Research article

Economics of Weed Management in Maize in Pailin Province Cambodia

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Abstract In Pailin Province, Cambodia, small-holder farm households derive most of their income from upland cash crops such as cassava, maize, soybean, mungbean and sesame. Since the end of the Khmer Rouge civil war in 1998, large areas of rainforest have been cleared opening the way for rapid expansion of cropping, especially maize. The crop expansion has occurred on ferrosols and vertosols which had high initial fertility after clearing. Continuous cropping with maize has resulted in a decline in soil fertility and an increase in losses due to biotic factors, especially weeds which have contributed to a decline in maize yields. Due to the increased cost of agricultural labour, farmers have rapidly taken up the use of herbicides for weed control in maize. A survey of 88 households in 6 villages was carried out to determine the effectiveness and economics of weed control methods for maize, being used by farmers. The results indicate that farmers are moving away from the traditional two cultivations for land preparation and two in-crop hand weedings. This has been due to replacement of the second ploughing with pre-sowing glyphosate, and the replacement of hand-weeding with selective in-crop herbicides in response to the cost and scarcity of labour. Although the current herbicide-based system for maize is working well, it is not likely to be sustainable without crop rotations and use of a wider range of herbicides. Maize crops in Pailin are being invaded by *Sorghum* weed species, and these species are not controlled by the commonly used atrazine. Rotation of crops and herbicides will be necessary to prevent a build up of naturally resistant weeds and development of genetic herbicide resistance in weed populations.

Keywords weed, management, maize, survey, rotation, economics

INTRODUCTION

Pailin town (12°50’47” N, 102°36’48” N) is located in North-Western Cambodia on the border with Thailand. The majority of farm households in Pailin Province depend on production of cash crops such as cassava, maize, soybean, mungbean and sesame. However, the most common crop is maize and production has expanded significantly since the end of the Khmer Rouge civil war in 1998.

Farmers usually grow two crops of maize in the rainy season. Early Wet Season (EWS) maize is planted in March-April and in the Main Wet Season (MWS), the crop is usually planted in July-August (Chan et al., 2009).

Much of the land under production of maize has been cleared of rainforest or forest regrowth over the last 20 years. Most of the soils used for cropping are derived from basalt or limestone parent material and have high natural fertility. The grain yield potential for maize in the region is 8 - 10 t/ha (Belfield and Brown, 2009). However, the average maize grain yield was estimated at 3.2 t/ha in 2011, less than half of the potential (Brown and Johnstone, 2012).

There are a number of factors such as abiotic (light, water, temperature and nutrient) and biotic (weeds, insects and pathogens) that contribute to decreased crop yields (Oerke, 2006). Weeds are one of the major causes of poor yields on small-holder farms in Pailin. Due to the increased cost of agricultural labour (USD 1/day in 2002 to USD 3/day in 2010) and shortage of labour, farmers have rapidly taken up the use of herbicides for weed control in maize.

OBJECTIVE

The aim of this study was to document weed management practices and to identify the social, economic and environmental constraints to the adoption of better weed management practices in Pailin Province, Cambodia.

METHODOLOGY

Data were collected from maize growers in six villages in Boryakha Commune in Pailin. A total of 88 households were selected randomly for the study. Sample size was determined using the Yamane formula (Yamane 1967) to give a 10% margin of error. Households were selected from the Villages of Borhuy (22), Boryakha (15), Rong Chak (11), Bortainsou (16), O Chra Lech (14), and O Sngout (10).

Qualitative data were obtained from the respondents using a pre-tested, structured interview conducted by enumerators who were familiar with the existing social settings. The interview schedule included both open-ended and closed-ended questions.

Descriptive statistical tools were used to analyze the quantitative data. The important statistical measures that were used to summarize and categorize the data were means, percentages, frequencies and standard deviations using Excel and the IRRISTAT statistical package was used for regression analysis (Anon., 2011).

Farmers were asked about the yield obtained, the price received for the crop and the variable costs of land preparation, seed, planting, weed control, harvesting, threshing and transportation. These data were used to calculate the gross margin (income minus variable costs).

