Agronomic Research on Arabica Coffee in Papua and New Guinea—Progress Report.

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ABSTRACT.

In the last twenty years, Arabica coffee has grown from negligible production to the second largest earner of export income for New Guinea, with exports in 1965-1966 *in excess of* 10,000 *tons. About half is produced on estates and the other half on small holdings. The crop is singularly free from pests, disease and other serious problems.*

Twelve years ago, the Territory Department of Agriculture, Stock and Fisheries began to lay down extensive agronomic trials, covering varieties, shade, spacing, pruning, mulching, fertilizing and cover cropping. The main trials are at the Highlands Agricultural Experiment Station, Aiyura, with subsidiary trials in other parts of the coffee growing area with markedly different environmental conditions. Interim results can now be interpreted with some confidence and are discussed fully.

INTRODUCTION.

IN a period of less than 20 years, the coffee industry in Papua and New Guinea has grown from virtually nothing until today it rivals cocoa for the position of the Territory's second most important earner of export income (the long established coconut industry retains its lead as highest earner of export income). In 1951-1952, coffee exports amounted to only 34 tons valued at $20,000. Ten years later, in 1961-1962 exports were 3,444 tons valued at $4,028,000. By 1964-1965 exports had grown to 8,687 tons valued at $7,296,000. Future expansion will be slower because of restrictions on planting imposed in accord with the International Coffee Agreement.

Some Robusta coffee is grown in lowlands areas but the greater part of the expansion of the industry has been in the production of Arabica coffee in highlands areas, generally between 4,000 and 6,500 ft. above sea level. About half is produced on estates and about half on village small-holdings.

Faced with such rapid expansion it was not possible for the Department of Agriculture (which itself had to build up from almost nothing after the 1939-1945 war) to keep ahead of the industry in research. Fortunately coffee production has been singularly free from serious problems and most plantings have produced well. The Department's main agronomy experiment programme with coffee got under way in 1954 but, as most field trials are of a fairly long-term nature, it is only now that their cummulative results are reaching a stage where they can be interpreted with some confidence.

Agronomic work with coffee is centred on the Highlands Agricultural Experiment Station, Aiyura, at an altitude of about 5,000 ft. The experiment programme undertaken has been ambitious, and includes variety trials and selection work ; study of the effects of various shades, spacings and pruning methods and their interactions with one another ; and study of nutritional requirements and responses to mulching, fertilizing and cover cropping. Staff available has frequently not been adequate to handle all the work that could be done on these trials, in sampling, testing, recording and analysing results, and often only the most essential work has been possible. Yields in all trials have been recorded as weight of fresh cherry produced and the relation between fresh cherry weight and weight of processed coffee beans has not yet been examined fully. Preliminary studies indicate that the conversion factor (from fresh cherry to processed coffee) differs substantially from variety to variety, and may also vary between different shade and fertilizer treatments and between different times and locations. Quality also may be affected by some treatments. These aspects are now being studied, and results should be fully applicable to the interpretation of the yield

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data already obtained. It must be emphasized that the present review is a progress report only, and many of the conclusions and recommendations are still tentative.

A brief description is given below of all trials which have been laid down up to the present. This is followed by a review of the results under the headings of the various factors involved. Most trials involve more than one factor, so results of a single trial may be discussed under more than one heading. Inclusion of several factors in a single trial permits an accurate assessment of their interactions (such as, for example, whether one variety may give highest yields at a close spacing while another yields its best at a wider spacing; or whether yields at different spacings are affected by presence or absence of shade). The review aims to present an overall picture of the economically significant results of the trials, as they affect management practices and yields. More detailed tabulations of the results of each trial are presented in the Annual Reports of the Department of Agriculture, Stock and Fisheries (1959-1960 et seq.).

LIST OF AGRONOMIC TRIALS WITH ARABICA COFFEE.

Notes.—The letters ACA stand for Aiyura *Coffea arabica*; this is part of a standard nomenclature for field trials used by the Department of Agriculture in Papua and New Guinea.

Spacings quoted as 'triangle' are equilateral triangle, except in a few instances where slight variations were made to fit the land available.

Trials described are located at the Highlands Agricultural Experiment Station, Aiyura; the Agricultural Extension Station, Goroka; and the Agricultural Extension Station, Korn Farm, Mount Hagen.

ACA1. *Shade x Spacing x Pruning Trial, Aiyura.*

To study the effects on coffee yields of four shade treatments (*Albizzia stipulata*—an introduced species; *Casuarina*—a local species; *Grevillea robusta*—introduced; and no shade) three spacings (7 ft., 8 ft. and 9 ft. triangle) two pruning systems (Single-stem and multiple-stem) on two sites (a hillside and pit-pit (peaty swamp) soil).

These treatments were all combined in a single trial in order to save space and also to enable study of any interactions between treatments.

Date.—Planted 1956.

Variety.—Blue Mountain.

Plot size.—Shade plots 0.4 acres, smallest sub-plots 0.1 acres.

Design.—Shade plots split for spacing, spacing split for pruning, four replicates on each site.

As the *Grevillea robusta* did not grow well enough to provide a suitable shade, it was cut out and these plots deleted from the trial in 1956. The deleted plots were used for ACA29.

ACA2. *Variety x Spacing Trial, Aiyura.*

Comparison of yields of five varieties (Blue Mountain, Arusha, Mocha, San Ramon, Bourbon) at two spacings (7 ft. 6 in. and 9 ft. triangle).

The variety Bourbon was planted a year later than the others, replacing a dwarf strain of San Ramon which appeared to have little potential.

Date.—Planted 1956.

Pruning.—Single-stem.

Plot size.—About 0.04 acres.

Shade.—*Albizzia stipulata.*

Design.—Randomized block, four replications.

ACA3. *Mulch—Cover Crop x Spacing Trial, Aiyura.*

To compare the effects on coffee yields of several forms of ground cover (clean weeding, weeds slashed, mulch, *Indigofera* and *Vigna* as cover crops) at two spacings (9 ft. triangle and 14 ft. x 5 ft. hedge).

The hedge spacing was designed to permit the use of cultivating or mowing implements to control ground cover, but the necessity for deep cross drains at the Aiyura site prevented use of such implements.

Date.—Planted early 1957, concluded 1961.

Variety.—Blue Mountain.

Shade.—*Albizzia stipulata.*

Plot size.—0.09 acres.

Design.—Spacing plots split for covers; four replications.

Results of this trial have been published (Schindler and Fraser 1964). Following conclusion of ACA3, the site was used for ACA14.

ACA4. *Omission Method Fertilizer Trial, Aiyura.*

An attempt to determine which elements were limiting coffee growth on this soil by omitting each in turn from an otherwise complete fertilizer mixture.

Treatments were—

- Complete fertilizer, containing N, P, K, Ca, Mg, S, Cu, Zn, Fe, Mo, Mn, B (Ca as $Ca(OH)_2$).
- Complete fertilizer with Ca as $CaSO_4$.
- Complete fertilizer with additional lime at 16 cwt. per acre.
- Omission plots, each one containing the complete mixture except for the omission of Ca, P, N, K, Mg, Cu, Zn, Mo, Fe or Mn.

Date.—Planted 1956, treatments commenced 1957.

Variety.—Blue Mountain.

Shade.—*Albizzia stipulata.*

Plot size.—Six trees (3 x 2), each plot surrounded by a drain, with a line of untreated guard trees between plots.

Design.—Randomized block, with six replications (twelve of complete fertilizer).

ACA5. *First Series Progeny Testing, Aiyura.*

Progenies from 53 mother trees, selected from mature stands of several varieties, were tested for yield in a search for local selections of better than average productivity.

Selections included 41 from Blue Mountain, four San Ramon, four Arusha, two Mocha, one Maragogipe, and one SL10.

