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Methods for short-term control of *Imperata* grass in Peruvian Amazon

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Abstract

The traditional control of *Imperata brasiliensis* grasslands used by farmers in the Peruvian Amazon is to burn the grass. The objective of this study was to compare different methods of short-term control. Biological, mechanical, chemical and traditional methods of control were compared. Herbicide spraying and manual weeding have shown to be very effective in reducing above- and below-ground biomass growth in the first 45 days after slashing the grass, with effects persisting in the longer term, but both are expensive methods. Shading seems to be less effective in the short-term, whereas it influences the *Imperata* growth in the longer term. After one year shading, glyphosate application and weeding significantly reduced aboveground biomass by 94, 67 and 53%; and belowground biomass by 76, 65 and 58%, respectively, compared to control. We also found a significant decrease of *Imperata* rhizomes in soil during time under shading. Burning has proved to have no significant effect on *Imperata* growth. The use of shade trees in a kind of agroforestry system could be a suitable method for small farmers to control *Imperata* grasslands.

Keywords: agroforestry, *Imperata brasiliensis*, slash-and-burn farming, small farmers, weed control

1 Introduction

The region of Ucayali in the eastern part of Peru (Amazon Basin) is confronted with the problem of the noxious weedy grass *Imperata brasiliensis* Trin. This grass currently covers large areas of degraded and abandoned agricultural land in Amazon Basin. Formerly the land was covered by rainforest but was replaced by agricultural activities through slash-and-burn farming. It is estimated that in the Peruvian Amazon during the highest deforestation period in 1980' and 1990', approximately 0.5% of the original rainforest was destroyed and converted to cropland or pasture each year (TCA - Tratado de Cooperation Amazonico, 1997). Between 1999 and 2005, disturbance and deforestation rates throughout the Peruvian Amazon averaged 632 km^2 yr^{-1} and 645 km^2 yr^{-1}, respectively (Oliveira *et al.*, 2007). However, the greatest rates of deforestation occur in around urban population centres, such as Pucallpa (Fujisaka *et al.*, 2000; Oliveira *et al.*, 2007) where the present study was carried out. Pucallpa, the capital of Ucayali region and a city of 350,000 inhabitants, is located about 860 kilometres from Lima (74°W and 8°S). With an average elevation of 150 m a.s.l., the location is characterised by a hot and humid climate with only slight variations throughout the year. Annual rainfall ranges from 1500 to 2100 mm (a mean of 1546 mm, with rainfall increasing to the west). Mean annual temperature is 26°C, whereas mean annual relative humidity reaches 80% (MINAG – Ministerio de Agricultura Ucayali, 2002). Soils around Pucallpa include alluvial, seasonally flooded, riverine systems Entisols, with pH about 7 and 15 ppm available P; and higher located,

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well-drained forest areas of acidic, low P and high Al Ultisols with low content of organic matter (Fujisaka *et al.*, 2000). In general, these soils are of low quality for agriculture, but anyhow they are used by migrant farmers that do not have access to more fertile alluvial soil.

Only scattered patches of untouched forest remain near Pucallpa and even the remaining primary forest shows some evidence of disturbance, for example the presence of weedy species. The slash-and-burn farming system used by local farmers is similar to that of other small-scale colonist areas in the lowland humid areas of the Amazon (Riesco, 1995). Increased population growth around Pucallpa has resulted in more forest land being cleared for agriculture. Length of the fallow period has become shortened, leading to reduction of soil fertility and weed proliferation. This has an immediate effect of reduction in yields and economic returns, and causes smallholders to engage in further forest destruction. As a result of poor agricultural production sustainability and weed invasion (like by *Imperata*), extensive degraded areas have appeared. These grasslands are usually the last stage of soil degradation. Each year during the dry season, large parts of these areas start to burn (intentionally or unintentionally) and it improves the grass proliferation and prevents tree regrowth. Based on the results of a study that was conducted among farmer-settlers near Pucallpa, more than 50% of respondents named *I. brasiliensis* as the worst weed followed by *Rottboellia cochinchinensis* (Fujisaka *et al.*, 2000). For extensive grazing, local farmers could only use the freshly grown *Imperata* grasslands short time after burning. After several weeks however, the grass becomes unpalatable for the cattle. Another alternative use was recently shown by Banout *et al.* (2008) who obtained promising results using *Imperata* as a primary feedstock for compost production.

