PN-AAT-842

# No-tillage Crop Production in the Tropics

Proceedings of a symposium held August 6-7, 1981, at Monrovia, Liberia, sponsored by the West African Weed Science Society and the International Weed Science Society in collaboration with the West African Rice Development Association.


Edited by:

- I. O. Akobundu, weed scientist, International Institute of Tropical Agriculture
- A. E. Deutsch, technical assistance / information Internationl Plant Protection Center


February 1983

Published for the West African and International Weed Science Societies by the International Plant Protection Center, Oregon State University, Corvallis, OR 97331 USA.

IPPC document 46-B-83



Best Available Document

PN-AAT-842

# NO-TILLAGE WEED CONTROL IN THE TROPICS

I. Okezie Akobundu

- Weed Scientist, International Institute of Tropical Agriculture, Ibadan, Nigeria

*

## INTRODUCTION

Weed control is one of the most expensive aspects of crop production. Many tillage practices and pieces of equipment have been developed over the years essentially to control weeds in various crops, especially row crops, resulting in varying degrees of weed control and soil compaction. Reasons commonly given to justify tillage include a need to: improve soil structure, bury crop residue, and kill weeds. Man has cultivated the land for nearly 8,000 years (Alder, et al., 1976) in pursuit of these objectives and to the point where the detrimental effects of tillage on soil physical properties can no longer be ignored.

Concern over damage to soil structure resulting from various conventional tillage operations has led to interests in other tillage techniques such as minimum tillage, mulch tillage, and no-tillage. These tillage techniques have been listed in decreasing order with respect to the extent to which the soil is disturbed in the course of preparing the land and planting the desired crops. Chemical no-tillage practice differs from conventional and other tillage techniques in that crop seeds are planted directly into chemically killed stubble or sod with no more soil disturbance than is necessary to insert the seed into the soil. This type of no-tillage

technique can be distinguished from the no-tillage traditionally practiced by smallholder farmers of the tropics who usually solve the problem of preplant fallow vegetation by a slash-and-burn technique, and dibble their crop seeds into the soil without tillage. The absence of a crop residue mulch predisposes the smallholder farmer's field to some erosion albeit at a lower magnitude than is experienced when conventional tillage is practiced.

## NO-TILL CROP PRODUCTION IN THE TROPICS

Smallholder tropical farmers recognized the fragile nature of tropical soils decades ago and contained the problem by combining the bush fallow system of agriculture with small farm sizes and use of light tools that enabled them to either dibble in seeds, or make small mounds for root crops without the need to disturb the entire top soil. The long fallow period reduced dependence on chemical fertilizer, herbicides, and insecticides. However, high human population densities, changing social values, and sheer economic consideration have, in recent years, increased cropping intensity, created a need for increased farm size, and placed emphasis on more efficient labor-saving crop production methods.

Intensive cultivation of tropical soils has been shown to cause irreversible deterioration in soil structure (Nye and Greenland, 1960; Pereira and Jones, 1954; Pereira, et al., 1958). On the other hand, several studies have shown that, with no-tillage techniques, more intensive cropping is possible in the tropics, especially if the no-tillage practices include the use of crop residues (Couper, et al., 1979; Juo and Lal, 1977; Macartney, et al., 1971). The advantages of no-tillage crop production in the tropics include a reduction in soil surface temperature, suppression of annual grass weeds, increased water infiltration rate, reduced erosion hazard, maintenance of soil structure, provision of organic matter, and a more favorable environment for biological activity in the soil (Akobundu, 1977; Jones, et al., 1968; Juo and Lal, 1977; Lal, 1974; 1975; 1976; Rockwood and Lal, 1974; Verinumbe, 1981). Most of these advantages can be derived if a crop residue mulch is provided through the use of preplant herbicides. It is through proper kill of the preplant vegetation that a plant residue can be established to protect the soil from erosion as well as to smother weed seedlings.

## PROBLEM OF NO-TILL WEED CONTROL

A primary consideration in no-tillage crop production is weed control. In the tropics where weed growth is more rapid and technology less developed, weed management towers above other considerations related to economic production of basic food crops. Weed management problems in no-tillage crop production range from control of fallow vegetation, through management of the fallow vegetation residue, to choice of appropriate herbicides for specific crops. These problems are examined in relation to the major ecologies in which crop production is important in the tropics.