Testing was conducted with four types of planting material—

Cuttings—i.e., clonal material from the mother trees.

Grafts—also clonal. As relatively few grafts were successful, this section was incomplete.

Self-pollinated seedlings—seed produced by bagging unopened flowers on the mother trees.

Open-pollinated seedlings.

Self-pollinated seedlings provide the best assessment of the value of trees as parents, and this group therefore served as standard for comparison of the other three sections of the trial.

Date.—Cuttings planted May, 1957, seedlings April, 1958.

Shade.—*Albizzia stipulata.*

Plot size.—Six trees in a single line.

Design.—Randomized blocks, with four replications. Cuttings, grafts and seedlings in separate trials; the seedling plots split for self-open-pollination.

ACA6. *Multiple-Stem Pruning Observations, Aiyura.*

Six methods of handling multiple-stem trees were tested in observation plots. The techniques used were exploratory and the tests were discontinued in 1961 after three years of observation. Coffee used was five-year-old, Blue Mountain and Arusha, under *Grevillea robusta* shade. Being on forest soil on a hillside, this shade tree grew better here than in ACA1.

ACA7. *High Level Fertilizer Trial, Aiyura.*

Testing the three main fertilizer elements (N, P, K) at two levels, the higher being three times the lower. Application rates of the fertilizers were (cwt. per acre)—

Sulphate of ammonia	$N_1 = 3$, $N_2 = 9$
Superphosphate	$P_1 = 2$, $P_2 = 6$
Potassium chloride	$K_1 = 1$, $K_2 = 3$

The following treatment combinations were applied—

$N_1P_1K_1$ $N_2P_1K_1$ $N_1P_2K_1$ $N_2P_2K_1$

$N_1P_1K_2$ $N_2P_1K_2$ $N_1P_2K_2$ $N_2P_2K_2$

The above eight combinations were all combined with a mixture of minor elements.

$N_2P_2K_2$ with no minor elements.

Nil fertilizer control.

Date.—Commenced in 1958 on five-year-old coffee.

Variety.—Blue Mountain.

Shade.—*Albizzia stipulata.*

Plot size.—Twelve trees (6 x 2) with a guard row receiving the same treatment as plot trees.

Design.—Randomized block with two replications of the factorial treatments and four of the $N_2P_2K_2$ without minors and nil control.

In December, 1964, the K_1 and K_2 levels were increased to 2 cwt. and 4 cwt. per acre respectively, and 'nil fertilizer' was altered to P_1K_1 to give a 'no nitrogen' comparison with $N_1P_1K_1$.

ACA8. *Preliminary Diagnostic Fertilizer Trial, Aiyura.*

This was an exploratory trial applied on two sites where young coffee was stunted and making very poor growth, if any. Treatments were various combinations of the following fertilizers:—

Ammonium sulphate (N); sodium phosphate (P); potassium chloride (K); magnesium sulphate (Mg); lime; and a mixture of minor elements.

Date.—Treatments applied August, 1955; trial concluded 1961.

Shade.—*Albizzia stipulata.*

Plot size.—Three trees unguarded.

Spacing.—Nine feet triangle.

Design.—Half replicate of 2^6, compounding on each of the two sites.

ACA9. *Variety x Spacing x Pruning Trial, Aiyura.*

A comparison of the performance of four promising varieties over a range of spacings and two pruning systems—four varieties (Blue Mountain, Arusha, Bourbon, San Ramon)—

Three spacings for each variety (9 ft. square, 8 ft. x 6 ft. and 8 ft. x 4 ft. 6 in. rectangles for the first three varieties; for San Ramon, the 9 ft. square was replaced by 5 ft. square, as San Ramon is smaller framed).

Two prunings (both multiple-stem, one having its frame developed on a capped seedling base (East African), the other on an arched base (Agobiada)).

Date.—Planted early 1959.

Shade.—*Albizzia stipulata.*

Plot size.—0.12 acres.

Design.—Randomized block with three replications for the variety-spacing treatments; plots split for pruning.

ACA10. *Second Series Progeny Testing, Aiyura.*

A comparison of open-pollinated seedling progenies from 23 mother trees.

Selections from the following varieties:—

Group 1.—Bourbon from Raipinka Lutheran Mission (2), Bourbon from Goroka Agricultural Station (4), Bourbon from Korn Farm Agricultural Station (2).

Group 2.—San Ramon (2), Mocha (2), SL10 (2), SL6 (1).

Group 3.—Blue Mountain (4), Arusha (3).

One Bourbon selection from Group 1 was also included in Groups 2 and 3.

Date.—Planted early 1959.

Shade.—*Albizzia stipulata.*

Plot size.—Nine trees (3 x 3).

Design.—Each group in randomized blocks with four replications.

ACA11. *Single-Stem Pruning Trial, Aiyura.*

A comparison of several forms of single-stem pruning, ranging from relatively light or no pruning to a heavy pruning of the orthodox type.

This trial is described fully elsewhere in this issue.

ACA12. *High Level Fertilizer Trial, without Shade, Aiyura.*

The *Albizzia* shade was removed from a portion of the field in which ACA7 was being conducted and an additional small trial was laid down in 1960 to study the effects of the same fertilizers in the absence of shade.

The site did not permit any replication and results were too variable to be of value, so the trial was concluded at an early date.

ACA13. *East African Variety Trial, Aiyura.*

This was the initial planting of six varieties introduced from Kenya in 1958; two standard varieties were included for comparison. Varieties in the trial were—

Dalle Mixed Green, Ke20, Kents, SL14, SL28, SL34, and local Blue Mountain and Bourbon.

Date.—Planted 1959.

Shade.—*Albizzia stipulata.*

Plot size.—Twenty-five trees (5 x 5).

Design.—Randomized block, with three replications on one site and one on another.

ACA14. *Mulch-Fertilizer Combinations, Aiyura.*

This trial aimed to examine more closely the effects of mulch and fertilizer on coffee yields, following up results of ACA3 and ACA29. ACA14 was laid down on the same site as ACA3 after a two-year period during which mulch was applied over the whole area in order to even out former treatment differences and restore poor plots. During this period the site was modified by the removal of *Albizzia* shade in late 1961 and conversion of the coffee trees from single-stem to multiple-stem pruning by a process of removing old laterals and notching the main stem to induce suckers for new upright growth.

New treatments were—

Clean weeding plus fertilizer (NK); mulching plus fertilizer; mulching without fertilizer; and modified mulching differing for the two spacings (see ACA3): 14 ft. x 5 ft. spacing received a 6 ft. strip of mulch along each row of trees, without fertilizer; 9 ft. spacing received mulch in one year, fertilizer in alternate years.

Date.—Treatments commenced November, 1963.

Design.—Randomized block, four replications. Treatments applied orthogonally on ACA3 treatments and blocks.

ACA15. *'Sea Magic' Foliar Spray Trial, Aiyura.*

To compare the effect on coffee yields of the organic leaf spray 'Sea Magic' and inorganic fertilizer treatments.

This trial is described fully elsewhere in this issue.

ACA16. *Fertilizer Trial, Aiyura.*

An experiment involving 24 combinations of the following fertilizers and rates, on a hillside site with no shade:—

Sulphate of ammonia—nil, 1, 2 and 4 cwt. per acre.

Sulphate of potash—nil, 131 and 262 lb. per acre.

Superphosphate—nil, and 2 cwt. per acre.

The levels of sulphate of potash are equivalent to 1 and 2 cwt. potassium chloride, as used in ACA7. Sulphate of potash was used in order to correct a possible sulphur deficiency. Gypsum was added to plots which did not receive sulphur in the other fertilizer combinations.

Date.—Coffee was planted in 1955 and treatments applied in March, 1962.

