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EFFECTS OF COVER CROPS ON SOIL STRUCTURE AND ON YIELD OF SUBSEQUENT ARABLE CROPS GROWN UNDER STRIP TILLAGE ON AN ERODED ALFISOL

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ABSTRACT

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Effects of weed fallow and of three grasses and five leguminous cover crops were investigated on soil structure of an eroded Alfisol. Crop growth and yields of subsequently grown arable crops were assessed under strip-tillage through the mechanically or chemically suppressed sods. Cover crops and fallowing improved soil organic matter content, total N, water retention and transmission properties, and decreaed bulk density only in the top 0—10 cm depth. The improvements rendered were, however, slight. Grasses were difficult to suppress with paraquat or mechanical mowing, which resulted in low or negligible yield of maize, cowpea, and cassava. Leguminous covers were easily suppressed with paraquat application, and resulted in good yield of maize and cowpea. Mechanical mowing was as successful as herbicide application for suppressing *Stylosanthes guianensis* and resulted in satisfactory yield of maize and cowpea. Yield of cassava tubers was extremely low due to shallow surface soil, compacted sub-soil horizons, and competition from weeds and regrown cover crops. Results are discussed in terms of the amelioration of eroded and degraded soil.

INTRODUCTION

Although the importance of fallow cover crops in soil and water conservation and in improving the structure and the fertility status of soils in the tropics is well established (Martin, 1944; Pereira et al., 1954, 1967; Kannegieter, 1969; Juo and Lal, 1977; Lal et al., 1979), agronomic practices of growing seasonal crops through suppressed sods are not yet adequately developed. The choice of a suitable cover crop depends on many factors, including its ability to be economically suppressed by chemical means so that seasonal crops can be grown. If the vast areas of the tropics already affected by severe soil erosion are to be brought back into production, effective reclamation techniques must be developed. Reclamation of eroded soil assumes in some cases the same importance as erosion prevention.

The importance of the reclamative effects of cover crops in restoring eroded and degraded soils in the tropics cannot be over emphasized. Cover crops can bring about improvements in soil physical, chemical and biological properties provided the fallow period is long enough. The more degraded the soil, the longer the duration of fallowing required for restoration. For example, Low (1955) observed in Tanzania that restoration can be a slow process, which may take 5 to 50 years depending on the degree of denudation, nature of the exposed sub-soil, cover crop, and intended land use.

The use of fallow cover crops for both soil reclamation and erosion control depends on chemical suppression of the cover crops for much of its effectiveness. The chemicals used are generally contact herbicides such as paraquat, which are often relatively expensive in some parts of the tropics. The herbicides used should effectively suppress the cover crop for the cropping duration, thus preventing competition between crop and cover crop. Adams et al. (1970) grew maize in five atrazine treated sod species. Elkins et al. (1979) investigated the effects of growth retardants on a range of sod species and observed that the growth retardants that resulted in the best combination for maize and grass production were maleic hydrazine, and fluridamide sulfonyl acetamide.

The objectives of the present study were to investigate the effects of various grass and legume covers on properties of an eroded and degraded Alfisol, and on growth and yield of subsequent arable crops grown under no-tillage through chemically and mechanically suppressed sod. This report is the third in a series. The first published report dealt with the effects of cover crops on soil properties and yield of subsequently grown arable crops on a non-eroded soil (Lal et al., 1978). The second report described the restorative effects of cover crops on properties of an eroded soil (Lal et al., 1979). The present report synthesizes the results of this three-part study and explains the agronomic crop response in terms of improvements in soil structure.

MATERIALS AND METHODS

The experiments were conducted at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The IITA experimental farm is located in the lowland rainforest zone of the West African tropics, 30 km south of the northern limit. The total rainfall varies from 1000 to 1500 mm annually with a bimodal distribution. The two growing seasons are from April to July and from August to November. The soil at the experimental site is classified as Oxic Paleustalf (Taxonomy) or Ferric Luvisol (FAO). Its general properties are given in Table I. Under forest cover, the sandy loam surface soil is covered with a 2—5 cm thick layer of worm casts and leaf litter and the soil structure is excellent for root development and water absorption and transmission. The texture of the soil changes to clay loam and clay in the sub-surface horizons. There is also a distinct gravelly horizon between about 30 and 80 cm depth with gravel concentrations ranging from 40 to 80%.