### A. Preplant Vegetation Management

With few virgin forests left in the densely populated parts of the tropics, most crop production activities center around the short duration bush fallows (2-4 year fallows). In the humid and subhumid regions, this fallow is a mixed vegetation of fast growing perennial broadleaves such as Alchornea spp., Combretum spp., Fiscus spp., Hippocratea pallens, Newbouldia laevis, Dioscorea spp., Albizia spp., Eupatorium odoratum, and some members of the Acanthacea family. The perennial grasses commonly encountered in short term fallows in the tropical forest and derived savanna regions are Panicum maximum (guineagrass), Ctenium newtonii, Pennisetum purpureum, Andropogon tectorum, Loudetia arundinacea, and Imperata cylindrica. In the savanna region, tussocky perennial grasses such as Andropogon, Hyparrhenia and Pennisetum spp. predominate. These species possess a remarkable ability for regrowth after the dead top growth is incinerated. A new flush of vegetative growth usually appears before the onset of rains. Other grasses include Digitaria scalarum, Cymbopogon and Sporobolus spp. The species richness of the different grasses varies with relief and microclimatic conditions.

Because the savanna is prone to fire during the dry season, perennial broadleaves tend to be those species that are able to resume growth after the dry season flash fires. Common among these are Daniellia oliveri, Butyrospermum parkii, Terminalia glaucescens, Lophira lanceolata, Isoberlinia spp. and Acacia spp. According to Keay (1959), these species produce new vegetative shoots after forest fires and before onset of rains. These perennials have a well-established root system that enables them to grow vigorously, often more vigorously than the planted crop. While competition

for nutrients may not be as pronounced as with annual weeds, the perennials may shade the crop, provide shelter for animal pests, and interfere with harvest operations.

Various fallow vegetation management practices have been tried. Slashing these perennials prior to cropping only sets them back, but does not prevent them from regrowing from basal stumps. The regrowth interferes with crop harvesting operations, an effect more severe in low growing crops such as cowpea (Vigna catjang Walp.) and soybean (Glycine max. Merr.) than in maize (Zea mays L.). Although paraquat has been successfully used for preplant vegetation control in no-tillage farming in temperate regions (Allen, 1974; Bachthaler, 1974; Triplett, 1966) this herbicide cannot be used exclusively as a preplant herbicide in the tropics because it is not effective against perennial weeds. Although glyphosate is effective against a wide range of tropical weeds (annuals and perennials), its high cost makes its use in a no-tillage package uneconomical for the production of most field crops. In addition, there are a few perennial weeds that are not controlled by glyphosate. These include Talinum triangulare, Ficus exasparata, and Hippocratea pallens. The control of Eupatorium odoratum with glyphosate is poor and often erratic.

In order for no-tillage weed control to be widely adopted and practiced in the tropics, herbicides that can effectively kill the mixed vegetation found in tropical fallow lands must be identified. These herbicides should be cheap, leave no residue that will interfere with the establishment of the crop plant, and provide a quick 'knock-down' effect of the fallow vegetation. When a preplant herbicide fails to completely kill the target fallow species within 3 weeks after application, annual weeds will invariably reinfest the field making it necessary for the farmer to apply paraquat prior to planting his crop to obtain the weedfree environment for germination and early seedling growth required by all food crops.

Herbicides such as 2,4-D, dicamba, picloram, amitrole and dalapon have been screened recently at the International Institute of Tropical Agriculture (IITA) for possible use in no-tillage preplant vegetation control. To date, no product has been found that is free from residue carry-over effect on the crop as well as capable of acceptable perennial weed control. An ideal herbicide for no-tillage preplant vegetation control in the tropics is one which has systemic action, little or no soil activity, quick 'knock-down'

effect (phytotoxicity occurring within 2 weeks of application), low cost, and a broad spectrum of activity against both perennial broadleaves and grasses (non-selective). It is unlikely that these attributes will be found in any one herbicide.

