Shade, Spacing and Fertilizing of Cocoa in Papua New Guinea

P. N. BYRNE, Agronomist-in-Charge, L.A.E.S., Keravat, East New Britain

Shade, spacing and fertilizing are the three major agronomic practices of importance to good cocoa yields. While there is a marked interaction between these, they will be discussed mainly as individual factors. Effective pest and disease control are equally important and should be given as much attention as agronomic practices.

THIS article deals mainly with sole planted cocoa as most agronomic trials have been carried out on this type of planting. However, on the whole, results are also applicable to cocoa interplanted to coconuts. The two main points to remember when applying these practices to interplanted cocoa are—

(*a*) Coconuts do provide shade so that interplanted cocoa will respond to various treatments in much the same way as sole cocoa under other types of shade.

(*b*) The dual cropping system, coconuts/cocoa is very demanding on soil nutrients and under these conditions one is committed to fertilizing by the time the cocoa is mature, if not sooner, if reasonable levels of cocoa and copra production are to be maintained. This applies particularly if all shade additional to coconuts is removed.

SHADE

While it is possible to establish cocoa without shade, its use is traditional. This tradition has very sound practical bases. Shade simulates the natural environment for cocoa, which is an under-storey forest tree.

Young seedlings make best growth under fairly heavy shade conditions but the cocoa tree's requirements for shade decrease as it develops. Opposed to this, shade at the same time tends to get more dense so that it is necessary to keep removing or trimming shade to meet the cocoa's need for increasing light. This aspect will be discussed in more detail later.

Cocoa can be planted using thinned out forest to provide shade but this has disadvantages, particularly in many areas of Papua New Guinea where insect pests occur, e.g., the cacao weevil borer (*Pantorhytes* spp.) The felling and burning of forest trees is a major factor in keeping some pests out or, at least, under reasonable control. For this reason only planted shade is recommended and discussed in this article.

Shade trees should be planted on a systematic pattern keeping in mind the final pattern of permanent shade trees. This gives a uniform shade and also helps considerably in shade control or manipulation.

Shade also has an important function, particularly in the early stages before cocoa forms a canopy, of suppressing grass and regrowth thus saving on maintenance and reducing competition for nutrients.

Generally speaking, shade should be fairly heavy when cocoa is planted. It is thinned out as the cocoa develops so that by the time the cocoa trees at normal spacing start to ramify there are, for example three Leucaena trees to each cocoa tree. It should be progressively thinned from then on, so that by the time the cocoa has formed a complete canopy, there is one Leucaena tree to each two cocoa trees, and eventually one well-developed Leucaena tree to each four cocoa trees. Other species of shade trees are thinned to give the equivalent cover. It may be necessary to modify this recommendation according to growth of both shade and cocoa trees.

Figure 1 shows suggested planting and thinning patterns for cocoa planted at 12ft triangular spacing and using Leucaena as shade. Further thinning will depend on local conditions, whether or not it is intended to use fertilizer, pest and disease situation, subsequent growth of shade trees, etc.

The importance of shade control is highlighted by results of trials carried out at Keravat. In general, the less mature cocoa is shaded,