TABLE I

General properties of the surface layer (0—15 cm) of the cultivated degraded Alfisol in comparison with that under forest cover

Properties	Under forest cover	After 5 years of cultivation	After 2 years of cover crops	
			Grasses	Legumes
pH (H_2O)	6.5	5.5	5.2	5.6
Clay (%, *w/w*)	18.4	21.2	—	—
Silt (%, *w/w*)	10.3	9.5	—	—
Sand (%, *w/w*)	71.3	69.3	—	—
Gravel (%, *w/w*)	5.0	20.0	—	—
Organic C (%, *w/w*)	1.7	1.2	1.5	1.6
Total N (%, *w/w*)	0.16	0.12	0.18	0.20
Bray-P (μg/g)	15	37	60	33
Exchangeable bases (meq/100 g)				
Ca	4.8	4.0	6.2	6.7
Mg	1.3	0.8	1.3	1.6
K	0.6	0.4	0.9	0.9
Bulk density (g/cm^3)	1.00	1.50	1.33	1.29
Infiltration rate (cm/h)	100	9	17	23

The soil is clayey skeletal, kaolinitic, isohyperthermic oxic paleustalf. Detailed analyses of the physical and chemical properties of this soil are described by Moormann et al., 1975.

The secondary forest regrowth of about 15 years was removed manually in 1970. The soil was subsequently cultivated for 5 years for maize, cowpea and soybean. These crops were grown after disc plowing to a depth of about 20 cm followed by one or two harrowings with a Rome plow. These operations were done twice every year, which resulted in severe soil degradation by accelerated erosion (Table I). For example, cultivation resulted in a decrease in pH by one unit, and in decreases of 0.5% (*w/w*) in organic carbon, 0.04% (*w/w*) in total nitrogen, 0.8 meq/100 g in exchangeable calcium, 0.5 meq/100 g in exchangeable magnesium and 0.2 meq/100 g in exchangeable potassium. On the other hand, there was a drastic increase in soil bulk density and the infiltration rate decreased substantially. An increase in gravel content of the surface layer from 5 to 20% was attributed to ploughing, bringing gravel from the sub-soil to the surface, and to subsequent erosion and removal of fine sediments by runoff water, exposing the gravelly subsoil.

The effects of three grass and five leguminous covers and natural regrowth of weeds were studied on the reclamation of this degraded Alfisol. The cover crops were seeded in April 1975 on plots approximately 20 × 20 m^2, laid out in a randomized complete block design with three replications.

The fallow cover crops consisted of the grasses: *Brachiaria ruziziensis* (prostrata signal grass), *Paspalum notatum* (Bahia grass) or *Cynodon nlemfuensis* (IBS, Star grass); and the legumes: *Pueraria phaseoloides* (tropical kudzu/puero), *Stylosanthes guianensis* (stylo), *Stizolobium deeringianum* (velvet bean), *Psophocarpus palustris* (wild winged bean) or *Centrosema pubescens* (centro). The control consisted of unplanted fallow of natural weeds and bush regrowth.

The leguminous cover crops were established by drilling the seeds in rows 75 cm apart. Grasses were established by vegetative propagation at spacings of 25 cm within rows 75 cm apart. All cover crops were weeded twice during the first 3 months of their establishment. There was no grazing. After two years (1977), at the time of recovering the land for cropping, two methods of suppression were applied to the cover crops in a split-plot design. For chemical suppression, the cover crops were sprayed twice with paraquat at a rate of 2.5 l/ha. The first application of the herbicide was made a week before seeding and the second at seeding. Mechanical suppression was performed by mowing with a tractor-mounted shredder.

Arable crops of maize (*Zea mays*), cowpea (*Vigna unguiculata*), and cassava (*Manihot esculenta*) were planted through the crop covers in 1977 and 1978. Four consecutive crops were grown with two crops each year. The first season crops were seeded during mid-April and second season crops in the 2nd week of August.

Crops were seeded in narrow strips, about 10 cm wide, manually cut in the mowed or chemically treated sod. While preparing this strip seedbed, care was taken not to disturb the soil. All crops were planted manually in 75-cm rows, except cassava which was planted in rows 1 m apart. The within row spacing was 25 cm for maize, 15 cm for cowpea and 1 m for cassava. Uniform fertilizer rates were used for the arable crops after all cover crops, but the rates differed between arable crops. Maize received 120 kg/ha N as urea (1/3 at planting and 2/3 at 4 weeks after planting), 20 kg/ha P as single superphosphate and 30 kg/ha K as muriate of potash. Cowpea received 30 kg/ha N and 13 kg/ha P at planting, and seeds were inoculated with appropriate rhizobium. Cassava received no fertilizer.

