IMPERATA MANAGEMENT FOR SMALLHOLDERS

An extensionist's guide to rational Imperata management for smallholders



INDONESIAN RUBBER RESEARCH INSTITUTE
SEMBAWA RESEARCH STATION

NRI
Natural Resources Institute

ICRAF
INTERNATIONAL CENTRE FOR RESEARCH IN AGROFORESTRY

IMPERATA MANAGEMENT FOR SMALLHOLDERS

An extensionist's guide to rational Imperata management for smallholders

This extension manual was prepared by members and consultants of the ODA/NRI *Management of Imperata cylindrica for smallholder farming systems project*

INDONESIAN RUBBER RESEARCH INSTITUTE
SEMBAWA RESEARCH STATION,
INDONESIA

NATURAL RESOURCES INSTITUTE,
UNITED KINGDOM
MARCH 1996

Printed by : SMKG Desa Putera - Jakarta
Jl. Desa Putera, Srengseng Sawah, Jagakarsa
P.O. Box 7210 JKSPM, Jakarta 12072
Indonesia

ACKNOWLEDGEMENTS

This manual has been prepared by the staff and advisors of Project F0028, *Management of Imperata cylindrica for smallholder farming systems*, funded by the United Kingdom Overseas Development Administration. This project was implemented jointly by the Indonesian Rubber Research Institute, Sembawa Research Station, South Sumatra Province, Indonesia, University of Bristol, Long Ashton Research Station and the Natural Resources Institute, UK.

Principle contributors include Anang Gunawan, Agus Gozali, Heru Suryaningtyas, H. Bagnall-Oakeley, D. Laycock, P. J. Terry, C. Conroy (*Imperata* project); D. Bird, (GTZ-GoI Integrated Forest Fire Management Project, Kalimantan); Dr E Mutert of The Potash & Phosphate Institute, Singapore. Assistance, materials and/or information were contributed by Ibu Retno Winahyu S, Dr. D. Garrity, M. E. Drilling (ICRAF staff and consultants); Bpk Zahir Zachri, Ibu Ranny Mutiara (Centre for Agricultural Extension, Jakarta); staff of the Agricultural Information Centre, Palembang, South Sumatra; Bpk Saragih and staff of the Directorate General of Estates Slipi, Jakarta; staff of Dinas Perkebunan in South Sumatra Province; staff of the Tree Crops Smallholder Development Project, Indonesia; Dr R. Dilts of the FAO Training and Development of Integrated Pest Management in Rice Based Cropping Systems Programme, and many others who generously gave time and information. Assistance of the Indonesia Association of Pesticide Producers and Manufacturers, Ir Wisnu Hermawan and H. Bijlmer of PT Monagro Kimia, Ir Nandang M. Holil of PT Zeneca Agri Products Indonesia, Ir Agus Darmawan of PT Dharma Ardha Forma, Jakarta, and Dr. J. Robinson of American Cyanamid, Singapore, is appreciated.

Illustrations were prepared by Wiyono of ICRAF, (figures.1 and.5 to 12) and Achmad Satiri of SEAMEO - BIOTROP (figure 2). Credits for Plates include Ir Wisnu, Heru Suryaningtyas, P. J. Terry, and D. Laycock.

A Companion volume which explores *Imperata* management in agroforestry and assisted natural forest regeneration is published by the International Centre for Research into Agroforestry.

March 1996

TABLE OF CONTENTS

ACKNOWLEDGEMENTS iii

TABLE OF CONTENTS v

1. INTRODUCTION 1
1.1 Economic importance 2

2. IMPERATA BIOLOGY 5
2.1 Description 5
2.2 Propagation. 5
2.3 Varieties of Imperata 8

3. WHY CONTROL *IMPERATA* 11

4. FARMER VIEWPOINT 15
4.1 Farmer's choice 15
4.2 Recommendations to the farmer. 17

5. *IMPERATA* MANAGEMENT METHODS 21
5.1 Pressing 21
5.1.1 Pressing methods. 22
5.2 Cultivation 24
5.3 Slashing and mulching 27
5.4 Legume Cover Crops (LCCs) 27
5.5 Crop competition / intercrops 31
5.6 Other weeds or shrubs 31
5.7 Herbicides 31
5.7.1 Contact herbicides. 32
5.7.2 Systemic herbicides, ... 32
5.7.3 Using glyphosate for *Imperata* control 36
5.8 Biological control 37

6. INTEGRATED *IMPERATA* CONTROL 39
6.1 Examples of Imperata control 41
6.1.1 Minimum tillage using a herbicide 41
6.1.2 Intercropping. Tree and annual crops using a cultivation and herbicide combination. 42
6.1.3 Rehabilitation of *Imperata* grasslands by improvement of soil fertility 44
6.2 Tree Circle and strip Maintenance 44
6.3 Maximising the benefits of insufficient or limited resources. 45

7. *IMPERATA* AND FIRE 47

APPENDIX A Application of herbicides 49

APPENDIX B General safety and handling of pesticides 55

CHAPTER 1

INTRODUCTION

Imperata cylindrica (L.) Raeuschel is a troublesome and noxious perennial rhizomatous grass weed found on all continents in the tropics and parts of the sub-tropics. It is particularly a problem in high rainfall areas of South-East Asia and West Africa. It occurs in perennial crops such as rubber, tea, oil palm, coconuts and teak plantations as well as annual food and industrial crops such as maize, soybeans, cotton and many others. No accurate assessment of the *Imperata* problem has been made. Estimates of *Imperata* areas range from 7.5 to as high as 65 million hectares in Indonesia alone. Land cleared of forest but not yet under intensive management is especially at risk.

Imperata has a low nutrient demand, thriving on infertile and fertile soils. It is also found in sandy and swampy soils. It has been recorded up to 2,600 m in Indonesia. *Imperata* can withstand long dry spells on light soils and waterlogging on heavy soils. It is intolerant of flooding for long periods of time.

As a pioneer species, *Imperata* is well adapted for colonising open areas recently disturbed by man. Examples of these include recently logged areas, forests, cleared scrublands, abandoned cultivation areas and roadsides. Frequent burning removes competition and allows the development of a dense *Imperata* stand. Underground portions are well adapted and resistant to survive heat from surface fires. Once established, *Imperata* grasslands can survive almost indefinitely with frequent burning. Grasslands revert to secondary forest only in the absence of fire.

Population densities in undisturbed natural swards range from 3 to 5 million shoots per hectare. The biomass dry weight can reach 18 t/ha for shoots and 11 t/ha for rhizomes.

Because of its rhizome-forming habit, *Imperata* cannot be easily eliminated by hand cultivation. This is often one of the reasons why settlers abandon their land after only a few years cropping.

1.1. Economic Importance

Imperata cylindrica is considered to be one of the world's worst weeds. It is also one of the most important grass weed in SE Asia. Seventy three countries report it as a weed in 35 crops which are as different in cultural systems as tomatoes, cotton, rubber, pasture and forestry. Competition from *Imperata* to economic crops is particularly serious and severe during crop establishment. Production in perennial crops is delayed and yield is reduced.

Exudates from living and decomposing rhizomes are known to reduce the rate of growth of rice and other seeded crops in some, but not all, situations. Old *Imperata* debris provides a ready fuel for fires which damage and destroy thousands of hectares of estate crops each year.

Box 1. Economic damage to crops by *Imperata*

- Death of young plants
- Reduced growth rates and stunting
- Delay in start of production in perennial crops (2 to 4 years in rubber)
- Yields reduced
- Quality of produce is lowered
- Lower returns from fertiliser applied to the crop
- Increase in disease levels of crop (e.g. panel mould in rubber)
- Drought stress increased under dry conditions
- Crop loss from fires

In some situations *Imperata* is not regarded as a weed but is actually valued. In other cases it is a very persistent vegetation type with limited, economic and environmental values. The leaves are used as thatch, the rhizomes are used in traditional medicines and the young leaves provide low grade fodder for cattle.

Young shoots are sometimes eaten by man. Soil erosion is prevented or reduced by *Imperata* (See Figure 1) and the soil condition (structure and cycling of nutrients) is improved for poor soils. *Imperata* is used to stabilise canal and railway embankments and as a sand binder for coastal sand dunes.

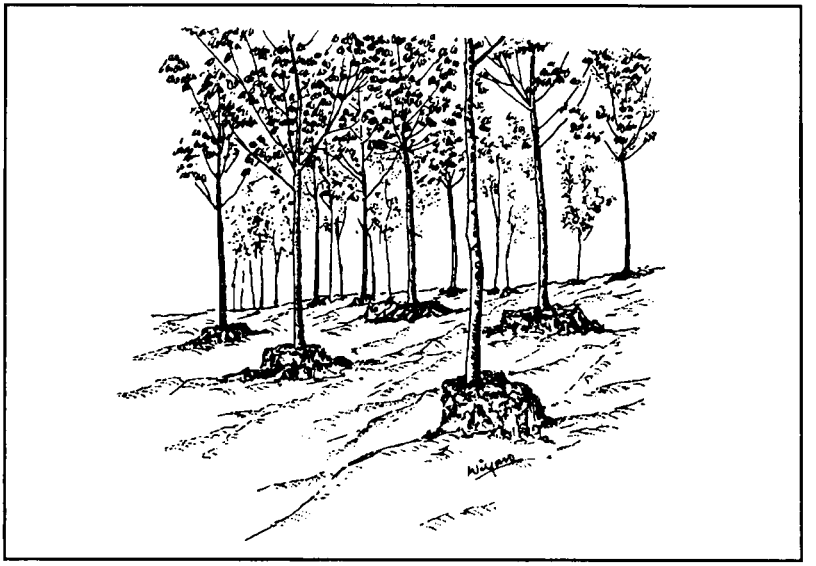


Figure 1. Soil erosion on soils without vegetation
Complete removal on Imperata without replacement vegetation is undersirable where soils are exposed to erosion.

