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Effect of pollarding frequency on biomass of *Erythrina poeppigiana* as a coffee shade tree*

RICARDO O. RUSSO and GERARDO BUDOWSKI

Department of Renewal Natural Resources, CATIE, Turrialba, Costa Rica

Key words: agroforestry, biomass production, coffee shade, *Erythrina*, pollarding, shade trees

Abstract. The use of pollarded *Erythrina poeppigiana* as shade tree in coffee plantations is apparently an old practice in Costa Rica. The tree is not native to this country but was introduced between late 19th and 20th century and was rapidly dispersed in the coffee and cacao areas. Currently, the *Erythrina* tree is widespread in the Turrialba Valley (elevation 600–1300 m) and in the Central Valley (elevation 1200 m) where the species is always associated with present or past coffee crops. Pollarding carried out by Costa Rican farmers constitutes a long dated and functional practice, hence the objective of this study was to evaluate the amount of biomass produced by pollarding of *Erythrina poeppigiana* used as shade in coffee crop planted at a density of 280 trees/hectare under different pollarding frequencies. Results showed that by pollarding once a year, 18,470 kg of dry matter per hectare are produced; with two pollardings per year 11,800 kg/ha are produced and with three pollardings per year 7,850 kg/ha are produced. The total amount of nitrogen removed is very similar for pollarding once and twice a year, but is lower for three times a year. The amount of nitrogen removed was approximately 230 kg/ha/year in the first two cases and 170 kg/ha/year in the last one.

The above observations suggest that a considerable supply of nutrients exist in the systems with shade trees, when they are periodically pollarded.

Finally some conclusions and follow up activities related to research on the species are suggested, such as higher biomass production techniques, appropriate planting practices, selection of genetic material, nutrient depletion when biomass is harvested, conversion of leaves to marketable feed sources (flour, pellets), alley cropping and green manure production and restoration of degraded areas and improductive savannas by planting large cuttings that would improve the soil by adding biomass and shade out undesirable grasses.

Introduction

Erythrina poeppigiana (Walpers) O.F. Cook is native of the Tropical Andean foothills and its distribution goes from Peru, Brazil, Venezuela up to Panama; it has been used as a shade tree since the last part of the 19th century (Cook, 1901) in Puerto Rico and other countries. However in Costa Rica, its use was reported only at the beginning of the 20th century (Fonseca, 1968). The use of the species as a shade tree in cacao is also common in the moist lowlands

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of Costa Rica. Another similar species, *Erythrina fusca* (*E. glauca*) is also commonly used as shade for coffee and cacao, the latter particularly in Mexico.

Currently, *Erythrina poeppigiana* trees are extremely widespread in the Turrialba Valley (elevation 600–1300 m) and in the Central Valley (elevation 1200 m), where the species is almost always associated with present or past coffee crops (Photos 1, 3 and 4). It is most conspicuous during the relatively moderate dry season (January to March) when the orange flowers cover the crown profusely. In these regions the farmers usually reproduce the trees between the coffee bushes, using large cuttings from branches (2.5 m long) planted at distances varying between 6 and 10 meters. The trees are pollarded once or, more commonly, twice a year (Beer et al., 1981; Budowski, 1982). The first pollarding takes place in December-January and the second in July or August.

The objective of the study was to evaluate the amount of biomass produced by pollarding *Erythrina poeppigiana* used as shade in coffee crop under different pollarding frequencies.

Materials and methods

Study area

Location. A coffee plantation shaded by *Erythrina poeppigiana* trees (poró) on the property of the Tropical Agricultural Center for Research and Training (known as CATIE in Spanish), Turrialba, Costa Rica (N 9° 53′, W 83° 40′, 602 m elevation above sea level), was chosen, for the experimental site because it had the following desirable characteristics: (1) the shade trees were relatively uniform; they were 9 years old, planted at the same time by seedlings in May, 1974 at a density of 280 trees/ha, at a spacing of 6 m x 6 m; all data from the present study were taken between September 1981 and September 1983; (2) the coffee plantation was established very recently, in 1980, at a density of 4,300 plants/ha with *Coffea arabica* var *Caturra*, and displayed a very uniform appearance; (3) the topography is level and uniform; (4) the coffee plantation is a commercial one managed and harvested according to local practices; it was never used as an experimental plot; and (5) it was conveniently located close to CATIE's headquarters, allowing careful supervision. The site is at an altitude of 610 meters above sea level, near the new Library Building of CATIE (see Figure 1).

