

*INTERPLANTING IN TEA

1.—EFFECTS OF SHADE TREES, WEEDS, AND BUSH CROPS

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1. Introduction

As shade trees have been traditionally planted in tea for many years, it is no wonder that their uses have often been discussed in the recent past (Walter, 1950; Portsmouth, 1951; Eden, 1952) and are still a subject for discussion at this Conference in which Dr Joachim (1961) has preceded me. More stress has been laid on their advantages than on their disadvantages, though more recently Christie (1960) has expressed some doubts as to their usefulness.

Apart from the undeniable fact that the trees provide shade, much of what has been said about shade trees has been presumptive and biased by the concept that tea is a "shade-loving" plant. Therefore, it seemed that an approach which questions rather than accepts the desirability of interplanting tea with shade trees might be more fruitful.

The discussion in this paper will be restricted to soil moisture, the mobilisation of nutrients, the supply of organic material to the soil, and the effects of weeds and cover crops. The influence of shade *per se* and its interaction with fertiliser applications will be reviewed later.

2. Shade-Tree Effects

2.1. SOIL MOISTURE RELATIONS UNDER SHADE TREES

Do shade trees conserve moisture during drought conditions? Opinion among planters is divided on this question. It is true that, on the one hand, shade trees, if unlopped, will lower the transpiration rate of tea, but on the other they will transpire a considerable amount of water themselves, which may exceed the amount conserved indirectly. This aspect of shade trees has been mentioned by Joachim (1961), who also observed that *Gliricidia* and dadap trees conserved moisture during the beginning of a drought but adversely affected it when the drought was of prolonged duration.

In Nyasaland (Anon., 1960), soil-moisture determinations in unshaded tea and in tea shaded by *Grevillea robusta*, *Gliricidia maculata* and *Albizia gummifera* showed that there were only small differences in soil moisture in the first foot. Below 5 ft. the moisture available under *Grevillea* and *Gliricidia* was slightly less and that under *Albizia* markedly less than when no shade was present. Presumably, the water evaporated by the *Gliricidia* was nearly balanced by the saving in evaporation of the tea under the fairly heavy shade provided by *Gliricidia*. The more vigorously-growing *Albizia*, however, did not save as much moisture by shading the tea as it evaporated itself. Other data on soil-moisture effects of *Grevillea* and *Albizia* in coffee (Anon., 1960a) and *Grevillea* in tea in South India (De Jong, 1950)

showed that *Grevillea* competes less for moisture than *Albizia* does and may even conserve a little in tea.

Removal of foliage drastically curtails the moisture requirements of a tree. The magnitude of the reduction in water uptake is indicated by soil-moisture determinations done on pruned and unpruned tea during the dry season in Nyasaland (Anon., 1959, 1960). Clean pruning delayed the depletion of the moisture reserves to the wilting point by 6-10 weeks as compared with no pruning. The favourable effect of defoliation by pruning is also reflected in the subsequent death rates of young tea plants after drought: clean-pruned (6%), cut-across (14%), and unpruned (31%).

Trees that are lopped at the start of a drought use less moisture but of course they no longer provide shade. Leaves of tea exposed to full sun may heat up by 4°C (say 7°F) above air temperature (De Haan, 1938; Hanipi & Reesink, 1959). This can contribute to scorch of leaves. It has also been observed that tea pruned into the dry weather in Nyasaland recovered twice as quickly under shade as without shade (Child, 1960).

2.2. SHADE TREES AND THE NUTRITION OF TEA

It has been implied that shade trees assist the tea in obtaining extra minerals and nitrogen (Eden, 1952; Joachim, 1961). First, it is assumed that the shade trees have a more robust root system and can penetrate soil layers that are impervious to tea roots; and where the tree roots go the tea roots might follow. Second, it is assumed that the shade trees, by allegedly exploiting deeper soil layers, can bring up essential nutrients and deposit them on the soil surface in their leaf fall and loppings, and thus provide a valuable system of nutrient rotation.

Since these observations are based on speculations rather than on hard facts, they require closer scrutiny.

- (a) When the tea has been planted on forest land, shade trees are unlikely to be of any *further* assistance to root penetration, because the forest trees have already opened up the soil.
- (b) On the non-proven assumption that trees root more deeply than tea, it still remains questionable whether they would also effectively exploit the deeper soil layers. This would presume that mineral deposits are not exhausted there or are replenished by sufficient quantities of leached-down fertilisers.
- (c) There are no grounds for believing that shade trees are any better equipped than tea is to overcome those adverse conditions that limit root depth, such as water logging, lack of aeration, hard pans, etc.
- (d) When most of the nutrients are to be found and applied on the soil-surface layers, it is more than probable that the main feeding-root systems will be at the same depth for tea bushes and for shade trees.

As is shown by figures given by Joachim (1961), considerable amounts of N, P, K, and other elements are returned to the soil in the form of loppings, but these as well as the minerals locked up in the tree structure, are probably obtained in competition with the tea. This view is not held by Eden (1952), who states that the competition for nutrients by shade trees is not of great importance. His view

assumes that the nutrients locked up by the tree can be neglected and that, in case of leguminous shade trees, the net nutrient gain from nodule-fixed nitrogen is of some consequence.