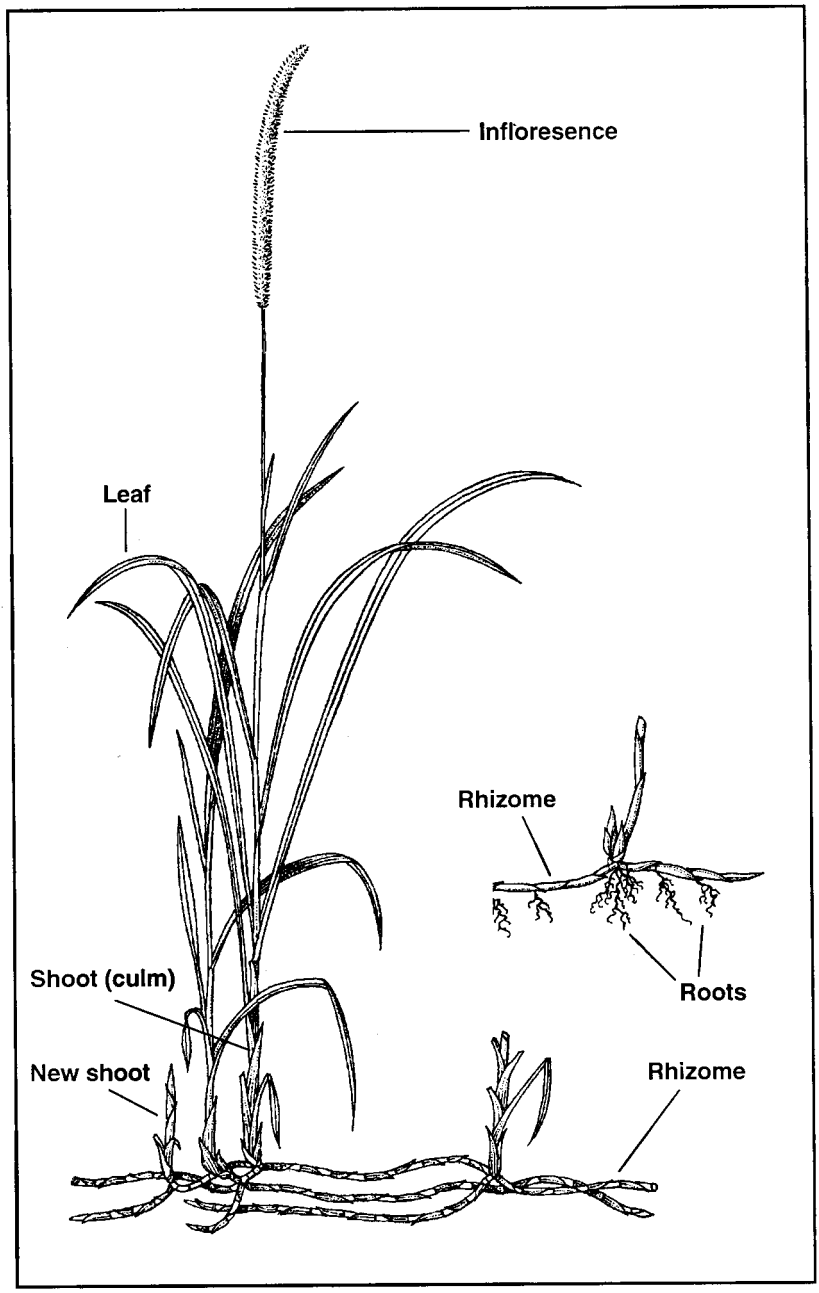


Figure 2. *Imperata Cylindrica* (L.) Raeuschel

CHAPTER 2

IMPERATA BIOLOGY

2.1 Description

Imperata cylindrica is a perennial rhizomatous grass. It grows in loose to compact tufts of shoots (culms) arising from tough, branched, extensive, creeping rhizomes. The stiff leaves are up to 150 cm long and 4 to 18 mm wide. A typical *Imperata* plant is shown in Figure 2 with identification of the various plant parts. The flowering shoots are 10 to 280 cm long and up to 8 mm diameter with one to four nodes terminating in a white spike inflorescence 3 to 22 (rarely to 60) cm long. Tillering occurs giving a dense tuft like appearance to the plant. The underground rhizomes are 2 to 4.5 mm in diameter. They grow horizontally in the top 15 to 20 cm of soil but grow deeper in light soils. Buds occur irregularly with leaf scales at nodes on the rhizome, but are absent from the first 10 cm. New shoots emerge from these buds away from the parent shoot. Broken rhizome fragments are important in the spread of the weed (Plate 1). The appearance and variations in plant morphology relate to both variety and the conditions under which the plant grows.

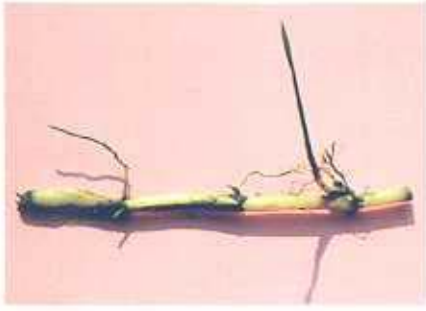
2.2 Propagation

Imperata propagates sexually by seed and vegetatively by the extensive rhizome system. The plant is a prolific producer of airborne seeds, up to 3,000 per plant. This enables dispersal and colonisation over long distances. Flowering is most common in the dry season. It mostly occurs after stress, such as burning, cutting or drought. Seeds have little or no dormancy and can germinate within a week. The seeds remain viable for over a year. Germination is promoted by light and a pH of less than 5. Seedlings have no rhizomes for four weeks.

Imperata grass normally spreads by means of underground rhizomes which proliferate in the soil giving rise to shoots at 25 to 50 cm intervals. Rhizomes fragmented by cultivation can produce new shoots and rhizomes very rapidly. A 15 cm rhizome fragment can produce more than 350 shoots in six weeks.



Germinating rhizome fragment.



New shoot arising from the rhizome fragment.



A new plant has now been established from the rhizome fragment. Note that new rhizomes are already growing.

Plate 1. Germination and growth of *Imperata* rhizome fragments



Ground view showing shoots.



Below ground view showing the rhizome system connecting the shoots.

Plate 2. New *Imperata* shoots arise from rhizomes

Sprouting is two to three times greater in the light than in the dark. The ability of rhizome fragments to regenerate decreases with an increase in depth of burial and a reduction in length of rhizome segment.

The dry weight of a rhizome fragment first decreases as leaves emerge and only begins to increase in weight after three to four leaves have emerged. This can be used to advantage in *Imperata* control by cultivations which first fragment and then bury rhizomes while food reserves are low.

Imperata is a light loving plant which can be shaded out or weakened under a dense canopy. It remains ready to invade areas which are opened up as a result of crop disease or leaf fall in the dry season. Shade reduces both shoot and root-rhizome mass, and also the competitive ability of the weed.

2.3 Varieties of Imperata

Five varieties of *Imperata cylindrica* have been described. These are (i) *major*, (ii) *europa*, (iii) *latifolia*, (iv) *africana* and (v) *condensata*. Clones occur within varieties and have different sensitivities to herbicides. The variety *major* is the most widespread and the most important in Asia. Based on 11 morphological characters and isoenzyme analysis, three clone groups of the variety *major* have been identified in Indonesia. These are Irian, Sulawesi/Kalimantan and Java/Sumatra clones.



Newly planted rubber which has made a good start. Compare this with the rubber shown below, which is 10 months old and has made a bad start from which it will not recover



Imperata control continued

Control of Imperata must be continued to prevent re-establishment and an increased fire hazard



Young rubber trees after an *Imperata* fire



Good *Imperata* management. Good trees which can tapped early. Note the good tree stand

Poor *Imperata* management has delayed and stunted tree growth. Trees killed by *Imperata* have been replanted. Trees in this plot have a risk of total loss from *Imperata* fires



3. Benefits from early Imperata control in rubber

CHAPTER 3

WHY CONTROL *IMPERATA?*

The presence of *Imperata cylindrica* in crops reduces both the yield and the benefit from inputs such as fertiliser. The risk of crop loss from fire is significantly increased (see Plate 3). *Imperata* causes plants to become stunted and delays the start of production in perennial crops.

Examples of the effects of *Imperata* on crops:

Rubber
- Annual growth reduced by more than 50% in the first five years after transplanting
- Start of tapping delayed by 2 to 4 years
- Yields are reduced during the economic lifetime of the tree
- *Imperata* rhizomes penetrate roots allowing the entry of disease causing organisms

Coconuts
- Inhibition of growth of surface feeding roots
- Yellowing of leaves and poor growth
- Flowering delayed
- Number of barren inflorescences increased
- Reduction in the number of nuts per productive bunch

Forestry
- Delays in *Imperata* control reduce the growth rate in new plantings of *Eucalyptus* and *Acacia*. For example, during the first ten months of growth after planting, *Eucalyptus urophylla* produced 3.8 m^3 of wood per hectare compared to 40.5 m^3 where *Imperata* was controlled by the herbicide glyphosate. For *Acacia mangium,* the respective figures are 10.8 and 29.1 m^3. *Eucalyptus* did not recover after late weeding

The control of *Imperata* has obvious benefits to the farmer but, as shown in Table 1, these benefits also have a cost. The reliance on a single control method can give other problems especially where continuous cropping is practised or where perennial tree crops, such as rubber, are grown.

A well balanced *Imperata* management programme combines several control methods or sequence of methods to eradicate, or limit, the negative effects to an

Table 1. Benefits and costs of *Imperata* and *Imperata* control

1	***Imperata* not controlled**			2	***Imperata* controlled**		
A	**Benefits**	**B**	**Costs**	**A**	**Benefits**	**B**	**Costs**
1.	Help reduce soil erosion	1.	Reduced crop yield	1.	Increased crop yield	1.	More intensive management required
2.	Help recycle soil nutrients	2.	Delay in crop production	2.	Earlier production in perennial crops	2.	Less erosion protection
3.	Provides thatch for housing	3.	Increased fire risk with associated crop loss	3.	Reduced chance of fires and crop loss	3.	Increased costs of inputs
4.	Low grade animal fodder	4.	Other weeds may become a problem	4.	Water conserved	4.	Labour required for implementation of control
		5.	Death of young crop plants	5.	Improved utilisation and benefits from fertiliser	5.	Other weeds may become a problem and require control
		6.	Use of fertiliser by *Imperata*				
		7.	Competition for water and increased water stress under dry conditions				
		8.	Increase in diseases				

acceptable level. Once *Imperata* is eradicated, long term management is necessary to maintain this condition. This can be achieved by the establishment of more useful species, such as food crops or legume cover crops. These help to suppress the regrowth of *Imperata* and other weeds, as well as to prevent erosion and restore and conserve soil fertility.

This appropriate mixing and matching of control options is known as **Integrated *Imperata* Management**. The combination of control options, rather than a single practice, allows some flexibility to match control options to the individual farmer's agronomic and socio-economic conditions. This may reduce the dependence on purchased materials.

The basic concept of integrated *Imperata* management is the combination of control measures in an effective and efficient way. For example, intercropping suppresses weeds while the crop is being established. In effect this makes the best use of the farmer's limited resources (cash and labour). Integrated *Imperata* management combines control options such as pressing, cultivation, legume cover crops, intercropping and herbicides into an overall system. The aim is to discourage or suppress the unwanted *Imperata* whilst promoting and encouraging the desired vegetation (crops). The choice and combination of methods will vary according to the situation. Their appropriateness will depend on soil type, climate, costs, local practices and preferences.

