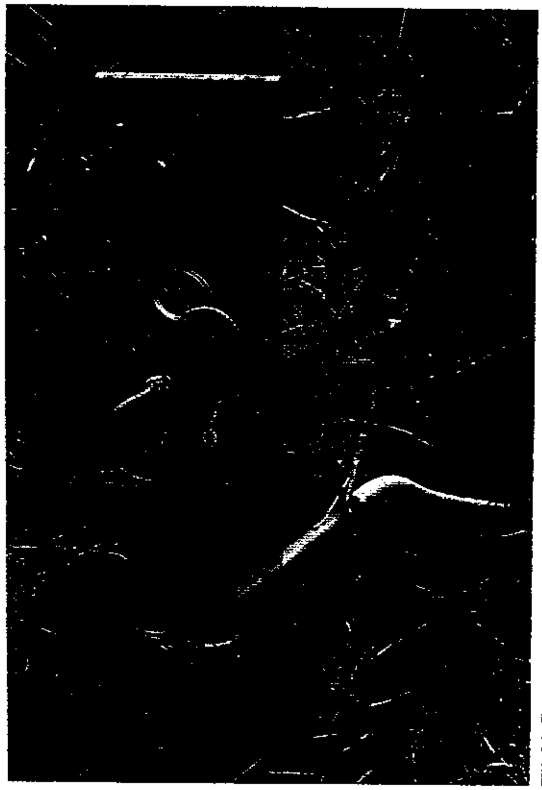
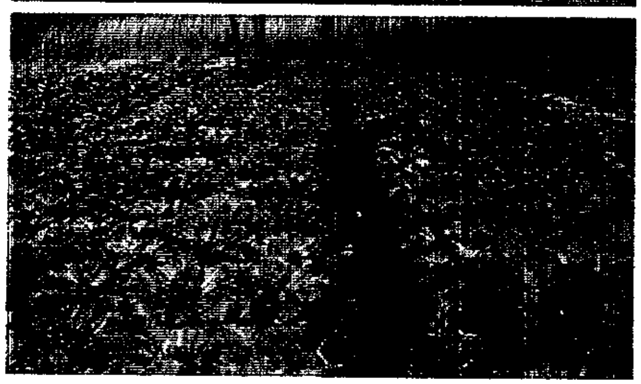
APRIL 2002

MALAWI AGROFORESTRY

TLC Malawi

# FIELD MANUAL FOR TREADLE PUMP IRRIGATION IN MALAWI





I.M. HAYES, Z.D. JERE, W.T. BUNDERSON, G. CORNISH AND M. MLOZI BANDA

TOTAL LANDCARE MALAWI

Publication No. 1

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## ACRONYMS

| | |
|---|---|
| ADMARC....... | Agricultural Marketing and Development Corporation |
| AF/SC.................. | Agroforestry/Soil conservation |
| DOI................. | Department of Irrigation |
| DSI.................. | Dispersed Systematic Interplanting |
| GOM................ | Government of Malawi |
| IDE.................. | International Development Enterprises |
| IFAD................ | International Fund for Agricultural Development |
| MAFE.............. | Malawi Agroforestry Extension |
| MGPPP............ | Malawi-German Plant Protection Project |
| MOAI............. | Ministry of Agriculture and Irrigation |
| MT .................. | Metric tonnes |
| NASFAM......... | National Smallholder Farmer's Association of Malawi |
| NGO................ | Non-governmental organisation |
| PWP................. | Public Works Programme |
| RDP................. | Rural Development Project |
| TLC................. | Total Landcare |
| ToT.................. | Training of Trainers |
| USAID............. | United States Agency for International Development |
| VI.................... | Village Irrigation |
| VIFOR............. | Village Irrigation and Forestry |

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The authors are responsible for the views expressed in this manual, which may not necessarily conform with the funding agencies.

Information has been drawn from a number of sources in preparing this field manual. The following documents were used extensively:

- *Smallholder Irrigation Manual for Schemes with Basin Irrigation. Vol. 1 Extension.* Ministry of Agriculture and Fisheries, Agricultural Education Department, P.O. Box 20401, 2500 EK The Hague, Netherlands. Anonymous, 1988.
- *Field Guide on Irrigated Agriculture for Field Assistants.* Edited by Gez Cornish (HR Wallingford) and Tom Brabben (IPTRID). International Programme for Technology and Research in Irrigation and Drainage Capacity Building Report No. 1. April 2001.
- *Taguta Self-help Garden Project Implementation Manual.* Agricultural & Rural Development Authority, Provincial Planning Unit, Masvingo, Zimbabwe and GTZ, Postfach 5180, Dag-Hammarskjold-Weg 1+2, D 6236 Eschborn, Germany. Anonymous, no date.

- *Treadle pump for irrigation in Africa.* Kay, M and Brabben, M. Knowledge Synthesis Report No. 1. International Programme for Technology and Research in Irrigation and Drainage, FAO, Rome. ISSN 1607-6613.
- *Training Manual for Treadle Pump Irrigation in Malawi.* Department of Irrigation, Ministry of Agriculture and Irrigation, Lilongwe, Malawi. Anonymous, July 1999.
- *Improved Vegetable Production Practices for Small Holder Farmers in Zambia.* Donald S. Mingochi and Sina W.S. Luchen. Small Holder Irrigation and Water Use Programme (SIWUP) IFAD Loan No. 377-ZM. Lusaka, Zambia. August 1999.
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The initial technical draft was prepared by Gez Cornish of HR Wallingford, United Kingdom under contract to the Malawi Agroforestry Extension Project. Subsequent additions, editing, design and layout were done by TLC Malawi and Malawi Agroforestry Extension Project staff, with comments from Public Works Programme, the Irrigation Department, Ministry of Agriculture and Irrigation, and farmers. The opinions expressed herein are those of the authors and do not necessarily reflect the views of the EU or USAID.

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*Other key individuals involved in producing this manual include:*

| | |
|---|---|
| **Assistance in Editing and Design:** | D. Hardesty and D.L. Whaley |
| **Illustrations:** | D. Chimutu |
| **Photographs:** | I.M. Hayes, W.T. Bunderson and Z.D. Jere |
| **Manuscript Review:** | C. Mzembe, J. Chisenga, T. Mahoney, P. Mautanga, and M. Kapalamula |

## Introduction

Improving household food security is one of the primary goals of the Government of Malawi (GOM). In previous years, the major impetus toward this objective has been to boost rainfed maize yields by increasing smallholder fertiliser use. This has been manifested in the Starter Pack Programme and its more recent reincarnation, the Targeted Inputs Programme.

It has become increasingly evident that reliance on rainfed agriculture is not sufficient to attain food security, particularly in view of the erratic rainfall pattern emerging over the last decade and falling crop yields from little or no use of fertilisers. Thus, attention has turned to the potential role that irrigation can play in supplementing rainfed food production.

The Department of Irrigation (DOI) of the Ministry of Agriculture and Irrigation (MOAI) examined a range of irrigation technologies, concluding in 1999 that the treadle pump is the appropriate technology for smallholder farmers. The DOI then embarked on an ambitious programme to promote the use of the treadle pump by smallholder farmers.

After investigating a range of local and externally-sourced treadle pumps, the DOI, with funding from the International Fund for Agricultural Development (IFAD) Smallholder Food Security Project, arranged for the purchase of 10,000 Advaith treadle pumps from India.

## Distribution, Marketing and Extension

The Agricultural Marketing and Development Corporation (ADMARC) and National Smallholder Farmer's Association (NASFAM) were contracted by the DOI to undertake the national distribution and marketing of the treadle pumps. The pumps were issued to ADMARC and NASFAM under a two-year loan with the sale price set by the DOI. IFAD funding permitted the pumps to be priced at a subsidised level, including a small administration charge.

The initial price for the pump with 25 m delivery pipe, 5 m suction hose, toolkit and spare parts pack, was about MK 3,500 (USD 65) in early 2000. In reponse to low sales the DOI reduced the price to MK 2,000 (USD 37) later in the year. This dramatically increased sales.

Unfortunately, the distribution and marketing strategy was not accompanied by a matching treadle pump extension effort. Few government extension agents were trained in improved treadle pump irrigation techniques and it soon became apparent that many farmers who purchased pumps had little idea of how to use and maintain them, or how to irrigate crops with them in a productive manner.

Without a complimentary and comprehensive field extension effort, the impact of smallholder pump uptake on irrigated maize production and food security will be limited.

In response to this, a number of field programmes have been initiated recently, two of which are described below.

## THE VILLAGE IRRIGATION AND FORESTRY PROGRAMME

The Village Irrigation and Forestry (VIFOR) Programme commenced in July 1999 under a partnership agreement between the GOM/EC Micro-Projects Programme and the Malawi Agroforestry Extension (MAFE) Project. Total Landcare (TLC) Malawi, a locally registered NGO, took over responsibility for the implementation of VIFOR from 1st October, 2000.

VIFOR had two components, forestry and irrigation, and was designed to serve as the pilot for the forestry and irrigation components of the Public Works Programme (PWP), funded by the European Development Fund, which started in April 2001.

### VIFOR Irrigation Objective

The primary objective of the VIFOR irrigation component, which commenced in June 2000, was to support groups of farmers in Lilongwe West interested and willing to invest in irrigated dimba crop production using treadle pumps for:

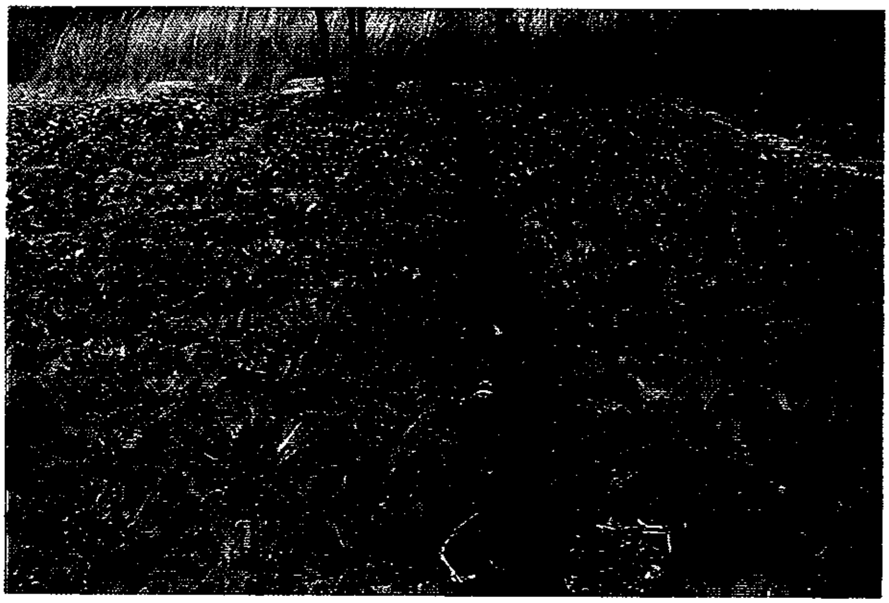
- increased incomes
- improved household food security
- improved household nutrition.

A secondary objective was to design and test an extension method suitable for the treadle pump technology under Malawian smallholder conditions. This was in response to the lack of a well-established, systematic extension approach.



MALAWI AGROFORESTRY

*Tradional dimba vegetable cropping*



*Improved dimba vegetable cropping using the treadle pump technology*

*The Advaith treadle pump with suction and delivery hoses attached*

*Recipients of a VIFOR treadle pump input package*

**Table 1: Sample Treadle Pump/Input Pack Repayment Schedule**

| | | Cash price | 6 months credit price | 12 months credit price |
|---|---|---|---|---|
| TPump, spare parts pack, 5 m suction, 25 m delivery pipe, inputs pack | **Initial deposit** | | MK 800 | MK 800 |
| | **Remaining Balance** | | MK 3,000 | MK 3,600 |
| | **Total Price** | MK 3,500 | MK 3,800 | MK 4,400 |

## VIFOR Irrigation Approach

The VIFOR extension method combined elements of group and individual approaches, with technical support to farmers over two seasons. It included a credit scheme to kick-start use of the treadle pump among resource-poor farmers (see **Table 1**).

Extension and training were conducted on a group basis, although the credit scheme operated on an individual basis. The individual element is important as the treadle pump technology lends itself to farmers operating independently on a commercial basis. The group component of extension and training is necessary to improve the efficiency of extension and outreach.

The credit scheme involved the issue of a treadle pump with accessories and a small improved crop inputs package of seed and fertiliser. Participating farmers were required to meet a range of criteria including:

- access to a dimba garden (a garden located in a low-lying area with shallow water table - known as dambos)
- access to a reliable water source e.g. shallow well, river
- recent active experience with dry season cultivation
- payment of a cash deposit
- member of a Village Irrigation Club.

The payment of a cash deposit before participation was designed to encourage commitment from the farmer. Credit repayments were scheduled over a maximum period of 12 months at a low interest rate, with earlier repayment encouraged through reduced interest charges. The repayment schedule is detailed in **Table 1**. Failure to repay in full after a 12 month period resulted in withdrawal of the pump and accessories with no money refunded to the farmer.

In the first season VIFOR provided training on group formation and dynamics culminating in the formation of Village Irrigation (VI) Clubs headed by an Irrigation Committee. All members of the club were required to sign a Village Irrigation Agreement which outlined the roles and responsibilities of VIFOR, the club members and the committee (see **Table 2**).

VIFOR then supplied the credit input package followed by practical, on-site farmer training on treadle pump use and maintenance, irrigation basin plot layout, compost-making techniques, improved vegetable nursery management, cultivation of horticultural crops, and implementation of complementary agroforestry and soil conservation practices (see **CHAPTER 6: COMPOSTING, AGROFORESTRY AND SOIL CONSERVATION PRACTICES**). Supervision of all irrigation activities was carried out up to, and including, crop harvest, followed by limited assistance in the identification of crop markets.

The responsibilities of the Irrigation Committee of each VI Club were as follows:

- liaise between VIFOR technicians and the VI Club
- ensure that all VI Club members sign and follow agreements laid out in the Village Irrigation Agreement
- encourage all VI Club members to follow recommended irrigation, agroforestry and soil conservation practices
- ensure that all VI Club members keep up with their pump repayments and withdrawing pumps from those that failed to repay within 12 months.

In the second season, VIFOR continued to provide technical support in irrigated horticultural crop production to VI Club members who met the following criteria:

- fully repaid their treadle pump loan
- complied with all VIFOR Village Irrigation Agreement conditions

## Table 2: Sample Village Irrigation Agreement Form

**All signed-up members of ................................... Village Irrigation Club, agree to:**

1. Elect an Irrigation Committee from the Club membership consisting of a Chairperson, Treasurer, Secretary and two other members willing to demonstrate and assist other farmers
2. Repay all moneys owed on the loaned treadle pumps and inputs package to the implementing agency within 12 months of receipt as per the schedule in **Table 1**:
   (a) Minimum repayment at any one time is MK500
   (b) Any treadle pump not fully paid for after 6 months automatically falls under the 12-month option with increased price
3. Forfeit any treadle pump NOT paid for within the maximum 12 months to the implementing agency through the Irrigation Committee, with no money back
4. Accept the horticultural inputs package
5. Follow the recommendations laid out in the Irrigation Manual regarding plot layout, crop husbandry methods and agroforestry and soil conservation practices
6. Complete plot layout in dimba garden within 6 weeks of recieving the pump.

**In Season 1 the implementing agency agrees to:**

1. Supply one treadle pump and crop inputs package to each Club member who meets these criteria:
   - Access to dimba garden with a reliable water source; recent active experience with dry season cultivation; payment of treadle pump deposit; member of the VI Club
2. Train Club members on group formation and dynamics, treadle pump use and maintenance, irrigation plot layout, cultivation of horticultural crops, selected agroforestry and soil conservation practices

**In Season 2,** for those Clubs with a minimum of 5 farmers per VI Club who have successfully accomplished the following in Season 1:

- Fully repaid their treadle pump; followed Irrigation Manual recommendations; complied with all Village Irrigation Agreement conditions; ongoing productive irrigated horticultural production.

**The implementing agency agrees to:**

1. Establish an Irrigation Investment Fund whose value will be determined by:
   - the number of elegible Season 2 farmers in the programme
   - the quality of adoption of irrigation, horticultural and conservation practices by all VI Club members in Season 1
2. Provide training for the Irrigation Committee in fund management
3. Continue with technical support in irrigated horticultural crop production.

- currently engaged in productive irrigated horticultural production
- followed recommended irrigation, agroforestry and soil conservation practices.

In addition, VIFOR provided an Investment Fund at the start of the second irrigation season (March/April) to those club members that met the above criteria. The purpose of the grant, which consisted of a small inputs package and a small amount of cash, was to enable the continuity and expansion of irrigated crop production.

The size of the grant was perfomânce related and depended on a combination of group and individual factors including:

- the number of successful Season 2 farmers in the VI Club
- the quality of irrigation, horticultural and conservation practices adopted by individual club members in the first season.

The results of the VIFOR programme were excellent both in terms of farmer implementation of the new technology and repayment of the treadle pump loans.

## THE PUBLIC WORKS PROGRAMME

VIFOR was subsumed by the Public Works Programme in July 2001. The overall objective of the PWP is poverty alleviation to be achieved through three components viz. roads, forestry and irrigation. The PWP will run for 3 years and will cover 5 districts in the Central Region including Lilongwe, Mchinji, Dowa, Ntchisi and Kasungu.

### PWP Irrigation Component

The irrigation activities started under the VIFOR programme in the 2001 dry season were transferred to the PWP Irrigation Component, mid-season. The irrigation component will be targeting 275 villages with 1,880 farmers to irrigate up to 450 ha of land with treadle pumps over the 3 year project life.

## LESSONS LEARNED

The following lessons were learned during the implementation of the VIFOR and PWP irrigation components:

- **Village sensitisation** - early and thorough farmer sensitisation will minimise participation problems.

- **Farmer targeting** - the best farmers to target are those already engaged in market-based dimba cultivation. Others can join as they learn and develop an interest.

- **Commitment to participate** - there should be a signed agreement between the service provider and the recipient covering all aspects of required performance in the field with loan repayments and sanctions clearly spelled out.

- **Credit deposit** - a deposit should be paid before participating in the irrigation credit scheme to minimise lack of commitment.

- **Individual treadle pump credit issue** - a pump should only be issued to one household to minimise ownership conflicts.

- **Crop input pack** - a pack of improved crop seed and fertiliser is a crucial element of the credit scheme as it allows farmers to experience that the treadle pump technology works best in conjunction with modern inputs and organic manure.

- **Household credit approach** - the decision to participate in the treadle pump loan scheme should be made by both spouses and not just the household head.

- **Early start** - it is essential to start the irrigation programme at the beginning of the dry season (April/May) to maximise the available irrigation period and minimise competition with traditional dimba cultivation practices.

- **Plot preparation** - the irrigated plot should be prepared within 6 weeks of the pump delivery. If not, the pump should be withdrawn.

- **Crop timing** - crop timing should consider the period to which the crop is most suited (e.g. cabbage in April/May) and when the crop fetches a good market price.

- **Extension materials** - a comprehensive and quality set of leaflets and an integrated treadle pump field manual are a prerequisite to facilitate staff and farmer training and field implementation.

- **Staff and farmer training/ supervision** - good results depend on well trained, motivated and resourced staff providing hands-on training to farmers in all aspects of treadle pump irrigation, followed by intensive supervision.

## THE WAY FORWARD

Recommendations are outlined below based on the lessons learned from two seasons of intensive treadle pump extension. If followed, the potential impact of treadle pump uptake on national food security will be maximised.

The **first** recommendation is the development of integrated, quality extension and training materials, targeted at extension staff and farmers. These should include:

- **Field manual** in English for extension staff as a reference guide - covering all related topics from the extension approach to using and maintaining the pump, plot layout, improved nursery and crop husbandry techniques, composting methods, irrigation requirements and selected agroforestry and soil conservation practices.
- **Training kit** for trainers - a set of overhead transparencies drawn from the manual that cover the key training points on each subject.
- **Leaflets** in Chichewa for farmers - covering the same ground as the manual with a pictorial bias.

The **second** recommendation is a national treadle pump irrigation training-of-trainers (ToT) plan to be drawn up under the auspices of the DOI.

The objective of the ToT course would be to maximise the number of extension agents and farmers effectively trained in treadle pump technology in the shortest possible time. This will be achieved by ensuring that each participant in the ToT course subsequently trains other extension agents who will in turn train farmers.

The target group for the ToT course should include at least one government extension officer from each Rural Development Project (RDP) or district and one participant from each non-governmental organisation (NGO) or project with an interest in treadle pump extension.

The ToT training will be a mix of classroom lectures and field practicals with participants expected to pass an examination at the end of the course. It will include the following topics:

- extension approach
- credit options
- treadle pump use and maintenance
- irrigation plot layout
- improved vegetable nursery practices
- composting methods
- horticultural crop husbandry and water management
- selected agroforestry and soil conservation practices.

The **third** element is a national treadle pump field extension effort. Armed with the requisite extension skills and training materials, the onus will then be on government, through the MOAI, led by the DOI, and the NGO community, to pass on this knowledge to as many farmers as possible who already have, or plan to have, treadle pumps. These efforts should be complemented by investigating possibilities of new credit-based programmes to reach farmers who are not in a financial position to purchase their own pumps.

The **fourth** requirement to enable a national impact are efficient input and output markets. Farmers need access to a reliable input supply both for crops (seed, fertiliser) and for treadle pumps (pumps, spares). At the other end of the chain, the importance of access to a good market for the crops grown cannot be overstated.

## ORGANISATION OF THE FIELD MANUAL

This manual outlines how to apply treadle pump irrigation technology in a way that will yield its full potential to improve smallholder farmer food security and income levels. The manual is arranged as follows:

### CHAPTER 2: THE TREADLE PUMP

Chapter 2 introduces the treadle pump, discussing water source and site selection for treadle pump irrigation, and how to set up, use and maintain the pump.

### CHAPTER 3: BASIN IRRIGATION

This chapter explains how to establish and manage the basin plot layout recommended for use with treadle pump.

### CHAPTER 4: VEGETABLE NURSERY MANAGEMENT

This chapter explains how to manage a vegetable nursery to produce strong, healthy seedlings.

### CHAPTER 5: IRRIGATION AND CROP HUSBANDRY

This chapter examines how to increase the quality and yield of various crops by applying the correct amount of water at the right time, and by utilising recommended crop husbandry practices.

### CHAPTER 6: CROP SPECIFIC DATA

This chapter contains key information on climate, plant spacing, fertilisation and pest and disease management for a range of common irrigated crops.

### CHAPTER 7: COMPOSTING, AGROFORESTRY AND SOIL CONSERVATION PRACTICES

This chapter covers a range of composting, agroforestry and soil conservation techniques that are compatible with treadle pump irrigation.

## INTRODUCTION

The treadle pump (**Figure 1**) is a portable, simple, low-cost, manually operated water pump suitable for drawing water from shallow wells, streams or dams where the water surface is less than 4 m below the ground-surface.

**Note:** The treadle pump discussed in this manual is the Advaith pump unless noted otherwise.

The pump comprises two cylinders and pistons positioned side by side and a rope, which passes over a pulley, that joins the two pistons together so that when one piston is being pushed down, the other is coming up. Each piston is connected to a wooden treadle. The operator stands upright on the treadles and presses them down alternately in a steady motion, similar to pressing the pedals on a bicycle.

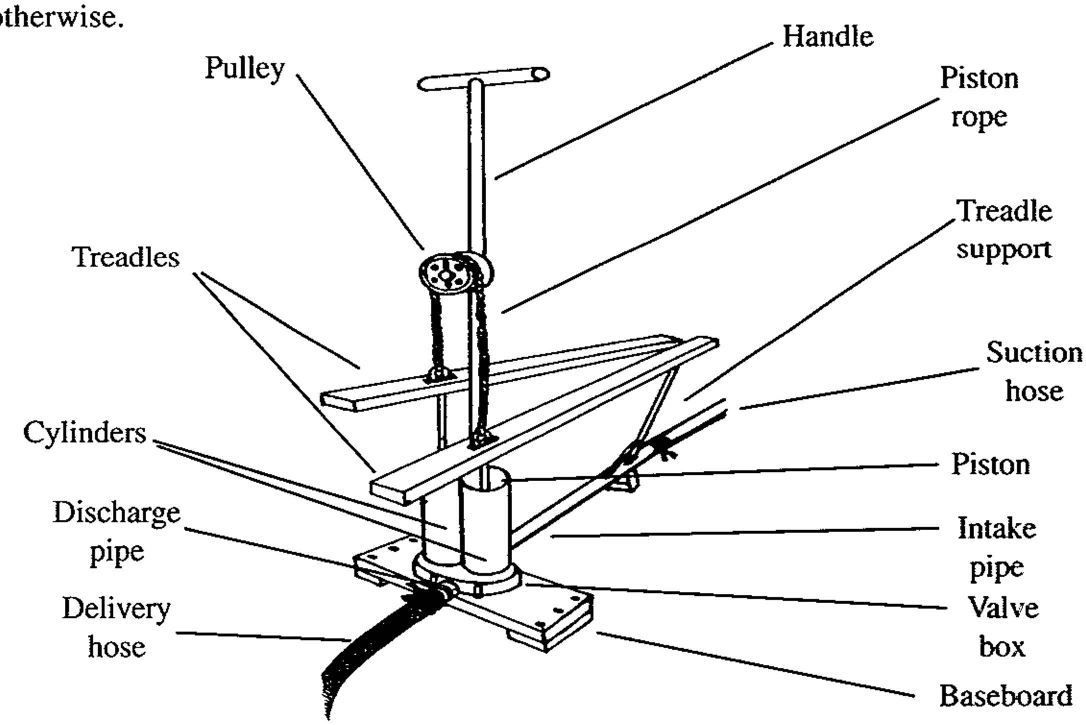



**Figure 1: Treadle pump schematic**

It can be operated by one person, or two people if they stand facing each other on the treadles. Two people increase the output of the pump and the operators will not tire as quickly.

The pump is supplied with 5 m of 50 mm diameter rigid suction hose and 25 m of 50 mm diameter "layflat" delivery hose. The suction hose connects the pump to the water source. The delivery hose is laid out to convey the water to the highest part of the field from where it is channeled to flow by gravity to irrigate the crops.

The pump works by creating a vacuum in the cylinder of the piston that is being raised. This sucks water into the pump through the intake pipe. On the downstroke of the piston, the water is discharged through the discharge pipe.

## SOME COMMON QUESTIONS AND ANSWERS

1. How much water can I pump with a treadle pump?

The amount of water pumped will depend on:

*Treadle pump operated by two farmers*

- the strength, weight and stamina of the operator
- the distance of the water below the pump intake
- the height the water is raised from the pump to the end of the delivery pipe
- the duration of pumping.

These numbers will differ in each situation but on average the pump will deliver about 1 litre/second (l/s) when operated by a single adult. The volume of water pumped will then depend on the length of time the pump is operating. An operator cannot pump continuously all day. Rather, the operator may pump for 20 or 30 minutes, rest, and then pump again.

If the total daily pumping time is 5 hours and the average rate of flow is 1 l/s, the volume of water pumped in one day of irrigation will be approximately 18,000 litres, equivalent to 900 buckets of water.

2. How much land can I irrigate with a treadle pump?

The area that can be irrigated is determined by the amount of water that can be pumped and the water requirement of the crop at the time of peak demand. If the farmer is willing to pump about 5 hours every day, and the water source is adequate, 18,000 litres per day is available.

The peak water requirement for irrigated crops grown in Malawi is about 5.5 mm/day in October. At this time, 18,000 litres is enough water to maintain a crop on approximately 0.3 ha.

3. How much does the treadle pump cost?

The price of the pump and its accessories (suction and delivery hose, spare parts and spanners) will vary between suppliers and over time of purchase. ADMARC has been selling a subsidised pump and accessories for a cash price of MK2,000 (US$ 30). The realistic open market price is about US$ 125.

4. Where can I buy a treadle pump?

The treadle pumps in Malawi at present have been imported from India (Advaith pumps) and distributed through ADMARC and NASFAM. Other options are the Shoroma pump from Zimbabwe and the International Development Enterprises (IDE) pump from Zambia. The former is more robust and powerful than the Advaith but more expensive at about US$ 145 without any accessories. Although cheaper than the Advaith pump, the IDE pump does not meet the same quality standards principally because it is not galvanised.

## SELECTING A WATER SOURCE AND SITE FOR TREADLE PUMP IRRIGATION

The obvious place to look for sites where treadle pump irrigation can be developed is in dambos and along stream banks where farmers are already carrying out some dimba cultivation, usually irrigating with watering cans. These sites have the following advantages:

- a water source is available, although its reliability throughout the dry season must be checked
- the farmers have some experience of growing vegetable crops although their knowledge of the crops is often very weak so provision of information on better cropping practices will be important
- farmers are likely to be already selling some of their vegetable produce although improved marketing will be important if production is increased through introduction of the treadle pump.

Dambos where a small dam has been constructed to retain water will normally offer a better water supply in shallow wells downstream of the dam. This is particularly true late in the dry season.

