Cover Crops, Mulch or Clean Weeding for Coffee (Coffee Arabica) in the Highlands of New Guinea.

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Introduction.

TREATMENTS aimed at maintaining the soil in good condition for growth and production of coffee involve considerable expense. For instance, Maiden *et al,* 1961, estimated that weeding and maintenance of a block of 100 acres of mature coffee represent approximately 20 per cent. of the total expenses on the plantation, and this is the most costly operation apart from harvesting. Some system of soil management is therefore required which will ease the financial burden of maintenance, and keep yields at a high level. Much research has been devoted to these problems in other coffee growing countries and the prime purpose of the work reported here was to assess the value to the coffee grower of the following four cultural practices :—

1. Clean weeding.
2. Weed slashing.
3. Mulching.
4. Use of cover crops.

The effects of spacing and pruning in relation to these practices were also studied.

Methods.

The two experiments reported were carried out in different localities in the Highlands of New Guinea : Experiment 1, at Aiyura near Kainantu in the Eastern Highlands District, and Experiment 2, at Korn Farm near Mount Hagen in the Western Highlands District. Guard rows were not used in either of the experiments. Rainfall and temperature data of the two localities are shown in the Appendix.

(*a*) *Experiment* 1, *Aiyura.*

Management Treatments.

1. Cover crop of *Vigna oligosperma.*
2. Cover crop of *Indigofera endecaphylla.*
3. Mulch of elephant grass (*Pennisetum purpureum*).
4. Clean weeded (weeds scraped with sarifs just below ground level).
5. Slash weeded (weeds cut with sarifs just above ground level).

Spacings.

1. 9 ft. x 9 ft. triangle, giving 621 trees per acre.
2. 14 ft. x 5 ft. in rows, giving 622 trees per acre.

Management treatments 1, 2, 3 and 4 were applied to Spacing 1, and Management treatments 1, 2, 4 and 5 to Spacing 2.

There were four replicates, giving a total of 32 plots.

For the 9 ft. x 9 ft. spacing there were 56 trees per plot, while the 14 ft. x 4 ft. spacing had 48 trees per plot, giving an area of 0.09 acres in each case. *Crotalaria anagyroides* was employed as a temporary shade and nurse crop, and was removed two years after planting the coffee. *Albizia stipulata,* the permanent shade tree, was planted in the rows of the 14 ft. x 5 ft. spacing giving a reduction in the number of trees to 48 but yields were corrected to be equivalent to the same plots, having 56 trees. In the 9 ft. x 9 ft. spacing, shade trees were planted between the rows. Three months after planting, the cover crops were established and mulching began. Cover crops were regularly removed from a strip two feet wide on each side of the stems of the coffee. A mulch of dried elephant grass, to a depth of about six inches (six tons per acre), was applied to each of the mulched plots in April, 1957, November, 1957, September, 1958, July, 1959, October, 1960 and April, 1961. Because the mulch could

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not be dried completely before application it had to be turned regularly to prevent it from taking root.

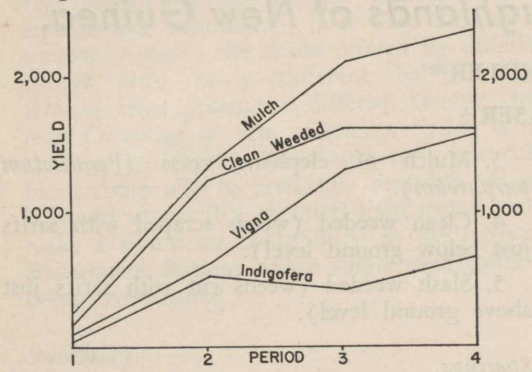

Figure 1.—Experiment 1, Aiyura. Yield in successive periods for each treatment at 9 ft. x 9 ft. spacing. (Period 1. June 1958 to March 1959; Period 2. April 1959 to March 1960; Period 3. April 1960 to March 1961; Period 4. April 1961 to September 1961.)