CHAPTER 4

FARMER VIEWPOINT

4.1 Farmer's choice

The following factors are all likely to affect the individual's choice of *Imperata* control measures. It is important, therefore, for the extension officer to be aware of them, and take account of the farmer's objectives in controlling *Imperata* when providing advice or making recommendations on how to control *Imperata*. The extension officer must also take into account the farmer's current level of knowledge and equipment available.

The farmer's household is a business enterprise

A smallholder household is a business unit composed of several different enterprises. Resources, especially cash and labour, are limited. Consequently, activities which use these household resources have to be prioritised. Demands on resources include expenditure for home consumption, on-farm purchases of fertiliser, seed and other inputs, as well as the hire of labour and equipment (see Figure 3). Off farm activities such as labouring and trading, also use resources. *Imperata* control must be viewed in the context of all household enterprises and not in isolation.

Imperata control may not be a high priority

Many smallholders in South East Asia do not effectively control *Imperata*, even though they may be aware of the damage it causes. The reasons given for not controlling *Imperata* are that the technology does not work, it cannot be afforded or there is no time available. This is often the case with the use of herbicides to control *Imperata*. Expenditure on herbicides or hired labour for *Imperata* control may not be high on a farmer's list of priorities. Farmers will have different priorities. They may spend their cash on school fees and consumables such as food and clothes, hire of labour and other agricultural inputs before they spend cash on *Imperata* control.

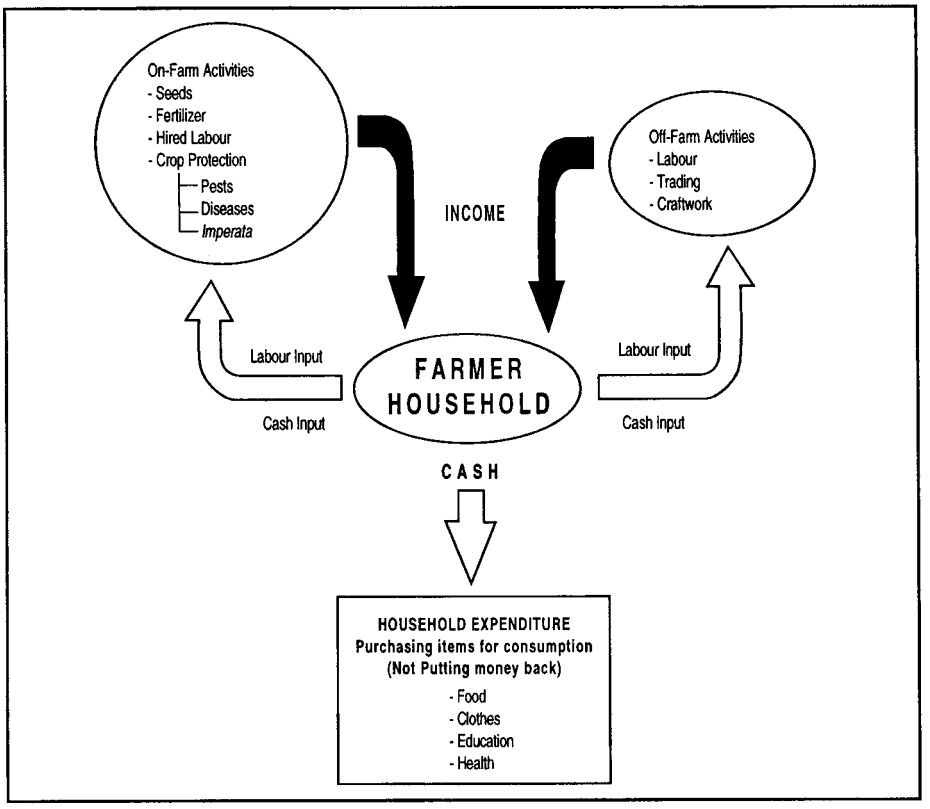


Figure 3. Household expenditures
Inflow and outflow of farmer's household labour and cash

Labour use allocation

Labour is another common constraint. If a farmer or other members of the household can get better returns on their labour from activities other than *Imperata* control, they may decide to give priority to working on these other activities. In this situation, they can either abandon the *Imperata* control or, if they have plenty of cash, they may adopt a more capital intensive and less labour intensive method of control, such as herbicide or draught animal power.

Annual variations in resource availability

Insufficient cash or labour may be less of a problem at some times of the year than others. There are usually some months when farmers are not so busy, and

some months when they have higher incomes or lower expenditure. Recommendations on the timing of *Imperata* control measures should take account of any seasonal variations of this kind.

Farmer's objective in controlling *Imperata*

The farmer's objectives are important for the extension officer to consider in the control of *Imperata*. Where a farmer is growing annual crops, his/her main objective is to reduce the competition between *Imperata* and the crops so as to maximise the yield of the crop, provided that the benefits of doing so significantly outweigh the cost.

In the case of tree crops, competition from *Imperata* delays the time when the farmer obtains a return from the crop. Yields are reduced in both the long and short term.

Fire

Farmers may have a another objective for controlling *Imperata* in tree crops. In many parts of South East Asia, *Imperata* makes a major contribution to the cause of fire during the dry season and these fires can result in the destruction of young and mature trees. In this situation, smallholders may regard minimising the fire threat to their tree crops a more important objective than reducing competition. This in turn influences the timing and perhaps choice of control methods. Farmers concerned about the fire threat may give priority to controlling *Imperata* at the end of the wet or beginning of the dry season. They can minimise the amount of *Imperata* that is present during the period when fires are most likely to occur.

4.2 Recommendations to the farmer

The extension officer should assess all the above factors before making recommendations to the farmer. No single control method or recommendation is suitable for all farmers or for all situations. There is a high degree of variation between individual situations which means that the most appropriate technology for *Imperata* control will also vary. It is necessary, therefore, for an extension officer to have a selection of appropriate control technologies to suggest to the farmer. These technologies can be mechanical, cultural, chemical, or a mixture of two or more (integrated control).

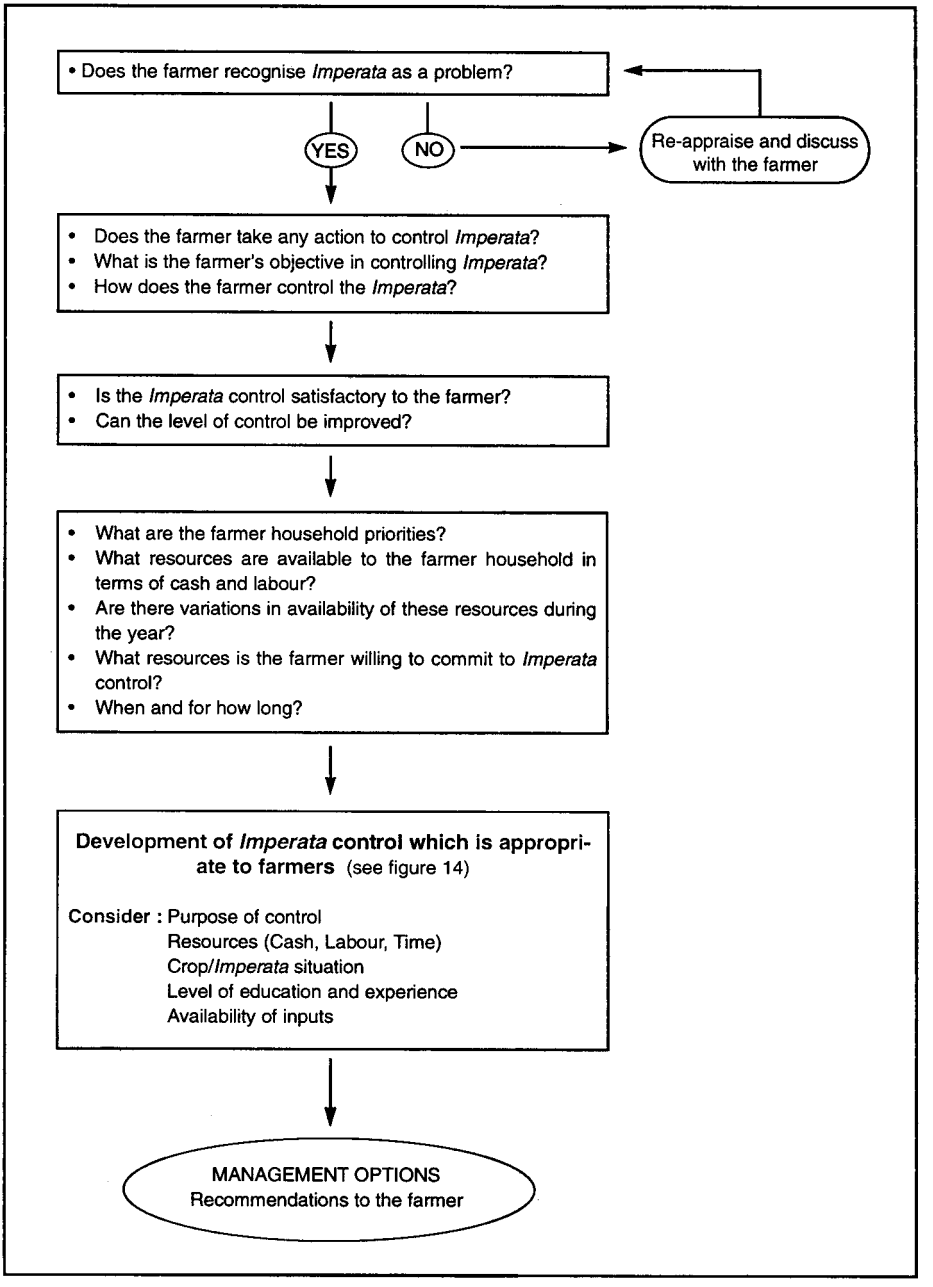


Figure 4. Appraising the farmer situation

The extension officer should discuss the various control technologies with the farmer in the context of the farmer's objectives in controlling *Imperata*. Figure 4 provides a short guide to the type of questions that the extension officer should discuss with the farmer. It is vital that all these questions are thoroughly discussed before considering the alternative *Imperata* control methods. No two farmers' situation will be exactly the same, so each farmer must be interviewed separately and individually. It is likely that these discussions will consist of several interviews.

Once the extension officer has a clear understanding of the farmer's reasons for controlling *Imperata,* how the farmer controls *Imperata* at present, and the resources (cash and labour) the farmer is prepared to allocate, then the extension officer can move on to discussing *Imperata* management options. These recommendations may be a mix of control methods or just one control method. Whatever is decided on, it must be within the resources and capabilities of the farmer.

CHAPTER 5

IMPERATA MANAGEMENT METHODS

Options for the control of *Imperata cylindrica* are described below. This is not an exclusive list of control options and local variations or alternatives may already be in use. Consider what the farmer wishes to achieve and the resources at his/her disposal when integrating options into a control programme.