**Note:** Streambank and dambo protection measures such as planting trees and vetiver grass are recommended to avoid erosion and run-off from cultivating these areas (see **CHAPTER 7: COMPOSTING, AGROFORESTRY AND SOIL CONSERVATION PRACTICES**) .

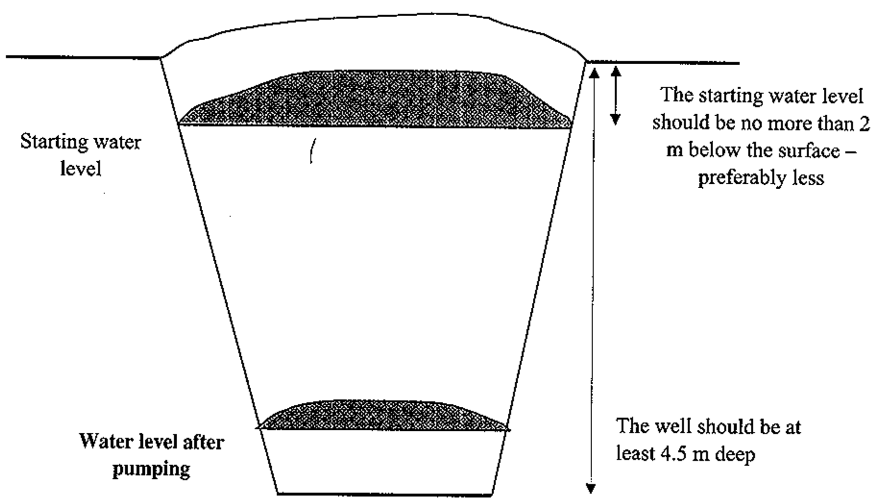
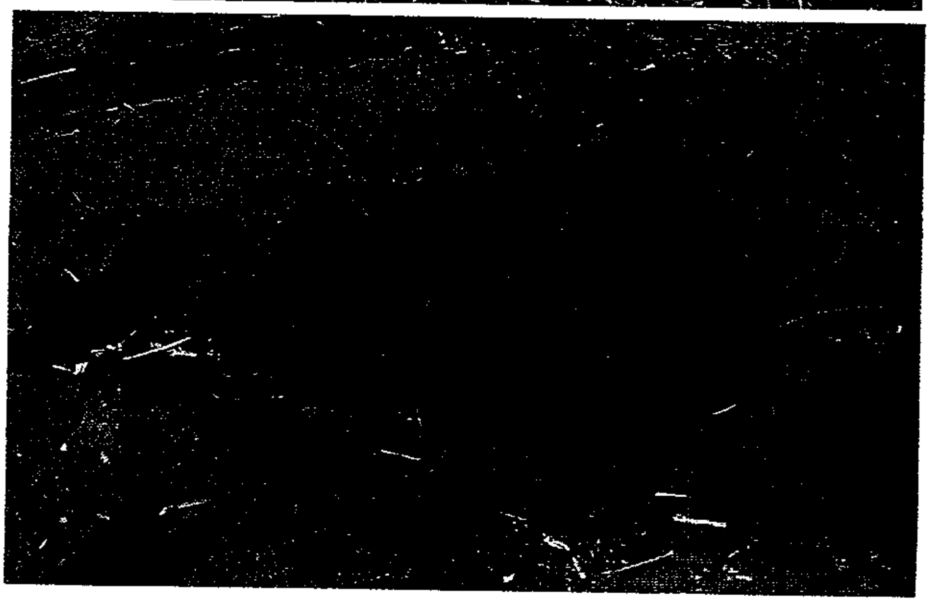
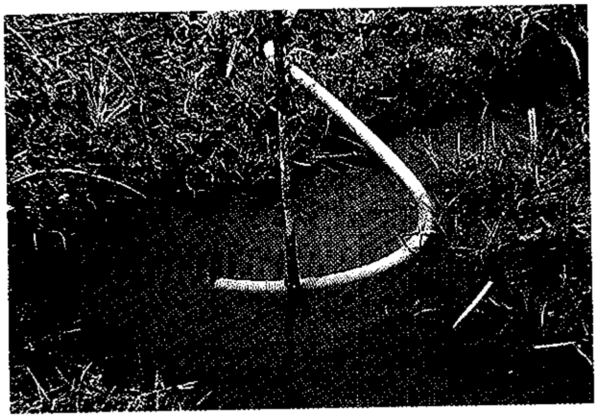



**Figure 2: Dimensions of a shallow well suitable for treadle pumping**

*Farmer transporting a treadle pump to the dimba garden*



*Shallow well in the process of being cleaned and deepened*



*Suction hose secured underwater to a stick in a small stream*

*Treadle pump delivery hose at full flow*

### The Water Source

The treadle pump can raise water from a maximum depth of about 4 m (6 m for the Shoroma pump) and is therefore suited to pumping from shallow wells in dambos or from streams, rivers and dams. Ideally the water surface should not be more than 2 m below ground level before pumping begins. As the water is pumped, the level in the well will drop. The well should be deep enough to allow the water surface to drop to at least 4 m below the ground level with the end of the suction pipe still under water (see **Figure 2**).

It is best to select wells in an area where farmers report that water levels do not fall greatly even after prolonged use. Ask the farmer whether the water source is reliable and continues to provide water all through the dry season.

Existing wells used for watering can or bucket irrigation are often small and very shallow. The bottom may also be covered with a deep layer of soft mud and rotting vegetation. This must be removed as it can easily be sucked into the treadle pump and clog the valve box. The well should be deepened and cleaned when the water level has been reduced by pumping. Care should be taken when deepening a well to avoid the sides collapsing.

If a single well does run dry when using a treadle pump, even after it has been deepened, the farmer can use several wells for a single plot. These should be as far apart as possible with the farmer moving the pump as each well runs dry. The farmer can return to a dry well following a suitable time lapse has allowed for recharging from the water table.

**Note:** Do not encourage farmers to invest in treadle pumps if a reliable water source is not available.

A stream or small river that flows throughout the year will provide a more reliable water source for the treadle pump but a strip of uncultivated land at least 5 m wide must always be left between the stream and the irrigated plot. There should be good, clear access to the side of the well or stream bank so the pump can be positioned close to the water and easily primed.

### The Field Site

The treadle pump irrigation technique recommended in this manual (see **CHAPTER 3: BASIN IRRIGATION**) relies on spreading the water into flat, level basins by gravity-fed channels. The best sites are therefore those that have a gentle and uniform slope where basins can easily be formed without having to move a lot of soil.

The topsoil should be relatively deep so that leveling can take place without exposing the sub-soil. Ongoing use of the site for dimba cultivation may indicate that the soils are relatively fertile and will not limit production because of important nutrient deficiencies.

If possible, avoid sites where the soil is very sandy to minimise water losses along the channels.

## SETTING UP AND USING THE TREADLE PUMP

### First Assembly, Checking and Greasing

#### Assembly

Assemble treadle pumps purchased in broken down form with reference to the Assembly and Operating Manual supplied with the pump. Two important points to note are:

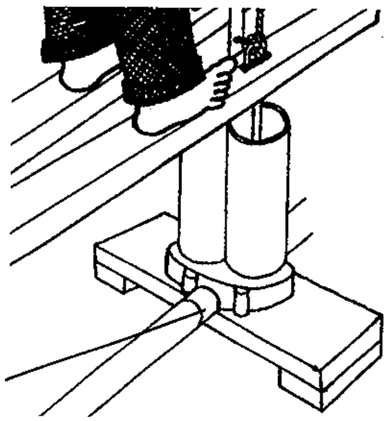



**Figure 3: Ensure the joint between the intake pipe and valve box is airtight**

1. the joint between the metal intake pipe and the valve box must be made airtight (see **Figure 3**). Apply Teflon thread tape (plumber's tape) on the intake pipe's thread. Tie the joint with a rubber strip if it is difficult to seal the joint using only thread tape, particularly on pumps with badly cut/damaged thread.
2. before delivery to farmers test and grease all pumps, and mark the intake pipe with an arrow showing the direction of water flow.

## Table 3: Treadle Pump Accessories and Spares

| Quantity | Description |
|---|---|
| 1 | Assembly and operating manual |
| | ***Pipes and fittings*** |
| 5 m | 50 mm suction hose |
| 25 m | 50 mm layflat delivery hose |
| 2 | 50 mm hose clip (jubilee clip) |
| | ***Tools and spares*** |
| 1 | 11 x 10 mm box spanner |
| 1 | 18 x 19 mm open ended spanner |
| 1 | 12 x 13 mm open ended spanner |
| 1 | 11 x 10 mm open ended spanner |
| 2 | Rubber piston cups |
| 2 | Rubber valve flaps |
| 1 | Polypropylene piston connecting rope |

### Accessories and Spares

At time of purchase ensure that the accessories and spares listed in **Table 3** are supplied with each pump. Make sure that the full package of pump, accessories and spares is then delivered to the farmer.

The following items are not supplied with the pump but are needed for effective assembly and operation in the field:

- one flat bladed screwdriver for fitting and removing jubilee clips
- 2 or 3 strips of rubber inner tube, about 30 mm wide x 500 mm long for sealing the suction and delivery hose connections
- one 500 ml tub of motor grease for lubrication
- 1 bucket or other container to lift water for priming the pump.

### Greasing

For effective operation, the rubber seals on the pistons must form an airtight seal against the metal cylinder walls. For this reason the seals fit tightly into the

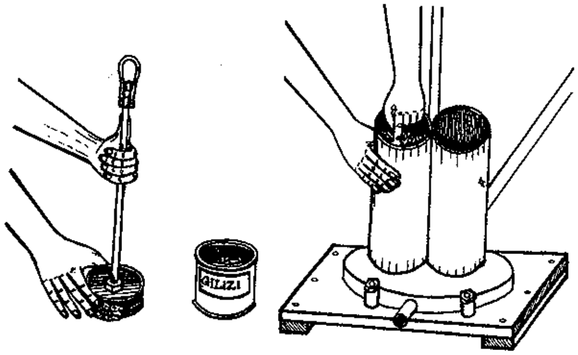


**Figure 4: Grease the inside of the cylinders and the piston seals**

cylinders. Without grease on the rubber cups and inside of the cylinders, the friction between the two surfaces will be very high, making the pump difficult to operate. Grease or vaseline must therefore be applied to

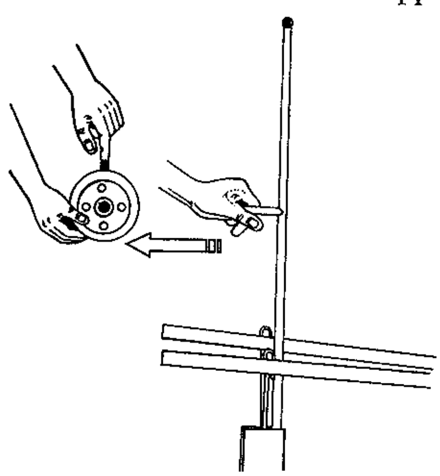


**Figure 5: Grease the pulley**

these surfaces before using the pump (see **Figure 4**). Also apply grease to the pin on which the pulley rotates and to the rim of the pulley to allow the rope to move without hindrance (see **Figure 5**).

**Routine Field Assembly**

For effective pump operation the following steps are required:

**Step 1** - Position the pump as close to the water source as possible on firm and level ground. Ensure that the pump is set up so that when the suction hose is connected it lies in a single, smooth curve between the intake pipe and the water source.

**Step 2** - If removed, replace and fasten the handle and pulley assembly. Replace the pulley split pin and tighten the handle fastening bolt using the 13 mm spanner. Check that the pulley is lined up correctly so that the rope connecting the pistons can pass smoothly over it.

**Step 3** - Loosen a jubilee clip and slide it over one end of the suction hose. Then slide the suction hose over the end of the intake pipe and tighten the jubilee clip with a screwdriver (see **Figure 6**). It is **very important** to make this connection between

**Figure 6: Tighten the jubilee clip with a screwdriver**

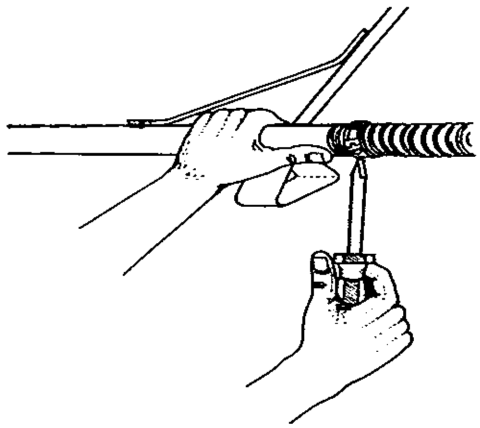
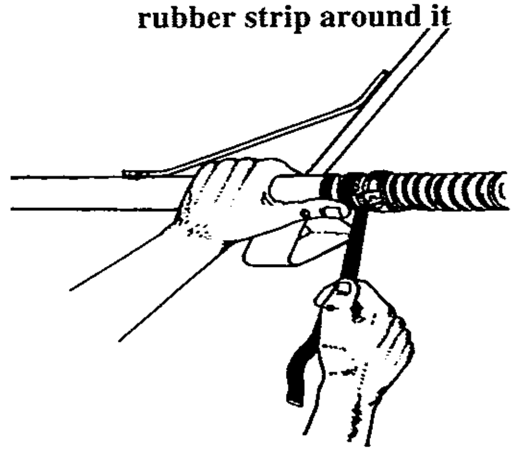


**Figure 7: Seal the joint by wrapping a rubber strip around it**



the suction hose and the pump completely airtight. Wrap a strip of rubber inner tube tightly around the joint to completely seal this connection (see **Figure 7**).

**Step 4** - Connect the layflat delivery hose to the discharge pipe using a jubilee clip and support this with a rubber strip even though an airtight joint is not essential (see **Figure 8**).

**Step 5** - Roll out the full length of the layflat delivery hose and ensure that there are no twists or sharp kinks in it. The hose should deliver water from the pump to the highest point of the irrigated plot (see **Figure 9**). Be careful not to puncture the hose on sharp objects such as branches or stones. Avoid dragging the hose over the ground.

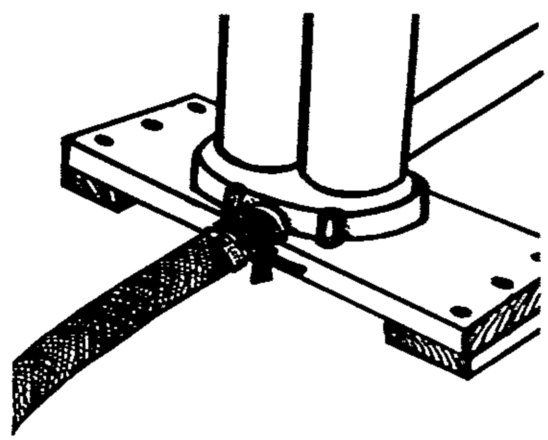
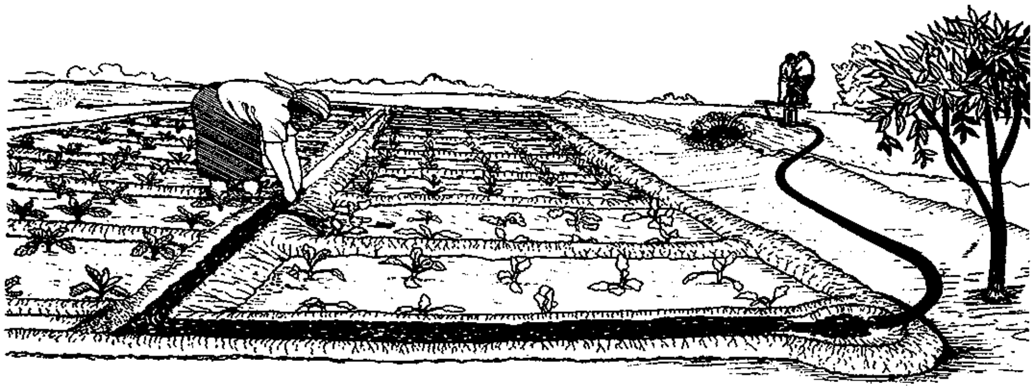


**Figure 8: Secure the delivery hose to the discharge pipe**

**Figure 9: Example of treadle pump positioning in relation to the plot**



**Step 6** - Check that the rope connecting the pistons is the correct length so that the pistons can move the full length of the cylinders, without hitting the bottom, for maximum pumping efficiency. Set the correct rope length as follows (see **Figure 10**):

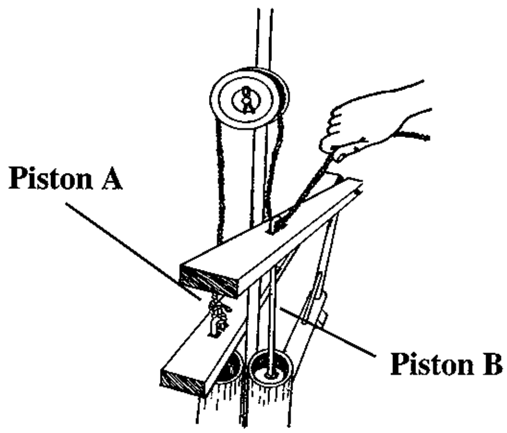


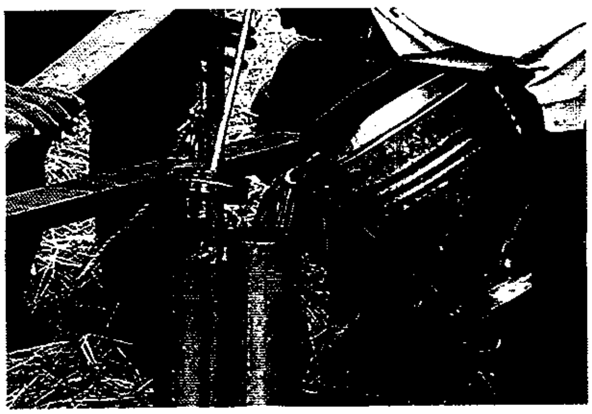

**Figure 10: Adjusting the rope to the correct length**

1. Raise **Piston B** until it is level with the top of its cylinder
2. Untie the rope from **Piston B**
3. Push **Piston A** to the bottom of its cylinder
4. Pass the rope over the pulley and raise **Piston A** slightly off the cylinder bottom.
5. Make sure the rope is taut and then re-tie the loose end to **Piston B**.

### Priming the Pump

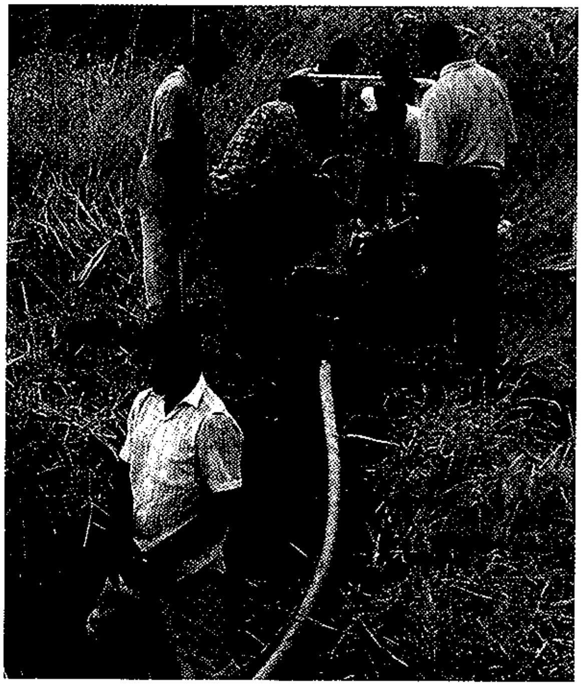
The pump may not work well if there is air in the suction hose. The air will expand and contract in the pipe as the pump is operated but there will be no movement of water. To get the pump working properly,

*Suction hose connected to the intake pipe sealed with a jubilee clip and rubber strip to make it airtight*



*Fill the cylinder with water to start the priming process*

*Priming without a footvalve*



most of the air must be removed from the suction hose and replaced by water. This is called "priming" the pump and can be done in a number of ways.

**Self priming**

If the following conditions are met:

- no air leaks where the suction hose is connected to the pump or where the intake pipe joins the valve box,
- the pistons create a good seal in the cylinders, and
- the suction lift is not great.

It should be possible to place the free end of the suction hose in the water source and prime the pump with a rapid treadling action. This action alone will draw the air out of the suction pipe and replace it with water.

In the absence of the above conditions, one of the following methods will be required.

**Manual priming without a foot-valve**

This method requires 2 people working together as follows (see **Figures 11 & 12**):

1. **Farmer A** pulls one of the pistons completely out of its cylinder ready to pour water from a bucket or can into the top of the cylinder so that it can pass into the suction hose.
2. To stop the water passing into the layflat delivery hose, **Farmer A** kinks that pipe and stands on it.



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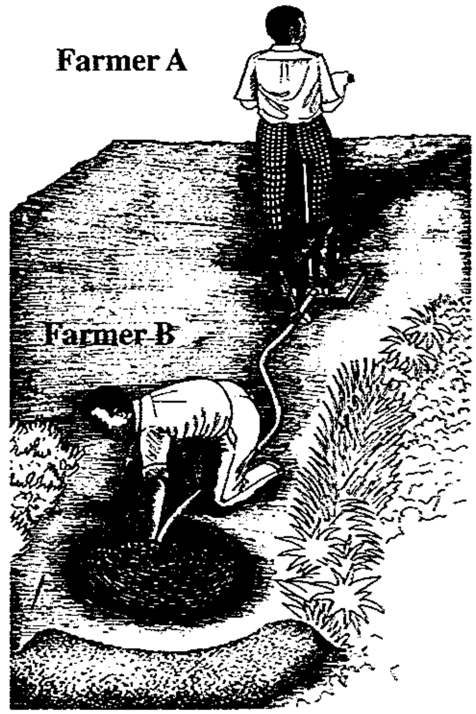
**Figure 11: Filling the cylinder while holding the end of the suction hose up**


3. **Farmer B** squats near the water source holding up the far end of the suction hose so that it is at the same level or slightly higher than the valve box.

4. **Farmer A** pours water into the top of the open cylinder. It will pass along the suction hose pushing the air out in front of it.

**Figure 12: Treadling rapidly after placing the end of the suction hose under water**




5. **Farmer A** continues adding water until the suction hose is full, checking that there are no large bubbles of air trapped in the hose.

6. **Farmer A** then puts the piston back into the top of the cylinder taking care not to damage the edge of the rubber seals. **Farmer B** keeps the suction hose

elevated while this is done. A little water will spill out as the piston is replaced in its cylinder.

7. If the water is close to the ground surface, **Farmer B** now puts his hand over the end of the suction hose to prevent loss of water then submerges the end of the hose below the water. If the water is too far below ground level for this to be done, **Farmer B** will simply drop the suction hose into the water.

8. **Farmer A** unkinks the delivery hose and starts operating the pump with a rapid treadling action as soon as the end of the suction hose is below the water surface.

9. To ensure that the end of the suction hose remains below the surface, a small rock or other weight can be tied to it, but check that the hose is not sucking mud from the bottom of the well or stream. To avoid this, tie the hose to a wooden stake driven into the bed of the stream or well.

### Manual priming with a foot-valve

A foot-valve is a non-return or one-way valve fitted on the end of the suction hose that allows water to enter the pipe but prevents it flowing back out. A 50 mm commercial foot-valve and suction hose insert costs about MK2,000 (US$ 30), the same price as the subsidised treadle pump and hoses package.

A much cheaper foot-valve can be made from a drilled 50 mm PVC end cap and a rubber flap cut from old inner-tube. Unlike the commercial valve the PVC foot-valve does make pump operation slightly harder work but the components only cost about MK 180 (US$ 2.70). For assembly details see **APPENDIX 1: ASSEMBLING A PVC FOOT-VALVE**.

Using a foot-valve makes the first manual priming of the pump much simpler since the water is retained in the suction hose without the need for a person to place their hand over the end of the hose. Additionally, the non-return valve keeps water in the suction hose so pumping can be stopped for some time and then resumed without the need to re-prime the pump.

To prime the pump with a foot-valve, follow the same procedure described above for priming without a foot-valve. The only difference is there is no need to hold or cover the end of the suction hose, thus requiring only one person.

## Operating the Pump

After the initial rapid treadling while priming, operate the pump with a regular, steady rhythm (see **Figure 13**). Each operator will find their own comfortable speed of treadling. Treadling too fast will only tire the operator quickly and may cause erosion in the irrigated plot from pumping water out at a rate too fast for the capacity of the receiving channel.

Do not drive the pistons all the way down the cylinder so that they hit the valve at the bottom as this can damage the valve box. The down-stroke should be stopped just before contact is made with the bottom of the cylinder.

Make the down-stroke as vertical as as possible by keeping the piston rod upright. If the treadles are allowed to move sideways on the down-stroke, the piston rod may get bent which may damage the piston seals.

The pump can be operated by one or two people (see **Figures 14** and **15**). If the latter, the two people face each other on either side of the handle. This will increase the discharge rate of the pump and make operation less tiring.

If the pump is not fitted with a foot-valve and pumping is stopped for more than a few minutes water may leak out of the

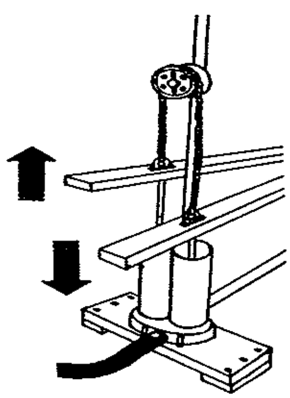


**Figure 13: Treadle with a slow, steady rhythm**

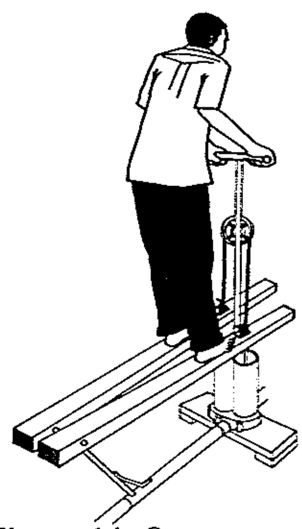
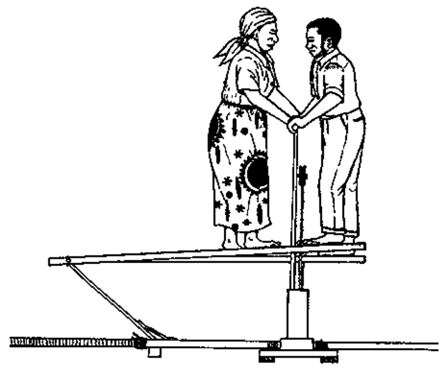


**Figure 14: One operator**

**Figure 15: Two operators**



suction hose to be replaced by air. When this happens, the pump has lost its prime and the priming process will have to be repeated before pumping can begin again. Any leaks between the intake pipe and the valve box, or where the suction hose is connected to the intake pipe, will cause the prime to be lost quickly. That is why it is important to seal these joints with a rubber strip.

If possible, use a wire mesh strainer on the end of the suction hose to prevent dirt and loose vegetation from being sucked into the valve box (see **Figure 16**).

**Figure 16: Wire mesh**

**Pump Maintenance and Storage**

**Regular maintenance**

Carry out the following checks or maintenance tasks on a routine basis:

1.Rope length

The length of the piston connecting rope needs to be regularly checked and adjusted as necessary (see above under **Routine Field Assembly**). If the rope stretches or the knots slip the rope can become too long so that the pistons only travel a small portion of the cylinder length when the pump is working. This will result in reduced pumping capacity

2. Cylinder and pulley grease

Apply grease to the cylinders, piston seals and pulley on first use and then at least once a week as described above under **First Assembly, Checking and Greasing.** Failure to do this will make pumping harder and may shorten the life of the piston seals.

3.Debris in the valve box

Mud or vegetation may be accidentally drawn into the valve box of the pump through the suction pipe if no mesh strainer is used. To remove such debris, lay the pump on its side and undo the 6 nuts that fix the wooden baseboard to the bottom of the pump. Take great care not to lose any of the nuts or washers. With the nuts and washers off, remove the baseboard and rubber gasket to give access to the valve box. Take out any debris and at the same time check the condition of the rubber flap valves which can be easily seen. When the valve box is clean, replace the rubber gasket, wooden baseboard and washers, and re-tighten the 6 nuts.