Taking *nitrogen fixation* first, there is considerable doubt whether this occurs to any great extent under conditions of heavy nitrogen manuring. Greaves and Jones (1950) state that legumes feed preferably on available nitrogen and turn to atmospheric nitrogen only if soil nitrogen is reduced to a level where it cannot meet the needs of the plant. Pot experiments by Allos and Bartolomew (1955) with seven leguminous crops showed that manuring with sulphate of ammonia at equivalent rates of 0, 26, 52 and 75 lb. N/acre every ten weeks (sampling 6" deep) depressed the N-fixation on an average by 0, 34, 53 and 70% respectively. Although N-fixation was thus reduced, at the very high rate of manuring of 390 lb./acre/annum, it did occur to an extent of 30% of the maximum. Thornton (1947) showed that the amount of nitrogen fixed by two leguminous crops was inversely proportional to the amount of inorganic nitrogen supplied to the plant. Norman and Krampitz (1946) found that for the soya bean crop, fixation of atmospheric nitrogen did not amount to more than 30 to 40% of the total absorbed, if nitrogen is given in quantities about equal to or in excess of that absorbed. A similar phenomenon was observed for non-symbiotic nitrogen-fixing organisms, such as *Azotobacter*, of which the fixation was found to be suppressed at nitrate concentrations exceeding 28 to 42 lb N per acre (Delwiche & Wyler, 1956). It seems probable, therefore, that under conditions of generous nitrogen applications, as in Ceylon, leguminous shade trees may fix reduced but still significant amounts of atmospheric nitrogen.

When no manure is supplied, leguminous shade is certainly advantageous, as has been found by Dutta and his co-workers (1954, 1958, 1959) in an experiment on the long-term effects of seven different shade-tree species on the yield of unmanured tea.

TABLE 1.—Annual yield in lb made tea per acre (averaged over 10 years) of unmanured tea respectively unshaded and shaded by leguminous (*Albizia stipulata*) and non-leguminous (*Aleuritis montana*) trees

Unshaded (1)	<i>Aleuritis montana</i> (2)	<i>Albizia stipulata</i> (3)
970	1,000	1,170

The difference between (1) & (2) is not significant; between (1) & (3) and (2) and (3) it is significant for most years.

Table 1, from Dutta *et al*, shows that the tea shaded by a leguminous tree yielded annually 170 lb more tea than tea shaded by a non-leguminous tree of about equal vigour (height); the latter yielded about the same as unshaded tea. Thus, at least when tea is under-manured, leguminous shade trees are preferable to non-leguminous species.

With regard to the competition between shade trees and tea, for nutrients, we determined the total dry weight of two *Grevillea robusta* and two *Albizia moluccana* trees (age 8-12 years) growing in old tea, as well as the N, P, K contents of the different tree parts. Table 2 gives the dry-weight figures and amounts of N, P, K per acre, calculated on the basis of 35 *Albizia* (at 35 ft. square) or 60 *Grevillea* trees (at 29 ft. square) per acre.

TABLE 2.—Amounts of dry matter and N, P₂O₅ and K₂O in lb per acre provided by the various parts of *Grevillea robusta* and *Albizzia moluccana* trees (about 10 years old)

Tree part	<i>Grevillea</i>				<i>Albizzia</i>			
	Dry wt.	N	P ₂ O ₅	K ₂ O	Dry wt.	N	P ₂ O ₅	K ₂ O
Leaves & twigs	1,990	30.5	7.5	20.3	2,020	42.1	10.5	21.3
Branches	2,910	9.1	2.8	24.1	2,840	8.9	2.7	27.8
Trunks	12,000	37.4	15.6	71.7	20,200	64.3	16.5	77.4
Roots	4,960	15.6	6.0	40.4	9,020	28.2	11.8	59.3
Total:	21,860	92.6	31.9	156.5	34,080	143.5	41.5	185.8

Table 2 shows that considerable quantities of N, P, and K are present in the various tree parts, the greater portion of which is locked up in the permanent tree structure (branches, trunk, and roots). This averages 8 lb N, 3 lb P₂O₅ and 15 lb K₂O per annum per acre, which is possibly an under-estimate for these 8–12 year old trees, as Lamb, Portsmouth and Tolhurst (1955) estimated that *Albizzia sumatrana* trees (timber + roots) had taken up 83 lb N, 9 lb P₂O₅ and 174 lb K₂O per acre in three years after planting.

If it is assumed that the tea field from which the trees came, which yielded about 900 lb tea annually, was manured at the recommended ratio (Lamb *et al.*, 1955), it can be calculated that on an average 11% N, 8% P₂O₅ and 39% K₂O of the total amount applied had been immobilized by 10-year-old shade trees. These figures indicate that relatively small amounts of nitrogen and phosphate but a considerable amount of potash is more or less permanently removed from circulation by the trees.

A better insight into the nutrient balance of a tea field interplanted with shade trees is obtained when both losses and returns of nutrients are considered. For this purpose we made use of our own data, calculating losses (permanent tree structure) and returns (leaves + twigs) on an annual basis; the latter estimations were used in combination with the data given by Joachim (1961), on the assumption that usually two shade-tree species would be interplanted. Furthermore, use was made of data on the removal and returns of nutrients by made tea (Eden, 1949; Vermaat, 1950; Child, 1957), foliage (Eden, 1949; Tolhurst, 1960) and prunings (Eden, 1949). Lastly it was assumed (a) that 1,000 lb made tea was produced per acre per year; (b) that foliage and prunings amounted to 0.8 and 1.1 ton per acre annually (Visser, 1960); (c) that 1/3rd of green loppings constitute dry matter; and (d) that the tea was manured at the standard ratio of 8 lb N in T. 500 form per 100 lb tea (*see* Tables 3 and 4).