5.1 PRESSING

Grass pressing, or assisted lodging, is a management technique suitable for tree crops and assisted forest regeneration situations. It is faster and more effective than slashing alone and can be done by women and children in addition to men.

Pressing reduces the competitive effects of *Imperata:*

- The bent or crimped stem and leaves die without stimulating rhizome bud growth in the same way as cutting and burning
- The flattened grass provides a living and dead mulch which shades out and reduces regrowth of *Imperata* and other weeds
- Pressing enables legume cover crops (LCC) to overtop the *Imperata* more easily

Regrowth of *Imperata* shoots will occur but the rate of regrowth is slower than with cutting and/or burning.

Best results are obtained by pressing high density *Imperata* stands when shoots remain permanently bent. Juvenile and isolated shoots are more difficult to press as they tend to return to their normal position. Dry shoots press better than young green shoots. However, pressing in the rainy season is better when used with legume cover crops as they are able to overtop the *Imperata* more quickly. Pressing the leaves in one direction to overlap each other provides the most complete suppression for the longest period of time.

Unwanted woody weeds and shrubs should first be cut or uprooted and removed to facilitate pressing close to the ground.

Benefits from pressing include easier access and a reduced fire risk. The pressed grass is a less flammable fuel than the standing grass and makes fires easier to control.

Pressing must be repeated every 3 to 4 months in established areas and at monthly intervals in the early stages.

5.1.1. Pressing methods

Planking

Use a wide plank or large bamboo pole 1.5 to 2 m long. Tie rope handles to the plank about 60 cm from the ends. Hold the rope with both hands and press the grass by putting one's full weight on the plank (see Figure 5). Lift the presser along the grass shoots and repeat. Use short, choppy steps. This method can be used close to trees and where tree stumps remain. One hectare requires 10 to 20 days labour.

A wide plank (flat or round bottom) of a strong lightweight wood (about 5 cm x 15 cm x 1.3 m) with wooden handles (1.3 - 1.5 m) securely attached can be used as an alternative model.

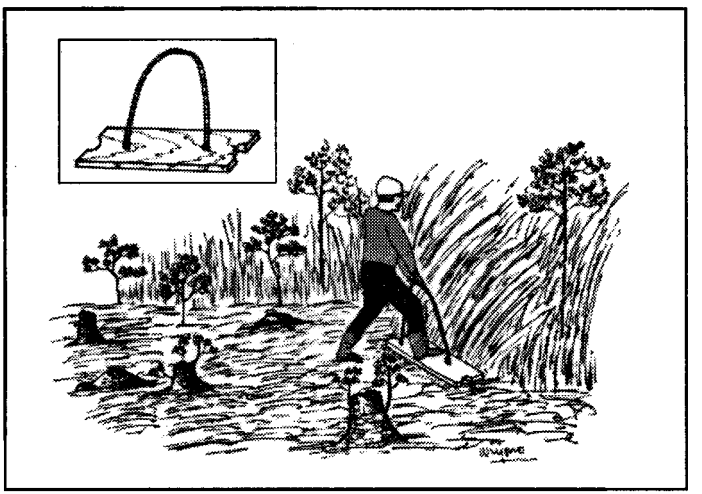


Figure 5. Pressing *Imperata* by planking

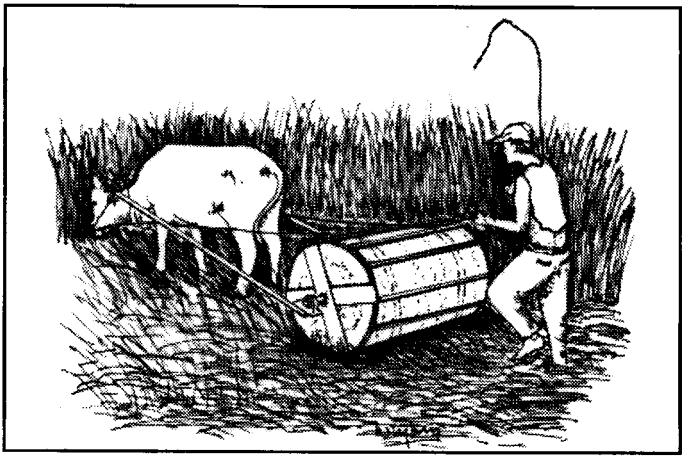


Figure 6. Rolling Imperata using a 200 litre drum pulled by draught animal

Rolling

Logs Use a coconut log, tree trunk or large banana plant stem about 2 m long which is heavy enough to press the grass. Push the log over the grass and step on it with the full body weight. Push the log over the grass and repeat. Logs work well on clear surfaces with few trees, rocks and stumps, but are heavy and bulky.

Drum A drum partially filled with water to give extra weight can be rolled manually over the grass or modified to be pulled by animals as shown in Figure 6. Welding small ribs along the drum improves performance. Two to three work days are required for manual rolling compared to one to one and a half work days when using draught animals.

Bending away from crop trees

Pressing or bending *Imperata* shoots around naturally regenerated young trees reduces competition and enables the tree to grow more easily. First press down the *Imperata* in a circle around the tree. Next press the remaining area of *Imperata* between the trees. This is appropriate in low maintenance, low cost situations where time may be insufficient to press all the *Imperata*. The use of this method in assisted natural forest regeneration is discussed further in a companion volume published by ICRAF.

5.2. Cultivation

Soil cultivation, or tillage, has long been used for *Imperata* control in the establishment of both food and tree crops. Hoeing (see Figure 7) requires a large expenditure of physical energy and time. Ploughing with draught animals and/or tractors can be used as an alternative to hoeing.

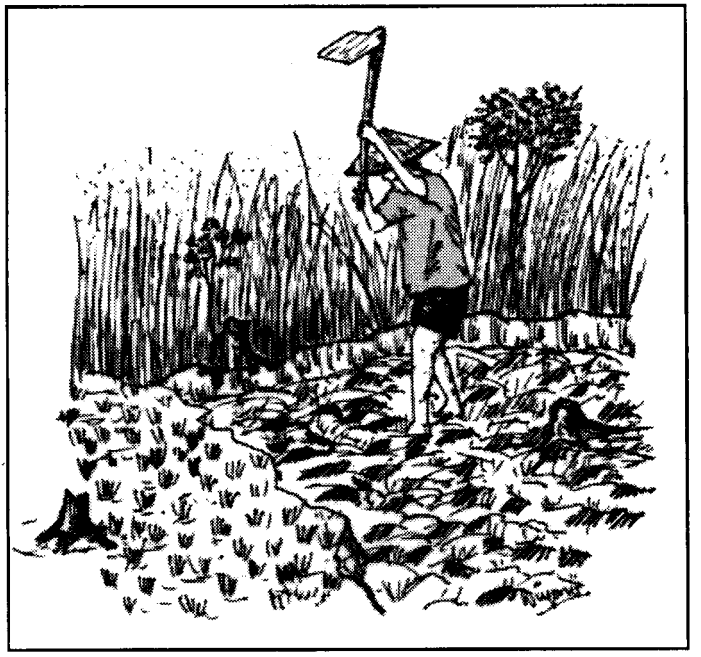


Figure 7. Hoeing Imperata to expose rhizomes to the sun

Cultivation turns the soil which breaks and brings underground rhizomes to the soil surface where they dry out under the sun and die. The soil should be cultivated to at least 20 - 25 cm and turned upside down to expose the underground rhizomes to the sun to dry out for a week. Clods protect rhizome fragments and should be broken by hoe or harrow. Cultivation can expose soil to erosion which could destroy existing crops.

Several cultivations are required to expose all rhizome fragments which would otherwise grow into new *Imperata* plants. Cultivation is more effective in the dry season than in the wet season. Under moist conditions, many rhizomes



Figure 8. Collection and burning of rhizomes

fail to dry out and are able to regrow quickly. Raking and harrowing with the collection and removal of rhizome fragments from the field between cultivations improves the drying out of rhizome fragments (see Figure 8), and reduces regrowth and the consequent re-establishment of *Imperata*. Dry rhizomes can be collected and burnt. An alternative is to dig a hole and bury the rhizomes under at least 45 cm of soil.

Imperata should be cultivated when it is less than 75 cm high. Where *Imperata* is more than 75 cm high, first slash and allow one to two weeks to dry out. Rake the dead leaves into the slashed area away from the standing *Imperata* and carefullly burn.

For plantation crops such as rubber, cocoa and coconuts, avoid damage to tree crop roots when hoeing or ploughing close to trees. Loosen the soil around the *Imperata* shoots and gently remove the rhizome by pulling (Figures 9 and 10).

In agroforestry situations, root pruning is desirable and is even recommended. Consult technical specialists before recommending pruning of roots during cultivation to remove *Imperata*.

Where land is ploughed, a second ploughing is required 2 to 3 weeks later. The land should be harrowed 5 to 10 days after each ploughing. The second



Figure 9. Cultivation near trees but avoiding root damage

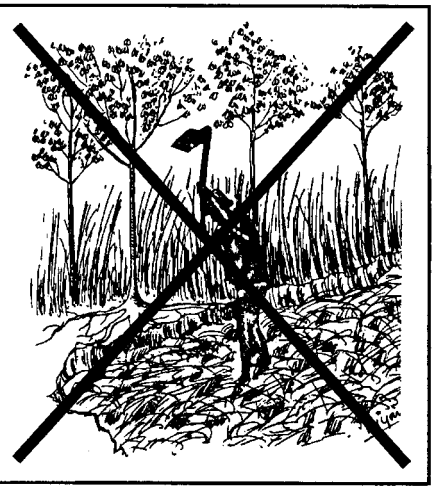


Figure 10. AVOID damage to roots of tree crops such as rubber

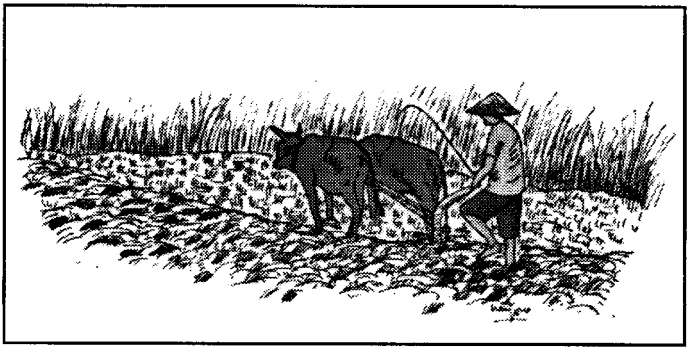


Figure 11. Tillage using draught animal power

ploughing is at right angles to the first. After the first ploughing, allow the remaining rhizome fragments to germinate and produce 2 to 4 leaves before the second ploughing. This gives a better kill by depleting their food reserves.