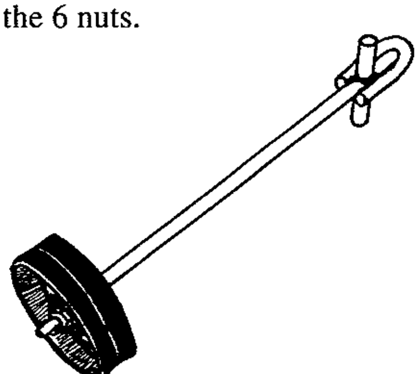


**Figure 17: Piston seals attached to the piston**

**Occasional maintenance**

1.Replacement of worn piston seals

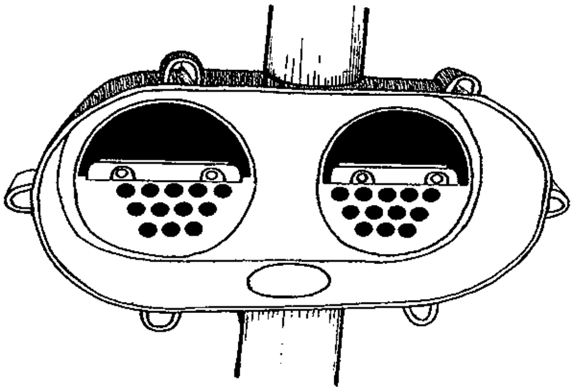
After a long period of use, the rubber seals (see **Figure 17**) on the pistons will wear down so that water leaks past the piston, which reduces the pump's performance. An obvious sign is that the piston is loose in the cylinder. Untie the connecting rope and remove the piston from the cylinder. It may be possible to increase the diameter of the rubber seals by tightening the clamping nut on the bottom of the piston. If this does not expand them sufficiently they must be replaced.

Two spare rubber seals are supplied with the pump. If proper replacement seals cannot be obtained, rings of rubber can be cut from old gumboots or the side walls of an old tyre and clamped between the three metal piston disks (see the Assembly and Operation Manual supplied with the pump).

2.Replacement of rubber flap valves

The pump contains 4 rubber flap valves, 2 in each cylinder (see **Figure 18**). These can be damaged by rodents or through general wear and tear. Two replacement flap valves are provided in the pump spares kit.

**Figure 18: Upper flap valves in the valve box**



Further valves can be made if needed from rubber inner tube. To replace the lower flap valves remove the wooden baseboard to allow access to the metal bars and clamping bolts that hold the flaps in place. The upper ones can be accessed through the top of the cylinders.

### Pump storage and care of hoses

After irrigation is finished on any occasion, drain all water from the layflat delivery hose. Roll up the hose properly in the field (see **Figure 19**) taking care not to drag it over sharp objects, and then carry it to the homestead. On no account should the hose be loosely folded and dragged over the ground from the field to the homestead as this will greatly shorten its useful life.

The suction hose is much stronger than the delivery hose but should also be drained of water, coiled and carried from the field to the homestead.

Store the pump and its fittings (hoses, hose clips, tool kit and spares) in a safe location. Pay particular attention to prevent damage to the hoses and rubber components by rats or other rodents. Seal the pump intake and discharge pipes to stop rodents gaining access to the flap valves in the valve box.

When carrying or storing the pump, take care not to dent the cylinders. If this happens the pistons will not move easily within the cylinders and water will leak between the rubber piston seals and the cylinder wall, making the pump less effective. Also try not to bend the piston rods.

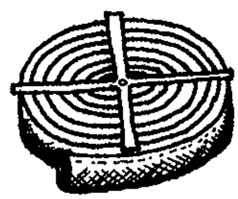


**Figure 19: Rolled up layflat hose**

## INTRODUCTION

There are two irrigation techniques suitable for broadscale use with the treadle pump in Malawi. The first is **basin irrigation** and the second **contour furrow irrigation**. Both require pumping water to an elevated point using the treadle pump to irrigate crops by gravity through an organised system of channels. This manual focuses only on the basin system.

Basin irrigation involves dividing a field or plot into equal sized sunken basins demarcated by small banks of earth. Each basin has a level surface to allow water to be applied evenly. Water is directed to the basins one at a time by gravity using a main channel and system of feeder channels. Crops are planted in the basins on the flat.

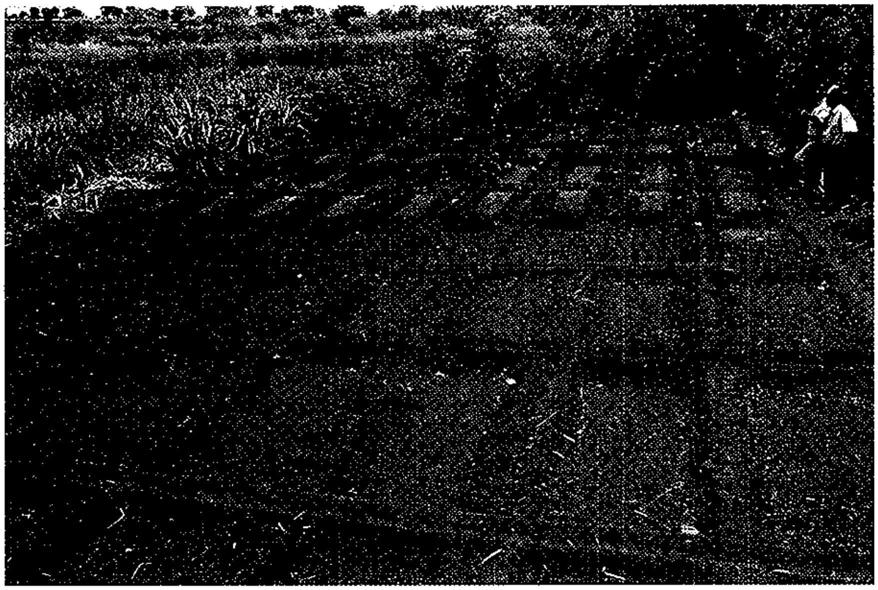
Contour furrow irrigation requires the construction of a block of contour ridges tied on one side. Water is fed into the furrows from the other side using a channel running down the slope. The furrows are ponded with water one at time to the required depth before the flow is diverted to the adjacent furrow. Crops can be planted either in the furrow or on top of the ridge. This system is particularly suitable for steeper slopes (over 2%).

**Note:** The treadle pump is not suitable for irrigating long, graded furrows which run downslope as the flow of water produced is insufficient to allow the necessary infiltration for crop growth.

## RECOMMENDATION

Basin irrigation has been successfully subjected to extensive farmer field testing under Malawian conditions. In contrast, the contour furrow system has only been introduced to farmers on a limited scale to date. Demonstrations carried out by the MAFE Project suggest that the contour furrow method may have several advantages over the basin technique:

- **plot construction** - the furrow system requires less labour to establish than the basin method
- **extension** - contour ridging is a concept many farmers have already been introduced to in relation to their upland fields
- **plant density** - the contour furrow method allows for more efficient land use as less area is lost to channels and paths than is the case for the basin system.



*Layout showing relative position of channels, paths and basins*

*Irrigating drumhead cabbage in basins using the main and a feeder channel*

One potential disadvantage is that the contour furrow method requires more water and time to irrigate because of the ridges.

In view of the foregoing, **basin irrigation is the recommended technique for treadle pump irrigation in Malawi.** Details on how to layout the channels and basins are described below.

### BASIN PLOT LAYOUT

**Materials required (see Figure 20)**

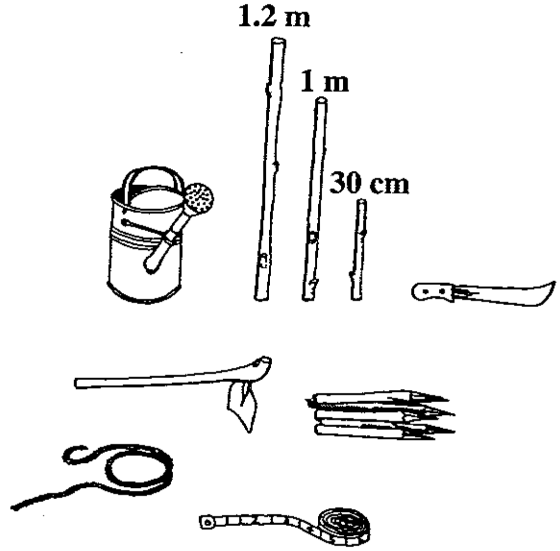
Tape measure; 3 measuring sticks - 1m, 1.2 m & 30 cm; panga knife; wooden pegs; string; hoes; watering can; stone or hammer for pegs; off-set line level (optional).

**Planning the plot layout**

This procedure describes the layout of a 156 m$^2$ (13 m x 12 m) rectangular plot but the same method will apply to laying out larger areas of up to 3,000 m$^2$. Plots larger than this need more than one treadle pump.

**Step 1: Plot selection** - choose a plot of land in the dimba garden that has:

**Figure 20: Plot layout materials**




- close access to a reliable water source
- soil with good water holding and releasing capacity and moderate drainage
- a gentle, uniform slope
- no current crops planted.

**Note:** If crops have already been planted on a plot, do not assume that the new basin layout will fit the existing pattern of beds.

**Step 2: Land slope** - carefully survey the land slope by eye to identify the **main** (**A**) and **minor** (**B**) slopes of the plot (see **Figure 21**). Layout the main channel at the top of the plot, running across the main slope, starting from the highest point. Feeder channels will run down the main slope.

**Step 3: Basin layout** - two key factors need to be considered for the basin layout:

- **the basins must be level** - this will ensure an equal wetting depth across the entire basin when flooding. The aim is to provide uniform irrigation to all basins.

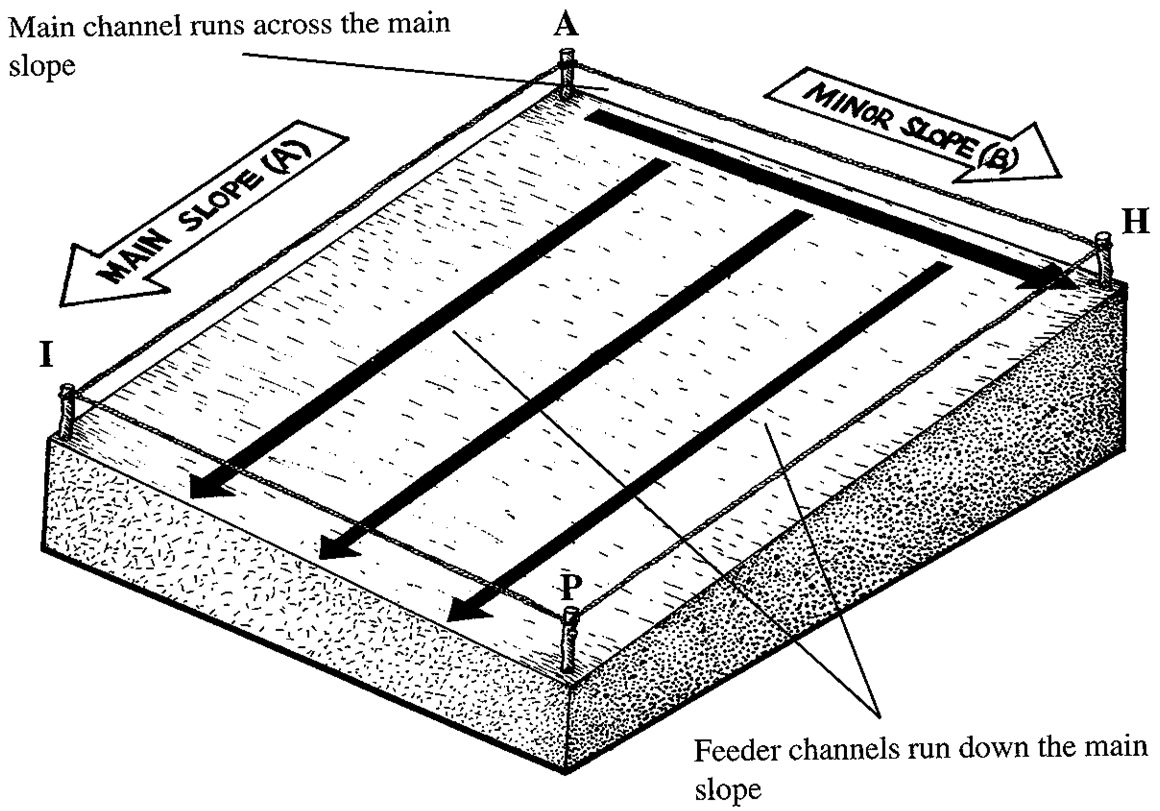



**Figure 21: Plot slope and demarcation**

- **the basins must be able to be flooded quickly** - the wetting depth will be uneven if it takes too long to uniformly flood the basin as more water will infiltrate at the end closest to the inlet.

**Basins 3 m long by 1.2 m wide are recommended in this manual**. This size of basin can be levelled easily by eye and/or with water, and can be flooded very quickly with a treadle pump.

Lay out equal size basins with their longer side running across the slope and shorter side running down the slope. This arrangement will minimise work in moving soil to level basins.

### Demarcating the plot

Demarcate a rectangular plot by eye, using the triangle method (see APPENDIX 3) to check for right angles, and then run string between the 4 corner pegs (see **Figure 21**).

## MARKING OUT AND CONSTRUCTING MAIN AND FEEDER CHANNELS

### Introduction

The main channel starts from the highest point of the plot at **Peg A** (see **Figure 22**). It runs at a gentle gradient downhill from there along the upper boundary of the plot to **Peg H**. This allows water to flow easily along the channel.

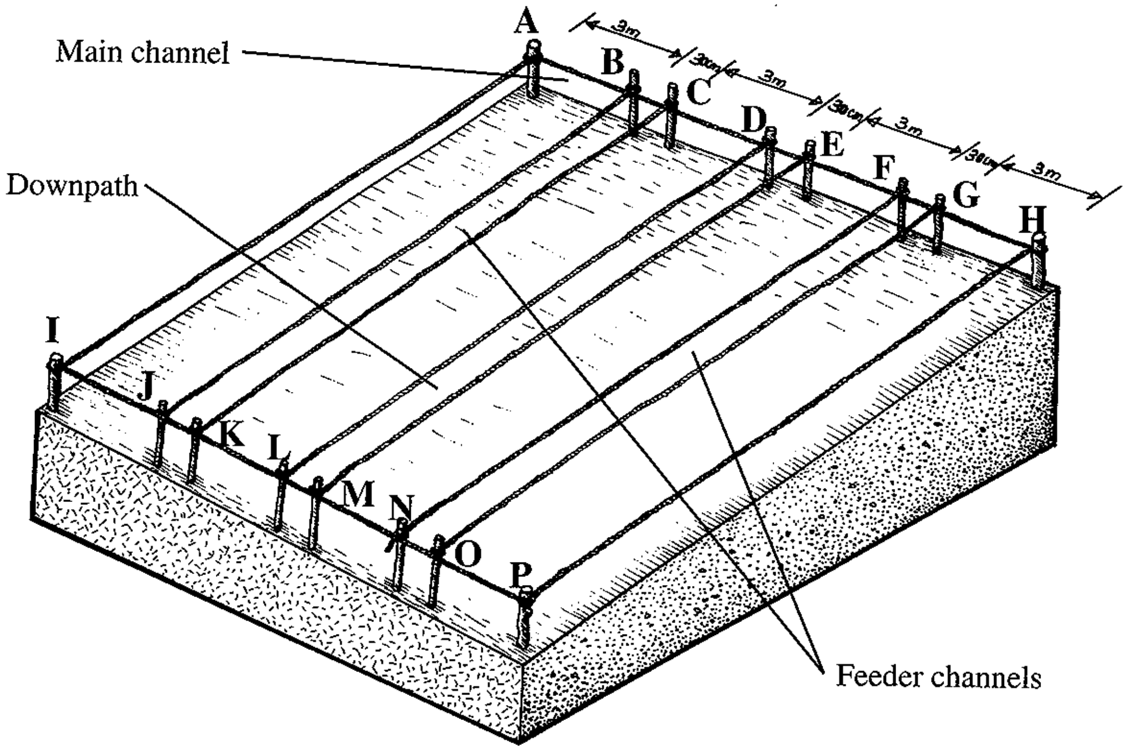
An off-set line level may be used to ensure the main channel has the required slope (see APPENDIX 2). A simpler option is to initially gauge the slope by eye and make adjustments following construction using water flow from the treadle pump.

The feeder channels run down the slope from the main channel (see **Figure 22**), each serving a line of basins on either side. The feeder channels alternate with downpaths running in the same direction. The latter are used to provide access to crops without having to walk in the irrigated basins.

All the channels are raised above the basins to facilitate the flow of water into them.

**Note:** If the soil is too sandy to permit raised channels, sunken channels can be used. This will require that the basins are deeper than normal to allow water to flow into them from the channels.

**Figure 22: Main and feeder channel marking**




**Channel marking (see Figure 22)**

Run the main channel from the highest point of the plot at **Peg A** (also known as the head of the main channel) along the upper boundary of the plot to **Peg H**.

Starting from the beginning of the main channel at **Peg A**, measure 3 m along the main channel line and insert **Peg B** to mark the first line of basins. From this point measure a further 30 cm and insert **Peg C**. This 30 cm strip is where the first feeder channel will be constructed. Another 3 m down the main channel line from this point, place **Peg D** to mark the second line of basins, followed by **Peg E** 30 cm away. This 30 cm strip marks a downpath between basins.

Another 3 m along **Peg F** marks the third basin line. A further 30 cm along **Peg G** marks the second feeder channel. Another 3m along **Peg H** marks the fourth basin line and the end of the main channel and plot.

Repeat this marking process along the lower boundary of the plot starting from **Peg I** and finishing with **Peg P**. Then run string between the opposing top and bottom pegs to mark out the 3 m long basins and 30 cm wide feeder channels and path. When done, check that the basins and feeder channels/paths are parallel.

**Channel construction**

**Main channel** - using a hoe, start construction by moving soil from either side of the string running from **Peg A** to **Peg H** to form a ridge about 30 cm high centred on the string (see **Figure 23**). Remove any grass and roots, and then make a channel in the top of the ridge with your hands (see **Figure 24**). Finally apply water to the ridge and compact the soil using feet or hoe blades to reduce water losses by seepage from the channel (see **Figure 25**). Use dambo clay to seal the top of the main channel to further minimise seepage.

**Feeder channels** - construct the feeder channels in the same way as the main

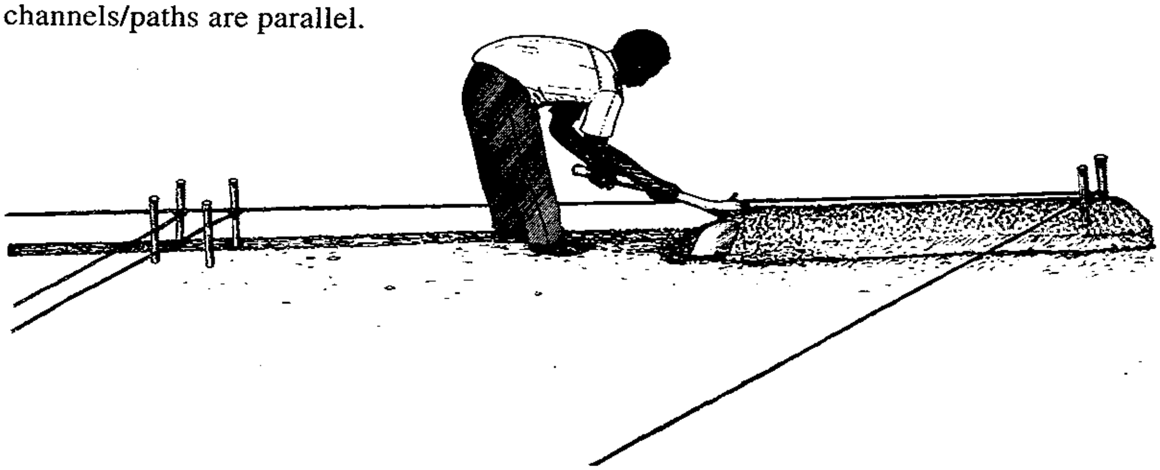
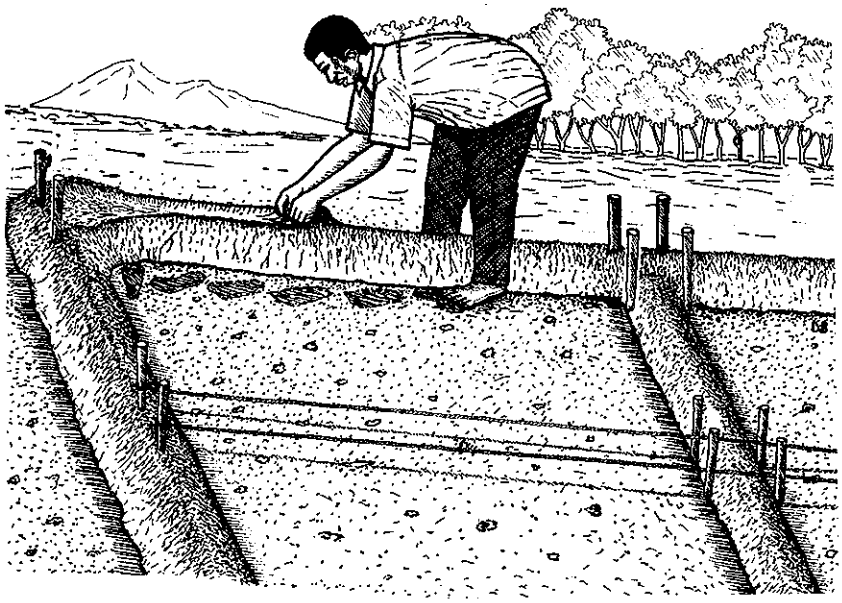


**Figure 23: Constructing a ridge for the main channel**

**Figure 24: Forming a channel on the top of the ridge**



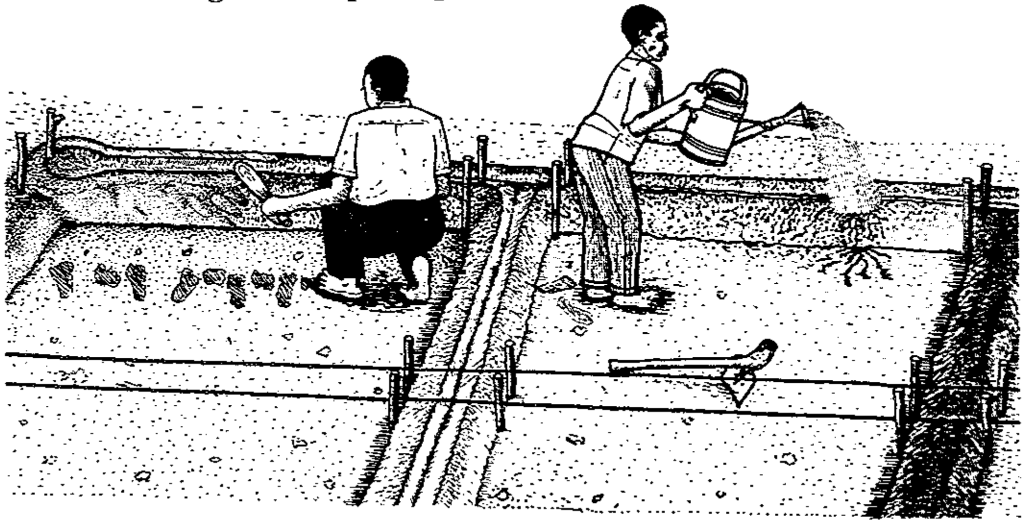
channel by building a ridge in the centre of each marked feeder channel (e.g. **Pegs B, C, J** and **K**). Then build a channel, followed by wetting and compacting. In the case of the downpath (e.g. **Pegs D, E, L** and **M**), simply construct an uncompacted ridge without making a channel.

**Note:** Try to avoid running the feeder channels down slopes greater than 3% as even the small flow of water may cause channel erosion. If neccessary, reduce the length of the feeder channels by reducing the plot size (see **CHAPTER 7: COMPOSTING, AGROFORESTRY AND SOIL CONSERVATION PRACTICES**).

### STILLING BASIN CONSTRUCTION

Protect the channel bed and sides from erosion at the discharge point of the delivery hose. Do this by constructing a larger pool or stilling basin about 40 cm diameter at the head of the main channel (see **Figure 25**). Protect the base and sides with plastic, stones, banana tree stems or

**Figure 25: Watering and compacting the main channel**



other vegetation. This small pool of water at the head of the channel will absorb much of the energy of the water as it comes out of the delivery hose.

## MARKING OUT AND CONSTRUCTING BASINS

### Basin marking (see Figure 26)

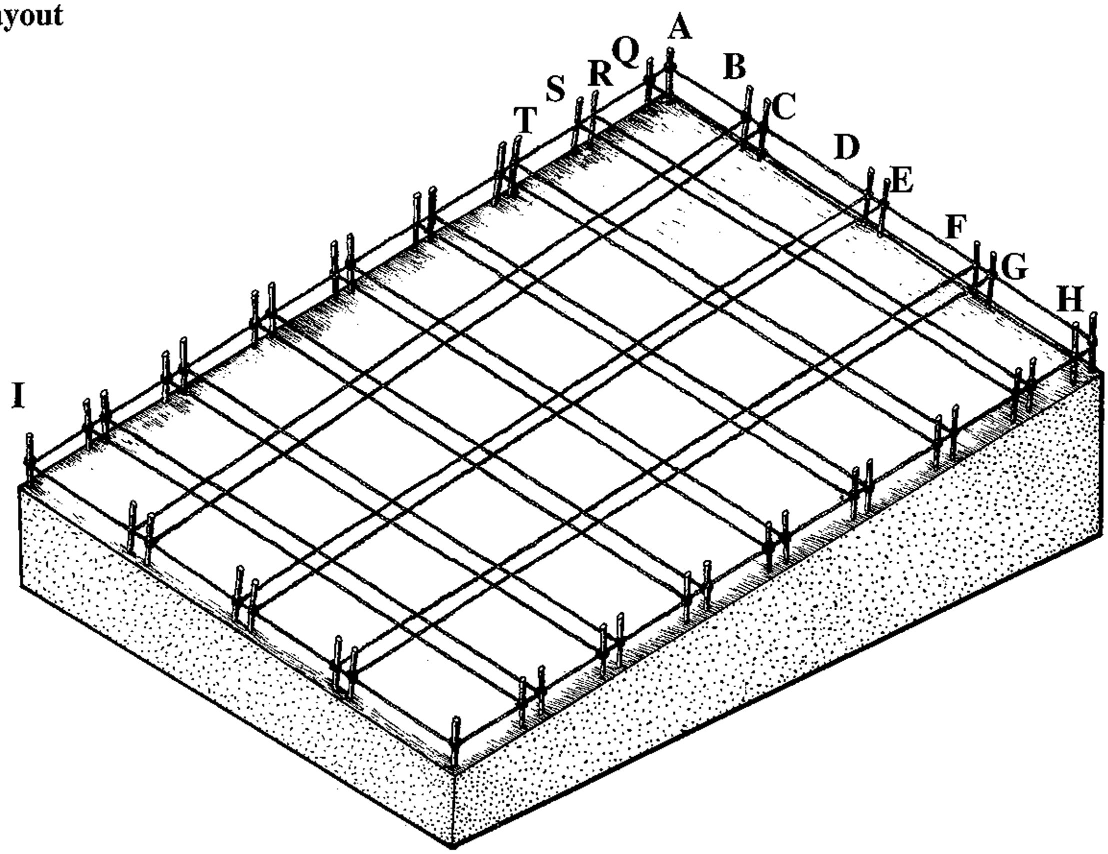
Starting from the upper left **Peg A**, place **Peg Q** 30 cm down the slope to mark the first crosspath. Crosspaths serve the same function as dowpaths which is to provide access to crops without having to walk in the irrigated basins.

Then place **Peg R** 1.2 m further down to mark the edge of the first row of basins. Mark the second crosspath another 30 cm down with **Peg S** followed by the second row of basins a further 1.2 m along at **Peg T**. Continue marking alternate crosspaths and rows of basins until the bottom of the plot at **Peg I**. Repeat this exercise along the other side of the plot. Then connect the opposing pegs across the slope with string to mark out a series of 3 m long x 1.2 m wide basins. Then insert pegs to mark out each basin.