Shade.—Original *Albizzia stipulata* and *Casuarina* shade was cut out in late 1961.

Variety.—Blue Mountain.

Pruning.—Single-stem.

Plot size.—Thirty-two trees (8 x 4) with treated guard row.

Design.—4 x 3 x 2 factorial, two replications.

ACA17. *Pruning Trial, Aiyura.*

A trial designed to test various systems of pruning coffee grown in hedge rows, a feature being that in some treatments a complete row of coffee is to be stumped each year instead of single uprights on each tree as in conventional multiple-stem pruning.

1. Three seedlings planted in each hole. Not capped or topped. One plant to be stumped each two years making a six-year cycle.

2. Single seedlings, not capped or topped. One row to be stumped each year, on a five-year cycle.

3. Seedlings capped in the nursery at 18 in. to carry four leaders each, not topped. One row stumped each year in a five-year cycle.

4. Seedlings capped, four leaders, topped at 6 ft. One row to be stumped each year, in a five-year cycle.

5. Seedlings capped, five leaders. One leader on each tree to be cut each year, on a five-year cycle.

6. Seedlings arched to Agobiada system, five leaders. One leader cut each year, on a five-year cycle.

7. Seedlings not capped, topped at 6 ft. To be handled initially as single-stem, later converted to multiple-stem. The only pruning in the single-stem stage to be desuckering.

8. Seedlings not capped. Alternate seedlings in each row—

(*a*) Arched to Agobiada, four leaders.

(*b*) Topped at 6 ft. for single-stem.

Single-stem bushes to be cut out when overcrowding becomes evident.

Date.—Planted 1963.

Variety.—Bourbon.

Shade.—*Crotalaria* temporary shade removed 1965, no permanent shade.

Spacing.—9 ft. x 4 ft. 6 in.

Plot size.—One hundred trees (five rows of 20).

Design.—Randomized block, six replications.

ACA18. *Variety Trial, Goroka.*

Test of six varieties under Goroka conditions—
Varieties : Blue Mountain, Arusha, Mocha, San Ramon Tall, San Ramon Dwarf, Hawaiian Kona.

Date.—Planted 1956.

Spacing.—Nine feet triangle.

Shade.—*Albizzia stipulata.*

Plot size.—Twenty-eight trees.

Design.—Randomized block, two replications.

ACA19. *Shade x Pruning Trial, Goroka.*

A much simplified version of ACA1, for Goroka conditions—

Five shades (nil, *Albizzia stipulata*, *A. fulva*—a local species, *Grevillea robusta*, *Casuarina*—a local species).

Two pruning systems (single-stem and multiple-stem).

Date.—Planted March, 1955.

Variety.—Blue Mountain.

Spacing.—Nine feet triangle.

Plot size.—One hundred and twenty-eight trees.

Design.—Shade plots split for pruning ; no replication.

ACA20. *Spacing x Pruning Trial, Goroka.*

A study of spacing and pruning effects under Goroka conditions—

Four spacings (7 ft., 8 ft. and 9 ft. triangle, 12 ft. x 6 ft. rectangle).

Two pruning systems (single-stem and multiple-stem).

Date.—Planted 1956.

Variety.—Bourbon.

Shade.—*Albizzia stipulata.*

Plot size.—About 0.04 acres.

Design.—Spacing plots split for pruning, two replications.

By 1962 it was considered that the multiple-stem pruning had fully established its superiority, and the single-stem bushes were stumped for conversion to the more easily managed multiple-stem system.

ACA21. *High Level Fertilizer Trial, Goroka.*

A similar trial to ACA7 at Aiyura, with identical treatments.

Date.—Planted 1955.

Variety.—Blue Mountain.

Spacing.—Nine feet triangle.

Pruning.—Multiple-stem.

Shade.—*Albizzia stipulata.*

Plot size.—As ACA7.

Design.—As ACA7.

ACA22. *Shade x Pruning Trial, Korn Farm.*

A similar trial to ACA19, but including more shade species—

Eight shades (nil, *Albizzia stipulata*, *Casuarina*—local species, *Grevillea robusta*, *Leucaena leucocephala*, *Piptadenia*—local species, *Gliricidia* sp., *Peltophorum* sp.).

Two pruning systems (single-stem and multiple-stem).

Date.—Planted March, 1956.

Variety.—Blue Mountain.

Spacing.—Nine feet triangle.

Plot size.—One hundred and sixteen trees (0.19 acres).

Design.—Shade plot split for pruning, no replication.

ACA23. *Variety x Spacing Trial, Korn Farm.*

A variety trial for local conditions.

Varieties.—Blue Mountain, Arusha, Mocha, Bourbon, San Ramon.

Spacings.—Seven feet and nine feet triangle.

Date.—Planted March, 1956.

Shade.—*Albizzia stipulata.*

Pruning.—Single-stem.

Plot size.—About 0.1 acre.

Design.—Spacings split for varieties, two replications.

ACA24. *Spacing x Cover x Pruning Trial, Korn Farm.*

Similar trial to ACA3 at Aiyura, but including also a comparison of single-stem and multiple-stem prunings.

Date.—Planted 1956, concluded 1961.

Results have been published (Schindler and Fraser 1964).

ACA25. *High Level Fertilizer Trial, Korn Farm.*

A similar trial to ACA7 at Aiyura and ACA21 at Goroka, but with three levels of potassium chloride (1, 3 and 5 cwt. per acre). Rates of sulphate of ammonia and superphosphate the same as ACA7.

Date.—Planted 1955.

Variety.—Blue Mountain.

Shade.—Nil.

Pruning.—Multiple-stem.

Spacing.—Nine feet triangle.

Plot size and design.—As in ACA7, but with three levels K in factorial treatments.

ACA26. *East African Introductions, Korn Farm.*

Small unreplicated plots of the following varieties, planted for observation :—

Planted April, 1959 : Dalle Mixed Green, Ke20, Kents, SL14, SL28, SL34.

Planted March, 1960 : SL6, SL10.

The site proved unsuitable for uniform growth and material was not sufficient for valid comparisons.

ACA27. *Pruning Observation Rows, Korn Farm.*

Several exploratory methods of handling multiple-stem coffee were tried on a bulk area of Blue Mountain coffee. Techniques tried to induce suckers for replacement uprights included bruising, deliberately breaking an upright at its base, and cutting roots on one side of a tree and pushing it into a leaning position.

Date.—Treatments commenced March, 1960, concluded in 1964.

ACA28. *Nitrogen x Sulphur Fertilizer Trial, Aiyura.*

Following indications of response to sulphur in earlier trials, in which sulphur had been included in such fertilizers as sulphate of ammonia but had not been specifically studied in its own right, this small new trial was laid down on a plot of rather poor coffee. All plots were given a basal dressing of muriate of potash to ensure that potassium nutrition was not limiting.

Treatments.—No fertilizer ; nitrogen (as urea, 156 lb. per acre) ; sulphur (as gypsum, 346 lb. per acre) ; nitrogen plus sulphur (same rates).

Date.—Planted 1954, treatments applied 1962.

Variety.—Blue Mountain.

Shade.—*Albizzia stipulata.*

Spacing.—Nine feet triangle.

Plot size.—Fifteen trees (5 x 3), with a single unfertilized guard row common to adjacent plots.

Design.—Randomized block, six replications.

ACA29. *Mulch-Fertilizer Combinations, Aiyura.*

When, in ACA1, *Grevillea robusta* failed to provide uniform shade and as unshaded coffee yielded well, the *Grevillea* was removed and the plots were used for a study of two pairs of mulch and fertilizer combinations. At the same time, fertilizing was commenced on the remaining plots of ACA1, so the 'no shade' plots of ACA1 provide some comparison of yields from fertilized unmulched plots.

