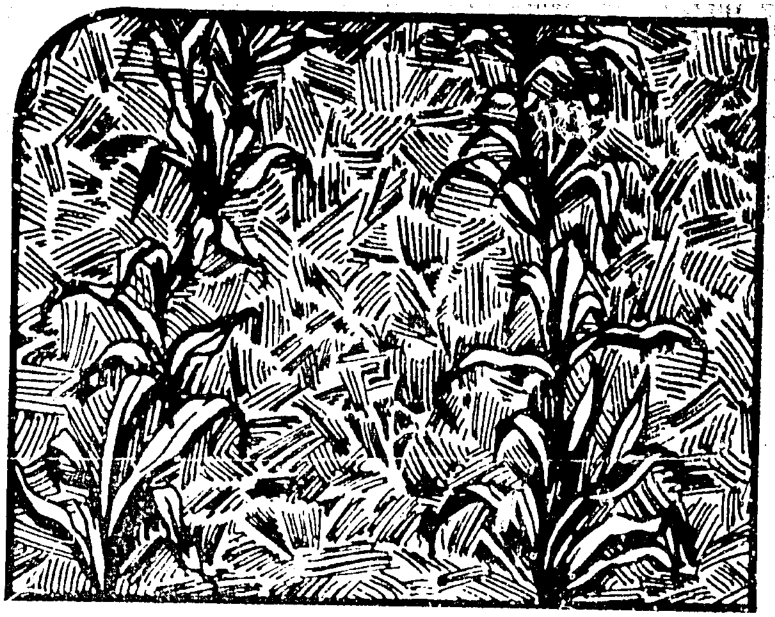

No-tillage Crop Production in the Tropics

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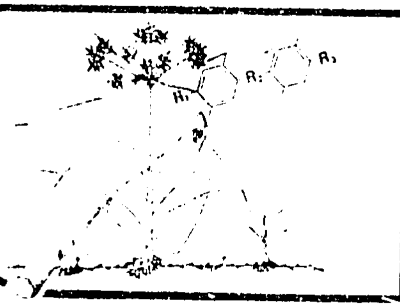

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PROVIDING MULCHES FOR NO-TILLAGE CROPPING IN THE TROPICS

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*

INTRODUCTION

In any agricultural system, optimum yields can be sustained only if the system has the ability to conserve those resources that are either non-renewable or renewed or restored very slowly. The soil, the natural medium for plant growth, stands out among the natural resources which, when lost or degraded, requires many years for replacement or restoration.

When human population in tropical regions was low, only small areas were cleared of forest for very short periods of cropping. Under this system--bush fallow--natural processes had ample time to restore soil fertility. Today, because of the population explosion, more land must be brought into production to meet food demand. Also, these lands must remain under production for longer periods. Unfortunately, conventional tillage techniques used for crop production in the tropics often are not compatible with soil and climate. Consequent soil erosion and degradation results in rapid yield decline.

For the humid and subhumid tropics, where rainfall is high, rain showers heavy, and soils highly erodible, soil erosion is a major hinderance to intensive cropping with sustained yields (Lal, 1975; Kowal, 1972; Fournier, 1967; Kannegieter, 1967, 1969).

Although maintaining a protective soil cover or mulch appears to be the most effective means to reduce or prevent soil erosion or degradation with continuous cropping in the humid tropics (Lal, 1975; Wilson, 1978b), mulching has not yet become a common practice.

Before the advent of no-tillage with chemical land preparation, (Phillips and Young, 1973) mulching was usually accomplished by spreading mulching material over already tilled soil. However, with chemical weed control, plus no-tillage planting techniques, it is now possible to consider recent developments that are potentially feasible for providing mulch for large scale production of tropical staples.

THE BENEFITS OF MULCH

The desirable benefits of mulch are well known, but some are stated here to strengthen the discussion to follow. Generally a mulch can be defined as: any covering placed over the soil surface to modify soil physical properties, create favorable environments for root development and nutrient uptake, and reduce soil erosion and degradation. Mulches also decrease soil moisture evaporation, increase infiltration rate, smother weeds, lower soil temperature, and enrich soils.