### Basin construction

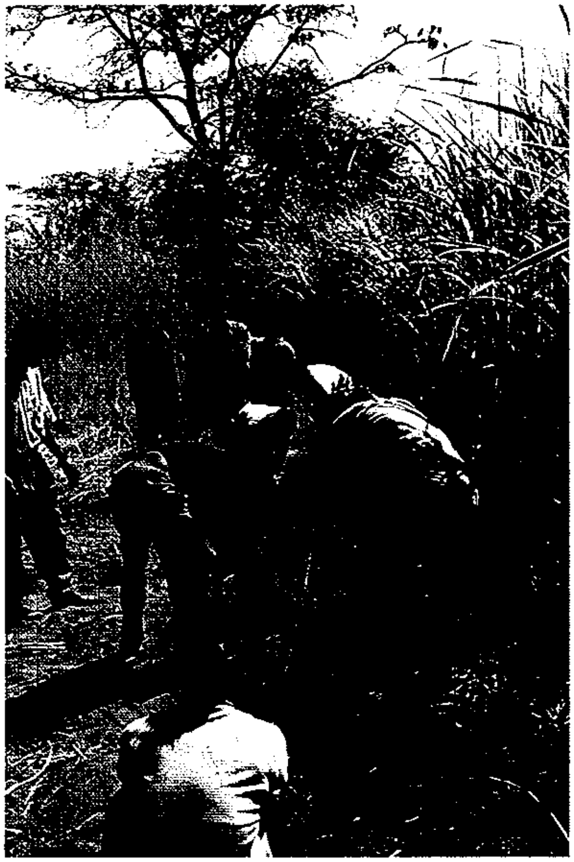
Using a hoe (see **Figure 27**), start constructing the first basin by making a

**Figure 26: Basin marking layout**

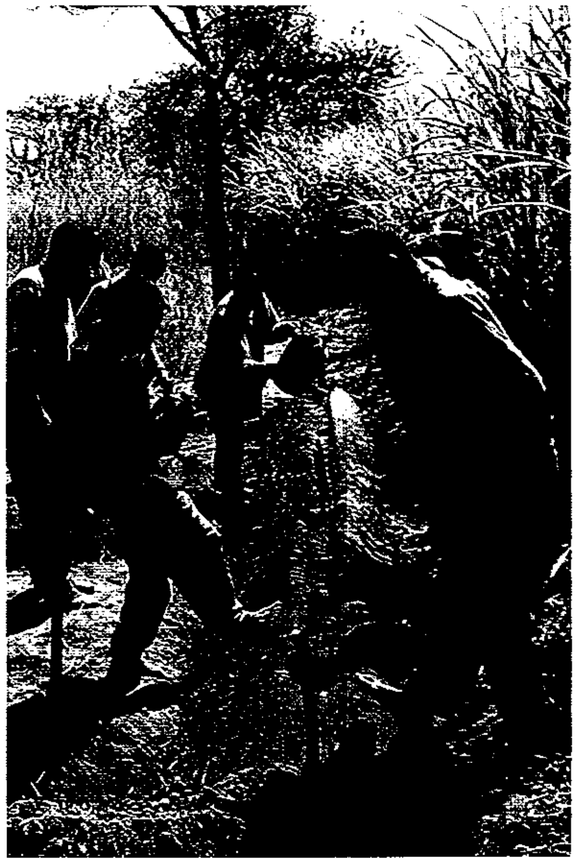



small ridge of soil along the line of the string marking out the 4 basin sides. Then add two pails of manure and till the basin to a depth of 30 cm, thoroughly incorporating the manure. Then level the soil by eye using a hoe. Repeat this process for all basins in the marked out plot.

Once all the basins are constructed, and before any crops are planted, check that



*Farmers constructing a ridge along the line of the main channel*



*Farmers applying water and compacting the main channel*

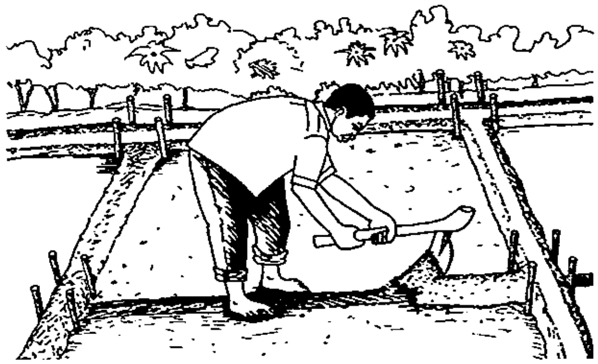
*Use heavy dambo clay to seal the main channel to prevent water seepage*

*Stilling basin at the head of the main channel covered with plastic to reduce erosion*



MALAWI AGROFORESTRY

**Figure 27: Basin construction**



they are level using water as a guide (see **Figure 28**). Fill the basins one at a time with water using the treadle pump and channels. Smooth off any high spots by transferring soil to low points within the basin.

**Figure 29** shows the finished plot layout complete with stilling basin, main and feeder channels, downpaths and crosspaths, and leveled basins ready for planting.

## IRRIGATING THE PLOT

### Introduction

Irrigating with a treadle pump requires at least two people. One person operates the pump while the second diverts water to the basins. Water is delivered from

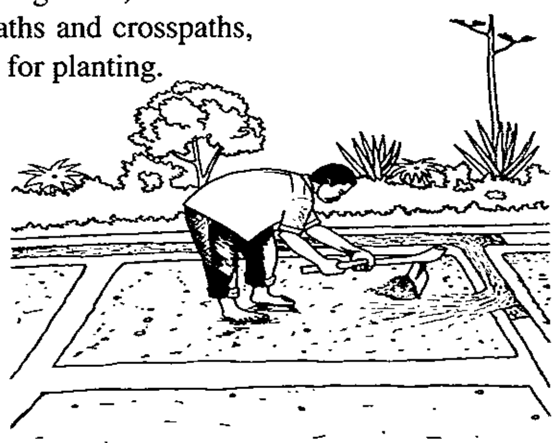


**Figure 28: Leveling a basin with water**

the pump to the stilling basin at the head of the main channel through the delivery hose. The water then flows by gravity along the main channel where it is diverted by small dams down feeder channels and into basins.

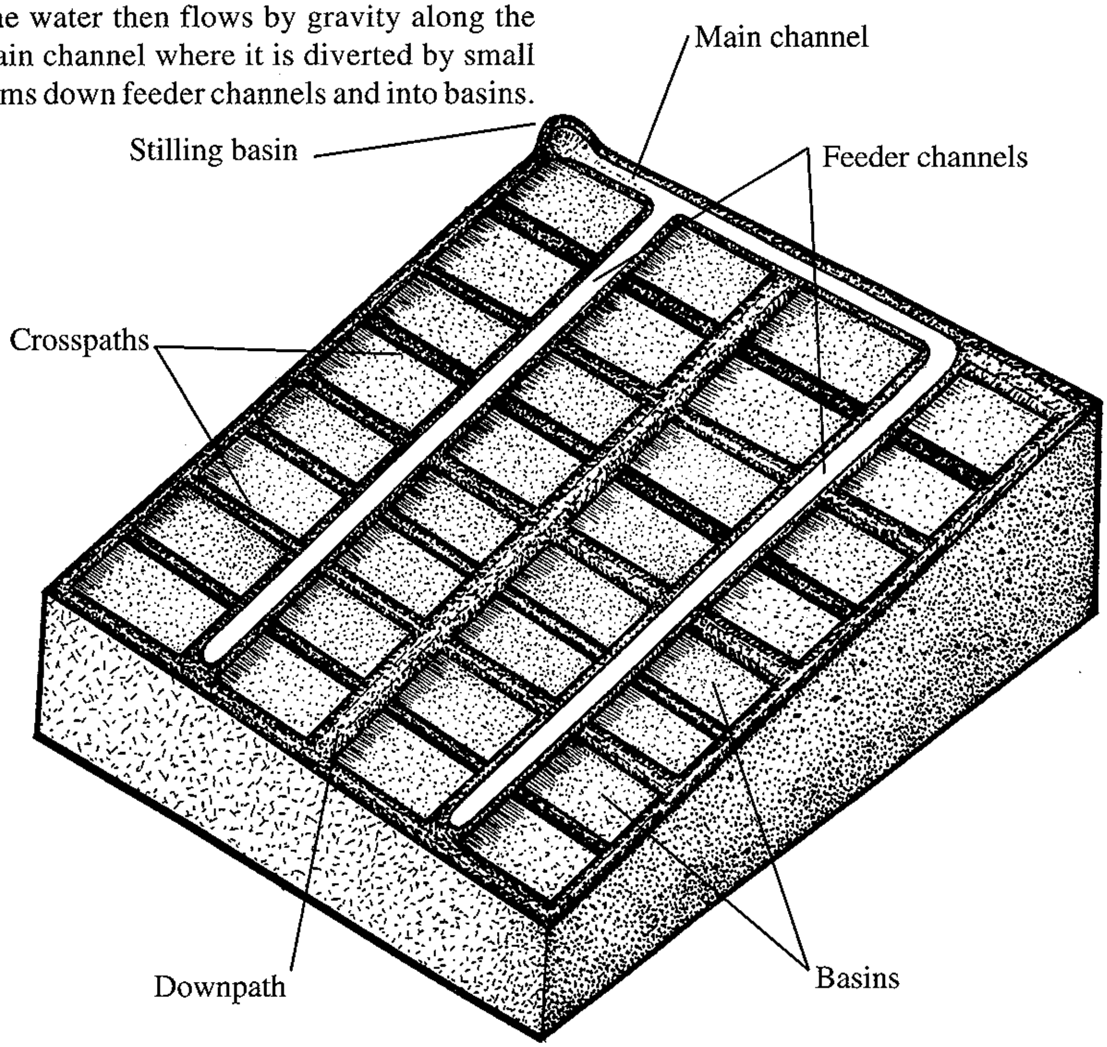



**Figure 29: Completed plot layout**

*Leveling a basin by eye using a khasu*

*Final leveling with water to ensure a proper level is attained*

*Irrigating a basin before planting*

*Irrigating maize basins one by one*

Key points to note are as follows:

1. **Fill one basin at a time**. Do not divide the flow between several basins as this will increase the time required to fill each basin. It will also affect the uniform application of water over different parts of the basin.

2. **Do not pass water through one basin to a second**. Each basin must be filled directly from a feeder channel. Using basins to convey water to other areas will result in over-watering and loss of soil nutrients.

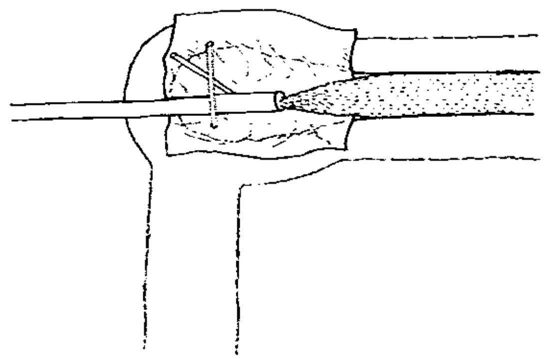
## Operation

The following steps describe the recommended irrigation routine:

**Step 1** - Set up the treadle pump correctly next to the water source and run the delivery hose in a smooth arc from the pump to the stilling basin (see **Figure 9** in **CHAPTER 2: THE TREADLE PUMP**).

**Step 2** - Secure the free end of the delivery hose in the stilling basin with sticks or bamboo to ensure that it does not leap out under the force of the pumped water (see **Figure 30**).

**Figure 30: Protect the stilling basin and secure the delivery hose**

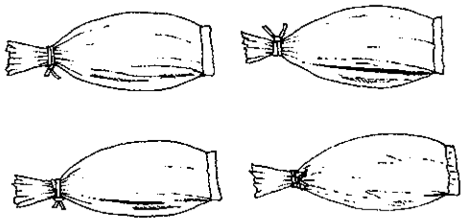


**Step 3** - Fill small plastic bags with soil to serve as dams for blocking channels and diverting water (see **Figure 31**).

**Step 4** - Dam off the main channel just beyond the first feeder channel. Dam off the feeder channel halfway down the first basin and cut a small breach in the feeder channel wall leading into Basin 1.

**Step 5** - Start pumping and the water will flow through the main and feeder channel into Basin 1 (see **Figure 32**). Let the basin flood evenly to a depth of 6-8 cm (see **CHAPTER 5: IRRIGATION AND CROP HUSBANDRY**).

**Figure 31: Use plastic bags for dams**



**Step 6** - Cut a breach in the feeder channel leading into Basin 2 opposite to the one leading into Basin 1. Immediately after this, dam the breach into Basin 1. Water will now divert into Basin 2 (see **Figure 33**).

**Step 7** - Move the feeder channel dam halfway down Basin No.3 and cut a breach in the feeder channel leading into Basin 3. Immediately dam the breach into Basin 2 to divert the water into Basin 3 (see **Figure 34**).

**Step 8** - Cut a breach in the feeder channel leading into Basin 4 opposite the one leading into Basin 3. Immediately after this, dam the breach into Basin 3 to divert water into Basin 4 (see **Figure 35**).

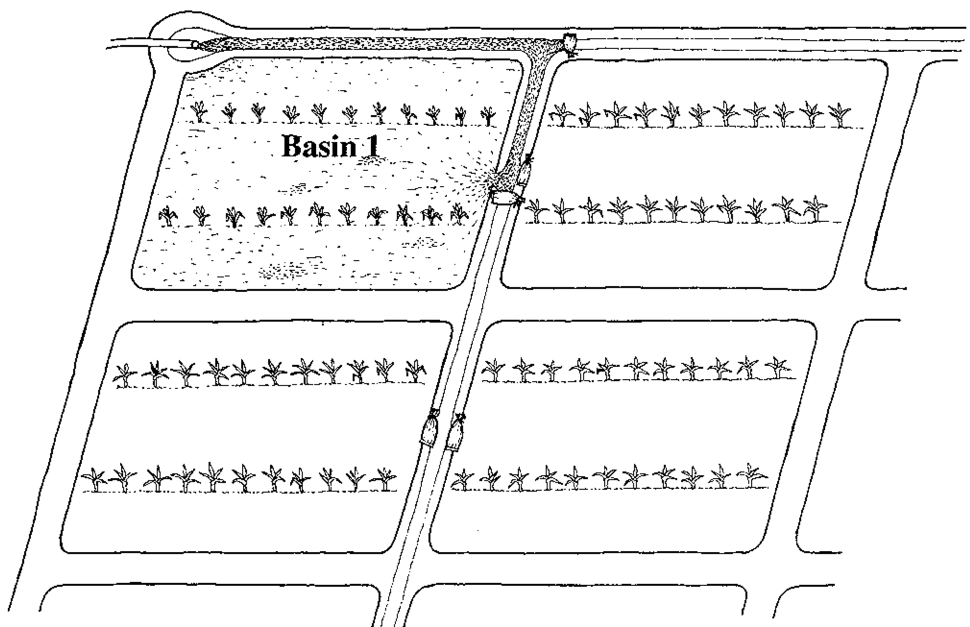
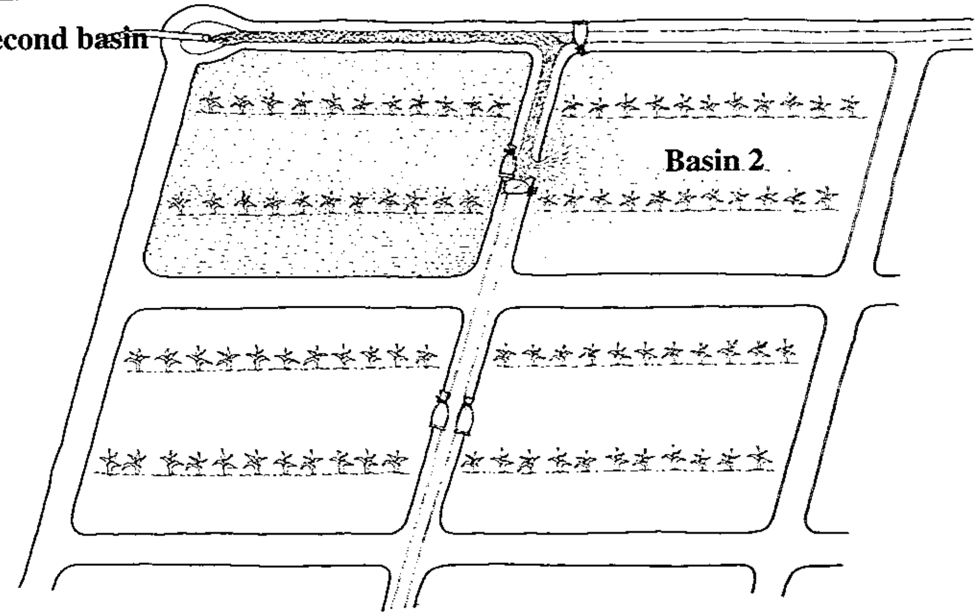



**Figure 32: Fill first basin**



MALAWI AGROFORESTRY

Figure 33: Fill second basin



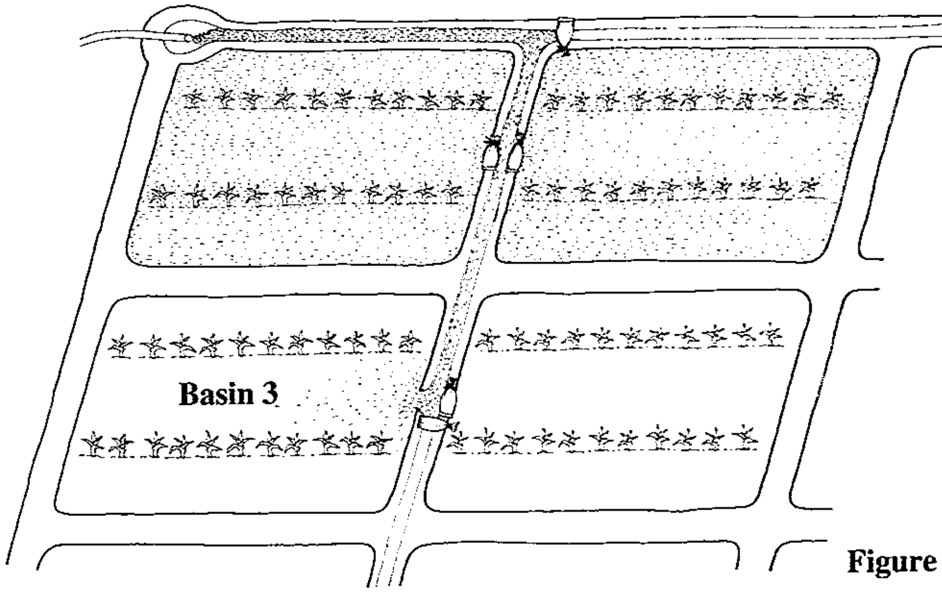
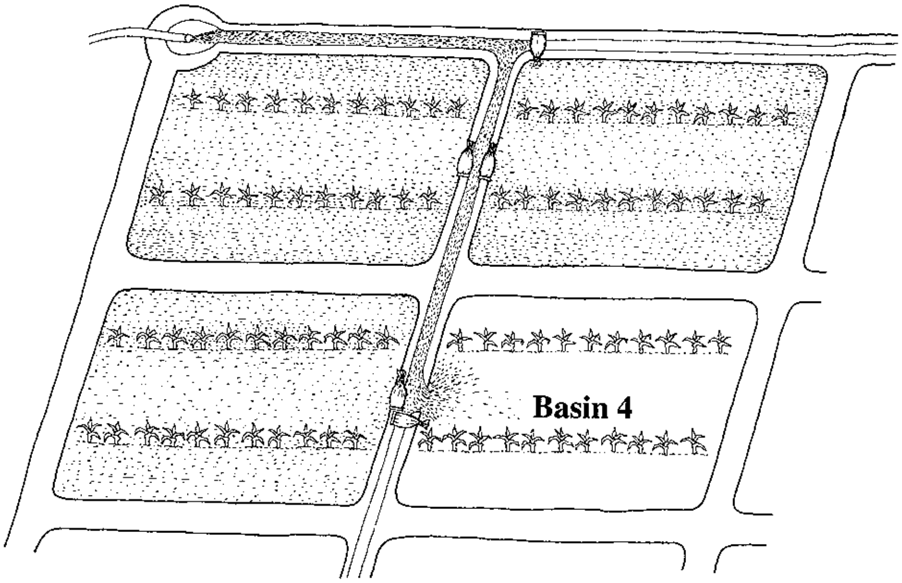




Figure 34: Fill third basin

**Figure 35: Fill fourth basin**




Continue this process until all basins served by the first feeder channel are irrigated. Then repeat the exercise for all feeder channels in your plot until all basins are irrigated.

As a general rule, irrigate every 5-7 days during the cool dry season (April-July) and every 3-5 days during the hot dry season (August-December). More frequent irrigation is required during hot weather and periods of rapid crop growth (**see CHAPTER 5: IRRIGATION AND CROP HUSBANDRY for more details**).

**Note:** Use plastic bottles or bamboo lengths as pipes from the feeder channels to the basins as an alternative to cutting and filling breaches in the feeder channel walls.

## INTRODUCTION

Most vegetable crops should be started in a nursery before transplanting in the field. Nurseries provide ideal conditions to raise strong, healthy plants that will grow well after transplanting. This is because a large number of plants can be easily managed in a small, fertile, well-protected area.

The following crops should be established in a nursery:

- tomatoes
- onions
- eggplants
- peppers
- cabbages
- lettuce.

## NURSERY SITE SELECTION

A good nursery site should be:

- on flat land to avoid soil erosion
- not shaded by trees
- close to a water source as the plants will need frequent irrigation with a watering can
- favoured with well-drained, fertile soil, and
- protected from livestock.

## NURSERY BED PREPARATION

### Calculating Nursery Bed Size

Nursery bed size depends on the field area and spacing of the crop to be grown. This will determine the number of seedlings that need to be raised. A standard nursery bed width of 1 metre is recommended which reduces the problem to calculating the length of bed required.

For example, calculate the nursery area to raise enough seedlings to plant 10 basins of Drumhead Cabbage as follows:

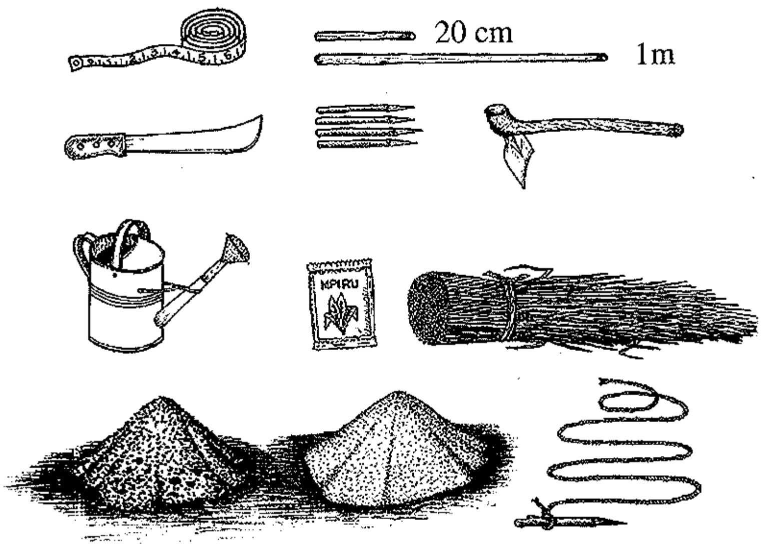
*Field*

70 cm x 60 cm crop spacing = 10 plants per basin (see CHAPTER 6: CROP SPECIFIC DATA for plant spacing recommendations).

10 basins x 10 plants/basin = 100 plants

Therefore **100 seedlings are required.**

**Figure 36: Materials for nursery construction**




## Materials Required (see Figure 36)

Tape measure; 2 measuring sticks - 1 m and 20 cm; panga knife; small pegs; string; hoe; watering can; manure or compost; sand; certified vegetable seed; grass for mulch.

*Nursery*

Seedling spacing within 1 metre rows (after thinning) = 6 cm

No. seedlings per row = 100/6 = 17

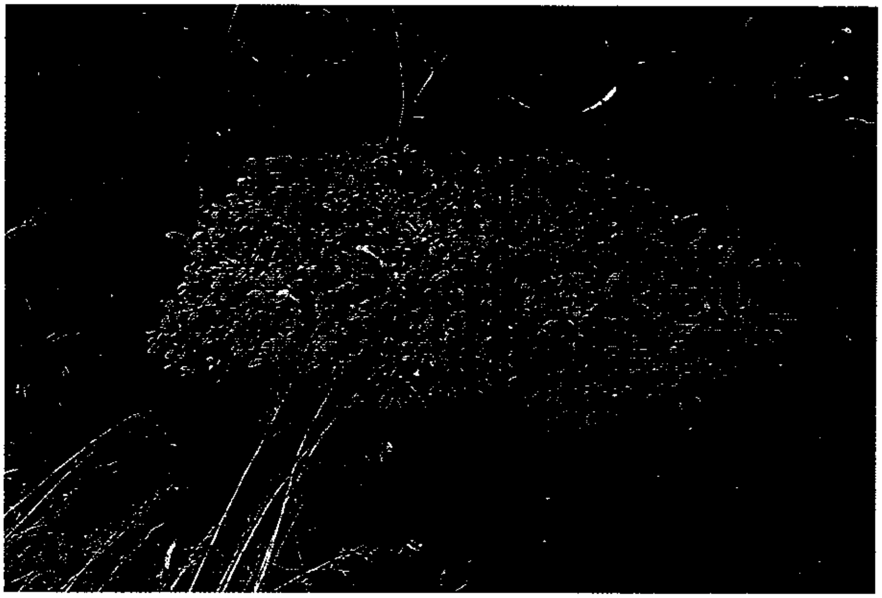
No. rows required for 100 seedlings = 100/17 = 6 rows

Inter-row spacing = 0.2 m

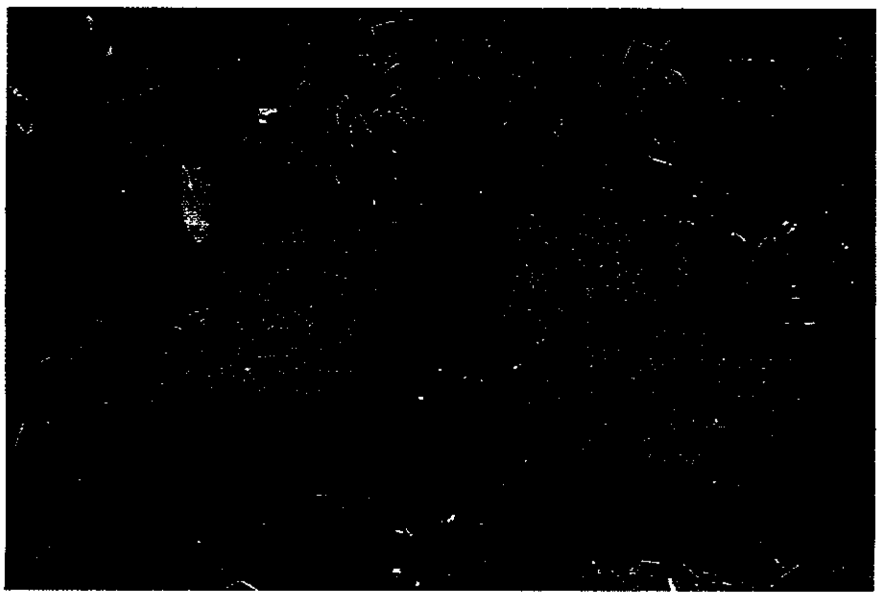
Nursery area required for 10 basins of drumhead cabbage = 6 rows x 0.2 = **1.2 metres long x 1.0 m wide = 1.2 m²**

## Preparing the Seedbed (see Figure 37)

Till the soil to a depth of 20 cm with a hoe. Add one bucket of animal manure or well-rotted compost per $2m^2$ to the soil and mix in thoroughly. Make a raised bed about 20 cm high, 1 m wide, and as long as necessary. Then level the top with a hoe and

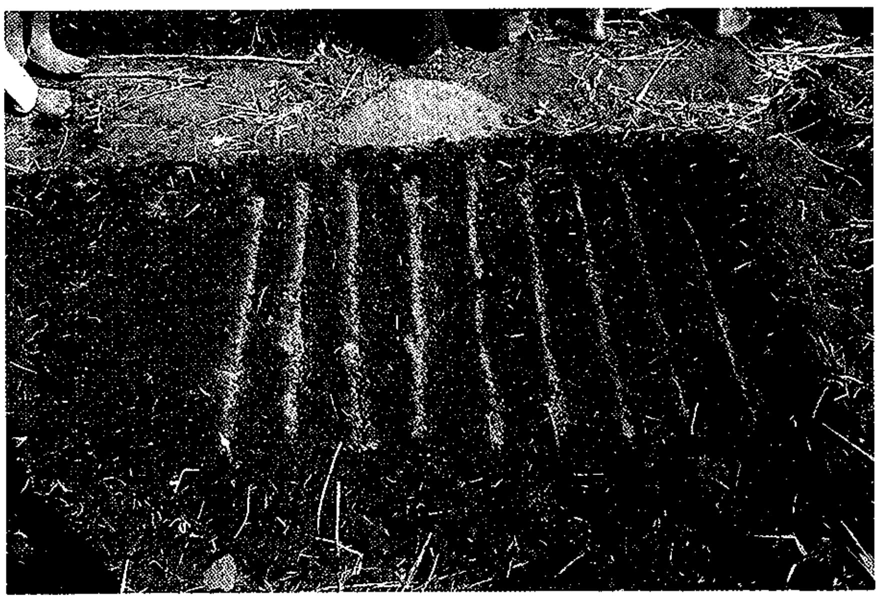


*Traditional vegetable nursery*



*Improved vegetable nursery ready for trans-planting*

*Watering the raised nursery bed one hour before sowing.*



*Sand lining the bottom of drills prior to sowing.*

thoroughly water the bed with a watering can (2 cans per $m^2$) 1 hour before sowing.

### DRILLING AND SOWING

Sow vegetable seeds in rows (drills) 20 cm apart for the following reasons:

- weeding is easier
- thinning is easier
- cultivating between drill lines is easier.

Start from one end of the bed and place small pegs at 20 cm intervals along both sides of the length of the bed (see **Figure 38**). Drill parallel lines across the width of the bed with your finger or a small stick, 0.5 cm deep, using string as a guide. Lightly cover the drilled lines with sand.

Sow individual seeds with your fingertips (see **Figure 39**) at 3 cm intervals along the drills. Lightly cover the seeds along the drills with some soil or sand.