(*b*) *Experiment* 2, *Korn Farm.*

Management Treatments.

1. Cover crop of *Vigna oligosperma.*
2. Cover crop of *Indigofera endecaphylla.*
3. Slash weeded.

Spacings.

1. 9 ft. x 9 ft. triangle.
2. 7 ft. x 7 ft. triangle.
3. 14 ft. x 5 ft. in rows.

Pruning.

1. Multiple Stem system.
2. Single Stem system.

There were two replicates, giving a total of 36 plots. *Crotalaria anagyroides* was used in the early stages as a nurse crop and temporary shade and *Albizia stipulata* was used as a permanent shade. At all spacings the permanent shade was planted between the rows of coffee.

RESULTS.

(*a*) *Experiment* 1, *Aiyura.*

Plot yields were recorded as coffee cherry weight in pounds. The percentage recovery of raw dry coffee beans was measured on a number of occasions and although recoveries bore an inverse relationship to the yield of cherry, variation between treatments was quite small in relation to the total cherry yield, which was thus the primary factor in yield of coffee per plot. Recoveries were not measured often enough to permit accurate conversion of cherry weight to raw coffee weight. However, in order to present the results in a more meaningful form the yields have been converted to pounds per acre raw coffee by dividing cherry yields by six (which gives a good estimate of average recovery), giving the results shown in Table 1.

The sequence in order of decreasing yield—mulch, clean weeded, *Vigna oligosperma*, *Indigofera endecaphylla*—held throughout the trial at the 9 ft. x 9 ft. spacing (Fig. 1). and also at 14 ft x 5 ft. spacing for the three treatments common to both (Fig. 2). Both *Vigna oligosperma* and slash weeded crops yielded similarly during the trial and their total yields were not significantly different. Although the 14 ft. x 5 ft. spacing yielded significantly more ($P < .05$) than the 9 ft. x 9 ft. spacing, for the total of common treatments, the difference was largely due to the very low yield of the *Indigofera endecaphylla* plots at the 9 ft. x 9 ft. spacing. However, the spacing treatment interaction was not significant.

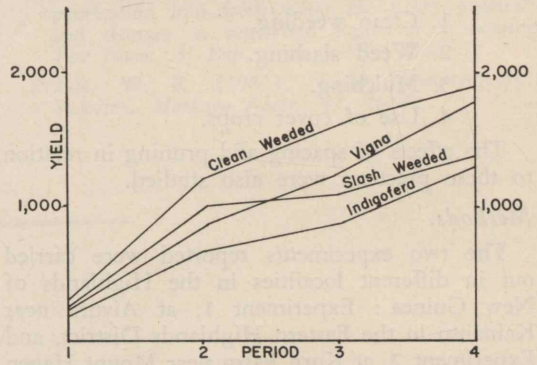

Figure 2.—Experiment 1, Aiyura. Yield in successive periods for each treatment at 14 ft. x 5 ft. spacing. (Period 1. June 1958 to March 1959; Period 2. April 1959 to March 1960; Period 3. April 1960 to March 1961; Period 4. April 1961 to September 1961.)

The trial was notable for the very large increases in yield obtained as a result of the addition of six tons of partly dried mulch per acre per year. (In Kenya 10 tons is commonly applied, see Jones *et al* 1960). The mulched plots yielded significantly more ($P < .01$) than plots of any other treatment.

Table 1.

Experiment 1, Aiyura, Yield (pounds per acre raw coffee beans).

