SYSTEMS, TECHNIQUES & TOOLS

CONSERVATION FARMING

For Small Farmers In The Humid Tropics

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CONSERVATION FARMING

For Small Farmers
In The Humid Tropics

Ray Wijewardene and
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This up-dated revision of the Conservation Farming manual
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1. Foreword

The last few decades have seen unprecedented advances in arable crop production over much of the tropics. The advances — the *Green Revolution* — were based on the breeding of new varieties (of rice and wheat, in particular) which responded with high yields on good soils when provided with high levels of management and purchased inputs; inputs such as chemical fertilisers and pesticides in addition to improved tillage and irrigation. However, the *Green Revolution* had little impact upon the vast majority of farmers in the tropics who farmed poorer soils at subsistence levels. They could not afford the inputs, nor were the fragile eco-systems upon which they existed conducive to such 'high-input' technologies.

The techniques of *Conservation Farming* have evolved primarily for these latter farmers. Through conserving the natural resources of the soil, its surface and sub-soil fertility, the water it receives from rainfall, and the natural recycling of forest vegetation, it aims to provide an essentially low-input but productive and self-sustaining system of farming. Farming for food and market as well as fodder for livestock and fuel for the hearth.

"Because most agricultural land has long been brought under cultivation, the objectives of agricultural research should be to develop land management systems to increase intensity and efficiency of production per unit area and unit time. Further, this increase in production should be achieved with minimal dependence on petroleum-based inputs, and with least damage to the natural resource base and environment" (Lal, 1982).

This Manual is revised and up-dated as a guide for *Conservation Farming* practitioners; for the farmer — trainer; for the extensionist and others wishing to try for themselves these methods and techniques. The authors have, therefore, commenced with a review of the tropical farming background and of the basic concepts which led to the development of the systems of *Conservation Farming*.

The techniques and associated tools are then described in greater detail in subsequent chapters. While the techniques — like any other skill — are best learned through demonstration, this Manual will serve to support such field training and to provide the technological background necessary to their better understanding.

2. The Background . . . Traditional Farming (Shifting Cultivation)

Traditional tropical farming systems such as shifting cultivation and the various stages of *bush-fallow* farming, were self-sustaining and required virtually no external inputs. Over 300 million people in the tropical world still eke a living out of bush-fallow systems! In this time-proven system, a plot of forest or bush is slashed of high shade which is then burned to bring light through to the fertile, weed free soils beneath, and onto which arable food crops are sown and tended for one or two seasons. However, under the severity of tropical rainfall, the bare soils quickly erode and fertility declines. Weeds then invade the plot leaving the farmer little recourse but to abandon the land and clear a fresh patch elsewhere.

Although condemned by those unacquainted with tropical agriculture as primitive and wasteful of land, the 'bush fallow' system was not an unstable or unproductive technique within its particular context of adequate land area for the small and scattered population living off it. Attempts, all over the tropical world, to replace it with an open-field tillage-intensive system, as prevails in the temperate countries, have invariably failed. Declining fertility, — despite added fertilisers, — and increasing competition from weeds have contributed to the abandonment of most of these endeavours. Recent, more scientific and thorough inquiry into such traditional systems of shifting cultivation and *bush-fallow* have established their rationality and the need to appreciate the principles underlying them before attempting to improve upon or replace them.

The key to the successful tradition of shifting agriculture was the fallow period which would ideally be long enough (often ten to fifteen years) to restore the fertility lost through erosion, leaching and cropping. The more competent of those farmers left the stumps and trunks of the forest trees lopped high enough so that while adequate light penetrated to the soil, regeneration thereafter, of the forest was quick. The trunks re-grew leaves and branches drawing upon nutrients from the sub-soil through well established root systems. In time these fell to re-form the protective and restoring litter or 'mulch' over the surface of the soil, which micro-organisms then broke down and thus fertility was re-established . . . . in time!

Investigations at Carare, in Colombia (Sanchez, 1979) showed that the mass of litter of a virgin forest floor was in the region of 10 tonnes per hectare with nutrient contents of about 140-N, 4-P, 17-K, 90-Ca, and 20-Mg; and that these levels of fertility were re-established in a forest fallow of about sixteen years duration.

Fig. 1. A clearing of an experienced forest farmer with trees lopped high for quick regeneration and sufficient to allow light through to the fertile soil below.

But, while the traditional bush-fallow system had the essential attributes of a stable agriculture, increasing pressures of population have greatly reduced the time for fallow on much of the terrain which was once forest covered. The ensuing almost-continuous-cultivation with meagre (if any) restorative measures has usually resulted in a staggering decline in yields corresponding with the declining fertility.

Table 1. below, from a long-term experiment in Northern Nigeria shows how the yields of peanuts, millet and sorghum declined steadily over several 5-year-periods of continuous cropping.

Table 1: **Declining yields of continuous cropping — Nigeria**

5 year cropping period	Peanuts (kernels) kg/ha	Millet (grain) kg/ha	Sorghum (grain) kg/ha
1931 — 1935	1015	920	540
1936 — 1940	785	455	330
1941 — 1945	700	320	105
1946 — 1950	320	545	90
1951 — 1955	510	300	discontinued

Source: Norman, 1979

3. Constraints To Tropical (Upland) Farming and Their Resolution

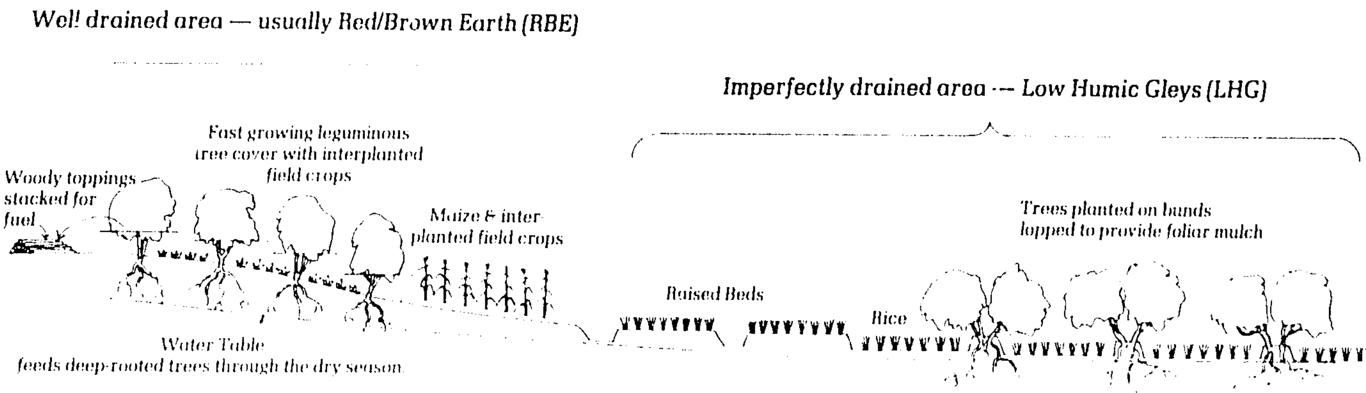


Fig. 2. **Optimised soil slope catena**

Farming in the humid — and semi-humid — tropics falls generally into two categories based upon the position of the farm plot on the soil-slope topo-sequence. The lowlands, usually flooded during the rainy season, and generally with poor drainage, comprise most of the valleys. The uplands — better drained, are usually undulating with slopes of 15 to 20 percent — comprise the major (usually over 80%) proportion of the land area. It is these uplands which have proven most difficult to farm on a sustained basis, and where shifting cultivation has provided the only stable agriculture so far.

Agricultural productivity in these tropical uplands is constrained by:

* The high intensity of tropical rainstorms which causes heavy *erosion*, and run off; also losses through leaching.
* General soil *infertility* aggravated by the erosion, the leaching and by cropping without restorative inputs.
* Heavy competition from *weeds* and inadequate (usually erosive) tillage-based weed control practices.
* Insect, *pest* and disease problems usually aggravated by the tropical heat.

3.1 Soil, water and fertility management

Soil and water management is based on two fundamental principles:

(1) Maintaining sufficiently high rates of rainfall infiltration.

(2) Disposal of run-off water without consequential erosion.

The impact of high-energy raindrops of intensive tropical rainstorms breaks up the surface soil aggregates on bare, exposed soils causing surface sealing and compaction. This seals off infiltration of the rainfall which then runs down the slope, accumulating in volume and velocity as it progresses, and leading to 'sheet' as well as 'gully' — erosion. The **first stage** in erosion prevention is therefore to avoid direct contact of the rainfall with bare soils and the splash erosion which thereby commences. This is achieved primarily through providing an intermediary, impact-absorbing, layer of mulch through which the rainfall then trickles (infiltrates) into the soil.

The **second stage** in erosion-prevention is to constrain such run-off, as still exceeds the rate of infiltration, by physical barriers such as contour-bunds, tied-ridges, etc.

Lal (1976) showed how a mulch cover of straw (6 t/ha) decreased erosion by 99% and run-off by 94% on a bare, fallow plot with 10% slope (Table 2).

Table 2: **Effect of ground cover on run-off and soil losses (10% slope)**

Mean annual value	Bare Ground	Mulched 6t/ha
Soil loss (t/ha)	232.6	0.2
Run-off (% of rainfall)	42.1	2.4

Adapted from Lal (1976)

Large quantities of organic matter and nutrients are lost through erosion and leaching. It has been estimated that on a 10% slope (quite an average slope upon which upland farming takes place), nearly 2 tonnes of organic matter and 200 kg of nitrogen are thus lost from a hectare of bare

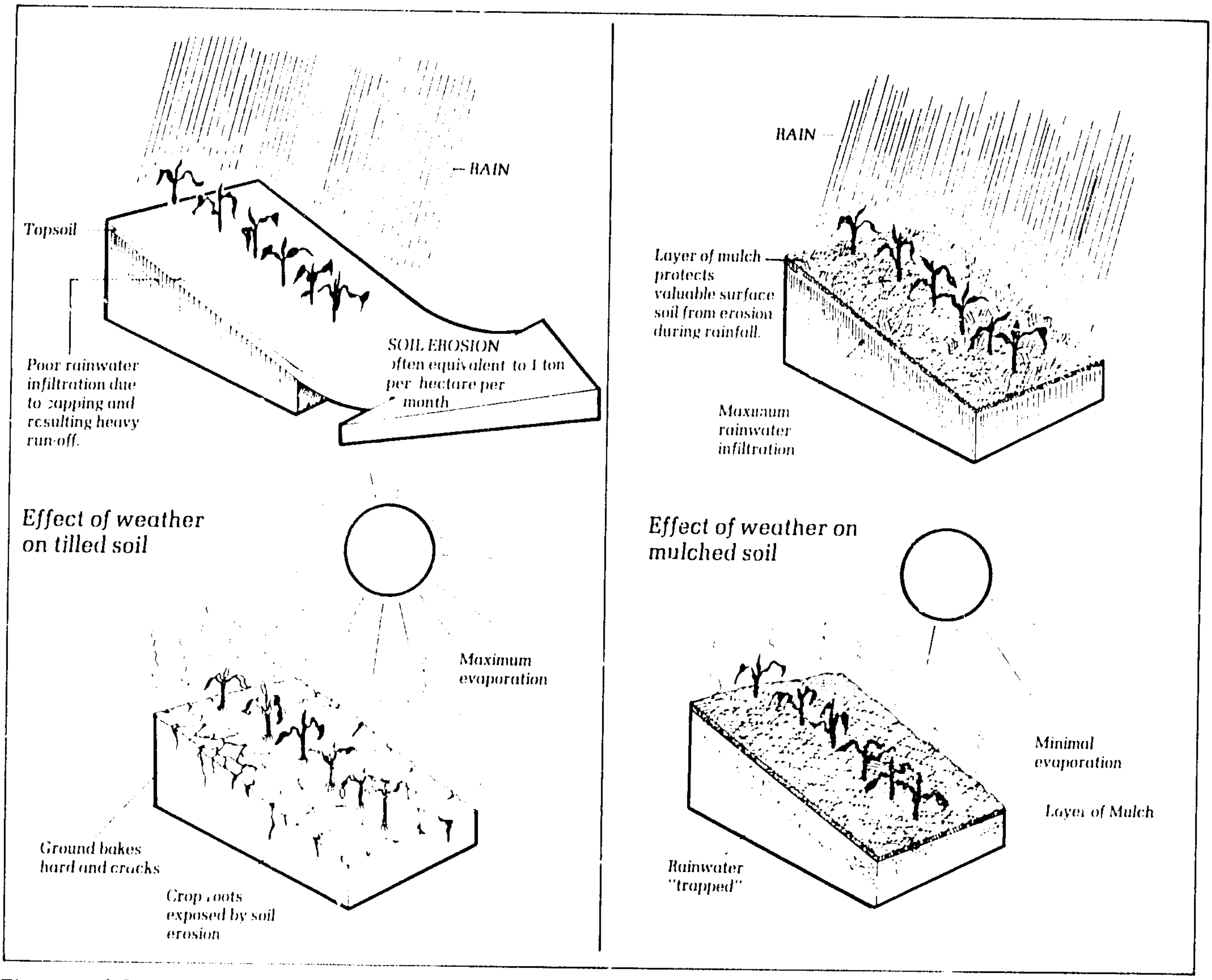


Fig. 3. **Mulch — for Erosion Prevention**

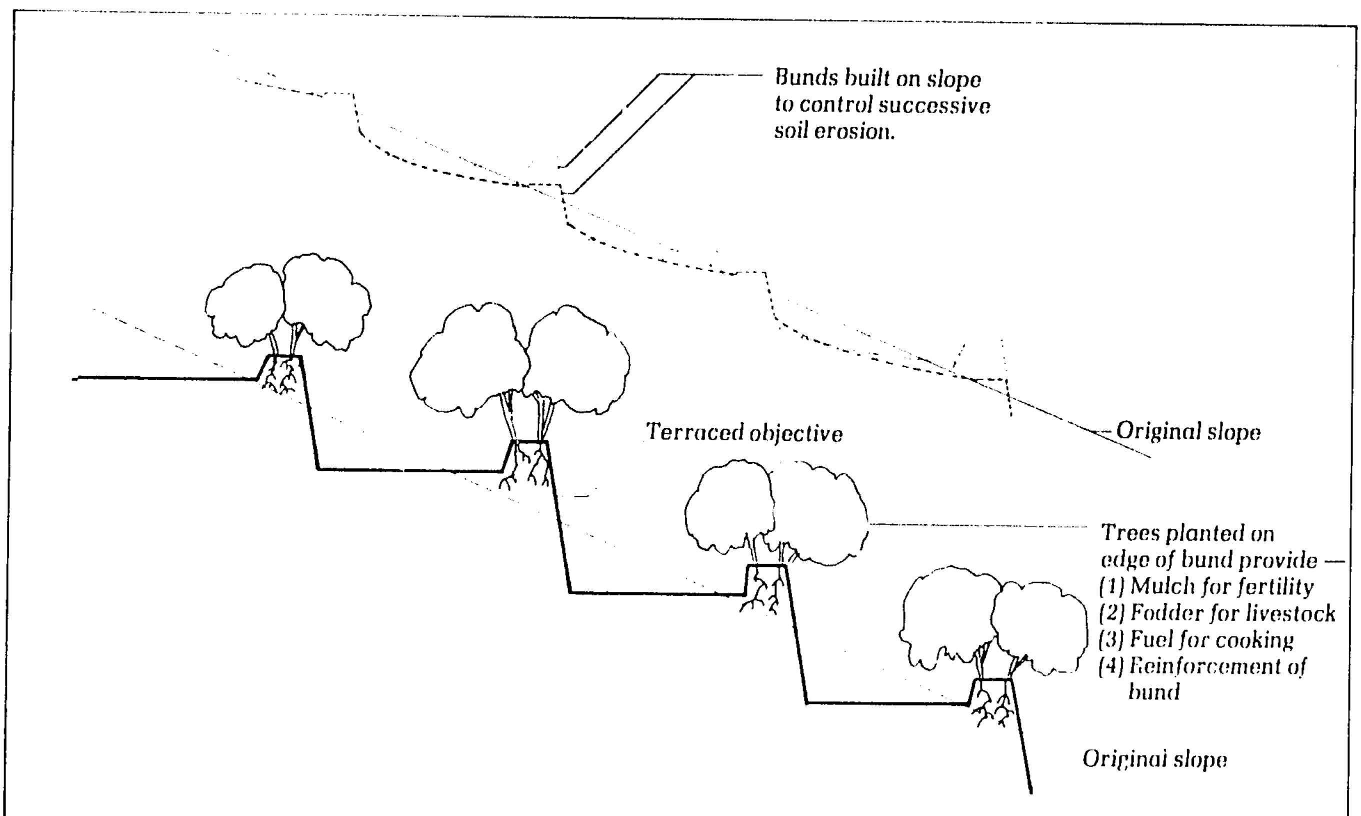


Fig. 4. **Contour bunds (and eventually terraces) — for Erosion Control**

land each year! It is for conservation of such natural resources that the techniques of conservation farming have been evolved.

Apart from decreasing erosion and increasing infiltration (and thus the capacity of the soil and sub-soil to absorb and hold water), mulching improves the organic matter content of the soil and hence its physical and chemical properties such as its bulk density, its moisture-holding capacity and base-exchange capacity.

Soil temperatures are lower and fluctuations of temperature are greatly reduced under mulches and vegetation cover. Mid day temperatures of the soil as high as 40 to 45°C, have been recorded on open lands whereas under forest covers they were only 25 to 30°C. High soil temperatures (over 36°C) can adversely affect crop-emergence, vigour and yields. Conservation farming techniques using mulch, trees and living ground covers and minimal disturbance of the soil greatly ameliorate temperature fluctuations in tropical soils.

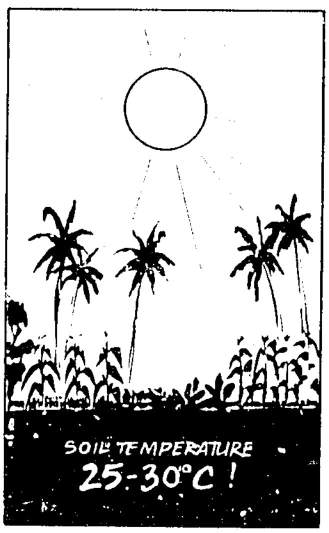


Fig. 5a. **Effect of mulch and vegetative cover on soil temperature**

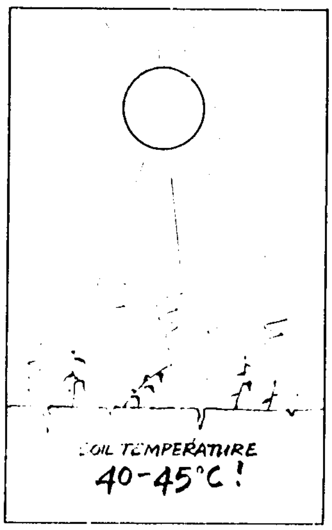


Fig. 5b. **The consequences of hot sun on bare soil**

Any organic matter such as leaves, twigs, crop-residue, etc. on the surface of the soil is termed mulch. Inorganic and plastic mulches have also proven successful but are usually much more expensive.

3.2 Land clearing and post-clearing management

The various methods by which land is cleared in the tropics and its subsequent management have tremendous impact upon soil fertility. There is good evidence that traditional (slash and burn) clearing is superior to modern mechanised clearing where soil and fertility conservation is concerned. Removal of the forest cover, irrespective of the method, initiates many soil deteriorating processes! Lal (1976) has shown that of the various mechanical methods used for rapid clearing of forest land, use of the bull-dozer — mounted shear-blade resulted in least damage to the soil, and particularly when followed by the 'no-till' technique of farming. This technique will

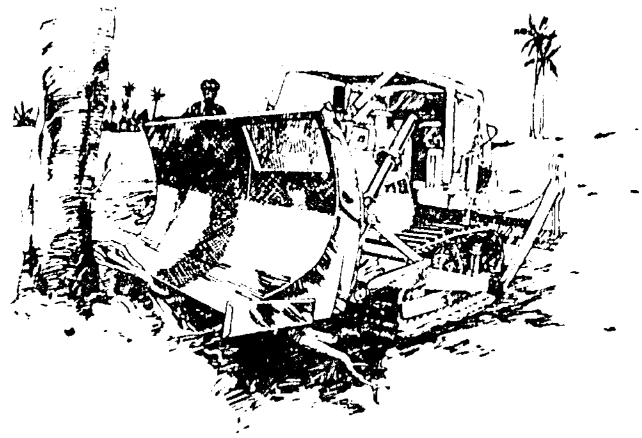
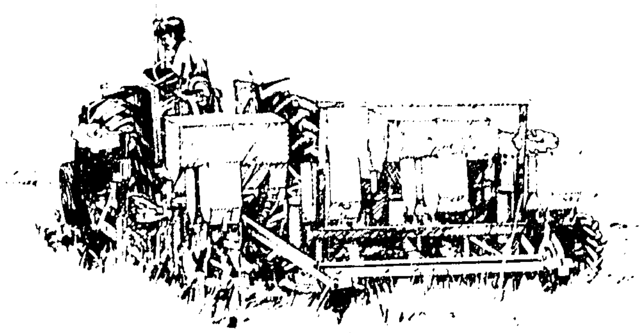


Fig. 6a. **Shear blade on bulldozer for clearing with minimum soil disturbance, followed by ......**



...... Fig. 6b. **No-till planter**

be described in a subsequent section. **Most** damage to the soil and its fertility was caused by the now customary process of bull-dozer with tree-pusher followed by wind-rowing and raking for subsequent 'tillage' with plough and harrow. These (latter) processes of clearing and farming have resulted in levels of erosion many **hundreds** of times greater than the newer (mechanised) techniques using the shear-blade to fell the trees at ground level, then followed by 'no-till' farming. Further details of these trials with alternative methods for land clearing may be obtained from the 1980 Annual Report of IITA (the International Institute of Tropical Agriculture); results show that yields from the bull-dozed and tillage-farmed fields were less than half those of conservation-farmed fields using the new techniques of 'no-till' following minimal soil disturbance during initial clearing of the land.

3.3 Weeds and their management

Weed management and fertility management are the two most critical aspects of tropical farming, — and the most expensive! Flinn (1974) has gauged that over 60% of tropical farmers' time on the land is spent coping with weeds. Even in the context of temperate farming, most of the implements used on a farm are for control of weeds; the plough, harrow, cultivator, row-planter, ... virtually all the high energy tools!

One of the most critical aspects of weed control is timeliness! With most tropical arable crops, competing weeds ideally need to be removed by the third week after the crop has been seeded — and certainly by the fifth week — or permanent damage results to crop yields! After this stage the crop is better able to cope with weed development as the crop canopy cover thereafter successfully suppresses (shades) the weeds.

Commonly used methods of weed control include:-

- Physical methods which include hand weeding, often assisted by simple hand hoes or animal-drawn 'cultivators' used between crops planted in rows for ease of weed control.
- Chemical methods (herbicides).
- Cultural methods — complementary Cropping Systems, etc.

Ideally, two or more of these methods need to be integrated for effective and economic control within the limited time available.