Soils. The experimental site falls within an area of alluvial soils, which was classified as a Typic Dystropept of the Order Inceptisols, series 'La Margot, normal phase' by Aguirre (1971). The texture is clay to clayloam; the pH is 4.6; organic matter content is high, ranging between 6.7 and 72.%; total N content varies between 0.25 and 0.43%; P between 17 and 35 ug/ml; and exchangeable K from 0.45 to 0.65 meq/100 ml of soil.

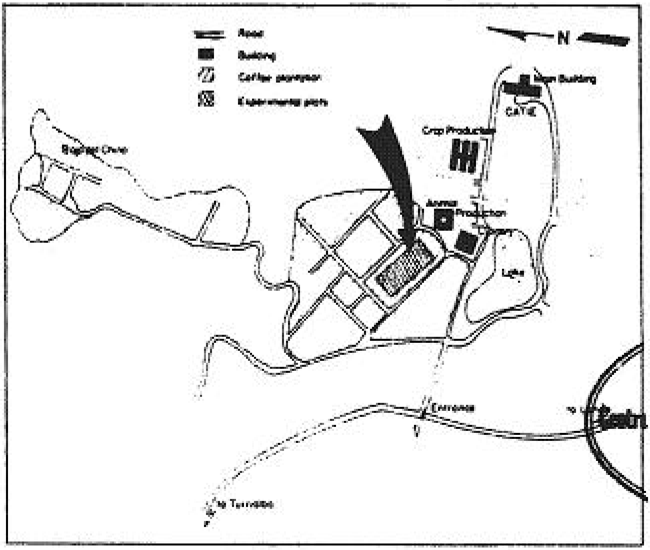

Figure 1. Location of the experimental plots in the CATIE coffee plantations. Turrialba, Costa Rica.

Available nutrients in the soil are considered low to medium in comparison with agricultural soils of Costa Rica (Hardy and Bazan, 1961; Martini, 1969). Soil organic matter, cation exchange capacity, and nitrogen are all high, presumably due to inputs of biomass from the periodic pollarding (lopping of branches) of *Erythrina* trees. Physical structure of the soil is good, and water retention is moderate, despite the high clay content (Gavande 1968; Ives, 1951). Though the soil is of moderate fertility, several factors suggest that it is highly weathered.

Climate. Temperature, precipitation and evaporation are presented in Figure 2.

Recently analyzed climatological data from the meterological station at CATIE (300 meters East of the site) are summarized as follows: mean annual temperature (1945–1983) is 21.7°C. Mean monthly maximum and minimum temperatures are 26.9°C. and 17.8°C., respectively: mean annual precipitation (1944–1983) is 2,637 mm; average relatively humidity is 87.5%; annual evaporation (tank A) is 1.194 mm; and average daily sunshine is 4.52 h.

Morrison and León (1951) describe four seasons, two of heavy rain (June–July, November–December), one of slightly less [illegible] (Augu[illegible]

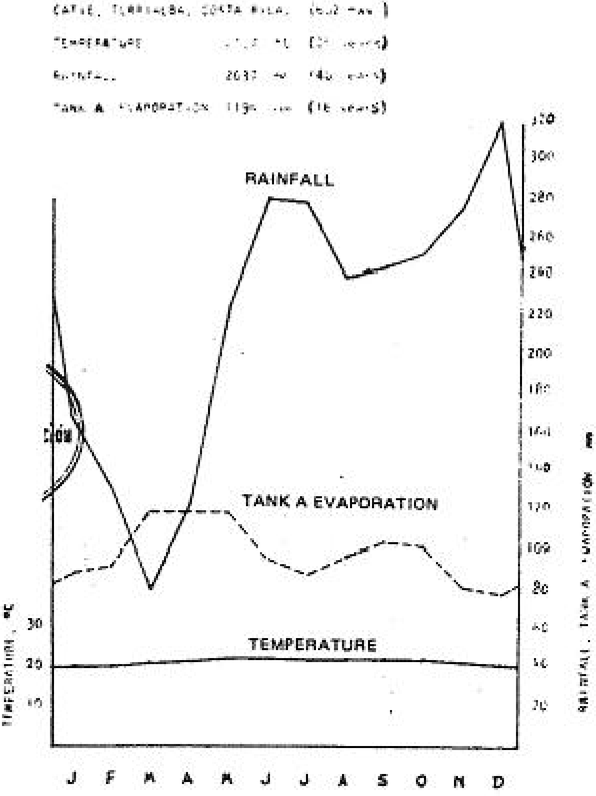

Figure 2. Climatological diagram considering temperature, rainfall, and tank A evaporation at CATIE, Turrialba, Costa Rica, Source: Data from CATIE meteorological station.

and one of 'distinctly less' rain (January –April). The last is commonly referred to as the dry season or summer ('Verano' in Spanish) and is characterized, at least for March and portions of February to April, by an excess of evaporation over precipitation. During the rest of the year, precipitation exceeds evaporation (Budowski and Schreuder, 1961; Aguirre, 1971).