Plant height measurements were made every week, beginning 2 weeks after planting. Grain and tuber yields were recorded at maturity. Soil physical and chemical characteristics were monitored before seeding the cover crops in 1975 and prior to seeding of arable crops in 1977. Soil bulk density was measured on undisturbed cores, and soil strength by means of a pocket penetrometer. Infiltration rates were monitored with a double ring infiltrometer in the sod during the dry season. Soil moisture content at 300 cm suction (pF 2.5) was monitored by subjecting the saturated soil to a centrifugal force equivalent to 1000 G for 30 min. Pore size distribution was computed from the pF-curves using the surface tension relationship at 15°C as follows:

$$r = \frac{0.15}{h}$$

where r is the pore radius (cm) and h is the soil moisture suction (cm). For a detailed derivation of this equation based on the surface tension relationship at 20°C, see Marshall (1959).

RESULTS AND DISCUSSION

Cover crops

All cover crops were established without difficulties and covered the soil within 6 months after planting. The fastest ground cover was achieved by *Stizolobium deeringianum*, followed by *Pueraria phaseoloides*, *Stylosanthes guianensis*, *Centrosema pubescens* and *Phosphocarpus palustris*. Among grasses, *Cynodon nlemfuensis* was the most vigorous in growth and provided the quickest ground cover, followed by *Brachiaria ruziziensis* and *Paspalum notatum*. *Stizolobium* suffered from drought stress during the prolonged dry season of 1975, and, therefore, the regrowth in the second year was from the seeds shed by the previous year's crop. All other cover crops survived the long dry season. Ground cover established by *Psophocarpus palustris*, *Pueraria phaseoloides*, and *Centrosema pubescens* is shown in Figs. 1, 2, and 3, respectively.

The effectiveness of various crop covers for weed control also depended on the vigour and the time required to achieve a complete ground cover. Weeds were effectively and quickly eradicated in *Stizolobium*, *Pueraria*, *Stylosanthes*, *Cynodon* and *Brachiaria*. Although complete cover was attained in other cover crops, it took a relatively long time for weeds to be eradicated.

Fig. 1. One-year old *Psophocarpus palustris* cover.

Fig. 2. One-year old *Centrosema pubescens* cover.

Fig. 3. Suppressed residue of *Pueraria phaseoloides* one week after paraquat application and before seeding the arable crops.

Cover crops such as *Pueraria*, *Cynodon* and *Stizolobium* were extremely vigorous and had a tendency to spread to adjacent plots. This required regular spraying with paraquat in the buffer zones between plots.

The response of cover crops to chemical and mechanical suppression varied among crop species. Only *Stylosanthes* was uniformly suppressed by both chemical and mechanical means. Mechanical suppression was ineffective for all grasses and less effective for *Pueraria, Centrosema, Stizolobium*, and *Psophocarpus*. Paraquat provided an effective control for all leguminous cover crops but was ineffective for all grasses. In cover crops, which were not effectively suppressed by mechanical or chemical methods, regrowth was very rapid.

Soil properties

Averaged for grasses and legumes, 2 years of fallowing increased the mean organic carbon content by 0.35% (*w/w*), total N by 0.07% (*w/w*), exchangeable calcium by 2.45 meq/100 g, and exchangeable Mg by 0.65 meq/100 g (Table I). Fallowing decreased bulk density, and increased infiltration rate. The high P status is partly attributed to the application of chemical fertilizers twice a year during the 5 years of cultivation prior to growing the cover crops. Fallowing drastically increased K status which may be due partly to the ability of cover crops to extract non-exchangeable K and recycle it from the sub-surface horizons (Juo and Lal, 1977). There were also slight differences between grass and leguminous cover crops. Soil pH, organic carbon, total N, and exchangeable cations were generally higher under legumes than under grasses. Bray-P, however, was higher under grass than under legume covers. Legume covers had a slightly lower soil bulk density and a higher equilibrium infiltration rate than grass covers (Table I). The improvements in soil physical properties are discussed below.

Effective rooting depth and earthworm activity

Most of the improvements in soil properties were probably due to the effects of roots. For example, N fixation by legumes and some grasses such as *Paspalum* and the loosening effect of root mass in creating additional channels are responsible for a decrease in soil bulk density and an increase in infiltration rate. The above ground biomass also added some plant nutrients and, more important, provided the protective mulch cover to prevent raindrop impact and soil erosion.

Earthworms are important in improving soil structure and porosity, and in mineralization of soil organic matter. Earthworms turn over the soil and mix the organic matter in the root zone. Cast building earhtworms such as *Hyperiodrilus africanus* were completely absent in the soil prior to seeding the cover crops. Five years of cultivation, accelerated soil erosion, compaction, lack of crop residue mulch, and continuous application of pesticides completely eliminated the worm population from this soil. However, worms did not recolonize the soil even after 2 years of cover crop growth. Recolonization attempts through application of surface soil containing these worms also failed. This implies that in this case the loosening effect and the honeycomb-like structure that was brought about by intense worm activity during forest fallow did not occur during the two years under cover crops. On a soil that had not been severely degraded prior to seeding the cover crops (Lal et al., 1978), soil bulk density was very low and infiltration rate was very high, due to high earthworm activity. As the worm activity declined during the cultivation phase so did soil structure and infiltration rate.