	9 ft. x 9 ft. triangle.					14 ft. x 5 ft. in rows.					
	June, 1958 -Mar. 1959.	April, 1959 -Mar. 1960.	April, 1960 -Mar. 1961.	April, 1961 Sept. 1961.	Total.	June, 1958 -Mar. 1959	April, 1959 -Mar. 1960.	April, 1960 -Mar. 1961.	April, 1961 Sept. 1961.	Total.	Over-all means (3 years).
Clean weeded	165	1,233	1,640	1,657	4,695	201	1,183	1,587	1,879	4,850	4,778
Indigofera endecaphylla	52	541	487	713	1,793	147	676	875	1,263	2,961	2,377
Vigna oligosperma	98	615	1,344	1,634	3,691	150	831	1,214	1,770	3,965	3,828
Slash weeded	....	....	....	....	....	191	970	1,087	1,360	3,608	....
Mulch	275	1,378	2,146	2,403	6,202	....	....	....	....	....	....
Least significant 5%	86	155	296	463	862	91	244	350	408	961	597
differences 1%	124	223	426	666	1,240	130	350	503	587	1,382	819
0.1%	182	328	626	980	1,823	192	515	739	863	2,032	1,094

Note.—

(1) The coffee began bearing in June, 1958.

(2) Most of the crop is harvested during the period April to September each year.

The amount of labour used for maintenance of the treatments was carefuly recorded from January, 1959, until the conclusion of the trial and is tabulated in Table 2.

Vigna oligosperma had to be weeded at times to ensure its survival, and because of this cannot be classed as a good cover crop. *Indigofera endecaphylla* required treatment only for the purpose of preventing it from completely smothering the coffee and, regardless of the fact that it was regularly pulled back leaving a clean weeded area two feet wide on each side of each row of coffee, root competition was such that in many plots the coffee was extremely poor (Plate I). The slash weeded plots in which all weeds except grasses were cut above the ground (the grasses were pulled up and removed from the plot), required more labour than the clean weeded plots. Slash weeding, combined with total grass removal, was tedious, and the weeds which remained were never completely killed. Slash weeding encouraged the growth of grasses rather than the soft weeds.

Table 2.

Mean number of man days required for maintenance per acre per year for the duration of the trial.

Treatment.	Man days.
Cover Crops	100
Slash Weeded	155
Clean Weeded	94
Mulch	* 228

* Includes labour for cutting, carrying and spreading the mulch.

(*b*) *Experiment* 2, *Korn Farm.*

Yields were recorded as cherry weight per plot but recovery of clean coffee was never measured. Results however, are given as pounds of raw coffee beans per acre, using a conversion factor of six, as at Aiyura.