TABLE 3. Estimated annual nutrient balance of tea bushes and shade trees; dry weight in tons per acre, nutrients in lb per acre

LOSSES					RETURNS				
Due to	Dry wts.	N	P ₂ O ₅	K ₂ O	Due to	Dry wts.	N	P ₂ O ₅	K ₂ O
Made tea	0.45	38.0	7.4	19.2	Tea foliage + prunings	1.9	57.1	11.7	35.2
<i>Albizzia</i> Wood	1.4	10.1	3.1	16.5	Loppings of <i>Alb.</i> + <i>Glir.</i>	1.6	71.0	18.7	42.0
<i>Grevillea</i> Wood	0.5	6.2	2.4	18.6	Loppings of <i>Grev.</i> + <i>Dadaps</i>	1.4	61.5	13.5	37.3

TABLE 4. *Estimated differences between amounts of nutrients per acre applied as fertilizers and those removed annually by 1000 lb made tea, prunings, and an average stand of medium-age shade trees in lb per acre*

	1	2	3	4	5	6	7
Nutrients	Made tea	2/3rd of prunings	Wood of shade trees	Total taken up	Total applied	Balance of deficit	
N	38.0	15.8	8.2	62	79	+ 17 (22%)	
P ₂ O ₅	7.4	4.7	2.7	15	39	+ 24 (62%)	
K ₂ O	19.2	12.5	17.5	51	45	- 6 (13%)	

The main picture which emerges from Table 3 (left half) is that the shade trees take away as much potash as the tea flush does, but they take away much less phosphate (about 1/3rd) and nitrogen (about 1/5th) than tea does. In both cases these losses have to be made up by chemicals. These figures have a rough qualitative value only, as they do not take into account possible returns by the decomposition of tree roots nor the possibility that two tree species may be present, causing greater losses.

On the returns side (right half of Table 3) it would appear that tea bushes and a mixed stand of shade trees are similar in the amounts of N, P, K that they put back into circulation. Also, in this case, some reservations must be made. With regard to the tea, the quantities returned by prunings were included, but the bulk of these are often removed by the labourers. The returns by shade trees are obviously dependent on their spacing and age, and on the severity and frequency of lopping. It will be seen from Table 4 (columns 5, 6, 7) that, assuming no losses of fertilizer by leaching out of the soil, the nitrogen margin, though narrow, is positive and would be supplemented to some extent by fixation of leguminous shade trees; the amount of phosphate applied may be excessive; and the amount of potash taken away by shade trees is so large that it may be desirable to increase the amount of it in the mixture applied. These ideas are supported by unpublished partial correlations from twelve estates totalling over 10,000 acres for 1951-57: yield and N gives + 0.987; yield and K gives + 0.697; yield and P gives + 0.070.

Micronutrient (zinc, boron, manganese) turn-over has been dealt with by Tolhurst (1960), who showed that ample is returned in the tea foliage.

Finally, mention must be made of the fact that it has been found possible to obtain reasonably good yields of tea for a considerable length of time *without manuring*, but *with a good stand of shade trees*. Although this phenomenon will be extensively discussed in my second paper (Visser, 1961), it is opportune to state here that this has little to do with the alleged role of shade trees as providers of nutrients which the tea on its own cannot obtain, because similar effects are obtainable under artificial shade. According to figures quoted by Barua (1960) on five long-term field experiments, yield increases of between 38% and 135% have been recorded following the shading by bamboo screens of unmanured tea. These increases can be attributed to the effect of shade *per se*, which markedly reduces the nutrient requirements of the plants. However, it should be realised that the yield under shade with no manuring will be less, as is borne out by a shade-tree trial of Dutta and Heath (1954), which shows a drastic drop in yield after manuring was stopped.

2.3. SHADE TREES AND SOIL FERTILITY

Do shade trees substantially contribute to the nitrogen or organic matter status of the soil?

Sampling of unshaded tea and of tea shaded by *Albizia* in Nyasaland (Anon., 1955) showed that in one location unshaded soil contained 0.13% N as compared with 0.18% N for shaded tea soil. On other estates, no differences were found between soil shaded by *Grevillea* or *Albizia*, but N-contents were higher (by 10%) than where there was no shade, while organic matter percentages were about 20% higher.

Gokhale (1960) investigated total soil nitrogen contents of a 3-ft profile in unshaded tea and in tea shaded by *Albizia chinensis* (with N, P, K treatments). He found after 15 years continuous treatment that total nitrogen for the unshaded tea was only 5.5% lower than that of shaded tea. Other observations of Gokhale (1959, 1960) showed that manuring, especially with nitrogen, has a markedly favourable effect on the N-status of the soil. He found that unshaded and unmanured tea soil lost, over a period of 27 years since planting, 41% of its original nitrogen as compared with a loss of 27% for the same soil manured at a rate of 120 lb N (plus 60 lb P & K).

The approximate gain of 5% in soil nitrogen due to the presence of shade trees does not seem large, but on Gokhale's determinations (personal communication) may amount to as much as an annual fertiliser application of 40 lb N (plus 20 lb P & K). However, it should be kept in mind that in Assam both annual pruning and fish-leaf plucking are practiced, so that the contribution made by the tea to soil organic matter is much less than when pruning cycles are longer and plucking is less severe.

When the starting point of a plantation is a jungle soil, certain losses in nitrogen are unavoidable, because tea obviously cannot replace a forest, as is clearly illustrated by the findings of Tolhurst (1961). However, Gokhale's graphs show that generous nitrogen applications stabilise the N-content not only at a higher level, but also sooner than when little or no fertilizers are applied. Figures given by Eden (1947, 1949) on St Coombs soils indicate that if the soil is less fertile (as for example is the case with many patana soils in Ceylon) tea cultivation may even significantly improve the soil nitrogen and organic matter contents.