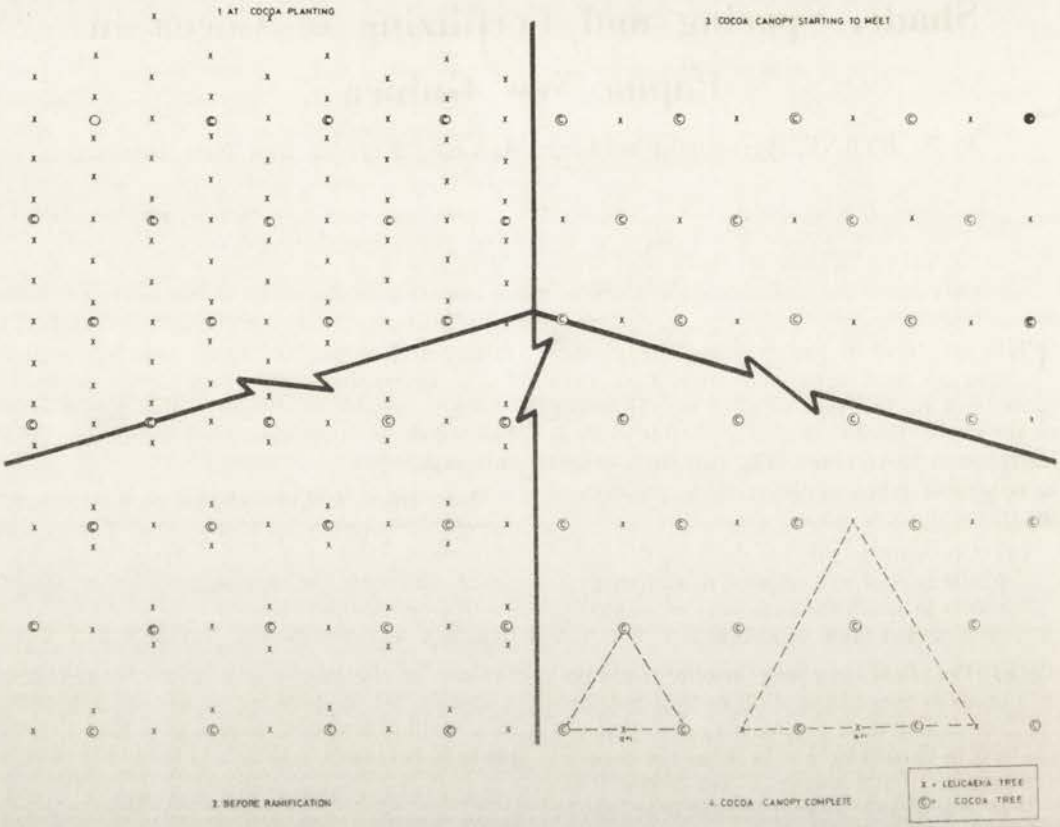

Figure 1.—Planting and thinning pattern for sole cocoa planted at 12 ft triangular spacing and using Leucaena shade. Further thinning would consist of removing alternate Leucaena trees in each line so that these are then on a 30 ft triangular spacing. Less drastic thinning on block edges is recommended as this could assist in keeping down infestation of pests such as the cocoa web moth (*Pansepta teleturga*)

the greater the production. In the main trial (KTC 2) there were four levels of shade:—

Nil shade: No Leucaena.

Quarter normal shade: One large Leucaena tree to four cocoa trees

Half normal shade: One large Leucaena tree to two cocoa trees

Normal shade: One large Leucaena tree to each cocoa tree

Cocoa was planted at 15ft on the triangle. However, shade was relatively old and very well developed so that in effect the quarter normal shade (shade trees on 30ft triangle) gave about as much shade as one Leucaena shade tree to four cocoa trees at 12ft spacing (shade trees at 24 ft triangular spacing).

Results for period 1959-60 to 1963-64 are given in *Table* 1 and these are shown graphically in *Figure* 2.

Table 1.—Yields in lb of dry cocoa per acre obtained by using an arbitrary conversion factor of eleven pods per pound of cocoa

Year	Nil Shade	¼ Normal Shade	½ Normal Shade	Normal Shade
1959-60	1729	1576	1331	1043
1960-61	1381	1176	974	799
1961-62	1288	1167	943	831
1962-63	1645	1400	1127	982
1963-64	1047	1240	926	887
Mean	1418	1312	1060	908
Ratio cocoa/ Leucaena tree	Nil	4:1	2:1	1:1

Table 1 gives support for the recommendation of thinning out eventually to one Leucaena