The distribution of rainfall during the period of experimentation, between September, 1981 and September, 1983 and accumulated monthly averages of 40 years, are presented in Figure 3.

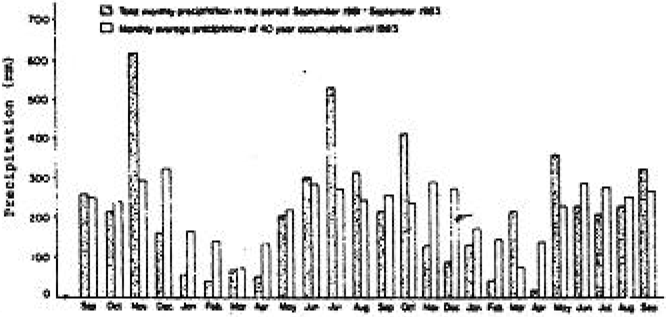

Figure 3. Distribution of rainfall during the period of experimentation and accumulated monthly average of 40 years.

Experimental design in the field

A randomized block design with three treatments and six replications was used. The following treatments were applied.

A. Pollarding of all branches twice a year, leaving the pollarded material on the ground as a mulch; this is the most common practice in Costa Rica's coffee farms, whenever shade are used.

B. Pollarding of all branches twice a year, removing the pollarded material from the plot; the reason was to detect an influence of the mulch on branch growth of the next 6 months period. Moreover leaves and young branches are a valuable protein rich fodder.

C. Pollarding of all branches once a year leaving the pollarded material on the ground.

A comment is warranted as to the planting of the "poró" trees established by seedlings. This is a rather unusual* practice since most trees are commonly planted by large cuttings derived from pollarding of older trees. However, after nine years of continuous pollarding, the appearance of the plot trees with adjacent trees planted by large cuttings is so similar that no difference could be detected.

Each 12 x 12 meter plot had four trees. Each 12 x 36 meter block contained therefore three plots with 12 trees and measured 432 m2.

The total area of the experiment was about 2,600 m2. Within each block the treatments were randomized using cards.

The variables considered and measured were the following: biomass from pollarding (kg), number of branches per tree, basal area of the crown (m2),

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*Further studies from questionnaires in different regions of Costa Rica, revealed that [illegible] 14% of the farmers use seed to establish poró while 86% plant cuttings. (Russo [illegible] 1985, unpublished manuscript).

diameter at breast height (dbh) of the trees (cm), total weight of the branches and amount of naturally fallen leaves.

Pollarding and biomass sampling

In September 1981 all trees were totally and uniformely pollarded (cutting all branches at the top of the bole). Six months later, on March 9–15, 1982, two thirds of all trees of the experiment were pollarded. At twelve months, in September 1982, all trees were again pollarded when one third of the trees had branches twelve months old and the rest six months old. To investigate a shorter sequence of pollarding, twelve more trees were pollarded on January, April, and September 1983 to compare biomass productions of four-months old branches with biomass produced from six and twelve-months old branches. At every pollarding, procedures were as follows: all branches were cut down with a 'machete', all leaves were removed, the branches were cut into sections, and all pollarded plant material was weighed fresh on the site. Afterwards, subsamples of the fresh material were collected, placed in bags and transported to the laboratory, where they were immediately weighed and oven-dried. The subsamples were then weighed again to determine the dry matter content.

Before each pollarding, the number of branches, the crown area, and the diameter at 1.3 m height, were measured for all trees.

An idealized profile of a coffee plantation shaded with *Erythrina*, with and without pollarding, is represented in Figure 4.

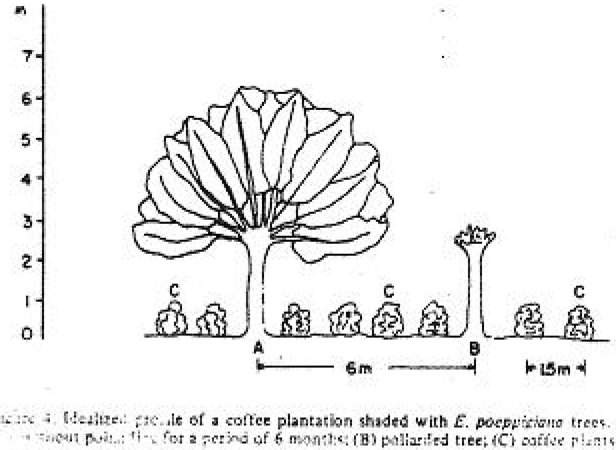

Figure 4. Idealized profile of a coffee plantation shaded with *E. poeppigiana* trees. (A) Tree without pollarding for a period of 6 months; (B) pollarded tree; (C) coffee plants