It should be understood that loppings from shade trees are not the only source of organic material in the soil. Both natural leaf fall and the foliage from prunings of the tea itself contribute substantial amounts, which may be of the order of several tons per acre annually (Eden, 1937; Goodchild & Foster-Barham, 1958; Visser, 1960). Accordingly the maintenance of a reasonable level of organic matter in the soil will depend very much on factors other than the presence or absence of shade trees, such as planting density, vigour of the bushes, manuring policy, pruning frequency and method, and plucking method. Since the contribution to organic matter by loppings from trees will also depend on many factors, such as tree species, lopping policy, and planting density, no general statement can be made regarding the relative contributions of the tea and the shade trees.

In those instances where the soil is properly covered by tea bushes, the question arises whether the mulch provided by the shade trees has any significant effect on tea production. Although no direct answer can be given to this question, some data derived from literature give an indication of the function of shade trees in this respect. At Kericho in East Africa, the effect of the removal of leaf droppings was investigated in a shaded experiment (Goodchild & Foster-Barham, 1958, 1959, 1960). It was found that the yield of plots (averaging 1,200 lb/acre), from which the leaf mulch was removed, decreased significantly, but the loss amounted to only 5% over a period of 3 years. At the same location, the influence of an added dosage of mulch was investigated in a factorial experiment on shaded tea (Eden, 1952, 1953,

1954) and in one on unshaded tea (Goodchild, 1955, 1956; Goodchild & Foster-Barham, 1957). A summary of the overall effects of mulch derived from the figures given, is presented in Table 5.

TABLE 5.—*The overall effect of the application of mulch at the rate of 15 tons per acre per year on the annual yield, in lb per acre (average of a 4-year pruning cycle), of shaded and unshaded tea*

	With mulch	Without mulch	Gain due to mulch
Shaded tea	1058	1052	+ 6(0.3%)
Unshaded tea	1226	1196	+ 30(2.5%)

It will be seen from Table 5 that the application of mulch over a 4-year pruning cycle had no appreciable effect on yield, irrespective of the presence or absence of shade trees.

Although the trials were not directly comparable and interactions with fertilizer applications and long-term effects have to be taken into account, it would seem from these three trials that in the case of tea which (judged by its yield) provided a good cover, shade trees did not provide much additional advantage as far as soil condition is concerned.

Apparently, the contribution made by the tea bushes themselves is the deciding factor, as can be seen from observations made by Dutta (1960). These showed that the continued removal of prunings from mature tea over a period of 8 years led to an average annual loss of 290 lb of made tea (25% loss) and a depression of the N-content of the soil. Figures given by Wight (1959) indicate that the presence of shade trees does little to counteract the yield decrease caused by removal of prunings. It appears, namely, that the removal of prunings over a 5-year period depressed the yield of shaded tea on an average by 34% and that of unshaded tea by 39%.

These losses are very high indeed and can be mainly attributed to the recurring lack of soil protection (annual pruning). This effect is aggravated by the practice of fish-leaf plucking in North India, which—though not immediately harming the bush—must mean that after the removal of prunings, the soil under the tea will have much less mulch from the tea itself (Visser, 1960) for a considerable period during the dry season. On many estates in Ceylon, where the pruning wood but not the twigs and foliage are removed by labourers, such removal is likely to affect yields much less when plucking cycles are reasonably long, when the bushes are single-leaf plucked for the greater part of their cycle, and when the tea provides a complete cover and is well manured.

In conclusion it can be said that the mulch provided by the shade trees is likely to have a favourable effect on the soil, but that the magnitude of such an effect will probably be small under conditions where the tea is generously manured, grows vigorously, and gives sufficient soil protection. On the other hand, where the cover provided by the tea is inadequate, shade trees constitute a definite advantage because of their direct and indirect beneficial influence on the soil.

2.4 THE INFLUENCE OF SHADE TREES ON DISEASES AND PESTS

Shade trees can influence the incidence of diseases and pests.

Well known is their indirect effect on Blister Blight. For instance, during the rainy season of 1958 it was found at St Coombs that the infection on an exposed unshaded field amounted on an average to 14% as compared with 42% on a sheltered shaded field (Visser, Shanmuganathan & Sabanayagam, 1961). The absence of shade trees would certainly reduce the incidence of Blister Blight and increase the effectiveness of a control system based on sunshine recordings.

More recently, indications have been obtained that *Albizzia moluccana* may be a source of the infestation of the tea by Shot-hole Borer, as it has been found that this beetle, which infests this tree species rather heavily in comparison with other trees (Judenko, 1960), can also breed in tea (Judenko, 1960a).

Shade trees that are infested by the same nematodes as tea might contribute to their spread. Fortunately, none of the more common shade-tree species appears to be a congenial host for Meadow Eelworm; the susceptibility of some, notably dadap, to Rootknot Eelworm is not such a danger, as this species affects only very young tea plants (Visser, 1959).

Mites on the other hand are often favoured by the absence of shade; and shade removal in the case of orange mite in Indonesia has been found to contribute significantly to the seriousness of mite attacks (De Weille, 1959).

These few examples may serve as a reminder that shade trees may be both disadvantageous and advantageous in connection with pests and diseases, though we do not know where the balance of advantage may lie.

3. The Effect of Weeds on Established Tea

On many estates in Ceylon, clean weeding is practised as a regular routine, mainly because it is feared that harmful species, particularly grasses, might become established, resulting in loss of crop.