A need exists, therefore, to consider herbicide mixtures or, where antagonism in action occurs, sequential herbicide application. Such a proposition appears logical for glyphosate and 2,4-D. Greater phytotoxicity in Eupatorium odoratum treated with 2,4-D alone at 1.0 kg/ha has been observed than when the weed is treated with a tank mixture of 2,4-D + glyphosate (1.0 2.0 kg a.i./ha). Similar observations on the antagonistic effects of 2,4-D on glyphosate have been reported by O'Donovan and O'Sullivan (1982).

B. Residue Management

Whether surface mulch per se, is a requirement for the success of no-tillage crop production, especially in the short run, is not clear presently. But the importance of crop residue in reducing soil erosion, preventing direct impact of rain drops on the soil surface, restoring organic matter to soil, reducing surface soil temperature, and smothering weeds is well known (Baeumer and Bakermans, 1973; Bennett, 1977; Jones, et al., 1968; Juo and Lal, 1977; Kannegieter, 1969; Lal, 1975; 1980; Meyer, et al., 1970). In the tropics, crop residue levels vary from excess residue in the humid tropics, to near absence of crop residue in parts of the savanna and most of the semi-arid tropics. A number of factors that account for the scarcity of crop residue mulch in the savanna and semi-arid regions include excessive grazing, forest fire, sparse vegetation, and limited moisture.

While the presence of a crop residue mulch has several advantages in no-tillage crop production, excess plant residue has many disadvantages. It is difficult to plant crop seeds when the plant residue is too extensive. Excess plant residue smothers crop seedlings and also provides shelter for animal pests. In addition, studies have shown that crop residue mulch may intercept herbicides and reduce the efficacy of preemergence herbicides (Addy, 1981; Erbach and Lovely, 1975). In a greenhouse study, Addy (1981) reported that maize stover mulch in excess of 5 t/ha (oven-dry weight basis) was found to intercept over 66% of the metolachlor that was applied broadcast on the soil surface.

Smallholder farmers have traditionally solved the problem of excess plant residue by burning the dry residues. This action is a low cost method for getting rid of excess vegetation and also destroying weed seeds and animal pests. In the Ultisols, such burning is known to increase soil pH and reduce the need for liming. Modern no-tillage crop production involving use of herbicides for preplant vegetation control is yet to find a solution to the problem of excess plant residue. Such a solution should identify the optimum residue level necessary to achieve most of the benefits of crop residue mulch without the adverse effects of this mulch.

In the savanna and semi-arid tropics where plant residue for mulch is very limited, studies show that the sparse surface mulch available is not as effective as cultivation in conserving moisture in the poorly structured soils (Nicou and Chopart, 1979). However, surface mulch could play a role in reducing erosion. Some crops such as millet (Panicum miliaceum Linn.), maize, and sorghum are more effective than others (e.g., cowpea) in generating plant residues. In other parts of the semi-arid tropics, the increasing demand for crop residues such as groundnut (Arachis hypogaea Linn.) stubbles for animal feed casts doubt on the prospects of crop residue mulch for erosion control in this region.

## C. Herbicides for No-tillage Crop Production

While no-tillage crop production in temperate agriculture generally involves planting a crop either in the stubble of a previous crop or in a sod, no-tillage in tropical agriculture invariably involves planting a crop in a bush fallow. Consequently, herbicide requirements for preplant vegetation control are different for the two regions. For several years, paraquat has met most of the weed control needs of the temperate no-till farmer. By contrast, the tropical fallow vegetation predominated by perennial broadleaves and grasses requires a systemic herbicide that has a broad spectrum of action and that will not persist so long as to injure the farmer's crops. This type of herbicide is not generally available in the tropics. Further, a herbicide should not readily leach through the soil profile and contaminate underground water. This consideration is important because most inland waters in the tropics are potable water.