Of the benefits listed above, soil moisture conservation has received the most attention; mulching is usually recommended where conditions favor rapid soil moisture evaporation (Rajput and Singh, 1970). Agboola and Udom (1967) observed that soil under 8.8-11 tons of straw mulch had a moisture content of 7.8%, compared with 4.3% in unmulched soil. The high soil moisture content associated with mulch should not be ascribed to evaporation reduction alone; mulch tends to increase water infiltration by reducing the impact of raindrops and preventing surface crusting. Mulching helps retain soil pore spaces creating better infiltration, less runoff, and less erosion (Table 1). Lal (1975) found that accumulated infiltration after 3 hours on a 1% slope was higher for mulched soil than for unmulched. He attributed the higher infiltration under mulch to minimal crusting and high earthworm and micro-organism activity.

In the tropics, where high soil temperatures often hinder seed germination and root development and function, mulches have been found to be effective in reducing soil temperatures (Lal, 1975; IITA, 1972, 1973; Jacks, et al., 1955) and suppressing weeds (Lal, 1975; Agboola and Udom, 1967; Okigbo, 1965).

Table 1

MULCHING RATE EFFECTS

mulch rate (t/ha)	slope % 1	5	10	15	rainfall lost
rainfall runoff	(mm)				(%)*
0	12.0	14.8	10.4	14.8	20
2	1.3	6.2	6.0	5.7	8
4	0.4	1.5	3.6	3.3	3
6	0.0	0.7	1.9	1.8	2
soil loss	(t/ha)				
0	0.48	12.2	27.0	12.3	
2	0.01	3.5	0.8	1.6	
4	0.0	0.7	0.1	0.3	
6	0.0	0.2	0.1	0.1	

* Total rainfall = 64mm
(After Lal, 1975)

The ability of plant residue mulch to improve soil physical properties depends on the soil (Jacks, et al., 1955) and the type of mulch. Upon decomposition, plant residues increase the humus content and thus the cation exchange capacity of the soil. The high organic matter content favors the activities of soil organisms which leads to improved soil physical properties (Lal, 1975; Russell, 1973; Jones, 1971; Ghildyal and Gupta, 1959). Most organic mulches, upon decomposition, also release nutrients beneficial to plant growth (Stewart, et al., 1966; Alexander, 1961; Jacks, et al., 1955; Griffith, 1951).

Many pests and pathogens are suppressed by mulch (Huber and Watson, 1970; Sayre, 1971; Oswald and Lorenz, 1956; Patrick and Toussoun, 1970). However, there are cases where mulches favor development of harmful organisms (Linderman and Gilbert, 1968), and release phytotoxic substance that may be deleterious to some crops (Langdale, 1970; Linderman, 1970).

Crop response to mulch represents the sum total of complex interactions between physical, chemical, and biological factors (Jacks, et al., 1955). In the tropics crop response to mulch is nearly always positive (Lal, 1975, Wilson, 1978a; Okigbo, 1965, 1972; Griffith, 1951).

NO-TILLAGE

According to Phillips and Young (1973) no-tillage is a system of crop establishment in which seeds are introduced into untilled soil with minimum soil disturbance. Usually seed is planted in a hole or narrow slit of adequate width or depth for good coverage and soil contact. A mulch of plant residue retained on the soil surface appears to be essential to the technique. Herbicides are used to destroy the pre-plant vegetation and control weeds during cropping.

On many soil types, tillage is necessary only for weed control, but not crop establishment (Russell, 1941; Faulkner, 1943). In North-America, no-tillage has become very popular; development of special no-till equipment has led to large scale commercial no-till grain production (Bennett, 1977).

No-tillage is by no means new to the tropics. In fact, it is the major crop establishment method in many indigenous bush fallow, slash and burn systems. After burning, seeds are planted with minimum soil disturbance. However, traditional no-till practice differs from chemical no-tillage in that burning off plant residue leaves the soil exposed and vulnerable to erosion. Attempts being made to develop herbicide based no-tillage systems for the tropics involve developing techniques for retaining a protective mulch and thus reducing soil erosion.