Treatments—

On pit-pit soil : No mulch, no fertilizer compared with mulch, no fertilizer.

On hillside soil : Mulch, no fertilizer compared with mulch, plus fertilizer.

Elephant grass (*Pennisetum purpureum*) was used for mulch, spread to a depth of about 6 in., in October to November each year (i.e., end of dry season). Fertilizer (potassium sulphate 2 cwt. per acre and urea 1 cwt. per acre) was applied split into two equal doses per year. Rate of potassium sulphate was increased to 3 cwt. per acre in 1964.

Date.—Planting details as ACA1, mulch treatments commenced November, 1961.

Differential treatments were discontinued on the pit-pit site in 1964, when it became obvious that coffee was dying in the no mulch, no fertilizer plots.

ACA31. *Processing Trial, Aiyura.*

Studies of the effects on quality and final weight of processed coffee of various methods of processing and drying.

ACA32. *Potash Frequency of Application Trial, Aiyura.*

Studying the effect of different frequencies of application of potassium fertilizer to coffee growing on potassium deficient soil. The trial also includes a comparison of two methods of conversion of single-stem trees to multiple-stem pruning.

The site had been used previously for ACA11 and ACA15. These were both concluded in 1964 and the whole area was uniformly fertilized for a period to even out any effects remaining from former treatments.

Pruning conversion.—A comparison of stumping the old tree 18 in. above ground, bringing away five new leaders ; with removal of all laterals on one side of the bush and notching the main stem deeply at a height of 18 in., followed by progressive removal of remaining laterals and the main stem over two years and bringing away five replacement suckers.

Fertilizer frequency.—Application of the same annual total in split applications at intervals of 1, 3, 6 or 12 months.

Fertilizer rates.—Potassium sulphate at 2 cwt. and 4 cwt. per acre per year. In addition a basal dressing of urea at 1 cwt. per acre is applied to all plots in two half-yearly applications.

Date.—Pruning conversions commenced November, 1964, and fertilizer treatments commenced in July, 1965.

Variety.—Blue Mountain.

Shade.—*Albizzia stipulata.*

Spacing.—Nine feet triangle.

Plot size.—Frequency sub-plots of 40 trees (8 x 5) surrounded by a guard row receiving the same treatment.

Design.—Pruning plots split for rate, rates split for frequency ; three replications.

ACA33. *Variety Trial, Aiyura.*

A new trial, planned for planting out in early 1967, which will test recent coffee introductions, including varieties resistant to some races of leaf rust and the more promising selections from progeny testing trials

ACA5 and ACA10. There will be a total of 42 varieties, as follows :—

(*a*) East African varieties from ACA13—6.
(*b*) Selections from ACA5—8.
(*c*) Selections from ACA10—5.
(*d*) Rust Resistant introductions—
1961 planting—7.
1963 planting—14.
(*e*) Controls—bulk Arusha and bulk Bourbon.

Shade.—Temporary *Crotalaria* shade for establishment, no permanent shade.

Spacing.—9 ft. x 4 ft. 6 in.

Plot size.—Fifteen trees (5 x 3).

Design.—6 x 7 rectangular lattice, with six replications.

ACA34. ***Variety Trial, Goroka.***

A trial similar to, but simpler than, ACA33, to test similar varieties in a different location. The 30 varieties to be used will include a smaller number of varieties from each of the groups listed under ACA33.

Design.—5 x 6 rectangular lattice with three replications.

Other details not yet finalized, but plot size will be larger than in ACA33 so as to give about equal total quantities of each variety.

ACA35. ***Variety Trial, Korn Farm.***

A repetition of ACA34 at a different site.

VARIETY TRIALS.

A number of introductions have been made of high yielding Arabica varieties from other countries and any which showed promise have been included in varietal yield trials. The following are some notes on the origins of the main varieties which have been grown :—

Blue Mountain.—Introduced to Wau from Jamaica ; brought to Aiyura from Wau in 1937.

Bourbon.—Brought to the Territory pre-war by the Lutheran Mission, and planted at Aiyura in 1956.

San Ramon ; Maragogipe.—Introduced from East Africa pre-war.

Mocha, Arusha (selection "D.R."), *SL*6 (selection from Kents), *SL*10 (selection from Harar).—Introduced from East Africa in 1950.

Hawaiian Kona.—Introduced from Hawaii in 1956.

Dalle Mixed Green, *Ke*20, *Kents*, *SL*14, *SL*28, *SL*34.—Introduced from Kenya in 1958.

Since 1960, a further 30 varieties carrying resistance to various strains of coffee leaf rust (*Hemileia vastatrix*) have been introduced from the United States Department of Agriculture, Beltsville, Maryland, and from Centro de Investigacao das Ferrugens de Caffeiro, Oeiras, Portugal.

The main series of variety trials (ACA2, 9, 18 and 23) included the varieties Blue Mountain, Arusha, Mocha, Bourbon and San Ramon. Results are summarized in *Table* 1 ; yields have been converted from the cherry weight actually recorded to dry coffee equivalent, on the basis of conversion factors established at Aiyura.

Precision has been low. Although ranking of the varieties has not been the same in all localities it is uncertain whether this indicates differences in adaptability to different environments. Varieties Arusha, Mocha and Bourbon have all performed better than Blue Mountain which was previously the most widely used variety in the Territory. San Ramon generally performed poorly, although in ACA9 it produced high yields at 5 ft. x 5 ft. spacing. San Ramon was very mixed, ranging from dwarf to fairly normal plants, and selection may produce a more satisfactory variety.

Other varieties have not yet been fully tested. In ACA13, results have been so variable that differences in yield between varieties have not been statistically signficant. All varieties in this trial appear to compare quite well with Blue Mountain, but further testing will be undertaken (ACA33). Hawaiian Kona did not perform well in ACA18.

SPACING OF VARIETIES.

As varieties differ in vegetative vigour, it could be anticipated that they might differ in their performance at different spacings. Accordingly, most variety trials included two or more spacings. Results have been inconclusive because of low precision. In no trial has any interaction between varieties and spacings been statistically significant, nor has there been any consistency between trials ; for example, in ACA2, Arusha and Mocha were the only two varieties to yield more at 9 ft. spacing than at 7 ft. 6 in. in their early years, whereas in ACA23 these same varieties were the only ones to yield more at 7 ft. than at 9 ft. In view of such inconsistency it appears that the varieties involved probably do not differ much in the spacing required for maximum yield or that any such differences are minor in respect to other factors affecting yield.

Trial ACA9 was laid out with the initial assumption that the variety San Ramon, a semi-dwarf type, would benefit from closer spacing than the other varieties, and it was therefore planted over a different range of spacings. Within the two spacings common to all varieties, San Ramon and Arusha show a greater advantage

Table 1.—Yields of five coffee varieties in five field trails.