Fallen leaves sampling

Four one by one meter quadrats or traps were placed within each plot at systematic intervals of one meter from the base of the trees. Collection and evaluation of fallen leaves was carried out each ten days. Each of the four trees in a plot had a trap placed at one of the four distances. A total of 48 traps were placed, 24 in the twelve months plots and 24 in the six-months plots (Photo 2).

Results

Until September 1982, a series of measurements showed that there were significant differences between the semiannual pollarding treatments and the annual pollarding treatment; however, there were no differences in biomass production between the plots where branches were left on the ground (and later decomposed to be incorporated into the soil) and those where they were removed from the plot. Data from biomass production for the treatments are presented in Table 1.

Table 1. Biomass production (kg/ha/year) for leaves and branches of *Erythrina poeppigiana* trees

Treatment	Leaves	Branches (kg/ha/year)	Poll. total biomass
2 pollardings/year branches left on the ground	3837 a[1]	7992 a	11829 a
2 pollardings/year, branches removed from the plot	4041 a	7803 a	11844 a
1 pollarding/year, branches left on the ground	3270 b	15200 b	18470 b

[1] Means with the same letter in the same column are not statistically different ($P < 0.05$).

Annual biomass production, expressed in kg/tree and kg/ha/year, for trees pollarded once, twice, and three times a year are summarized in Table 2 and in Figures 2 and in Figures 5 and 6. The nutrient content of pollarded biomass of four, six and twelve months old branches, corresponding to pollarding frequencies of three times, twice, and once a year respectively, are summarized in Table 3.

Nutrient removal with three different pollarding frequencies with one, two and three pollardings per year (respectively every 12, 6 and 4 months), for leaflets (laminae), petioles, branchwood and bark, are presented in Table 4. The highest percentage of dry weight for the five elements was found in the leaves in all cases. Nitrogen showed consistently the highest percentage

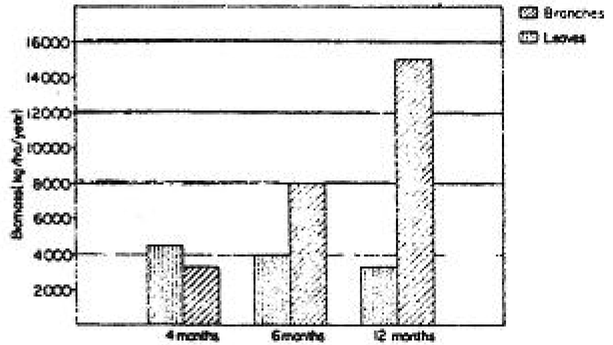

Figure 5. Annual biomass production (kg/ha/year) for leaves and branches of *E. poeppigiana* pollarded once, twice and three times a year in Turrialba, Costa Rica.

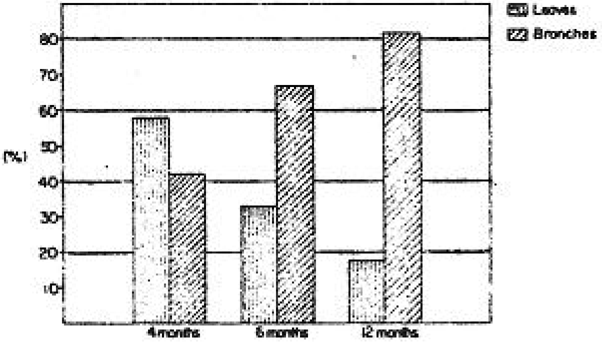

Figure 6. Percentage of leaves and branches of *E. poeppigiana* pollarded at 4, 6 and 12 months.

content in foliage and branches and phosphorus the smallest. The highest nitrogen content was always found in the leaf laminae. Their percentage of total nitrogen found in the biomass was 40%, 53%, and 67%, with pollarding frequencies of respectively one, two, and three times a year. The total amount of nitrogen removed was very similar when pollarded once and twice year but with three times a year, the total amount of nitrogen removed was lower.