Soil bulk density

Bulk density measurements were made in January 1978 at the end of the 1st year of growing arable crops. Cultivation increased the bulk density from 1.31 (Table I) to 1.45 g/cm^3 (Table II) during the 1st year. This increase in bulk density was due to rapid decomposition of crop residue mulch, and to the raindrop impact on the exposed soil. There were no differences in soil bulk density due to suppression method or to type of cover crop. In the previous study the soil bulk density of the 0—10-cm layer was 1.35 g/cm^3 during the cultivation phase. In the present investigation lack of good soil structure resulted in a rapid increase in soil bulk density because of the absence of earthworm activity, and due to crusting and compaction. High bulk density also adversely affected root development of the arable crops.

TABLE II

Effects of cover crop and method of suppression on soil bulk density (g/cm^3) of the 0—10-cm layer under no-tillage, January 1978

Cover crop	Sprayed	Mowed
Grasses		
Brachiaria	1.50 ± 0.07	1.48 ± 0.10
Paspalum	1.49 ± 0.08	1.49 ± 0.10
Cynodon	1.41 ± 0.06	1.43 ± 0.08
Legumes		
Pueraria	1.44 ± 0.07	1.45 ± 0.06
Stylosanthes	1.45 ± 0.06	1.46 ± 0.09
Stizolobium	1.46 ± 0.04	1.45 ± 0.08
Psophocarpus	1.42 ± 0.08	1.46 ± 0.07
Centrosema	1.44 ± 0.07	1.47 ± 0.06
Control		
Ploughed	1.39 ± 0.07	1.38 ± 0.10
LSD (0.05)		
Suppression	0.072	
Cover crop	0.083	

Water infiltration

There was some improvement in water transmission properties by fallowing. However, the magnitude of improvement was not as much as that observed in the presence of earthworms reported in the previous study (Lal et al., 1978). Water infiltration, measured at the end of two years in January 1977, showed significant differences due to crop covers (Fig. 4). Compared with the pre-seeding control, water infiltration characteristics were significantly improved by 2 years growth of *Psophocarpus, Centrosema, Pueraria, Stizolobium*, and *Stylosanthes*. Both accumulative infiltration and equilibrium

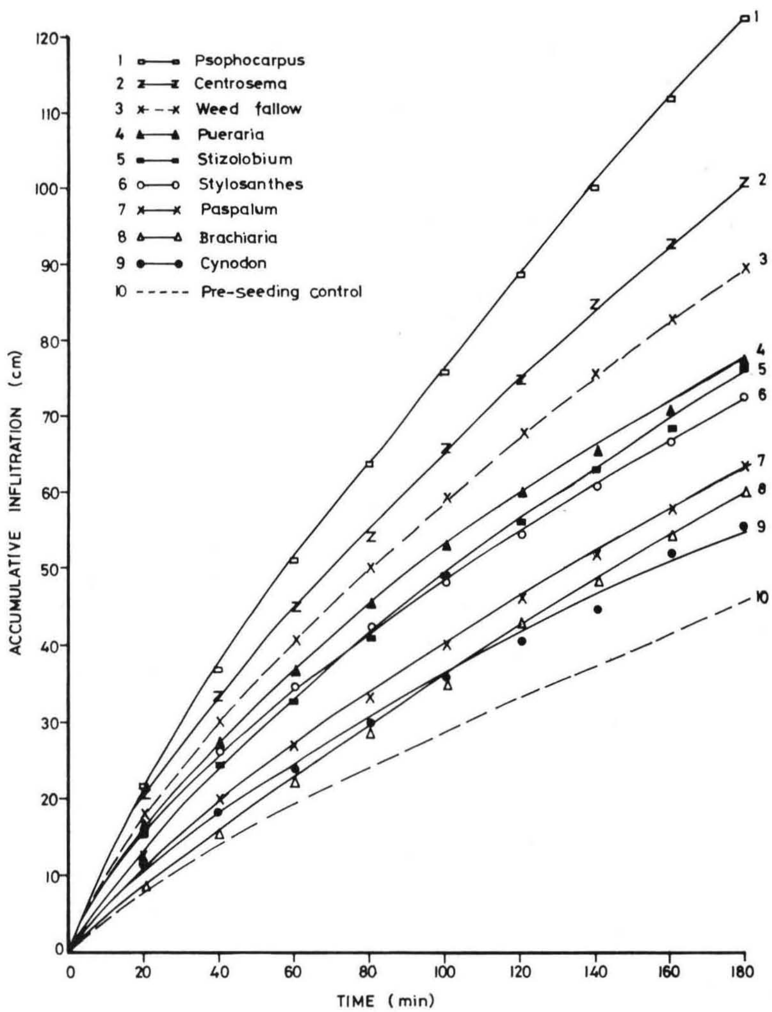

Fig. 4. Effects of two years of grass and leguminous fallow on the infiltration characteristics of a severely eroded tropical Alfisol.