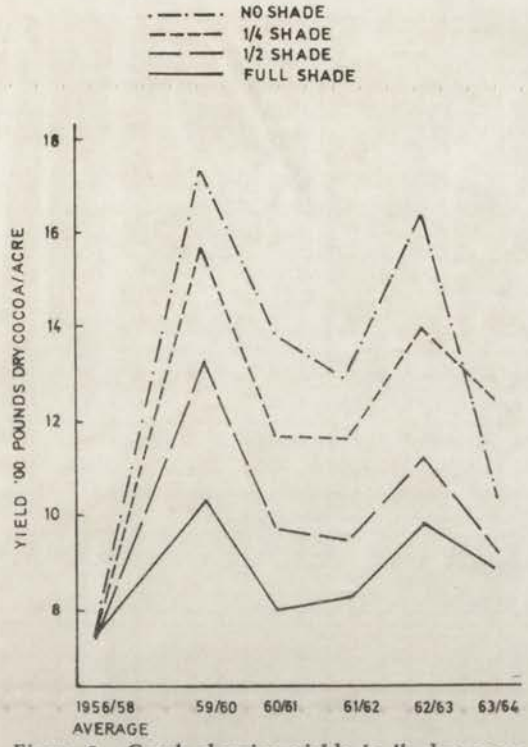

Figure 2.—Graph showing yields in lb dry cocoa per acre at 4 shade levels (Trial KTC 2). Cocoa planted at 15 ft triangular spacing and Leucaena shade

tree to each four cocoa trees under normal conditions. Further response to complete shade removal could be anticipated but this would be recommended only if it is intended eventually to use fertilizers where this will not accentuate problems of pests and diseases and where soil and climatic conditions are suitable.

With drastic reduction or complete removal of shade, conditions become much more favourable for build-up of some insect pests particularly *Pansepta* (cocoa web moth) and *Pantorhytes*. In the case of *Pansepta* early recognition and treatment by cutting out and burning infected branches will keep this pest under control but emphasis must be on early recognition and treatment. Where *Pantorhytes* are present shade removal will be dependent on the seriousness of the infestation and probably response of *Pantorhytes* to shade removal in the particular area. The advice of entomologists should be sought if you are not sure how *Pantorhytes* are likely to respond to shade removal.

Some of the shades in use are discussed below.

Coconuts

For new coconut plantings a 30 feet triangular spacing is recommended. A closer spacing will give a too dense shade and consequently this will depress cocoa yields. With fertilizing, which is almost inevitable with interplanted coconuts/cocoa, coconut fronds will be larger and more luxuriant and this will result in greater shading and further affect yields.

In most cases the shade provided by coconuts is not adequate for establishing cocoa and this can be overcome by either planting additional shade or the use of fertilizer. The latter has definite advantages provided maintenance is consistent and of a high standard.

It should be noted that new and well-maintained coconut plantings must be 3 to 4 years old before interplanting cocoa, otherwise the cocoa, which grows rapidly in the early stages, will out-compete coconuts for light. Coconut losses will be high and survivors will be retarded, except on road edges, etc.

Leucaena leucocephala (*syn.* L. glauca)

This is the most widely used shade for cocoa in Papua New Guinea. As a shade it is almost ideal but has two main disadvantages—

(*a*) Seedling regrowth can become a major problem when shade is not properly managed or where there are heavy losses of cocoa allowing penetration of sunlight to the ground and encouraging germination of Leucaena seed.

(*b*) Leucaena is a host for some of the leaf eating caterpillars, e.g., in Popondetta the moth of *Tiracola plagiata* (army worm) lays its eggs on the leaves of Leucaena. These hatch out and the small larvae or caterpillars later descend on to the cocoa tree and cause serious damage. Where army worm and certain other caterpillars are found, Leucaena is not recommended.

Leucaena can be established either by sowing seed directly into the field or by transplanting seedlings. The latter has advantages in shade control as it allows planting on a systematic pattern.