The lack of an appropriate, low cost herbicide for control of the fallow vegetation is a major limitation to large-scale adoption of no-tillage

systems in the tropics. While a farmer with fields heavily infested with Imperta cylindrica may be willing to make a once-and-for-all investment to rid his field of this rhizomatous perennial weed by using glyphosate at rates of 2.9-3.6 kg/ha at a current cost of over U.S.$250 per ha, the same farmer will be unwilling to use glyphosate regularly as part of a no-tillage herbicide package because of its high cost. The reason why there are so few alternatives for the tropical no-till farmer can be traced to the fact that very few tropical weeds are included in primary screening of herbicides during early testing of proprietary products. Consequently, herbicide use in tropical agriculture has centered on discovering new uses for products developed, for example, for Avena fatua L. (wild oat) control in small grains, or control of Xanthium pensylvanicum Wallr. (cocklebur) in soybean in temperate agriculture.

### D. Animal Pest Problems in No-tillage

Little research has been done to quantify damage by animal pests in no-tillage crop production in the tropics. However, insect, bird, and rodent damage has been observed to be greater in no-tillage maize than in a conventionally tilled crop. The presence of crop residue appears to favor insect damage in maize. Musick (1970) reported poor seedling emergence and increased insect damage of no-till corn. Damage by above-ground insects in no-till crop was confirmed by Gregory (1974).

The problem of pests and their control in no-tillage crop production was recently reviewed by Gregory and Raney (1979). The animal pest problems identified included insects, field mice, birds, and slugs. According to these authors, killing fallow vegetation with herbicides destroys the natural food source of field mice who then turn to crop seedlings for food, causing serious damage. Control measures used in temperate agriculture have emphasized increased use of pesticides--a practice that may not be readily acceptable in the tropics. It is generally accepted, however, that insect management under no-tillage is difficult because of pesticide application problems.

## RECENT ADVANCEMENTS IN NO-TILL WEED CONTROL

The widely accepted advantages of no-tillage crop production in the tropics include reduced soil erosion, energy conservation, reduced soil

compaction, reduced moisture loss through evaporation, improved moisture regime through increased infiltration, reduced soil temperature, and increased land use. In order to derive these advantages, weeds must be properly and more precisely controlled than in a conventional tillage system. A myriad of weed problems tends to complicate weed control efforts. Perhaps the greatest impediment to effective solution of weed problems in the tropics is a shortage of manpower to deal with the challenge. There are only three institutions known to this author that are deliberately working on weed control in no-tillage crop production in the tropics. These are the International Institute of Tropical Agriculture, Ibadan, Nigeria, the joint International Plant Protection Center/Centro Agronomica Tropical de Investigacion y Ensenanza program in Central America, and the research centers in West Africa coordinated by the Institut de Recherches Agronomiques Tropicales, Montpellier, France.

Although earlier reports by Lal (1980) include cassava (Manihot utilissima Pohl.) among crops that can be grown in no-tillage, more detailed study by Akobundu (1982) shows that both weed control and crop yield are significantly poorer in no-tillage than in conventionally tilled cassava. However, the no-tillage system is applicable to grain legumes and cereals.

Advances in no-tillage weed control have occurred in two distinct directions: (a) chemical; and, (b) biocontrol. In the chemical no-tillage system, effort has centered on identifying suitable herbicides for preplant weed control together with appropriate herbicides for preemergence weed control. The currently used packages for maize and cowpea weed control are listed in Table 1.

For biocontrol, current research centers on manipulating herbacious tropical legumes for weed control in food crops. One aspect of this research has been the use of annual legumes, such as Mucuna utilis (mucuna), which either can be interplanted in maize or used as a fallow crop. The legume dies off during the dry season and maize can be grown without tillage in the mulch left by the mucuna. The mucuna mulch helps smother weeds and thus reduces the rate of herbicide needed. One problem associated with this dead mulch system is the control of volunteer mucuna in the maize. The presence of volunteer mucuna precludes growing a legume crop in this system.

Table 1

NO-TILLAGE WEED CONTROL PACKAGE FOR COWPEA AND MAIZE

| preplant herbicides | |
|---|---|
| annual weeds | perennial weeds |
| Paraquat 1.0 kg/ha | Glyphosate 2-3 kg/ha |
| | Glyphosate 1.5 kg/ha fb 2,4-D 0.5-1.5 kg/ha |

| preemergence herbicides** | |
|---|---|
| cowpea | maize |
| 1. metolachlor | 1. atrazine + metolachlor |
| 2. metolachlor + metobromuron | 2. atrazine + pendimethalin |
| 3. metobromuron + pendimethalin | 3. atrazine + alachlor |
| | 4. atrazine fb 2,4-D |

*fb = followed by.