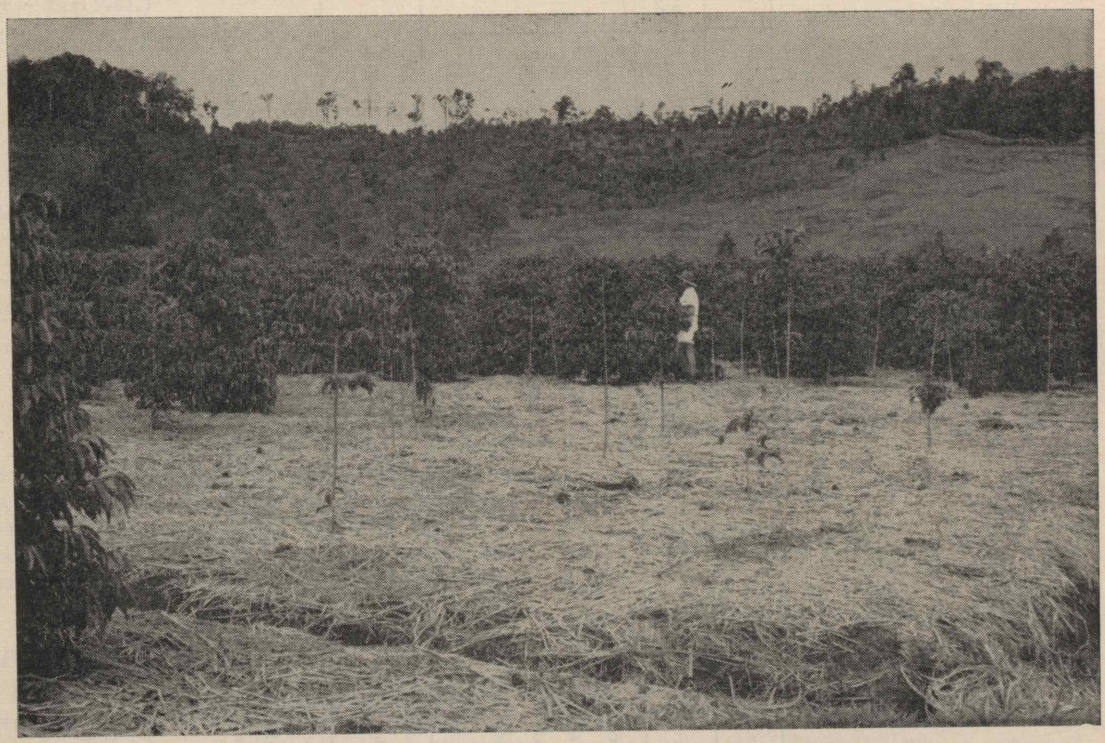

Plate I.—*Indigofera endecaphylla* plot in the foreground with coffee showing the effects of severe competition from the cover crop. The picture was taken shortly after conclusion of the trial when the cover crops had been removed and the plots mulched to help their recovery. At this stage also the *Albizia stipulata* shade had been removed to allow the implementation of a new trial without shade.

Table 3.

Experiment 2, Korn Farm, Yield (pounds per acre raw coffee beans)

	7 ft. x 7 ft. triangle				9 ft. x 9 ft. triangle				14 ft. x 5 ft. in rows.				
	July, 1959 -Mar. 1960 (1).	April, 1960 -Mar. 1961 (2).	April, 1961 -Mar. 1962 (3).	Total.	July, 1959 -Mar. 1960 (1).	April, 1960 -Mar. 1961 (2).	April, 1961 -Mar. 1962 (3).	Total.	July, 1959 -Mar. 1960 (1).	April, 1960 -Mar. 1961 (2).	April, 1961 -Mar. 1962 (3).	Total	Over-all means (3 years).
Clean weeded	310	1,274	1,321	2,905	147	915	881	1,944	148	644	905	1,698	2,182
Indigofera endecaphylla	259	713	902	1,875	163	535	297	995	101	482	651	1,366	1,412
Vigna oligosperma	438	1,367	1,135	2,940	297	1,156	932	2,385	161	1,011	953	2,124	2,483
Means	336	1,118	1,119	2,573	202	869	703	1,775	137	712	836	1,729	

Least significant differences between treatments in all spacings—

	Period 1.	Period 2.	Period 3	Total
5 per cent	133	403	220	675
1 per cent	202	610	330	1,022

The effect of pruning systems is shown in Table 4.

Table 3 shows the results of the soil management treatments and spacings. The serious decline of the *Indigofera endecaphylla* plots is again evident, and although the *Vigna oligosperma* plots often yielded more than the clean weeded plots the differences never attained significance. *Vigna oligosperma* did not achieve a good cover and weeds were always present.

Table 4.

Experiment 2, Korn Farm. Pruning and Spacing. Total Yield (pounds raw coffee beans per acre).

	7 ft. x 7 ft.	9 ft. x 9 ft.	14 ft. x 5 ft.	All spacings.
Single Stem	2,101	1,593	1.527	1,740
Multiple Stem	3,046	1,956	1,843	2,282

Multiple stem pruning gave significantly higher yields in the 33 months of trial ($P < .001$) than single stem pruning. The treatment/pruning interaction reached a level of 5 per cent. only in the period April, 1961, to March, 1962, when competition from the cover crops seemed to favour multiple stem pruning. Within the clean weeding treatment the difference between pruning treatments was small.

DISCUSSION.

(*a*) *Mulching.*

Increases in yields of coffee attributable to applications of mulch have been found to be quite substantial in other countries (Table 5).