The most common cause of poor take of Leucaena seedlings is planting too deep and failure to firm-in at planting. Leucaena seedlings, at least as thick as one's little finger, are

Plate I.—Sole seedling cocoa planted at double 12 ft triangular spacing under Leucaena shade. This is a dieback area and double spacing has been used to compensate for possible high loss of seedlings

either pulled out or the main root cut 4 to 6 inches below soil surface. The side roots are trimmed off and the tap root, if still remaining, is cut back to 4 to 6 inches and the whole topped back to 3 to 4 feet. When planting, the original collar should be no more than 1 to 2 inches below ground level. Leucaena stakes can be used but losses can be very high and therefore they are not usually recommended.

Gliricidia maculata

While this is used overseas, it has only recently been seriously considered for use in Papua New Guinea to replace Leucaena. The entomologists have found that army worm will not feed on it. Further advantages of Gliricidia are that it does not seed in the lowlands and it will stand heavy cutting back which, in fact, is necessary to maintain it as a satisfactory shade.

Gliricidia is brittle and susceptible to wind damage. Its growth habit is often straggly but this can be kept in control by judicious pruning.

Hardwood cuttings from 1½ to 6ft long are used. These must be well firmed-in when planted.

Other Permanent Shade Trees

These include Albizia, Casuarina, Erythrina, etc., which have their uses under certain conditions.

Temporary Shade Plants

A number of these have been recommended and used over the years. These include *Crotalaria anagyroides, Tephrosia* spp., *Flemingia congesta,* etc.

N.B. The above recommendations are based on Gazelle Peninsula conditions. It may be necessary to modify for other areas. For example, less shade would be recommended for Buin which has more cloud cover.

Plate II.—Clonal cocoa (cuttings) planted under Gliricidia shade

SPACING

Current recommendation based on trials is a 12 feet triangular spacing for sole-planted seedling cocoa. For sole-planted clonal cocoa (cuttings) this should be modified slightly to give a close hedge spacing to make the stand more accessible for machinery. For inter-planted coconuts/cocoa, recommendations are based on experience and observation only.

Spacing recommendations for various types of planting material and conditions are given below.

Sole Seedling Cocoa

Twelve-feet triangular spacing is recommended. This is a planting density of 348 trees per acre. There may be slight advantages in planting at a slightly closer spacing.

Seedling spacing trials at Keravat indicated that for the first 3 years of bearing a 12ft triangular spacing gave better yields per acre than a 15ft triangular spacing. In one trial (KTC 4) yields of dry cocoa per acre during the first 3 years of bearing were 2,404lb for the 12ft spacing and 2,118lb for the 15ft spacing. This is a difference of 13.5 per cent. However, there were no significant yield differences between these two spacings in subsequent years, but both spacings continued to out-yield wider spacings. Results of this trial are given in *Table* 2.

***Table* 2.—Yields in lb dry cocoa per acre for five different triangular spacings. Seed planted at stake in 1965. Dieback affected this stand of cocoa to such an extent that only yields up to the end of 1963 are reported**

	Triangular Spacing				
Year	12 ft (348)	15 ft (224)	17 ft 2 in. (174)	20 ft (126)	24 ft (87)
To Dec					
1960	507	342	300	222	201
1961	696	636	375	441	478
1962	1201	1140	1046	684	804
1963	1499	1473	1365	952	867

(....) Trees per acre

It is possible that a slightly closer spacing may be the optimum. The only experimental evidence under our conditions is that an 8ft triangular spacing is too close. Thus all that can be said is that the optimum triangular spacing for sole seedling cocoa lies somewhere between 8ft and 12ft but probably near 12ft.

Wide hedge spacings for seedling and clonal cocoa have been tried at Keravat but it was found that the cocoa canopy took a long time to cover the space between hedges, resulting in increased maintenance and grass competition. The same applied to wide triangular spacing trials: closer spaced cocoa formed a complete canopy sooner than the wider spacings.

Where New Guinea cocoa dieback occurs, planting at double 12ft triangular spacing is a wise precaution in anticipation of heavier losses than under normal conditions. A double 12ft triangular spacing is in actual fact a 10.4ft x 6ft rectangular spacing. This will require a modification of shade planting pattern. Should there be a high percentage of survivors it may be necessary to thin out the cocoa stand to reduce inter-tree competition to reasonable levels. Thinning out excess trees is far easier than planting at normal spacing and later having to replace losses.