The typical method of *Imperata* control used by local farmers is to burn the grassland. After several years of agriculture, the field is infested considerably by *Imperata* wherefore farmers decide to use fire to get “clean” land again. However, burning encourages the weedy grasses to grow more aggressively and results in the extension of *Imperata* grasslands (Wibowo *et al.*, 1996). Hence farmers are not able to control the weed and have to abandon the field to cultivate new land for farming. This leads to deforestation and the slash and burn cycle starts again (Fujisaka *et al.*, 1999). This problem does not only occur in Latin America. In South-East Asia and West Africa *I. cylindrica* infested extensively agricultural land and agroforestry systems with improved tree fallows and cover crops were applied successfully to solve the *Imperata* problem (Chikoye, 2003; MacDicken *et al.*, 1996). The shade conditions within rubber or fruit agroforestry systems effect a decline in the density of pest weeds (Garrity *et al.*, 1996). Another possibility is the use of herbaceous leguminous cover crops as the genera *Calapogonium* sp., *Crotoleria* sp., *Mucuna* sp. and *Pueraria* sp. (MacDicken *et al.*, 1996; Chikoye *et al.*, 2006a; Obiri *et al.*, 2007). A farmer assessment, made by Obiri *et al.* (2007) in Ghana, revealed the benefits of this method for suppressing weeds like *Imperata*. Researchers have identified and demonstrated effective management techniques but the adoption rate among farmers is still low. In Nigeria slashing, hand-pulling, burning, deep digging and fallowing were the most common control methods used by farmers, however these are very labour intensive and ultimately not effective (Chikoye *et al.*, 2006b). In extensive systems where *Imperata* infestation is tolerated, cassava or sugarcane is often the crop with the longest period of viable production as the land degrades (Van Noordwijk *et al.*, 1996).

We tested the hypothesis that artificial shading will contribute to the control of *Imperata* grass infesting agricultural land in the Amazon. The method of artificial shading was compared to other methods, either used traditionally by local farmers (manual weeding and burning) or found in literature (herbicide spraying and leguminous cover crop). The main objective of the present study was to determine effective methods for weed suppression adapted to local conditions of upland soil with low fertility (usually deforested and degraded) and to local farmer’s management practises. As the local farmers have very short horizon of planning, we would like to identify a suitable method that brings positive result in a relatively short-time (up to one year).

2 Materials and Methods

The experiment was carried out during a one year period (July 2005 – June 2006) in the village of Antonio Raymondi, located 25 km west from the city of Pucallpa and surrounded by extensive *Imperata* grasslands. An non-flooded, deforested and degraded upland area of 600 m^2 of *Imperata* grassland was slashed manually and all vegetation debris was removed. The original vegetation consisted mainly of *Imperata brasiliensis* (90–95% of vegetation cover) and to a lesser extent of *Pueraria phaseoloides* (Fabaceae), *Pteridium aquilinum* (Pteridophyta; Dennstaedtiaceae) and *Urena lobata* (Malvaceae). The site was previously used for growing food crops such as cassava, maize and beans but had been left fallow for five years. In total 24 plots with a size of 25 m^2 (5×5 m) each were established. Six treatments including control were tested: (1) burning, as traditional method and (2) artificial shading, (3) herbicide spraying (glyphosate), (4) manual weeding and (5) leguminous cover crop (tropical kudzu - *Pueraria phaseoloides*) as alternative methods as well as (6) control. The experimental design is a completely randomized block design with four replications per treatment. The alternative methods were already evaluated in other studies (MacDicken *et al.*, 1996; Chikoye *et al.*, 2006a) and were suitable for local conditions. (1) Under traditional burning treatment the sward was not slashed as in all other treatments but burnt at the beginning of the experiment. During the dry season the vegetation is withered and thus highly flammable. (2) To simulate a natural tree shade cover, artificial shading was used. A wooden construction of 1.5 meters in height was built and covered with palm leaves (*Attalea* sp.), traditionally used in local houses as thatching material. Due to the artificial shade cover, the light intensity declined from 155,000 lux (full daylight intensity) to 15,000 lux. (3) Using a water solution of glyphosate 0.9 $g\,l^{-1}$, herbicide spraying was applied 20 days after slashing the original vegetation when new *Imperata* shoots reached a height of 10–20 cm. (4) After slashing all rhizomes and roots of *Imperata* to 20 cm depth were dig out in the manual weeding treatment. (5) To establish the leguminous cover, certified seeds of Pueraria phaseoloides, the most common leguminous cover crop species of this region, were dispersed on the soil using 100 g of seeds per plot immediately after slashing and incorporated into the soil by hoeing. (6) The control plots were only slashed, biomass removed and the vegetation left to regrow.