In Kenya the increase in yield has been attributed to assistance of water penetration and control of soil and water loss by erosion (Jones *et al* 1960). It is doubtful if the effect reported here could be explained in the same way because rainfall is more uniformly distributed, total annual rainfall is generally higher and the trial was planted on flat land on which water run off was slow.

Leaf samples collected and analysed in November, 1961 after the conclusion of the trial gave the results shown in Table 6.

Table 5.

Examples of yield increases obtained using mulch in other countries.

Country.	Type of Mulch.	Percentage increased in yields.	Authority.
Tanganyika	Banana trash. (Elephant grass, Guinea grass also tried—Banana trash gave largest increase)	50	Sanders 1953.
Kenya	Elephant grass	Up to 100	Ann. Rpt. and Accounts, Coffee Board of Kenya, 1961.
Brazil	Unspecified grass	58	Medcalf J. C. *et al* 1955.
Brazil	Unspecified grass	72	Medcalf, 1956.
Venezuela	Banana stems	100	Venezuela, Ministry Agric. and An. Hus., 1959.

Table 6.

Percentage of the indicated elements on a dry weight basis in the leaves.

Treatment.	N.	P.	K.	Ca.	MG.
Clean weeded	2.34	0.107	0.57	0.85	0.50
Mulch	2.35	0.112	1.11	0.77	0.34

The notable feature of Table 6 is the higher potassium level and lower magnesium level in the mulched treatment compared with the clean weeded treatment. The response to mulch is therefore thought to be mainly due to an increase in potassium available for growth of the coffee. Warden J. C., 1961, and Robinson and Chenery, 1958, both report increased potassium uptake from mulch but the response to mulch was apparently primarily due to the favourable effect on available soil water.

Table 7 shows that returns from application of mulch exceeded costs in the third year of bearing and from the 5th year on they could be expected to show a substantial net return.

(*b*) *Cover Crops.*

Similar competitive effects to those reported here, though probably not as severe, have been described from Columbia (Rodriguez, 1958), and Venezuela (Venezuela Ministry of Agric. and Animal Hus., 1959). *Vigna oligosperma* was not vigorous enough in its growth habits to survive competition from common weeds amongst the coffee, although it exists in some places in the New Guinea Highlands mixed with low growing grasses. Thus two extremes of cover crops were tried, one competing so strongly that the coffee suffered and the other too weak to survive without removal of the competing weeds.

The cover crops were planted as a means of reducing weeding requirements and because they might have been expected to increase available soil nitrogen. They were not intended as soil erosion inhibitors although, had they been beneficial to the coffee, then this aspect of potential value would have been examined.

The yields from the *Vigna oligosperma* and weeds-slashed treatments were similar throughout, as would be expected since the poor performance of the *Vigna oligosperma* rendered the two treatments more or less equivalent. The two types of cover apparently competed with the coffee to a similar extent and the *difference in yield between the clean weeded plots* and plots under these treatments is probably a direct measure of the competition involved.

Table 7.

Balance sheet for mulching. (Experiment 1).

	January, 1958-March, 1959.	April, 1959-March, 1962.	April, 1960-March, 1961.	April, 1961-September, 1961.
Yield increase from clean weeded to mulch plots (lb. /acre).	110	145	506	746
Value of increase at 2s. 0d. per lb. (a)	£11	£15	£51	£75
Increase in cost of labour from clean weeded to mulch plots (£'s/acre). (b)	£42	£42	£42	£42
Net return from mulch	Minus £31	Minus £27	Plus £9	Plus £33
Cumulative net return.	Minus £31	Minus £58	Minus £49	Minus £16

(a) From figures given by Maiden et al 1961, it can be calculated that with coffee selling at 3s. 8½d. per pound the return on operator's labour, management and capital (listed as plantation surplus) amounts to very nearly 2s. 0d. per pound of coffee produced. It must be borne in mind however, that there is an extremely wide variation in costs of production, and hence growers should not use the above table without regard to individual production and labour costs.

(b) Labour data extracted from Table 2 (cost of labour at 6s. 2d. per man day).