—		Blue Mountain.	Arusha.	Mocha.	Bourbon	San Ramon.
ACA2 (Aiyura)						
Average	lb. cherry per acre	9,357	11,585	11,796	12,228	8,921
Yield	lb. dry coffee per acre	1,460	1,552	1,675	1,736	1,204
1960-61 to	Yield (dry coffee) as per					
1965-66	cent. of Blue Mountain	100	106	115	119	82
ACA18 (Goroka)						Tall Dwarf
Average	lb. cherry per acre	6,543	8,654	7,193	9,483*	4,988 3,256
Yield	lb. dry coffee per acre	1,034	1,186	1,043	1,403*	728 475
1959-60 to	Yield (dry coffee) as per					
1964-65	cent. of Blue Mountain	100	115	101	136*	70 46
ACA23 (Korn Farm)						
Average	lb. cherry per acre	6,780	8,972	9,255	6,519	4,731
Yield	lb. dry coffee per acre	1,071	1,229	1,342	965	691
1961-62 to	Yield (dry coffee) as per					
1964-1965	cent. of Blue Mountain	100	115	125	90	65
ACA13 (Aiyura)						
Average	lb. cherry per acre	7,044	....	....	8,752	....
Yield	lb. dry coffee per acre	1,078	....	....	1,365	....
1962-63 to	Yield (dry coffee) as per					
1965-66	cent. of Blue Mountain	100	....	....	127	....
ACA9 (Aiyura)	(8' x 6' and 8' x 4½')					
Average	lb. cherry per acre	10,529	15,532	....	12,789	9,355
Yield	lb. dry coffee per acre	1,779	2,252	....	2,008	1,516
1961-62 to	Yield (dry coffee) as per					
1965-66	cent. of Blue Mountain	100	127	....	113	85
ACA9 (Aiyura)	(all spacings)					
Average	lb. cherry per acre	8,937	13,866	....	11,710	10,837
Yield	lb. dry coffee per acre	1,510	2,011	....	1,838	1,756
1961-62 to	Yield (dry coffee) as per					
1965-66	cent. of Blue Mountain	100	133	....	122	116

* Bourbon was not included in ACA18, but yield from ACA20 alongside is shown here.

at the closer spacing than Blue Mountain and Bourbon, but the difference between the varieties in this respect does not approach statistical significance. These trees are still fairly young and something more definite may emerge as the trees grow older.

SELECTION WORK.

Progenies of individual high-yielding trees of various varieties have been tested in two trials, ACA5 and ACA10. Certain progenies appear to be superior and will be further tested in a new trial, ACA33.

Trial ACA5 studied several aspects of selection and progeny testing work. It included 36 progenies of Blue Mountain selections and also unselected Blue Mountain seedlings. Average yield of the progenies of selections was no higher than the yield of unselected seedlings, indicating that bulk selection of apparently superior trees for seed parents is probably quite ineffective for improving yield. The trial also included comparison of the selections as clones multiplied by cuttings. There was very little correlation between the relative performance of clones and progenies, and it would appear that clone testing would not be an effective method of selecting superior parents. A further comparison was made between self-pollinated and open-pollinated progenies of the selected parents, the main interest being in whether open-pollinated progenies would rank in the same order of yield as self-pollinated progenies. Results indicated that the ranking was the same and that progeny tests based on open-pollinated seed should be as reliable as tests using self-pollinated seed.

SPACING.

Several trials (ACA1, 2, 3, 9, 17, 20, 23 and 24) have studied spacing effects. Most trials have compared planting densities within the range 600 to 1,000 trees per acre, mostly on equilateral triangle or square patterns, but some rectangular (or hedge) patterns have been used.

Results have not been entirely consistent, but within the range 7 ft. to 9 ft. triangle yields have generally been higher at the closer spacing. However, at 7 ft. spacing trees become so overcrowded as they age that they impede harvesting and for triangle planting nothing closer than 8 ft. could be recommended. There has been a trend in some trials, especially in ACA9, for the initial advantage of the closer spacing to be reduced as the trees grow older. This is what would be expected, and there appears to be a good case for close initial planting to give early high yield, with subsequent thinning for ease of access, or hedge planting which may or may not need thinning for maintenance of yields. This will be studied in ACA17 which has been planted at 9ft. x $4\frac{1}{2}$ ft. spacing.

In two trials (ACA3, 20) hedge spacings with wide gaps between rows (14 ft. in ACA3, 12 ft. in ACA20) have not yielded well in comparison with triangular spacing.

SHADE.

Although coffee is grown without shade in some parts of the world, use of shade is almost universal in Papua and New Guinea. Practical experience has shown in some cases that coffee without shade, or from which shade has been removed, has produced very high yields for a few years, but subsequently has shown extensive die-back and in some cases death of trees.

Trials at Aiyura, Goroka and Korn Farm (ACA1, 19 and 22) have compared different shade tree species and have also included nil shade. The unshaded coffee at Goroka has generally yielded poorly and trees have shown pronounced biennial bearing and scorching of the cherries. At Korn Farm, the trial has given inconsistent yield results, but by 1966 the unshaded coffee was very unhealthy in comparison with well shaded plots. At Aiyura, unshaded coffee was slower to commence bearing, but subsequently it has consistently out-yielded shaded coffee. However, it must be noted that this coffee has been fertilized and the trials clearly show that the shade requirements of coffee in the Territory cannot be considered apart from nutrition. At Aiyura, in ACA1, *Grevillea robusta* was originally included as a shade tree, but grew very poorly and the trees were removed in late 1961. These plots then received treatments to study the effects of elephant grass mulch (ACA29) and at the same time regular fertilizing was commenced on all other plots in ACA1. Some trees in the former *Grevillea* plots received no mulch or fertilizer and although yields continued fairly high, in 1963 most trees were completely defoliated and about 15 per cent. dead. Subsequently, mulch and fertilizer were applied in an effort to save the surviving trees and by 1966 they were showing a good recovery. At Korn Farm, although unfertilized trees in the shade trial looked very unhealthy, fertilized trees in ACA25, which has no shade, remained very healthy and productive.

Maintenance costs are probably substantially higher for unshaded coffee, because of greatly increased weed growth. Any overhead shade substantially reduces weed growth while *Casuarina* in ACA1 and *Grevillea* in ACA22 have formed a mulch of leaf on the soil which has almost completely suppressed weeds. The extra cost in weeding unshaded coffee would be only partially offset by savings in establishment and maintenance of shade trees.

In addition to extra maintenance costs, sunburning of cherries probably lowers the quality of coffee produced. This aspect is under study.

Conclusions from this work are still only tentative, but are as follows :—

(1) Growth of coffee without shade in any New Guinea area is somewhat risky, but under conditions of good rainfall (80 in. per year or more) and no severe dry season it could be expected that trees will survive and produce very high yields provided they are mulched or fertilized heavily enough. At Aiyura, over seven years' bearing unshaded coffee out-yielded coffee under *Casuarina* by an average of 600 lb. of dry coffee per acre per annum, worth about $200 at a price of $800 per

ton. With a gross return of this magnitude it is probable that extra costs of maintenance and of higher levels of fertilizing required would be amply reimbursed.

(2) Shade removal could not be recommended for areas experiencing a more severe dry season, or for shallow soils or hillside sites subject to drought.

(3) In any area, temporary shade is necessary for establishment.

Shade Species.—Results have shown that choice of shade tree species must be based on local conditions. *Albizzia stipulata* and the indigenous *Casuarina* are the most generally satisfactory, but *Casuarina* tends to fail at an early age on some soils and *Albizzia* grows so large that shade control is difficult. Silky oak (*Grevillea robusta*) has made excellent growth at Korn Farm but rather poor at Goroka. At Aiyura it failed completely on a shallow hillside soil and grew only moderately on a pit-pit area, but was quite reasonable on a forest clearing at a slightly higher altitude. *Leucaena* is satisfactory at Wau and seems to be fairly satisfactory on several properties near Goroka and Minj, and in a small plot at Aiyura, but at Korn Farm it has been quite unsatisfactory. No general recommendation can be made ; planters should be guided by local experience.

PRUNING.

Comparisons between single-stem and multiple-stem pruning have been made in five trials (ACA1 (two sites), 19, 20 and 22). Two have shown a yield advantage for multiple-stem, one for single-stem, and two have proved variable (*Figure* 1). The general conclusion is that neither system is in itself superior as regards yield, but multiple-stem pruning is cheaper in application and therefore probably preferable.