Sole Clonal Cocoa (Cuttings)

A cutting is actually a cocoa tree without a trunk with branches coming out at ground

level. Thus the canopy is that much closer to the ground and hampers movement between lines. To overcome this problem a modified hedge spacing is recommended. This modification is essential to allow relatively free movement through the cocoa stands, particularly if tractor-mounted machinery is used for spraying, fertilizing, etc., or even motorized knapsack sprayers. This applies even more when clones are relatively young.

Spacing between hedges must be a compromise between being wide enough for easy access but close enough to ensure that the canopy fairly rapidly covers the space between hedges. This saves on maintenance, reduces grass competition and ensures that shade can be thinned at about the normal time. It is considered that a spacing of 15ft between hedges will meet these requirements.

Trials on spacing between clones within hedges are to be conducted. These will include the following spacings: 12ft (242 trees/acre), 10ft (290 trees/acre) and 8½ft (343 trees/acre). The wider spacing probably will result in lowered yields for the first 2 or 3 years of bearing but this will be offset, in part at least, by the lower capital outlay for planting material. Rooted clonal cuttings at present are being sold at Keravat for ten cents each.

In areas where dieback occurs, double spacing to allow for losses, as recommended for seedlings, is not necessary. Dieback resistance in selected clones is more uniform than in seedlings and, due to their growth habit, they are better able to withstand pruning out of dieback infections.

Interplanted Cocoa/Coconuts

The advantages of a 30ft triangular spacing for coconuts have already been mentioned.

It is recommended that cocoa, both seedlings and clones, be planted in a single line

Plate III.—Seedling cocoa interplanted to coconuts showing strip in cocoa planting line maintained in a weed-free condition

midway between coconut rows and also in the coconut lines. This is preferred to planting two lines of cocoa between coconut lines. This pattern gives better access for machinery (spraying, grass cutting, etc.) and the cocoa trees are further away from the palms, thus lessening chances of damage from falling fronds and nuts.

Recommended planting distance between cocoa trees in the line midway between coconut lines is 10ft. In the coconut lines two positions are planted to cocoa between each two coconut positions, e.g., with coconuts at 30ft triangular spacing cocoa would be planted:— coconut palm—10ft space—cocoa tree —10ft space—cocoa tree—10ft space— coconut palm and so on (see *Figure* 3).

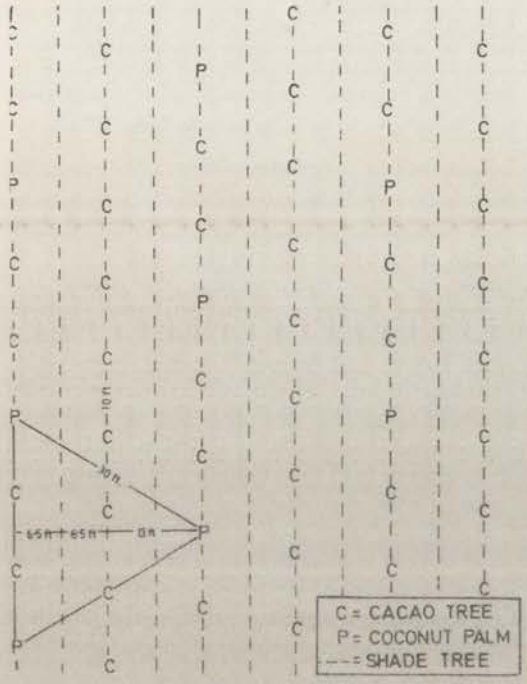

Figure 3.—Recommended planting pattern for interplanted cocoa/coconuts. This is for coconuts planted at 30 ft triangular spacing

With palms planted on 30ft triangle and cocoa planted at spacing recommended above, planting densities will be 56 palms and 280 cocoa trees per acre.