3.3.1 Chemical weeding

While still not commonly used at subsistence levels of farming — except under more intensive, (settled) farming conditions — the use of herbicides needs better understanding as they are a valuable tool where supplies are available. The use of cheaper (off-patent) herbicides is increasing in several developing countries and is clearly an economic practice. However correct use of the sprayer requires skills (as with any new tool) and better farmer training in this area is vital — for safety reasons too! The knapsack sprayer has often proven to be the first step in mechanization adopted by the tropical farmer. This will be discussed further, later in this Manual.

3.3.2 Cultural methods: seed rate and row width

Often a useful way to manage weeds is to increase net plant density through a higher rate of seeding than the technical optimum. Also the use of closer row-spacing generates earlier shading of the inter-row spaces, where weeds tend to accumulate, and thus reduces the period (quantum) of weed control otherwise required.

3.3.3 Cultural methods: mixed cropping, inter-cropping

Mixed cropping in traditional farming systems has inherent weed management attributes. Sowing two or more crops with multi-storey attributes — either sequentially or concurrently — enables quicker coverage of the soil with desirable crops and thus a shading out of weeds before they emerge. It often also provides higher returns than the main crop alone, and with less effort. Greater skills, however are required of the farmer in respect of times for planting of the related crops. Examples of such traditional complementary or combination cropping include growing cowpea or mung bean between rows of the taller sorghums, as also the growing of surface creeping vines such as melon or sweet potato between taller crops, of maize or cassava. The reader is referred to the Annual Reports of the IITA, ICRISAT, IRRI, and CIAT for detailed information on the more recent developments in multiple cropping.

Fig. 7. **Mixed (complementary) cropping — Maize, Cowpea, Melon, Soya**

Table 4 from the IRRI Annual Report for 1973 demonstrates how the gross income from the combination cropping of corn (maize) and mung can be higher than from either corn or mung grown alone, apart from the need for no additional weed control.

Table 3: Gross returns for corn, mung, and corn-mung intercrop

Crop	Gross returns Pesos/ha		Increase
	No weed control	With weed control	%
Corn alone	1300	2450	88
Mung alone	2480	2930	18
Corn & Mung	2370	3920	65

IRRI (1973) Annual Report

Corn grown alone yielded 88% higher when weed were controlled, as might be expected. Yet yields for the corn-mung intercrop provided higher gross income whether with or without physical suppression of weeds, as the system had such good inherent control of weeds.

3.3.4 Cultural methods: fallowing

In the bush-fallow system, weeds are usually shaded out by the high shade of the re-growing bush and trees. Therefore weeds are rarely a problem after an extended fallow period. and the farmer only needs to lop and remove the high shade before sowing his crop-seed into the mulch-fertilised soils below, without recourse to tillage. This feature of 'shade-control' of weeds is exploited in the techniques of 'live-mulch-cropping' (or cover-crop-fallowing) and of 'avenue-cropping' (or 'alley-cropping') which are described later in this Manual.

4. 'Zero' and 'Minimum' Tillage

4.1 Background

Zero tillage or 'no-till' farming is as old as agriculture. It was practised by primitive farmers who felled and burned a patch of forest, and dibbled seed into the ash-mulched soil. Any weeds were desiccated by the burn before seeding.

Subsequent crops were, however, infested with weeds, and the farmer resorted to tillage to control them. However, tillage aggravated erosion and consequent loss of soil fertility which are most serious under the intensive rainfall of the humid tropics.

The advent of herbicides in the 1940s, and development in more recent years of total weedkillers such as paraquat and glyphosate, paved the way to crop establishment without tillage. Crops can now be seeded directly into the sod left after killing weeds with a herbicide. This method has also greatly benefitted from the even more recent development of selective pre- and post-emergence herbicides. Post-planting weed control too can now be achieved without tillage or soil disturbance.

The question then is 'Why do we till the soil'? The answer was provided as far back as 1886. Following the classical experiments conducted at the New York Experimental Station, Sturtevant and Lewis (1886) concluded: "Strangely enough, we have during the existence of this Station, not been able to obtain decisive evidence in favour of cultivation". Their work established convincingly that tillage was actually for weed control. Following similar experiments in England in the 1940s, over a six year period, comparing a number of cultivation methods, E.W. Russell and Sir Bernard Keen concluded that 'the primary function of tillage is weed control'. However, benefits other than weed control are generally claimed for tillage. They include the improvement of the soil tilth; its aeration; breaking of surface crusts and associated increased infiltration; and seed bed preparation for good crop establishment. In some situations the benefits may be realistic but in others to the contrary!

However, and particularly with the more fragile (weak-crumb-structured) tropical soils, the aggregates break down if the soils are cultivated too wet or too dry. Soil moisture characteristics are often such that optimum conditions last for so short a period that conventional tillage is invariably performed at the wrong time.

But in certain specific situations tillage may still be necessary, and reduced (minimum) tillage techniques, ideally in conjunction with mulching, may still be appropriate. Three decades ago, Abeyratne (1956) recommended the use of non-inversion tillage implements that leave crop and weed residues on the surface, for seed bed preparation, in conjunction with the use of herbicides for weed control. Alternatively, the technique of zonal or strip tillage for seed bed preparation has also been recommended (Lal. 1975), in which only narrow strips (planting rows) are tilled (chiselled) and the inter-row area maintained under a mulch cover.

4.2 Features of the 'no-till' and 'minimum tillage' systems

4.2.1 Soil conservation

The surface mulch of weed and crop residues is vital to the sustained success of 'no-till' and reduced tillage systems. In the tropics, in addition to protecting the surface soil against the impact of raindrops, and keeping the soil intact, the mulch helps development and maintenance of surface aggregates due to activities of worms and other soil animals, thus ensuring rapid infiltration of water.

Greenland (1975) reported that the loss through erosion from an alfisol on a gentle 10% slope under a cover of maize could be as high as one ton per hectare per month on conventionally tilled soils. This erosion was reduced by about 98% through leaving the soil untilled. Runoff was reduced by more than half in the no-till soils when compared with tilled soils (Table 4).

Table 4: **No-tillage effects on soil and water loss on under maize (IITA, Ibadan; rainfall 780mm; first season, 1973)**

Slope (%)	**Soil loss** **No-tillage**	**(tons/ha)** **Ploughed**	**Runoff mm** **No-tillage**	**Ploughed**
1	0.03	1.2	11.4	55.0
10	0.08	4.4	20.3	52.4
15	0.14	23.6	21.0	89.9

Source: Greenland (1975)

4.2.2 Water conservation

The greatly improved infiltration (decreased runoff) is an important characteristic of the 'no-till' system. The mulch cover and the usually higher organic matter content under 'no-till' increases the retention of soil moisture and decreases evaporation losses from the soil. For example, Nanju (1977) recorded higher soil moisture contents for zero tilled ('no-till') plots than for cultivated plots on an alfisol cropped to cowpea and soybean.

4.2.3 Soil fertility

Soil organic matter contents are usually higher and bulk densities lower under 'no-till' than under conventional tillage systems. Moreover, large quantities of nutrients and organic matter are saved from erosion by the 'no-till' methods (see earlier Section 3.1 on erosion losses of organic matter and nutrients).

However, leaching, particularly in coarse-textured (eg. sandy) soils with low organic carbon content, can be higher under 'no-till' than under conventional tillage. Also, although soil bulk density is generally lower initially with continuous cropping, soil compaction can become a problem under 'no-till'. This is certainly more serious where heavy machinery is used for spraying and planting. In some heavy-textured (very clayey) soils, poor aeration and high soil moisture levels (water logging) have been observed with the 'no-till' method, resulting in poor crop growth (Annual Report, IITA, 1980).

4.2.4 Soil temperatures

Soil temperatures and diurnal fluctuations thereof are usually observed to be lower under 'no-till'. This is essentially a result of the mulch cover. Differences as much as 10°C in diurnal soil temperatures within the surface 5 cm of soil have been recorded between no-till and bare (ploughed) plots at times of peak soil temperatures (early afternoons). At such times, the soil temperature which was as high as 45°C, could adversely affect crop emergence and growth (Lal, 1975).

4.2.5 Crop yields

Tillage systems interact with soil, climate and agronomic factors in determining crop yields. In general, zero-tillage ('no-till') and 'reduced tillage' systems have given better crop yields under continuous cropping than conventional methods of cultivation. This is to be expected from the overall beneficial attributes of these systems on soils and soil fertility. A classic experiment with large scale machinery (tractor, heavy planter and sprayer) was conducted on an alfisol at the IITA over a period of six years, to compare 'no-till' with conventional tillage. Maize was continuously cropped at the intensity of two successive seasons a year. The grain yields were always higher under the 'no-till' system; but after the eighth season, yields under both systems declined drastically (Diagram 1). Soil compaction, (possibly due to the continued use of heavy machinery) and soil acidification are considered to be the causes of

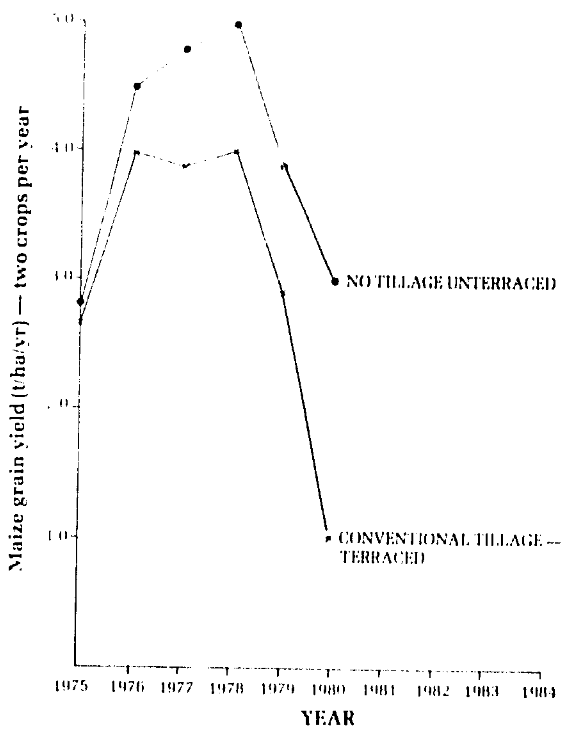


Diagram 1. **'Till versus 'No-till' yields as affected by soil compaction.**

Source: IITA Research Highlights, 1981 this decline. The data also emphasises the limitation of certain tropical soils such as these for continuous high-intensity mono-cropping even under 'no-till'! In order to overcome such limitations, periodic non-inverting tillage (chisel-ploughing) and fallowing are being investigated at the IITA.

It should be noted, however, that this experiment endeavoured to review an extreme mono-cropping situation, whereas, under normal farming practices, crop rotations or fallows interposed between cropping spells would have arrested this soil deterioration.

4.2.6 Weed control

Theoretically, the minimal disturbance of soil associated with 'no-till' and the extensive use of herbicides to control weeds, would be expected to decrease weed populations over the seasons under this system. However, dispersal of seeds and other propagules of weeds into the 'no-till' plots from the surrounding areas often counteracts the benefits of herbicide use.

Continued use of herbicides, on the other hand, can also cause resistant weeds to proliferate. This is particularly true for perennial grasses and sedges, some of which are difficult to control even with the current range of herbicides. Such situations may sometimes require localised and minimal tillage for the control of these weeds. It is, however, a fact that indiscriminate (tractor) tillage has contributed to the spread of **Cyperus rotundus** through the dispersal of tubers by the tillage implements!

4.2.7 Energy, time and economics

Tillage, both mechanical and manual, is highly energy-consuming. It is not often realised that tillage of one hectare of land just 10 cm deep involves the physical movement of about 1300 tons of soil with each pass — a massive earth-moving exercise! This is particularly pertinent considering that an average human being can barely expend one-tenth of a horse-power on a continuous basis! 'No-till' techniques have shown a remarkable reduction in the energy required — to about one tenth of the energy and time — for conventional farming for both temperate (Mathews, 1975) and tropical smallholder farming (Wijewardene, 1980). A comparison of the man hours involved in farming 'no-till' and conventional tillage is shown in Table 5 using hand tools only.

These dramatic savings in time and energy enable theoretical increases in the productivity of small farmers in the order of about ten times, without recourse to tractor power. This is,

Table 5: **Comparison of Man-power Requirements for "No-Till" and Conventionally tilled Fields Over Two Successive Seasons Using Hand-Tools Only, Fashola, Nigeria, (1978)**

Field Operation	First Season Man-hrs/ha		Second Season Man-hrs/ha	
	Conv.	No-till	Conv.	No-till
A. Field Preparation:				
a. Burning	4	4		
b. Clearing, slashing	132		76	
c. Manual tillage & ridging	127		85	
d. CDA Spray, (Contact-herbicide)		8		6
B. Seeding (maize and cowpea)				
a. Manual planting (low population)	35		35	
b. Planting:- RIP (Rotary Injection Planter 25 x 75 = 53,00 stand/ha)		13		9
C. Pest Control				
a. Manual weeding — once[2]	190	4	150	3
b. CDA spray (pre-emergent-herbicide)		9		5
c. CDA spray (cowpea) insecticide, — thrice		2		2
D. Fertilizer application:				
a. Manual dibbling along rows	25		25	
b. Using IITA fertilizer band applicator	3	8		8
Totals: a. Man-hrs per hectare	513	48	371	33

Source: Wijewardene, 1980.

Notes:

1. Two additional men were employed to lay ropes for lining on the planting rows during the first season only. The line of stubble provided ample lining for the second and subsequent seasons planting.
2. Occasional manual spot weeding was undertaken on no-till plots to eradicate resistant weeds.
3. The fertiliser-band-applicator was used for basal application on both maize and cowpea, and for top-dressing, also on maize.
4. Crops grown were maize and cowpea, planted on separate fields. Yields were consistently higher on the 'no-till' plots in this trial, due to better weed and pest control and timely application of fertiliser.

however, only pertinent to situations where land area is not limiting, and where small-farmer productivity is constrained by the extent of land he could weed by conventional methods. (Never plant a garden more than your wife can weed'!).

Fig. 8. Manual tillage

Table 6 presents comparable costs (in Sri Lanka) for land preparation for the 'no-till' and conventional tillage methods of rice farming. The zero-tillage system -1 is generally suitable for situations where pernicious weeds such as perennial grasses and sedges are difficult to control, and which require an effective (although expensive!) systemic total weedkiller (see later Section). Nearly 80% of the cost (Rs 1720) of land preparation here is the cost of the herbicide Roundup! However, not all weed situations require this herbicide, and System - 2 (or similar alternatives) would be sufficiently effective in pre-plant weed control. The resulting reduction in cost by more than half the cost of tillage systems is remarkable.

Table 6: **Comparative costs (Sri Lankan Rupees/ha) for land preparation and weed control under 'conventional tillage' and 'no-till' systems. 1981 — 1982 Main Season.**

	Conventional tillage		Zero tillage	
	Tractor	Buffalo	System 1	System 2
First ploughing	960	720	—	—
Second ploughing	720	480	—	—
Levelling	240	240	—	—
Pre-plant herbicides	—	—	1720	575
Post-plant hand weeding	600	600	—	—
Pre-emergence herbicides	—	—	480	480
Total S.L. Rs/ha	2520	2420	2200	1055

System 1 — Roundup (3l/ha) followed by paraquat (2l/ha).
System 2 — Paraquat (3l/ha) followed by 2l/ha. Pre-emergence herbicide treatment, which is marginally cheaper than hand weeding, can also be used in the conventional tillage systems.

Source: Wijewardene and Weerakoon (1982)

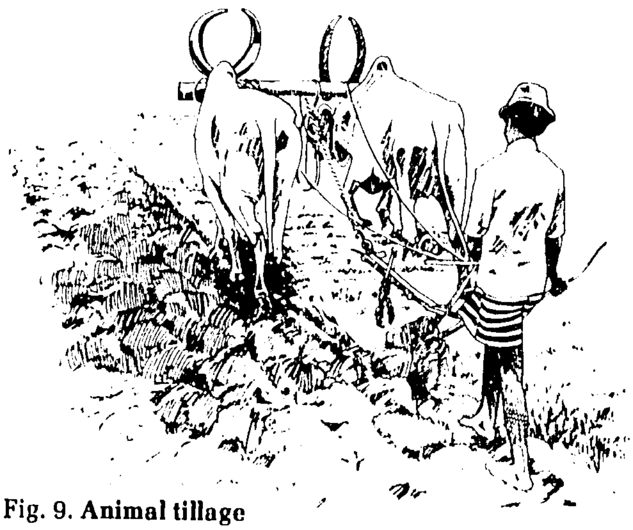


Fig. 9. Animal tillage

In practice, however, the farmer may have to shift between Systems 1 and 2 depending on the weeds that he has to cope with, but yet might find the no-till method more economic than conventional tillage in the long run, both in terms of cost and sustainability.

4.3 'No-till' Farming: The Technique

Basically the technique of 'no-till' farming appears quite simple. But it is a skill which needs to be learned, and which develops with experience. The intention of this manual is to provide a simple guide to these techniques, and ideally to complement a course of practical demonstration and practice.

As with conventional (tillage) farming, one needs, first, to control weeds before seeding or planting (pre-plant weed control). This is to eliminate competition to one's crop from the weeds already established and growing on the field. One also needs to control weeds which are dormant in the soil as weed seeds and which emerge with, or shortly after seeding of the planted crop (post-plant weed control). In 'no-till' farming, these operations are performed using herbicides (chemical weed-killers) which have now been developed for a wide range of crops and situations in the field. They need to be applied by sprayers in carefully metered doses. Very small quantities are used, but need to be extremely evenly applied.

One also needs a means for inserting the crop seed — again in accurately metered quantity — into (or 'onto' in the specific instance of saturated rice soils) the un-tilled soil at controlled depth and at controlled spacing for the required plant density. Special 'injection planters' have been developed for this, such as the 'punch planter' as earlier used in U.S. corn farming, and the more recent 'rolling-injection-planter' (RIP). On very small fields however, a forked stick is quite adequate though somewhat laborious, and time consuming!

The authors of this text do not claim 'expertise' in the technique. They only wish to share their experience over several years, with others who may wish to avail themselves of the benefits of 'no-till' farming.

4.3.1 Pre-plant herbicide weed control

In the no-till system, pre-plant weed killing by the application of a total weedkiller is equivalent to the laborious tasks of ploughing and harrowing under conventional cultivation, ... and which, in fact, are practised mainly for weed control! A good kill of weeds before seeding or planting is an essential pre-requisite to successful no-till farming. (The system is however, still constrained by the need for a cheap **systemic** herbicide which will kill all weeds rapidly, but leave no residues in the soil, toxic to the crops!).

Currently glyphosate (Roundup) is the only herbicide which even partially meets these requirements, but its present high cost is a major limitation, particularly in the context of the small farmer. It is a foliar-applied, highly systemic (absorbed by leaves and effectively translocated to other parts of the plant) herbicide which is particularly effective against perennial grasses. However, it takes a week to ten days to show effect and this timing is a very real constraint to the system. Because glyphosate activity increases with increasing concentration, very low-volume (V-L-V) spraying (see Section 4.4.1), at about 40 litres application volume per hectare, enables the use of smaller quantities than are recommended for normal (400-500 l/ha application volume) spraying.

The other, widely used, total weedkiller, paraquat, is also a foliar-applied herbicide which, however, is not sufficiently systemic. It is not adequately effective against perennial grasses and certain broad-leaved weeds which regenerate rapidly following temporary desiccation when treated with paraquat. It is however, quick in action and shows effects within a few hours of application — specially under bright sunlight.

While glyphosate has very low mammalian toxicity, — as do most herbicides — this qualification does not apply to paraquat. It is definitely toxic, particularly if ingested into the lungs, and needs special care in use.

Some observations on preplant weed control in the tropics, and mainly in the context of glyphosate and paraquat are summarised as guidelines below:

1. In situations with predominantly perennial grasses, effective control can be achieved with 3 to 5 l/ha of glyphosate applied CDA or VLV (see later Section) at a volume rate of 40 l/ha. A follow-up application of paraquat (2-3 l/ha) is sometimes necessary 7-10 days later, at time of planting (mixed with the pre-emergence herbicide), to kill any remaining weeds which are not completely killed by the first spraying; and also any weeds which may have emerged from seed, subsequently.
2. In situations where perennial grasses are heavily grazed by animals, the new flush of growth with the first rains of the cropping season can be controlled with glyphosate at 2 l/ha followed by paraquat (2-3 l/ha) applied 7-10 days later.
3. Where perennial grasses and sedges are not a problem, a split application of paraquat applied as an initial dose of 2-3 l/ha followed about ten days later by a further 2 l/ha (mixed with the pre-emergence herbicide as necessary) at planting is quite adequate and effective.
4. Where one crop is to be planted immediately after the other, and the weed growth is sparse (with no perennial grass problem), paraquat applied 3-4 l/ha is adequate.
5. Applications of 4 kg dalapon/ha followed, 4-5 days later, by 2-3 l/ha paraquat is often quite adequate, and low in cost, for the control of grass weeds. The same quantity of dalapon with the addition of 2 kg of 2,4-D/ha and followed thereafter by paraquat will also be found quite adequate in mixed weed populations. Dalapon copes well with annual grasses, but inadequately with perennial grasses. Dalapon and 2,4-D are both rapidly broken down in tropical soils. However, residual toxicity may be a problem if crops are planted within a week or ten days after application of these herbicides.
6. When paraquat alone is used, scattered patches of resistant weeds may sometimes be observed which may be hand or hoe-weeded.

4.3.2 Post-plant herbicide weed control

After the crop is planted, weed seeds which are in the soil germinate and grow together with the crop. Under conventional peasant farming, they are controlled either by hand or hoe weeding, and less commonly by the use of selective herbicides. In 'no-till' farming, **selective**, pre- or post-emergence herbicides (which are non-toxic to the crop but toxic to weeds) are exclusively used for post-plant weed control. Pre-emergence herbicides are applied soon after seeding and prior to crop emergence. They are designed to kill weed seeds as they germinate but are selectively non-toxic to crop seedlings. The activity of pre-emergence herbicides usually persists for several weeks, allowing the crops to achieve a substantial start over any weeds that may subsequently emerge, and then shade them into submission. Some pre-emergence herbicides which are more persistent in the soil (eg. simazine) may be 'carried

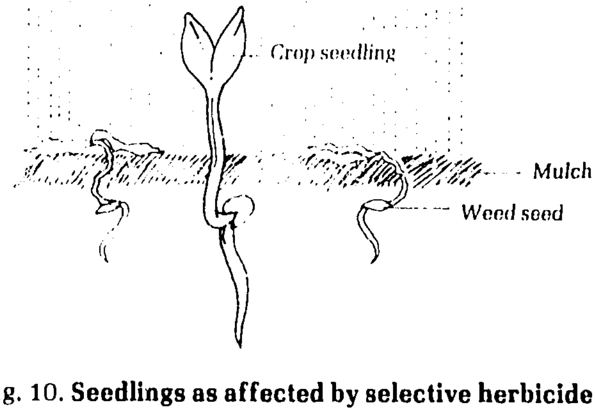


Fig. 10. **Seedlings as affected by selective herbicide**

over' to the next season damaging susceptible crops. This is, however, not so serious in the tropics as under temperate conditions because of the faster breakdown of herbicides in tropical soils.