Every 45 days, the *Imperata* growth was measured in all experimental plots. At each sample date, three subplots of 0.5×0.5 m per one plot each were chosen randomly (at least 1 m from the border) and average height of 10 plants was measured (in total 72 subsamples per sample date). To determine the *Imperata* above-ground biomass, the weed cover was cut on ground level and other weed species (e.g. *Pueraria phaseoloides*, *Pteridium aquilinum*) were excluded. The bellow-ground biomass of *Imperata* included all vital grass roots as well as rhizomes and was trenched to the depth of 20 cm. Samples from all plots were dried in an electric oven at a temperature of 70°C for 24 hours and weighed on the precision scale (±0.1 g) to determine dry matter yield.

Analysis of variance (ANOVA) and Tukey HSD test (Statistica software 7.0 CZ) were used to analyse the impact of the six treatments on *Imperata* biomass growth (plant height, above- and belowground biomass) and for significant differences among the six treatments. Statistically significant difference was set at the 5% level ($p \leq 0.05$). The graphs were performed by Excel (Microsoft Office 2007 CZ) based on ANOVA mean values.

3 Results

All plots, with the exception of the plots with manual weeding and herbicide spraying treatment, were dominated by *Imperata* within four weeks. In a short time after burning (4–5 weeks), the new *Imperata* plants started to flower and seeds were produced quickly, enabling a better spread to surrounding areas. Burning has proved to have no significant effect on above- or belowground *Imperata* biomass growth compared to control neither in short nor long term (Table 1.). The manual weeding and herbicide spraying significantly reduced

Table 1: *Imperata growth under different treatments in time.*

Treatment	*Aboveground biomass (g)*			*Belowground biomass (g)*			*Plant height (cm)*		
	45 days	*180 days*	*360 days*	*45 days*	*180 days*	*360 days*	*45 days*	*180 days*	*315 days*
Artificial shading	12.82±3.90 ^{b}	16.95±3.81 ^{a}	11.58±11.93 ^{a}	122.53±93.46 ^{b}	37.97±24.76 ^{abc}	26.60±25.92 ^{a}	81.75±15.13 ^{c}	97.50±2.89 ^{b}	100.00±20.00 ^{a}
Herbicide spraying	0.00±0.00 ^{a}	16.08±24.37 ^{a}	66.98±47.45 ^{b}	0.00±0.00 ^{a}	19.90±26.27 ^{ab}	38.70±9.84 ^{a}	0.00±0.00 ^{a}	27.50±55.00 ^{a}	128.75±16.52 ^{a}
Manual weeding	0.29±0.58 ^{a}	26.46±21.18 ^{a}	93.23±48.84 ^{b}	0.29±0.58 ^{a}	11.88±3.13 ^{a}	45.60±27.65 ^{a}	0.00±0.00 ^{a}	101.25±8.54 ^{b}	127.50±9.57 ^{a}
Leguminous cover	25.99±2.84 ^{c}	82.03±22.29 ^{ab}	143.30±43.27 ^{c}	111.43±52.22 ^{b}	68.80±15.14 ^{bc}	88.85±13.99 ^{b}	54.75±6.06 ^{b}	98.75±8.54 ^{b}	122.50±5.00 ^{a}
Burning	35.04±9.27 ^{d}	129.26±31.26 ^{b}	160.25±15.55 ^{c}	106.60±35.65 ^{b}	82.12±12.05 ^{d}	89.05±23.88 ^{b}	57.50±2.89 ^{b}	113.75±4.79 ^{b}	133.75±7.50 ^{a}
Control	27.32±8.89 ^{cd}	101.28±59.22 ^{b}	200.93±71.73 ^{c}	114.87±36.42 ^{b}	78.68±33.42 ^{cd}	110.20±12.77 ^{b}	56.25±7.50 ^{b}	107.50±9.57 ^{b}	128.25±30.00 ^{a}
% of factor influence	88.59	50.33	39.19	62.23	54.27	46.53	95.84	48.36	11.00

Means ± standard deviation with different letter in a column are statistically different (Tukey, $p \leq 0.05$).

both above- and belowground biomass during the whole experiment. The strongest *Imperata* biomass growth (above- and belowground) was found in the control plots and burning plots. The *Imperata* biomass growth at the artificial shading and leguminous cover treatment fluctuated between these extremes.