If shade additional to coconuts is used this should be planted in the same lines as the cocoa; additional lines midway between cocoa lines may be planted. Where coconuts are at 30ft triangular spacing the former will give shade lines 13ft apart and the latter 6½ft apart.

Reference to *Figure* 3 shows spacing recommended where coconuts are planted on 30ft triangle. Basically the same pattern would be followed for other spacings but distance between cocoa lines would vary according to coconut spacing. Spacing between cocoa trees would remain at 10ft, but the distance between coconuts and cocoa trees in the cocoa lines would have to be varied.

FERTILIZERS FOR COCOA

Nitrogenous fertilizers under conditions of little or no shade and in some areas, potash, are the only fertilizers to which cocoa in Papua New Guinea has shown a general economic response. Phosphate deficiency has occurred in a few areas while other deficiencies, particularly iron, zinc and copper, do occur to some extent. There have been a few isolated cases of sulphur deficiency in cocoa, but cocoa is apparently very efficient in taking up sulphur from the soil. Some of the so-called responses by cocoa to sulphur have been indirect ones; mainly cocoa shade (Leucaena) has responded and this in turn has benefited young cocoa.

While areas where, and conditions under which, responses to various fertilizers can be expected are fairly well defined, there are occasions when a more positive assessment is required. This situation is catered for by the soil and leaf analysis service supplied by the Department. Samples for analysis can be taken by the owner or manager provided correct sampling techniques are followed and full information relating to samples is supplied. Unless both of these requirements are met, results of analyses and interpretation of results can be grossly misleading and even very costly.

Instructions for sampling and details of information required will be supplied by the Department on request.

Nitrogenous Fertilizers

Under conditions of heavy shade a response to nitrogen is unlikely, but under little or no shade a response can be expected. One trial quoted to support this statement is the Shade x Spacing x Fertilizer Trial (KTC 3) carried out at Keravat.

Shade was removed progressively from the no shade treatment during 1953-54. By 1957-58 the initial boost to yields from shade removal appeared to have been lost and at this stage a fertilizer treatment was superimposed using urea initially at the rate of 224lb per acre (10oz per tree at 12ft spacing and 15oz per tree at 15ft spacing) and changed in December to 4lb/tree/year in four applications.

There was no response to fertilizer under shade but a marked one under no shade. This resulted in a 37 per cent yield increase. Yields for period 1959-60 to 1963-64 are summarized in *Table* 3.

***Table* 3.—KTC 3 mean yields of lb dry cocoa per acre. Yields for 12 and 15 ft triangular spacing combined**

	Not Shaded	Shaded
Fertilized	1671	1224
Not fertilized	1272	1217

These were converted from pods per acre to lb dry cocoa per acre using an arbitrary conversion factor of 11 pods per pound dry cocoa.

Considering other fertilizer trials, a lower rate of fertilizing may have given as good an economic response. In one trial (KTC 9) urea was applied at two rates (1 and 4lb per tree per year) and two frequencies (6 and 3 monthly). This trial is being carried out on a stand of mature cocoa interplanted to coconuts in an area which has been badly infected by New Guinea cocoa dieback, hence low yields, but even so increased yields from fertilizing are worthwhile. Results are given in *Table* 4.

***Table* 4.—KTC 9. The yields have not been corrected for pretreatment effects**

Treatment	lb dry cocoa/acre per year	Percentage of Control
Controls (no fertilizer)	585	100
6 monthly application: 1lb urea/tree/year	804	137
6 monthly application: 4lb urea/tree/year	873	149
3 monthly application: 1lb urea/tree/year	878	150
3 monthly application: 4lb urea/tree/year	972	166

The important point of this trial is that ¼lb urea every 3 months gave as good a yield response as 2lb urea every 6 months. Taking cost of urea and its application into account the 'little and often' rate would give a better net return. Whether or not 1lb urea per tree every 3 months would give a better net return would largely depend on cocoa prices. However, there is a suggestion that 4lb of urea per year may be excessive and in the long term result in lowered yields. This effect has not been proven but heavy rates of urea should be used with caution.

