29	13.13	3.92	5.35	0.23
60–72	3.13	0.00	2.80	0.00	7.17	1.12	2.37	0.10
72–84	1.97	0.00	0.94	0.00	2.83	0.29	1.00	0.04
84–96	0.12	0.00	0.09	0.00	0.00	0.00	0.04	0.00
Total	2198.74	2551.58	2255.97	1886.24	2641.33	2555.77	2348.26	100.00

FIG. 1. Tree showing average conditions of the trees studied.

RESULTS

Ninety-four percent of the root system was found in the topmost 12 inches of soil; 4.36 percent in the 12 to 24 inch level and 1.05 percent in the 24 to 36 inch level. The roots present in the 84 to 96 inch level were negligible. (Table I, figure 2.)

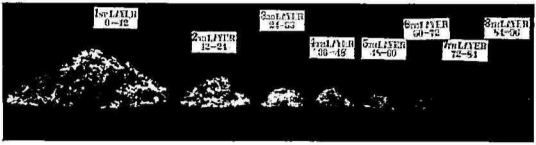


FIG. 2. Roots found per layer through the 96 inches of soil excavated.

The measurements of tops showed that the mean height was 348 centimeters; the mean lateral spread 323 centimeters and the mean trunk diameter 8.08 centimeters. The mean weight of tops was 9521 grams, the mean weight of roots 2348.27 grams and the ratio of tops to roots was 4 to 1.

The primary roots comprised 57.22 percent of the whole root system, the secondary 25.72 percent and the tertiary 17.06 percent. (Table II.) The primary roots were found in the 0 to 24 inch level only; the secondary roots in the 0 to 72 inch level and the tertiary roots in all layers down to 96 inches.

TABLE II. *Distribution of the various types of roots of 21-year-old coffee trees by layers*

LAYERS	PRIMARY ROOTS	SECONDARY ROOTS	TERTIARY ROOTS	TOTAL
Inches	*Grams*	*Grams*	*Grams*	*Grams*
0–12	7525.3	2943.2	1753.1	12221.6
12–24	537.7	453.0	283.0	1273.7
24–36		84.9	84.9	169.8
36–48		56.6	113.2	169.8
48–60		28.3	56.6	84.9
60–72		56.6	56.6	113.2
72–84			28.3	28.3
84–96			28.3	28.3
Total	8063.00	3622.60	2404.00	14089.6
Percent	57.22	25.72	17.06	100.0

Tertiary roots were found mostly in the uppermost 12 inches of soil (over 72 percent of tertiary roots in this layer). Absorption of water and plant nutrients is, therefore, confined mostly to this surface layer.

In general, trees with heavy tops had the most extensive root systems. Big trunk diameter and heavy root systems were found to be correlated as in previous studies (I, II).

Roots were found extending laterally 4 feet from the trunks. As in the case of young trees growing in Catalina and Coloso soil types, the root system has the form of an inverted cone of broad base and relatively short height.

CONCLUSIONS

It is concluded from our results that the root systems of young and old coffee trees follow the same distribution in the soil.

RECOMMENDATIONS

The root system of coffee trees should be induced to grow deeper than the 12 and 24 inch levels so that the nutrients and moisture available in lower levels be utilized by the plants. This would increase the resistance of the trees to drought. It could be accomplished by digging deep trenches around the trees.

Trees with superficial root systems like that of coffee should not be planted in coffee groves, thus eliminating competition for plant food.

A good mulch should protect the soil surface around coffee trees to prevent loss of moisture.

The planting distance for coffee should not be less than 8 feet.

SUMMARY

1. Ninety-four percent of the roots of 21-year-old coffee trees growing in Catalina soil are found in the uppermost 12 inches of soil.

2. A well developed and heavy tree top was found to be correlated with a heavy and extensive root system.

3. The top to root ratio was 4 to 1.

4. Primary roots comprised 57.22 percent of the whole root system; secondary 25.72 percent and tertiary, 17.06 percent.

5. Primary roots were confined to the first 24 inches, secondaries to the 0–72 inch levels, while tertiary roots were found distributed throughout the 0–96 inch levels.

6. While the lateral spread of roots was over 8 feet, the penetration was slightly over 3 feet.

ACKNOWLEDGMENTS

The writers wish to express their appreciation to the Redentorists Fathers for the use of their farm located at Barrio Miradero, Mayaguez, Puerto Rico, where this work was performed, and to Mr. Robert Cole formerly of the Puerto Rico Experiment Station (U.S.D.A.) for the photographs taken.

RESUMEN

1. El 94 por ciento de las raíces de cafetos de 21 años de edad se encontró en las primeras 12 pulgadas del suelo.

2. Los arbustos con partes aéreas bien desarrolladas tienen un sistema radical extenso.

3. El peso de la parte vegetativa es 4 veces mayor que el peso de las raíces que es a la vez casi la misma proporción que la de árboles de 7 años de edad cultivados en el mismo suelo.

4. El sistema radical de safetos de 21 años es superficial en el suelo del tipo Catalina, y la forma es la de un cono invertido.

5. A los 21 años de edad el desarrollo lateral de las raíces es de más de 4 pies radialmente y la penetración vertical es poco más de tres pies.

6. De todo el sistema radical, las raíces primarias representan el 57.22 por ciento, las secundarias el 25.72 por ciento y las terciarias, o raíces de absorción, el 17.06 por ciento. El 72 por ciento de las terciarias se encuentra en las 12 pulgadas superficiales.

7. Recomendaciones:

(*a*) Las plantas de un sistema radical igual o parecido al del cafeto no deberán plantarse para evitar la competencia por los elementos nutritivos necesarios para el cafeto.

(*b*) La distancia de siembra de cafetos debe de ser de 8 x 8 pies o más, pues se encontró que las raíces de cafetos de 21 años se extendían a poco más de cuatro pies del tronco.

(*c*) Deben construirse hoyos o minas profundas para estimular el crecimiento de raíces en las capas inferiores mediante la aeración y la acumulación de materia orgánica.

(*d*) Toda hojarasca y material que provea materia orgánica debe de amontonarse cuidadosamente alrededor de los arbustos para conservar la humedad y aumentar la cantidad de materia orgánica.

(*e*) Debe promoverse la aeración del suelo.

LITERATURE CITED

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