infiltration rate were also improved by the weed fallow control (Fig. 4). The largest improvements in accumulative infiltration as well as in the equilibrium infiltration rate were observed in soil under *Psophocarpus*, and by those under *Stizolobium*, *Pueraria* and *Centrosema*.

In the presence of earthworms as reported in the previous study (Lal et al., 1978) both accumulative infiltration and infiltration rate were much greater for the same cover crop than observed in this study (Table III).

TABLE III

Effects of cover crop on infiltration characteristics with and without worm activity[a]

Cover crop	Accumulative infiltration (cm/3 h)		Equilibrium infiltration rate (cm/h)	
	With worm activity	Without worm activity	With worm activity	Without worm activity
Brachiaria	490	64	75	19
Centrosema	220	72	30	18
Pueraria	270	76	90	16
Stylosanthes	390	74	60	16

[a]Data with worm activity is recalculated from Lal et al., 1978.

Soil moisture retention

Soil moisture retention at pF 2.5 shown in Table IV indicates differences due to cover crops. Fallowing with *Cynodon*, *Psophocarpus*, and *Centrosema* resulted in higher soil moisture retention than with other cover crops and weed fallow control, which was in conformity with the infiltration data for *Psophocarpus*, and *Centrosema* (Fig. 4). These cover crops improved soil structure more than other covers (Table V). Furthermore, the overall improvement in total porosity by fallowing was larger under legume than under grass covers, and was largest in control plots with predominant perennial woody and shrub weeds. This differential improvement was probably related to differences in the nature of root system development and canopy characteristics. Covers with deep and tap root systems and those that quickly provide a canopy cover bring about quicker and larger improvements in soil structure than those with shallow root systems and delayed ground covers.

Fallowing with different cover crops increased transmission pores $> 5\ \mu m$ radius. The improvement was brought about mainly by an increase in the volume of macropores $> 15\ \mu m$ radius. In addition, cover crops such as *Psophocarpus*, *Centrosema*, *Cynodon*, and *Stizolobium* also increased the volume of pores with radii between 1.5 and 3 μm.

TABLE IV

Effect of cover crop on soil moisture content at 300 cm suction (pF 2.5)

Cover crop	Soil moisture content at pF 2.5 (%, *w/w*)
Grasses	
Brachiaria	11.2
Paspalum	13.0
Cynodon	13.6
Legumes	
Pueraria	12.5
Stylosanthes	12.6
Styzolobium	13.0
Psophocarpus	13.5
Centrosema	13.2
Control	
Weed fallow	12.0
LSD (0.05)	2.0

Growth and vigour of arable crops

Germination and seedling establishment

Seed germination was good in all cover crop treatments but seedling establishment was variable. Grasses were not satisfactorily suppressed either chemically or mechanically. Therefore, seedling establishment in grass covers was poor, irrespective of the method of sod suppression, and particularly bad with *Paspalum* and *Cynodon*. Seedling establishment was good in all legume covers, particularly those that were treated with foliar spray of paraquat. Quick and upright growing crops such as maize grew through the sod and suffered minimum shading damage compared with the slow growing cassava and low growing cowpea. Maize seedlings established through the residue of *Stizolobium* and maize and cowpea established through the in situ mulch of *Stylosanthes guianensis* are shown in Figs. 5 and 6, respectively.

Plant growth and vigour of maize and cowpea were significantly influenced by cover crops and the method of their suppression (Figs. 7 and 8). In general, plants were higher on chemically sprayed than on mowed treatments. Differences in plant height due to method of suppression were less pronounced in *Stylosanthes* because it was effectively suppressed by both chemical spray and mechanical mowing. Crop growth with grass covers (*Brachiaria*, *Paspalum* and *Cynodon*) was poor, irrespective of the method of suppression. Some climbers (e.g. *Psophocarpus*, *Pueraria*, *Stizolobium* and *Centrosema*) recovered quickly in mowed plots and climbed on the maize, cowpea and cassava plants and thus suppressed their growth.