PROVIDING THE MULCH

With conventional tillage, mulch was associated with the introduction of material from some source outside the field. This involved transporting and handling large quantities of materials, a time-consuming practice so expensive that it was limited to use only on high value crops. In a no-tillage system, transportation of plant residue for mulching is unnecessary provided that plant residue can be obtained either from a previous crop or fallow vegetation. The major problem, therefore, is to ensure that a suitable mulch is available in a weed-free situation on the soil surface at planting. The methods presently being tested for providing no-tillage mulch in the tropics can be classified as follows.

A. Crop Residue

Cereal straw and stalks are the most commonly used crop residue for no-tillage mulch. Where these crops are combine harvested, the stubble plus the chaff forms the mulch (Phillips and Young, 1973). In the tropics, the most likely crops for leaving suitable residue for mulch tillage are rice, sorghum, millets, and maize. So far, only maize has been tested extensively in no-tillage systems in the tropics to produce residue used for mulch (IITA, 1972, 1975, 1978, 1979).

In a study covering a 10-year period, maize yield from no-tillage plots--using retained maize residue as mulch--consistently produced equal or better yields than conventionally tilled maize; both systems relied on hand-operated equipment. Termites could be a serious problem for the no-tillage system by destroying the crop residue and leaving the soil relatively bare. Organic residue decomposition is fairly rapid in the tropics. Consequently, a large proportion of residue may decompose prior to planting if the interval between one crop and the next is fairly long.

B. In-situ Mulch

In situations where crop residues do not persist long enough to provide mulch for the next crop, attempts must be made to establish plants that, when killed, will provide the necessary residue. Lal (1975) suggested that lush weed growth killed with chemical could provide suitable mulch. However, this system has many disadvantages. The weeds are not uniform and some sections may decompose too quickly leaving bare patches. Weeds are likely to carry seeds which will germinate later and become a problem. Kannegieter (1967, 1969) observed that when Pueraria phaseoloides, a popular tropical cover crop, was killed with herbicide, it left a uniform mulch through which maize could be planted. The maize yield was similar to maize planted in conventionally tilled land, but there was no erosion with the mulch. Research at the International Institute of Tropical Agriculture (IITA) has shown that many other tropical cover crop legumes and grasses left a uniform mulch when killed with herbicide. Even during establishment the mulch encouraged earthworm activity (Table 2). The performance of maize, cowpea, and pigeon pea grown with no-tillage and in-situ mulch from three grasses and four legumes was usually as good or better than that established with conventional tillage (Table 3). Invariably the grasses were more difficult to establish and to kill, and thus research emphasis shifted to the legumes.

Table 2

EARTHWORM ACTIVITY UNDER DIFFERENT COVER CROPS

cover crops	weeks after planting					
	2-4		4-7		7-10	
	maize	cowpeas	maize	cowpeas	maize	cowpeas
	casts/m²/week					
Panicum	1680	1708	75	35	157	27
Setaria	1531	1477	109	64	192	56
Brachiaria	1879	1454	431	253	340	122
Melinis	1257	1280	463	343	419	153
Centrosema	1340	956	100	59	131	33
Pueraria	1233	1139	101	96	45	29
Glycine	1131	833	25	33	59	13
Stylosanthes	1011	976	227	38	189	9
control (no residue)	37	23	8	0	36	0
LSD (0.05)	1200	1066	165	81	193	20

(After Lal, *et al.*, 1978)

Table 3

CROP YIELD AND COVER CROP RESIDUE

cover crop	crop yield maize	cowpea	pigeon pea
	(t/ha)		
Panicum	3.36	0.67	1.06
Setaria	4.36	0.66	0.90
Brachiaria	5.02	0.61	1.42
Melinis	3.96	0.77	1.35
Centrosema	4.34	0.71	1.40
Pueraria	3.38	0.71	1.23
Glycine	3.39	0.72	0.90
Stylosanthes	5.73	0.72	1.25
control	4.08	0.23	1.10
LSD (0.05)	1.06	0.50	0.25

Criteria for plants potentially useful for in-situ mulch are:

(1) be easy to establish, especially with no-tillage planting;

(2) have rapid early growth and be competitive enough to overcome weeds;

(3) be adapted to the climatic region and able to survive stresses (e.g., drought) normal to the region;

(4) be able to produce seeds or other reproductive structure under the local climate;

(5) be free from pests or diseases harmful to other crops in the rotation;

(6) be easily killed with known herbicides that are compatible with crops in the rotation;

(7) be capable of producing a uniform mulch which will persist long enough to keep the soil covered until the crop canopy closes;

(8) not become a weed in fields in which it was used;

(9) produce a residue layer thin enough to allow both planting with available no-tillage equipment, and seedling establishment;

(10) have a dormant seed that can reestablish a cover following the crop; and,

(11) be able to grow on soils low in the major nutrients while possible improving the nutrient, as well as physical, status of that soil.

Table 4

COVER CROP ESTABLISHMENT

legume	establishment one year after planting: conventional tillage	establishment one year after planting: no-tillage
	ratings	ratings
Centrosema pubescens	3.0	3.7
Pueraria phaseoloides	4.0	4.3
Psophocarpus palustris	3.3	3.3
Stylosanthes guianensis	2.7	4.3

rating values:

0 = no legume; 1 = very, poor, less than 20%

2 = 20 - 50% 3 = 50 - 70%

4 = 70 - 90% 5 = 90 - 100% legume cover

To date most plants that satisfied the preceding criteria were aggressive creeping or climbing legumes (Wilson, 1978a). Tests with four popular cover crops showed that no-tillage planting was slightly superior to conventional tillage planting (Table 4). Techniques have been developed to establish a cover crop for in-situ mulch in association with other crops (IITA, 1978). *Pueraria phaseoloides*, *Psophocarpus palustris* and *Mucuna utilis* have been successfully established with maize. Establishment of cover crops between arable crops should be attractive to peasants who are unlikely to plant and tend cover crops from which there are no direct returns.

Wilson and Caveness (1980) investigated the effects of certain leguminous cover crops as suppressors of plant parasitic nematodes. While Centrosema pubescens and Stylosanthes guianensis were effective suppressors of the three types of nematodes observed, P. palustris suppressed the spiral nematode, but increased the prevalence of rootknot nematodes (Table 5).

Table 5

COVER CROP EFFECT ON NEMATODES

species population: suppression = +, build-up = -	nematode types Meloidogyne spp.	Helicotylenchus spp.	Pratylenchus spp.
Centrosema pubescens	+	+	+
Pueraria phaseoloides	+	+	+
Indigofera sublata	+	-	-
Stylosanthes guianensis	+	+	+
Crotalaria juncea	+	-	-
Psophocarpus palustris	-	+	+

Wilson (1978b) found that tomatoes grown with in-situ mulch from P. phaseoloides responded to fertilizer, but the response was less than where the mulch was removed. No-tillage maize grown in a cover crop residue tends to show marked nitrogen deficiency symptoms when nitrogen is not added. The nitrogen requirement, however, is less than maize grown with conventional tillage[1/]. Thus, even, where legumes and their associated symbiotic Rhizobium bacteria have added to the nitrogen level in the environment, such

[1/] Wilson and Akapa, unpublished data.

nitrogen is not readily available to crops while tied up in the mulch. A large part of the nitrogen in the mulch could also be lost through volatilization.

Residue from some cover crops sometimes exceeds the mass that available no-till equipment can penetrate. For example, no-till maize planters that were effective with 5 t/ha, dry weight, of residue form Mucuna utilis were ineffective with 10 t/ha residue from Pueraria phaseoloides. Table 6 indicates that mulch obtainable from some legumes used for in-situ mulch for no-tillage cropping is too great for available no-tillage equipment. Where the in-situ mulch is uniform and thick, pre-plant herbicide application is usually unnecessary as the mulch itself suppresses weeds.

