The role of herbicides for adapted weed management in conservation farming

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Summary
Adapted weed management in conservation farming aims to supplement physical, biological and ecological methods of weed control with adapted rates of herbicides to reduce soil degradation and sustain farm productivity. In alley-cropping systems, for example, low rates of herbicides could be adapted with legume mulches and manual weeding to manage weeds to a level where farm profit is optimized over weed competition. Below this level, weeds are part of the vegetative cover to minimize soil erosion. Post-emergence herbicides are favoured because they are applied only when necessary and avoid soil disturbance. In future, new herbicide technology must satisfy economic, social and environmental needs.

Introduction

Weed control is a critical component of small-scale farming systems in the tropics. Farmers use little herbicide because of economic constraints due to low farm productivity or limited know-how of herbicide technology. Weed control is achieved largely by physical means including burning, manual or cultural methods such as animal- or tractor-drawn implements. These weed control options have accelerated soil erosion and degradation, particularly on sloping land, leading to declining soil fertility. As such, efforts at intensifying crop production have failed to improve yield and the socio-economic status of farmers significantly. The need to sustain farm productivity has encouraged conservation farming techniques such as contour planting, hedgerow cropping, agroforestry and reduced tillage for the management of both crops and weeds (Fujisaka and Garrity 1989; Lal 1989; Kang *et al.* 1990).

Conservation farming is an ecological approach to the management of surface vegetation by preserving resources including the soil, water, nutrients, energy and also agrochemicals in order to sustain farm yield and reduce environmental risks. Soil degradation and, in certain situations, herbicide persistence already are dictating the trends of both chemical and non-chemical methods of weed control. In the continuing search for new and better solutions, CIBA-GEIGY is integrating these new trends into research imperatives to meet the changing needs in economic weed management and environmental protection (Ebner 1989; Zoschke *et al.* 1990; Williams 1991). One of such on-going projects is adapted weed management, in which herbicides at low rates are being adapted to complement non-chemical methods for better farm efficiency, productivity and sustainability. The non-chemical methods available are many and include physical (manual and cultural practices), biological, and ecological (crop rotation, crop density and spacing, cover crops and legume mulches) methods. This paper appraises herbicide use in relation to manual weeding and legume mulches for adapted weed management in tropical, small-scale farming systems.

Rationale for Adapted Weed Management

A chosen weed control measure, be it chemical or non-chemical, should optimize benefits over costs, taking into account the economic, social and environmental impacts. In the humid tropics, most soils are acidic and infertile. On such soils, complete vegetation removal can lead to soil erosion and degradation, resulting in even less fertile soils and poorer yields.

Weeds must be considered as part of the land vegetation that needs to be managed at a balanced or optimum level as dead or living mulch for erosion control (Zoschke *et al.* 1990). As such, near-perfect weed control throughout the growing season may not be necessary. A better management practice would be to reduce weed infestations to a level where the overall benefit is optimized in relation to weed competition and crop yield.

Use of Legume Mulches in Alley-Cropping Systems

The potential benefits of alley cropping are that the fresh loppings from legume trees can be used as mulch to suppress weeds, increase soil fertility through organic matter and nutrients cycling, and reduce soil erosion (Kang *et al.* 1990). There is evidence that mulches from alley crops suppressed weeds (Budelman 1988). However, alley trees require optimum management in order to minimize competition between the alley crop and intercrop as well as to produce adequate mulch for effective weed suppression.

Table 1 compares the use of legume mulches in conservation farming systems of alley cropping with hedgerow cropping using natural grass-strips at Rembau, Malaysia. Species such as calliandra (*Calliandra calothyrsus* Meissn.) and gliricidia (*Gliricidia sepium* (Jacq.) Kunth ex Walp.) produced adequate mulches, which when applied at sowing, effectively reduced weed cover to below 25% at 30 days after sowing (DAS) in both maize and soybean. The major weed species were broadleaf buttonweed (*Borreria alata* (Aubl.) DC.), garden spurge (*Euphorbia hirta* L.), common asystasia (*Asystasia pangetica* (L.) T. Anders), and goosegrass (*Eleusine indica* (L.) Gaertn.). Calliandra, gliricidia, flemingia (*Flemingia macrophylla* (Willd.) Merr.) and leucaena (*Leucaena leucocephala* (Lam.) de Wit), being faster growing species than falcataria (*Paraserianthes falcataria* (L.) Nielsen), required a second cut at about 40 DAS to minimize competition between the alley trees and food crops. Fresh yields of mulches from the second cut yielded less than 2 t/ha, which were ineffective in suppressing weeds. Overall, the calliandra and gliricidia mulches reduced weeding from the normal two rounds to just one at about 40 to SO DAS. Except for gliricidia, maize yields were correlated with the quantities of mulches added.

Use of Manual Weeding and Herbicides in Alley-Cropping Systems

Compared to manual and cultural methods of weed control, herbicides have saved substantial time, labour and fossil energy (Combellack 1989). Production costs have decreased and crop yields have increased in the major farming systems of the world. In small-scale farming systems, some use of herbicides at low doses or reduced frequency to supplement non-chemical methods of weed control will improve cost-effectiveness and timely weeding (Ebner 1983).

At Rembau, Malaysia, we compared two times of manual weeding (hoeing) with two treatments of post-emergence herbicides in the gliricidia/maize system (Table 2). The herbicides included a sulfonylurea at 20 g ai/ha for dicot control at 22 DAS and paraquat at 540 g ai/ha for grass control at 69 DAS in

Table 1. Effectiveness of fresh legume mulches from alley crops for weed suppression in maize and soybean over two seasons.