Some foliar-applied selective herbicides are also used in post-plant weed control. They are, however, much less common than pre-emergence herbicides.

Some observations on selective pre-emergence weed control in maize and grain legumes are given below:

Maize

Premixtra (a mixture of atrazine and metolachlor) at 3-5 l/ha will be found effective for selective control of weeds in maize. Where annual grasses are not a serious problem, even atrazine alone at 0.75 to 1.0 kg/ha should be effective and cheaper than **Premixtra.**

Grain legumes (cowpea, soybean, black gram and green gram)

Lasso (alachlor) at 3-4 l/ha, **Dual** (metolachlor) at 1.0 to 1.5 l/ha or **Galex** (metolachlor + metobromuron) at 2-3 l/ha all provide effective selective weed control with all the above legumes. Even slightly lower levels appeared sufficient with the faster spreading cowpea (*Vigna unguilicata*) and black gram (*Vigna mungo*).

There are however, many alternative pre-emergence herbicides which also effectively control weeds in these crops.

4.3.3 Contact + pre-emergence herbicide

In some circumstances it is expedient to apply a small dose of a quick-acting contact (total) weedkiller such as paraquat mixed with the pre-emergence herbicide. The contact herbicide is intended to kill any weeds which may have emerged since the preceding application of the pre-plant weedkiller, such as glyphosate, as the latter takes some 7-10 days to show activity.

4.3.4 Post-seeding weed control in rice

'No-till' is not yet a technique which can confidently be recommended for rice. None of the herbicides claimed as selective for use in rice are sufficiently so at dosages which will be really effective against some of the more serious grasses **(e.g. Cyperus)**. Certain new herbicides — some containing 'safeners' to enhance their selectivity — have been demonstrated and perform impressively in trial, but at time of writing, have not become available on the market. These 'safened' herbicides appear to hold particular promise in lowland rice culture on saturated soils upon which the pre-germinated rice is broadcast. The safened herbicide applied directly thereafter has demonstrated excellent weed control with no signs of toxicity to the rice. Should such herbicides reach the market at reasonable prices, they hold very great promise for effective post-planting weed control in rice.

4.3.5 Injection planting

After a good (pre-plant) weed kill has been achieved, the seed to be sown is 'injection-planted' through the mulch, into the soil. Injection planters are designed to pierce the mulch and open a narrow slot in the soil into which the seed is deposited, and subsequently firmed over. The surface mulch should be left undisturbed, after planting, particularly the area opened over the injected seed, through which the seedling emerges. Two types of injection planters have been developed: The 'punch planter' suitable for use on small farms (of about half a hectare) and the 'rolling-injection-planter' (RIP) which is designed for use on larger farms, in single or multi-row models.

When small extents of land are to be 'no-till' planted, even a pointed stick may be employed to drill seed into the soil. The RIP has been found particularly useful in inter-cropping and multiple or relay-cropping where it can ideally be used to quickly inject-plant a row of, say, maize between emerging rows of ground-nuts; or of cowpea between rows of maize, without need for prior tillage or loosening of the soil.

4.3.6 Soils suitable for 'no-till'

Generally, crops grown on well-drained soils respond best to no-till techniques. Crops grown in imperfectly-drained soils which are lower in the soil-slope catena, do not always respond as well as when they are grown on raised-beds. If such beds have already been prepared, it is then quite simple to practise 'no-till'.

The importance of mulch cannot be over-emphasised for successful no-till farming. On bare or totally grazed soils, as in many semi-arid areas, no-till techniques do not perform well.

4.3.7 Crops for 'no-till'

Theoretically, most arable crops, cereals and grain legumes — that grow on well-drained soils, can be successfully grown by the 'no-till' method. 'No-till' is not yet considered suitable for growing transplanted, horticulture crops such as chillies or capsicum, etc. which appear to perform better under conditions of loose soils.

'No-till', obviously, cannot be applied to root and tuber crops such as cassava and (sweet) potatoes, but herbicides have been found which are adequately selective to these crops (e.g. metolachlor) and enable minimum tillage to be practised with good yields and minimal expenditure of energy for field preparation and subsequent post-planting weed control.

4.3.8 Fertiliser application in no-till farming

The no-till system is **not** to be considered as an alternative to the application of chemical fertiliser. While the increased organic content of 'no-till' soils ensures better conservation and availability of applied fertiliser, and also considerable reduction in losses through erosion or through leaching, the effectiveness of the applied fertilizers appears to vary with the inherent fertility status of the soil. On fertile soils even low levels of applied fertilizer provide as good (or slightly better) yields with 'no-till' farming as with conventional tillage farming. On basically infertile soils, low levels of applied fertiliser do not yield quite so well under 'no-till' as under tillage systems (IITA Research Highlights 1981).

However, when reviewed over successive seasons in a number of years, yields from areas consistently farmed 'no-till' have invariably been higher than on conventionally tilled areas, whether at low or high levels of applied fertiliser.

It bears repeating here that 'no-till' cannot be recommended for use in soils which are devoid of mulch. Mulch and the build up in soil organic content beneath it, are essential for success with 'no-till'.

4.3.9 Precautions

Timeliness

Timing is usually critical ('the right operation at the right time' is the axiom of good farming the world over). Generally, the seeding of 'no-till' crops occurs earlier in the season than with tilled crops delayed by the time and effort of tillage. So plans for seeding generally need to be advanced — usually between two and four weeks.

Soils

Seeding (planting) needs to be undertaken into **moist** soils; not wet or sticky soils. Attempts to plant into wet soils will usually be frustrated by blockages of the seeding points of the planter; and poor germination, in any case! Injection planting is best timed for when soils are just moist enough for germination, and when continued rainfall is ensured. (Otherwise should there be a lull in the weather after the first rains, the farmer may lose his seed too!) It is always preferable to seed (plant) into soils covered by a mulch as this also keeps (wipes) the jaws or points of the planter clean and enables rapid, trouble-free planting.

Mulch

"How much mulch?" This differs with the crop. Usually a (3-4 t/ha) mulch cover which shows hardly any exposed soil is excellent. A thicker mulch will help smother weeds, but will also impede emergence of the crop being seeded.

When using a thick mulch of rice or wheat straw on wet fields, the products of decomposition could also affect crop emergence and growth. Therefore short stubble is preferred as a mulch on rice fields. If the stubble or straw in the field is long, a light burn is usually beneficial as erosion is negligible on levelled and bunded fields.

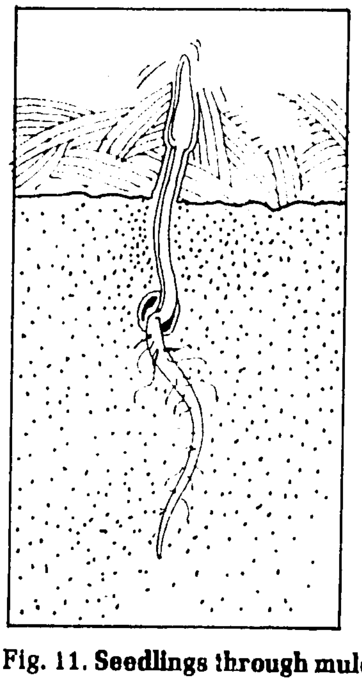


Fig. 11. Seedlings through mulch

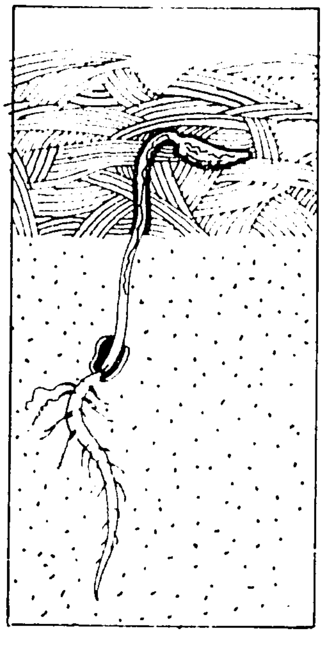


Fig. 12. Mulch too thick for seedling to burst through

Stubble

Allied to mulch is stubble and the question is often asked "how long should the stubble be?" Ideally, stubble should be as short as possible, and if long should be grazed or burned before herbicide application. With ratooning crops such as rice or sorghum the ratoon crop emerging from a short stubble is easily controlled with an application of contact (ideally systemic) herbicide on the actively growing **green portions** of the ratoon.

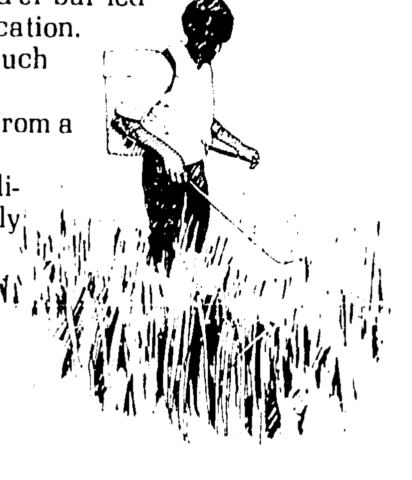


Fig. 13. Stubble too long

4.4 No-till farming: the tools

4.4.1 Herbicide Applicators

The problem with conventional spraying systems — knapsack or tractor-mounted — is the high volume of liquid required; usually about 400 to 500 litres per hectare (40 to 50 gallons per acre). It is logistically impossible for the small farmer to carry this volume on his back, and cover half a hectare of land thoroughly (even if such a quantity of water were available!)

It was necessary therefore to look for alternative spraying systems which would drastically reduce the volume of liquid carried by the farmer and still provide effective coverage.

Two very appropriate types of herbicide applicator have emerged which reduce the volume of liquid required to about 1/10th of that needed by conventional sprayers.

1. The C-D-A (Spinning Disc) Sprayer as manufactured by:
Micro Sprayers Ltd. (HERBI)
Bromyard,
Herefordshire,
England HR7 4HU
*C-D-A = Controlled Droplet Application
and

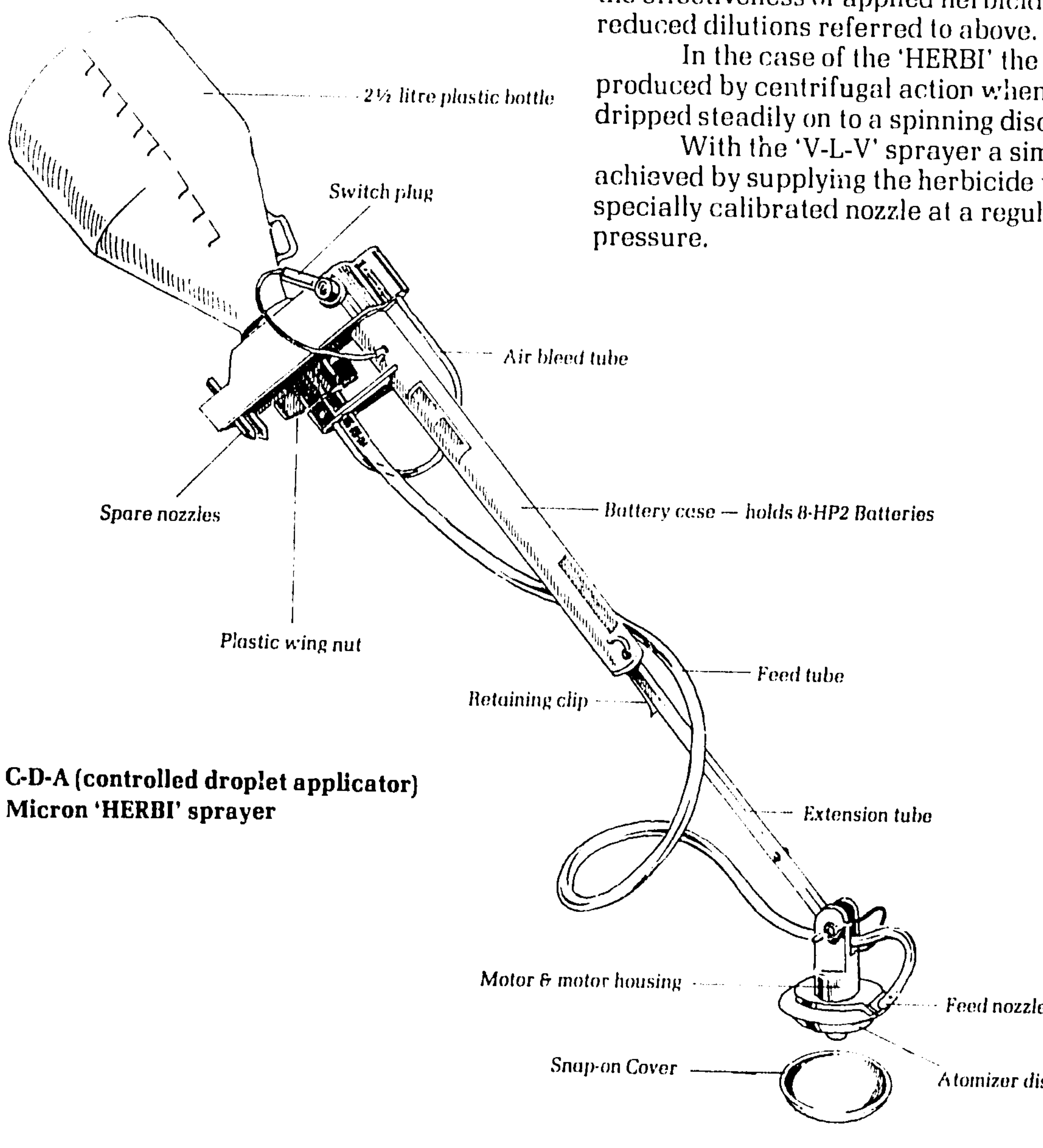


Fig. 14. **C-D-A (controlled droplet applicator) Micron 'HERBI' sprayer**

2. The 'V-L-V (Very-Low-Volume') knapsack sprayer with pressure regulation and 'V-L-V' nozzle as manufactured by:-

Cooper Pegler Ltd.,
Burgess Hill,
Sussex,
England RH15 9LA

A. Baur & Company,
62 Jethawana Road,
Colombo 14,
Sri-Lanka

American Spring & Pressing Works Private Ltd.,
Post Box No. 7602, Malad.
Bombay 400 064 India.

EMCA Combine (V.L.V. nozzles only)
152-A Colombo Road,
Negombo,
Sri Lanka

These differ from conventional sprayers in that they produce an even swathe of herbicide, about 1 m in width composed of droplets within a limited size range of about 200 microns. It is the evenness of droplet size and droplet distribution across the swathe that is believed to account for the effectiveness of applied herbicide at the greatly reduced dilutions referred to above.

In the case of the 'HERBI' the droplets are produced by centrifugal action when herbicide is dripped steadily on to a spinning disc.

With the 'V-L-V' sprayer a similar effect is achieved by supplying the herbicide through a specially calibrated nozzle at a regulated, low, pressure.

4.4.1.1 Using the Micron HERBI

Three nozzle sizes are provided with the MICRON applicator, the smallest is blue, the medium yellow and the largest is red. For practical purposes when spraving herbicide the yellow nozzle is used and this provides a flow of 125 ml/minute, which **at ½ meter/second** walking speed (i.e. 125 ml over 30 square meters) provides an applied volume of about 40 litres per hectare. This is reasonable and adequate for comprehensive coverage of the ground.

During spraying the head containing the spinning disc should be held horizontally about 20 cm (see illustration) above the crop or mulch so that the spray falls evenly over the surface as one walks over it.

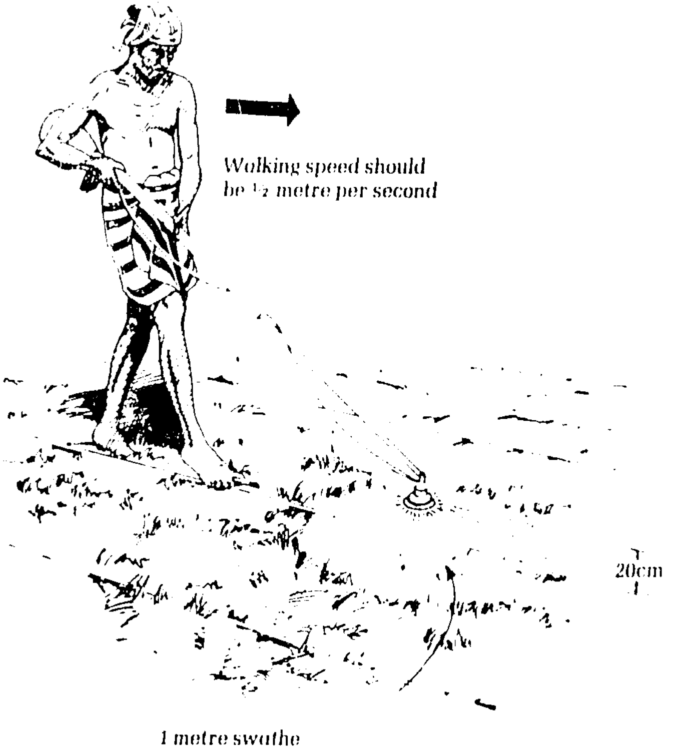


Fig. 15. **Spraying with the C-D-A**

Walking speed is critical, so time yourself to achieve the required, slow, **1/2 meter/second** speed, by gauging your walking speed over a 30 metre distance, which should be covered in exactly 1 minute. On harder surfaces, one tends to walk faster, and on softer (e.g. in wet paddy fields) one walks very much slower. So learn to gauge the correct speed.

The effective swathe width is 1 metre, so lay out ropes 1 metre apart in the field to be sprayed and walk with the he t of the applicator at the correct 20 cm height over this rope. After the first 'no-till' crop is established, which will be at plant-spacings of even fractions of a metre, use the line of stubble as the spraying line. For example, with rice seeded 6 rows to a metre (i.e. at 15 cm between rows) one would need to walk down every 6th row to achieve the 1 metre swathe width.

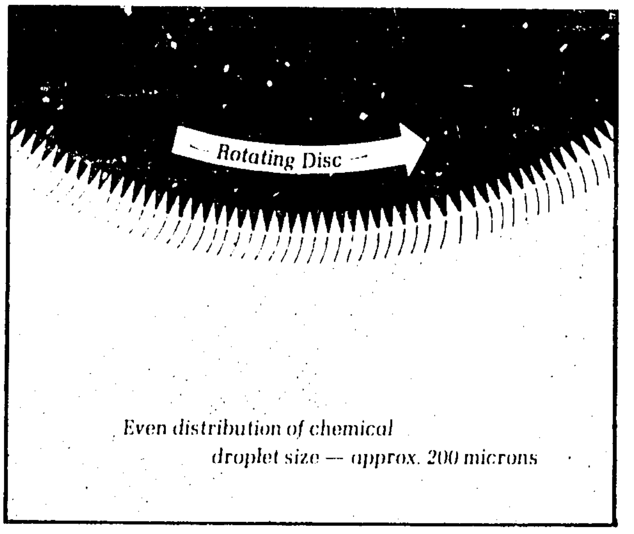


Fig. 16. **Spray pattern of the C-D-A**

4.4.1.2 Using the Cooper-Pegler "CP – 15" V-L-V Sprayer

The CP-15 sprayer is one of the few knapsack sprayers which is fitted as standard, with a pressure regulator to regulate the pressure to 1 bar (about 14 lbs per square inch) in the 'L' or low pressure setting and about 3 bars (40 lbs per square inch) in the 'H' or high pressure setting. The 'L' low-pressure, setting is used for herbicide spraying and in conjunction with the VLV-50 nozzle provides a flow rate of 250 ml/minute over an effective swathe width of 1 metre, for a coverage of about 40 litres per hectare* — when walking at ½ metre per second. Guide ropes 1m apart should be laid out on the field in the same way as with the 'Herbi'. (The 'H' setting which produces a much finer droplet size is often used effectively for 'drift' spraying of insecticides).

$$* \quad \frac{250}{1,000} \times \frac{10,000}{60} = 41.6$$

The flat swathe of the spray is clearly visible, and the correct width is obtained by holding the nozzle at 50 cm over the field or vegetation to be covered. A chain or weighted cord 50 cm long, can be hung from just behind the nozzle so that it touches the stubble, thus ensuring that correct height is maintained.

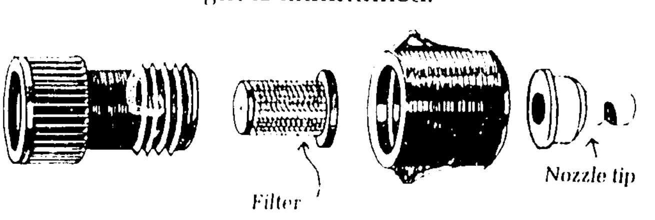


Fig. 17. **V-L-V Nozzle**

As the CP-15 'V-L-V' knapsack sprayer is fitted with a pressure regulator, the operation of the regulating valve can be heard, and it is only necessary to pump the handle occasionally — say, once in 4 to 6 paces, and very gently — to keep up this pressure. There is thus very little effort required to operate this very precise sprayer.