**Rate of herbicide varies with soil conditions and rainfall.

Another biocontrol approach involves the live mulch system. In this no-tillage practice crop seeds are directly planted into a living perennial legume mulch without tillage and without need for either preplant or preemergence herbicide. Maize production in this system has been described earlier by Akobundu (1980). A comparison of crop production in conventional tillage, no-tillage, and a live mulch system under continuous cropping conditions shows that maize yield was greater in the live mulch and no-tillage systems than in conventional tillage under continuous cropping (Figure 1). High maize yield was obtained in the no-till crop through use of high rates of nitrogen fertilizer, while the live mulch cropping system produced a favorable crop yield at low nitrogen levels. On the other hand, maize yield dropped in the continuously cropped conventional tillage plots in spite of high inputs in nitrogen fertilizer. The return of organic matter to the soil

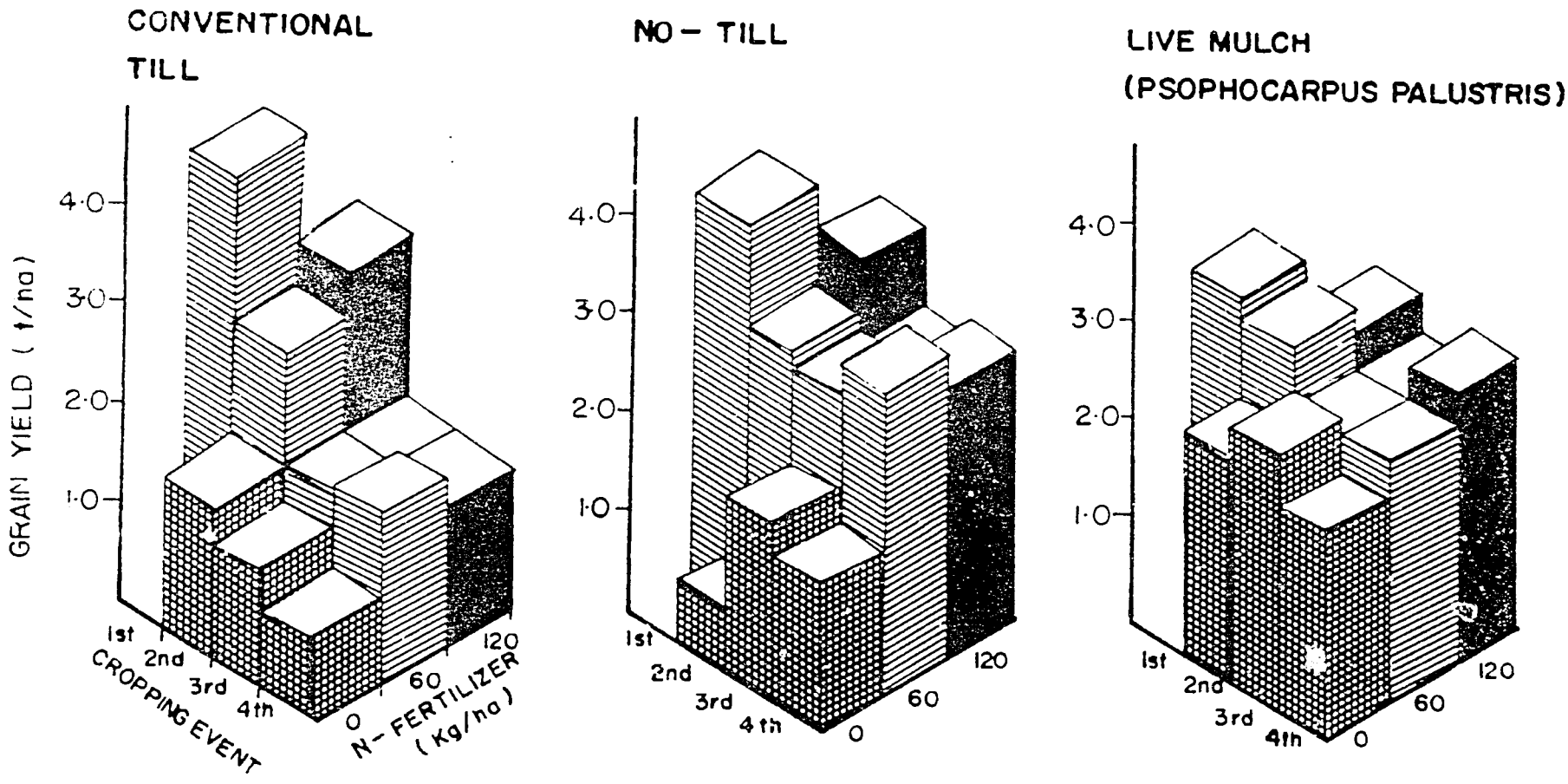


Figure 1. Effect of Land Management, N-Fertilizer, and Cropping Intensity on Maize Yield (I.I.T.A., Ibadan, Nigeria, 1979 and 1980).

in the no-till and live mulch systems is implicated in the soil conditions that favored better crop performance in these systems.

## CONCLUSION

No-tillage crop production is evidently necessary if the carrying capacity of arable lands is to be improved in the face of increasing human population. In order to derive the benefits that are associated with no-tillage crop production, proper weed management practices that incorporate weed control and reduction in weed seed population in the soil must be developed and made available to farmers. Although no-tillage has merit, it must be recognized that its successful adoption requires skilled management in order for the no-till benefits to be realized.