Phosphorus showed the lowest total amount among the five nutrients studied. No differences were found for potassium content from the pruned biomass between the three pollarding frequencies. The amount of calcium

Table 2. Annual biomass production (dry weight) from *Erythrina poeppigiana* pollarded once, twice and three times a year in Turrialba, Costa Rica (280 trees/ha, corresponding to a spacing of 6 X 6 m).

Pollarding frequency per year	Leaf biomass	Branch biomass	Pollarded total biomass
1 (12 month interval	kg/tree 11.70 + 3.39 kg/ha 3270	54.28 + 13.82 15200	65.98 + 17.17[1] 18470
2 (6 month interval	kg/tree 13.93 + 3.99 kg/ha 3900	28.20 + 8.11 7900	42.13 + 12.67[2] 11800
3 (4 month interval)	kg/tree 15.50 + 4.95 kg/ha 4340	12.52 + 4.85 3510	28.02 + 9.80[3] 7850

[1] Data from 24 trees, one pollarding

[2] Data from 48 trees, sum of two pollardings

[3] Data from 12 trees, sum of three pollardings

Table 3. Nutrient content (%) of pollarded biomass of *Erythrina poeppigiana* by pollarding frequency in Turrialba, Costa Rica.

Pollarding frequency	Branch part	N	P	K	Ca	Mg
4 months	Leaves	3.82	0.20	1.25	1.47	0.35
	Branches	1.16	0.14	1.18	0.70	0.33
	Ratio	3.3:1	1.4:1	1:1	2.1:1	1:1
6 months	Leaves	3.60	0.18	1.22	0.94	0.35
	Branches	1.08	0.13	1.15	0.60	0.32
	Ratio	3.3:1	1.4:1	1:1	1.6:1	1.1:1
12 months	Leaves	3.35	0.18	1.16	1.52	0.46
	Branches	0.84	0.13	0.60	1.15	0.27
	Ratio	4:1	1.4:1	1.9:1	1.3:1	1.7:1

removed was highest with annual pollarding due to the particularly high content of calcium in the woody part of branches, which can be explained by the high ratio of branches to leaves in annually pollarded biomass when branches reach the largest size. Magnesium showed similar trends to calcium although in smaller amounts.

Nutrient removal data through natural leaf fall is shown in Table 5 and Figure 7 together with the assessment of total nutrients removed by pollarding and fallen leaves for the three different frequencies of pollarding. As can be seen, the greatest amount of biomass is removed with only one annual pollarding.

Table 4. Biomass and nutrient content (kg/ha/year) of pollarded biomass of *Erythrina poeppigiana* represented by pollarding frequencies of one two, and three times of year, for leaflets, petioles, branchwood and bark

Pollarding frequency	Total biomass	N	P	K	Ca	Mg
				(kg/ha/year)		
1 pollarding[1] per year						
Leaflets	2.260	94.9	4.1	26.2	34.4	10.4
Petioles	1.010	14.9	1.8	11.7	15.4	4.7
Branchwood	13.370	80.2	16.0	80.3	153.8	36.1
Bark	1.830	47.2	2.2	11.8	21.1	4.9
Total	18,470	237.2	24.1	130.0	224.7	56.1
2 pollardings[2] per year						
Leaflets	2,710	121.3	5.3	33.1	25.5	8.9
Petioles	1.190	18.3	2.2	14.5	11.2	3.9
Branchwood	6.790	52.9	8.9	78.1	40.7	21.6
Bark	1,110	35.1	1.5	12.7	6.6	3.6
Total	11.800	227.6	17.9	138.4	84.0	38.0
3 pollardings[3] per year						
Leaflets	3.045	116.3	6.1	61.2	44.8	10.6
Petioles	1.295	15.0	2.6	16.2	19.0	4.5
Branchwood	2.990	25.1	4.2	35.5	20.9	9.9
Total	7.850	173.4	13.6	118.9	88.4	26.7

[1] Data from 24 trees, one annual pollarding
[2] Data from 48 trees, sum of two pollardings
[3] Data from 12 trees, sum of three pollardings

Discussion

Comparison among trees pollarded once, twice, and thrice a year

Considering total annual biomass production for three pollarding frequencies, once a year was the highest of the three regimes investigated. However, there are marked differences in the relationship between leaves and branches. These differences between foliage percentage in relation to branches can be attributed mainly to the leaf fall (the mean life period of the leaflets until abscission was approximately four months), while branches continue to grow. In contrast, considering the annual production of leaves, the three times a year pollarding frequency was the most productive of the three treatments. This fact is significant, particularly for small farmers who might want to use the foliage mainly as a high protein fodder.