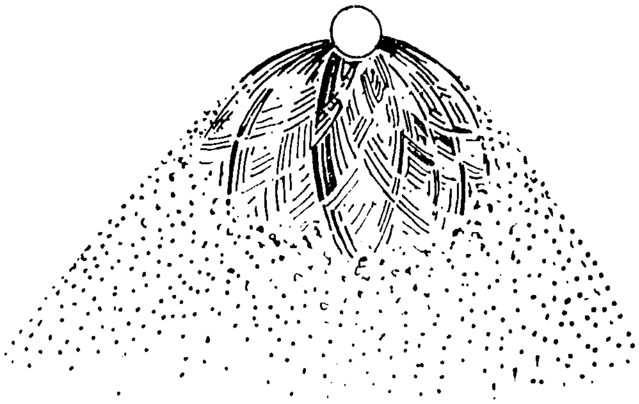


Fig. 18. **V-L-V nozzle pattern**

4.4.1.3 Using the Baurs' or the 'ASPEE' 'V-L-V' Sprayer

The simplicity and ease in use of the 'V-L-V' sprayer has encouraged several other manufacturers of popular knapsack sprayers to adapt their equipment for V-L-V application. The "IRIS" V-L-V sprayer manufactured by A. Baur & Company in Sri Lanka and "ASPEE" V-L-V sprayer by American Spring & Pressing Company in Bombay, India — are typical and will be described here. The standard 15 litre capacity spray tank and pump system is easily converted for V-L-V application by replacement of the conventional high-volume (400 l/hr) lance and

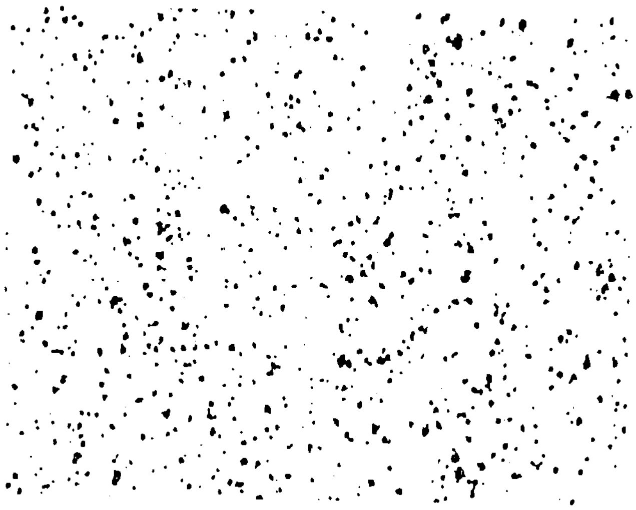


Fig. 19a. **Droplet pattern of the C-D-A Sprayer**

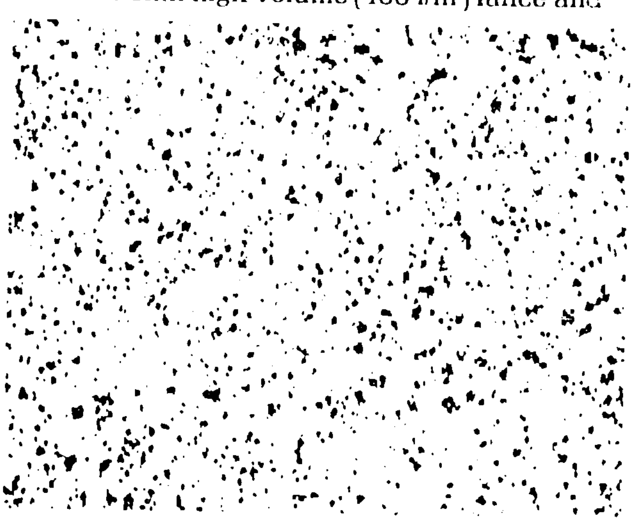


Fig. 19b. **Droplet pattern of the V-L-V Sprayer**

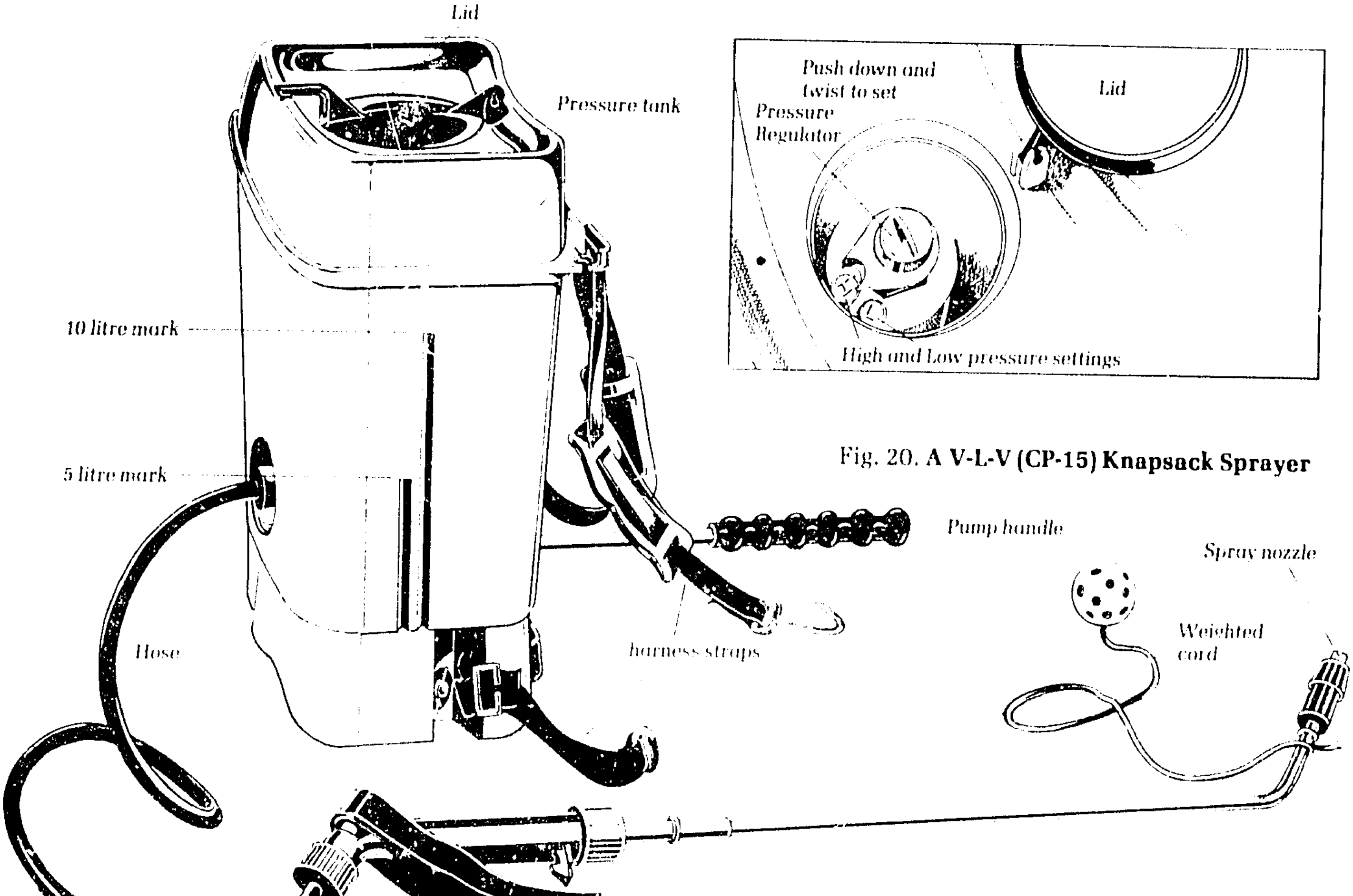
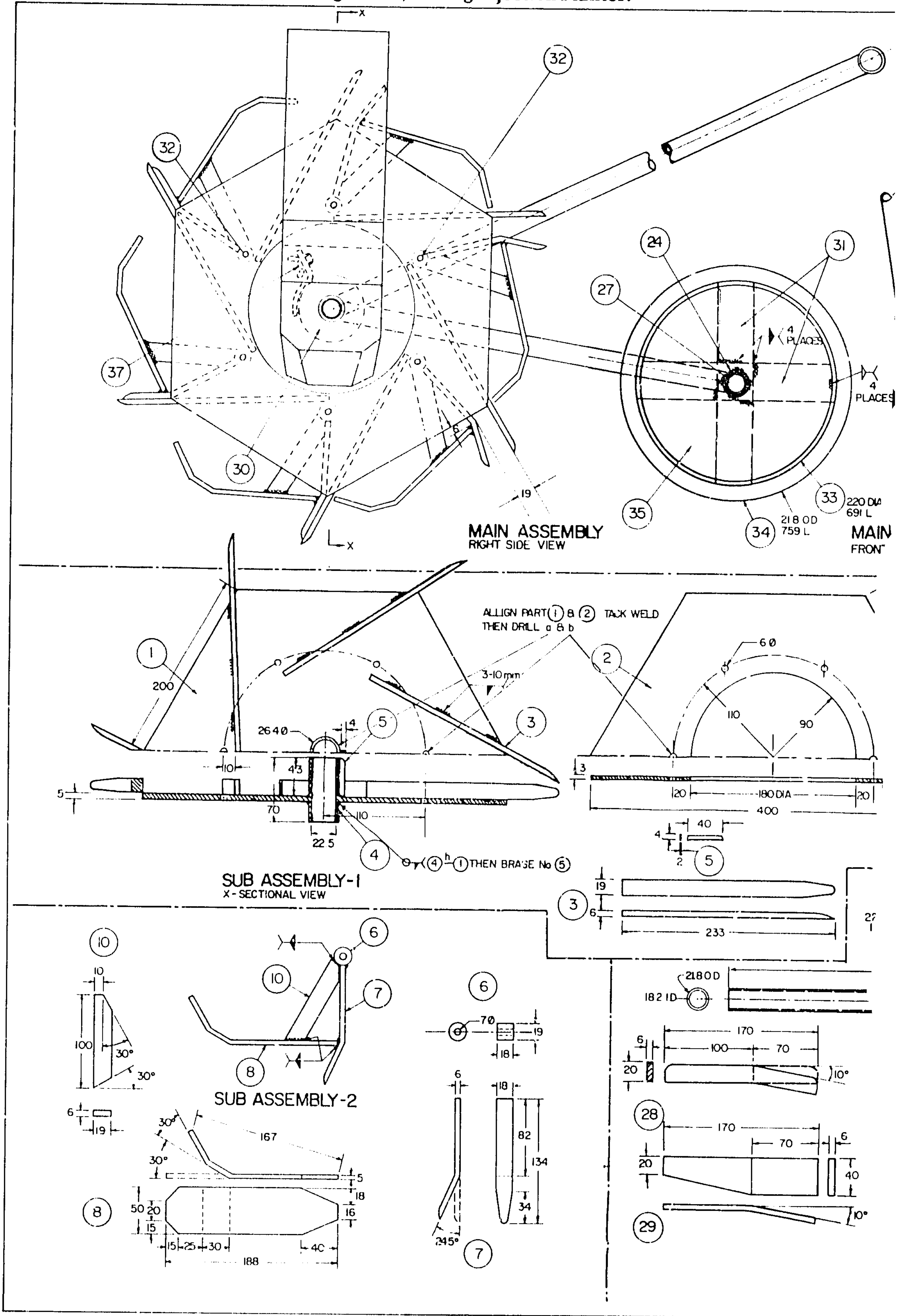
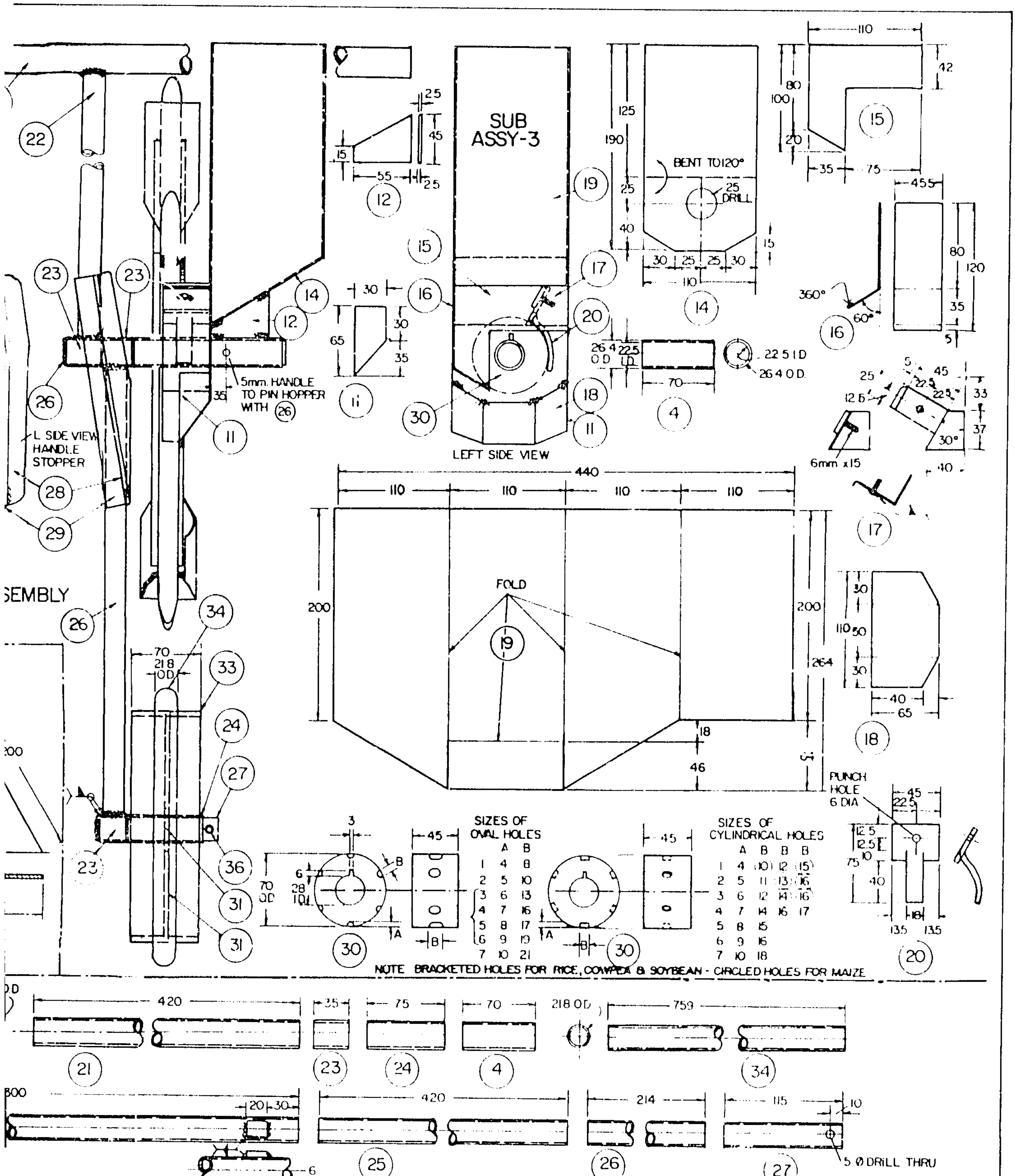


Fig. 20. **A V-L-V (CP-15) Knapsack Sprayer**

Working Drawing for The 6 Jaw, Single Row, Rolling Injection Planter.





TERIALS	DESCRIPTION	PCS REQ	NO	MATERIALS	DESCRIPTION	PCS REQ	NO	MATERIALS	DESCRIPTION	PCS
			26	GI PIPE	218 OD X 21	1				
FLAT	2 5 x 45 x 55	1	25	GI PIPE	218 OD x 1' 0	1				
SHT.	1 x 30 x 65	1	24	GI PIPE	22 5 ID x 75	1	37	WING NUT	6mm NC THREAD	1
AT BAR	5 x 18 x 125	6	23	GI PIPE	22 5 ID x 35	3	36	PINS	5 x 50 (split)	2
			22	GI PIPE	218 OD x 1,300	1	35	CEMENT	1 x 2 MIXTURE	1
AT BAR	5 x 50 x 200	6	21	GI PIPE	264 OD x 420	1	34	GI PIPE	218 OD x 759	1
AT BAR	6 x 18 x 138	6	20	3¼ x 18 TIRE	CUT FROM SIDE WALL OF TIRE	1	33	GI SHT	1 x 70 x 691	1
UND BAR	18mm dia x 18	6	19	GI SHT	1 x 264 x 440	1	32	PINS	6 x 25 (Expansion)	6
.PLATE	2 x 4 x 40 (KEY)	1	18	GI SHT	1 x 65 x 110	1	31	FLAT BAR	6 x 40 x 215	2
I.PIPE	264 OD 22 5 ID x 70	2	17	GI SHT	1 x 60 x 75	1	30	WOOD OR EQUIVALENT	70 OD x 45 L	8
AT BAR	6 x 19 x 240	6	16	GI SHT	1 x 45 5 x 120	1	29	FLAT BAR	6 x 40 x 170	1
PLATE	3mm x 200 HEX	1	15	GI SHT	1 x 110 x 100	1	28	FLAT BAR	6 x 20 x 170	1
PLATE	5mm x 200 HEX	1	14	BI PLATE	2 5 x 110 x 190	1	27	GI PIPE	21 8 OD x 115	1

No	REVISION	BY	DATE
5	HANDLE	IITA	4/5/81
4	SUB ASSY 3	IITA	20/10/81
3	SUB ASSY 2	IITA	17/4/81
2	SUB ASSY 1	IITA	14/5/79
1	ORIGINAL CONCEPT	GEORGE BANBURY	12/10/77

INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE
PMB 5320, OYO ROAD, IBADAN, NIGERIA

SCALE 1 4 TOLERANCE ± 0 5MM OR SPECIFIED	REVISED ROLLING INJECTION PLANTER	
DRAWN BY N C N / APPROVED BY	DATE 17/4/82	DWG NO 1 OF 1

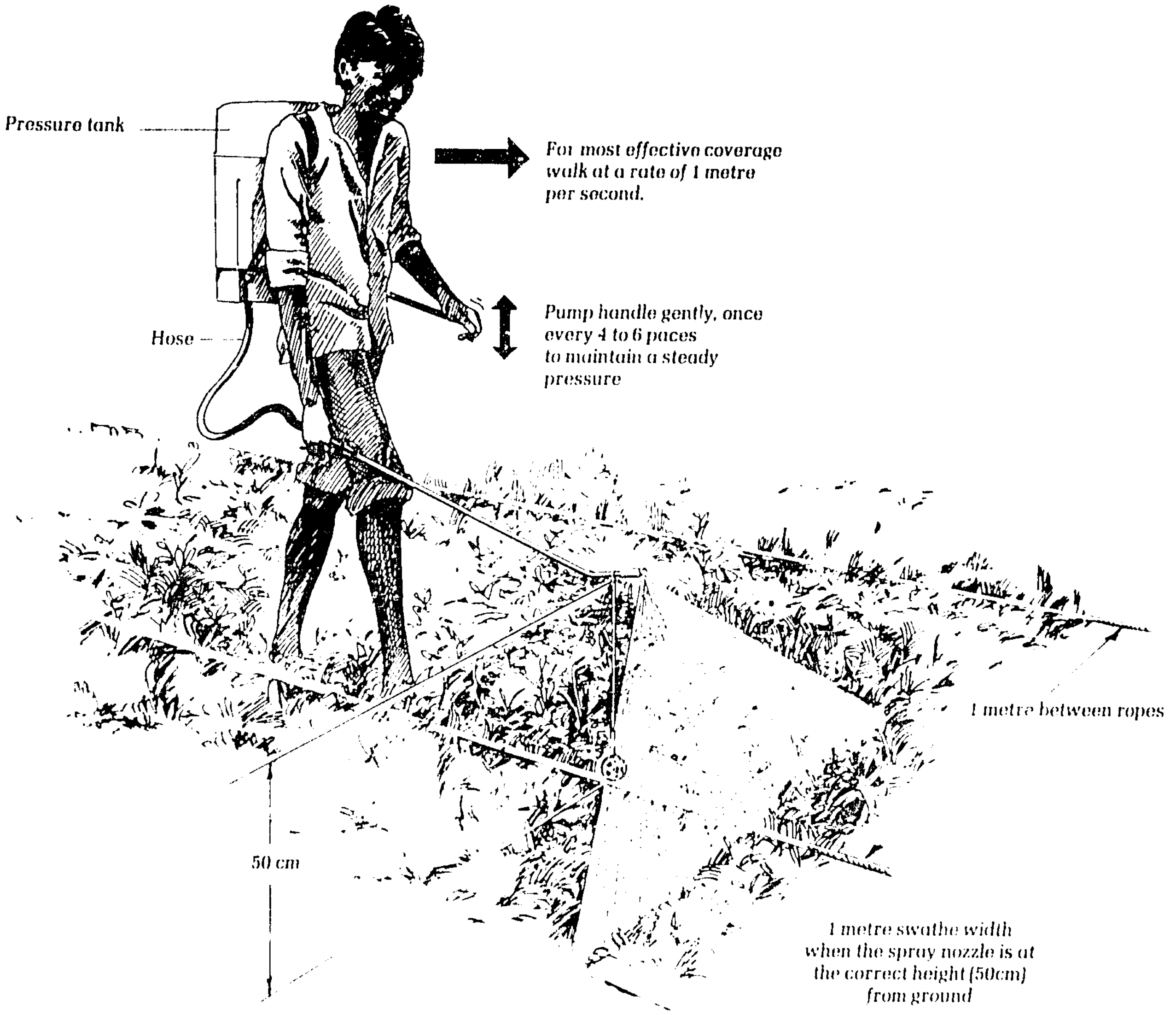


Fig. 21. **V-L-V Spraying** (V-L-V = Very Low Volume)

nozzle with a specially designed pressure-regulated lance and V-L-V nozzle. The V-L-V lance incorporates a pressure-regulator in the handle which limits the pressure in the lance to 1 bar. The nozzle of the lance is also changed to take the V-L-V nozzle and tip (with special 100 micron filter, incorporated). The low (1 bar) pressure and V-L-V nozzle combine to provide the ideal flow rate of 250 ml/minute over an even and effective swathe width of 1 metre, thus again providing coverage at 40 litres per hectare when walking at 1 metre per second.

Locally priced at around half the price of the imported CP-15 V-L-V sprayer, the Baur 'V-L-V' sprayer and other similarly converted knapsack sprayers have demonstrated, at decreasing costs, the ease, value and facility of V-L-V spraying at application volumes one-tenth that of conventional knapsack sprayers.

Fig. 22. **Using the V-L-V** (Baur's "IRIS" or ASPEE) **Knapsack Sprayer**

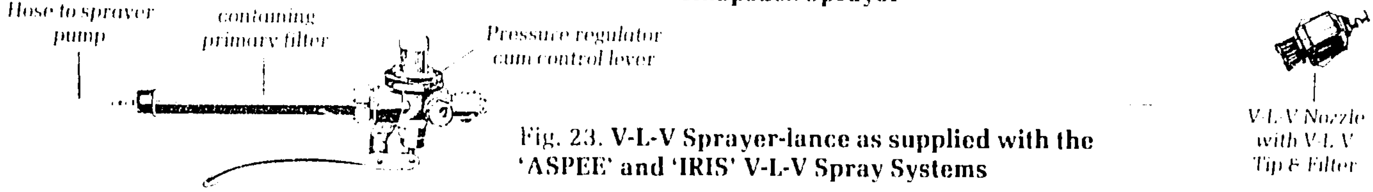


Fig. 23. **V-L-V Sprayer-lance as supplied with the 'ASPEE' and 'IRIS' V-L-V Spray Systems**

4.4.1.4 Mixing of the chemical (Product) in the correct ratio with water

Let us say, for instance that the required **product** application rate is 2.5 litres per hectare. Then since the total volume of liquid applied by both the Herbi and 'V-L-V' is 40 litres per hectare, 37.5 litres of water must be mixed with 2.5 litres of product, to achieve the required dilution for spraying one hectare of land (i.e. a dilution of 15:1). Similarly if the recommended product application rate is 5 litres per hectare then 35 litres of water must be added (i.e. 7:1) and so on.

However, since the Herbi is supplied with a bottle of 2.5 litres capacity and the "V-L-V" with a tank of 15 litres capacity, marked in 5 litre gradations (i.e. 5, 10 and 15 litre marks) it is necessary to mix only enough herbicide as is required at any one time. Table 7 below shows the amount of product that must be measured out into the container of the sprayer, and then diluted to the mark with water, for various recommended product application rates and for different container volumes.

For example, if one is using the 'V-L-V' sprayer and wishes to spray a quarter of a hectare, then the total volume of liquid to be applied would be 40 x 1/4 litres = 10 litres. If the recommended product application rate is 3 litres per hectare, then to find the correct amount of **product** that has to be measured out, read down the left hand side of Table 7 to find the volume row corresponding to 3 litres of product per hectare i.e. the sixth row down. Now read across the row to find the column corresponding to an applicator container volume of 10 litres, i.e. the third column in the square where the row and column meet is a figure of 750 ml. This is the amount of **product** that must be measured into the 'V-L-V' tank and which should then be topped up to the 10 litre mark with clean water.