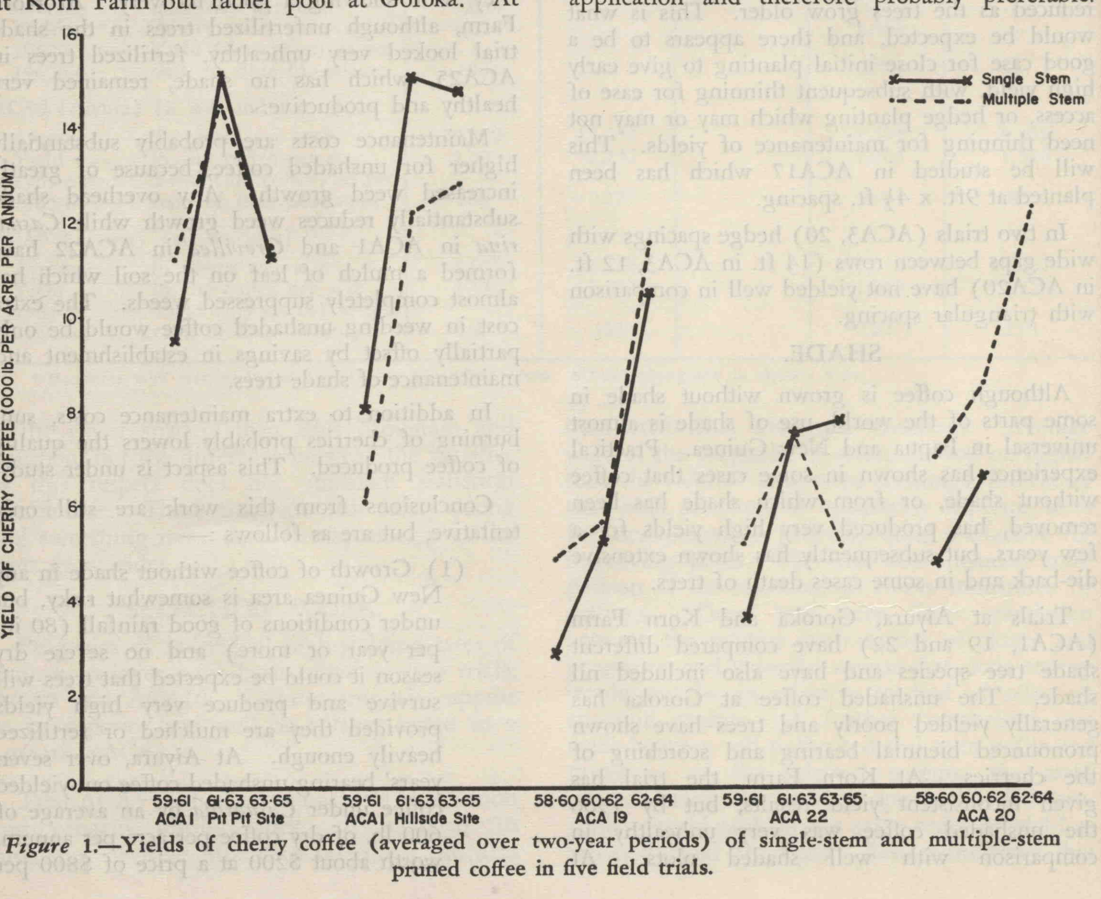

Figure 1.—Yields of cherry coffee (averaged over two-year periods) of single-stem and multiple-stem pruned coffee in five field trials.

This statement however, may be true only of a fairly intensive system of single-stem pruning and results of ACA11 (see paper " Single-Stem Pruning in Arabica Coffee " by R. S. Carne in this issue) indicate that virtually unpruned single-stem trees gave as good yields as more intensively pruned trees over the duration of the trial. Later results may have changed this picture, since unpruned single-stem trees could be expected to decline in yield through excess vegetative growth at the expense of bearing wood. It could nevertheless prove economic on a long-term system to allow trees to grow to a single-stem with little pruning, but later convert to multiple-stem pruning. A comparison is being made in ACA32 of two methods of conversion, and this will give a measure of how much crop is lost in the process.

Pruning for maximum yield is undoubtedly an art, and ideally each tree should be treated individually according to its growth. Under plantation conditions, with pruning performed by relatively unskilled personnel, this is almost impossible. In some of the experiments reported here, multiple-stem pruning has been at a disadvantage because pruning has been applied uniformly throughout a trial and some areas of poorer growth have suffered from pruning too early. This was the probable reason for the poorer performance of multiple-stem plots on the hillside site of ACA1 than on the pit-pit site.

Trial ACA9 compares two systems of multiple-stem pruning, the arch or 'Agobiada' system and the East African system of capping in the nursery to bring away three or four leaders. The East African system gave higher yield initially but subsequently Agobiada made up the difference and yields have been about equal over the course of the trial. Agobiada has proved easier to manage in later years as new leaders come away more readily. In contrast to the ACA9 result, in ACA17 Agobiada is giving better early yield than East African, because the nursery capped seedlings fared very badly after transplanting under unfavourable weather conditions.

Experience at Aiyura has shown weaknesses in most standard pruning methods, and trial ACA17 has been designed to study alternative systems. A problem in multiple-stem systems has been that, on well grown plants, new leaders tend to be long and spindly because of the amount of foliage surrounding them ; sometimes replacement leaders fail to come away at all. In ACA17 methods aiming to overcome this problem include annual stumping of one complete row in five (in contrast to one stem in five on each row) and planting three seedlings per point to be stumped one at a time, with the idea that leaders are more likely to be stimulated when a complete bush is cut back. Another weakness of standard pruning systems is that any pruning before bearing will delay production ; quickest yields are obtained if seedlings are allowed to grow unhindered to a single-stem unpruned tree, although subsequently such a tree may prove unmanageable. In ACA17, various approaches are made aiming to obtain the early yield of an unpruned tree with provision for some subsequent conversion to a more manageable system ; these include the two mentioned above and also a compromise system where alternate trees will be (*a*) pruned to Agobiada and (*b*) left unpruned except for capping at 6 ft., with the unpruned seedlings to be removed entirely when the stand becomes overcrowded. All treatments are planted at 9 ft. x 4 ft. 6 in. spacing. It will be several years before results can be evaluated.

SHADE, SPACING AND PRUNING INTERACTIONS.

Trial ACA1 is a large scale trial to determine whether shade, spacing and pruning treatments interact with each other—that is, whether optimum spacing differs under different shade treatments or pruning systems, etc. It also includes a comparison between two sites at Aiyura, differing in soil type and drainage characteristics.

Figure 2 shows yields for spacings within pruning within shades for the two year periods 1959-1960 to 1960-1961 and 1961-1962 to 1962-1963, and the three year period 1963-1964 to 1965-1966. These graphs illustrate the main treatment effects as well as their interactions.