Table 5. Estimation of total nutrients received from pollarded biomass and fallen leaves from *Erythrina poeppigiana* trees, planted at a density of 280 trees/ha corresponding to a spacing of 6 m × 6 m, with three pollarding frequencies, in Turrialba, Costa Rica

Component	Pollarded biomass (kg/ha/year)			Fallen leaves (kg/ha/year)			Total recycled (kg/ha/year)		
	1 poll.	2 poll.	3 poll.	1 poll.	2 poll.	3 poll.	1 poll.	2 poll.	3 poll.
Dry matter	18470	11800	7850	4280	1914	–	22750	13714	7850
Nitrogen	237.2	227.6	173.0	93.3	41.7	–	330.5	269.3	173.0
Phosphorus	26.0	17.9	13.6	6.4	2.9	–	32.4	20.8	13.6
Potassium (K)	130.0	138.4	118.9	25.4	11.5	–	155.7	149.9	118.9
Calcium (Ca)	224.7	84.0	88.4	94.2	42.1	–	318.9	126.1	94.2
Magnesium (Mg)	56.1	38.0	26.7	30.0	13.4	–	86.1	51.4	26.7

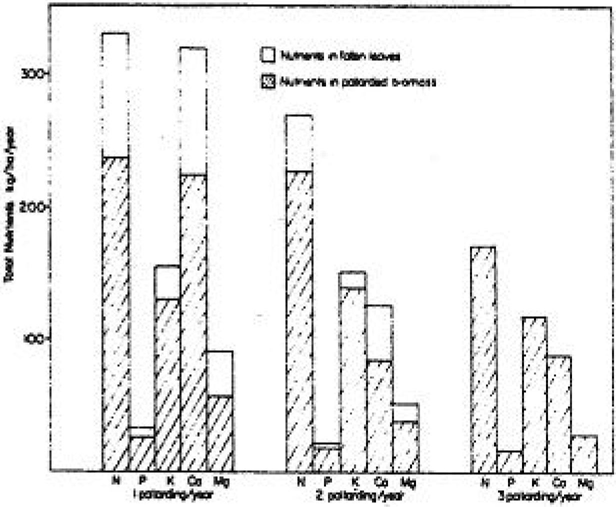

Figure 7. Total nutrients recycled by pollarding and fallen leaves from *Erythrina poeppigiana* trees, used as shade in coffee crop, planted at density of 280 trees/ha in Turrialba, Costa Rica.

Nutrient removal through pollarding

The total amount of nitrogen removed is very similar for once and twice pollarding frequencies, but for three times a year it is lower.

The amount of nitrogen removed was approximately 230 kg/ha/year in the first two cases and 170 kg/ha in the last one. This amount is estimated to be adequate for most crops if both the fallen leaves and the pollarded biomass are left on the ground. For instance, Sánchez (1983) quotes that crops such as maize and rice, require nitrogen fertilization rates of 80-100 kg/ha during their life cycle. Of course, not all nitrogen content in pollarded biomass and fallen leaves may be incorporated into the soil but it can be assumed that half of the amount could be mineralized. This opens very promising possibilities for alley cropping, a matter which is in fact investigated by several ongoing projects at CATIE.

Pollarding of shade trees and their effects on associated crops

The above observations suggest that a considerable supply of nutrients exists in the system with *Erythrina* shade tree, when these are periodically pollarded. On the other hand, so far it can not be said that one system of pollarding is better than the other since this depends on the farmer's objectives and what products will be exported from the site or left on the ground. Usually the farmer chooses those practices that are beneficial to the associated crop, in this case coffee.

Moreover, farmers consider various factors when deciding which tree species to use in an agroforestry system and what shape it should take. These factors when applied to *E. poeppigiana* associated with coffee do not coincide with usual forestry criteria of straightness of trunk, absence of low branches, as well as physical qualities of the wood. In fact a naturally grown *Erythrina poeppigiana* tree, 30 meters tall, is substantially different from the small sized (2–4 meters), heavily pruned shade tree of the same species, pruned over and over; another relevant quality sought for shade trees in agroforestry combinations is the capacity to coppice or grow new branches after being cut back; thus, excellent timber species may be rejected as shade trees because they do not conform to-on farm needs.

The present data are comparable to those reported by Alpizar et al. (1984), Glover (1981), and Glover and Beer (1983), and it can be concluded that *E. poeppigiana* fulfils a useful function which as in the present study, can be quantified. On the basis of surface unit, the species when periodically pollarded, is likely to contribute to, and in fact accelerate, the recycling of nutrients, when compared to open grown trees without pollarding. As to nitrogen fixation capacity, it is not yet clear how pollarding affects nodule formation, but it can reasonably be expected that pollarded trees improve the soil structure because many rootlets are dying and air space is improved; also the addition of pollarded material to the soil is likely to maintain high levels of fertility although no measurable differences could be detected after 12 months when the pollarded material was removed from the plot but this is very likely to change after a few more years. It is significant that 12 years ago on the same site where the study was carried out, similar quantities of organic matter, nitrogen contents, as well as similar physical soil characteristics, were already reported (Aguirre, 1971).