4.4.1.5 Precautions for handling pesticides

All pesticides including herbicides should be treated with care and respect.

DO : Wash your hands and any other contaminated parts of your body with soap and water after using pesticides.

DO : Avoid contamination of any part of your body with pesticides. Wear protective gear, if available, or at least, clothes so as to cover the body well. Even skin contamination by certain pesticides can be very harmful.

DO : Wash out your herbicide applicator carefully with clean water and soap after use.

DO : Mix only the amount of herbicide that is required for immediate use.

DO : Only store pesticides in the clearly marked container supplied by manufacturer, out of reach of children and farm animals.

DO : Keep pesticides away from contact with food or drinking water supplies.

DON'T : Pour excess pesticides into streams, ponds, rivers or other water.

DON'T :Use empty pesticide containers for other purposes until they are thoroughly washed several times, with soap and water and no further smell remains.

Table 7

Recommended PRODUCT Application Rate litres/hectare	**Applicator Container Volume-litres**			
	'Herbi'	**'V-L-V'**		
	2.5	**5**	**10**	**15**
1	60 ml	125 ml	250 ml	375 ml
1.25	75 ml	150 ml	300 ml	450 ml
1.50	90 ml	185 ml	370 ml	555 ml
2	125 ml	250 ml	500 ml	750 ml
2.25	150 ml	300 ml	600 ml	900 ml
3	190 ml	375 ml	750 ml	1125 ml
4	250 ml	500 ml	1000 ml	1500 ml
5	300 ml	600 ml	1200 ml	1800 ml

.... Measured **Product** Volume ml ....

Measured **Product** Volume ml

Top Container up to mark with clean water!

4.4.2 No-till planters

4.4.2.1 The stick

An ordinary forked stick (see sketch) can be employed for drilling seed when the extent of land to be planted is small (i.e. less than ½ ha). The distance between the two arms of the fork depends on the in-row spacing of the crop, usually about 15 cm. In the seeding operation, one worker drills the holes with the stick (at walking speed) whilst another dibbles seed into the holes and covers them up. It is estimated that two persons can plant one acre of maize (spaced 15 by 75 cm) or about half-acre of cowpea (planted 15 by 30 cm by this method in a day.

Fig. 24. **Forked stick penetrates soil and mulch at regular spacing and seed is dropped in**

4.4.2.2 The IITA Automatic-feed 'Punch planter'

Specially designed for very low-cost construction, yet capable of accurate seeding, the 'Punch' planter was developed from the early American design (circa 1900) of hand-fed 'Jab' planter. Working Drawings are available from IITA in Ibadan, Nigeria. See inside back cover for address.

The correct 'slide' must be selected for the seed being planted. The slide with the 15mm diameter hole is used for large seeds, such as maize (corn), while the slide with the 10mm diameter hole is preferred for smaller seeds such as rice and cowpea. With maize, one seed per 'hill' is usual, while cowpea and rice are often seeded using two and 5 to 6 seeds per hill, respectively.

The compactor pad, attached to the swivelling 'jaw-arm' is about 25 cm from the jaws. This is intended to provide accurate spacing of 25 cms between 'hills'.

Fill the hopper half-full with seed. Then lift the planter off the ground to check its operation. On raising the compactor-pad, the jaw arm should open smoothly to drop the seed, while the slide moves in to the hopper simultaneously to collect a metered quantity of seed. When the pad is released the jaws should close very securely, (permitting no ingress of soil) while the slide is simultaneously extracted from the hopper to expose the metered seed in the hole, which then falls into the closed jaws, ready for the next operation.

In use it is best, the first season, to lay a rope along the lines to be planted. This will not be

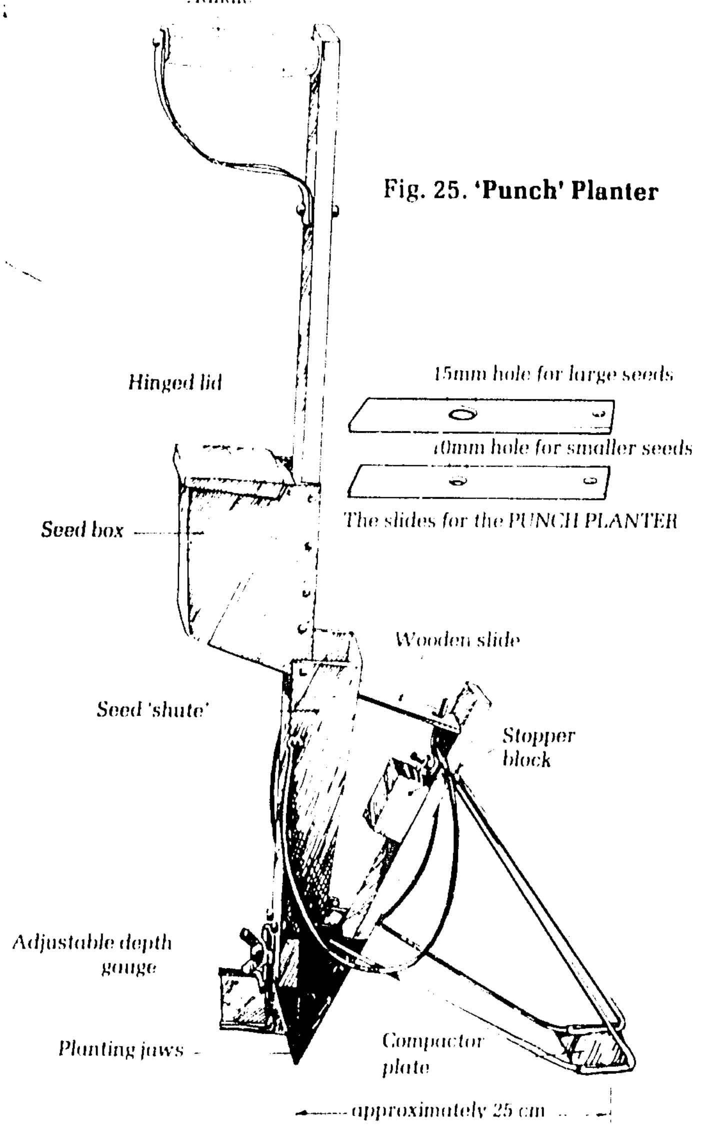


Fig. 25. **'Punch' Planter**

required thereafter as the lines of stubble will be clearly visible and enable one to maintain accurately spaced rows.

The operator walks backwards with the line to his right. This is, curiously enough, easier than planting while walking forwards, and appreciably faster!

The 'punch-planting' operation is in three stages, — all three blended into one smooth cycle.

Stage 1
The operator has his back to the line to be planted and punches the point of the planter into the soil, through the mulch, at an angle of about 20 degrees to the vertical, and as far as the depth-plate will permit (the depth of seeding can thus be regulated). The seed is already within the jaws.

Stage 2
The planter is levered forward, the jaw still in the soil, so that the compactor now presses onto the soil or mulch and causes the jaws to open and deposit the seed in the soil. The jaws open no further than is permitted by the stopper block.

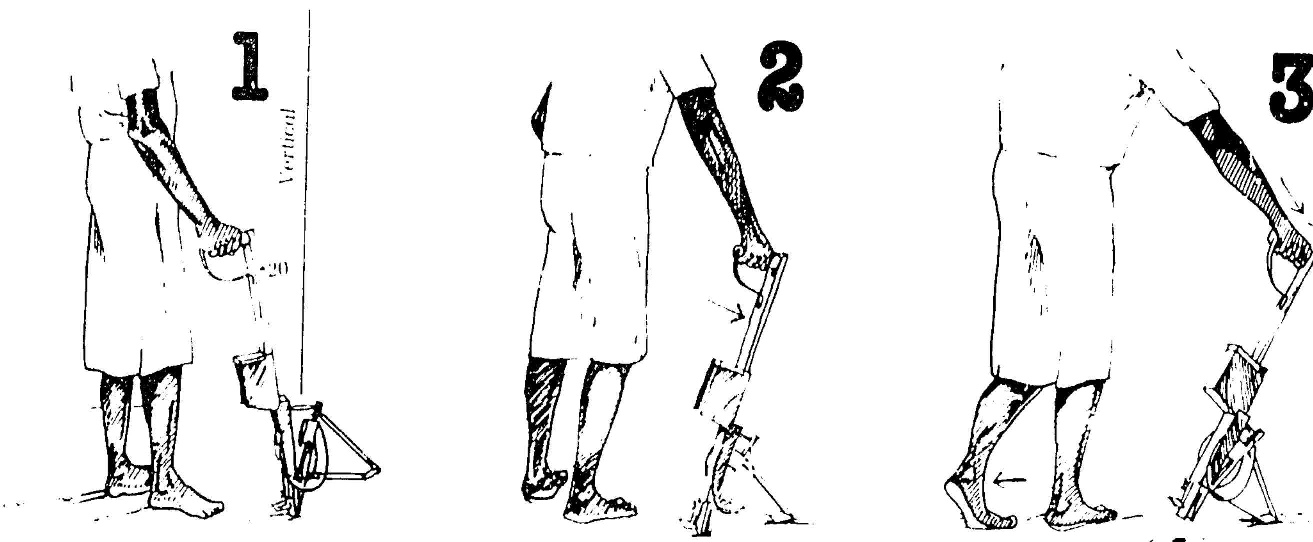
Stage 3
Further levering of the planter forward hinges the planter about the compactor-pad and the jaws are thus extracted in the open position. Raising one arm further releases the tension on the spring which closes the jaws after the planter comes out of the soil. If the jaws close while in the soil, they invariably pinch a large chunk of soil which clogs the planter.

Stage 4; repeat Stage 1, etc.
but also taking a short step backwards and aiming the **compactor-pad** at the preceding, open, hole with seed. The jaws then insert into the soil approximately 25 cm from the preceding hole while the compactor pad presses down, when the planter is levered forward to compact soil over the seed.

A little practice enables one to do this in a smooth circular movement of the arm, at the rate of about one 'punch' per second or an average of 3600 'hills' per hour. Planting maize at a stand of 30,000 to 40,000 'hills' per hectare, takes about 10 hours.

Always listen for the sound of the seed dropping into the jaws as the planter comes out of the soil. Should you not hear this, then check the metering slide which may be blocked.

Fig. 26. **Using the 'Punch' Planter**



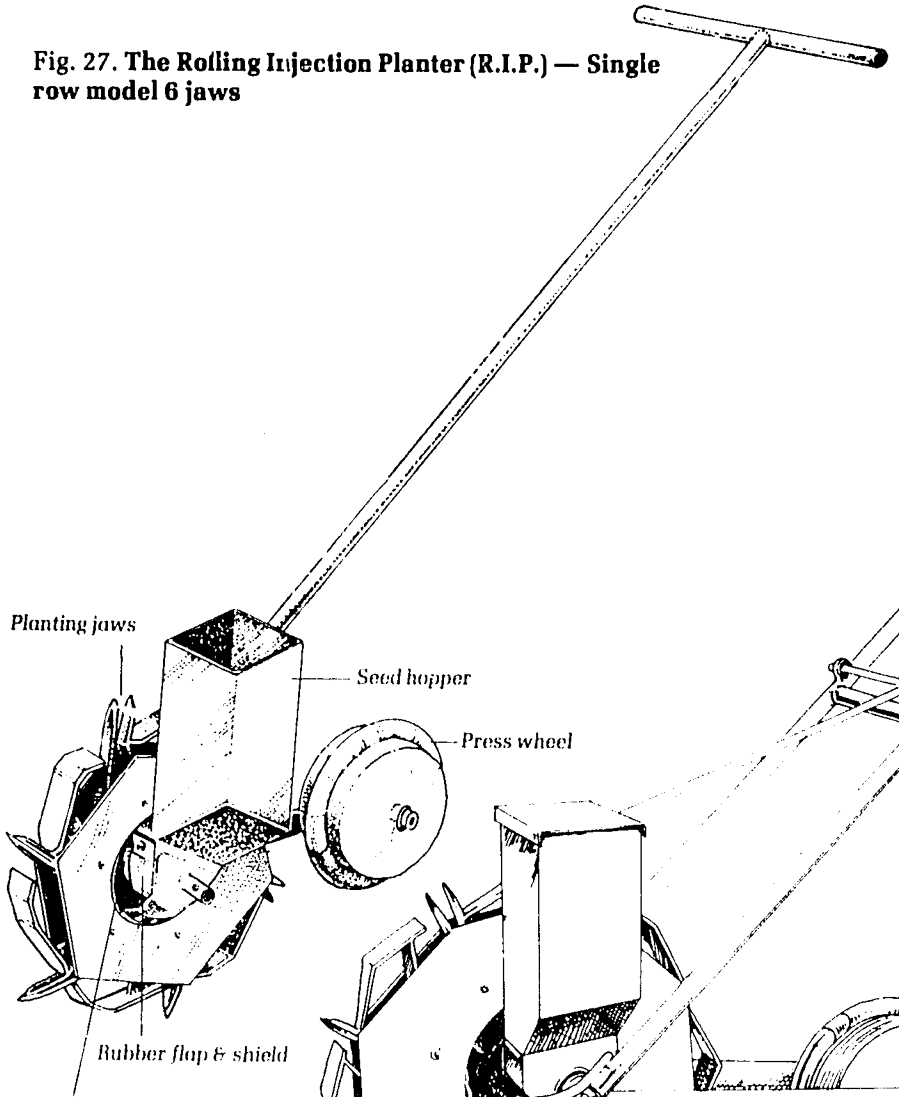
4.4.2.3 The IITA 'Rolling-Injection-Planter' — RIP

This was designed to achieve an appreciably higher rate of injection planting, than the one hill-per second rate achievable with the 'Punch' planter; and is better suited to the farmer with more than 1/2 a hectare of land.

The RIP is available as a single-row model for planting of crops such as maize, cowpeas, etc. at relatively wide inter-row spacings, and achieves a sustained planting speed of 3 'hills' per second (over 10,000 hills per hour.) Maize can therefore be planted in about 3½ hours per hectare (that is about 35,000 hills).
Two variations of the single-row planter are available. One with six points on its periphery (see working drawing centre pages) for in-row-plant spacings of 25 cm, and the other with eight points on its periphery (sketch) for spacings of 15 cm in the row.

Further variations have been developed such as a two row planter with variable between-row spacings from 15 cm to 75 cm in multiples of 15. Use of the two-row planter is recommended for a farmer experienced in the no-till planting of crops. A beginner will prefer the single-row planter, for ease, initially of getting acquainted with the technique.

Fig. 27. **The Rolling Injection Planter (R.I.P.) — Single row model 6 jaws**



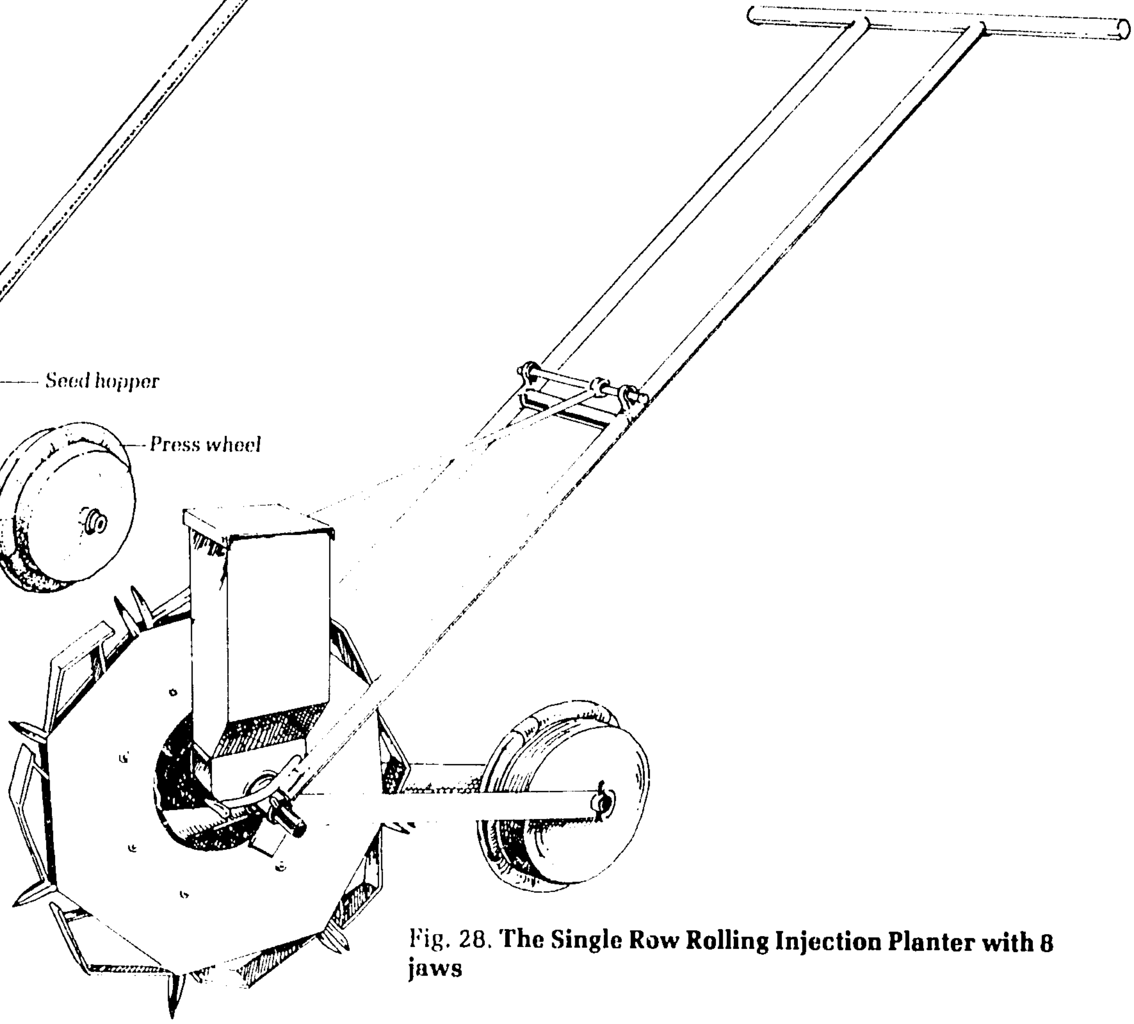


Fig. 28. **The Single Row Rolling Injection Planter with 8 jaws**

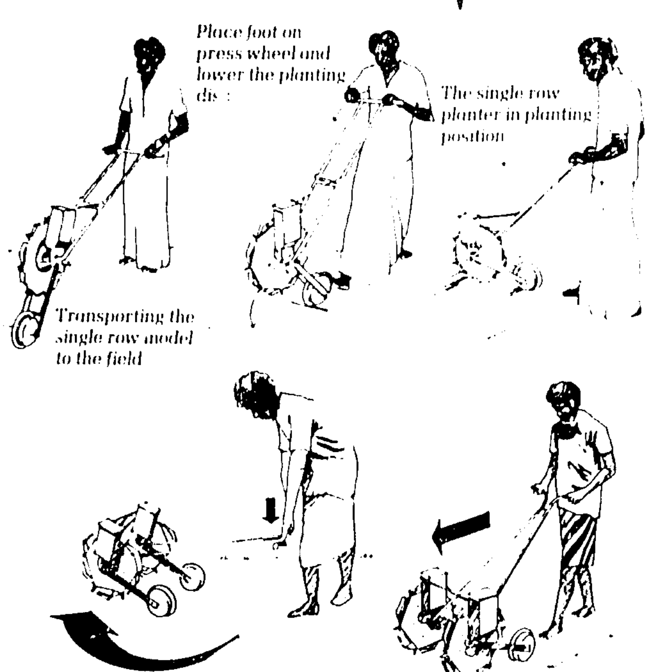


Fig. 30. **Transporting and handling the R.I.P. single row and double row.**

The 15 cm in-row spacing is often used for crops such as upland rice, cowpea, etc. in Asia, for its advantages of better weed-control through shading of the soil below the plants. A 25 cm in-row spacing is customary however, in drier areas with less problems with weeds.

The single and two row models can conveniently be transported to the field with the compactor-wheel(s) swivelled forward, and pushed, wheel-barrow style. For turning from one row to the next, pressing downwards on the handle pivots the planter up and along the wheel or it can conveniently be positioned in the subsequent row.

4.4.2.4 Seed Metering

Metering reels are provided — usually made of a hardwood such as satin or ebony, or even of aluminium or moulded plastic — with holes (oval shaped or circular) for a wide range of tropical and temperate seeds. The variations

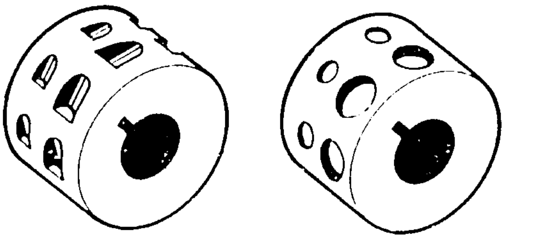


Fig. 31. **Metering Reel — tangential and radially cut seed pockets (see working drawing, centre pages)**

available (see Sketch) are in diameter of the metering hole and depth. Some initial experimentation is necessary in a country to identify the size of metering hole best suiting the dimensions of the seed available locally and the number of seeds required per hill. While maize and cowpea are usually planted to one seed per hill, rice is often planted with five or six seeds per hill. There is also much variability in the size of locally available seed. For example maize seed may require metering holes varying in diameter from 10 mm to 16 mm.

After the planter is assembled, adjust the setting of the rubber flaps so as just to touch the metering reel. This ensures that any surplus seed is gently brushed off by the flaps within the hopper so that only the metered seed passes under the flaps, through the funnels, and into the respective planting jaws. Should the rubber flap be pressing too hard on the metering reel, some 'milling' of the seed will be noticed.

4.4.2.5 **Planting**

Half fill each hopper with seed. Both hoppers of the two row planter should have roughly the same quantity. This will enable you to see after a few rows of planting, whether the seeding rate through both the hoppers is equal. If not, the rubber flaps may need adjustment.

Ideally a rope should be stretched, straight, across the field to be planted and along which the planter is pushed. The rope is then shifted by the amount of the between-row spacing to enable the farmer to maintain the correct row spacings. A short 'spacing-stick' might usefully be kept at either end of its rope and marked with the between-row spacing used. When using the two-row planter, the 'spacing-stick' should be marked to **twice** the row-spacing required.

When planting in rather hard soils, it is sometimes useful to lay a weight, — perhaps a bag of sand or seed — on the planter (preferably on either end of the axle), to help penetration to the full depth of the planting jaws. Should the jaws not penetrate to their full depth, there is often a tendency for the jaws to open inadequately to release the seed, thereby also resulting in entry of soil into the partially open jaws.

Speed of planting should be between ½ and 1 metre per second. Too fast a speed often results in seed being thrown out of the planter.