After 180 days until the end of experiment, artificial shading significantly suppressed *Imperata* aboveground biomass growth, and after 360 days shading even suppressed aboveground biomass significantly stronger then all other treatments. The shading also affected the belowground biomass growth, after 360 days the biomass was significantly lower than that of control, burning and leguminous cover treatments. Kudzu leguminous cover was not effective to suppress *Imperata* growth. During the whole experiment we did not found any significant effect on *Imperata* biomass growth compared to control and burning. In contrast to *Imperata* biomass growth, plant height was not affected by the different treatments. After 45 days, plant height of *Imperata* was significantly higher in the shade treatment plots compared to the other treatment plots. After 180 and 360 days, there were no significant differences in plant height among all treatments. Table 1 also shows that the influence of the treatment evaluated by factor of influence was high at the beginning of the experiment and diminishes during time.

Development of *Imperata* over time can be seen in Figure 1. With regard to the biomass growth in relation to treatment in time, we found a significant decrease of belowground biomass under shading conditions, whereas aboveground biomass remained unchanged over the time of 360 days. The other treatments affected a significant increase of both above- and belowground biomass in time, particularly within the second half of the experiment, but were slower under herbicide spraying and manual weeding. The biomass yield and grass height at the end of the experiment is presented in Figure 2.

4 Discussion

According to their efficiency to control *Imperata* grass growth in one year period, treatments can be divided into two groups. Shading, herbicide spraying and manual weeding were effective treatments as they were able to suppress effectively above- and belowground biomass growth. The use of leguminous cover of tropical kudzu was much less effective and burning was proved to be ineffective in controlling *Imperata* growth.

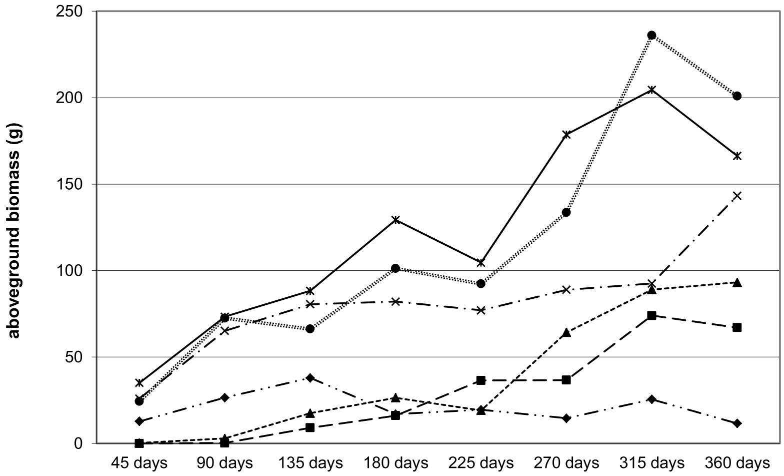
We found that glyphosate spraying and manual weeding are very effective methods for reducing growth of above- and below-ground biomass in the first 45 days, and their effects persist for at least one year. It seems that shading can effectively reduced aboveground *Imperata* growth in a relatively a short time, but for suppressing the growth of *Imperata* rhizomes longer time would be needed, as these rhizomes are very persistent in soil.

After one year, the *Imperata* biomass growth under shading, glyphosate application and weeding was significantly lower compared to the control. These treatments reduced aboveground biomass by 94, 67 and 53%; and belowground biomass by 76, 65 and 58%, respectively, compared to control. In a study from Nigeria, Chikoye *et al.* (2006a) could show that glyphosate application reduced above- and belowground *Imperata* biomass by 26 and 76%, respectively. It seems that shading can effectively suppress growth of *Imperata* shoots but can also reduce the amount of underground rhizomes during time. Compared to the control treatment, the leguminous cover crop could not suppress significantly the growth of above- or belowground *Imperata* biomass. In Nigeria Chikoye *et al.* (2006a) have reached best effect of control by combining glyphosate application with cover crop of Velvet bean (*Mucuna* spp.), above- and belowground biomass was reduced by 52 and 69%, respectively.