The use of animal- and tractor- drawn ploughs is restricted to flat areas and gentle slopes with few tree stumps. Hoes are more useful in the presence of tree stumps, small areas and corners of fields where ploughing is difficult. Ploughing with draught animals requires 6 to 7 work days of 4 to 6 hours a day for one

hectare. This compares to 90 to 100 work days working 7 to 8 hours a day for hoeing. Actual current costs in South Sumatra for cultivation of *Imperata* grasslands to grow annual crops are around $150 and $45 per hectare for hoeing and ploughing respectively.

5.3. Slashing and mulching

Cutting *Imperata* temporarily reduces competition to the crop but must be repeated at very frequent intervals (monthly in the wet season) to be beneficial. Regrowth is fast as cutting stimulates growth. Mulching round the base of trees with *Imperata* leaves is recommended to delay *Imperata* regrowth. Care must be exercised to avoid cutting the tree crop.

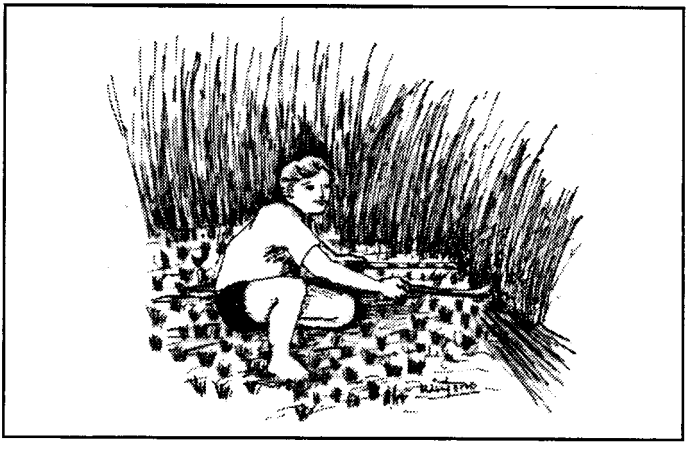


Figure 12. Control of *Imperata* by slashing

5.4. Legume Cover Crops (LCCs)

Fast growing leguminous vines can quickly cover, shade out and suppress *Imperata*. Pressing of the cover crop and *Imperata* are complementary and enable the LCC to overtop the *Imperata* more quickly. Suitable species include *Centrosema pubescens*, *Pueraria javanica*, P. *triloba*, *Calopogonium mucunoides*, *Mucuna* spp. and *Stylosanthes guyanensis.* These are usually used in mixtures.



Imperata suppressed by legume cover crop allows good tree growth

Imperata has not been controlled and has reduced tree growth

Plate 4. Three year old coconuts grown with and without suppression of Imperata Cylindrica by legume cover crops

Legume cover crops will not grow vigorously everywhere in the tropics as is sometimes believed. Each species has its own requirement for soil pH, temperature and amount of sunlight. Phosphate applied at planting helps to establish the legume quickly, especially on poor soils.

Legume cover crops have several functions in the rehabilitation of *Imperata* grasslands:

- Suppression of *Imperata* regeneration
- Rapid surface coverage
- Prevention of soil erosion
- Transformation of mineral P into organic P
- Fixation of nitrogen
- Provision of mulch
- Improvement of soil structure, organic matter, moisture retention and microclimate
- Stimulation of the soil flora and fauna

Box 2. Using a legume cover crop and herbicide combination

1. Spray 2 m wide strips along the tree planting lines
2. When the Imperata begins to dry out, make 2 furrows 5 cm deep and 70 cm apart. Keep the soil at the edge of the furrow. Leave the dead Imperata as mulch. In sloping areas make sure the furrows run along the contour
3. Use legume species and quantities and seed as recommended locally, for example a mixture 2 kg/ha of each of *Pueraria javanica*, *Centrosema pubescens*, and *Calopogonium mucunoides*. Mix the 6 kg of seed with 12 kg starter fertiliser (Triple Super Phosphate)
4. Spread the seed and fertiliser mixture evenly in the furrow using about 100 g of mixture per 10 m of row
5. Cover with a 1 cm layer of soil leaving the remaining soil at the furrow edge to slowly fill the furrow in the rainy season
6. Broadcast Triple Super Phosphate (188 kg/ha) along both sides of the furrow a month after emergence of the LCC

Several LCCs can be planted as rooted cuttings to reduce seed costs. Phosphate should be mixed with soil in the planting holes before transplanting.

The LCC grows to fully cover the planting row and spreads into the adjacent inter-row (*Imperata)* area about 5 to 8 weeks after planting. Press the *Imperata* in the inter-row nearest to the LCC to assist the vines to climb onto the pressed *Imperata*. Do not press the whole inter-row yet. Four to six weeks later repeat the pressing process with new *Imperata* adjacent to the LCC. The rolling pattern is shown in Figure 13. Make sure that each pressing overlaps with the preceding one. Continue until all the *Imperata* is pressed and over-topped by the LCC.

Once the *Imperata* is suppressed, periodic maintenance pressing is required. Continue pressing, but extend intervals to 2 to 4 months to maintain the LCC and prevent re-establishment of *Imperata*. The LCC will lose leaves during the dry season allowing light to enter and stimulate *Imperata* growth. Pressing early in the rainy season will reduce this weed growth.

The LCC will compete with the crop for water in the dry season. They may burn if it becomes very dry. Press the LCC early in the dry season to reduce the fire hazard. Clear circles of LCC around the base of trees, 1 to 2 m radius, and use the foliage as a mulch round the tree base. During the wet season, clear circles of LCC around trees and remove vines growing on the trees every 3 to 4 months.

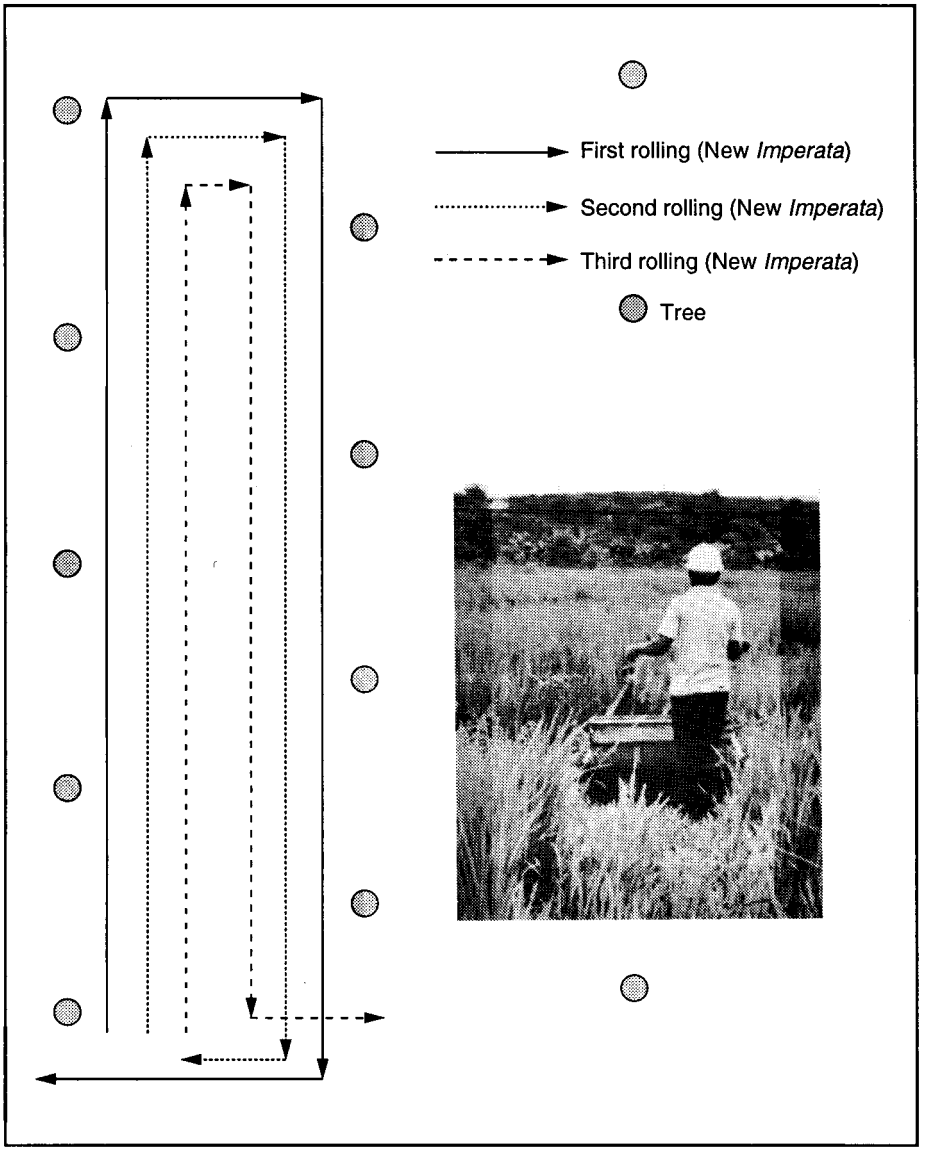


Figure 13. Method of pressing Imperata and cover crop in the inter-row area

5.5 Crop competition / intercrops

The susceptibility and poor growth of *Imperata* under shade can be used to advantage by planting fast growing crops or encouraging the growth of shrubby weeds such as *Chromolaena* and *Lantana*.

Many annual and perennial food crops, such as beans and rice, can successfully compete with and eliminate *Imperata* when given a competitive start. Fertiliser, especially phosphate, must be applied at planting to promote rapid crop growth. Rock phosphate is especially good as one large application will last for several seasons. No further phosphate application will be required (see page 44). Relay cropping to maintain ground cover is more successful than rotations which leave the soil surface unshaded.

Before planting the food crop, the *Imperata* must be managed or removed. Two such systems are described later (below and page 44).

Tree plantation crops shade out *Imperata* as they develop a full canopy, but some *Imperata* remains and will grow rapidly if tree death or defoliation occurs.

5.6 Other weeds or shrubs

In the absence of fire, *Imperata* grasslands convert to a mixture of shrubs and woody species such as *Chromolaena* and *Lantana*. These species reduce the fire risk but they can still burn and cause damage. They are easier to control than *Imperata*. Shrub development is encouraged by preventing fire. Pressing, without cutting, helps to suppress *Imperata* and favours shrub growth.

5.7. Herbicides

The farmer may only be able to afford a limited quantity of herbicide. Whatever quantity of herbicide is applied, it is important that it is used in the most effective way possible. This may require the herbicide to be used with other methods to obtain the best control of *Imperata*.

Herbicides enter plants through the roots or leaves. Foliar applied herbicides, those entering the plant through the leaves, are of two types, contact and systemic. Their effects on *Imperata* are shown in Plate 5.

5.7.1. Contact herbicides

Contact herbicides, such as paraquat and MSMA, kill the leaf quickly by desiccation of the aerial plant parts. They are useful where time is short and a rapid kill of leaf growth is required for planting. Regrowth occurs relatively rapidly, within weeks, so that control is only temporary. These kinds of herbicide have very limited value for *Imperata* control.