Based on the above, recommendations for nitrogenous fertilizers are for ¼ to ½lb urea per tree or its equivalent in other fertilizers applied every three months (i.e., 1 to 2lbs urea/tree/year).

The rate will depend on spacing, e.g., the lower rate (1 lb per year) is for a 12ft triangular spacing and the higher rate for an older type of interplanted cocoa. On the other hand it may be advisable to double up the rates for the initial and even second application where trees are obviously very nitrogen deficient.

The above recommendation applies only under conditions of little or no shade.

Where shade is completely removed or drastically reduced there will be initial boost to yields but this will probably disappear after a few years. While fertilizing will give a further boost, it is not necessary for the first couple of years but should be used later if high yields are to be maintained. However, complete shade removal would be recommended only when it is intended eventually to fertilize and where it would not lead to complications already mentioned in the section on shade.

Recommendations are for urea or its equivalent. Urea contains 46 per cent nitrogen compared to 21 per cent in ammonium sulphate; i.e., ammonium sulphate has slightly less than half the nitrogen content of urea. However, for all practical purposes it is applied at double the rate of urea. Nitro-potash containing 20 per cent nitrogen is also applied at double the rate of urea.

The initial effect of urea on a soil is to raise the pH of the soil for a short duration. This results from its conversion into ammonium carbonate by the enzyme urease. Once nitrification (i.e., conversion to nitrate form) processes commence, urea, like ammonium sulphate, then induces an acidification of the soil to which it is added (i.e., it lowers the pH). Prolonged

use of urea fertilizer does not depress the pH of a soil to the same extent as sulphate of ammonia.

There are differences between fertilizers in losses due to leaching, volatilisation, etc., availability to the plant and effects on other soil nutrients. However, this has not been studied in cocoa under Papua New Guinea conditions.

Relative costs of nitrogenous fertilizer are based on the landed (on the plantation) cost per unit of nitrogen. For example urea at $92 per ton costs $2 per unit but ammonium sulphate at $67 per ton costs $3.19 per unit. At these prices urea would be the cheapest source of nitrogen.

Sulphur

Cocoa apparently is very efficient in taking up sulphur and only a few confirmed cases of sulphur deficiency in cocoa have been reported, mainly in young cocoa. On the other hand some shade trees are very susceptible to sulphur deficiency, e.g., Leucaena which will be very retarded and thus fail to provide adequate shade for young cocoa.

Despite the claim that cocoa is not very sensitive to low levels of soil sulphur, it is considered a wise precaution to substitute ammonium sulphate (A.S.) or ammonium sulphate nitrate (A.S.N.) for urea for occasional dressing in areas known to be sulphur deficient. In these areas A.S. or A.S.N. should be substituted in one application out of four.

If sulphur deficiency is present, the use of urea will accentuate the effects of this deficiency unless it is corrected by the above recommendation.

Potash

Papua New Guinea's coral-derived, mature clay loams are amongst the known potash deficient soils and are one of the major soil groups on which cocoa is grown. These soils occur on New Ireland, south coast of New Britain, etc. Response to potash by cocoa grown on these soils has been obtained under conditions of shade ranging from heavy to nil.

Cocoa fertilizer trials on these soils have not been running long enough to make any but tentative recommendations. However, it would appear that under conditions of little or no shade, nitrogen will accentuate a potash deficiency. Therefore the potash deficiency will have to be corrected before a response to nitrogen can be expected. Recommendation for potash on coral-derived mature clay loams for mature trees is $\frac{3}{4}$ to $1\frac{1}{2}$ lb muriate of potash (KCl) per tree per year in a single dressing, the amount depending on spacing.

Fertilizing Coconuts in an Interplanted Coconuts/Cocoa Stand

The economics of applying nitrogenous fertilizers to coconuts is doubtful, but they do benefit from nitrogen applied to interplanted cocoa. On the other hand, there have been marked responses to both potash and sulphur where these deficiencies occur.