Trials on the effects of various kinds of weeding on yields of tea have been done in India (Dutta, Basu & Sharma, 1959; Dutta *et al.* 1960), in Nyasaland (Anon., 1946, 1947, 1948, 1949, 1951, 1952, 1953, 1954, 1957) and in Ceylon (Eden, 1944, 1948; Portsmouth, 1952; Kehl & Piyasena, 1956). In cases where there is reason to believe that the soil was not thoroughly covered by the tea, weeding increased yield by over 30%, indicating that weeds could compete seriously with immature tea. With a good cover of tea, which depresses weed growth, differences between weeded and unweeded tea were much smaller and appeared to depend on the method of removal and disposal of the weeds. But the planting of Seychelles grass (*Panicum umbellaticum*) had an adverse effect (25%), probably because it grew well even in the shade of the tea. The adverse effects of root disturbance and of soil erosion, when weeding is done with a tool, may be almost as great as the adverse effects of weed competition, or at any rate, they complicate interpretation of the experiments.

4. The Effect of Bush Crops on Young Plants

Bush crops are often planted in young tea in order to provide both shade and loppings for thatching. It will be useful to consider, on the strength of the known facts, whether this is a good practice or a bad one.

Of interest in this connection is a trial carried out at Bvumbwe in Nyasaland on young coffee (planted in 1953) and which comprised 4 treatments: (a) no shade

and mulched with grass; (b) interplanted with *Sesbania punctata* (18 ft. square) with mulch; (c) coffee grown under tall bananas; and (d) *Sesbania* without mulch. The *Sesbania* and bananas were removed in 1956 and 1957 respectively and replaced by shade trees and mulch (Anon., 1955a, 1956a, 1957a, 1958, 1959a, 1960a).

TABLE 6.—The effect of mulching and bush crops on growth, soil moisture status, and annual yield of young coffee in lb per acre (average of 3 years cropping)

1	2	3	4	5
Treatments 1953/55	Treatments 1956/59	Girth '55 in cm.	Moisture '55 in %	Yield 1957/59
Mulch, no shade	Same	2.65	16.5	1176
<i>Sesbania</i> & mulch	<i>Albizia</i> & mulch	1.64	13.9	504
Bananas, mulch of stems	<i>Grevillea</i> & mulch	1.85	10.0	347
<i>Sesbania</i> , no mulch	<i>Albizia</i> & mulch	1.56	8.6	336

The outcome of this trial, presented in Table 6, clearly shows the marked detrimental effect of *Sesbania* and of bananas on tree growth (column 3). This effect, as judged by the yields (column 5) persisted after these plants were removed and replaced by shade trees and the soil was mulched. The depressed yield was not due to subsequent planting of shade trees, because in a parallel trial (Anon., 1960a) in which coffee was directly planted under *Albizia*, differences between unshaded and shaded plots were negligible. As there were no significant interactions between treatments and manuring during the early years, it is evident that the set-back in tree growth had been mainly due to the adverse effect of the original crops on soil moisture availability (column 4).

Trials were also carried out in Nyasaland on the effect of different treatments on the establishment of young tea in the field. Comparisons were made between the performance of young plants protected by open-collared earthenware pots and shaded by *Tephrosia vogelii*, with and without a starter fertilizer (Anon., 1955, 1956, 1957). These trials were done at two locations and in three successive years; they showed that the number of deaths recorded a year after planting was on the average nearly twice as high under *Tephrosia* as with the plants protected by pots, namely 28.6 versus 15.6%; prunings obtained from the surviving plants 12 to 16 months after planting averaged 218 and 745 lb respectively.

TABLE 7.—The effects of shade and starter fertilizer (1 oz at planting) on the prunings of young tea plants, in lb fresh weight

Treatment	Without fertilizer	With fertilizer	Increase due to manuring
Protected by pots	389	699	310 (80%)
Shaded by <i>Tephrosia</i>	215	329	114 (50%)

It is evident both from the quoted figures and from Table 7 that *Tephrosia*, compared with the plants sheltered by open pots, had a markedly detrimental effect

on survival and growth of the young plants. The bush crop also depressed the effect of the starter fertiliser.

Results similar to those obtained in Nyasaland were found in a trial carried out in Ceylon by Kehl (Visser, 1960) on the effects of *Crotalaria anagyroides* and *Stylosanthus gracilis* on young tea.

TABLE 8.—The influence of cover and bush crops on the survival and growth of young tea plants one year after planting (from Visser, 1960)

TREATMENTS	% dead	Average girth in cm.	Mean no. of leaves per plant
(a) No shade	12.5	1.29	222
(b) Fern	0	1.52	285
(c) <i>Crotalaria</i> in alternate rows—lopped	17.5	1.03	154
(d) <i>Crotalaria</i> in both rows—lopped	3.0	1.05	188
(e) <i>Crotalaria</i> in alternate rows—unlopped	37.5	1.04	147
(f) <i>Stylosanthus</i> in alternate rows	35.0	0.82	83
(g) <i>Stylosanthus</i> in both rows... ..	52.0	0.69	55
(h) <i>Stylosanthus</i> and <i>Crotalaria</i> in alternate rows	37.5	0.85	87

It can be seen from Table 8 that, as in Nyasaland, the best results were obtained in the absence of a cover crop with no shade at all, or better still, with plants protected by fern. *Crotalaria* in alternate rows or in both rows, whether lopped or not (loppings used as thatch), depressed growth; *Stylosanthus* was even more detrimental. Presumably, *Stylosanthus*—though lopped around the plants—is particularly harmful as it depletes soil moisture. Determinations in Nyasaland in pruned tea showed that the soil with *Stylosanthus* as a cover crop started to dry out two months earlier and stayed near the wilting point for one to two months longer than clean-weeded soil (Anon., 1959).