It can be concluded that the benefits of pollarded *E. poeppigiana* are numerous: recycling and adding nutrient back to the soil, beneficial effects of shade already reported over eighty years ago (Cook, 1901), improved nitrogen status of the soil-plant system (nodules) and greater stability of yields over time (Enriquez, 1983, Fassbender, 1977; Alpizar et al. 1984). It remains however to be seen whether such knowledge will be sufficient to convince farmers to maintain well pollarded shade trees in coffee plantations. In fact it is not clear if all farmers are fully aware of the beneficial effects of *Erythrina*. For instance, in the Heredia Province in the Central Valley, of Costa Rica, some farmers are eliminating *Erythrina poeppigiana* trees from their coffee plantations, as well as in La Suiza, Turrialba Valley, although they still may claim that the trees are beneficial for the coffee crop. They are obviously attracted by greater yields that can be obtained by heavy additions of fertilizers, more intensive use of pesticides, and closer spacing of coffee as well as the attractives of easy credit policies for those who apply 'modern technologies'. Even coffee specialists, although very knowledgeable about coffee varieties, planting and pruning techniques, fertilization regimes and pest control, may be quite ignorant on shade trees, particularly as regards interactions between different shade trees and coffee yields as well as maintenance of yields and soil fertility over the years. They often look at shade trees mostly as "shade", when actually much more is involved (Budowski, Kass and Russo, 1984). Even more than the farmers, coffee specialists often tend to favor new technologies that involve coffee varieties cultivated without shade at closer spacings, with heavy inputs of fertilizers and extensive use of herbicides and pesticides. Many of such practices have in fact proved to be unpractical or simply not acceptable to the small farmers for a variety of socio-economic reasons (Lagemann and Heuveldop, 1983; Espinoza, 1983).

Conclusions and follow-up activities

The results derived from experimental plots, indicate that there are specific differences among trees pollarded once, twice and three times a year, as to biomass production, amount of fallen leaves, and nitrogen recycled. When the frequency of pollarding per year increases, the total biomass produced, the amount of natural leaf fall, and the total amount of nitrogen recycled, all decrease. However, in considering only pollarded biomass and not the fallen leaves, there are no differences in nitrogen content between pollarding once and twice a year. The latter is relevant because two pollarding frequencies constitute a very common practice among Costa Rica farmers that use *E. poeppigiana* as a shade tree.

On the basis of some of the data gathered, research is now warranted to make future plantations of *E. poeppigiana* more productive and to design widely applicable techniques for management. Some examples are: (a) Development of management techniques to maximize biomass production according to different uses and local needs such as biomass production for mulch, fodder for cattle, cuttings for more tree planting, etc. Research should provide guidelines for (i) appropriate techniques for the establishment of shade trees whether by large cuttings or seeds, plantation spacing, pollarding intervals, as well as other management practices; (ii) identification of varieties of *Erythrina* species and cultivars showing the best qualifications for different uses (forage, mulch and soil improvement, shade, etc); the possibility of producing pulp, paper, fiberboard, particleboard, and other cellulose derivates from the wood and branches of *E. poeppigiana* deserves investigation. (b) The long term stability of agroforestry systems with *E. poeppigiana*, particularly in relation to nutrient depletion in the soil when the pollarded biomass is 'exported' from the site, should be investigated over longer periods of time, e.g. five or more years. (c) Forage production and nutritive value should be evaluated for a longer period, to assess the value of *E. poeppigiana* forage for sustained use as a component of protein-rich feeds. It may also be worthwhile exploring the possibility of producing flour and/or pellets of high protein content from leaves, for use in animal feeding, including poultry feed.

The value of *E. poeppigiana* in other agroforestry systems also merits more testing, since little innovation is required to integrate the tree into agroforestry systems with other crops. Green manure production and/or use in alley cropping, all deserve to be investigated more carefully.