In interplanted stands where potash or sulphur (or both) are deficient, separate fertilizer programmes are required for both crops rather than a combined programme.

An article by Mr J. Sumbak recently published in *The Papua New Guinea Agricultural Journal*, Vol. 22 No. 2, gives recommendations for fertilizing coconut palms.

Establishing Interplanted Cocoa Without Shade Additional to Coconuts

This can be successfully carried out provided ground maintenance is of high standard and use is made of fertilizers to compensate for high light intensities.

Maintenance consists of keeping the immediate area around cocoa seedlings weed-free. In actual practice this is best done by maintaining a weed-free strip 3 to 4ft wide in the cocoa lines in preference to ring-weeding.

Recommended rates for fertilizing young inter-planted cocoa are given in *Table* 5. It should be noted that in potash deficient areas it may be necessary to apply muriate of potash at these rates to sole cocoa planted under shade, particularly if the area has been used for gardening or other cropping.

Applying Fertilizers to Cocoa

Young seedlings should not require any special ground maintenance before fertilizing as it should be kept clean weeded at all times. Fertilizer should be scratched in around seedlings and cuttings up to 12 months old, taking care that fertilizer does not come in contact with the seedling.

Application of fertilizers to older trees should be preceded by close cutting of grass, if present. Exposing soil by removing leaf litter is not

Table 5.—Fertilizer rates for interplanted cocoa grown without shade additional to coconuts

Age of Cocoa	Fertilizer Rates		Remarks
	Urea per Tree	Muriate of Potash per Tree (2)	
3 months	½oz(1)	2oz	Cuttings and seedlings from nursery taken as 3 months old when field planted
6 months	½oz	—	
9 months	½oz	—	
12 months	1oz(1)	4oz	
15 months	1oz	—	
18 months	1oz	—	
21 months	2oz	—	
24 months	2oz(1)	4oz	
27 months	2oz	—	
30 months	2oz	—	
33 months	3oz	—	
36 months	3oz(1)	—	
39 months	3oz	½lb	
42 months	3oz	—	
45 months	4oz	—	
48 months	4oz(1)	¾lb	
Thereafter(3)	4 to 8oz	—	Every three months
Thereafter(3)	—	¾ to 1½	Every twelve months

(1) In areas of sulphur deficiency substitute ammonium sulphate or ammonium sulphate nitrate at double the above rates.

(2) Applies to areas where potash deficiencies occur.

(3) Rates will depend on number of cocoa trees to the area.

recommended. This can expose surface roots resulting in damage and is too labour-consuming.

After the tree ramifies, apply fertilizer uniformly to area covered by the canopy but again do not allow fertilizer to come in contact with tree. Once a complete canopy is formed, or nearly formed, fertilizer should be applied evenly over the whole block.

It is emphasised that fertilizers should be applied uniformly to the area covered by the canopy. It should not be applied in a narrow band or a heap as this will result in root damage and poor uptake.

Once the cocoa canopy is well developed tractor-drawn fertilizer spreaders, where they can be used, give good distribution and uniform application.

Interaction Between Shade, Spacing and Fertilizing

There is no doubt that there is an interaction between shade, spacing and fertilizing. No single trial to tie up these three factors has been completed under our conditions. The only trial laid down for this purpose was so severely affected by dieback that it had to be abandoned.

Taking into account the various trials already mentioned, reports on overseas research and personal observations, one cannot help but come to the conclusion that maximum yields per acre will be obtained by a combination of—

(*a*) close spacing within the limits already discussed;

(*b*) under light shade or no shade conditions once the cocoa canopy meets; and

(*c*) fertilizing according to soil type. Nitrogenous fertilizers certainly are essential eventually to maintain yields after shade has been drastically thinned or removed while 3-monthly application has been superior to 6-monthly application.

There are pitfalls associated with shade removal, as already mentioned, such as build-up of *Pansepta* and *Pantorhytes* infestations and where cocoa dieback occurs. If there is an awareness of these pitfalls and precautions are taken accordingly, cocoa can be expected to give good yields under these conditions.