In general, interactions between the three factors have been fairly small and barely significant statistically. There is some indication that treatments only began to interact as the trees grew older, but this has not been entirely consistent. The most probable explanation for the interactions is that, as the trees reach a size where they compete, yield is largely determined by crowding of the stand and competition for

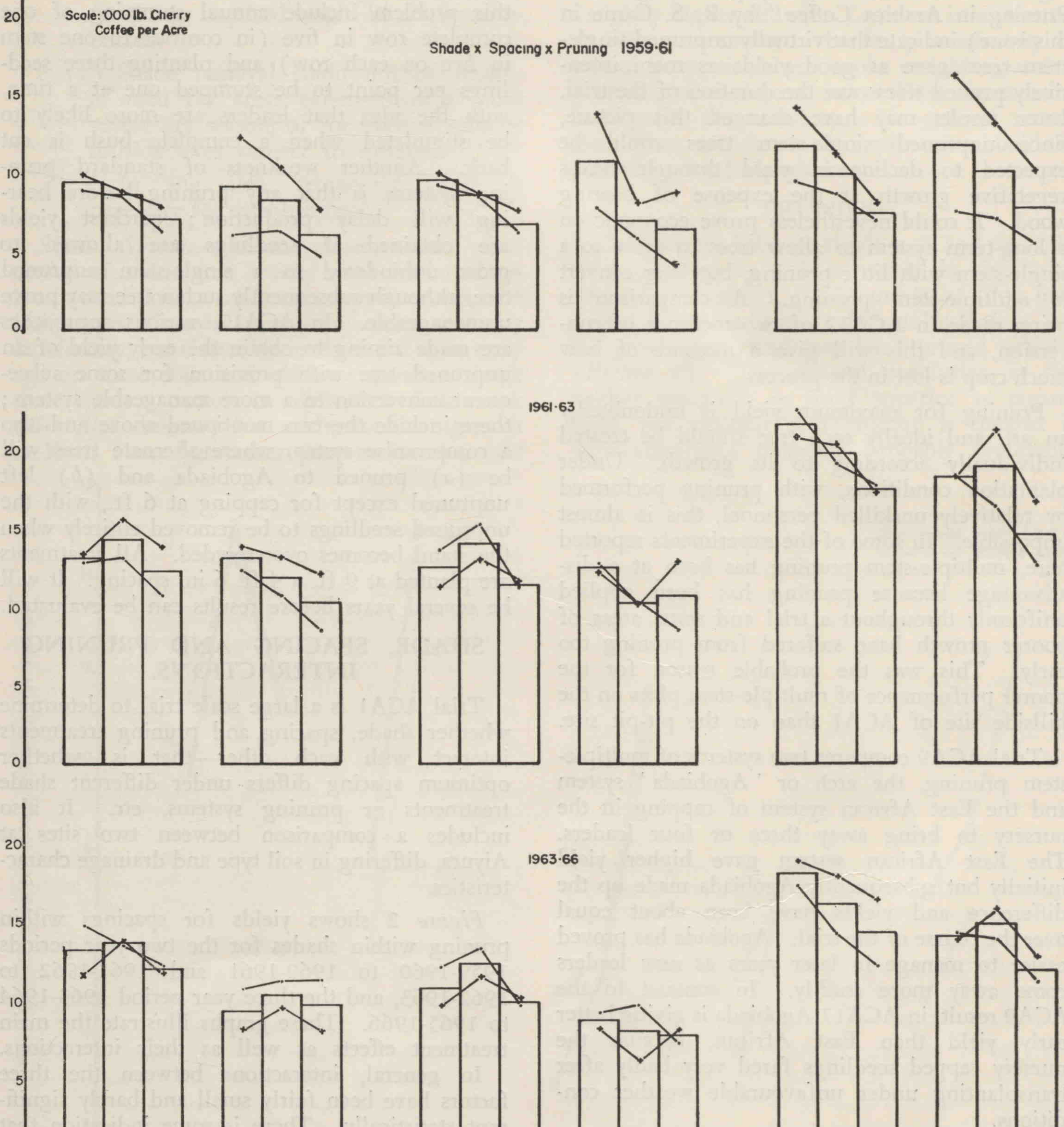

Figure 2.—Yields of cherry coffee in ACA1 Shade x Spacing x Pruning Trial at Aiyura. The histograms show averages over the two sites, while points marked by + and . and connected by continuous lines are average for the pit-pit site and the hillside site respectively.

available light. The effect of spacing on crowding is obvious ; as the trees age, closer spacings become crowded and the initial yield advantage is lost. Multiple-stem pruning can produce a more spreading tree and increase crowding, but the pattern of removal of old stems and replacement with new ones results in variation in size of bushes, hence little consistency in the spacing-pruning interaction. Crowding effects would be accentuated under shade, either because of there being less light available for fruit production or because branches grow longer and leaves larger under reduced light conditions. This would explain why the advantage of closer spacing has been maintained longer under nil shade than under the two tree species. Over the three years 1963-1964 to 1965-1966, consistently higher yield of 7 ft. over 8 ft. and 8 ft. over 9 ft. was maintained only in the single-stem plots of the no shade treatments ; this accords with the explanation given above, as these plots would be least crowded and have most light available for fruit production.

Highest yields have thus been obtained from 7 ft. triangle unshaded, single-stem coffee—the average over the seven years in which this trial has been bearing has been almost 3,000 lb. dry coffee per acre. The highest yield from multiple-stem pruned plots has come from 8 ft. spacing ; over both sites, this yield has been more than 400 lb. lower than from 7 ft. single-stem, but on the pit-pit site the difference amounted to only 200 lb. per acre per year (as has been noted above, multiple-stem has performed rather poorly on the hillside site probably because first pruning was carried out before trees were large enough). Since it could prove more difficult to maintain high yields in later years on the single-stem plots and because of the higher pruning costs, 8 ft. spacing with multiple-stem pruning may prove as economic in the long term.

FERTILIZING.

Several fertilizer trials have been conducted at Aiyura, Goroka and Korn Farm. These will be reviewed only briefly as coffee nutrition is discussed fully in other papers in this Journal. Development of analytical techniques would render some of the exploratory trials unnecessary now, but there is no alternative to a field trial for determining the magnitude of fertilizer response.

The magnitude of yield response depends on soil type and climatic conditions as well as on controllable factors such as variety, management practices and frequency and rate of fertilizer application. The potential for fertilizer response is illustrated by ACA7 where soils are deficient in potassium but other factors (management, climate) are favourable. The response to fertilizer (that is, the difference in yield between fertilized and unfertilized plots) over a period of six years has averaged 7,000 lb. of cherry (more than 1,000 lb. of processed coffee) per acre per annum. Foliar analysis results and trends in yields in the trial itself indicated that even larger response may have been obtained with heavier fertilizing.

On the other hand, at Goroka, where soils are more fertile and where trial ACA21 has shown very little fertilizer response, yields have been substantially lower than in fertilized plots at Aiyura. The difference is probably a result of less favourable rainfall distribution and excessive shade on the trial plot over much of the period. At Korn Farm, in trial ACA25, fertilizer responses have been substantial, averaging 5,000 lb. of cherry (750 lb. of processed coffee) per acre per year over six years, but yields of the best fertilized plots have been substantially lower than those of the best fertilized plots at Aiyura. Again there must be some other factor limiting yield.

It follows, therefore, that although it is often possible on the basis of foliar analysis or some other technique to predict that yields of a block of coffee could be improved by fertilizing, the amount of increase to be expected cannot be predicted with confidence as many other factors are involved.

Another point worth mentioning is that yields and tree vigour may be adversely affected by factors which cannot be ameliorated by fertilizing. Soil moisture is an obvious factor ; at Aiyura, several patches occur where the soil is kept excessively wet through seepage and trees have grown poorly or have died despite all efforts at drainage and fertilizing. In ACA16, by contrast, large numbers of trees died in 1964 and fertilizers did not prevent the deaths ; this was probably a result of drought on shallow soil with no shade protection. In ACA1, the coffee on the pit-pit area has shown very marked biennial bearing whereas coffee on the hillside has not shown any such fluctuating yield. In ACA7, one replicate is planted on pit-pit soil and the other on grassland soil immediately adjacent. Biennial bearing has been extremely pronounced on the pit-pit soil and far less marked on the grassland soil, but the best fertilizer plots have shown as much year to year fluctuation as unfertilized plots.

MULCHING.

Results of initial mulching trials at Aiyura (ACA3) and Korn Farm (ACA24) have already been published (Schindler and Fraser 1964). These trials showed major yield response with mulching, but costs were high and an economic return was not completely assured.