4.4.2.6 **Precautions**

1. DO NOT use the planter to inject seed into wet soils! Not only will germination be very poor, but the seeds will tend to stick around the jaws thus causing blockages. Ideally the soil should be just moist after the first rains.
2. DO watch the flow of seed coming under the rubber flaps and trickling through the funnel into the jaws. Stop and check if the flow in any planter stops.
3. DO TRY to ensure that you are planting through at least 2 cms of mulch. This helps wipe the injector-jaws as they go in and out of the soil and ensures that no lumps of soil work their way into the jaws.
4. DO Watch the jaws as they rotate to ensure they are clean and not clogged.
5. DO Check depth of planting, as rice prefers very shallow planting (no more than 1 cm deep). Maize can cope with deeper planting, even to 5 cms depth, as their seedlings are much stronger than the delicate rice seedlings. It may be necessary to remove the compactor wheels when planting rice, to ensure better emergence of the seedling.
6. DO NOT turn the planter with the injector jaws in the soil. Raise the planters out of the soil before turning.
Turning the planter with the jaws in the soil invariably results in soil ingestion which clogs the jaws.

4.4.3 Fertilizer Applicator

This tool has been developed to dibble, very quickly, an accurately metered band of fertilizer beside a row of seedlings or plants. Drawings may be obtained on request from IITA in Ibadan, Nigeria.

The basal application should be banded a few days after emergence, and so has to be deposited, on the mulch, about 5 cm away from the line of emerging plants. The operator should walk with the line of emerging plants to his left; likewise when applying a top-dressing of urea.

As the metering of flow is related to the number of revolutions made by the wheel, it is not very sensitive to speed. Fertilizer can thus be applied, very quickly and accurately, at a brisk walking pace.

Fertilizers vary in consistency. Thus the applicator should be calibrated before use. A cup is suspended below the outlet spout and the quantity of fertilizer flowing into it when the applicator is propelled over, say, 10 metres can be measured and the metering slide adjusted until the required rate is obtained.

The following formula and examples will help calculate this:

When Q = Application rate required in kilogram per hectare (kg/ha)
S = Inter-row plant spacing in metres
R = Rate of flow required in grammes per metre (g/m)

$$\text{Then } R = \frac{Q \times 1000 \times S}{10000} \text{ or } \frac{Q \times S}{10}$$

Example:
if Q = 50 kg/ha
S = 0.75 m
$R = \frac{50 \times 0.75}{10} = 3.75$ gm/metre

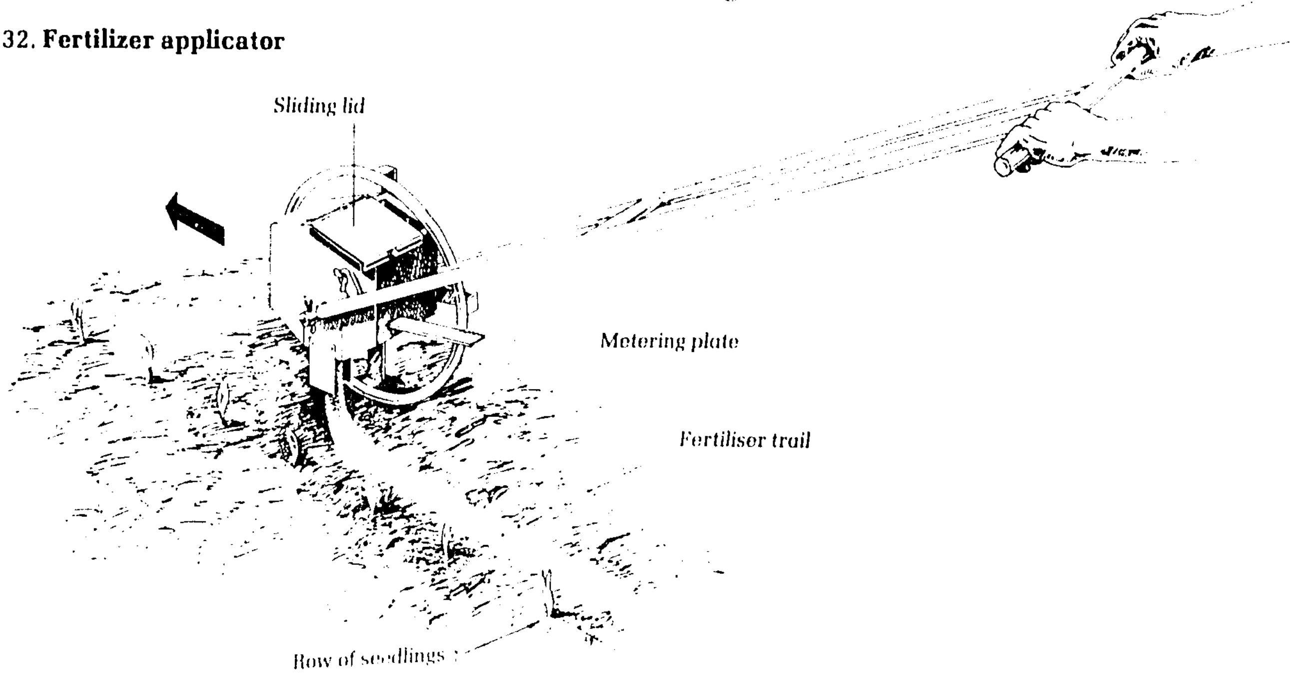
When calibrating, propel the applicator for 10 metres. The quantity of fertilizer flowing into the cup should be adjusted on the metering plate to as near as possible to 37.5 grammes in the field. This rate of application will be maintained as long as the consistency of the fertilizer does not vary.

Precautions.

ALWAYS wash the applicator, thoroughly, and immediately after use.

ALWAYS apply some oil on the axle, bearings, and onto the helical coil to prevent these parts rusting.

Fig. 32. **Fertilizer applicator**



5. Fertility Regenerating Systems

It will be evident from the foregoing sections that zero- and minimum tillage techniques with mulching greatly help conserve soil, water, fertility and energy. However, these techniques do not completely arrest soil deterioration ensuing from continuous cropping. Soil compaction, acidification in some soils, and nutrient losses by leaching, fixation in the soil and crop removal yet remain constraints to sustained crop productivity. Moreover, at his resource level, the subsistence farmer can hardly afford restorative inputs of chemical fertilizer; not that chemical fertilizers have been able fully to support a sustained productivity in the marginal soils on which much of upland arable farming takes place.

Of over-riding importance is the role of organic matter in the fertility of tropical soils. Because of higher temperatures, it decomposes some five times faster in the tropical soils than in temperate soils. Crop-weed residues becoming available under 'no-till' farming are often inadequate to maintain the organic matter content at sufficiently high levels. It is now clear that continuous inputs of both organic matter and nutrients are essential to maintain high productivity levels under continuous cropping. This fact has stimulated research into new aspects of cover cropping, and more importantly, tree and shrub-based fertility recycling systems which follow upon the principles of the bush fallow to provide both organic carbon and nutrients.

Apart from food, the rural population needs fuel for the hearth and fodder for their livestock; both of which are fast dwindling resources. Thus the demand for comprehensive upland farming systems which will ideally produce fuel and fodder as well as food. Many of the trees and shrubs researched under tree-based arable crop production systems are fuel and fodder trees. Thus the integration of trees and arable crops (agroforestry) appears a tangible way towards meeting the more comprehensive needs of the rural populace.

5.1 In-situ mulches

The importance of mulching has already been discussed. But the cost of procuring mulch in adequate quantities and of labour for spreading it are major constraints to the wider use of mulching in arable farming. Moreover, crop residues often constitute an important source of animal feed. These factors have stimulated research into systems of mulch production **in situ**, which can conveniently and inexpensively be integrated into arable cropping systems.

In one approach, legumes or grasses have been grown as covers and then killed with herbicides (eg. paraquat or glyphosate) to provide the mulch. Crops are then grown 'no-till' through, and with minimal disturbance of, the mulch. Crop yields have consistently been comparable with or better than those under conventional tillage systems (Wilson and Akapa, 1979). In this system, legume covers have proven more advantageous than grasses because the former fix nitrogen. However, the cost of cover re-establishment season after season and the attendant weed problems are a disincentive.

Fig. 33. **Climbing legume cover (eg. Psophocarpus) competing with maize**

Fig. 34. **Crops growing in live creeping mulch (eg. Arachis prostrata or Desmodium spp.) without competition**

In an alternative method, annual creeping legumes such as **Mucuna utilis** and **Calapogonium mucunoides** which produce substantial quantities of litter and viable seed before dying out during the dry season, prove useful alternative mulches. Here, the thick mulch of litter suppresses the weeds, and arable crops can then be grown in rows cleared of mulch to facilitate emergence. With a little selective weeding, the cover can be encouraged to re-establish from the seed shed in the previous season, whilst the crop is growing, and in fact, function as a live mulch.

More research is, however needed with this system, especially with regard to the management of weeds and of the live cover crops.

5.2 Live mulches

The importance of legume covers (live mulches) under plantation crops of rubber, coconut, oil palm and cocoa is well established. There is currently much interest in extending live mulches into arable crop production. In the system under research, crops are directly planted into living covers which had earlier been established. The legumes are then so managed as to minimise their competing with the planted crop. At the end of the cropping season, the cover is allowed to grow freely to smother any regrowth of weeds.

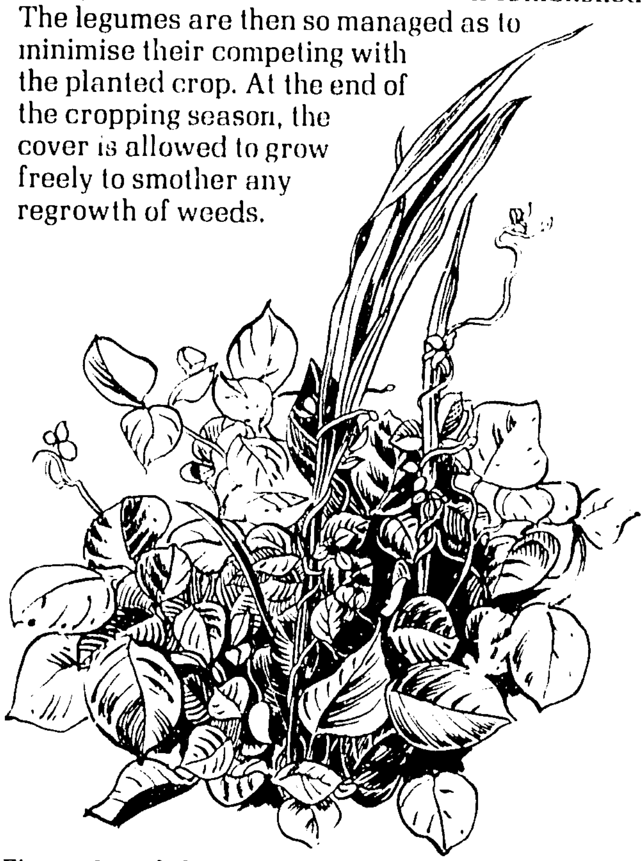


Fig. 35. **Weeds being stifled by live mulch**

5.2.1 Legume species

The following legumes listed below and others are being investigated in the role of live mulches at the International Institute of Tropical Agriculture, Nigeria and at the Maha Illuppallama Research Station of the Department of Agriculture, Sri Lanka:

Pueraria phaseoloides
Centrosema pubescens
Arachis prostrata (propagated from cuttings)
Psophocarpus palustris
Macroptilium atropurpureum (Siratro)
Calapogonium mucunoides
Mucuna utilis

5.2.2 Live mulch attributes

The following characteristics are expected of an ideal live mulch:

1. Should be easy to establish and have early **horizontal** growth vigour to cover the ground rapidly. Climbing covers are difficult to manage.
2. Should be weed competitive.
3. Should produce adequate amounts (say 5-6 t/ha) of litter.
4. Should preferably be deep rooted (below the crop root zone).
5. Should be perennials, or else annuals which die out during drought to re-establish during the cropping season from seed. The latter characteristic is perhaps preferable towards reducing competition with the crop, especially during dry spells.
6. Should fix nitrogen at levels required for arable crops.
7. Should withstand slashing or other cultural treatments as would be necessary for crop establishment and growth with minimal competition.
8. Should not harbour pests or diseases affecting arable crops.
9. Should be shade-tolerant to be able to withstand shading by crops.
10. Should produce sufficient seed for re-establishment.

5.2.3 Establishing 'covers'

Seeds of many cover legumes have hard coats and are dormant. The dormancy should be broken, for rapid germination of a high percentage, before seeds are sown. This may be accomplished by treatment either with hot water or with concentrated sulphuric acid. The optimum temperature of water in the hot water treatment varies with the species of seed. In general, seeds are placed in a large volume of water at 70-80°C, and allowed to soak overnight. Alternatively, the seed may be immersed in boiling water for 30 seconds (not longer!) followed by soaking overnight in cold water. To achieve maximum success, the optimum temperature of water, length of treatment and the volume of water to seed should be worked out for each species through simple tests. Hot water-treated seed cannot be stored and should be planted immediately.

Done properly, the acid treatment is more reliable and gives a higher germination percentage. Here, moisture-free seed is placed in a **dry** glass or strong plastic container, and just enough concentrated sulphuric acid (specific gravity 1.84) to wet the seed is poured over and stirred well with a stick or glass rod. After 15-20 minutes (some seeds such as **Desmodium ovalifolium** need 30-45 min.) the seed is very quickly rinsed in a large excess of water, and the water drained off, using if necessary a strainer. Note that adding acid treated seed to cold water rapidly raises the temperature of the water. The treated seed should then be washed thoroughly with several further rinsings to remove all traces of acid. Acid-treated seed can be stored for a week or two after drying well.

To ensure rapid and effective nodulation, the seed may be inoculated with a suitable Rhizobium inoculant. Usually good nodulation takes place even without inoculation, from rhizobia in the soil, especially if legumes such as cowpea had been grown previously in the field.

Ideally seed may be sown in rows 2 m apart, with an in-row spacing of about 25 cm. Four or five seeds are drilled at a point. Square seeding of 1 m by 1 m is also recommended. Post-plant weed control may be achieved using pre-emergence herbicides as used with grain legumes. Alternatively hand or hoe weeding may be undertaken, in which case, row seeding is preferred.

Application of rock phosphate (say 200 kg/ha) and muriate of potash (100 kg/ha) assists in expediting spread of the covers, especially in situations where these nutrients are deficient in the soil.

5.2.4 Management of covers

During crop establishment, the live mulch should be suppressed sufficiently to eliminate competition with the planted crops. This may be achieved by spraying with a plant growth regulator (inhibitor) that suppresses growth of the cover temporarily, and until such time that the crop canopy itself is able to suppress the legume cover by shading. Alternatively, the cover should periodically be slashed during establishment of the crop.

Usually, however, most vigorous covers produce so much mulch — both live cover and litter — that crop emergence may be impeded if crops are directly seeded into the mulch. Therefore, clearing of narrow strips along intended crop rows is recommended. Seed can then be directly drilled into the soil either with an injection seeder or by hand with a stick.

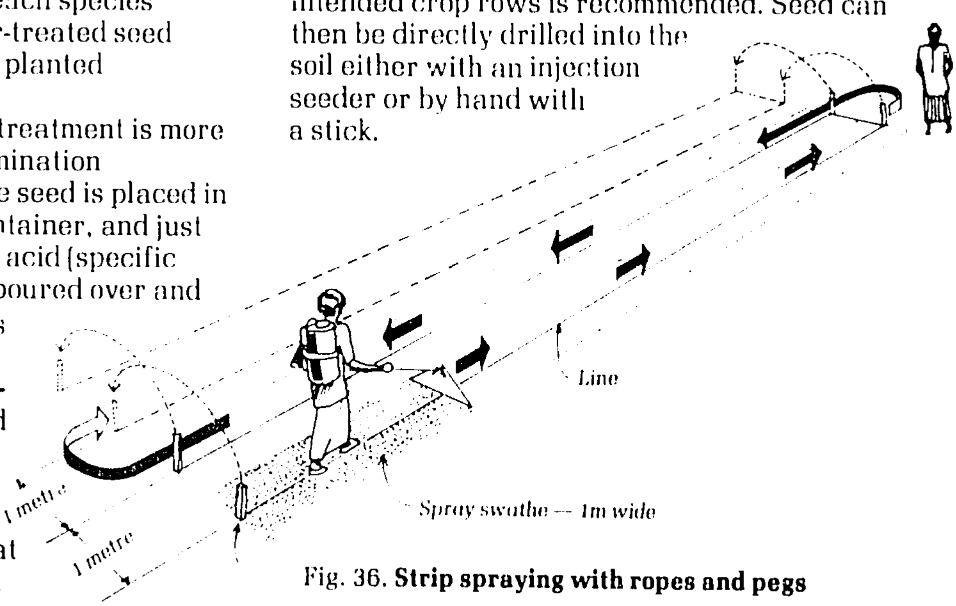


Fig. 36. **Strip spraying with ropes and pegs**

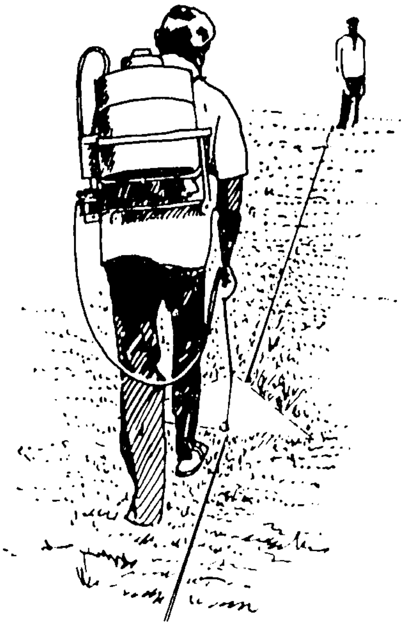
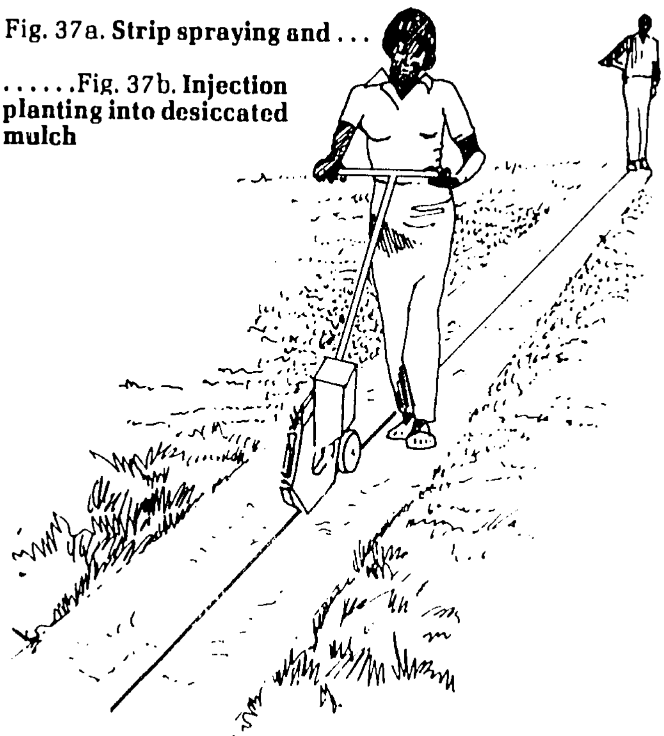


Fig. 37a. **Strip spraying and . . .**



. . . . . .Fig. 37b. **Injection planting into desiccated mulch**

It needs to be stressed that management of such live mulch cover is not easy. It requires skill, and often hard work, too, to prevent the mulch from smothering the planted crop. One of the most suitable live mulches, however, **Arachis prostrata** is difficult to establish as it does not seed and must be grown from cuttings. This is slow and tedious. It does, nevertheless, establish horizontally and does not climb.

5.2.5 Weed Management

A primary aim of the live mulch concept is the replacement of a complexity of weeds by one, fast-growing and easily-manageable weed — the live mulch. The data in Table 8 suggest that this expectation has been substantially realised. Here, the legume covers controlled grass weed much more effectively than the broad-leaved weeds. It would appear that the covers had a greater depressing influence on the light-demanding grasses due to shading than upon the less-light-requiring broad-leaf weeds. It was also reported (IITA Ann. Rep., 1979) that the weed suppressing attribute of live mulches of **Centrosema pubescens, Arachis repens** and **Psophocarpus palustris** was, in fact, significantly better than 10 tons of maize stover mulch/ha. There is also evidence that legume covers are an effective means of controlling **Cyperus rotundus** — often referred to as the world's worst weed!

Table 8 — **Effect of land preparation and legume covers on weed growth**

	Weeds (kg/ha)	
	Broad leaves	**Grasses**
Conventional till	700	2190
No till (using herbicides)	430	1170
Arachis sp.	480	130
Centrosema sp.	270	90
Psophocarpus sp.	360	0

Source: Adapted from IITA Annual Report, 1979

5.2.6 Nutrients and organic matter

Live mulches contribute large quantities of organic matter, especially from the litter through which nutrients are recycled back continuously to the top soil, although the recycling may not be as effective as with the more deep-seated root systems of trees and shrubs. Yet, the biomass of legume covers 'locks up' large quantities of nutrients, which are released slowly through decomposing litter thus reducing leaching and other losses. An important factor with legume covers is their ability to fix large amounts of atmospheric nitrogen biologically. This nitrogen is also released to the soil for use by other crops through the decomposing litter, roots and nodules. Estimates revealed that a cover of **Pueraria** produced 3.5 to 4 tons of dry leaf matter as litter alone, per hectare per year; the nitrogen accretion from which amounted to 125-150 kg/ha/yr (Waidyanatha, 1978).

5.2.7 Soil physical characteristics

Live mulches protect the soil from splash erosion and maintain better soil structure and infiltration rates. The moisture retention in live mulch plots is also higher than in unweeded plots, whether farmed 'no till' or 'tilled'. But the moisture depletion rate was highest under the live mulches indicating higher transpiration rates (IITA Ann. Rep. 1981). Therefore, live mulches are not suited to situations where moisture stress might frequently affect the planted crops.

Earthworm activity was far greater under live mulches and under maize stover mulch than under 'conventional till' or even under 'no till' (IITA Ann. Rep., 1979). This points to highly favourable biotic activity under mulches, live or dead.

5.2.8 Crops and crop performance

So far maize, in particular, has been most successfully and widely tested with live mulches. Other tall crops, particularly, nitrogen-demanding cereals such as sorghum and millets should perform well under live mulches. Aggressive, climbing legume mulches impose severe management limitations on crops that can thus be grown. However, for shorter crops, low-growing and non-climbing covers such as **Arachis prostrata** and **Desmodium spp.** need further investigation.

Fig. 37a. **Maize growing in fertile soil under live mulch**

Fig. 37b. **Maize growing on bare soil (infertile and weedy)**

A study at the IITA (see IITA Annual Report, 1981) over six successive seasons has compared several land management systems including conventional tillage, zero tillage and live mulches (no-till), each at three levels of nitrogen, **viz.** 0.60 and 120 N/ha/season. The results (Fig. 38) show that yields which were initially marginally higher under 'conventional till' and 'no-till' than under the live mulch, decreased rapidly over the seasons in the first two systems, whereas the decrease was relatively small under the live mulch. In the absence of applied N yields were strikingly higher (**ca** 2t/ha) under the live mulches than under conventional or zero tillage (**ca** 1t/ha). Particularly interesting is the evidence that by the sixth successive season, maize — a crop which demands high levels of fertility — yielded as much under the live mulch **with no applied N** as under conventional tillage with 120 kg/ha of applied N.