Thus the use of cover and bush crops for the establishment of young plants in the field cannot be recommended. The best results are obtainable by thatching the soil and lightly shading the plants with fern, pots, or baskets.

5. Summary and Conclusions

A review of the effects of shade trees, weeds, and bush crops, on soil moisture and nutrient relations and the performance of tea has led to the following observations.

(1) It is improbable that shade trees assist in conserving soil moisture; they are more likely to compete for it. The degree of competition depends on the species, age, and spacing of the trees and can be greatly reduced by lopping. But lopping removes the shade.

(2) Shade trees are not likely to play a significant part in the root penetration of tea planted in forest clearings, nor is it certain that they would be of greater importance in that respect under different conditions of land.

(3) It is not proven that shade trees substantially assist tea in providing it with nutrients which it cannot obtain for itself; the effective root depths of tea may not differ greatly from those of trees.

(4) Competition for nutrients between shade trees and the tea occur. Although much of the nutrient is returned to the soil by the shade trees, some (especially potash) is locked up and removed in the timber. The amounts of nutrients returned to the soil as organic material by the tea itself are of the same order as those returned by foliage of shade trees.

(5) Estimates of the returns and losses of nutrients in tea which is inter-planted with shade trees suggest that the quantity of fertilisers applied at the 8 lb ratio may be deficient for potash, near-marginal for nitrogen, and ample for phosphate.

(6) Some leguminous plants fix atmospheric nitrogen, which subsequently becomes available to surrounding plants, especially through leaf fall. But the richer the soil already is in nitrogen, the less active this nitrogen fixation process becomes. Nevertheless some fixation still occurs in soil that is well supplied with inorganic nitrogen.

(7) There are indications that shade trees are not essential to maintain soil fertility under a good stand of tea. Soil fertility would seem to depend mainly on manuring rates and the condition of the tea itself, especially with regard to the direct soil cover it provides and the contribution it makes to mulch in terms of leaf fall and prunings. The presence of shade trees is desirable if the tea provides an unsatisfactory cover and if soil fertility is low.

(8) The presence of shade trees effects the incidence of diseases and pest, in certain instances favourably, in others adversely.

(9) The presence of weeds in mature tea can significantly reduce yield, but losses in crop may be small or negligible, provided the tea covers the soil well and outstandingly obnoxious weeds are kept out; under such conditions undue cultivation may do more harm than good. On steep slopes or in a poor stand of tea, weeds are to be preferred to soil erosion.

(10) Cover and bush crops in young tea are detrimental and therefore not to be recommended. Thatching of the bare soil should be a standard practice in order to reduce soil exposure and loss of moisture to a minimum; light shading of the plants in the early stages is also commendable.

(11) More scientific data are needed on the root growth of tea and shade trees, on the nutrient balance of inter-planted tea, and on soil moisture and organic matter relations.

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Question—Anon.

In very poor areas subject to recurrent drought would you recommend the planting of shade trees such as *Grevillea*, *Albizzia*, dadap and *Gliricidia*?

Dr Joachim: Dr Visser may not recommend such shade trees in these circumstances, but personally I would do so. Where the shade trees are rather dense, particularly with medium shade, it is better not to lop all of them at one time, but to lop alternate trees in the area and leave the loppings as a mulch.

Dr Visser: As has already been pointed out, Dr Joachim and I have deliberately arranged to give different points of view, to show how confused the position is and how uncertain is our information about shade. But Superintendents have to make practical decisions—to do nothing is still effectively the result of a decision—and so our different opinions may help them. Our intention has not been this, however, but to stimulate re-thinking, discussion and experiment. I do not want at this stage to discuss poor areas, areas with low soil fertility, because I shall deal with that in my next paper. But I can express an opinion on shade in very young tea. I would not plant shade trees but I would thatch the ground, and if I could, I would give temporary, non-rooted, shade to my young plants with fern or baskets. Mr Nelson Parker told me of a cheap and effective method: after having taken out the Guatemala grass, you then put up a few stalks of the grass over the plant to break the wind.

Question—Mr G. H. Hartley, Morratenne, Mawatagama.

Dr Haworth once suggested as a private opinion, that it would be better to remove all shade trees, and instead uproot 10 to 20 rows of tea per 100 rows, and plant this area up in Guatemala grass, using this as a thatch. Do Drs Visser and Joachim agree with this?

Dr Visser: If we could sell Guatemala grass as well as we can sell tea, it would be an excellent proposition. If thatch is badly needed then it would be better to uproot patches of the worst tea, for example eelworm patches, rather than uproot at regular intervals irrespective of the health of the bushes. But both tea and

Guatemala grass must be competing with the neighbouring tea for water and nutrients. There are cases in which interplanting might pay, but it would be most unwise to put forward a general rule for all circumstances.

Question—Mr C. B. Perera, S.D., Mahacoodagalla Estate.

(1) Is not the ultimate quantity of nitrogen in organic matter derived from the decomposition of woody material greater than the nitrogen used by such woody material in the process of decomposition?

(2) If it is, is it not advisable to fork in prunings?

Dr Joachim: I think Dr Eden did some work on St Coombs some years ago, and in some instances there was a loss, and in other instances there was a gain of nitrogen. When the material has totally decomposed there will be a gain. But during the process of decay there may be a severe drain on nitrogen in the soil, a severe shortage for roots in the neighbourhood, such as you get with any undecomposed organic matter in quantity.

Question—Mr Burroughs, Dyraaba Estate.

In areas affected by frequent drought and wind, casualties and damage are often attributed to scorch. Would Dr Visser advocate the maintenance of medium shade and wind breaks planted in tea in such areas?