TABLE V

Pore size distribution before (B) and after (A) 2 years of cover crops, computed from the pF curves reported by Lal et al., 1979

Cover crop	Total porosity (%, *v/v*)		Volume of pores (%, *v/v*) for different size (radius, μm) ranges															
			>15		5–15		3–5		1.5–3		0.75–1.5		0.5–0.75		0.1–0.5		<0.1	
	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Grasses																		
Brachiaria	46.4	50.2	21.0	25.1	6.5	8.2	1.8	1.1	1.0	0.7	0.9	2.5	2.1	0.4	1.9	1.1	11.2	11.1
Paspalum	51.8	55.2	26.4	28.9	4.8	7.0	2.6	2.1	0.9	2.1	1.6	1.2	1.1	0.3	1.8	0.9	12.6	12.6
Cynodon	52.3	53.7	25.8	28.1	5.8	8.0	1.0	1.3	1.7	2.7	3.1	1.6	0.5	1.0	1.6	0.2	12.8	12.8
Legumes																		
Pueraria	46.0	52.4	22.2	28.1	2.9	5.8	2.5	1.5	1.0	1.0	1.6	1.7	1.6	2.2	1.3	0.0	12.9	12.1
Stylosanthes	45.7	53.6	19.2	28.1	5.3	6.0	1.5	2.1	1.0	1.5	2.9	1.2	1.4	1.4	0.8	0.0	13.6	12.2
Stizolobium	47.7	53.5	22.3	28.2	3.3	6.4	1.9	0.7	1.4	2.9	1.6	1.2	1.5	1.3	2.7	0.0	12.8	12.9
Psophocarpus	49.6	51.3	26.1	26.1	2.0	5.2	2.5	1.6	0.7	3.4	1.5	0.3	1.9	1.3	1.6	0.4	13.3	13.2
Centrosema	49.4	50.7	24.3	26.3	3.2	4.2	1.7	1.3	1.3	3.9	1.6	0.1	2.2	1.7	2.0	0.0	13.1	13.2
Control																		
Weed fallow	44.4	53.3	22.2	31.1	0.2	1.7	1.8	2.3	1.2	2.1	2.0	0.7	2.1	2.9	1.6	0.0	12.5	12.6

Fig. 5. Cowpea and maize growing in the *in situ* mulch of *Stylosanthes guianensis*, three weeks after seeding.

Fig. 6. Maize seedlings growing in the residue mulch of *Stizolobium deeringianum*.

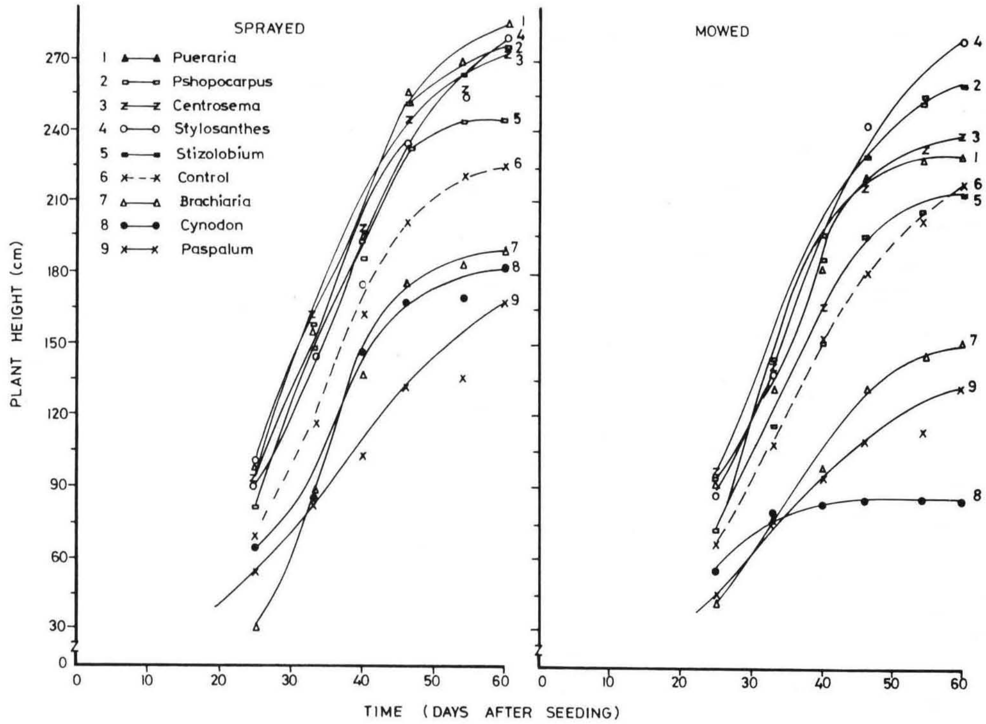

Fig. 7. Plant height of maize in the course of time.