This data is of great significance as it establishes that a sustained productivity at reasonable levels of yield can be achieved under live mulches even at minimal levels of applied inputs.

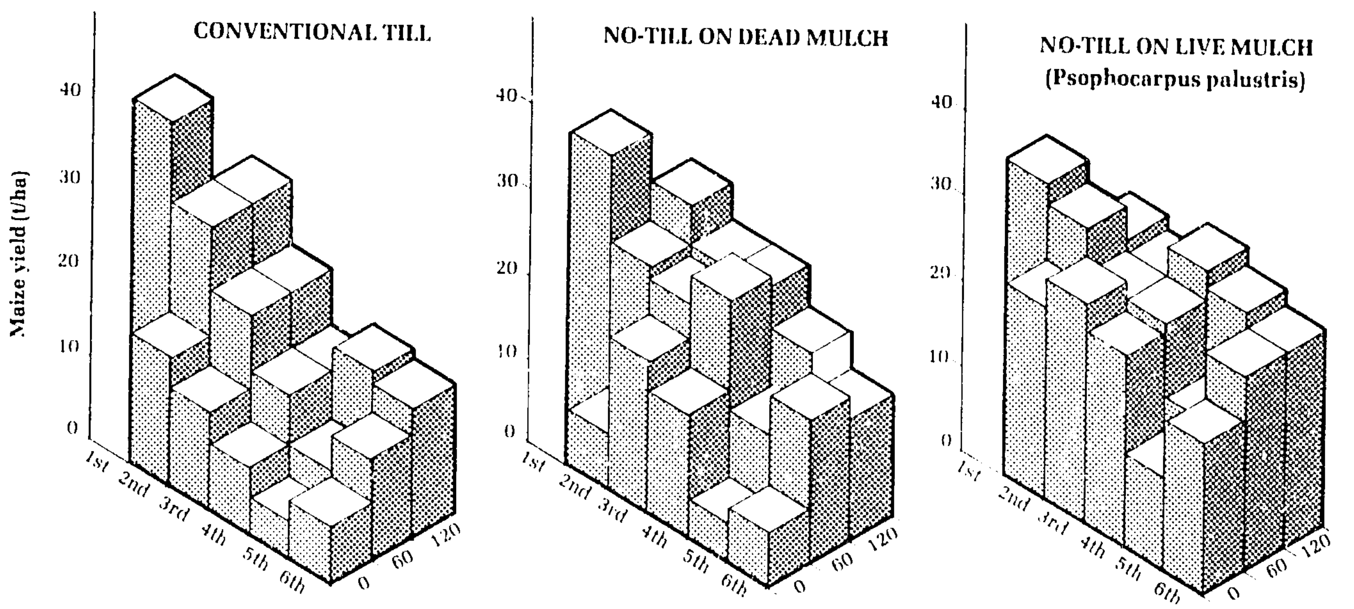


Fig. 38. Effect of three Land Management Systems, Conventional Tillage, 'No-Till' on dead-mulch, and 'No-Till' on live mulch, at three levels of nitrogen fertiliser and over six successive cropping seasons on maize yields.
(IITA 1979-81)

5.3 Avenue (Alley) Cropping

This agro-forestry technique integrates on a continuous basis, the soil-restorative attributes of the bush fallow with upland arable cropping through simultaneous culture of arable crops and fast-growing perennial trees side by side.

Here, trees or shrubs are established in avenues (hedgerows) spaced (two to four metres) apart. At the beginning of the cropping season, the tree rows are lopped at appropriate heights, and loppings laid in the avenues between tree rows as mulch. The woody material, removed after leaf fall, constitutes an important source of firewood or stakes. Crops are then planted in the avenues through the leaf mulch. The tree regrowth may have to be lopped once, or more often, in order to avoid shading of the growing

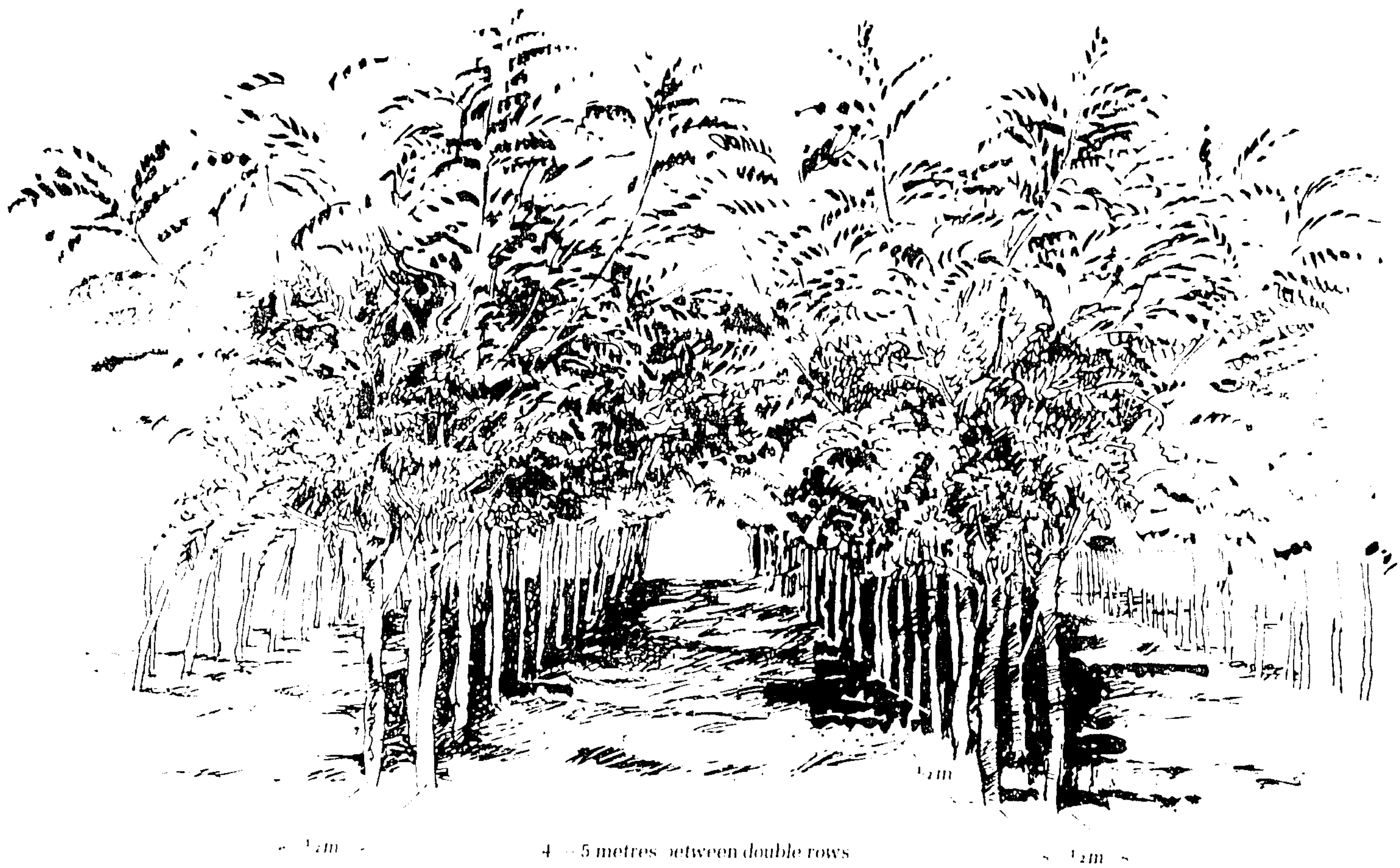


Fig. 39. **Double-hedge rows planted in Gliricidia or Leucaena forming dense shade over the avenues during dry (non-farming) season**

Fig. 40. **Hedgerows lopped, and mulch laid on avenues**

crop. The loppings of the re-growth may be applied to the crops as a 'top dressing'. During the fallow period the trees re-grow freely, shading out the weeds.

5.3.1 Trees for avenue cropping

Many trees and shrub species, in particular legumes, are currently under investigation with regard to their suitability for use with alley cropping, examples being **Leucaena leucocephala, Gliricidia maculata, Tephrosia candida, Cajanus cajan** and **Sesbania sp.** Of these **Leucaena** is so far the species most widely experimented with. Investigations at high altitudes (more than 1000 m) such as at the foot hills of Himalayas, have shown that tree species such as **Leucaena diversifolia** (suitably inoculated) and **Rcbenia pseudoacasia** are suitable in this role at up to altitudes of 2000 and 3000 metres.

Fig. 41. **Crops growing in the avenues in light shade from the hedgerows which are then lopped periodically during the growing season for "top dressing" mulch and to provide optimum light for the maturing crop.**

Trees used in Avenue Cropping systems need to be fast-growing and 'coppicing' or 'pollarding' i.e. with the ability to sprout fresh shoots from the stem when lopped repeatedly.

The criteria of suitability for avenue cropping will include the ability to regenerate about 5 tonnes of leaf and an equal quantity of wood within a year of being lopped.

Fig. 42. **Coppiced and regrowing tree**

5.3.2 Establishment and management of the trees

Trees and shrubs may be established by direct planting of seeds or seedlings in the field. However, in order to reduce costs of establishment and early maintenance, experiments (IITA Ann. Rep. 1979, 1980) have been conducted to ascertain whether legume trees can be successfully interplanted with crops (maize). When interplanted with maize, early growth of **Cajanus,** has been good but that of **Leucaena** and **Gliricidia** poor. With the exception of **Gliricidia,** which was established from cuttings, the others were established from seed. Alternatively, trees producing viable seed such as **Leucaena** may be raised initially in polybags in a nursery. For trials in Sri Lanka, **Leucaena** seedlings were raised in polybags (10 cm diameter, 20 cm height). Seeds were treated with concentrated sulphuric acid or hot water (80°C for 5 minutes, and then soaked in cold water for 12-24 hr). They were then inoculated with the appropriate **Rhizobium** (CB 81 from Australia for acid soils and NGR-8 or NGR-35 from Papua New Guinea for alkaline soils) inoculant before planting in polybags. Small quantities of rock phosphate and muriate of potash (3-4 kg of 2:1 mixture/ton of soil) were incorporated into the soil

Fig. 43. **Legume tree seedling in poly-bag nursery**

placed in polybags. When transplanted in the field at 3-4 months of age, (approximately the diameter of a pencil) excellent establishment and growth of plants from the polybags were observed.

Fig. 44. **Gliricidia tree**

Certain species such as **Gliricidia** can, ideally, be propagated from stem cuttings. Usually stems about 6 months old (i.e. 2.5 cm in diameter) and about 1½ — 2 metres in length are suitable. They may be planted about 20 cm deep at the beginning of the rainy season. Rooting of cuttings takes place about six weeks after planting, and nodulation, ten to twelve weeks after planting (Chadhokar, 1982).

Many questions on lopping height and regimes, and spacing of trees remain to be fully answered. Indications, so far, are that for **Leucaena,** single hedgerows wider than 2 m apart may not be optimally productive. However, shading of crops by rapidly regrowing hedgerows and loss of croppable space are two limitations of close (eg. 2m) hedgerow spacings. On the other hand, wider spacings reduce the biomass yield of the loppings (Torres, 1982; IITA Annual Report, 1981). Perhaps one possible means of mitigating this problem is by the use of double hedgerows with the two rows very close (eg. 0.5 m apart) to each other and wider (eg. 4 m) avenue spacing. This system appears well worth further experimentation.

As regards lopping height, an investigation in Sri Lanka (Table 9) indicates that, for **Leucaena,** 0.5 m is possibly batter than 1.0 m for avenues planted with both maize and cowpea. In many other studies with **Leucaena** lopping heights of 15 to 30 cm have been employed (see Torres, 1982). Competitive shading of the avenue-grown crops is possibly reduced at the lower lopping heights. For **Gliricidia,** where re-growth after lopping is much slower than with **Leucaena,** higher lopping is perhaps feasible, but this needs further study.

Table 9: **Crop yields as affected by Leucaena hedges 2 m apart at two lopping heights (kg/ha)**

Crop	Leucaena lopped at 0.5 m	Leucaena lopped at 1.0 m	Bare (no Leucaena)
Maize	2472	2275	1677
Cowpea	439	387	590

Source: Wijewardene and Weerakoon (1982)

Fig. 45. **Gliricidia — close-up of branch.**

Experience indicates that retaining a branch or two ('lungs') at lopping, especially when the trees are lopped low, can be vital for their survival in situations with prolonged droughts.

5.3.3 Leaf, wood and nutrient contribution

The amount of organic matter and nutrients contributed would depend, amongst other factors, on the tree species, age of trees and their spacings. In Nigerian work (IITA Ann. Rep., 1981) increasing the inter-row spacing of **Cajanus, Teprosia, Leucaena** and **Gliricidia** from 225 to 675 cm decreased the total productivity of all four species. In the fourth year of planting, hedgerows of **Leucaena** and **Gliridicia** produced 5.6 and 6.3 tons of leaf dry matter/ha/yr (Table 10) which contained 233 kg of N. Yields of wood and other nutrients were not indicated but conservative estimates would be in the order of 4 tons of wood, 10 kg of phosphorus and 100 kg of potassium.

Table 10: **Leaf yields and estimated N contribution of shrub legumes at cutting back and first pruning**

Legume	Total dry weight (kg/ha)	N in dry matter %	N in dry matter kg/ha
Tephrosia candida	3453	3.8	131
Cajanus cajan	2312	3.6	83
Leucaena leucocephala	5595	4.2	234
Gliricidia sepium	6286	3.7	233

Source: Adapted from IITA Anr. Rep., 1981

As there is relatively little data available regarding 'avenue-cropping' or 'simulated-forest' using hedgerow trees other than **Leucaena** the data presented by Handawela (1983, Table 11) is of particular interest. The **Gliricidia** hedgerows in this particular trial were planted 3 m apart in the row and 5 m apart between rows. The results obtained in the second year, 1981, are of special interest as they show yields of maize within the 'simulated forest' (i.e. avenues between **Gliricidia** hedgerows) without added fertilizer (1561 kg/ha) greater than the yields obtained in the open (1354 kg/ha) with fertilizer inputs of 60N, 60P, and 60K. This was a significant testimony to the value of the 'avenue-cropping' or the 'simulated-forest' concept and of its ability to provide the avenue-planted crops with a major part of the nutrients required for sustainable crop yields, at reasonable levels of productivity.

It has been a traditional practice to use loppings from live fences as organic fertilizer in rice farming in Asia. In a preliminary study simulating this practice, grain yield increased by 28% when loppings (2.6t/ha) of **Leucaena,** planted 5 m apart on ricefield bunds, were incorporated into the soil (Weerakoon, 1982).

Further work done in Sri Lanka (Table 12) has shown that in the second year after planting, **Leucaena** hedgerows (2 m by 0.5 m) yielded as much as 7.5 tons of leaf dry matter and an equal quantity of wood in a total of five loppings, two in the minor season and three in the major season. In trials with **Gliricidia,** five-year hedgerows spaced 3 m by 0.43 m yielded about 7.5 tons and 9.5 tons of dry leaf matter/ha/yr when the trees were lopped every two and three months resprectively. The wood yields were about 40% of the total yield (Chadhokar 1982).

Table 11: **Effect of 'simulated forest' and fertilizer on maize yields over two years (1980 and 1981) Sri Lanka**

Treatment	Loppings added — 1980, kg/ha	Grain yield — 1980, kg/ha	Loppings added — 1981, kg/ha	Grain yield — 1981, kg/ha
A. Simulated forest (#)				
1 No added fert'er	561	1373	2811	1561
2 + 60N	—	—	3129	1921
3 + 60N,60P,60K	579	3002	2963	2728
B. Without Simulated forest				
1 No added fert'er	—	1163	—	680
2 + 60N	—	—	—	1385
3 + 60N,60P,60K	—	—	—	1354

Handawela, J., 1983 # Gliricidia planted 5 m x 3 m, and Maize grown in avenues between.

Table 12: **Dry matter yield (kg/ha) of wood and leaf of Leucaena loppings**

	'81/82 main season	'82 minor season	Total
Leaf	4754	2873	7627
Stem	5096	2506	7602

Source: Adapted from Wijewardene and Weerakoon (1982)

Although the nitrogen contribution from leaf mulches of trees such as **Leucaena** and **Gliricidia** is high (see Table 10), it is generally accepted that only about 50% of the applied leaf nitrogen will be available to the crop in the first year. It increased by 25% in the second year, and a further 17% in the third and fourth years after initiation. However, the higher denitrification (particularly in the case of **Leucaena** on account of its low C/N ratio) and leaching may further decrease the efficiency of availability of leaf nitrogen to crops. On the basis of the foregoing figures, it appears that after about three years of continuous application of **Leucaena** prunings, a steady state level of about 50% N-use-efficiency can be expected from the **Leucaena** prunings.

5.3.4 Crop yields

In considering crop yields, it should be remembered that the hedge-rows of trees might take up part of the space that would otherwise be occupied by crops. This would, however, depend upon the relative spacing of crops and trees.

The yield of crops would depend on many factors such as crop species, tree species, its spacing, organic matter and nutrient contribution, lopping height, the effects of shading, and root competition between the trees and crops.

A study of the Leucaena-maize system (Fig. 46) in Nigeria demonstrated clearly the fertility benefits accruing from the application of

Leucaena loppings as mulch to the interplanted maize. Maize grain yields were substantially higher when the loppings were applied to the crop than when they were removed from the plots. The loppings amounted to over 6 tons of dry matter/ha containing over 200 kg N/ha in one year; but additional applications of inorganic nitrogen (80 kg/ha) significantly increased yields further. This is perhaps explained by the possibility of low efficiency of **Leucaena** N availability in this instance. However, the maize grain yield of about 3.8 tons/ha/yr for two consecutive years in this trial with applications of loppings only (no inorganic N) is a substantial return for this low input system (Kang **et al**, 1981).

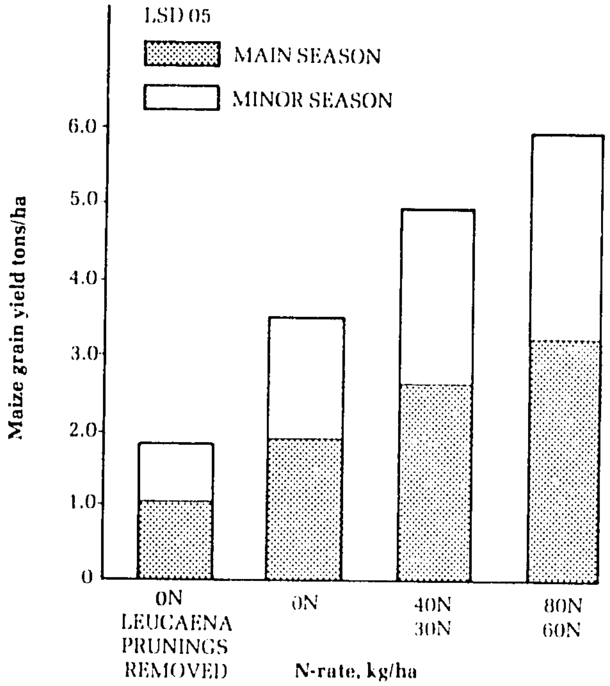


Fig. 46. **Maize grain yield 1979. Main season variety TZPB and minor season variety TZE. (Main season N rates 0, 40, 80 and 120 kg N/ha; minor season N rates 0, 20, 40 and 60 kg N/ha).**

Source: Kang et al (1981)

In the Sri Lankan study (Table 9), maize grain yields were, on average, 40% higher but cowpea yields 30% lower when the crops were grown between **Leucaena** hedgerows 2 m apart, and supplied with the loppings, than when grown in the open without **Leucaena** hedgerows. Nitrogen contribution is an overriding factor in the alley cropping system. It is, therefore, possible that in the case of grain legumes (cowpea) which can fix their own nitrogen, the benefit from **Leucaena,** (at least in the short run), was not of importance, whereas the shading effect of the re-growing trees was more critical to the yield of the shorter-statured (grain legume) crops growing in the avenues. **Crop yield is thus a reflection of the balance between the beneficial and the adverse effects of the avenue-cropping system, and responses will doubtless vary, crop wise, depending on the limiting requirements of the crop.** In general it appears that, for short crops in particular, light limitations imposed by the trees are critical constraints to crop growth and yield.

5.3.5 Crop competition

As mentioned in the foregoing section, undoubtedly, some competition for available light, moisture and nutrition between crops and the legume hedgerows is to be expected. As regards root competition, however, a study of the root distribution of **Leucaena** hedgerows showed that only a few absorbing roots were present in the upper 20 cm of soil which the bulk of most arable crop roots might occupy (Kang **et. al.**, 1981). Therefore, root competition is unlikely to be a major constraint to arable crop productivity. From the same study, there is evidence, however, that shading by the re-growing legume trees significantly decreased crop (maize) yield, and that the effect is more severe on plants closer to the hedgerows. Thus further investigations are warranted on hedge-tree row-spacings, lopping height and frequency towards optimising crop growth and yield, and particularly of cereals (upland rice, sorghum, millet), and such non-legume crops, which are likely to benefit most from the alley crop system.

5.3.6 Weed management

The inherent ability of the avenue cropping system to suppress weeds is of considerable importance. The shading of the avenues which occurs during the off-crop period, has been found helpful in controlling grasses such as **Imperata cylindrica** (IITA Ann. Rep., 1980) and other light-demanding weeds. Weed infestation in cowpea and maize growing in alleys of **Leucaena** was reduced by some 80% when compared with weeds in the crops growing in the open (Table 13).

Table 13: **Dry weight (g/m^2) of weeds growing between maize and cowpea planted in Leuceana avenues c/w open field.**

Treatment	**Maize**	**Cowpea**
Grown in Leucaena avenues	19	17
Grown in open (control)	96	123
LSD (0.05)	20	35
Percentage suppression	80	86

Weerakoon & Seneviratne (1982)

The weeds which remain at the end of the dry season, and at the commencement of the rains — and despite the shading of the regrowth in the hedgerows overhanging the avenues — are usually easily controlled before lopping with a light spray of paraquat (2-3 l/ha). In the rare instance that there are still some perennial grasses in the avenues, a light spray of glyphosate (3 l/ha) should eliminate the spots where these persist. Care should, however, be taken with the glyphosate to ensure none of it contacts the lower leaves of the **Leucaena** or other hedgerow tree, or severe set-back is likely in their re-growth.

It is usually not necessary to adopt complete post-plant weed control apart from occasional 'hand-pulling'. However, in the first few seasons of avenue cropping, the use of the appropriate pre-emergence herbicide is an advantage.