Farming system	Fresh leaf mulch (t/ha)		Weed cover (%) at 30 DAS		Crop yield +SE (t/ha)		
	Maize	Soybean	Maize	Soybean	Maize*	Soybean*	Total
Grass-strip/intercrop	0	0	77	77	0.99±0.08	0.10±0.05	1.09
Gliricidia/intercrop	11.7	9.3	4	23	1.67±0.04	0.26±0.04	1.93
Calliandra/intercrop	10.9	9.1	20	25	2.59±0.30	0.55±0.21	3.14
Falcataria/intercrop	15.2	5.1	12	77	2.91±0.39	0.19±0.05	3.10
Flemingia/intercrop	8.7	4.3	11	59	1.94±0.13	0.18±0.03	2.12
Leucaena/intercrop	6.4	3.5	66	59	1.04±0.03	0.20±0.03	1.24

*Fertilizers(maize):20N, 20P, 28K kg/ha at 0 DAS and 20N kg/ha at 30 DAS: (soybean): 20P, 28K kg/ha at 0 DAS.

the interrows of maize. Maize yields in both manual and chemical weeding were similar, but the use of herbicides significantly reduced the labour required; manual weeding required 79 man-day/ha. Gliricidia did not produce sufficient mulch to suppress the weeds significantly. With manual weeding, the exposed top soil is vulnerable to erosion and the uncertainty of seasonal labour can delay timely weeding, particularly when farm size increases (Lorenz and Errington 1991). A possible compromise is to apply a post-emergence herbicide that avoids soil disturbance in the first round and then follow up with manual weeding later in the season, when labour availability is not as critical.

Table 2. Weed management on maize yield in alley cropping of gliricidia/ maize. Gliricidia produced fresh mulches of 3.5 t/ha at 0 DAS and 6.3 to 8.2 t/ha at 50/69 DAS.

Weed management	Weeding (man-day/ha)	Maize yield +SE (t/ha)*	Proportion of check (%)
Untreated check	0	0.60±0.06	100
Manual weeding	79	0.73±0.11	122
Post-emergence herbicides	6	0.77±0.09	128

*Fertilization: 25N. 25P. 35K kg/ha at 0 DAS.

Weed control methods also can affect weed dynamics. In the herbicide treatment (Table 2), the sulfonylurea herbicide controlled the dicots (mainly *B. alata* and *A. gangetica)* but selected for the grasses (mainly southern crabgrass, *Digitaria ciliaris* (Retz.) Koel.). A herbicide recommendation with broad spectrum activity would be more suitable for small-scale farmers. Weed control options that remove mixed species of weeds equally tend to maintain weed populations in equilibrium and reduce the chances of likely shifts towards intractable species.

Optimizing the Timing of Weeding in Adapted Weed Management

Economic thresholds of individual weed species (critical weed densities below which weed control is uneconomical) increasingly are being explored as a criterion to decide whether or not to weed (Cousens 1987). Decisions on weed control based on economic thresholds are less adaptable to small-scale farmers in the tropics for three reasons. Firstly, weed infestations in the tropics are extremely high due to the warm and humid climate and, thus, weed control is more a function of time than weed counts. Secondly, weed populations are usually heterogeneous in terms of species, size and distribution, and rarely exist as uniform stands. Thirdly, the economic threshold may not fit the different socio-economic goals and perceptions of small-scale farmers.

A more useful, but somewhat less precise criterion, is the optimum timing of weeding that will be most effective and economical. This optimum timing is usually about 20 to 40 days after sowing of many annual crops (Zimdahl 1980). To be useful, however, area-specific data must be generated on-farm. In general, weeding out 80% of the weeds within this period would solve the major weed problems (Ebner 1983). Although more subjective than economic threshold, it is simpler, more flexible and adaptable according to the perceptions of small-scale farmers.

Table 3. Time of weed removal on maize yield and labour use in gliricidia/ maize and natural grass-strip/maize systems. Manual weeding was carried out by hoeing.

Farming systems	Maize yield ±SE (t/ha) at different weeding times after sowing of maize					
	Weed-free check	15 DAS	20 DAS	30 DAS	40 DAS	50 DAS
Grass-strip/maize	2.57±0.17	2.57±0.17	2.57±0.17	2.57±0.17	2.57±0.17	2.57±0.17
Gliricidia/maize	2.57±0.17	2.57±0.17	2.57±0.17	2.57±0.17	2.57±0.17	2.57±0.17
Manual weeding (man-d/ha)	137	79	79	79	137	198

In natural grass-strip/maize and gliricidia/maize systems at Rembau, mixed weeds of mainly *E. indica* and *A. gangetica* were removed by hoeing at different times after sowing (Table 3). The optimum timing of weeding was around 15 to 30 DAS based on both maize yield and labour requirements for manual weeding. Translated into soil cover occupied by the mixed weeds, weeding time at 15 to 30 DAS was equivalent to 10 to 20% weed cover. Later weeding would be more expensive (Table 3) and possibly less effective because weeds were larger. Postemergence herbicides could be adapted at lower doses to fit the optimum timing when the weeds are most susceptible.

Future Research Needs

Decisions on weed control in future must include the economics, social and environmental considerations. Adapted weed management aims to balance all these aspects with acceptable weed management solutions for the optimization of farm profits. Since herbicides are the cost effective means of weed control, the logical approach is to adapt herbicides at lower doses or reduced frequency to complement physical, biological and ecological methods in conservation farming systems (Ebner 1983). However, much on-farm research is required to generate useful local recommendations for farmers. We need to understand more about the interactions between crops and weeds, between mulch and pre-emergence herbicides, the effective timing of postemergence herbicides, and the long-term effectiveness and sustainability of adapted techniques. There is also a need to continue to develop new herbicide technology that satisfies economic, social and environmental needs.

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