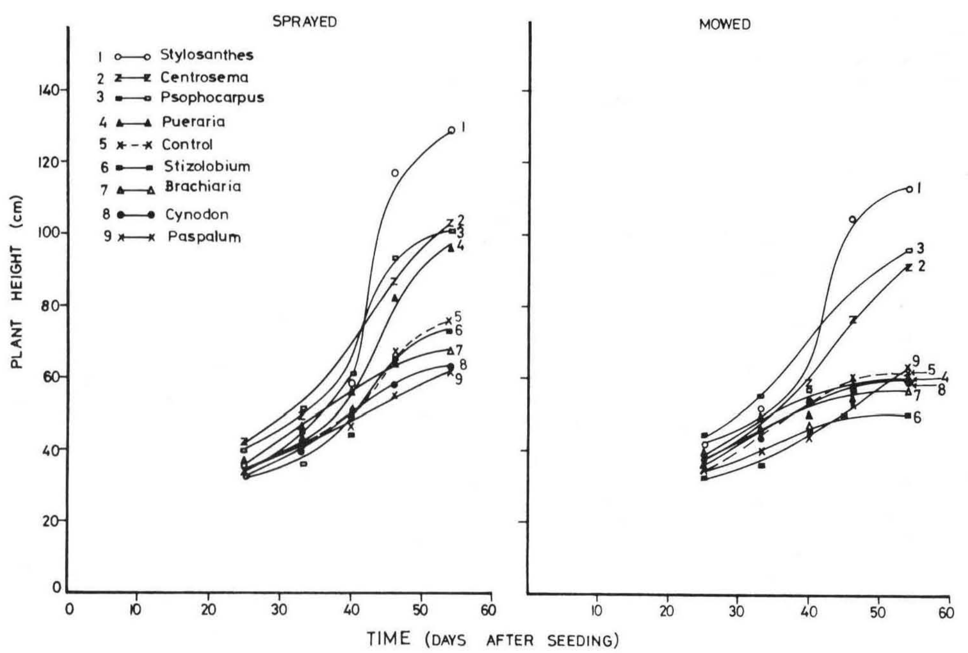

Fig. 8. Plant height of cowpea in the course of time.

Yield

Maize got off to a good start and escaped early competition by weeds and leguminous covers. Maize grain yield was significantly affected by the cover crops and the method of suppression (Table VI). In 1976 maize grain yield was very low with grass covers because they were not effectively suppressed by chemical or mechanical means or by subsequent maize growth. With chemical spray, high grain yields were obtained with *Psophocarpus*, *Stylosanthes* and *Pueraria*. Among the paraquat sprayed treatments in 1976, the maximum yield of 3.6 t/ha was obtained with *Psophocarpus* and it was significantly different from all grass covers, control, *Stizolobium* and *Centrosema*. Among the mechanically mowed treatments, the maximum yield was obtained with *Stylosanthes* (Table VI).

TABLE VI

Effect of cover crop and method of suppression on grain yield (t/ha) of subsequent maize crops

Cover crop		1976		1977	
		Sprayed	Mowed	Sprayed	Mowed
Grasses					
Brachiaria		0.3	0.1	2.0	0.3
Paspalum		0.1	0.0	0.2	0.0
Cynodon		0.1	0.0	0.0	0.0
Legumes					
Pueraria		3.2	2.0	1.9	0.3
Stylosanthes		3.1	3.0	2.8	2.0
Stizolobium		2.1	1.0	0.9	0.8
Psophocarpus		3.6	2.2	2.2	1.0
Centrosema		2.2	1.8	1.8	0.9
Control					
Weed fallow		1.8	0.8	1.3	0.3
LSD (0.05)	Cover crop	0.7		0.8	
	Suppression	0.3		0.5	

In 1977, the highest maize grain yield was obtained with *Stylosanthes* irrespective of the method of suppression. Similar to the performance in 1976, the grain yield of maize was low in all grass covers regardless of the suppression method. In 1977, *Brachiaria* cover sprayed with paraquat yielded 2 t/ha of grain indicating a more effective suppression in the 2nd than in the 1st year. Maize stover yield followed a pattern similar to that of grain yield (Table VII). High stover yield was obtained in chemically sprayed

TABLE VII

Effect of cover crop and method of suppression on maize stover yield in the first season and on grain yield of cowpea in the second season, 1977