The fact that the avenue-cropping concept utilises the dry season to regenerate its fertility recycling medium and also control weeds by the shade of their rapid development, signifies a substantial step forward in the harnessing of the year round availability of solar energy in the tropics. During the rainy season it is harnessed for arable crop culture and during the dry season for the culture of the deeper rooted legume trees to regenerate fertility as well as the fuel wood and fodder requirements of the rural population.

5.3.7 Economics of avenue cropping systems

The labour required for establishment and lopping of hedgerows is a major economic factor. However, this may be more than compensated for by labour savings on weeding, tillage and firewood gathering, because a very substantial yield of firewood is continuously provided in this system (see Table 12).

The highest benefits in terms of crop yields may be expected in situations where existing production levels are low. In the short term, soil nitrogen level is a major factor that could well decide the trend of response to avenue cropping systems (see also Torres, 1982).

Perhaps the greatest economic advantages are long term, and are associated with the sustainability of the system leading to increased availability of land for arable cropping, which would otherwise have been abandoned to rehabilitate slowly through natural fallow ..... too slowly for the population growth taking place throughout the tropical world.

5.3.8 Avenue cropping on steep slopes (terraces)

In the Philippines, on slopes often steeper than 100% farmers clear land and densely seed **Leucaena** along narrow contour rows 1 to 2 m apart. The resulting dense Leucaena hedges form barriers against which the farmers scrape the soil above to form terraces, or the eroded soil settles forming terraces naturally. The hedgerows are lopped low, and crops such as onions, tobacco etc. are planted on such terraces.

It would seem that this semi-intensive alley cropping system is ideally suited for situations where the land/man ratios are sufficiently large, or, in other words, land is not the major limiting factor. With population growth and the consequent demand for greater productivity from the land, there would be a slow shift towards more intensive use of both the horizontal and vertical space as exemplified by multi-storey cropping systems already traditionally practised in very densely populated locations of the humid tropics. An outstanding example of this system is the so-called Kandyan (Sri Lanka) 'forest gardens' (homesteads) comprising often 20 to 30 species of economically useful herbs, shrubs and trees, though not always optimally spaced for maximal trapping of the sun's energy and the nutrients and water from the soil.

As Raintree (1983) succinctly describes "To obtain the final measure of potential productivity from this evolving agroforestry system, the farmers may turn to the vertical dimension and superimpose additional layers of middle and upper-storey food, feed and fuel producing trees on part of the land in a manner analogous to the Javanese "home garden".

Fig. 47. **Avenue cropping on slope**

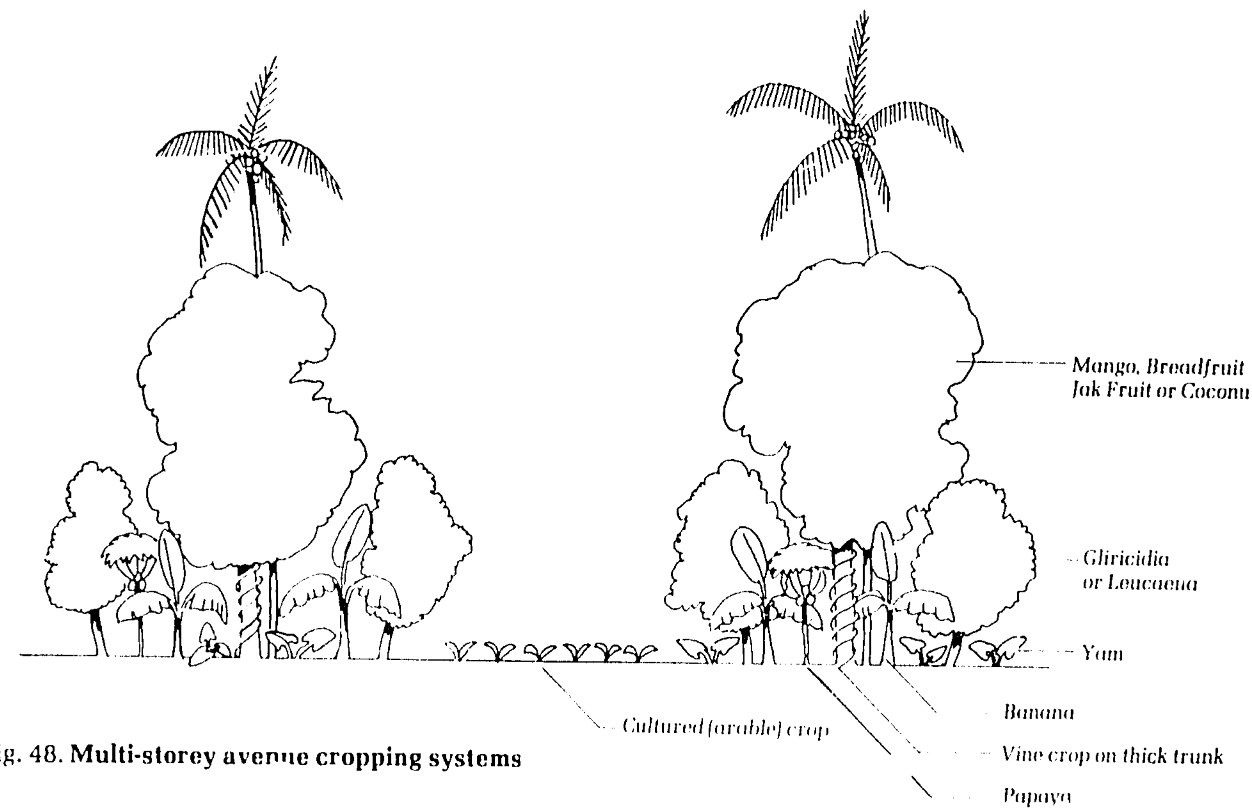


Fig. 48. **Multi-storey avenue cropping systems**

6. Pest And Disease Management Under Conservation Farming

The question is often raised whether the mulches, which form an essential component of 'no-till', 'avenue-cropping' and similar conservation farming systems, do not also harbour insect pests of the crops planted therein. This is, of course a very real possibility, but trials continuing in S. America as well as in Nigeria and in Sri Lanka have not found insect pests in mulch farming systems any more of a problem than in conventional tillage farming. In fact the contrary has been experienced in some situations, and this is possibly due to the build-up also of the predators and parasites of the pests within the eco-environment of the mulch.

Similar experience was gained earlier in the instance of intercropping. The intercropping of corn and peanuts resulted in the decreased incidence of corn borer (IRRI Ann. Rep., 1974) in the Philippines. In northern Nigeria, cowpea is often intercropped with sorghum and millet which is known to result in reduced insect damage to the pest-sensitive legume (Litsinger & Moody 1981).

The interplanting of marigold (**Tagetes** sp.) adversely affected the parasitic nematodes of the tea plant due possibly to the exudation of chemicals toxic to nematodes by the roots of the marigold (Visser & Vythelingham, 1959).

In 'avenue-cropping' systems the pest-predator balance is known to undergo predictable changes. Fernando and Wijeratne-Banda (1982) have reported that incidence of the **Maruca** pod-bearing pest of cowpea was greatly reduced when the crop was grown between hedgerows of **Gliricidia maculata;** although such a reduction was not observed in the avenues between hedgerows of **Leucaena.** The **Gliricidia** apparently acted as a diversionary host or 'trap-crop' and was heavily attacked.

A study by Shenk and Saunders (1979) in Costa-Rica showed that insect pest damage was reduced and maize crop yields increased in 'no-till' systems in contrast to ploughed (tilled) fields. Uncontrolled insects (**Spodoptera sp.** and **Diabrotica sp.**) reduced maize yields 44.4% in ploughed fields, but only 24.1% in fields farmed 'no-till'.

On the other hand, under very wet conditions, mulches tend to encourage disease-causing organisms, such as the fungi **Pythium** and **Rhizoctonia;** whereas during very dry weather, mulches often support termites or white ants — a common problem with endeavours to promote 'no-till' and mulch farming techniques in semi-arid regions.

Increased use of pesticides has been suggested for the control of insect pests under 'no-till' in temperate countries, but pesticides may not be sufficiently effective against insects shielded by a cover of mulch.

Legume live mulches may develop beneficial as well as adverse effect as can dead mulches, and could well harbour snails, slugs, rodents and other small animals which damage crops. Some legume covers also host virus diseases which can spread to the legume crops planted into them.

It is necessary that this Manual presents some of the problems experienced with the endeavours to adopt 'no-till' and mulch farming systems, as skills need to be developed for coping with them. The predator build-up may cope with the problem as it develops and the farmer should be advised against too hasty recourse to broad-spectrum pesticides which can have drastic repercussions on the natural pest-predator balance.

It is therefore best to commence 'no-till' techniques, 'avenue-cropping' etc., in small areas first and develop one's own skills in resolving the inevitable number of problems which can develop, before venturing onto larger extents. Considerable research endeavours also continue to explore and resolve the techniques of farming under mulches — both dead as well as live — as the great potential benefits of these systems make it well worth continued experimentation.

7. Fuelwood Trees

There is now unprecedented global concern that by the turn of the century, the supply of fuelwood may well outpace the demand. According to World Bank estimates, some 250 million people will soon be deprived of fuelwood for their minimum cooking and heating needs unless an additional 20-25 million hectares of trees are planted by the year 2000. But at the current rates of reforestation, this requirement is ten times more than will be achieved. A revealing slogan in India suggests that she will soon produce enough food but not enough fuel to cook it! Clearly, the indiscriminate decimation of forests for fuelwood and timber and the burning of animal dung are leading to massive scales of environmental destruction and the decreasing productivity of croplands. One cannot over-emphasise the need for planting of trees for fuelwood and timber, as also for fodder and fertility!

Some more recent developments in agro-forestry and high density forest (HDF) plantings for fuel-wood and timber production are reviewed below. Environment protection, especially soil improvement and conservation as also fodder production are major 'spin-offs' of these systems.

7.1 Avenue cropping (agroforestry)

Although various systems of (indigenous) agroforestry have been practiced for ages, quantitative data from them pertaining to wood, food and fodder production has been lacking; and it is only in very recent years that scientific attempts at defining systems and evaluating their productivity have begun. Avenue (alley) cropping which has already been described is just one system where some information is available on biomass productivity of the trees (hedgerows). It is seen (Table 12) that the loppings of the regenerated hedgerows provide 7 t/ha/yr of (oven dry) wood. Assuming that an average person burns about one ton of firewood per year for cooking and heating, this quantity is quite sufficient for an average family farming one hectare.

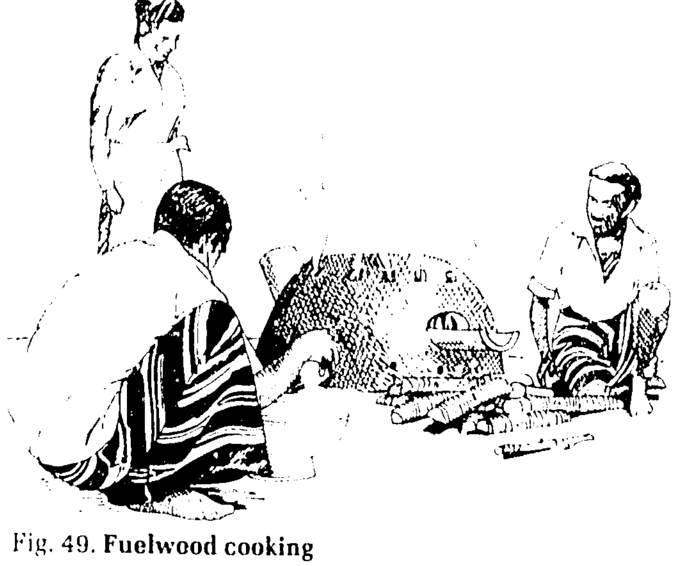


Fig. 49. **Fuelwood cooking**

7.2 High density forestry (HDF)

This technique implies culture, usually under good management conditions, of fast-growing trees at high densities (close spacings), say, of 2 m x 1 m, 1 m x 1 m or even 0.6 m x 0.6 m.

The spacing is usually dependent on the tree species. Very high tree densities demand greater amounts of water and nutrients from the soil environment for maximum biomass productivity than under conventional forest farming. Therefore substantial inputs of nutrients and supplemental irrigation under dry conditions are necessary for optimal tree productivity under HDF. Close tree spacings also encourage vertical growth, and when harvested in short rotations of a few (3-8) years, the better trunks can be marketed at premium prices as posts, rafters or bullies, and the remainder (including branches) as firewood and pulp (Patel 1983).

7.2.1 Tree species

The suitability of species for a particular location would depend on its climate, soil, demand and other socio-economic factors. The main characters of some of the more important species as recommended for three major agroecological regions of the tropics may be obtained from the publication "Firewood crops — shrubs and tree species for energy production" — published by the National Academy of Sciences, Washington, D.C. The reader is referred to this book for more information on species.

8. Fodder Trees

Trees rather than grasslands are the natural endowment of the humid tropics, but tree fodders yet remain a much neglected but high-potential source of animal feed. It is also now the considered view of many tropical pasture specialists that in the humid and semi-humid tropics undue emphasis has been given to pastures for too long, with a consequential neglect of many valuable alternative indigenous forage resources and particularly of fodder trees.

Several important factors augur for greater recourse to fodder trees:
— Productive legume-based pastures yet remain largely an illusion to small farmers at their level of inputs and management.
— Many of the small farmers, especially those in the densely populated areas, do not have sufficient land to allocate exclusively to pasture. Fodder trees are often grown along fences so that additional land is not utilised for the purpose.
— Some of the fodder-yielding trees are in fact multi-purpose trees; eg. the jak tree (**Artocarpus integra**) which is grown essentially for its edible fruit and timber.
— Fodder trees, many of them by virtue of their deep root system, withstand drought better than pastures and are often the main source of forage for animals during prolonged droughts.
— Many of the pasture legumes in the wet tropics are creeping legumes of the type **Pueraria phaseoloides** and **Centrosema pubescens** which are sensitive to over grazing, and unless managed very carefully, disappear rapidly from mixed pastures. By contrast tree legumes (eg. **Leucaena, Gliricidia**) can be grown appropriately spaced in association with grasses and under minimal management, to give highly productive and nutritious (protein-rich) pastures.

In a foregoing Section, under 'Fuelwood Trees', many trees with potential as fodder trees have already been mentioned. Many of the fodder trees are legumes which can fix substantial quantities of nitrogen — a vital attribute. Of these, the two trees that have been most widely researched so far are **Leucaena leucocephala** (Ipil-Ipil) and **Gliricidia maculata (sepium)**.

8.1 Leucaena leucocephala

Some information on this species has already been mentioned. Two plant types, the shrubby 'Hawaiian' type (eg. K341) and the arboreal 'Salvador' type (K 8) are commonly used under intensive management as fodder plants.

One major limitation with **Leucaena** is that its productivity is low in acid soils (say, pH below 5.0) and many tropical soils are acidic. However liming such soils with 1-2 tons of lime/ha together with lime-pelleting of the seed with **Rhizobium** (CB 81) inoculant improved biomass yield by nearly three-fold in an acidic (pH 4.5) soil in Malaysia (Wong **et al.**, 1982).

In biomass productivity studies in Hawaii, the cultivar K 6 (Salvador type) produced 11.7 t forage and 9.6 t of stem per ha/yr at a tree spacing of 15 cm x 155 cm, and the cultivar K 341

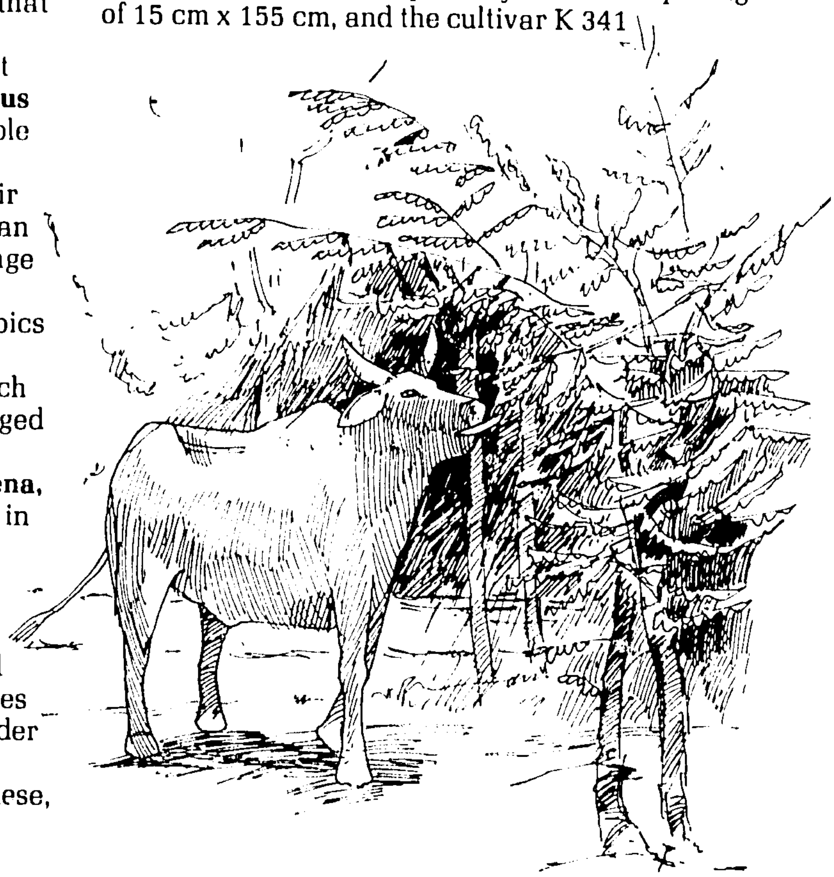


Fig. 50. **Fodder trees being browsed by cattle**

produced 14.0 t forage and 10.1 t/ha/yr stem at a spacing of 30 cm x 155 cm. Usually, however, the Salvador type is known to be, by far the better yielder.

Yields increased with increasing cutting height and frequency: when the height increased from 55 to 155 cm the annual yield of forage fraction increased 28% while the stem fraction increased 240%. It was concluded that dense planting (15 x 50 cm) and cutting at 1 m height were near optimal for forage yield, higher forage to stem ratio, forage quality and flowering behaviour (more flowers were observed with less dense planting). A cutting frequency of about 3 months also appeared desirable (Guevarra **et. al**, 1978).

The above study (Guevarra **et al.**, 1978) also revealed that K 8 and K341 contained about 500 and 600 kg N/ha/yr in the biomass.

The mimosine (toxic amino acid) content in **Leucaena** is about 6.0%. Mimosine can cause loss of hair and tainting of milk etc. when consumed above a certain limit. However, it is known that the toxic effects of mimosine are expressed only when the **Leucaena** content in the diet is consistently above 30%. Therefore, mimosine toxicity will hardly be a problem when the **Leucaena** content in the forage is maintained below 30%.

Wong **et al.**, (1982) observed live weight gains of cattle of 644 and 577 kg/ha/yr grazing **Brachiaria** and native pastures containing 8-20% **Leucaena.** Comparable or slightly higher live weight gains were observed with **Brachiaria** pasture only when fertilized with 300 kg/N/ha/yr. Thus the economic advantage of the **Leucaena** based forage, cannot be overemphasised, considering the high cost of nitrogen fertilizer This is particularly relevant in the context of the small farmer.

8.2 Gliricidia maculata

Gliricidia is a deep-rooted small tree growing to a height of about 10 metres. It grows well up to an elevation of about 1000 metres, and on poor and acidic soils. It is widely grown as a shade tree in tea and as a live fence around home gardens and rice fields (ill-drained conditions) in many Asian countries.

It is thus of interest that **Gliricidia** can thrive under conditions where **Leucaena** cannot.

Gliricidia is usually a poor seed producer where a variety of species is not available as it is often 'seed sterile'. It establishes well from mature cuttings (six months or more old) of 1-2 m length when planted about 15 cm deep during the rainy season. Rooting takes place in about 6 weeks after planting, and nodulation, a further 4-5 weeks later.

Biomass production studies (Chadhokar, 1982) have shown that well grown five year old plants spaced 0.43 x 3.0 m and harvested every three months yielded about 9.5 t/ha leaf dry matter. Yields should be higher with a denser planting. The percentage of leaf matter as well as of total biomass (stem and leaf) decreased when the cutting frequency decreased gradually from 3 to 6 months. Also the crude protein content of leaves decreased from 27.4% to 23.3% and likewise the concentration of phosphorus and calcium.

Gliricidia leaves are succulent but may not be very palatable to animals when first introduced. However, livestock freely eat them when they become accustomed to the taste. In feeding trials with sheep, **Gliricidia** when supplemented (up to 75% on a fresh-weight basis) with poor quality **Brachiaria miliformis** had very marked improvement on both ewes and their lambs, and on the percentage of lambing and weights of lambs at birth (Chadhokar & Kanthiraju, 1980).

Gliricidia when fed with grass from 0 to 100% for one month to Jersey milch cows had no adverse effect on their health or milk production (Chadhokar and Lecamwasam, 1982). However tainting of milk when **Gliricidia** is fed above 50% supplementation level has been reported; but this may be avoided if feeding of this material is stopped a few hours before milking.

A comparison of nutritive value of **Gliricidia** and **Leucaena** (Chadhokar, 1981) revealed that many chemical constituents, (particularly several essential amino acids in proteins) are higher in **Gliricidia.**

Far greater emphasis is required on research into the culture and management of hitherto under-exploited fodder trees and towards optimising their productivity and nutritive value.

Fig. 51. **Mulch formed by Gliricidia maculata**

9. Future Directions

9.1 Continuing research needs

The package of technologies described in this manual — zero and minimum tillage, live mulches, avenue-cropping with fuel-wood and fodder trees — form part of a system of productive land and water use which can achieve sustained agricultural production on rainfed uplands through conservation and re-cycling of natural resources. Such a system is of vital importance to small farmers in the tropics in the current situation of increasing land shortages and spiralling costs of fertilizer, agro-chemicals, fuel and machinery.

Farmers in many parts of the developing world are already using components of the **Conservation Farming** system with very positive results, as for example the **Lamtoro-nisasi** program in Indonesia. However, the system needs first to be **adapted** through research in the various agro-ecological zones of the tropics. Research such as that recently reported from Taipei (Yau-Lun Kuo et al, 1982) is an essential pre-reguisite to its wider use in a particular region, also to identify the most appropriate hedge-tree species and avenue widths for each agro-climatic zone. The various components of the system as well as the overall economic costs and benefits need further testing in different situations to ensure they are adapted to local conditions, and that their financial, management and ecological implications are fully understood.

To do this a co-ordinated programme of multi-disciplinary research and development is needed, through field trials and demonstration plots, established with the full involvement of farmers as well as agricultural research and extension workers, policy makers and planners.

9.2 Extension and Training

Skills in the use of the tools and techniques described in this manual must be developed by both the extension workers and farmers. A different approach to the timing of all farm operations is required. For this purpose, practical training of farmers and extension workers, and appropriate methods of agricultural extension, are needed.

Departments of Agriculture in the countries concerned, and international as well as non-governmental organisations, should provide the mechanism for delivering such extension and training.

It is hoped that this manual will make a modest contribution towards achieving these ends, and will help to make available a sustainable and productive form of land use to the millions of small farmers in the tropical regions of the world.

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