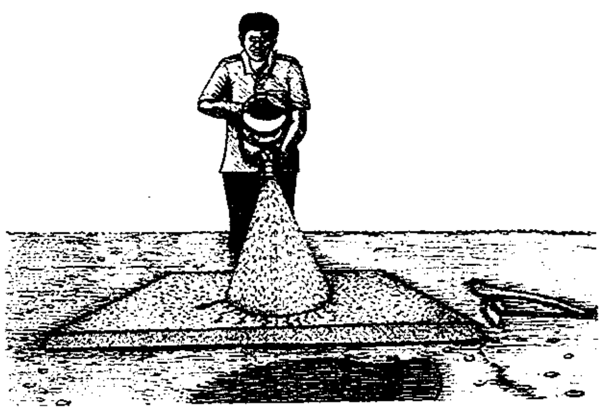


**Figure 37: Construct a raised bed and water thoroughly one hour before sowing**

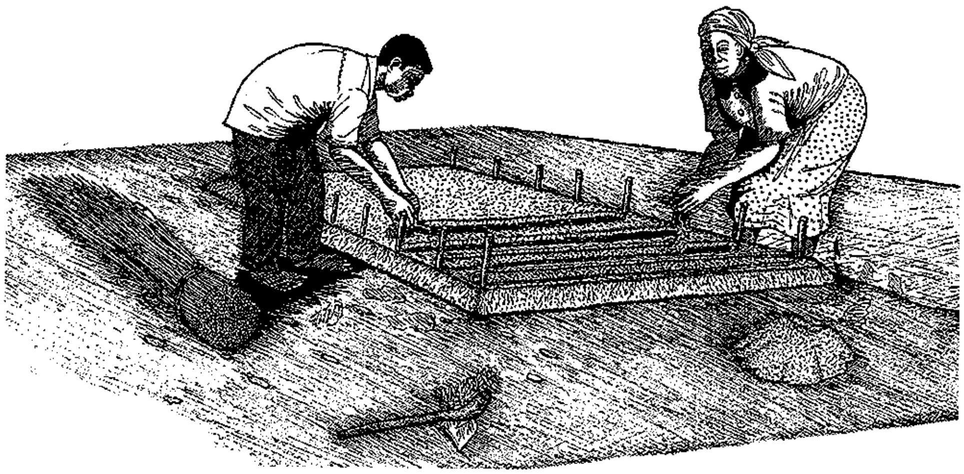


**Figure 38: Drill 0.5 cm deep rows 20 cm apart and line with sand**

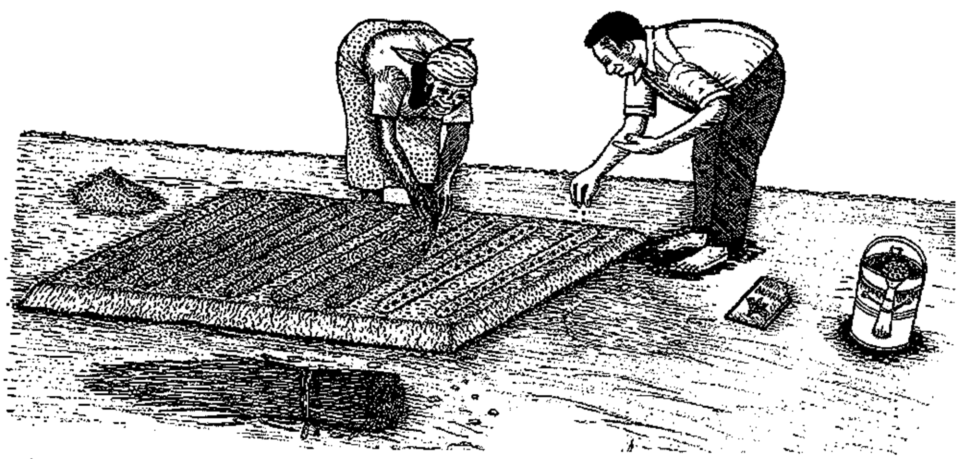


**Figure 39: Sow individual seeds along the drills and lightly cover with soil or sand**

## MULCHING AND WATERING

Cover the surface of the bed with clean dry grass to avoid rapid drying of the nursery bed soil (see **Figure 40**). Spread the grass evenly over the bed so that no light reaches the soil. Then water the bed again after mulching to avoid washing out the seed (see **Figure 41**).

Continue to water the bed twice a day, using approximately 1 can/m$^2$. Keep the bed moist but avoid over-watering. Always use a rose on the watering can (or perforated bucket or tin) so that the watering is gentle.

## GERMINATION AND SHADING

Check every day to see if the seedlings are emerging. As soon as they have emerged, the grass must be removed gently so as not to disturb the seedlings. Germination time varies by crop but is generally 3-5 days after sowing. Some crops such as sweet pepper may take 2-3 weeks to germinate.

Immediately after germination, make a grass roof about 30 cm above the bed (see **Figure 42**). This will provide shade for the young seedlings and reduce evapo-transpiration.

**Figure 40: Mulch with clean dry grass**

**Figure 41: Water thoroughly after sowing and mulching**

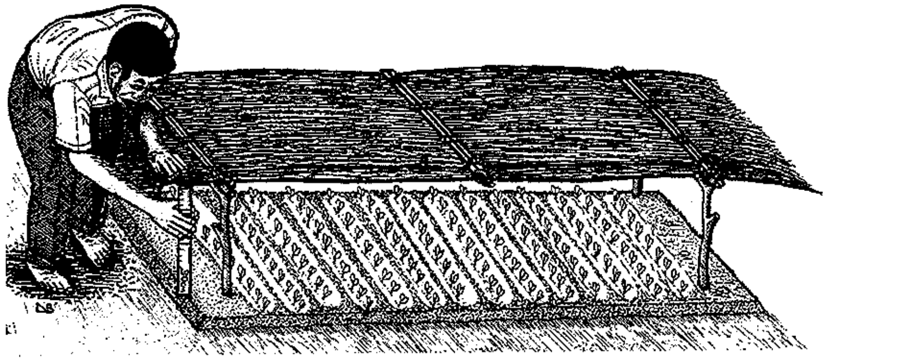


**Figure 42: Make a raised grass roof after germination for shade**

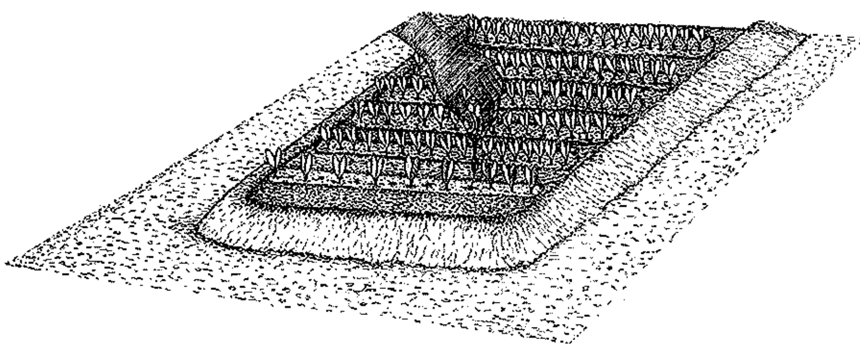


**Figure 43: Thin seedlings to reduce plant competition in the nursery**

Continue watering twice a day after germination, lifting the grass roof as required for access to the seedlings. Reduce watering to once a day and remove the shade roof two weeks after germination.

### WEEDING AND THINNING

Thin the seedlings to one plant every 6 cm along each row or drill when the seedlings develop 2-3 leaves (see **Figure 43**). Water thoroughly before thinning so that the surplus plants can be easily lifted from the soil by hand. Remove the weaker plants first and then as many stronger plants as required to achieve the 6 cm spacing. Thinning minimises competition for light and nutrients between plants to produce strong seedlings.

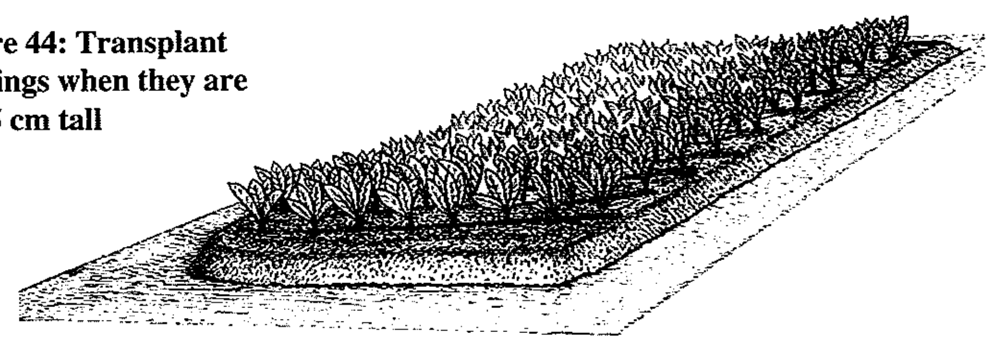
Keep the nursery bed weed-free at all times to further minimise plant competition. Water before weeding to make the weeds easier to remove from the soil.

### HARDENING OFF

Seedlings are ready for transplanting when they are 10-15 cm tall (see **Figure 44**). This is generally 4-6 weeks after sowing although some crops, such as onions, may take 6-7 weeks before reaching transplanting size.

Reduce the amount of water applied to the nursery bed one week before transplanting. This will harden the seedlings so that they can better overcome the shock of facing the stressful environmental conditions prevailing in the field.

**Figure 44: Transplant seedlings when they are 10-15 cm tall**



## INTRODUCTION

This chapter describes how to plant and manage a range of vegetable and cereal crops, transplanted from the nursery or direct-sown. Crop specific details are covered in **CHAPTER 6: CROP SPECIFIC DATA.**

**NOTE:** Instructions below relate to **3 x 1.2 m** basins.

## BASIN PREPARATION

Undertake the following before planting crops in the basins:

- add 2 buckets of manure or compost to each basin and till to a depth of 30 cm (see **Figure 45**)
- ensure that the basins are level
- irrigate the basins one hour before planting

## CROP SPACING

The spacing of crops, between and within rows, is described in **CHAPTER 6**. Mark out the correct spacing for the crop you wish to plant in each basin. Use measuring sticks cut to the required length and mark the planting stations with a small hole or peg (see **Figure 46**).

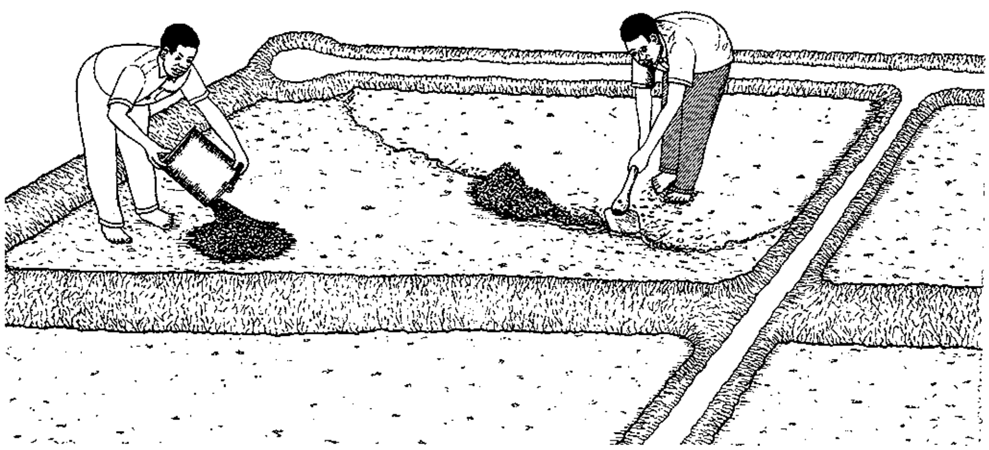
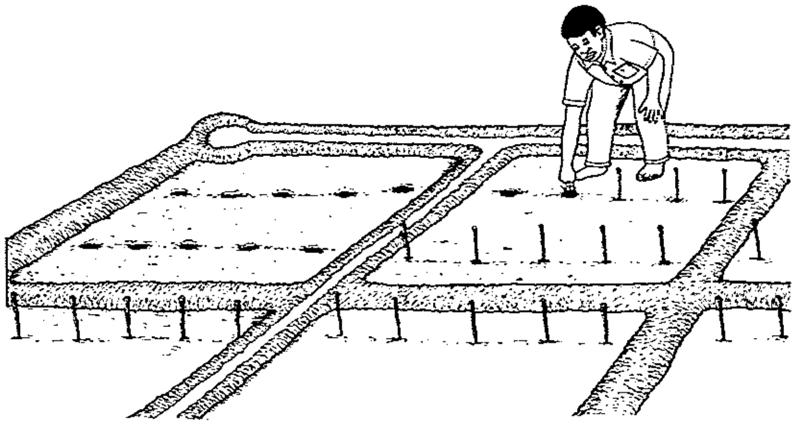


**Figure 45: Apply 2 buckets of manure to each basin and mix in thoroughly and uniformly across the basin**

**Figure 46: Marking out cabbage planting stations at 70 x 60 cm**



## PLANTING

### Transplanting seedlings

**Step 1** - Plan to transplant seedlings either early morning or late afternoon to reduce evapo-transpiration. Water the nursery bed one hour before transplanting.

**Step 2** - Lift the seedlings carefully one by one by digging with your hand in the wet soil to remove the seedling with its roots covered with a ball of soil (see **Figure 47**). Do not lift more than can be planted in a short period of time to minimise seedlings left to wilt in a container for long periods.

**Step 3** - Place the seedlings carefully in a bucket, basket or bowl and transport them immediately to the planting site (see **Figure 48**). At the planting site, carefully separate any seedlings that may be joined together by the roots (this will only happen if the nursery was not thinned properly).

**Step 4** - Hold a seedling in one hand and using two fingers of the other hand make a hole 3-5cm deep at a marked position (see **Figure 49**). Then carefully place the seedling in the planting hole with the roots pointing down (see **Figure 50**).

**Step 5** - Press the soil firmly around the root collar of the seedling with your fingers to keep it upright and to expel all trapped air (see **Figure 51**).

**Figure 47: Carefully lift seedlings one by one**

**Step 6** - Repeat Steps 4 and 5 until all seedlings are planted.

**Figure 48: Carry seedlings in a bowl**

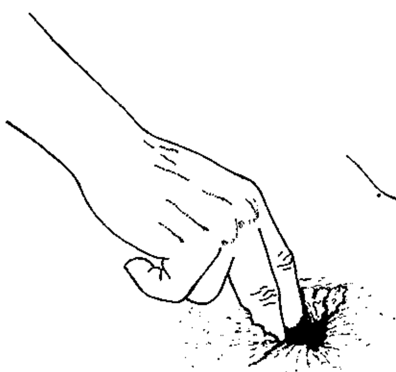


**Figure 49: Make a 3-5 cm deep hole**

**Figure 50: Place seedling in hole with roots down**

**Figure 51: Firm the soil around the root collar**

### Direct sowing

Some crops such as maize, beans, watermelon and cucumber can be directly sown into basins. See CHAPTER 6: CROP SPECIFIC DATA for details on planting depth and number of seeds per station.

**Step 1** - Make holes to the required depth at the marked planting stations (see **Figure 52**).

**Step 2** - Place the correct number of seeds in each planting hole (see **Figure 53**) and then cover them with soil.

## IRRIGATION

### Introduction

This section discusses key factors that influence the amount of water that a crop requires for optimum growth. They include:

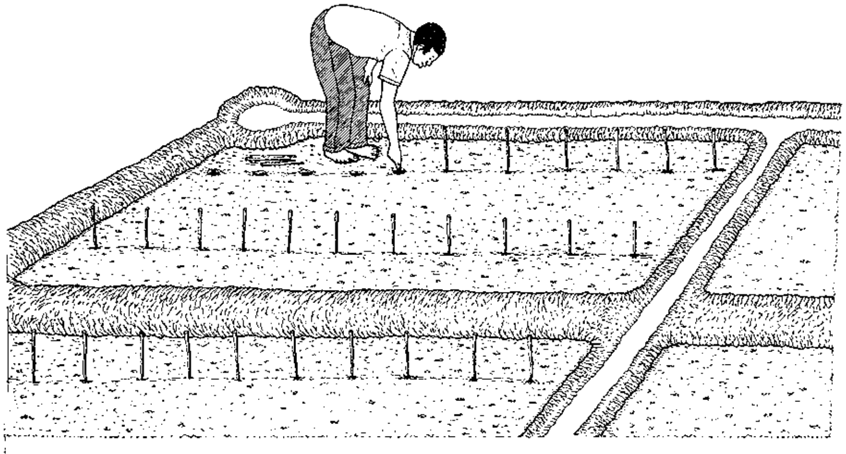
- soil characteristics
- crop type, rooting depth, water extraction potential and growth stage
- weather conditions.

### Soil Wetting Depth

The objective of irrigation is to supply the required amount of water, for plants to extract through their roots, for optimum growth. When water is applied to a basin it penetrates the soil moving downwards over time. The more water applied the deeper the wetting depth. **The golden rule is not to wet the soil below the root depth**. Water below root level is unavailable to the plant and applying too much water on a regular basis can reduce crop yields due to:

- a rise in the water table into the root zone which can:
    - reduce the root depth as there is no air which plant roots require to take up water and nutrients from the soil.
    - cause accumulation of salts as a result of continuous surface evaporation of water.
- a temporary absence of air in the soil due to prolonged waterlogging after irrigation.
- loss of plant nutrients as they are carried below the rooting depth by the water so becoming unavailable to the plant.

**Figure 52: Marking out hybrid maize planting stations at 75 x 25 cm**



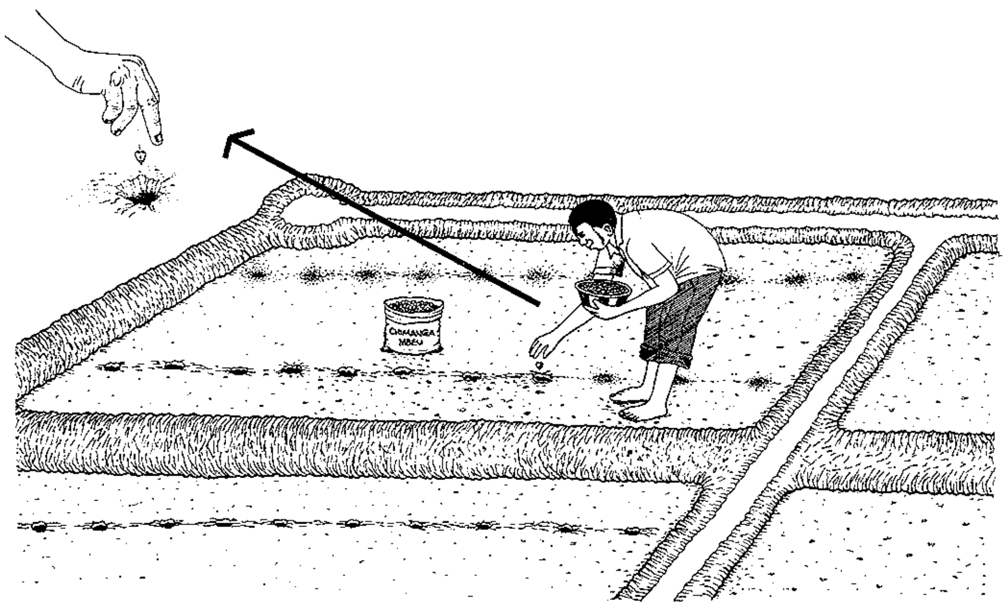


**Figure 53: Planting hybrid maize at one seed per planting station**

**Table 4: Rooting Depth of Mature, Well-Irrigated Crops**

| Shallow Rooted 0 - 0.6 m | Moderately Rooted 0.5 - 1.2 m | Deep rooted 1.0 - 2.0 m |
|---|---|---|
| Broccoli (0.3-0.6) | Beans (0.5-0.7) | Maize (1.0-1.7) |
| Cabbage (0.4-0.5) | Carrots (0.5-1.0) | Sorghum (1.0-2.0) |
| Lettuce (0.3-0.5) | Groundnuts (0.5-1.0) | Sugarcane (1.2-2.0) |
| Onions (0.3-0.5) | | |
| Potatoes (0.4-0.6) | | |
| Spinach (0.3-0.5) | | |

## Root Depth

In general, **root depth is approximately equal to the height of the plant.** The root depth increases as the plant grows to maturity. **Table 4** lists approximate maximum root depths for mature well-irrigated crops.

Very frequent irrigation will not allow the development of a deep root system as the roots will not need to go down far to extract water. This is not recommended as it will limit the amount of water the plant can extract from the soil during periods of water shortage.

## Basin Water Depth

Having established the approximate depth to which the soil should be wetted for a particular crop, the next question is how much water to put in the basin to achieve this level. The water depth is simply the depth of the water ponded in the basin when irrigating. The greater the water depth, the deeper the soil will be wetted. For any given water depth in the basin, the wetting depth is primarily dependent on the soil type.

The type of soil determines how fast water moves through the soil, and the amount of water that can be stored and made available to the plant. Water moves much faster through sandy than clay soils which means that the sandy soil will be wetted deeper than the clay soil by the same depth of water in the basin. This means lighter soils require less water to fill the root zone.

On the other hand, the water storage capacity of sandy soils is lower than that of clay soils. This means that lighter soils

**Table 5: Basin Water Depth to Fill Root Zone (cm)**

| Soil Type | Basin water depth by crop root depth | | |
|---|---|---|---|
| | Shallow 50 cm | Medium 100 cm | Deep 150 cm |
| Clay | 4 | 8 | 12 |
| Clay loam | 4 | 9 | 13 |
| Loam | 4 | 8 | 12 |
| Sandy Loam | 3 | 6 | 9 |
| Sand | 2 | 4 | 6 |

require more frequent irrigation than heavy soils. In summary, light soils such as sandy loams require more frequent but lighter irrigation than heavy clay soils.

**Table 5** gives an indication of the basin water depth required to wet different soil types to a specified rooting depth. In practice, the wetting depth has to be determined by the farmer by trial and error. Do this by digging into the basin 1 or 2 days after irrigation (1 for light soils and 2 for heavy soils) to see how far down the moisture has traveled in the soil. If it is not as deep as the roots, then more water needs to be applied at each irrigation.

**As a general rule, a basin water depth of 6-8 cm is adequate.**

## Crop Water Requirements

Crops require water for growth. Water is extracted from the soil by the roots and transported to the leaves where it transpires. If the soil is too dry insufficient water will reach the leaves. This will restrict growth and yields and the crop will eventually die if water is not applied. Wilting is a physical sign of a water shortage in the plant.

The amount and timing of irrigation required varies by crop. Different crops also require different amounts of water at different stages of growth and vary in their tolerance to periods of water stress. The latter characteristic is related to the ability of different crops to extract water from the soil (see **Table 6**). Maize is very tolerant to

**Table 6: Crop Water Extraction Ability**

| | Group | Crops |
|---|---|---|
| Increasing ability to extract water ↓ | 1 | Onion, pepper, potato |
| | 2 | Banana, cabbage, pea, tomato |
| | 3 | Bean, groundnut |
| | 4 | Maize, sorghum, sugarcane |

periods without water and requires less frequent irrigation than vegetables like cabbages or onions.

As the crop develops, its water demand increases along with the depth of the roots. Therefore, crops need to be irrigated more frequently but with less water during the early stages of development.

Most crops have critical growth stages when water shortages are more damaging to crop yield than at other times. It is crucial to ensure that adequate irrigation is provided at these times. **Table 7** lists the critical development stages for some common crops.

The weather also affects crop water requirements. Crops planted in the cool dry season (April/May) will require less

**Table 7: Critical Development Stages for Some Crops**

| Crop | Critical Stages |
|---|---|
| **Beans** | During flowering and pod filling |
| **Cabbage** | During head enlargement and ripening |
| **Maize** | Flowering (from emergence to pollination) and grain filling |
| **Onion** | During rapid bulb growth |
| **Peas** | At the start of flowering and when the pods are swelling |
| **Potato** | Start of potato formation, early vegetative period and ripening |
| **Sugarcane** | During periods of tillering and stalk elongation |
| **Tomato** | From flowering to harvest |

**Table 8: Approximate Irrigation Frequencies for Treadle Pump Irrigation in Malawi**

| Time of planting/ transplanting | Crop type | Growth stage | Irrigation interval (days) |
|---|---|---|---|
| **Cool dry season** April-July | **Sensitive Vegetables** – Onion, pepper | Initial | **3** |
| | | Development | **4–5** |
| | | Mid to late season | **3–4** |
| | **Tolerant vegetables** – Tomato, cabbage, rape | Initial | **4–5** |
| | | Development | **7-8** |
| | | Mid to late season | **7** |
| | **Green maize** | Initial | **6-8** |
| | | Development | **9-11** |
| | | Mid to late season | **6-8** |
| **Hot dry season** August-November | **Sensitive Vegetables** – Onion, pepper | Initial | **2–3** |
| | | Development | **3–4** |
| | | Mid to late season | **3** |
| | **Tolerant vegetables** – Tomato, cabbage, rape | Initial | **4-5** |
| | | Development | **5** |
| | | Mid to late season | **4** |
| | **Green maize** | Initial | **5-7** |
| | | Development | **5-7** |
| | | Mid to late season | **4-6** |

**Notes:**

1. The irrigation frequencies, in days, given in this table are only a very approximate guide and do not account for differing soil types, different locations within the country or short-term weather conditions. The best guide is always to feel the soil and examine the crop for any sign of stress.

2. The development stages correspond to:
**Initial** – germination and early growth with less than 10 percent crop cover.
**Crop development** - up to the time when the crop achieves full ground cover.
**Mid to late season** — from full cover through flowering and fruit set until maturity.

irrigation than those planted later during the hot dry season (July/August).

**Note:** The time of day when irrigation is applied is not considered important as far as crops are concerned. Early morning or late afternoon irrigation may be preferable from the farmer's point of view as it is cooler to work at these times.

## Irrigation Frequency

An approximate guide to irrigation frequencies using a treadle pump is provided in **Table 8**. A rigid irrigation schedule is not recommended due to the multitude of factors influencing the crop water requirement described above. A better option is for the farmer to examine the crop and the soil for indications of the amount of water in the soil, then apply water as required.

### Method 1 - Crop Appearance

Physical signs to look for in the crop include the colour and condition of the crop cover. If the leaves seem discoloured (greyish green) or wilted in early morning or late evening, this is a good indication that the plant is stressed and needs water. However, plants wilting temporarily in the heat of the day but recovering in late afternoon is not a sign of water shortage.

### Method 2 - Feel of Soil

Taking a sample of the soil and 'feeling' it can provide an indication of the available water content. Take the sample from a suitable depth, depending on crop rooting zone, and not simply from the surface. **Table 9** relates the feel of the soil to its water content. Except for very sandy soil, if the soil cannot be moulded into even a weak ball, then irrigation should be given.

The norm for most crops is to irrigate:

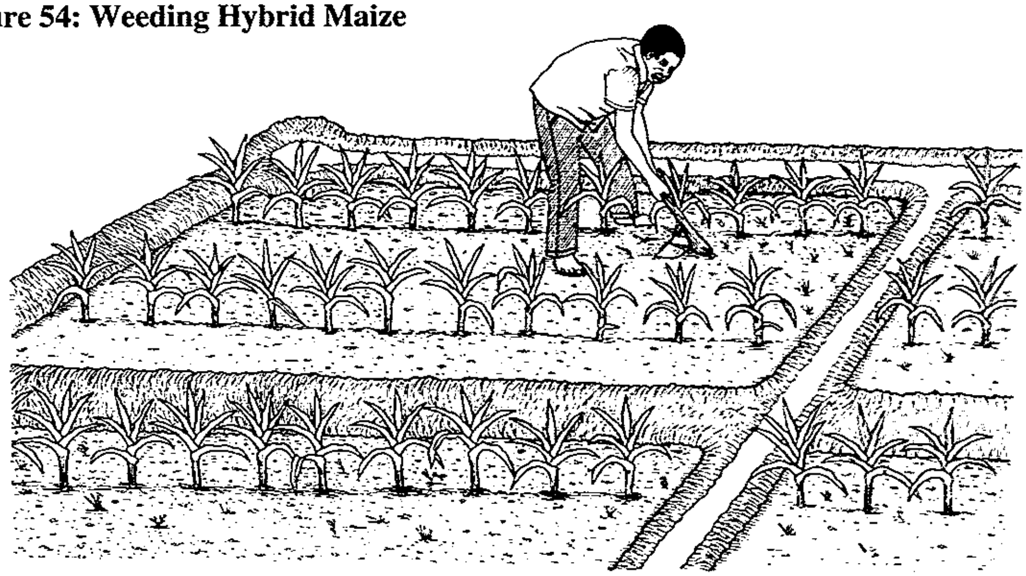
- every **5-7 days** during the **cool dry season (April - July)**
- every **3-5 days** during the **hot dry season (August - December).**

**Note:** Take rainfall into account as this can replenish soil moisture. Do this by examining the depth of soil penetration one day after the rainfall. If no significant wetting depth is found the contribution of the rain can be ignored and irrigation should continue as normal.