Cover crop		Maize stover yield (t/ha)		Grain yield of cowpea (kg/ha)	
		Sprayed	Mowed	Sprayed	Mowed
Grasses					
Brachiaria		5.8	1.0	821	236
Paspalum		0.8	0.8	96	118
Cynodon		0.0	0.0	0	10
Legumes					
Pueraria		7.9	6.0	359	395
Stylosanthes		8.4	6.9	629	416
Stizolobium		3.4	2.3	457	356
Psophocarpus		7.8	5.0	711	716
Centrosema		8.7	3.6	761	639
Control					
Weed fallow		5.3	1.3	174	221
LSD (0.05)	Cover crop	1.9		330	
	Suppression	0.8		99	

plots of *Stylosanthes*, *Centrosema*, *Pueraria* and *Psophocarpus*. With the exception of *Brachiaria*, yield was low in all grass covers irrespective of the method of suppression.

Cowpea grain yield was significantly affected by the crop covers and the method of their suppression (Table VII). In the chemically sprayed treatments, significantly high grain yield was obtained with *Brachiaria*, *Centrosema*, *Psophocarpus* and *Stylosanthes* as compared with weed fallow control and the other grass covers. The method of suppression had a significant effect on cowpea yield on plots with *Brachiaria*, *Stylosanthes*, *Stizolobium* and *Centrosema*, sprayed treatments being superior to mowed plots. Grass covers *Paspalum* and *Cynodon* produced low yields, irrespective of the method of suppression.

Surprisingly low and highly variable yields of cassava (Table VIII) were found both in 1977 and 1978. Even the maximum yield of 3 t/ha observed in the mowed *Stylosanthes* treatment during 1978 was barely 25% of the normal yield level on these soils. This low yield may be attributed to a multitude of interacting factors. First, cassava is very slow to develop a canopy cover, and seedling establishment was most difficult even through effectively suppressed covers. The climbing legumes completely covered cassava seedlings and virtually suffocated them. Secondly, cassava was har-

TABLE VIII

Effect of cover crop and method of suppression on yield (t/ha) of subsequent cassava crops

Cover crop		1st year (1977)		2nd year (1978)	
		Sprayed	Mowed	Sprayed	Mowed
Grasses					
Brachiaria		1.19	0.08	1.49	0.28
Paspalum		0.14	0.89	0.14	0.00
Cynodon		0.08	0.07	0.00	0.00
Legumes					
Pueraria		0.17	0.69	0.58	2.44
Stylosanthes		0.14	1.61	2.44	3.06
Stizolobium		0.14	0.58	2.31	1.31
Psophocarpus		0.58	1.25	1.36	1.61
Centrosema		1.36	0.53	0.97	0.39
Control					
Weed fallow		0.39	0.31	1.44	0.28
LSD (0.05)	Cover crop	0.98		0.55	
	Suppression	0.46		0.31	

vested already about 9 months after seeding while normally the bulking and the maximum yield is obtained 15 to 18 months after seeding. This early harvesting was necessary because the experiment had to be terminated earlier. A short duration variety that bulks earlier would have produced a better yield. Third, because of severe erosion during the 5 years of cultivation, rooting depth for tuber development may not have been adequate. Fallowing with grass and leguminous covers for 2 years improved the physical and chemical properties of the 0—10-cm soil layer but did not improve soil depth. This lack of improvement in soil depth may partly be attributed to the failure of earthworms to colonize. The effective rooting depth above the gravel horizon is barely 20 cm even for a soil that has been fallowed under secondary forest regrowth of 15 to 20 years (Moormann et al., 1975). However, this factor of rooting depth may be least important among the three factors listed, because cassava roots can penetrate hard and compact layers better than cereals (Maduakor and Lal, 1982). Competition from weeds and suffocation by climbing cover crops, especially during the seedling stage from seeding to three months after seeding was the most important factor responsible for the low yield. Satisfactory tuber yield of cassava reported in the previous study (Lal et al., 1978) was due to the fact that the soil was not severely eroded prior to fallowing, and the earthworm activity improved soil moisture and rooting depth.

CONCLUSIONS

Shallow rooted grain crops can be grown after 2 to 3 years of fallowing with suitable crop covers on severely eroded Alfisols.

The leguminous cover crop *Stylosanthes guianensis* can be effectively suppressed by both chemical or mechanical means, which leads to good yields from grain crops such as maize and cowpea.

Grass cover crops cannot be sufficiently suppressed by paraquat or mechanically and, therefore, they are not suitable unless appropriate and economic herbicides are available to suppress them.

Cover crops improved soil structure, infiltration rate, and porosity. The improvement in porosity was brought about by an increase in transmission pores $> 5\ \mu m$ in radius. It was larger in deep rooted legume covers than in shallow rooted grasses.

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