Two approaches to no-tillage crop production in the tropics have been suggested. A no-tillage system that depends on herbicides for its implementation, and an alternative system that depends for its success on the use of mulch (living and dead) from herbacious legumes. Effective transfer of these technologies to the farmer requires trained personnel to assist with the transfer in developing countries. It also requires that herbicides, where they are to be used, should be available in consumer useable packages. Ultimately, the success of food production in the tropics requires recognition of these constraints and a demonstrable willingness on the part of researchers and policy makers in government to solve the research, staff, and infrastructural problems that directly and indirectly limit food production.

## LITERATURE CITED

Addy, B.N.A. 1981. The effect of crop residues on the efficacy of preemergence herbicides in no-tillage crop production in the tropics. M.S. thesis, Univ. of Reading, Reading, U.K. 84 p.

Akobundu, I.O. 1977. Advances in weed control in conventional and no-tillage maize. Proc. Weed Sci. Soc. Nigeria 7:10-18.

Akobundu, I.O. 1980. Live mulch: a new approach to weed control and crop production in the tropics. Proc. Brit. Crop Prot. Conf.-Weeds 2:377-382.

Akobundu, I.O. 1983. Weed control in no-tillage cassava in the humid and subhumid tropics. In: Akobundu, I.O. and A.E. Deutsch, eds., No-tillage Crop Production in the Tropics (in press).

Alder, E.F., G.C. Klingman, and W.L. Wright. 1976. Herbicides in the energy equation. Weed Sci. 24:99-106.

Allen, H.P. 1974. ICI Plant Protection Division experience with direct drilling systems, 1961-1974. Outlook Agric. 8(spec. number):213-215.

Bachthaler, G. 1974. The development of the weed flora after several years' direct drilling in cereal rotations on different soils. Proc. 12th Brit. Weed Cont. Conf. 3:1063-1071.

Baeumer, K. and W.A.P. Bakermans. 1973. Zero-tillage. Adv. Agron. 25:77-120.

Bennett, O.L. 1977. Conservation tillage in the Northeast. J. Soil and Water Conser. 32:9-12.

Couper, D.C., R. Lal, and S. Claassen. 1979. Mechanized no-till maize production on an Alfisol in tropical Africa. Pg. 147-150, in: Lal, R., ed., Soil Tillage and Crop Production, Proc. series no. 2. IITA, Ibadan, Nigeria.

Erbach, D.C. And W.G. Lovely. 1975. Effect of plant residue on herbicide performance in no-tillage corn. Weed Sci. 23:512-515.