## Table 9: Field Test for Judging Water Content in a Soil

| Depletion of available soil moisture in percent | Coarse/light textured soil | Moderately coarse textured soil | Medium textured soil | Fine textured/Heavy soil |
|---|---|---|---|---|
| **0 (Field Capacity)** | On squeezing, no free water appears on the soil ball but a wet outline is left on the hand. | On squeezing, no free water appears on the soil ball but a wet outline is left on the hand. | On squeezing, no free water appears on the soil ball but a wet outline is left on the hand. | On squeezing, no free water appears on the soil ball but a wet outline is left on the hand. |
| **0–25%** | Tends to stick together slightly and may form a weak ball under pressure. | Forms a weak ball that easily breaks. | Forms a ball, soil is pliable. Feels slippery if clay content is high. | Easily rolls out into a ribbon. |
| **25–50%** | Feels dry and will not form a ball even under pressure. | Will form a ball under pressure but it will not hold together. | Will form a mouldable ball. | Will form a ball and can be rolled into a ribbon |
| **50–75%** | Feels dry and will not form a ball even under pressure. | Feels dry and will not form a ball even under pressure. | Somewhat crumbly but will hold together under pressure. | Can be moulded and will form a ball under pressure. |
| **75–100% (Permanent wilting point)** | Dry, loose, soil grains run through fingers. | Dry, easily crumbles through fingers. | Powdery, dry, may be slightly crusted but easily powdered. | Hard, baked and cracked with loose crumbs on surface. |

**Figure 54: Weeding Hybrid Maize**



## WEEDING AND SUCKERING

Keep crops weed-free at all times (see **Figure 54**). Competition from weeds for nutrients and light will reduce crop yields, particularly during the early stages of crop growth.

Suckering (also known as pruning) involves the removal of excess shoots from the plant to encourage better fruit size and quality. Removal by hand is recommended when the shoots are small to minimise damage to the plant. Suckering is particularly recommended for maize and tomato plants.

## FERTILISATION

This manual recommends a combination of organic (e.g. animal manure) and inorganic (e.g. CAN) fertiliser. The addition of organic manure can improve the use efficiency of inorganic fertiliser, particularly in soils deficient in organic material. This complementary relationship means that lower than recommended rates of inorganic fertiliser can be applied to good effect.

The organic manure recommendation is to thoroughly mix 2 buckets of animal or compost manure into every basin before

*Drumhead cabbage before heading*

*Chinese leaf ready for harvesting*

*Good stand of dry season hybrid maize*

*Hybrid maize under the treadle pump basin system (left half of picture) compared with irrigation using a watering can (right half of picture)* planting (see **Figure 45**). Agroforestry alternatives such as dispersed systematic interplanting with soil-improving trees are also encouraged (see CHAPTER 7: COMPOSTING, AGROFORESTRY AND SOIL CONSERVATION PRACTICES).

Crop specific inorganic fertiliser application rates are detailed in the next chapter. Use Compound D (or 23:21:0+4S) for the basal dressing and CAN (or Ammonium Nitrate) for the top dressing.

Apply the basal dressing 3-4 days after transplanting seedlings, or immediately after emergence for direct sown seed. A split top dressing is recommended with the first applied 3 weeks after planting/ transplanting, followed by the second 2 weeks later.

Apply fertiliser in the soil close to the roots of the crop. Make a hole 3-5cm deep with a stick close to the plant, place the the fertiliser in the hole with a bottletop, and then cover the hole (see **Figures 55** & **56**). In the case of maize (see **Figure 57**) and beans, apply the fertiliser between planting stations.

Broadcasting fertiliser on the surface is not recommended as it is not accessible by the roots and can be lost through run-off or volatilisation.

## PEST MANAGEMENT

Vegetable crops are particularly vulnerable to diseases and pests which can

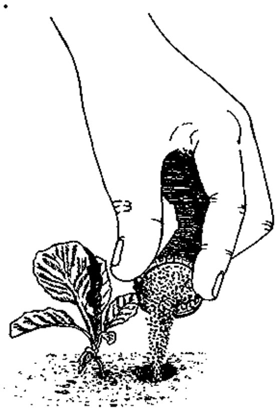


**Figure 55: Place fertiliser in the hole**

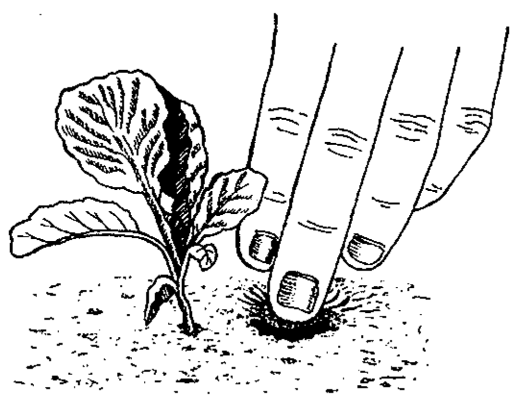


**Figure 56: Close the hole afterwards**

**Figure 57: Top Dressing Maize with CAN**


significantly reduce yields and quality. Chemical pesticides can be used to mitigate pest and disease problems (see **CHAPTER 6: CROP SPECIFIC DATA**) but they are expensive, and may be hazardous to the farmer and environment. Alternative methods of reducing pest and disease problems include:

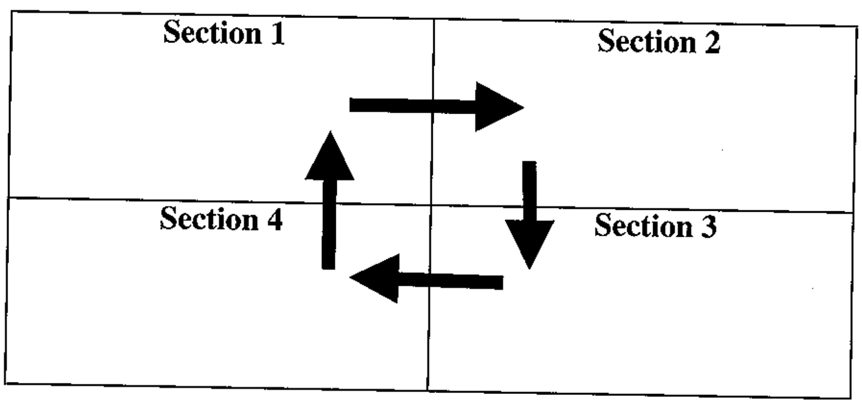
- Using certified seed that is disease free and has good germination characteristics.
- Promoting vigorous plant growth by following recommended manuring, fertilising, weeding and irrigation practices will allow the development of strong plants less susceptible to pests and diseases.
- Crop rotation (see next section) will prevent build up of pests and diseases over crop seasons.
- Growing crop cultivars resistant to common diseases and pests.
- Isolating the cropping area from thesurrounding vegetation with a wide, clean cultivated strip of land.

- Regular scouting of crop fields for pests and diseases to allow early intervention.
- Growing crops prone to pests and diseases earlier in the dry season (e.g. plant tomatoes and cabbages in May/ June).
- Using extract of *Tephrosia vogelii* leaves as an organic pesticide (see CHAPTER 7: COMPOSTING, AGROFORESTRY AND SOIL CONSERVATION PRACTICES.

## CROP ROTATION

Crop rotation is the alternating of different crops, or crop families, each season. This reduces build up of pests and diseases common to a particular crop family and helps maintain soil fertility. A sample rotational plan is detailed in **Figure 58.**

**Figure 58: Crop rotation plan**

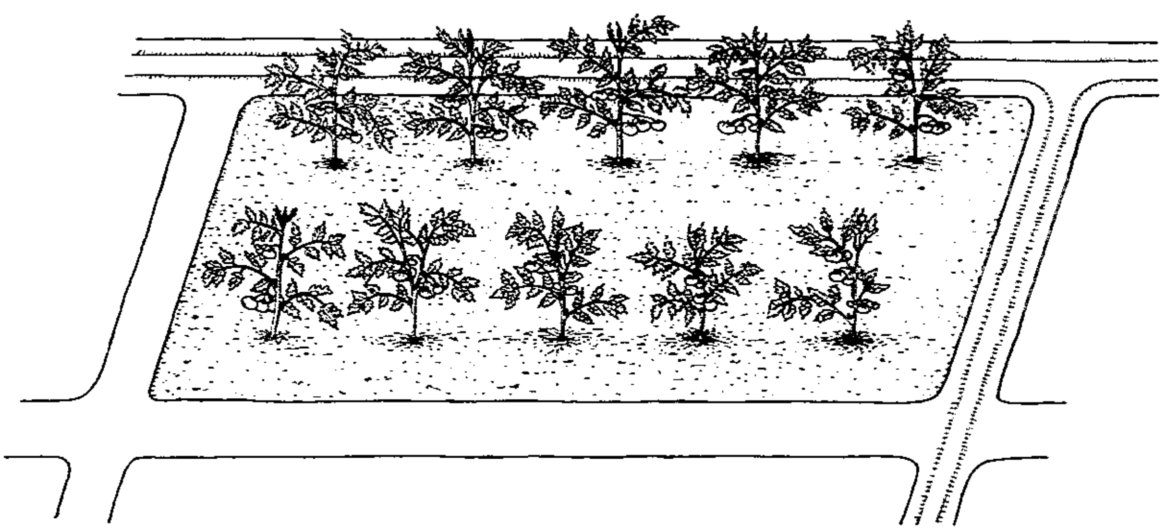



**Section 1: Solanaceae** - tomato, eggplant, green pepper
**Section 2: Cruciferous** - drumhead cabbage, chinese leaf
**Section 3: Root/bulb crops and legumes** - onions, garlic, carrots and beans
**Section 4: Cucurbit and Cereals** - cucumber, watermelons, maize

## INTRODUCTION

This chapter provides a general guide on growing selected horticultural and cereal crops. Consult the RDP Horticulturist for more detailed information on how to grow each of these crops. For more information on pests and diseases consult the **Handbook on Major Pests and Diseases in Malawi** produced by the Malawi-German Plant Protection Project (MGPPP).

**Figure 59: Tomato - one seedling per station at 90 x 60 cm**



**Crop: TOMATO** (*Lycopersicon esculentum* )

**Family:** Solanaceae

**Common varieties:** Moneymaker; Roma VF

| Climate and soil requirement | Planting & Spacing | Fertiliser | Pest and Disease Control |
|---|---|---|---|
| Prefer cool to warm, dry with temperatures of 21 - 24°C.<br><br>Heat retards growth and fruit set. During wet season tomato suffers badly from disease and fruit fails to ripen.<br><br>Tomatoes can tolerate a wide range of fertile well-drained soils. | Transplant seedlings when 10–15cm tall at 90 cm between rows and 60 cm between planting stations.<br><br>When 15 cm tall use wooden stakes to keep plants upright and off the ground.<br><br>Prune side shoots to increase fruit size. Prune by hand when shoots are still small. | **Manure:** 2 buckets manure per basin before transplanting.<br><br>**Basal**: 2 heaped bottletops Compound D per planting station (200 kg/ha or 33% recommended rate) 3-4 days after transplanting.<br><br>**Top dressing 1**: 1 level bottletop CAN per planting station (67.5 kg/ha or 75% recommended rate) 3 weeks after transplanting.<br><br>**Top Dressing 2**: apply two weeks later at same rate as first top dressing. | **Pests:**<br>(a) Red spider mites<br>- Isolate new from infested crops.<br>- Burn all crop residues after harvest.<br>- Spray with acaricides (Propargite/Dicofol)<br>- Intercrop with garlic or onions.<br><br>(b) African bollworm<br>- Spray with Alfamethrin (Fastac), Lambdacyhalothrin (Karate) or Cypermethrin at 1 ml/l.<br><br>**Diseases:**<br>(a) Early and late blight<br>- Weekly spraying with Mancozeb (Dithane M45) 2g/litre; Chlorothalonil (Daconil 2787 W-75) 40g in 14 litres of water for knapsack or one litre of water for ULV sprayer.<br>- Destroy old crop residues; isolate new from old crop.<br>- Follow field hygeine practices.<br><br>(b) Bacterial wilt<br>- Crop rotation and remove infested plants and crop debris.<br><br>(c) Root knot nematodes<br>- Crop rotation.<br>- Nematicides such as Carbofuran (Furadan) 4 g per plant or Ethylene Dibromide (EDB) 4 cc per station, applied two weeks before planting. |

**Crop: Drumhead Cabbage** (*Brassica oleracea* )

**Family:** Cruciferae

**Common varieties:** Gloria (small head), Hercules (large head)

| Climate and soil requirement | Planting & Spacing | Fertiliser | Pest and Disease Control |
|---|---|---|---|
| Cooler temperatures of 15 - 20°C preferred.<br><br>Cabbages prefer fertile, moisture-retentive soil rich in humus. | Transplant seedlings when 10–15cm tall at 70 cm between rows and 60 cm between planting stations. | **Manure:** 2 buckets manure per basin before transplanting.<br><br>**Basal:** 2 heaped bottletops Compound D per planting station (267 kg/ha or 33% recommended rate) 3-4 days after transplanting.<br><br>**Top dressing 1:** 1 level bottletop CAN per planting station (80 kg/ha or 67% recommended rate) 3 weeks after transplanting.<br><br>**Top Dressing 2:** apply two weeks later at same rate as first top dressing. | **Pests:**<br>(a) Aphids<br>- Spray with Dimethoate 40 EC. 1.2ml/litre of water or Alfamethrin (Fastac) or Lambdacyhalothrin (Karate) at 1 ml/l.<br>- Spray with *Tephrosia* solution.<br><br>(b) Diamondback moth<br>- Spray with Alfamethrin (Fastac) or Lambdacyhalothrin (Karate) at 1 ml/l of water.<br>- Destroy all brassica plants after harvest.<br>- Isolate new from infested crop.<br><br>(c) Serpentine leafminer<br>- Spray with Fenthion at 1 ml/l of water.<br><br>**Diseases:**<br>(a) Black rot and Soft rot<br>- Improve field drainage.<br>- Crop rotation, rogueing and removal of all debris.<br>- Grow resistant varieties such as Hercules.<br><br>(b) Downy mildew<br>- Spray with Chlorothalonil (Daconil) at 2.5g/l of water.<br>- Destroy all crop residues after harvest.<br><br>(c) Damping-off<br>- Raise seedlings in clean, sterilised nursery soil.<br>- Apply copper-based fungicide. |

Figure 60: Drumhead Cabbage - one seedling per station at 70 x 60 cm

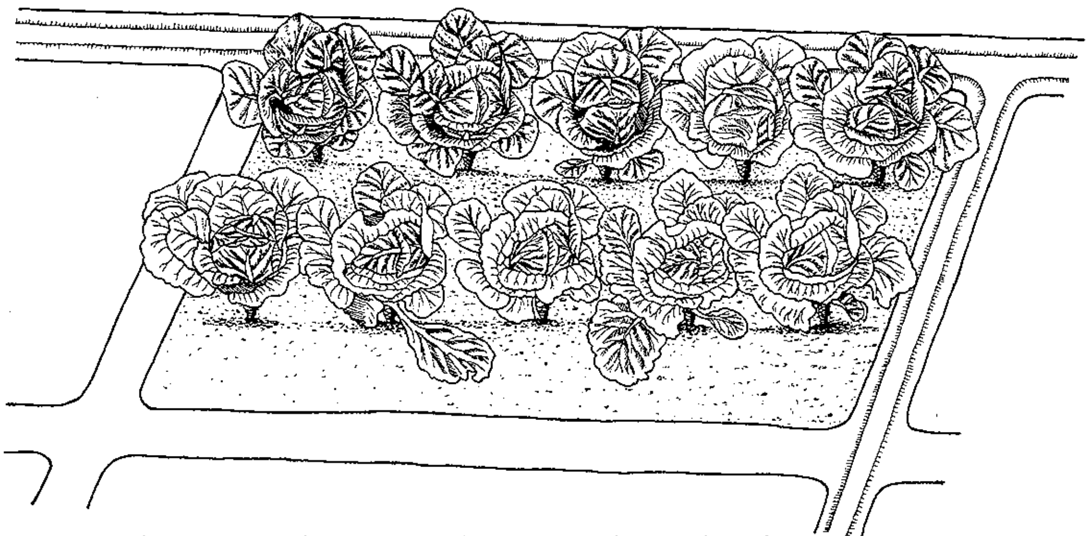
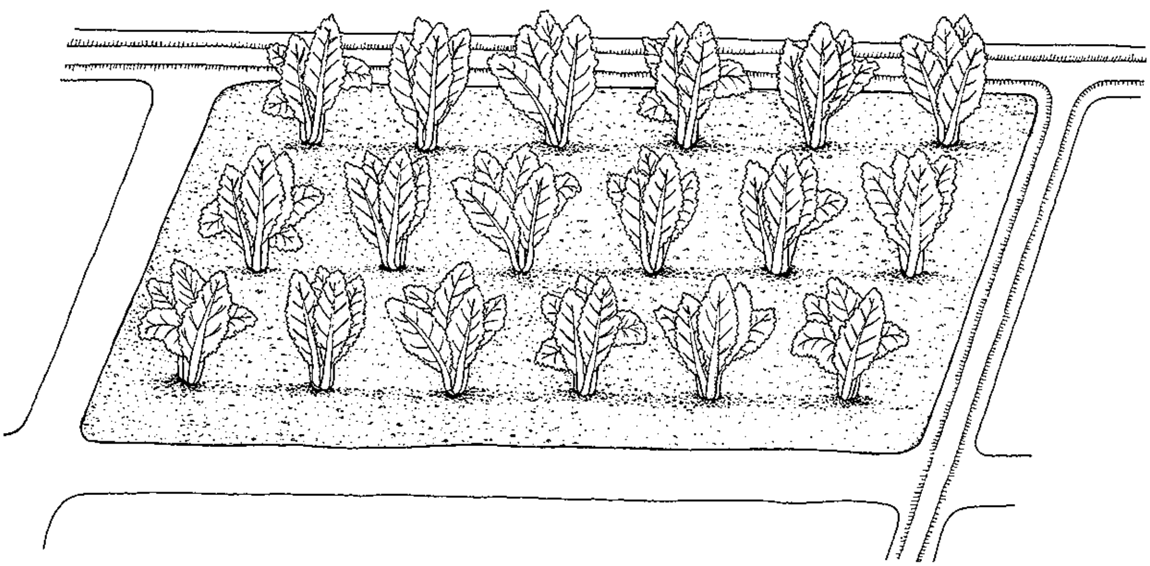


Figure 61: Chinese Leaf - one seedling per station at 45 x 45 cm



**Crop:** **Chinese Leaf** (*Brassica chinensis*)

**Family:** Cruciferae

**Common varieties:** Chihili, Kinap F1, Tropa F1

| Climate and soil requirement | Planting & Spacing | Fertiliser | Pest and Disease Control |
|---|---|---|---|
| Can be grown all year round but grows better during cool dry season.<br><br>Prefers fertile, moisture-retentive soils rich in organic matter. | Transplant seedlings when 10–15cm tall at 45 cm between rows and 45 cm between planting stations. | **Manure:** 2 buckets manure per basin before transplanting.<br><br>**Basal:** 2 level bottletops Compound D per planting station (400 kg/ha or 50% recommended rate) 3-4 days after transplanting.<br><br>**Top dressing 1:** ½ bottletop CAN per planting station (90 kg/ha or 75% recommended rate) 3 weeks after transplanting.<br><br>**Top Dressing 2:** apply two weeks later at same rate as first top dressing. | **Pests:**<br>(a) Diamondback moth<br>- Spray with Alfamethrin (Fastac) or Lambdacyhalothrin (Karate) at 1ml/l of water.<br>- Destroy all brassica plants after harvest.<br>- Isolate new crop from infested crop.<br><br>**Diseases:**<br>(a) Soft rot<br>- Improve field drainage.<br>- Crop rotation, rogueing and removal of all debris. |

**Crop: Green Pepper** (*Capsicum annuum* )

**Family:** Solanaceae

**Common varieties:** California Wonder, Florida Resistant Giant

| Climate and soil requirement | Planting & Spacing | Fertiliser | Pest and Disease Control |
|---|---|---|---|
| Can be grown all year round but grows better during cool dry season. Temperatures above 30°C may reduce fruit set and cause buds and flowers to drop.<br><br>Moderately deep, fertile well-drained soil preferred. | Transplant seedlings when 10–15cm tall at 90 cm between rows and 45 cm between planting stations. | **Manure:** 2 buckets manure per basin before transplanting.<br><br>**Basal**: 2 heaped bottletops Compound D per planting station (266 kg/ha or 33% recommended rate) 3-4 days after transplanting.<br><br>**Top dressing 1**: 1 level bottletop CAN per planting station (100 kg/ha or 67% recommended rate) 3 weeks after transplanting.<br><br>**Top Dressing 2**: apply two weeks later at same rate as first top dressing. | **Pests:**<br>(a) Whiteflies<br>- Spray with Alfamethrin (Fastac) at 1ml/l of water.<br><br>(b) Aphids<br>- Spray with a selective aphicide such as Primicarb (Pirimor).<br>- Spray with *Tephrosia* solution.<br><br>**Diseases:**<br>(a) Fusarium wilt<br>- Improve field drainage.<br>- Field hygeine, crop rotation, rogueing and avoid mechanical damage to plants.<br>- Uproot and destroy all infected plants. |

Figure 62: Green pepper - one seedling 90 x 45 cm

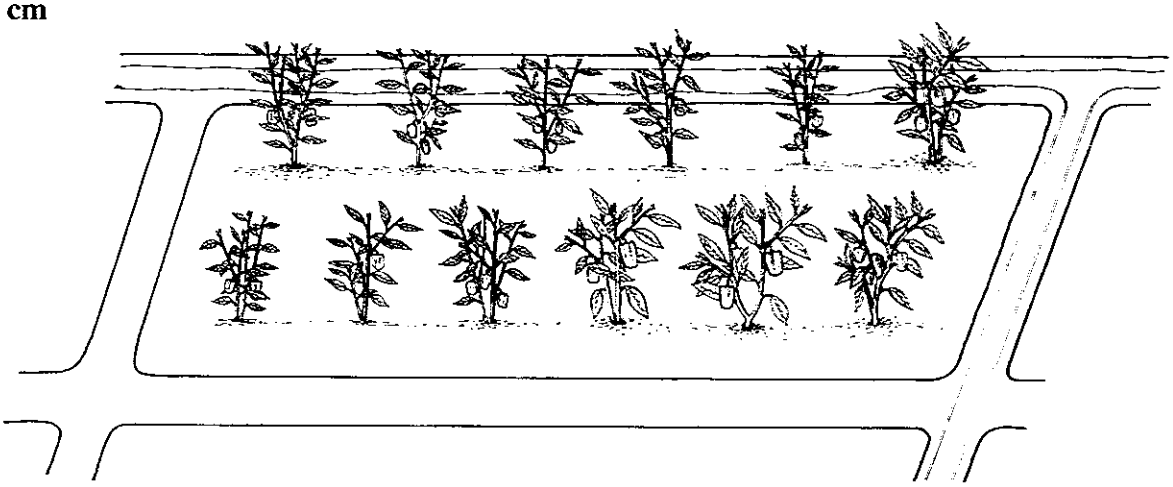
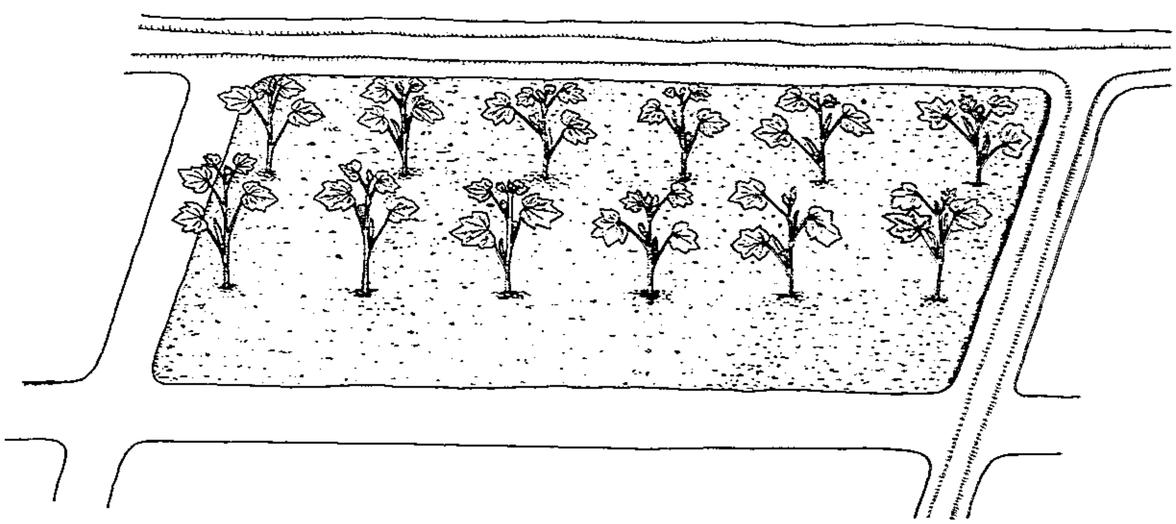


Figure 63: Okra - two seeds per station (thin to one) 90 x 45 cm



**Crop: Okra** (*Abelmoschus esculentus*)

**Family:** Malvaceae

**Common varieties:** Clemson Spineless, Green Velvet, Perkin Spineless

| Climate and soil requirement | Planting & Spacing | Fertiliser | Pest and Disease Control |
|---|---|---|---|
| Either cool or warm dry season. Well adapted to high temperatures. Optimum growing temperatures of 20 - 30°C.<br><br>Okra prefers well-drained soils. | Direct sowing at 90 cm between rows and 45 cm between planting stations.<br><br>2 seeds per station 2½ cm deep.<br><br>Thin to one plant per station. | **Manure:** 2 buckets manure per basin before transplanting.<br><br>**Basal:** ½ bottletop Compound D per planting station (133 kg/ha or 33% recommended rate) immediately after emergence.<br><br>**Top dressing 1:** ½ bottletop CAN per planting station (92 kg/ha or 75% recommended rate) 3 weeks after planting.<br><br>**Top Dressing 2:** apply two weeks later at same rate as first top dressing. | **Pests:**<br>(a) Aphids<br>- Isolate new from old crop.<br>- Destroy Okra plants after harvest.<br>-Spray with a selective aphicide such as Primicarb (Pirimor).<br>- Spray with *Tephrosia* soulution.<br><br>(b) Red cotton bugs<br>- Isolate new crop from old crop.<br>- Spray with Fastac 1 ml/l of water.<br><br>(c) African bollworm and other caterpillars<br>- Spray with Fastac 1 ml/l if infestation is serious.<br><br>**Diseases:**<br>(a) Powdery mildew<br>- Spray with fungicides such as Benomyl (Benlate) 1 g/l, Chlorothalonil (Bravo) 2.5 ml/l or Hexaconazole (Anvil) 2 ml/l.<br><br>(b) Root knot nematodes<br>- Crop rotation.<br>- Use certified seed.<br>- Apply decomposed manure. |

**Crop: Runner Beans** (*Phaseolus vulgaris* )

**Family:** Leguminosae

**Common varieties:** Maluwa, Nasaka

| Climate and soil requirement | Planting & Spacing | Fertiliser | Pest and Disease Control |
|---|---|---|---|
| Grows best during the cool dry season with temperatures of 16 - 30°C.<br><br>Beans grow best in rich, well-drained light soils. | Direct sowing at 40 cm between rows and 20 cm between planting stations.<br><br>2 seeds per station 2½ cm deep. | **Manure:** 2 buckets manure per basin before transplanting.<br><br>**Basal:** ½ bottletop Compound D per planting station (300 kg/ha recommended rate) immediately after emergence.<br><br>**Top dressing:** no top dressing recommended. | **Pests:**<br>(a) Bean beetle<br>- Spray with Carbaryl 85 WP. 6g/litre water.<br><br>**Diseases:**<br>(a) Anthracnose<br>- Crop rotation.<br>- Destroy crop residues after harvest.<br>- Spray with Mancozeb (Dithane M45) 2-3 g/litre of water.<br><br>(b) Bacterial blight<br>- Crop rotation.<br>- Isolate new from old crop.<br>- Destroy infected crop residues after harvest.<br>- Spray with Mancozeb (Dithane M45) 2-3 g/litre of water.<br><br>(c) Mosaic virus<br>- Use certified seed.<br>- Rogue infected plants.<br>- Spray Primicarb against aphids. |