5.7.2. Systemic herbicides

Systemic herbicides, such as glyphosate and imazapyr, move from the leaf into the rhizome killing many of the underground buds and reducing regrowth. New *Imperata* shoots will emerge from parts of the rhizome not reached by the herbicide and from unsprayed shoots because they are covered by other vegetation at spraying. Correction spraying, that is local spot spraying of the new *Imperata* shoots two to three months later, is necessary to provide complete control. The full recommended dose of herbicide must be used.

The desiccation of leaves by systemic herbicides is not immediately obvious and requires up to a month for glyphosate or up to four months for imazapyr. Any regrowth which occurs will not be apparent for several months. The short term and long term effects of contact and systemic herbicides are shown in Plate 5.

The most commonly used systemic herbicide for *Imperata* control is glyphosate. It is available in several formulations and under many different product names.

To get the best result from glyphosate, one has to consider several factors. These include the growing condition of the *Imperata*, humidity, sunlight, quality of water used for spraying, herbicide formulation, application and the interval between application and rainfall. These factors are summarised in Box 3.

Active growth

The fresh green leaves of actively growing *Imperata* plants favour rapid entry of glyphosate into the plant and promotes rapid movement away from the leaf to action sites within the rhizome system. Glyphosate activity is reduced when leaves become old or when the plant switches from vegetative growth to seed production.

Box 3. Factors which influence the activity of glyphosate

Activity promoted	Activity reduced
• Leaves fresh, green and actively growing	• Leaves old, slow growing or senescing
• Large leaf area	• Small leaf area
• Leaves turgid	• Leaves wilting or under moisture stress
• Before flowering	• Plants flowering
• High humidity	• Low humidity
• Soils moist but not flooded	• Area flooded
• Sunshine	• Dark
• No rain for at least 8 hours after application	• Rainfall within 2 hours of application
• Good even coverage of leaf by spray droplets	• Poor uneven cover of leaves
• Clean water	• Dirty water

Slash and preferably burn old *Imperata* vegetation to stimulate regrowth. When the new growth reaches 40 to 60 cm high, usually after 4 to 8 weeks, spray the herbicide using clean water. A delay in spraying increases the target leaf area, but if the delay is too long the plant may begin to flower while still small. In this case, apply the herbicide just before flowering. The addition of two to four spoons of urea or ammonium sulphate or ammonium nitrate sometimes promotes herbicidal activity.

Weather

High humidity and sunshine promote the opening of leaf stomata which speeds up herbicide entry into plant leaves. Conversely, moisture stress closes stomata, and reduces entry into, and movement within the plant.

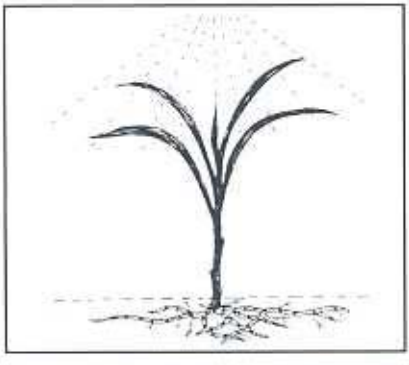
Rain shortly after application washes the herbicide from the leaf, thereby reducing the amount applied. Additives are available to speed the entry of glyphosate into the leaves of *Imperata* but their performance is inconsistent.

Under flooded conditions, glyphosate movement to the rhizome is inhibited or very slow.

SYSTEMIC HERBICIDE



Imperata leaves have already turned brown two days after application of paraquat



Contact herbicides remain on the leaf surface



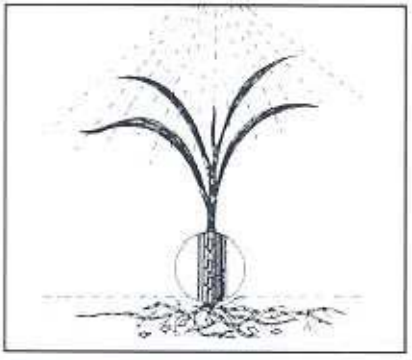
Imperata regrowth has already occured 35 days after spraying with a contact herbicide

Plate 5. The comparison of contact and systemic herbicides on Imperata at different interval after application

CONTACT HERBICIDE



Two days after spraying with glyphosate there is no apparent effect on *Imperata* leaves



Systemic herbicides move into and through the plant to the underground rhizomes



35 days after spraying with glyphosate the *Imperata* is dead

Active photosynthesis promotes herbicide movement to the rhizome. Glyphosate does not move out of the leaf in the dark. Early morning applications are preferable to those in the late afternoon.

5.7.3. Using glyphosate for *Imperata* control

Good spraying is essential to obtain the best and most cost effective control of *Imperata*. The spray should cover the target area as evenly as possible with the correct dose. Both plant and weather conditions need to be suitable. The use and calibration of sprayers, choice of nozzles and spraying technique is given in more detail in APPENDIX A.

Herbicide dose

Glyphosate is available in many products at different strengths. Read the label to find the quantity of product recommended for *Imperata* control. The concentration of herbicide is given on the label as acid equivalent (a.e.) or active ingredient (a.i.) per litre of product. The usual range of a.e. required for *Imperata* control is 1.6 to 2.2 kg a.e. / ha. Lower doses will burn down leaves without killing the rhizome and regrowth occurs. Calibrate the sprayer under field conditions before starting to spray to determine the amount of herbicide to use in each spray tank. Spot and correction spraying require the same concentration of spray solution.

Spray volume

Glyphosate can be applied in spray volumes ranging from 100 to more than 800 litres a hectare. The volume rate using manually operated knapsack sprayers fitted with low pressure flood jet nozzles ranges from 350 to 600 litres spray solution per hectare. Lower volume rates can be used with special nozzles or equipment such as the Controlled Droplet Applicator (CDA) or mist blowers. Here, clean water is essential to prevent nozzle blockage. Extra precautions are required to prevent damage from spray drift.

CAUTION

Spray drift of glyphosate onto crop leaves and the green bark of trees must be avoided. The herbicide can enter the plant through these green tissues to reduce crop vigour or even cause death.

Re-application after rain

Rain within a few hours of application washes glyphosate from the leaves and reduces the herbicide activity. The effectiveness of re-application is very variable. The partial kill of leaves may be sufficient to make respraying ineffective especially when delayed for a few days.

5.8. Biological control

At the present time there are no appropriate and effective biological control systems for *Imperata* control.

CHAPTER 6

INTEGRATED *IMPERATA* CONTROL

Combinations of different *Imperata* management options usually provide better control at a lower cost than one single method. Furthermore they offer the farmer more flexibility.

For an individual farmer, the optimal management of *Imperata* is obtained by a combination of the methods outlined above. When devising an appropriate combination of treatments the extension worker must consider the farmer's situation, including :

- Availability of capital
- Skills and knowledge level
- Proximity of the field to the home
- Time and labour available for *Imperata* control
- The fertility and physical nature of the area
- Availability of clean water if herbicides are used
- Crops to be planted and other weeds

Complete or total elimination, however desirable, is unnecessary for maximum production in many tree crops. Local elimination in planting strips and/or circles is sufficient, provided they are large enough. Unfortunately, areas of *Imperata* constitute a fire hazard which can destroy or seriously damage the crop. Management in these areas is desirable.

An outline for the development of an integrated *Imperata* management programme is shown in Figure 14. Discuss options and develop the management programme with the farmer at all stages. Will the farmer require special training or other assistance to implement the programme?

Remember, once it is controlled, continual management of *Imperata* is necessary to prevent regrowth. This will require regular evaluation of actions to ensure resources are not being wasted and to identify the need to change options at an early stage.

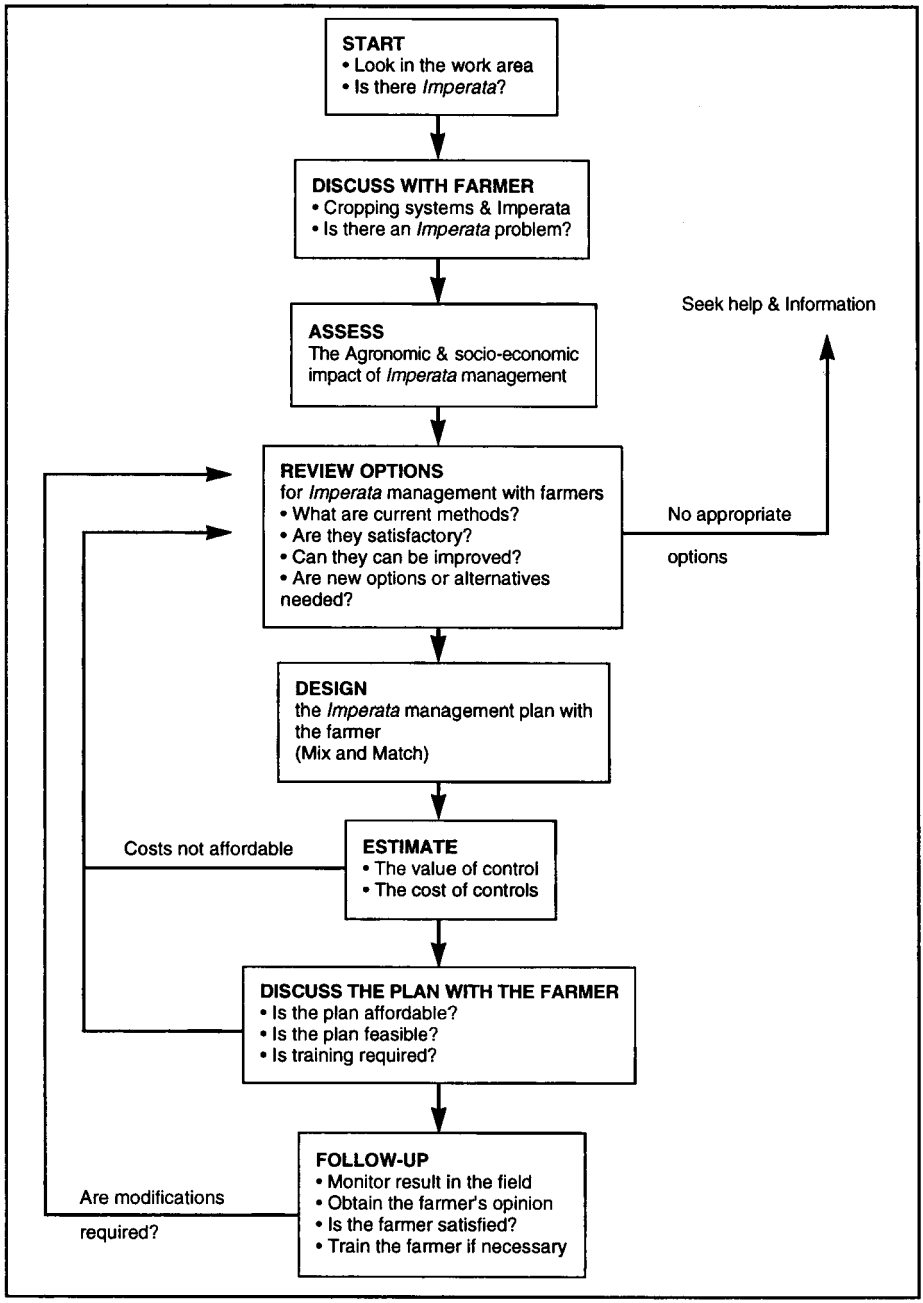


Figure 14. An extensionist's guide to *Imperata* management actions

Follow-up by monitoring both the results in the field and the farmer's opinion. Are modifications required? Can improvements be made? Discuss with the farmer to see if he/she has suggestions for improvements to the programme.