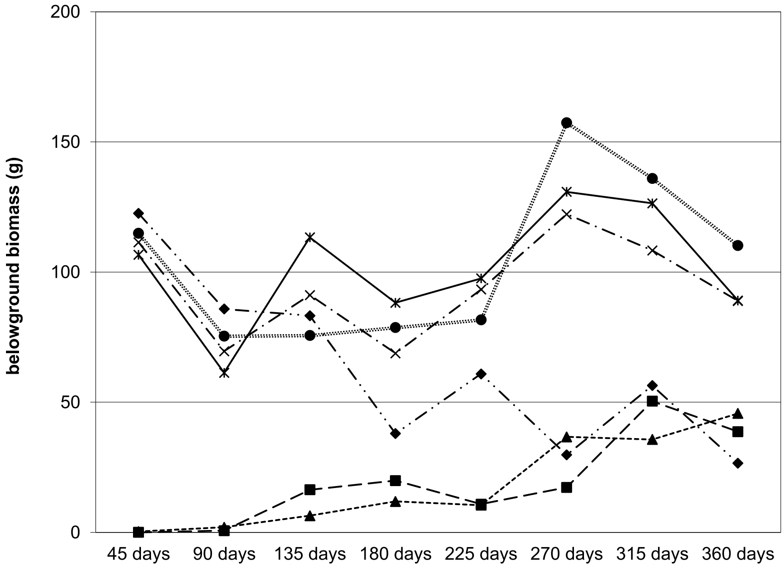
Herbicide application is an effective but expensive method. However for financial advantaged farmers, who want to control large areas, spraying could be a useful way of control weed pests. Manual weeding of *Imperata* rhizomes seems also to be effective even in the long-term but requires a lot of labour. We estimate the need at least 150 man-days per ha to remove *Imperata* rhizomes and roots, but the majority of farmers are not willing to invest a lot of labour in this treatment. This method could only be used in small plots, e.g. home gardens or vegetable plots. Herbicide use can substantially decrease labour needs for weeding (Chikoye *et al.*, 2006a), but farmers need extra cash and application equipment, which in turn limit the adaptability of this management practises.

Farmers assess the success of *Imperata* control through labour and cash requirements, material availability, effectiveness, time span to achieve control and crop yields (Chikoye *et al.*, 2006b). Therefore, the implementation of a shade cover could be a promising and simple method to control *Imperata* grasslands. In our research we used artificial shading, but the use of shade trees can be a suitable method for small farmers. Our results confirmed the conclusions of Garrity *et al.* (1996) and MacDicken *et al.* (1996) that *Imperata* does not grow well in a shaded environment such as agroforestry systems, tree fallow and reforested areas. But Chikoye *et al.* (2006b) argue that longer fallow periods and reforestation are effective but impractical if the pressure on land intensifies from population growth.

a)



b)



c)

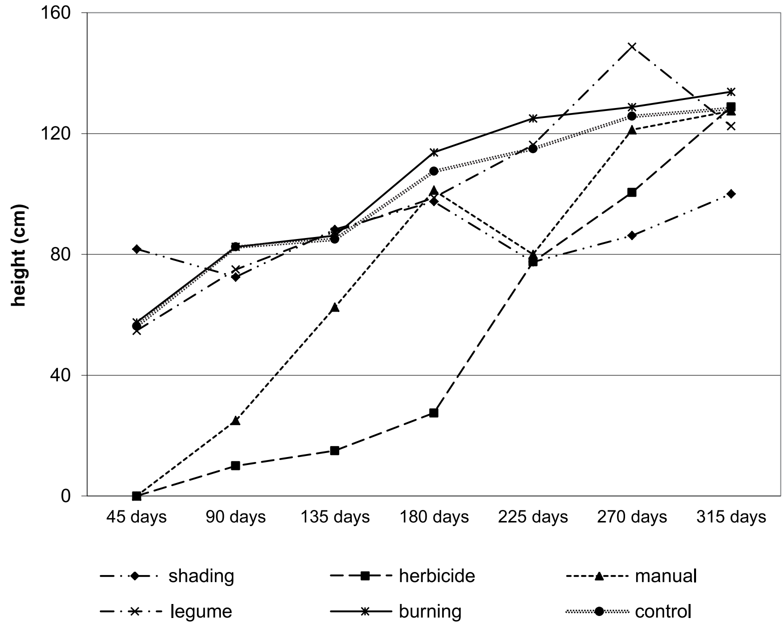


Fig. 1: *Development of Imperata growth over time [a) aboveground biomass, b) belowground biomass and c) plant height].*