Where deforestation and erosion are severe, trials with *E. poeppigiana* planted as large cuttings and serving as a tool for soil restoration deserve to be tested, for instance, as a first step towards large reforestation programs in the humid tropics. These plantations, because of rapid development of a crown and subsequent loppings of branches, could produce in a few years a favorable environment for other crops or shade out agressive grasses such as *Imperata*. If initial trials are successful, they may eventually be transferred to large areas, originally of rain forest but presently covered by agressive grasses and used for extensive – and usually destructive – grazing, under very poor and often costly management practices, resulting in problems of weed invasion, repeated fires and soil compaction. Such a planting scheme with *Erythrina* could be a first step for soil improvement and productivity restoration over very large tropical areas.

Naturally, one should also investigate the possible uses of the wood and fodder produced by *Erythrina* plantations on these sites.

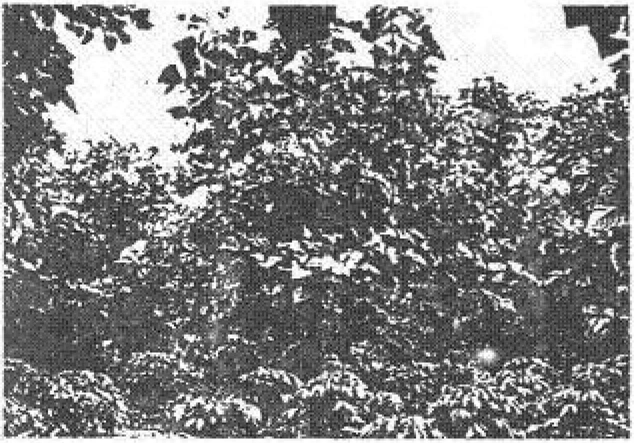

Photo 1. *E. poeppigana* trees with six months old branches as shade in a coffee plantation in Turrialba, Costa Rica.

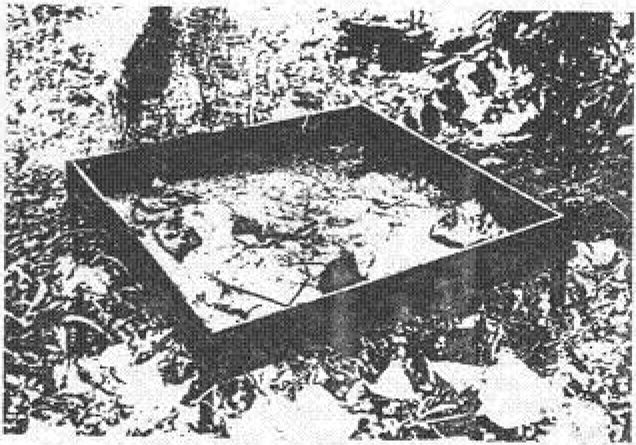

Photo 2. Trap (1 × 1 meters for collection of fallen leaves.

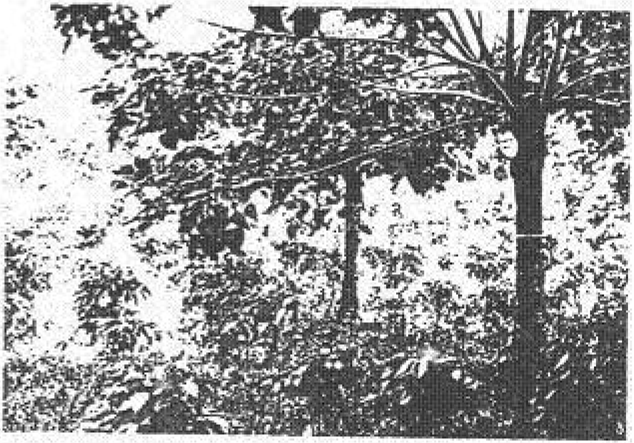

Photo 3. *E. poeppigiana* tree as shade in a coffee plantation.

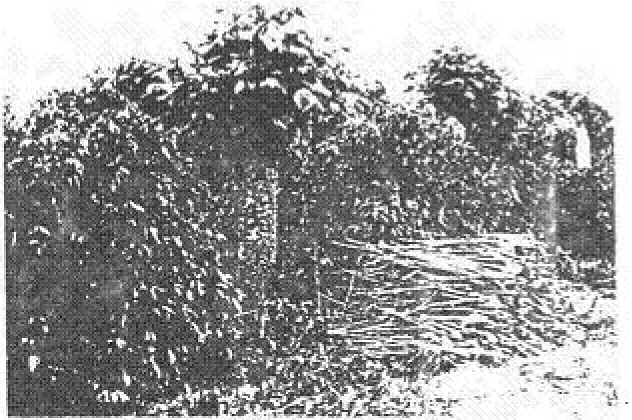

Photo 4. *E. poeppigiana* trunk pollarded at 2.5 m height with 4 weeks regrowths.

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