6.1. Examples of *Imperata* control

6.1.1. Minimum tillage using a herbicide

Labour requirements are reduced by the use of a systemic herbicide to control *Imperata* and direct planting without cultivation. As an added advantage the farmer has a longer period of time to complete planting before further *Imperata* control is required than with conventional tillage. Payment of labour can be spread over a longer period of time or, in the case of share cropping, be delayed to harvest.

Box 4. Minimum tillage control of Imperata using a herbicide and annual food crop (see Plate 6)

1. Spray actively growing *Imperata* with the recommended dose of glyphosate
2. Wait until the *Imperata* leaves are dead (usually 3 to 4 weeks after spraying), then press flat by rolling or planking
3. Plant the crop in rows or at individual stations
   For seeded crops such as rice, maize and legumes, bend the *Imperata* away from the planting positions to aid seedling growth
4. Apply phosphate at planting and other fertilisers as recommended to promote rapid crop growth to shade out *Imperata* regrowth
5. Remove weeds by pulling. If necessary loosen the soil round the roots

The initial growth of seeded crops in zero tillage situations is usually slower than in cultivated areas but yields are similar. Advantages of minimum tillage *Imperata* management include:

- Reduction in labour required to prepare land for planting
- Minimisation of soil erosion
- Damage to tree crop rooting systems from cultivations is minimised
- Soil water is conserved by the *Imperata* mulch and infiltration of rain water is improved

- General suppression of weeds in addition to *Imperata* control
- In the long term, soil fertility and organic matter are improved

When using *Imperata* herbicides with a soil residual activity, delay planting for the label-recommended interval. For example, delay sowing rice and maize for 4 to 6 weeks after application where imazapyr-based herbicides are used. Tree crops can usually be planted shortly after application.

6.1.2. Tree and annual intercrops using a cultivation and herbicide combination

Cut the *Imperata*. Burn the residue when dry.

Tree crop rows

Mark tree planting positions with stakes. Allow the *Imperata* to regrow to 40 - 60 cm in height (4 to 6 weeks after burning) and spray with glyphosate. Use the full dose recommended for *Imperata*. Keep the nozzle 30 - 40 cm above the *Imperata* leaves when spraying.

Food crop inter-rows

The inter-row area can also be sprayed and planted with annual crops. Intercrops used include maize, rice, groundnuts and soybean. Food crops should be planted at least 1 m away from the tree base and no closer than the crop canopy. These crops should be weeded as required. The growing of annual intercrops is usually only possible for 2 to 3 years after which shading reduces production. Continue to spot weed *Imperata*, even in the absence of an economic crop, otherwise re-infestation will present a serious fire risk. Promoting the growth of LCCs into the inter-row areas helps to control weeds in general and *Imperata* in particular.

Reminder

Continual maintenance is required to prevent *Imperata* regrowth in the strips. Maintain the tree crop strips by manual weeding, spot spraying or wiping with a herbicide, or planting a LCC in the strips. Continue to remove *Imperata* from the inter-row areas after finishing with annual crop production. Prevention of *Imperata* re-establishment reduces the chance of crop loss through fire. Growing of LCCs, spot spraying, uprooting or pressing are some of the suitable options available.



The dead Imperata is pressed to the ground a month after spraying with glyphosate. This makes the planting easier and also suppresses weed growth.



A food crop is planted directly into the soil. The *Imperata* is moved to the side of the planting line to assist planting and crop emergence.



A young maize crop growing through the *Imperata* mulch in a previously sheet *Imperata* area.

Plate 6. Food crop production into sheet Imperata sprayed with glyphosate

6.1.3. Rehabilitation of *Imperata* grasslands by improvement of soil fertility.

The Potash & Phosphate Institute have successfully demonstrated the rehabilitation of *Imperata* grasslands into productive agricultural land. They recommend using a combination of improved soil fertility, cover crop and intensive food cropping.

- The *Imperata* vegetation is reduced or eradicated by burning and/or the use of herbicide
- Broadcast reactive rock phosphate (one ton per hectare) to correct calcium and phosphate deficiencies
- Plant a fast growing leguminous creeper such as *Mucuna cochinchinensis* to prevent weed growth, to mobilise soil nutrients and to reduce erosion. Use 60 - 70 kg seed (spacing 50 cm x 50 cm, one seed per hole)
- The *Mucuna* will die after 6 months to leave a relatively weed free mulched field. Plant food crops such as maize and rice into this mulch and shortly before they are harvested, plant a drought resistant legume crop, such as cowpea. Intensify crop rotation and cropping pattern, replace fertiliser

After a heavy initial application of reactive rock phosphate no further phosphate is required for 5 - 7 crops.

Using 40,000 planting points / ha (50 x 50 cm) and one seed per planting point requires 60 - 70 kg of *Mucuna* seed. In some cases a spacing of 1 x 1 m, with 2 seeds per hole (30 - 35 kg seed) is sufficient. Quality seed is expensive (e.g. $5 per kg for *Mucuna* seed) but costs can be reduced by local production.

The application of this technology can produce an annual farm income of $1,200 to $1,600 per ha, sufficient to be profitable in the first year.

6.2. Tree circle and strip maintenance

Tree circles and strips can be maintained *Imperata*-free by careful removal of both leaves and rhizomes. Circles, 1 to 1.5 m diameter, are cleared of *Imperata* at planting by hoe or herbicide. These circles should be increased in size to the same as the tree canopy (that is the same area as within the drip line) as the tree grows. General weeds are removed by slashing to the soil surface with a shallow cultivation or scraping to minimise crop root damage. The *Imperata* shoots and

rhizomes must be carefully pulled out. Loosen the soil to ease the removal of rhizomes. These operations should be done when required but at least every 3 to 4 months. They can be combined with fertiliser applications.

6.3. Maximising the benefits of insufficient or limited resources

Where farmer resources are insufficient to manage the whole *Imperata* area, control should concentrate on areas close to the crop. Later, when more capital is available, the inter-row *Imperata* can be controlled. In areas prone to soil erosion, complete *Imperata* eradication is undesirable without the establishment of alternative vegetation to protect the soil.

Band spraying the 2 m wide planting strip in rubber with glyphosate reduces the herbicide to a third of the amount needed for blanket spraying. Controlling *Imperata* in circles (2 m radius) in coconuts reduces rates to a fifth. Manual cultivation costs are reduced in similar proportions. Whilst competition to the crop from *Imperata* is minimised, the risk of complete crop loss or severe damage from fire remains. Management of inter-row *Imperata* is especially important in the dry season. Pressing inter-row *Imperata* early in the dry season reduces the fire hazard. *Imperata* management costs are spread with little, if any, adverse effect on the tree crop.

Reminder and cautionary note

Efforts and resources used to eliminate *Imperata* are wasted without measures to prevent the re-establishment of the weed. Useful plants must be quickly established to prevent this.

CHAPTER 7

IMPERATA AND FIRE

Fire causes *Imperata*! *Imperata* brings fire! These two statements show the inter-relationship between *Imperata* and fire. In South East Asia, as forests are cleared, the area of *Imperata* grassland is increasingly coupled with an increase in the number and size of wildfires. *Imperata* burns so readily and spreads or reinvades so quickly into burned areas, that an even greater fire problem occurs. Countries with few wildfire problems in the past now have many causing considerable damage. One of the best ways to reduce fire damage to property and the environment is to reduce the amount of *Imperata* in rural environments.

Fires can be reduced by two means, (a) preventing the start of a wildfire, and (b) quickly suppressing those that do start. Brush and trees will become established if fire can be kept out of *Imperata* grasslands for 4 - 5 years. This will suppress the *Imperata*.

Prevention

Almost all fires are caused by the activities of people who are entering into *Imperata* areas to work, live and visit. Thus, fire prevention targets people. All persons involved with fire management should know something about fire prevention; why it is so important and how to discuss it with members of the public and those living and working in the fire-prone *Imperata* areas.

The purpose of a fire prevention programme is to eliminate or reduce risk (i.e. the cause of the fire) and/or hazard (i.e. what burns). Three key components of a fire prevention programme are engineering, education and enforcement (Table 2).

Education and enforcement programmes are used to reduce fire risk, whilst engineering is deployed against fire hazards. A comprehensive fire prevention programme uses all three components to reduce risk and hazard. People need to be educated as to how and why they should not start fires.

Tactics for suppression depend upon locally available equipment to make a fire break around the area at risk. Techniques for making firebreaks include removal of vegetation by cutting, cultivation and controlled burning. Pressing

Table 2. The three components of a fire prevention programme

	Key elements	Examples
Engineering	• Separating heat sources from fuels (i.e. *Imperata*)	• Creating and maintaining fuel breaks
	• Reducing or eliminating fuels when heat sources must remain	• Clearance around structures and power-lines
	• Shielding fuels from heat sources to prevent contact	• Design and installation of spark arrester
		• Development of fire codes and regulations
Education	• Informing the public of wildland fire prevention practices	• Schools and civic group programmes
		• Person to person contacts
	• Changing attitudes and behaviour	• Parades, exhibits and displays
	• Creating awareness of fire prevention	• Posters and billboards • Public service contacts on TV and radio
Enforcement	• Compliance with local and national fire codes and regulations	• Inspection for compliance with fire safety laws and regulations
	• Fire cause and determination	• Investigation of fire cause
	• Law and enforcement action	• Red flag patrolling and closure of areas
		• Law enforcement and court action

(crushing or lodging) *Imperata* is a simple method of building a fire break. A fire burning up to such a fire break will immediately decrease in intensity and be easily suppressed. Pressing of *Imperata* will reduce the flame height by a minimum of 50%. The flame height in a 1-meter tall stand of *Imperata* is reduced to less than 50 cm, making fire suppression less difficult and much safer.

Fire breaks should be one and a half times as wide as the height of the adjacent *Imperata* or other burnable vegetation. If the *Imperata* is 1 meter tall, then the fire break should be $1^1/_2$ m wide.