It had been intended that mechanical cultivation should be employed in the wide rows of the 14 ft. x 5 ft. spacing in lieu of hand weeding. This proved impracticable, however, because of the extensive system of drains which had to be dug to dispose of surface water and because the ground was impassable to a tractor for a large portion of each year.

(c) Spacings.

That the management treatments gave similar results with each spacing was the most important aspect of spacing effects in this trial. The 7 ft. x 7 ft. yielded more than other spacings in early years, as was expected, since this conforms to current trends in other trials at Aiyura. In both experiments yields were related to the density of planting rather than to the planting system. It is questionable whether this relationship would have continued to hold in later growth.

(d) Prunings.

The system of pruning also was of secondary importance in this trial. It is however, noteworthy that multiple stem pruning out-yielded the single stem system during the trial period. Multiple stem pruning is generally used in coffee plantations in the New Guinea Highlands for it is far easier to manage. At the same time, the greater advantage of multiple stem pruning when cover crops are used is of no practical importance because use of cover crops could not be recommended on present evidence.

Multiple stem gave superior results at the 7 ft. x 7 ft. spacing. This result is not supported by evidence from other coffee trials at present in progress at Aiyura and is therefore probably coincidental.

Conclusion.

Although labour requirements for mulching were fairly high, the yield increase obtained in the third and fourth years more than compensated for the extra cost involved. The advantage of mulching could be expected to increase, or at least to be maintained over the ensuing years.

Recommendations.

Although no specific recommendations can be made as a result of this trial regarding optimum quantities or time of application, it appears that a yearly application of six tons of elephant grass mulch per acre, whether in one application or two separate applications, would be sufficient to give a worthwhile return. Alternatively, any native grass or other plant material obtainable near the plantation would be useful and, if applied in large enough amounts, would give economic increases in yield. At Aiyura elephant grass has been established along creeks and in other places where it had to be cut and carried by hand. All the mulch was obtained within a radius of a mile of the coffee block to which it was applied. The cost of mulching included cutting, carting, spreading, turning, and weeding when necessary.

In weeding it is essential that the weeds be completely destroyed (clean weeded) rather than having their tops cut (slash weeded) for, in the long run as labour figures show, total weed destruction will cost less.

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APPENDIX.

Temperature and rainfall data for Aiyura and Mount Hagen (based on recordings from January, 1956, to May, 1962).

Month.	Av. Max. Temp.		Av. Min. Temp.		Average Monthly Rainfall (ins.)		Av. Daily hours of sunshine Aiyura.
	Mount Hagen.	Aiyura.	Mount Hagen.	Aiyura.	Mount Hagen.	Aiyura.	
January	77.1	75.4	55.7	56.8	9.4	7.4	4.4
February	75.5	75.1	55.8	57.7	11.9	9.9	4.2
March	75.3	75.1	55.7	56.9	11.7	10.5	4.4
April	75.5	74.6	56.5	57.2	11.4	8.9	4.6
May	76.7	74.4	55.7	56.5	7.8	4.8	6.4
June	75.3	72.5	53.6	55.9	4.4	3.3	5.1
July	73.7	71.4	54.1	55.0	6.1	4.1	5.0
August	73.5	71.5	54.1	55.8	6.9	6.3	4.9
September	74.6	72.5	53.8	54.4	7.8	4.4	5.8
October	75.4	73.9	53.3	54.6	7.9	7.4	5.8
November	76.0	75.3	54.7	55.2	7.5	7.6	6.0
December	76.3	75.3	55.7	57.5	9.3	12.3	4.5

Mount Hagen weather data by courtesy of Meteorological Office, Lae, New Guinea.)

Soil Description—

Aiyura—grey to dark grey heavy clay developed on tertiary alluvia (unpublished information from a soil survey carried out by officers of the Department of Agriculture, Stock and Fisheries).

Korn Farm—black friable loam developed on tertiary alluvia. (C.S.I.R.O., 1959, Divisional Report No. 58/1.)