Gregory, W.W. 1974. No-tillage corn insect pests of Kentucky.... A five year study. Proc. Nat. No-tillage Research Conf. 1:46-58.

Gregory, W.W. and H.G. Raney. 1981. Pests and their control. Pg. 55-68, in: Phillips, R.E., G.W. Thomas, and R.L. Blevins, eds., No-tillage Research: Research Reports and Reviews. Univ. of Kentucky, Lexington, KY, U.S.A. 151 p.

Jones, J.N., J.E. Moody, G.M. Shear, W.W. Moschler, and J.H. Lillard. 1968. The no-tillage system for corn (Zea mays L.). Agron. J. 60:17-20.

Juo, A.S.R. and R. Lal. 1977. The effect of fallow and continuous cultivation on the chemical and physical properties of an Alfisol in the tropics. Plant and Soil 47:567-584.

Kannegieter, A. 1969. The combination of short term Pueraria fallow, zero cultivation and fertilizer application, its effects on a following maize crop. Trop. Agriculturist J. (Ceylon) 125:1-18.

Keay, R.W.J. 1959. An outline of Nigerian vegetation. Federal Government Printer, Lagos, Nigeria. 46 p.

Lal, R. 1974. No-tillage effects on soil conditions and maize production in western Nigeria. Plant and Soil. 40:321-331.

Lal, R. 1975. Role of mulching technique in tropical soil and water management. IITA Tech. Bull. 1. 38p.

Lal, R. 1976. No-tillage effects on soil properties under different crops in western Nigeria. Proc. Soil Sci. Soc. Amer. 40:762-768.

Lal, R. 1980. Crop residue requirements with no-tillage systems. Pg. 337-343, in: Akobundu, I.O., ed., Weeds and Their Control in the Humid and Subhumid Tropics. Proc. series no. 3, IITA, Ibadan, Nigeria. 421 p.

Macartney, J.C., P.J. Northwood, M. Dagg, and R. Dawson. 1971. The effect of different cultivation techniques on soil moisture conservation and

the establishment and yield of maize at Kong central Tanzania. Trop. Agric. (Trinidad) 48:9-23.

Meyer, L.D., W.H. Wischemier, and G.R. Goster. 197[illegible] Mulch rate required for erosion control on steep slopes. Proc. Soil Sci. Soc. Amer. 34:928-931.

Musick, G.J. 1970. Insect problems associated with no-tillage corn production. Proc. Northeast No-tillage Conf. 1:44-59.

Nicou, R. and J.L. Chopart. 1979. Les techniques d'economic de l'eau dons les sols sableux de Senegal. Pg. 249-257, in: Lal, R., ed., Soil Tillage and Crop Production, Proc. series no. 2, IITA, Ibadan, Nigeria.

Nye, P.H. and D.J. Greenland. 1960. The soils under shifting cultivation. Tech. Comm. No. 51, Commonwealth Bureau of Soils, Commonwealth Agr. Bureaux, Bucks, U.K. 156 p.

O'Donovan, J.T. and P.A. O'Sullivan. 1982. The antagonistic action of 2,4-D and bromoxynil on glyphosate phytotoxicity to barley (Hordeum vulgare). Weed Sci. 30:30-34.

Pereira, H.C. and P.A. Jones. 1954. A tillage study in Kenya. II. The effect of tillage practices on structure of soil. Empire. J. Expl. Agric. 23:323-330.

Pereira, H.C., R.A. Wood, H.W. Brizostowki, and P.H. Hosegood. 1958. Water conservation by fallowing in semi-arid tropical soil of east Africa. Empire. J. Expl. Agric. 26:213-228.

Rockwood, W.G. and R. Lal. 1974. Mulch tillage: A technique for soil and water conservation in the tropics. SPAN. 17:77-79.

Triplett, G.B. Jr. 1966. Herbicide systems for no-tillage corn (Zea mays L.) following sod. Agron. J. 58:157-159.

Verinumbe, I. 1981. Economic evaluation of some zero-tillage systems of land management for small scale farmers in southwestern Nigeria. Ph.D. thesis, Univ. of Ibadan, Nigeria.