APPENDIX A
Application of Herbicides

Spray application

Herbicides can provide effective weed control when applied using manually operated knapsack sprayers if :

- The appropriate herbicide is used
- The correct rate of herbicide is used
- The correct nozzle is fitted
- The application is made under suitable conditions (weed and weather)
- The operator makes a uniform application

Nozzles

Three commonly used nozzles supplied with knapsack sprayers are illustrated in Figure 15. Neither the cone nor the fan nozzle is suitable for large area treatments of *Imperata*. Floodjets are available to spray 0.75, 1.0, 1.5 and 2.5 m wide swaths. It is usual to use the larger swath when spraying *Imperata*. Floodjets operate at low pressures making them very suitable for application of systemic *Imperata* herbicides. Although they are usually supplied with new knapsack sprayers, floodjet nozzles are under-utilised because farmers are unaware how to use them. The bottom of the sprayer lance should be bent upwards so that the nozzle directs the spray downwards as shown in Figure 15. Check that the swath width is the same on both sides of the nozzle when holding the lance in the normal spraying position.

Measuring the herbicide

For some herbicides the bottle top is designed for use as a measure (see Plate 7 and note the top is calibrated). Use the calibration marks to measure the correct amount of herbicide. Avoid completely filling the measure/top.



Plate 7. Calibrated bottle top for measuring herbicides

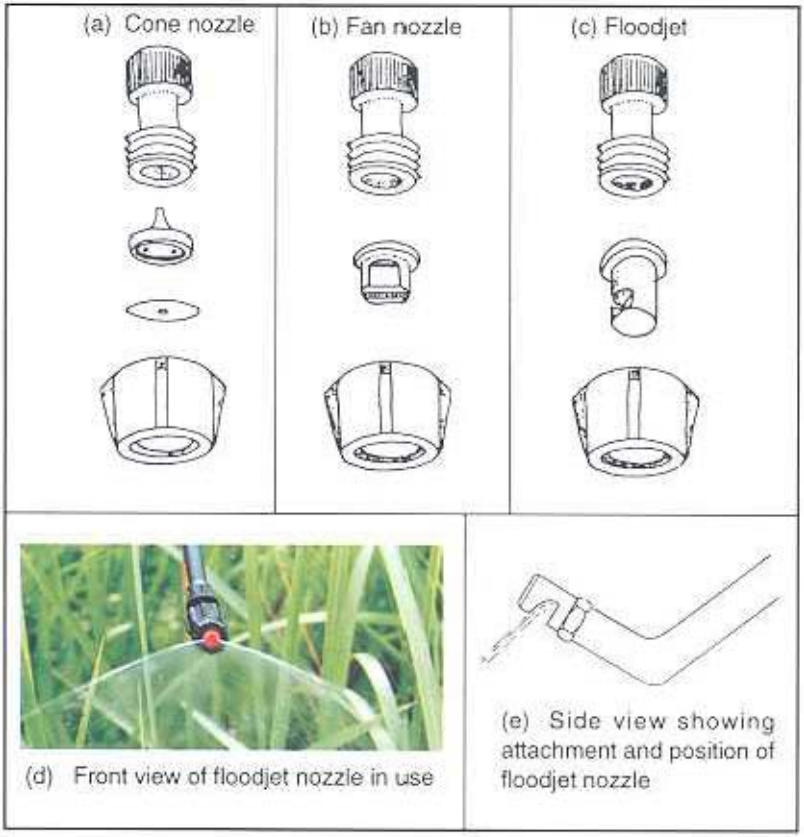


Figure 15 Sprayer nozzles

Sprayer calibration

The effective control of *Imperata* with a herbicide requires that a specific weight or volume of the herbicide is applied evenly over a target area. The sprayer must be calibrated to determine the amount of spray delivered and the correct amount of herbicide to put into the tank. This is necessary for:

- Effective *Imperata* control
- Prevention of the waste of resources
- Minimising any environmental problems and hazards

The rate of application depends on the following factors:

1. The pressure in the spray tank
Pumping must be regular to maintain the pressure as constant as possible during spraying

2. Size of the nozzle orifice
This regulates the amount of spray solution passing through the nozzle. Dirty, blocked or damaged orifices affect the liquid flow rate and can influence the spray pattern

3. Spray swath
The width of the spray swath is affected by the distance between the nozzle and the spray target. The higher the nozzle the wider the swath

4. The walking speed of the sprayman
The walking speed determines the area of field covered in unit time. The greater the speed the lower the spray volume applied.

Good spraying requires

- Constant pressure (pumping)
- Constant speed
- Constant nozzle height above the target

There are several ways to calibrate a sprayer. The one described below is suitable for farmers with the minimum of equipment. The calibration of the sprayer should be done under the same conditions as the field to be sprayed. It is easier to maintain a constant walking speed on a flat area free of obstructions than on uneven hilly ground covered with *Imperata* and other vegetation.

Steps in knapsack sprayer calibration

1. Prepare the sprayer

- Rinse and clean the sprayer, filter, nozzles and hoses, with clean water
- Fill the sprayer with clean water
- Pump to apply pressure and check for leaks

2. Check the nozzles

- Visually check the condition of nozzles. Reject damaged nozzles
- Look at the spray pattern for streaks and drips (Figure 16)
- Spray onto a dry soil surface and look for streaks which indicate faulty nozzles (Figure 17)

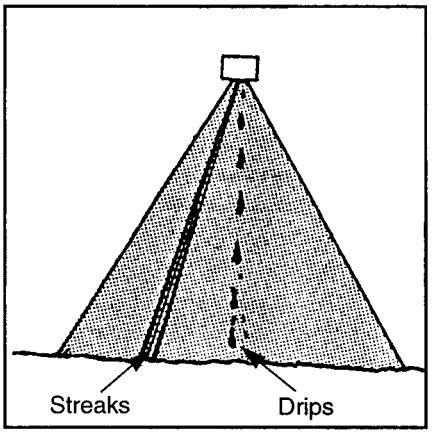


Figure 16. Examination of spray pattern to examine the nozzle condition

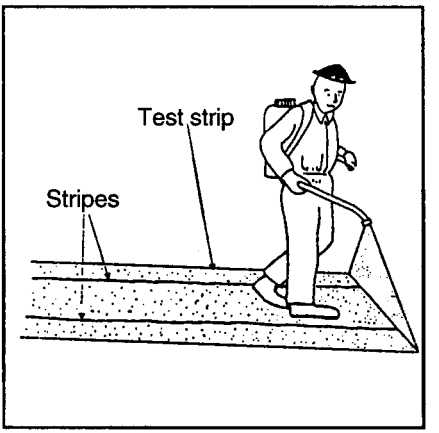


Figure 17. Assessing sprayer nozzle condition by spraying onto a dry surface

3. Check the walking speed

- Mark a starting point in the field
- Walk at a normal and constant speed for two minutes carrying a full spray tank while pumping. Mark the stopping point. Keep the nozzle at a constant height
- Repeat several times to get a constant speed
- Put a known volume of water in the sprayer tank (at least half the tank capacity). Pump up the sprayer and spray.

Make several passes until the tank is empty. Measure the length of ground sprayed

4. Determine the area of the spray swath

- Holding the nozzle at a constant height spray onto a dry surface. Measure the swath width which will be clearly visible

5. Calculate the spray volume per hectare and area sprayed with one tank

- The area sprayed = swath width x length sprayed
- Divide this into the volume in litres of water sprayed and multiply by 10,000 to get the spray volume per ha. Divide this by the spray tank capacity (litres) to determine the number of tanks required for one hectare
- Example
  If the swath width is 2 m and the length of field sprayed 250 m using 10 l of water then the spray volume per hectare is
  = 10,000 x (10 ÷ 2) x 250
  = 200 l / ha
- For a 15 l tank (200 ÷ 15) sprayer tanks are required, i.e. 13.33 tanks

6. Determine the amount of herbicide to put in each tank

- Divide the rate of herbicide (number of litres per hectare to be used) by the number of tanks to be used for one hectare to get the amount of herbicide to add to each tank
- Continuing with the above example.
  The herbicide dose required is 5 l/ha, then the amount of herbicide to add to each tank
  = (5 ÷ 13.33)
  = 0.375 litre of herbicide per tank

Field application of herbicides

1. Choose the appropriate herbicide for the problem
   e.g. a glyphosate herbicide recommended for *Imperata* control
2. Read the label carefully
3. Calibrate the sprayer (page 52)
4. Mix the spray solution in the sprayer tank as follows :
   - Half fill the tank with water
   - Add the measured amount of herbicide to the water
   - Shake to mix
   - Add the remaining water and shake again
5. Spray the herbicide
   Remember constant pumping
   Constant speed and
   Constant height above the target
6. After spraying, empty the tank of all remaining herbicide by spraying it on the target or waste area. Never empty the tank into waterways. Never leave unused herbicide in the sprayer tank
7. Clean the sprayer
   Add water to the tank, shake and empty
   Add water, shake and pump through the nozzle
   Repeat at least two more times

APPENDIX B
General Safety and Handling of Pesticides

- Make sure pesticides purchased are packed in the **original and fully labelled container**. Keep in this container
- **Never transfer pesticides to other containers** especially beverage bottles and food containers
- **Read the label carefully**. Be sure the instructions for mixing, application and storage are fully understood. Follow the instructions carefully
- Store pesticides away from food, children, animals, seeds and fertilisers. **Store** in a separate locked ventilated area if possible
- **Avoid carrying over pesticides**. That is storing open, partially used containers. Try to estimate in advance the quantity needed and purchase only that
- **Protective clothing** should be worn when applying pesticides. Clean long-sleeved shirts, long trousers, rubber boots, hat, and rubber gloves should be worn if possible. Wash these regularly and do not wear if they become heavily contaminated with pesticide
- **Avoid exposure to pesticides**. Never eat, drink, rub your eyes or touch your mouth when working with pesticides
- **Wash thoroughly after using pesticides**, especially before drinking and eating. Keep clothes used in spraying separate from other clothes and wash separately
- **Do not leave pesticides unattended** in the field.
- **Check equipment** using clean water only **before spraying**. Are there leaks, blocked nozzles, blocked filter or other problems?
- **NEVER blow out clogged nozzles or blocked hoses with your mouth**
- **Clean sprayers and other equipment immediately after use.** Remember to flush clean water through the sprayer to clean the pump. Wash measures immediately after use

- **Rinse empty pesticide containers** and pour the liquid rinse into the sprayer tank. Do not pour into streams or areas used by the general public
- **Puncture and crush empty pesticide containers** so that they cannot be reused, especially to carry water or food
- **Avoid contamination of waterways** and irrigation systems with pesticide. Do not wash out containers in streams or spray pesticides into streams