Table 6

CREEPING COVER MULCH ACCUMULATION

legume	weight after one year: fresh	dry
	(t/ha)	
Psophocarpus palustris	35	11
Glycine wightii	12	6
Centrosema pubescens	21	13
Pueraria phaseoloides	17	10

C. Live Mulch

Live mulch is similar to in-situ mulch except that the cover crop is not killed. At the time of crop establishment, growth of the cover crop is halted by a chemical growth retardant which keeps the plants dormant for a period sufficient to minimize competition between crop and mulch. By the end of cropping, the cover crops are actively growing and capable of smothering weeds (IITA, 1979; Akobundu, 1980). Live mulch cover crops need the same attributes as in-situ mulch cover crops except that they must be sensitive to the growth retardant used.

In the humid tropics where trees and woody shrubs dominate the climax vegetation, herbaceous fallows are often difficult to maintain. The same is also true in semi-arid regions where shallow-rooting herbaceous plants are likely to succumb to moisture stress during a long dry season. To overcome these difficulties, Wilson and Kang (1980) developed alley cropping; crops are grown in an alley formed by rows of vigorous, fast-growing trees and shrubs (usually legumes). At crop establishment, the trees or shrubs are cut back and the leaves and twigs placed on the soil surface to form a rough mulch. The fallow plants are kept pruned during cropping to reduce competition for light, nutrients, and moisture. All prunings are added to the soil, not only to add mulch, but also to increase the soil nutrient level (Wilson and Kang, 1980; IITA, 1979, 1980). The potential nutrient contribution from tree legume prunings in alley cropping systems deserves consideration (Table 7). In addition, the larger stems and branches can be used as yam stakes or firewood.

Table 7

TREE LEGUMES: MULCH AND NUTRIENT

species	mulch dry weight	nutrient content*			maize yield
		N	P	K	
	(kg/ha)				
Cajanus cajan	4100	151 (3.6)	9 (0.2)	68 (1.6)	3173.4
Tephrosia candida	3067	118 (3.8)	7 (0.2)	49 (1.4)	1912.2
Leucaena leucocephala	2467	105 (4.2)	4 (0.2)	51 (2.0)	2601.6
Gliricidia sepium	2300	84 (3.7)	4 (0.2)	55 (2.5)	2587.3
control	-	-	-	-	2030.3
LSD (0.05)	-	19	2	8	N.S
cov (%)	-	8	13	7	

* Values in parenthesis show % nutrient content.

The mulching techniques described are relatively new and may require several more years of research before the basic concepts embodied can be refined to meet the requirements of tropical crop production. While the physical aspect of mulch has been emphasized, the potential for contribution by chemicals was not totally forgotten.

Nearly all crops used for supplying mulch are legumes, well known for nitrogen fixation. Henzell and Norris (1962) estimate that most tropical legumes have nitrogen fixation potential of between 73 and 577 kg/ha/year and this potential could be raised with improved legumes and rhizobium symbiotics. If mulching techniques for no-tillage crop production are developed, the contribution of legumes to tropical crop nitrogen needs will increase. The aim is to create an efficient biological system in which nitrogen fixed by legumes and bacteria are transferred to crops through a soil environment adjusted to facilitate maximum absorption of nutrients recycled through the biological system. With these techniques, it may become necessary to reevaluate current thinking concerning soil-plant relationships in the tropics as well as fertilizer recommendations and application techniques. Organic mulch generates high infiltration rates induced by mulch which, in turn, causes leaching losses subsequently increasing demand for highly soluble and mobile mineral nutrients.

Though not used extensively in the experiments cited, grass species have an important role in mulching techniques for the tropics. With some of the newer herbicides that can effectively control grasses, in-situ grass mulch also could become common in tropical savanna where grasses dominate the fallow vegetation. Natural regeneration would eliminate the cost and other problems of establishing in-situ mulch.

While most mulching techniques are transferable to peasants using hand tools, others are not ready for mechanized farming. There is an urgent need for research to develop suitable no-tillage equipment to meet the needs of these tropical systems. Unfortunately, work on large scale implements is almost absent in the tropics and systems developed to improve large scale production may lag behind because of the anticipated slow pace of engineering research in the tropics.

The outlook for tropical agriculture is bright because available soil conservation techniques now make possible the control of erosion, once the scourge of the tropics.

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