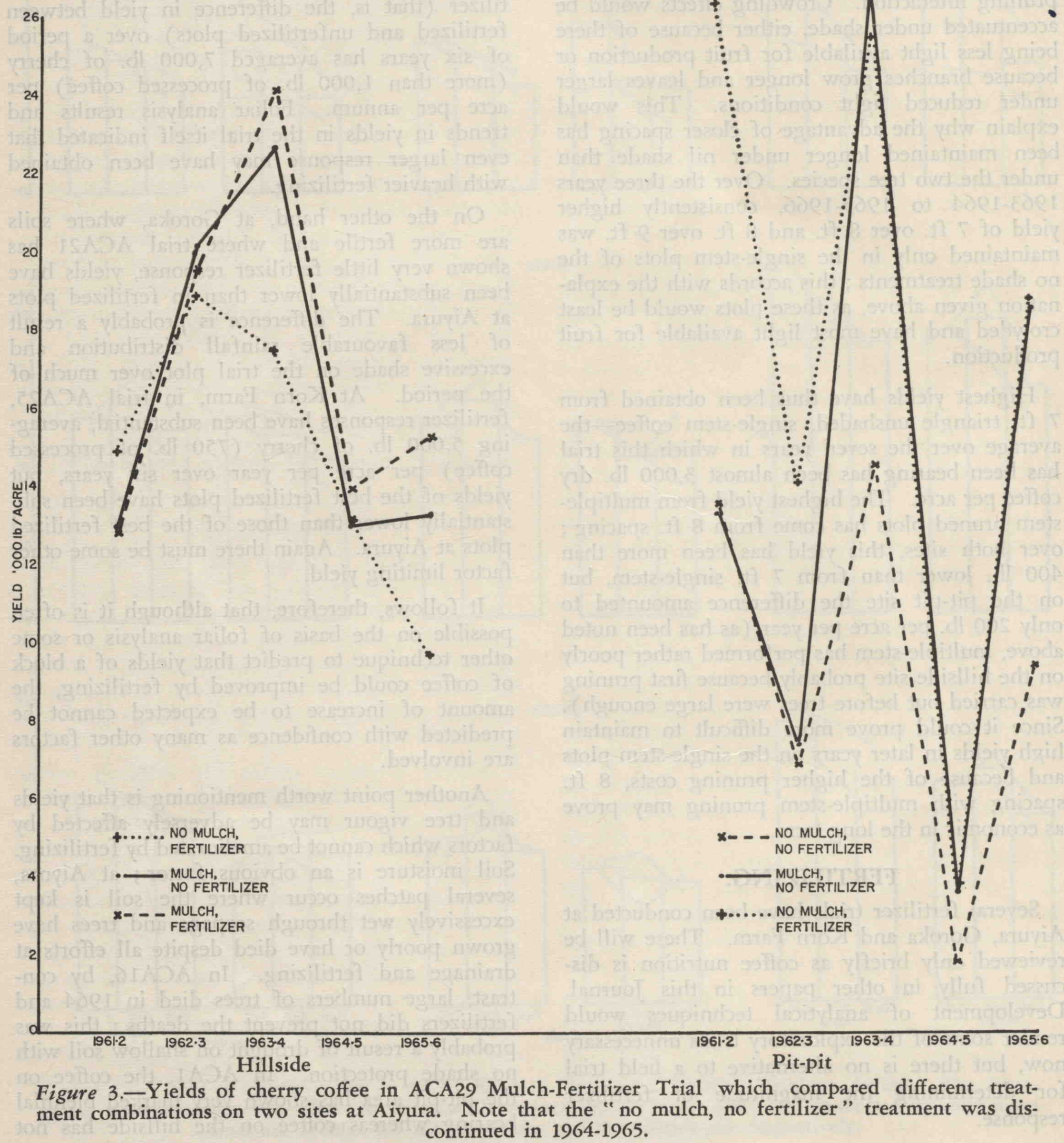

Figure 3.—Yields of cherry coffee in ACA29 Mulch-Fertilizer Trial which compared different treatment combinations on two sites at Aiyura. Note that the " no mulch, no fertilizer " treatment was discontinued in 1964-1965.

Further observations on mulch effects have been made in trial ACA29, superimposed on the former *Grevillea* plots of ACA1. This compared mulch versus no mulch, without fertilizer, on the pit-pit site ; and mulch with and without fertilizer on the hillside site. In both cases comparison was possible with the unmulched, fertilized no-shade plots of ACA1 (*Figure* 3).

On the pit-pit site, before mulching yields of the ACA29 plots were much lower than yields of the ACA1 no-shade plots. Mulching restored yields to a level similar to the no-shade plots (now receiving fertilizer). The unmulched ACA29 plots deteriorated. In 1964, defoliation occurred on all plots but most severely on the unmulched unfertilized plots, and many trees died. A count in June, 1964, showed 14.8 per cent misses in unmulched plots, compared with 2.5 per cent. in mulched plots. Subsequently, all these ACA29 plots were mulched and fertilized as a restorative measure. Yields were still low in 1965-1966 but the trees looked fairly healthy by June, 1966.

On the hillside soil, yields of mulched plots (both with and without fertilizer) rose above those of the unmulched, fertilized ACA1 no-shade plots and have continued substantially higher. There has been an indication of additional benefit where fertilizer was applied with the mulch, but this has not been statistically significant.

Effects of mulching are being studied further in trial ACA14. This should provide a more accurate comparison of the relative value of mulch and fertilizer and it includes also a comparison of combinations of mulching with fertilizing which will be less expensive than mulching alone.

EXPERIMENTAL METHODS.

Precision has been low in all trials, as a result of extreme variability in vigour and yield between plots. This situation at Aiyura could possibly have been ameliorated to some extent by a higher level of fertilizing to ensure adequate nutrition (except, of course, in fertilizer trials) but, as indicated in the discussion on fertilizing, factors other than nutrition were almost certainly involved in the variability, and many of them were uncontrollable.

This indicates that block size should be kept as small as possible (consistent with considerations of inter-plot competition and guarding requirements) and treatments should be replicated as many times as possible. Where large numbers of varieties or selections are to be compared, incomplete block designs should be used.

Where a trial is laid down on established coffee, use of girth x height of the trees as a co-variate in analysis of subsequent yields has substantially improved precision. Yield over periods of a year or less has not proved a useful co-variate.

None of the Aiyura trials has yet run long enough to establish long-term results, but indications from data so far are that, in trials where ageing of the bushes is not likely to affect comparisons (for example, variety trials as opposed to spacing or fertilizer trials), the order of merit of treatments shown in the first three to four years' bearing is not likely to change much in later years. This means that fairly firm conclusions may be drawn after a few years' recording in trials of this type. To some extent a corollary of the above, in trials where treatment differences are not statistically significant in yields from a two-year period because of high variability within treatments, it is unlikely that continued recording over a longer period will appreciably reduce variability. It is therefore not worth continuing such trials unless there is an expectation that treatment effects will increase to the extent where they will attain significance despite the variability.

ACKNOWLEDGEMENTS.

We are especially grateful to Mr. G. A. McIntyre of the Division of Mathematical Statistics, C.S.I.R.O., Canberra, for advice and assistance in design and analysis of trials. Mr. A. W. Charles, Chief of Division of Plant Industry, had a prominent part in planning experiments. Field work and recording have been carried out by Agronomists A. J. Schindler, K. Newton, R. R. Fraser and one of the authors R. S. Carne, with assistance from Messrs. K. H. van Horck, the late H. H. Nitsche, officers of the Extension Division at Goroka and Korn Farm, D. J. Kingston, R. Smythe, J. G. Davis, J. W. Barrie, J. J. Nitsche, and Technical Assistants S. Meara, J. Guguna and G. Seloka. Miss J. O. Vause assisted in computation and preparation of graphs.

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