Question—Mr Victor Ratnayake, Deniyaya.

If you were to recommend total removal of shade, would there not be a loss of crop due to heavy seasonal wind damage?

Dr Visser: I would first ask what is sun scorch due to? I strongly suspect that it is not simply due to heating up by the sun, uncomplicated by anything else. For example, the soil may be depleted of water by numbers of shade trees which are sufficient to do this but insufficient to give shade to certain of the bushes; wilting may then occur prematurely and perhaps wilted leaves will scorch more readily. But it is a well-known fact that certain deficiencies in manuring show up when the bush is under stress—especially shortage of water. It is also known that unshaded tea requires more nitrogen applied as fertiliser. It is thus possible that so-called sun scorch is partly due to lack of manure.

I cannot say much about sun scorch of bark. But if there is such an uncomplicated effect of the sun on pruned wood, it is a little surprising to see dry-season pruning of the tea accompanied by total lopping of the shade trees. Do estates that follow this practice get a lot of scorch? Or is it only when there are other deficiencies that even bark scorch occurs?

As for wind, does the regularly planted shade that is so common act as an effective wind break? Or would belts of trees—such as you see in Nuwara Eliya—break the wind more effectively, without competing with so many of the tea bushes?

Question—Mr K. D. Seelanatha, Matale West Estate.

Is inoculation of soils around leguminous shade trees with *Azotobacter* likely to increase nodulation?

Dr Joachim: As Dr Visser said, and I said, we do not yet know what useful function a leguminous plant plays in respect of nitrogen fixation under our acid-soil and high manuring conditions. Whether inoculation of soil with the necessary bacteria, as practised in temperate countries, would be beneficial or not we cannot say. That is one reason why I suggested in my talk that the appointment of a micro-biologist who would study these matters would be very advantageous.

Question—Mr C. B. Perera, S.D., Mahacoodagalla Estate.

Quite apart from the merits and demerits of forking in prunings, is it not beneficial to leave behind prunings in the field? As prunings are inevitably removed by labour for domestic use, is it not advisable to fork in prunings at least with a view to retaining the prunings in the field?

Dr Visser: It is quite clear that leaves of the prunings must be left amongst the tea. The wood of the prunings may be another matter, for it may be necessary for your labour to have it for fuel. But the prunings must be left until the leaves have dried and fallen off. In any case, forking in the wood of prunings on a healthy field in such a way that they cannot readily be pulled out, must cause quite a lot—possibly too much—disturbance to the tea roots.

Question—Mr Frank de Silva, Epalawa Estate, Kegalle.

Can wilting of tea be prevented during dry weather without high shade?

Director: There are two kinds of wilting of course: there is the temporary wilting which is the plant's form of protection against excessive water loss in times of shortage; and there is permanent, irreversible, wilting which results in the leaves dying. I don't know whether it would be a good thing to prevent wilting altogether. The question of protecting plants, tea plants, from wilting by using high shade is, to my mind, an unsettled one, for high shade is using water from the soil—water which should otherwise be available to the tea. Not only during the time of stress in very dry weather, but also in the dry period leading up to that dry weather, water is being taken up by the trees, and the time when permanent wilting may occur may be brought nearer by the trees in certain circumstances, and I think it remains to be determined exactly where the balance of advantage lies.

There is one thing which is becoming clear from work all over the world, arising from the work of Penman at Rothamsted, that if you have an acre which is completely covered by green vegetation, and if the soil has sufficient water in it, then the amount of water evaporated does not depend much, if at all, on the nature of the vegetation; that is to say, the shade trees do not save water, some of which will be lost from them instead of from the tea. Your trees are not economising water for you at all. Indeed, high shade forming a second layer of vegetation, might increase losses a little. If the tree roots do go deeper, they are perhaps taking water from the deeper layers, perhaps from the same layers as the tea; they may well be reducing the store of water which the tea could use and the time will then be nearer at which the leaves will wilt, heat up in the sunshine, and perhaps scorch. I do not know if our two experts—I am not an expert on this, of course—will think that there may be something in that—nothing for nothing, take what you want, but you will have to pay for it somehow.

While other questions are coming in, there is a remark which I would like to make. I want to draw a contrast between the work of Mr Foster-Barham and the discussions that we have been having, for example, about shade trees. Mr Foster-Barham has a most responsible advisory job which he discharges in a responsible

way; he realises that when he gives advice, people will usually take it. It is his job to see that no recommendation that is dangerous is made. When he is in doubt he says so. On the shade-tree question, however, we have introduced you to a controversial question that is under discussion, and we are not at present making recommendations except on the classical method, in which the judgement about shade trees is an art, and not a science. It is the art which is practised by Superintendents, Visiting Agents and, to some extent, by the T.R.I. So that distinction should be very clear. *Recommendations*, on the one hand, responsible and careful; and on the other hand *scientific discussion* of a subject which is in its infancy.

Mr Foster-Barham rather slurred over what seems to be an important fact about advisory work—the difference between an optimist and a pessimist is that the optimist says that the whisky bottle is half full, and pessimist says that it is half empty. Two-thirds of the estates of substantial size in this country have consulted the T.R.I. in the last few years. That I think is a very significant fact; it may also be of pessimistic significance that we haven't heard from the one-third of them for quite a long time.