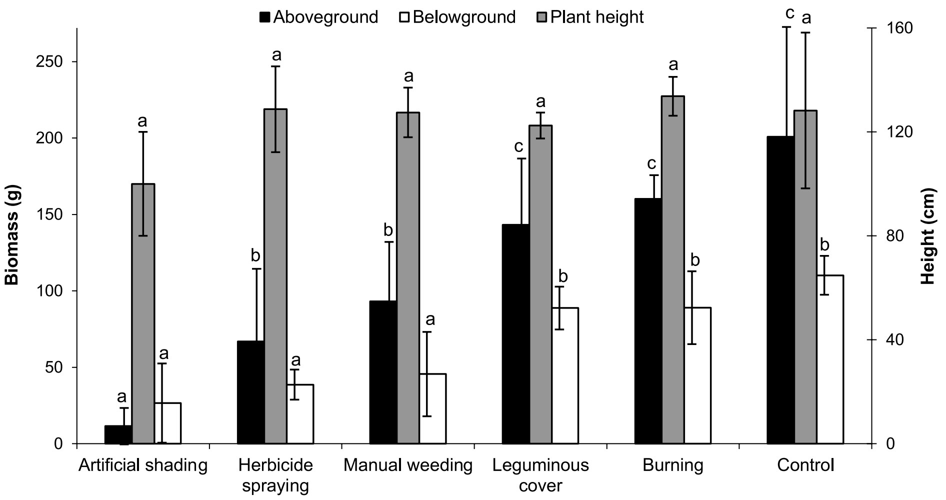


Fig. 2: *Imperata growth (above- and belowground biomass and plant height) at the end of the experiment (Means ± standard deviation, bars with different letter are statistically different, Tukey,* $p \leq 0.05$*)*

Leguminous cover of kudzu was not much effective in suppressing *Imperata*, compared to the promising results obtained by Obiri *et al.* (2007) in Ghana (*Mucuna*, *Pueraria*, *Calapogonium*, *Crotoleria*). It could be probably a result of the relative short experimental time of one year, as kudzu did not established well and was growing slowly due to highly infested and infertile soils. Hence legumes will need more time to suppress effectively the grass growth. However, kudzu can be used in the tree plantations as a cover crop for nutritive properties (as legumes enrich the soil, particularly with nitrogen) and as a prevention of re-infestation of the field by *Imperata*.

Burning *Imperata* was proved to be contradictory as also confirmed by Fujisaka *et al.* (1999). Burning *Imperata* encourages the grass to grow even more aggressively, to flower and to produce seeds earlier and also inhibits the growth of woody species.

Plant height was only affected by artificial shading after 45 days, which might be explained by the need of *Imperata* for higher light intensities, which only occur in the upper stratum of agroforestry systems. Although plants under shade conditions were higher, the plant body itself was unincisive.

5 Conclusion

This study could show that *Imperata* weed can be suppressed by several management practises that differ within small and large-scale cultivation. The most effective methods in controlling *Imperata* growth are manual weeding and herbicide spraying, but they are also the most expensive methods. In the longer term the planting of shade trees could be a suitable (easy and inexpensive) and efficient method for farmers in the study area to control *Imperata* infestation.

Our study confirms that shading suppresses significantly the growth of above- and below-ground *Imperata* biomass. Hence, if farmers would cultivate the trees and crops in an agroforestry system, which also serves as a source of other products like fuel or fruits, they could rehabilitate *Imperata* grasslands. Although weeding would still be necessary until tree canopies offer sufficient shade, the advantages of tree shading are obviously regarding a low need for agrochemicals and labour inputs.

In conclusion, the most effective method for *Imperata* control is a combination of shade trees with other short-term effective methods such as manual weeding or herbicide spraying. The herbicide spraying or manual weeding could be used first to clean the soil, and then farmers should plant suitable shade trees that can control *Imperata* re-infestation in longer-term. The important recommendation is avoidance of fire, either wild or intentional because of the ineffectiveness of burning in controlling *Imperata*, the negative impact on natural succession and the damage on young tree seedlings.

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