**Figure 64: Runner beans - 2 seed sper station 40 x 20 cm**

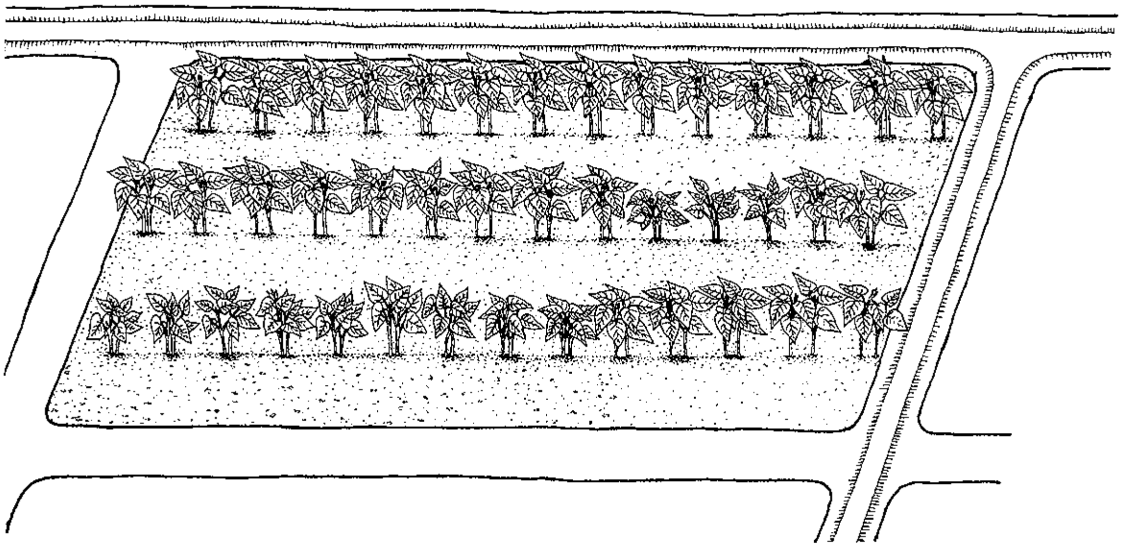
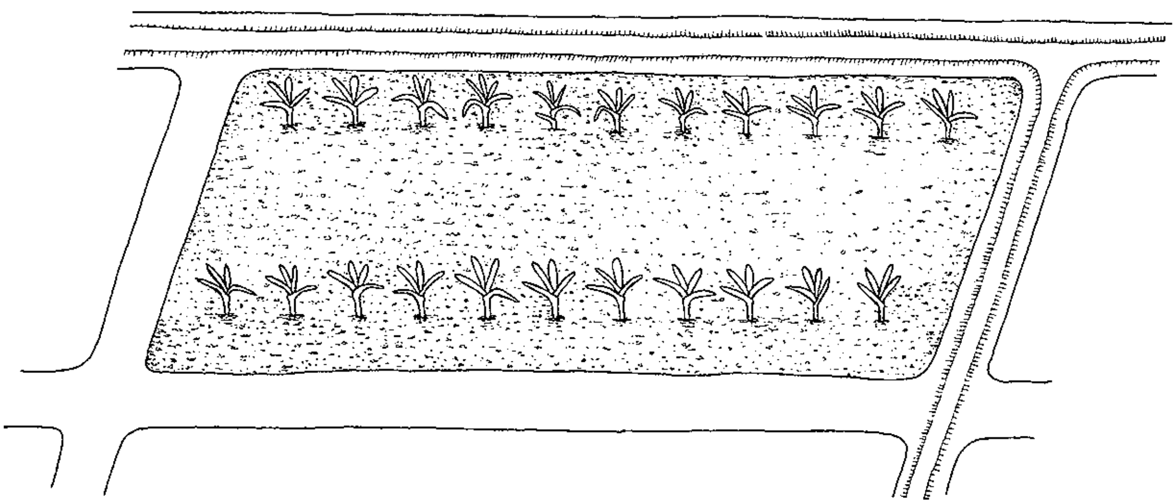


**Figure 65: Hybrid maize - one seed per station 75 x 25 cm**



**Crop: Hybrid Maize** (*Zea mays* )

**Family:** Cereal

**Common varieties:** NSCM 41, NSCM 51, SC401, SC403, SC405

| Climate and soil requirement | Planting & Spacing | Fertiliser | Pest and Disease Control |
|---|---|---|---|
| Either cool or warm dry season. Well adapted to high temperatures.<br><br>Maize can be grown on a wide range of soils. | Direct sowing at 75 cm between rows and 25 cm between planting stations.<br><br>1 seed per station 3-5 cm deep. | **Manure:** 2 buckets manure per basin before transplanting.<br><br>**Basal:** ½ bottletop Compound D per planting station (110 kg/ha or 50% recommended rate) immediately after emergence.<br><br>**Top dressing 1:** ½ bottletop CAN per planting station (100 kg/ha or 67% recommended rate) 3 weeks after planting.<br><br>**Top Dressing 2:** apply two weeks later at same rate as first top dressing. | **Pests:**<br>(a) African armyworm<br>- Spray with Fenvalerate (Sumicidin) 1.85 ml/l of water.<br><br>(b) Maize stalkborer<br>- Apply Trichlorfon (Dipterex) 2.5% granules one pinch per plant funnel (8 kg per ha).<br>- Apply *Tephrosia* leaf solution.<br>- Destroy all crop residues.<br><br>(c) Larger grain borer<br>- Apply Pirimiphos-methyl (Actellic) dust at 40 g to 90 kg stored maize.<br>- Use flinty maize varieties.<br>- Apply dried and ground up *Tephrosia* leaves.<br><br>**Diseases:**<br>(a) Maize streak virus<br>- plant early with streak resistant varieties.<br><br>(b) Head smut<br>- Use resistant varieties<br>- Crop rotation.<br>- Remove abnormal tassels from the field before spores mature. |

**Crop: Eggplant** (*Solanum melongena* , *S. aethiopicum* )

**Family:** Solanaceae

**Common varieties:** Black Beauty (Aubergine), African Eggplant White

| Climate and soil requirement | Planting & Spacing | Fertiliser | Pest and Disease Control |
|---|---|---|---|
| Does best planted at the end of the cool dry season (i.e. August). They prefer temperatures from 25 - 30°C.<br>Below 20°C growth may be slowed.<br><br>Eggplants prefer deep, fertile, well-drained soil. | Transplant seedlings when 10–15cm tall at 90 cm between rows and 75 cm between planting stations. | **Manure:** 2 buckets manure per basin before transplanting.<br><br>**Basal**: 3 level bottletops Compound D per planting station (200 kg/ha or 33% recommended rate) 3-4 days after transplanting.<br><br>**Top dressing 1**: 1 level bottletop CAN per planting station (42 kg/ha or 67% recommended rate) 3 weeks after transplanting.<br><br>**Top Dressing 2:** apply two weeks later at same rate as first top dressing. | **Pests:**<br>(a) Aphids<br>-Spray with a selective aphicide such as Primicarb (Pirimor).<br>- Spray with *Tephrosia* solution.<br><br>(b) Leaf eaters (beetles)<br>- Spray with Karate or Fastac 1 ml/l of water.<br><br>(c) Fruit borers<br>- Spray with Fastac 1 ml/l of water.<br><br>(d) Red spider mites<br>- Isolate new from other infested crops.<br>- Spray with acaricides such as Propargite or Dicofol.<br>- Burn all crop residues after harvest. |



MALAWI AGROFORESTRY

**Figure 66: Eggplant - one seedling per station 90 x 75 cm**

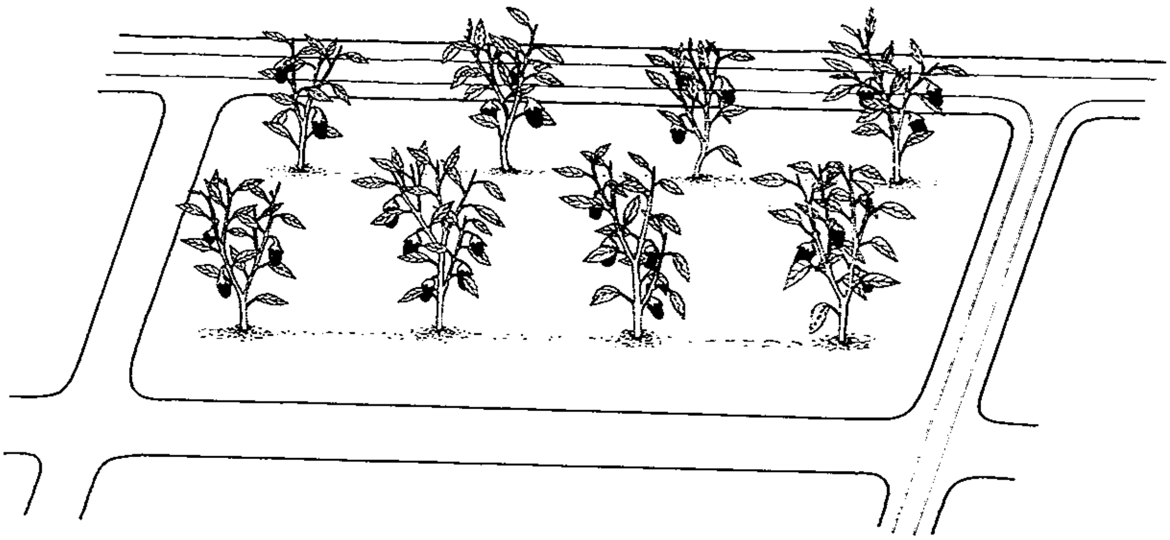
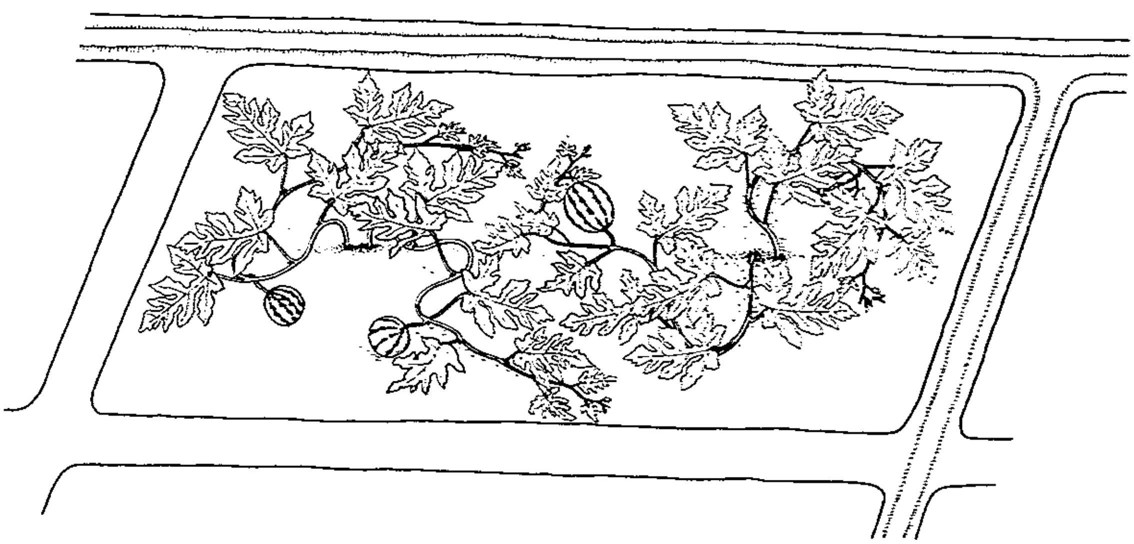


**Figure 67: Watermelon - two seeds per station 150 x 150 cm**



**Crop: Watermelon** (*Citrullus lanatus* )

**Family:** Cucurbitacae

**Common varieties:** Crimson Sweet, Chilean Black, Congo, Charleston Gray

| Climate and soil requirement | Planting & Spacing | Fertiliser | Pest and Disease Control |
|---|---|---|---|
| Watermelon does best planted at the end of the cool dry season (i.e. August). They prefer temperatures from 25 - 30°C.<br><br>Watermelons prefer well-drained sandy loam soils. | Direct sowing at 150 cm between rows and 150 cm between planting stations.<br><br>2 seeds per station 2½ cm deep. | **Manure:** 2 buckets manure per basin before transplanting.<br><br>**Basal:** 3 level bottletops Compound D per planting station (133 kg/ha or 33% recommended rate) immediately after emergence.<br><br>**Top dressing 1:** 1 level bottletop CAN per planting station (40 kg/ha or 67% recommended rate) 3 weeks after planting.<br><br>**Top Dressing 2:** apply two weeks later at same rate as first top dressing. | **Pests:**<br>(a) Fruitfly<br>- Crop rotation.<br>- Destroy old cucurbit plants after harvest.<br>- Spray with Alfamethrin (Fastac) 1 ml/l of water.<br><br>**Diseases:**<br>(a) Powdery Mildew<br>- Spray with fungicides such as Hexaconazole (Anvil) 2 ml/l or Macozeb (Dithane M45) 2 g/l. |

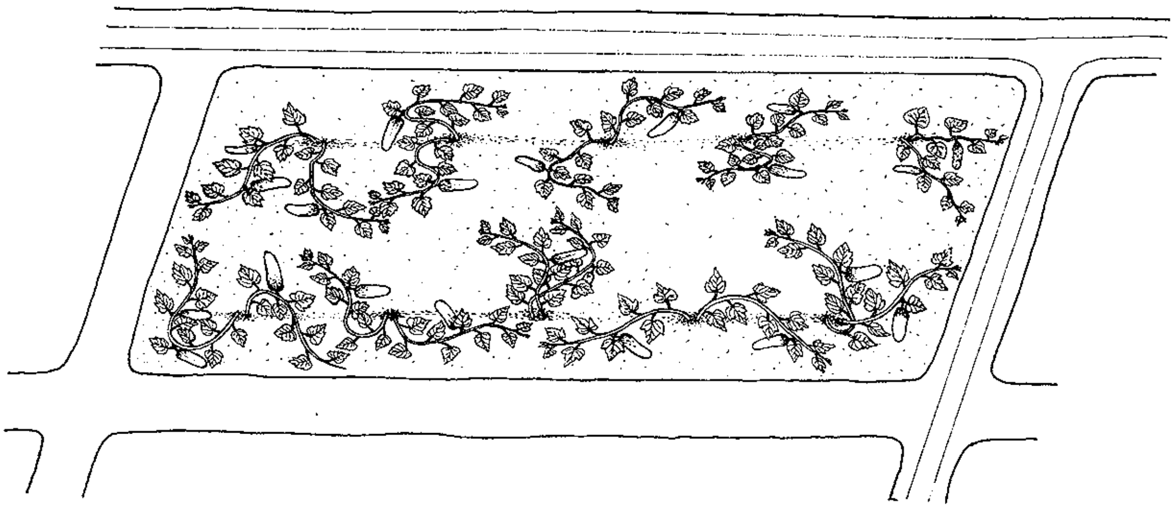
**Crop: Cucumber** *(Cucumus sativus)*

**Family:** Cucurbitacae

**Common varieties:** Sweet Crunch, Palomar DMR

| Climate and soil requirement | Planting & Spacing | Fertiliser | Pest and Disease Control |
|---|---|---|---|
| Does best in the warm dry season with mean teperatures of 18 - 30°C.<br><br>Cucumbers prefer fertile, humus-rich, well-drained soils. | Direct sowing at 60 cm between rows and 60 cm between planting stations.<br><br>2 seeds per station 2½ cm deep. | **Manure:** 2 buckets manure per basin before transplanting.<br><br>**Basal:** ½ bottletop Compound D per planting station (133 kg/ha or 33% recommended rate) immediately after emergence.<br><br>**Top dressing 1:** ½ bottletop CAN per planting station (63 kg/ha or 100% recommended rate) 3 weeks after transplanting.<br><br>**Top Dressing 2:** apply two weeks later at same rate as first top dressing. | **Pests:**<br>(a) Fruitfly<br>- Crop rotation.<br>- Destroy old cucurbit plants after harvest.<br>- Spray with Alfamethrin (Fastac) 1 ml/l of water.<br><br>(b) Aphids<br>- Spray with a selective aphicide such as Primicarb (Pirimor).<br><br>(c) Leaf eaters (beetles)<br>- Spray with Karate or Fastac 1 ml/l of water.<br><br>**Diseases:**<br>(a) Powdery Mildew<br>- Spray with fungicides such as Hexaconazole (Anvil) 2 ml/l or Macozeb (Dithane M45) 2 g/l.<br><br>(b) Anthracnose<br>- Crop rotation.<br>- Destroy crop residues after harvest.<br>- Spray with Mancozeb (Dithane M45) 2-3 g/litre of water. |

**Figure 68: Cucumber - two seed sper station 60 x 60 cm**



## INTRODUCTION

This chapter covers a range of composting, agroforestry and soil conservation techniques that are compatible with treadle pump irrigation. The use of organic manure from composting and/or agroforestry in conjunction with low rates of chemical fertilisers is recommended as an economic option to maximise crop yields.

The recommended agroforestry options include dispersed systematic interplanting of soil-improving trees such as *Faidherbia albida*, natural regeneration of existing dimba trees, streambank protection with grass and trees, live fencing with thorny species such as *Ziziphus mauritiana* and green manure banks with species like *Senna spectabilis*. *Tephrosia vogelii*, planted in areas not subject to waterlogging, is valuable for use as an insecticide for common crop pests such as aphids.

The use of vetiver grass as a barrier against soil erosion and run-off within and on the boundaries of irrigation plots is recommended.

## COMPOSTING PRACTICES

Two composting methods are described below, both in common usage in Malawi.

### Chinese or Changu Compost

**Materials**

Hoe; composting material such grass; maize stalks; groundnut haulms; watering can; animal manure; string.

**Method**

1. Demarcate a circle with a radius of 75 cm using a string and stick as a compass. Mark the circle in a shady spot to minimise evaporation from the compost heap.
2. **1st layer** - place a 20 cm thick layer of grass/maize stalks/groundnut haulms on the circle and thoroughly wet the layer. If grass is long, cut it into 30 cm lengths to aid decomposition.
3. **2nd layer** - place a 3-5 cm layer of khola manure on top of the first layer and apply more water.
4. **3rd layer** - place another 20 cm thick layer of grass/maize stalks/groundnut haulms

on top of the animal manure and apply water.

5. **4th layer** - place another 3-5 cm layer of animal manure on top of the third layer and apply more water
6. Continue this layering process, reducing the radius of the circle until you have a cone shape mound about 1.5—2 m high.
7. After 6 days, turn the compost heap splitting the exposed material into three groups:

    **Group A** — top layer not decomposed

    **Group B** — middle layer starting to decompose

    **Group C** — bottom layer mostly decomposed

8. Rebuild the cone after splitting by putting Group A as the first layer, then Group C as the second layer followed by Group B as the third layer. Apply water to each layer while rebuilding.
9. Repeat this exercise every 6 days until all the material is fully decomposed (18-21 days).

## Chimato Compost

### Materials

Hoe; composting material such as grass, maize stalks, groundnut haulms; watering can; animal manure; stick; clay soil, bricks.

### Method

1. Demarcate a rectangle 1.5 m wide by 2.0 m long. Mark the rectangle in a shady spot to minimise evaporation from the manure heap.
2. Arrange the bricks in 3 pairs of lines 10 cm apart along the length of the rectangle, with 60 cm between each pair of lines, to provide bottom ventilation to speed up the composting process (see **Figure 69**).
3. **1st layer** - place a 20 cm thick layer of grass/maize stalks/groundnut haulms on top of the bricks and thoroughly wet this layer. If grass is long, cut it into 30 cm lengths to aid decomposition.

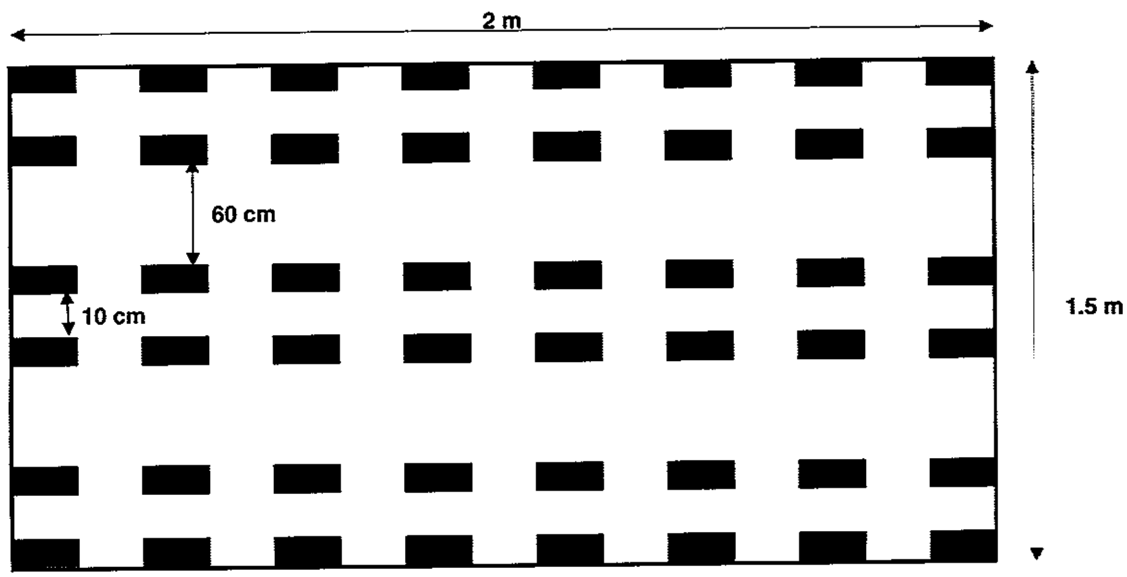
3. **2nd layer** - place a 3-5 cm layer of animal manure on top of the first layer and apply more water.

4. **3rd layer** - place another 20 cm thick layer of grass/maize stalks/groundnut haulms

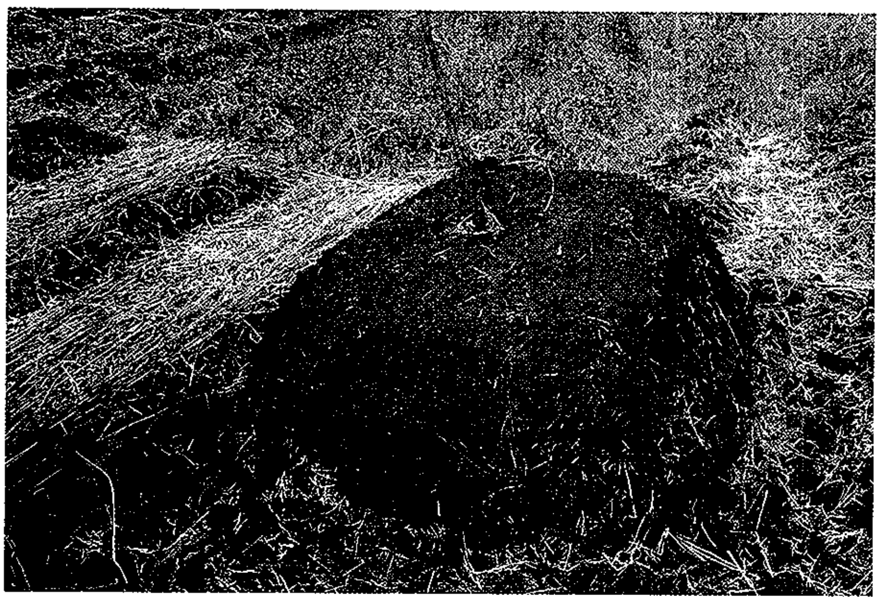
on top of the animal manure and apply water.

5. **4th layer** - place another 3-5 cm layer of animal manure on top of the third layer and apply more water.
6. Push a 1.5—2 m long vertical stick through the middle of the heap to the bottom
7. Continue the layering process until the mound is 1.5—2 m high, reducing the size of the rectangle so that the sides are sloping, with the vertical stick poking out the top.
8. Cover the heap with a thin layer of mud to create a seal.
9. Wiggle the vertical stick in the middle of the heap to create a small ventilation chimney leaving the stick in place to ensure the chimney does not collapse.
10. Apply a can of water through this ventilation hole every 7 days to speed up the composting process.
11. The material is fully decomposed after about 6-8 weeks.

**Figure 69: Chimato compost brick layout**



*Chinese compost heap*



*Chimato compost heap*

## AGROFORESTRY PRACTICES

### Dispersed Systematic Interplanting

#### Purpose and Recommended Species

Dispersed systematic interplanting (DSI) involves planting certain types of trees with crops at a wide spacing for a range of different uses and products:

¥ to improve soil fertility and crop yields

¥ to supply fuel, building material, fodder and other products for use or sale.

*Faidherbia albida* (msangu) is the tree most commonly recommended for this practice, but *Acacia polyacantha* (mthethe) and *A. galpinii* (nkunkhu) are also valuable. All are large, fast-growing leguminous trees, indigenous to Malawi, and well adapted to a wide range of habitats. They have multiple uses, and are easy to raise from seed, sources of which are abundant and easy to collect.

Planting trees in a wide but systematic manner provides uniform coverage of the area, and facilitates farm operations. This practice is popular with smallholders because it builds upon traditional agroforestry practices to sustain farm productivity over the long term, while providing other useful tree products to meet different farmer needs.

**Note on *Faidherbia albida*:** This tree is particularly beneficial for soils and crops from its unique feature of dropping nutrient-rich leaves by the start of the rains. Its bare canopy and leaf fall at this time offer light and soil conditions ideal for good crop growth. Farmers in Malawi have maintained crop yields beneath *Faidherbia albida* trees for long periods without adding fertilizers. *Faidherbia albida* also has other uses such as fuelwood and building material, shade during the hot dry season, and high quality fodder from its abundant yields of nutritious pods.

While primarily an upland agroforestry technology, DSI is also compatible with treadle pump irrigation in dambo areas. The three recommended tree species grow well in low-lying areas prone to flooding in the rainy season.

#### Nursery Production

Refer to **Landcare Practices in Malawi**, MAFE Publication No. 42 for details on tree seedling production. Start tree nurseries in May/June to allow for outplanting in the irrigated plots in August/ September. Nursery stock is recommended

*Three-year old* Faidherbia albida *trees planted at a spacing of 10 x 5 m*

*Systematic tree inter-planting of* Faidherbia albida *with a healthy stand of beans*



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for all 3 species. Direct sowing is strongly discouraged due to poor field results.

**Note:** Since *Faidherbia albida* is sensitive to root pruning, raise seedlings off the ground on platforms made of wood and reeds or bamboo (see **Landcare Practices in Malawi**, MAFE Publication No. 42). This eliminates damage from root pruning. Use medium to large open-ended polytubes, i.e. 20 x 15 cm.

### Tree Spacing

Mark planting stations on the crosspaths at a spacing of 2.7 x 6.6 m with 560 seedlings/ha. This is every other crosspath down every other line of basins (see **Figure 70**). This spacing will help ensure an adequate density of healthy surviving trees. It also provides a faster benefit to the crop when the trees are still young.

### Outplanting

Dig planting pits 30 cm in diameter and 60 cm deep in the middle of the crosspath in the marked positions. Loosen the soil at the base of the hole to reduce waterlogging and to enhance deep root growth after the seedling is outplanted. Replace the soil loosely in the pits. Start with the top soil, then add the subsoil to encourage roots to grow deeper and more quickly.

Plant seedlings in August/September. Make a hole in the loose soil of the pit large enough to fit the seedling. Squeeze the polytube so that it can be lifted off easily after placing it in the hole with the root collar level with the ground. Partially fill soil around it, then carefully pull the tube up and over the seedling. Continue filling soil around the seedling up to the root collar. Then **firmly pack down** the loose soil with the heel of your foot. Take care throughout to minimise damage to the roots and loss of nursery soil.

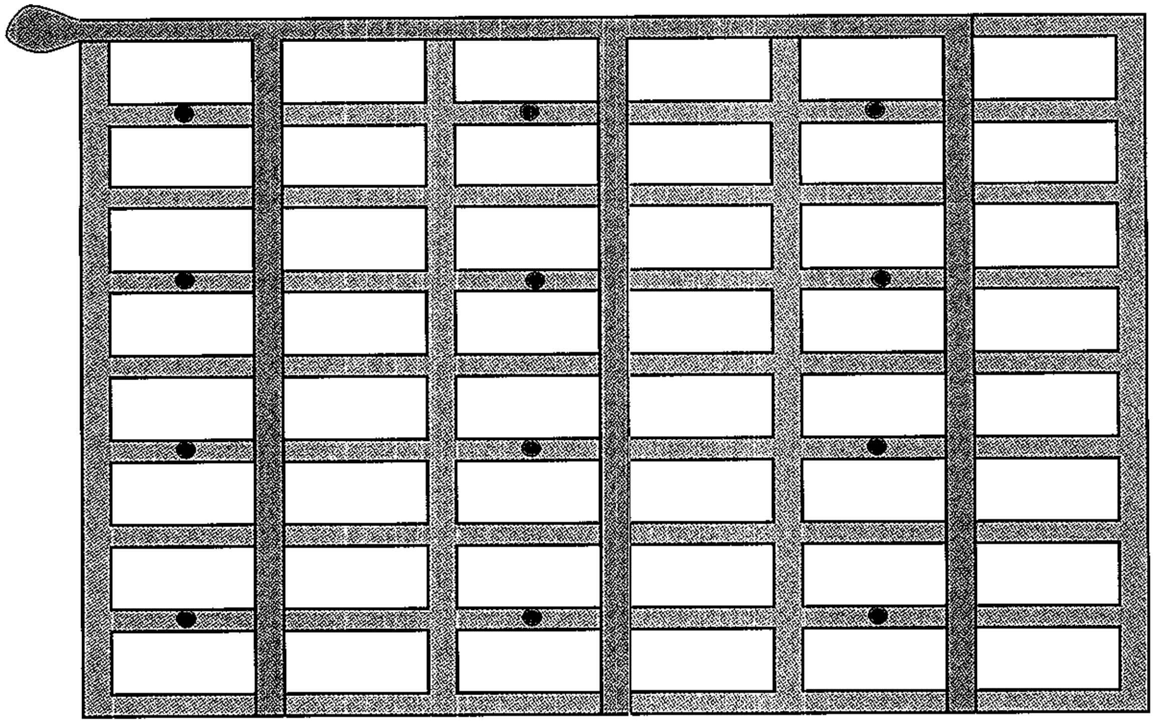
### Watering

Water the seedlings with a can once a week for three weeks. After this the trees should be able to extract enough water from the crop irrigation cycle.