Director: There are a number of questions about differences between the low-country and other parts of the island in respect of tea, with a long one here from Mr Frank de Silva of Epalawa, Kegalle, regarding shade. It is to be expected that in the low-country things will not be the same as in the high-country; more than that, they may vary as greatly in some respects within the low-country as they differ between low and high. One question is very much to the point: "Is it not likely that the problem is not so much shade or no shade as the correct control of shade?" No doubt that is the right question in many circumstances. Perhaps the most pertinent question at this time is this: Since Dr Visser quotes Tocklai in his tables, and we have here Mr Gokhale from Tocklai, is it not appropriate to ask Mr Gokhale to come and talk?

Mr Gokhale: Well, Gentlemen, when I was sent here, my Chairman told me to come and learn, and not to talk at all. However, since certain data from Tocklai have been quoted, I think I should clarify what we mean by shade, and the conditions under which the experiment is carried out at Tocklai are entirely different from what you are discussing here, and you should keep that in mind. Shade itself from sau trees, or similar trees that we use in North East India, does give us a response which is something of the order of that obtained from about 80 lb. of nitrogen. Actually we have figures from different experiments which range from about 30 and up to 90 or even 100 as Dr Visser said. That is quite true. In addition the kind of tea also makes a difference. You do not get response to nitrogen with all kinds of tea. Just as you are having a controversial conference here, we had one about ten years ago when Dr Wight propounded a theory that in the case of certain agrotypes the application of nitrogen does not pay at all under shade. I believe in that theory. The trouble is one does not know how to find out which kinds of tea do or do not respond. It is not so simple as that. The tea of commerce is a mixed hybrid, and to classify it under field conditions over six hundred thousand acres is not an easy thing at all. And in practice it is jolly difficult to tell in advance, or merely from paper records, whether or not a given section of tea will, or will not, respond to nitrogen under shade. The only way of course is to carry out a field trial. We are carrying out a large number of field trials, and I can assure you that, so far at least, I have not seen any instance where tea has not responded to nitrogen under shade. We are still searching for such areas, and I dare say we shall be able to save on our nitrogen in some manner, but at the moment our recommendation definitely is to apply nitrogen under shade, but of course lower doses

than we would apply either with no shade or with poorer shade. Dr Visser quotes data from two of my studies which suggests that the effect was only 5% of the soil nitrogen status. That is quite true. That result was obtained in Borbhetta Area 5. It is an experiment where half the plots are shaded and half the plots are not shaded. He also quotes data from some other trial which is totally unshaded and has been so for the last thirty years. Now the rate at which soil nitrogen drops there with time, which is rather a different thing, is quite staggering and in the case of the unmanured plots we found that the soil nitrogen had dropped by about 41% over a period of 26 years; but where fertiliser was applied—in this instance an N.P.K. mixture 2: 1: 1—the nitrogen loss was lower. That means the soil nitrogen benefited by inorganic N.P.K. application, but if you look at the data carefully (I have the results of this which I shall hand over to Dr Visser) you will find that at the end of 15 years from this unshaded tea experiment the difference between the manured plots and the control plots is in agreement with a previous figure which is, namely, that shade increased soil nitrogen by about 5% at the end of 15 years in Area 5. In this Area 43, inorganic applications of N.P.K. mixture at the rate of approximately 60 lb. or thereabouts also increased soil nitrogen by about 5% at the end of 15 years. The point I am driving at is that shade does give you higher yield at very much lower cost under our conditions. Now, is it wise to forego that crop and would it pay more to spend money on fertilisers rather than on shade trees? Under our conditions we do not think so; but of course under your conditions it is a totally different matter and I would not like to express any opinion on that, and, I gather, neither does Dr Visser. It all boils down to this; you must carry out more trials. We will be very pleased to keep in touch with your work and will be most interested in it.

Director: I want to emphasise one point: what Mr Gokhale described as being good shade is where all the tea bushes are more or less equally shaded with the kind of reticulum of shade; in the high country of Ceylon that is very seldom the case. In many fields some of the tea bushes are not shaded at any time of the day, and in most fields most of the bushes are in full sunlight for a large part of the day. The dense shade often seen in the low country is hardly ever seen higher up. Assam is more like our low country and practises shading in a big way.

Dr Visser: Well, Gentlemen, I am glad that Mr Gokhale made the position of Tocklai very clear because, even if I have quoted the figures in a biased way, Mr Gokhale has been too polite to say so. We must say this: that we have to admit that we have no shade trials—it is not your fault and it is perhaps not our fault either—but it is a fact. Tocklai started thirty years ago with trials on shade trees and screens and they have amassed a large amount of information. We should now go ahead as fast as possible. After all we have doubled our yields in twenty years and wish to do so again.

Director: Mr Creighton says that the main effect of these papers and the discussions has been to make everybody completely confused and the lesson of that is that we want more experiments in various conditions in Ceylon. I think everybody will agree with that. There are, however, two remaining questions which I might combine to end the discussion. One is, does not removal of shade give increased yield on the short term? Is not the immediate effect of removing shade, without changing your manuring programme, to increase yields? The second question is: In a particular tea area due for uprooting, how soon before uprooting begins do you recommend the removal of shade *in toto*?

I think it is the general experience of planters who have removed shade completely either on fields, or on a whole estate that, for the first year or two in the up-country, and parts of the mid-country, there is a big rise in crop; in the third year the crop falls almost catastrophically below the original level. That is to say, if you

are going to uproot the tea for replanting, it is worth while not only doing slaughter plucking and getting extra crop from that, but also getting your shade trees out a year or two before the uprooting of the tea is to begin and get a little contribution towards your replanting. It must be recognised, of course, that the crop comes from somewhere. I suppose the decaying root systems of the trees provide the nutrients, and if we take them off in increased crop before uprooting, we shall have to re-supply as inorganic fertilisers during rehabilitation under grass.