### Pruning

Prune bottom branches of seedlings after the first season to promote straighter, healthier trees, and to reduce interference with field operations. Prune when trees begin active growth to reduce die-back, fungal diseases and termite attack. This is

**Figure 70: DSI Tree spacing example**



**Key:-**

● = Tree

April-May for *Faidherbia albida* and September-October for other species.

Make clean angled cuts with a sharp blade or saw to reduce injury to the tree. As trees grow to maturity, a few branches may be selectively lopped to reduce the density of the canopy. Spread the cut foliage on the ground to act as green manure, or use it as animal feed if the tree is a good fodder species. Collect the wood for fuel or other uses.

**Thinning**

After 3-5 years reduce tree numbers by half while retaining uniform coverage of the plot. Select the weakest trees first for removal. Thinning will prevent crowding and supply wood and fodder.

### Regeneration of Natural Trees

Encourage farmers to protect naturally regenerating trees in their dimba gardens. This is the **easiest** agroforestry system to adopt as it requires no tree nurseries or outplanting, and the trees are already adapted to the area.

**Recommended Species**

Choice of species depends on individual farmer preferences. Soil improving leguminous trees are recommended as this is the primary aim. Suitable species include *Acacia galpinii, A. nigrescens, A. polyacantha, Albizia versicolor, Bauhinia thonningii, Erythrina abyssinica, Faidherbia albida* and *Lonchocarpus capassa*. Non-leguminous trees are also retained on cropland by farmers for a variety of uses, although their effect on soil fertility is lower. Common species include *Azanza garkeana, Combretum* spp., *Ficus natalensis, Kigelia africana* and *Terminalia sericea.*

**Management**

Natural trees need care from weeds, fires and animals just like planted ones. As they grow in size, they also need attention to minimise shade effects on crops, and to supply wood and other products desired by the household. Follow the pruning practices specified above for healthier, straighter growing trees, taking care to avoid over-pruning which retards the ability of trees to regenerate.

**Figure 71: Streambank protection with planted vetiver and trees**

## Streambank Protection

Stream banks are the most vulnerable land areas in Malawi. They have long been cultivated due to fertility from sediments deposited by regular flooding. Despite this, stream bank soils typically have low cohesion and hence are prone to degradation. Protection is vital to stabilize stream flow and to reduce the risk of flooding, siltation, land slides and loss of arable land (see **Figure 71**).

## Establishment of vegetation

1. Demarcate a strip to cover the bank of the stream channel adjacent to your plot. The width depends on the size of the stream, e.g., 5 m for small streams; 15-30 m on the upper reaches of bigger rivers, and 30-40 m further down stream.

2. **Grasses:** Plant vetiver or bamboo inside the strips. Space vetiver at 0.45 x 0.45 m, and bamboo at 1 x 1 m.

3. **Trees:** Planting is recommended in strips at 2 x 2 m in staggered lines. Species recommended include: *Acacia galpinii, A. polyacantha, A. seiberiana, Faidherbia albida, Ficus natalensis, Khaya nyasica, Rauvolfia caffra, Trichilia emetica, Ziziphus abyssinica, Z. mauritiana* and *Z.mucronata*.

## Live Fences

### Purpose and Uses

Live fences are permanent or semi-permanent structures that serve a variety of purposes. Their main function is to eliminate the cost of constructing, maintaining and replacing other types of fences. Most often, live fences are planted to keep out domestic or wild animals where they are not well controlled. This is particularly relevant for irrigated dimba gardens where it is vital to keep animals out of crop during the dry season (see **Figure 72**). The live hedge is also used to mark boundaries of farm plots, gardens, or homesteads. Depending on the species used, they provide other products and uses such as fodder, green manure, fruits, wood for fuel and farm tools, as well as privacy.

### Recommended Species

Species recommended for most environments in Malawi include *Acacia galpinii, A. polyacantha, Ziziphus abyssinica, Z. mauritiana*, and *Z. mucronata*. These are thorny species that provide effective protection against unwanted intrusions. They need protection during the first year of growth as they are palatable to livestock.

### Nursery Production

Refer to **Landcare Practices in Malawi**, MAFE Publication No. 42 for details on tree seedling production. Tree nurseries should be started in August/ September to allow for outplanting in the dimba at the start of the rains. Nursery stock is recommended for all species.

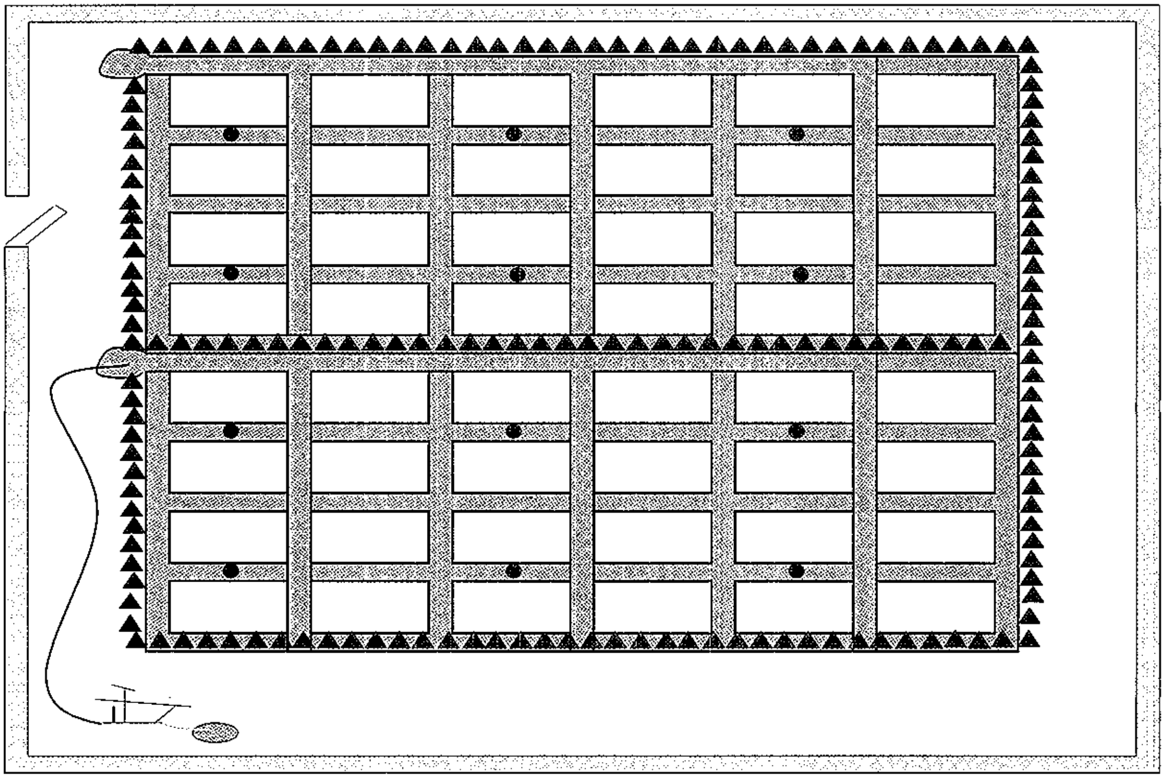
### Tree Spacing

Mark planting stations 40 cm apart along the perimeter of your plot area.

### Outplanting

Follow instructions given for DSI outplanting earlier in this chapter.

**Figure 72: Irrigated plot with vetiver and live fence**



Key:-
● = Tree ▲ = Vetiver ░ = Live fence

### Trimming

At the onset of the second or third season, trim hedges to 50-75 cm high to encourage low and dense lateral branching. Trim sides and tops of plants to 1 m to 1.5 m periodically to prevent excessive spreading growth. Trimmed branches can provide fuelwood, fodder, and thorny material for protecting other seedlings or crops.

## Green Manure Banks

### Purpose and Recommended Species

Tree banks may be established for green manure using species such as *Leucaena, Sesbania, Tephrosia, Gliricidia and Senna spectabilis*. The pruned leaves are collected and transferred to cropping areas for use as fertiliser by applying the leaf matter to the soil.

### Spacing

*Tephrosia:* 0.90 x 0.45 m

*Gliricidia, Leucaena, Sesbania:* 0.9 x 0.9 m

*Senna:* 1.8 x 1.8 m

### Pruning

Prune branches at the start of the growing season to supply fresh leaf material for direct application to the desired crop. Prunings at the end of the rainy season provide the bulk of the biomass produced during the year. After sun-drying the branches for a few days, shake off the leaves and store for use next season. Stems may again be collected for fuelwood or other uses.

### Application of Leaf Manure

Bury or apply fresh or dry leaves on the surface around the planting stations within 15 days of crop emergence. Apply leaves at a minimum rate of 1.5 MT/ha or roughly a double handful per station (120 g/station).

Once the green manure bank is fully established and producing 2 MT or more per hectare, a less labour-demanding system of application may be used. Leaves shaken off the pruned branches at the end of the crop season may be incorporated into basins with crop residues. It is important to do this immediately after pruning to avoid nutrient losses from leaching and volatilisation.

When the bank has outlived its usefulness in terms of productive biomass, farmers may opt to remove the bank to cultivate crops, or to replant the bank.

## Tephrosia

Encourage farmers to plant a pure stand of *Tephrosia vogelii* close to their irrigation plots but not on land subject to waterlogging during the rains. *Tephrosia* has insecticidal properties that can reduce damage from aphids, leaf eaters and stem borers.

**Plant Management**

Direct sow *Tephrosia* with the start of the rains in a pure stand with 3 seeds per station at a spacing of 0.45 x 0.45 m. Do not plant the seeds too deep and refill any gaps within two weeks of planting. Keep the field weed free to increase survival and growth for good biomass production.

**Pesticide Use**

After one year there should be sufficient biomass for pesticide use. Proceed as follows:

1. Strip 2 kg of fresh leaves from the plant in the late afternoon.
2. Pound them in a pestle and mortar, and place them in a bucket of water to steep overnight.
3. Sieve off the leaves in the morning keeping the remaining solution in a dark place as sunlight will reduce its effectiveness.
4. Spray the solution onto pest-infected crops using a hand sprayer or flick it on with a grass brush if no sprayer is available.
5. Repeat this exercise at regular intervals as required.

## SOIL CONSERVATION

Basin irrigation on steep slopes can lead to soil erosion and gullying from rapidly moving water down the feeder channels. The recommendation in such cases is to split the irrigated plot in smaller sections using vetiver grass as a protective barrier (see **Figure 72**).

Splitting the plot entails planting lines of vetiver grass at regular intervals across the slope which necessitates the construction of an additional main channel for each section of the original plot. This shortens the length of the feeder channels which reduces water velocity with the vetiver serving as a barrier against erosion and runoff.

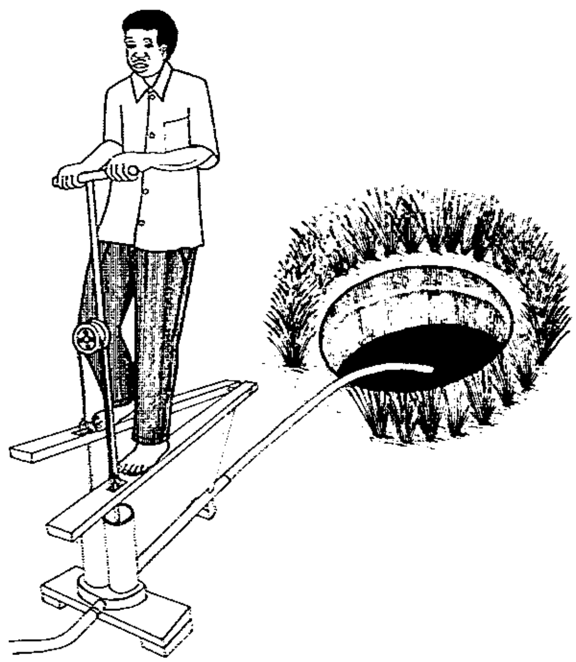
Plant additional lines of vetiver along the boundaries of the irrigated plot. This will demarcate the plot, help prevent any upland runoff from entering the plot, and assist in any streambank and shallow well protection measures.

Vetiver grass can also be planted around the perimeter of shallow wells to protect them from runoff and erosion, and to prevent the walls collapsing (see **Figure 73**).

### Nursery Material and Planting

Refer to **Landcare Practices in Malawi**, MAFE Publication No. 42 for details on how to establish vetiver nurseries and plant vetiver in the field.

**Figure 73: Shallow well protection with vetiver**



# APPENDIX 1: ASSEMBLING A PVC FOOT-VALVE

## MATERIALS REQUIRED

Paper or card; hand or electric drill with 4 mm, 8 mm, 10 mm and 12.5 mm drill bits; 50 mm PVC end cap; 10 cm length of 50 mm PVC pipe, rubber inner tube; sharp knife; drawing compass; 4 x 15 mm nut, bolt, flat and spring washers; PVC solvent.

## STAGE 1 - DRILLING THE ENDCAP

1. Make up a paper or card template for drilling holes in the end cap (see **Figure 74**).
2. Make small, neat holes in the card or paper template at the centre of each of the five large circles and the central small circle using a 4 mm drill bit.

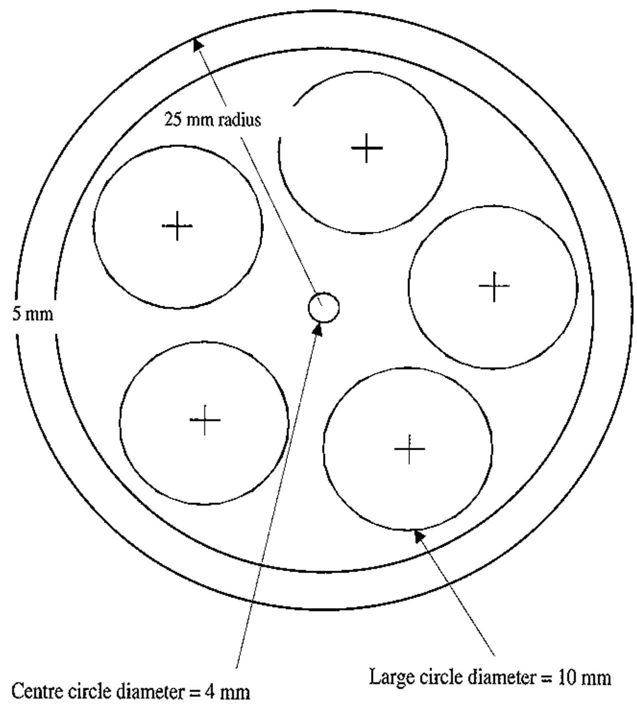



**Figure 74: Endcap drilling template**



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3, Push the template into the PVC end cap making sure that it fits snugly with no creases or folds.

4, Carefully mark the 6 hole centres (5 big plus the centre hole) on the PVC base of the end cap using an indelible marker pen.

5, Remove the template from the endcap taking care not to damage it so that it can be re-used.

6, Place the endcap, nose down, on a flat wooden surface. Using the 4 mm bit, drill through the PVC base at the 6 positions marked with the marker pen. This will require 2 people - one to hold the end cap and the second to use the drill.

7, Change the drillbit to 8 mm and enlarge the 5 outer holes leaving the centre hole at 4 mm.

8, Further enlarge the 5 outer holes to 10 mm.

9, Remove any rough burrs from the edges of the holes. In particular make sure that the inside surface of the endcap is completely smooth. Use the 12.5mm drill bit to remove any rough edges to the holes by turning it very gently in the holes while holding it in your hand - do not use the electric or hand drill for this procedure.

### STAGE 2 - CUTTING OUT THE RUBBER FLAP VALVE

1. Cut a strip of rubber a little more than 50 mm wide from a rubber inner tube.
2. Using a ball-point pen in a drawing compass, mark a circle of 49 mm diameter on the rubber, and mark the centre of the circle - where the compass point marks the rubber.
3. Cut the rubber circle out carefully to exactly 49 mm diameter and check that it will fit neatly inside the endcap without rubbing on the side at any point. Trim any rough points as required.
4. Cut a very small hole in the centre of the rubber. Do this by folding the rubber exactly in half and snipping away a small amount of rubber at the centre point.

### STAGE 3 - FIXING THE FLAP VALVE IN THE ENDCAP

1. Use a 4 mm x 15 mm bolt to fix the rubber flap into the bottom of the endcap. Place two washers of increasing diameter onto the bolt before pushing it through the hole cut in the centre of the rubber.

2. Place the flap in the endcap with the bolt passing through the 4 mm hole previously drilled in the centre of the PVC base.
3. Put a spring locking washer onto the bolt and screw on the nut.

### Stage 4 - Cutting and fixing the PVC pipe into the endcap

1. Cut a 10 cm length of 50 mm diameter PVC pipe. Ensure that the cut is as straight as possible.
2. Clean the outside of one end of this pipe length using sandpaper and clean the inside of the endcap in the same way.
3. When the PVC pipe is glued into the end cap it is very important that it is not pushed all the way to the bottom of the cap as it would get in the way of the rubber flap. To avoid this make a pencil line on the PVC pipe 2 cm from the end to indicate the maximum it should be pushed into the end cap.
4. Apply PVC solvent cement to the inside of the endcap and on the outside of the PVC pipe and slide the pipe into the cap up to the pencil mark.
5. Leave the assembly to dry for a couple of hours before using it.

## APPENDIX 2: ASSEMBLING AND USING AN OFFSET LINE LEVEL

### Materials Required

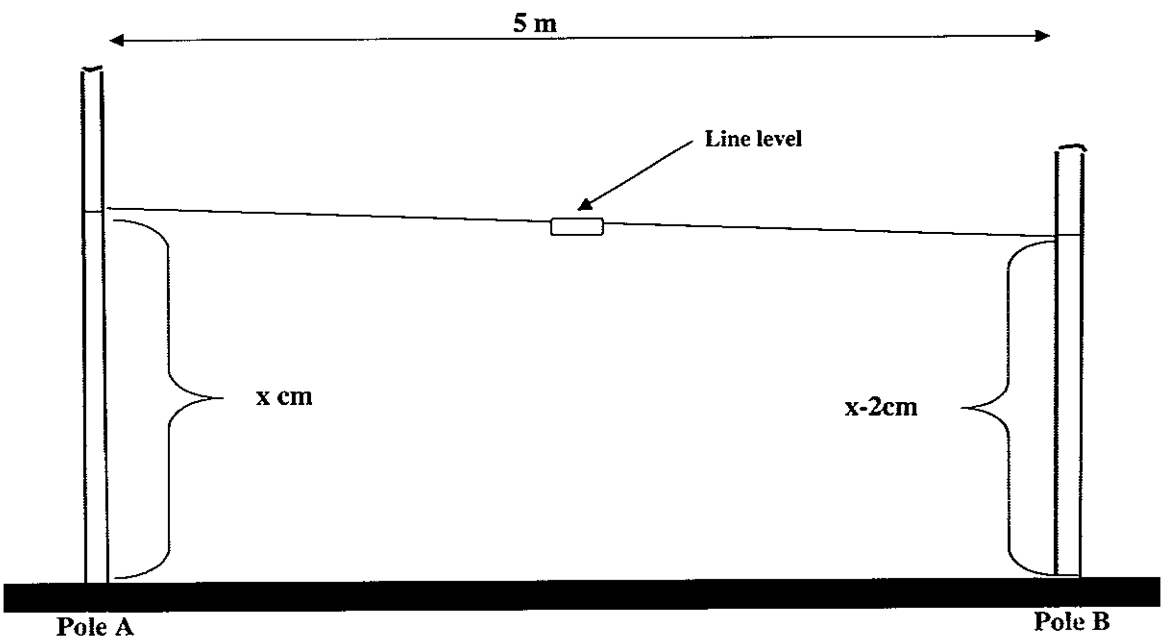
Panga knife; tape measure; two straight poles 1.5 - 1.8 m long, one longer than the other; 5 m of string; line level.

### Assembly (see Figure 75)

1. Measure and cut two poles 1.3-1.5 m long. **Pole A** should be longer than **Pole B**.
2. Cut a groove around **Pole A** (the longer pole at about chest height.
3. Cut a similar groove on **Pole B** (the shorter pole) 2 cm lower than that on **Pole A**.
4. Tie 5 m of string between the two poles in the grooves and suspend the line level in the middle of the string.

5 If the length of the string between the poles is 5 m, the line level will fix positions that have a slope of 2 cm in 5 m or 0.4%.

**Figure 75: Off-set line level schematic**




### MARKING OUT THE MAIN CHANNEL

1. Start marking out the position of the main channel by placing a peg and holding **Pole A** (the longer pole) at the point where the main channel will begin.
2. A second person places **Pole B** at a point on the approximate line of the main channel, i.e. running across the slope.
3. A third person checks the line level bubble and tells the person with **Pole B** to move slightly up or down the slope until the bubble registers dead centre (i.e. the string is level). A second peg is placed at that position.
4. **Pole A** is then moved to that marked position and the person with **Pole B** moves further across the slope to a new position and the process is repeated, with a third person reading the bubble.

5 In this way a series of pegs, at 5 m intervals, is set out across the main slope of the plot. The pegs indicate a line that has a 0.4% gradient to it.

**Note:** If the plot has a shallow slope of less than 0.4 %, then a smaller off-set or a greater length of string between poles must be used. A 1 cm off-set with 5 m between the poles will give a main channel with a slope of 0.2%. If a 1 cm off-set is used with the string length increased to 10 m the resulting gradient will be 0.1%.

6 String is then run between all of the pegs to indicate the alignment of the main channel.

# APPENDIX 3: TRIANGLE METHOD OF MEASURING A RIGHT-ANGLE

## MATERIALS REQUIRED

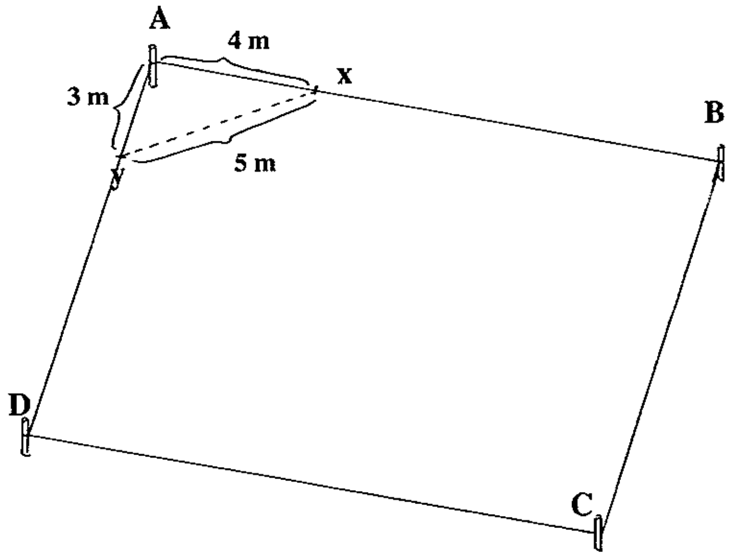
A tape measure, string and pegs are required.

## METHOD

Use the hypotenuse of the triangle method as follows to ensure a demarcated plot is rectangular (see **Figure 76**):

1. Insert **Pegs A** and **B** and run string between them to mark out the main channel.
2. Using a tape measure mark point *x* exactly 4 m down from **Peg A** in the direction of **Peg B**.
3. Mark another point *y* exactly 3 m along from **Peg A** in the direction of **Peg D**, keeping **Peg D** out of the ground for the present.
4. Move **Peg D** with string attached to **Peg A**, as required, keeping the string taut, until the distance between *x* and *y* is exactly 5 m. Then insert **Peg D**.

**Figure 76: Triangle method schematic**




5. The angle DAB is now $90^0$. Repeat this method using **Peg B** as the fixed point and moving **Peg C** to ensure that ABC is a right angle.
6. Then, making sure AD is the same length as BC, simply connect string between **Peg C** to **D** to complete the rectangle.

## COMMON CROP DISEASES

**Anthracnose** (*Colletotrichum spp.*): A fungal disease causing black sunken lesions on pods, stems and cotyledons, often occurring as a secondary infection following insect damage, for example.

**Bacterial blight or wilt** (*Pseudomonas solanacearum*): A bacterial disease characterised by multiple leaf spots with yellow haloes or localised dead areas on leaves. Leaf spots can also be reddish brown with distinct margins.

**Blackrot** (*Xanthomonas campestris*): A bacterial disease causing large chlorotic blotches on the leaf margins with veins turning black. May occur through contaminated seed. Most likely to occur in hot, humid weather conditions.

**Damping-off** (*Pythium spp.* and *Pythopthtora spp.*): A fungal disease which affects germinating seed and seedlings causing destruction of the root system. Occurs in wet, over-crowded conditions.

**Downy mildew** (*Peronospora parastica*): A fungal disease occurring in moist, humid conditions causing small yellow spots on affected leaves. These turn brownish with bluish black marks later.

**Early blight** (*Alternaria solani*): A fungal disease causing dark spots on cotyledons, leaves stems and true leaves. On older plants dark-brown spots with concentric rings may develop.

**Fusarium wilt** (*Fusarium oxysporum* f.sp. *lycopersicae*): A fungal disease causing leaf yellowing progressing upwards from the plant base. Wilting occurs before the plant dies.

**Head smut** (*Sphacelotheca reiliana*): A fungal disease that attacks maize plants at tasselling and silking. Causes malformed and overgrown tassels with black fungal spores developing inside the male flower.

**Late blight** (*Phytophthora infestans*): A fungal disease causing patches of brown discoloration on leaf tips and edges. In damp conditions patches may be ringed with a white, fungal growth.

**Maize streak virus:** A viral disease transmitted by *Cicadulina mbila* leaf hoppers showing initial symptoms of small, round scattered leaf spots. Leaves formed after infection show broken yellow streaks contrasting with the normal dark green foliage.

**Mosaic virus:** A viral disease causing mottling of leaves, shoot tip die back, dying of leaf veins, plant stunting, distortion and stunting of pods. Can be transmitted by aphids or mechanically.

**Powdery mildew** (*Erysiphe encifarum*): A fungal disease typically affecting the leaves, inducing a whitish powdery appearance. Common in the cool dry season (April to July).

**Root knot nematodes** (*Meloidogyne spp*): Microscopic worms that can attack okra, tomato, eggplants and melons. Evidenced by formation of galls on the roots, yellowing of the leaves and stunted growth of affected plants. Nematodes can drastically lower yields.

**Softrot** (*Erwinia carotovora*): A bacterial disease which causes affected plant parts to become watersoaked which then rot with a distinctive foul smell. Most likely to occur in hot, humid weather conditions.

## COMMON CROP PESTS

**African bollworm** (*Herlicoverpa armigera*): Caterpillars emerge from eggs laid on the upper leaf surface and feed on foliage and fruits.

**Aphids** (*Aphis spp.*): Small green, yellow, brown, pink , grey or black sucking insects up to 5 mm long. They can transmit viruses and cause infected leaves to become yellow, pale, sooty, waxy or curled. Young plants become stunted with fruit quality reduced.

**African army worm** (*Spodoptera exempta*): Larvae are usually black with green underneath and can occur following infestation of adjacent pastures.

**Bean beetle** (*Ootheca bennigseni*): Oval shiny beetles with orange to brown head and black body or vice versa.Adults feed between leaf veins causing defoliation while larvae cause damage to lateral roots.

**Diamondback moth** (*Plutella xylostella*): Small grey moths with a diamond pattern on the wings. The caterpillar is pale green and about 12 mm in length. Larvae feed on the underside of leaves causing holes in the leaf surface between the veins.

**Larger grain borer** (*Prostephanus truncatus*): Small, reddish-brown to dark-black beetles that feed on stored grain, particularly on the cob, leaving floury dust residue.

**Maize stalkborer** (*Busseola fusca, Chilo spp*): Yellow, black-spotted larvae which initially cause rows of oval perforations in the leaves of young plants. Larvae then bore into the plant stem and leaf mid-rib causing severe damage.

**Red cotton bugs:** Red sucking bugs with black spots on the back which suck the sap from plant pods lowering quality.

**Red spider mites** (*Tetranychus evansii*): Tiny reddish-brown mites that pierce leaves and fruits to suck sap causing bronzing and yellowing of same.

**Serpentine leafminer** (*Liriomyza spp*): Larvae make silver tunnels under the leaf cuticle with damage occurring when in large numbers only.

**Whiteflies** (*Bemisia tabaci*): Tiny 1 mm long white-coloured flies which feed on the underside of the leaves. Whiteflies are particularly harmful as vectors of viruses.