RESULTS AND DISCUSSION

The average household size in the study area is 5.25 people, of which 3.13 are working age adults and the average area of crop fields per household is 4.04 ha (Brown and Johnstone, 2012). This means that all of the activities such as planting, weeding and harvesting cannot be completed manually by family members. As a result Pailin farmers have begun to mechanize land preparation, and planting and have replaced in-crop hand weeding with selective herbicides.

The average yield was 4.07 t/ha and the average price was USD 172/t giving a total income of USD 700/ha. The average total cost of inputs for maize was USD 275 per hectare, and the highest and lowest costs were USD 491 and USD 143 respectively. The average gross margin was USD 425 per hectare, and some farmers had gross margins up to USD 1,152 while the others made losses of as much as USD 62. On average, farmers obtained a return of USD 1.54 per USD 1 spent which was considered a good return on investment. Break-even yield is the yield at which the gross margin equals zero and is calculated by dividing variable costs by the expected price (Table 1).

Table 1 Economic analysis of maize production in Pailin (per hectare)

Costs	Average	Maximum	Minimum	Median
Yield	4.07	8.27	1.05	3.97
Income	USD 700	USD 1,422	USD 180	USD 682
Variable costs	USD 275	USD 491	USD 143	USD 271
Gross margin	USD 425	USD 931	USD 37	USD 411
Gross margin/USD cost	USD 1.54	USD 2.35	USD (0.43)	USD 1.15
Break-even yield	1.60	2.86	0.83	1.58

The breakdown of variable costs is given in Table 2. The traditional practice for land preparation is for two ploughings and often a harrowing. Pailin maize farmers have reduced the amount of cultivation where only 59% are ploughing the field a second time. This reduction is consistent with the number of farmers using glyphosate which is 33%. It is assumed from these data that farmers are beginning to replace the final cultivation with a glyphosate application. This is a positive trend because reduced cultivation reduces the potential for soil degradation, increases the conservation of soil moisture for the crop and can improve the timeliness of sowing.

Table 2 also shows that there has been a strong trend away from hand planting with 44% of farmers hand planting compared to 52% machine planting. There is also a minority of farmers using hand-weeding for weed control: 34% for one hand-weeding and only 16% hand-weeding a second time.

The reduction in hand-weeding is associated with a high adoption of selective in-crop herbicides with 80% of maize farmers using atrazine and 78% using 2,4-D; with more than 97% of the two herbicides being mixed together and spayed at one time. The study also showed that a few farmers had used Atrazine alone to control weeds without the combination of 2,4 D. There are also 68% of farmers using paraquat as a late post-emergence directed in-crop spray.

Table 2 Breakdown of variable costs for maize production in Pailin

Input	Farms (%)	Average input cost
1st ploughing	98	USD 43.29
2nd ploughing	59	USD 20.86
Seed	100	USD 59.96
Hand planting	44	USD 15.39
Machine planting	52	USD 14.97
1st hand weeding	34	USD 6.58
2nd hand weeding	13	USD 1.62
Atrazine	80	USD 3.69
2,4-D	78	USD 2.46
Paraquat	68	USD 9.18
Glyphosate	33	USD 3.71
1st spraying	39	USD 2.37
2nd spraying	85	USD 7.23
3rd spraying	76	USD 6.58
Harvest	100	USD 58.49
Threshing	2	USD 0.59
Transport	80	USD 18.10
Total variable costs	100	USD 275.37

The overall average input costs do not give an accurate idea of input costs for the different cultivation and weeding strategies. Therefore the data were re-analyzed according to the following classifications:

Replacement of the second cultivation with glyphosate with treatments being:

1. No second cultivation and no glyphosate;
2. Second cultivation and no glyphosate;
3. Second cultivation plus glyphosate;
4. Glyphosate only.

Replacement of hand-weeding with in-crop herbicides with treatments being:

1. Hand-weeding only;
2. Hand-weeding plus in-crop herbicide;
3. In-crop herbicide only.

This analysis confirmed the trend for pre-sowing glyphosate being used to replace the second cultivation (Table 3). The input cost for glyphosate (USD 19.95/ha) was significantly lower than for cultivation (USD 34.69/ha). The cost of a second cultivation plus glyphosate (USD 47.22/ha) was significantly greater than cultivation or glyphosate alone. There were no significant effects on crop yield or gross margin for the substitution of the second cultivation with glyphosate. However,

reduction in cultivation is likely to reduce soil fertility decline and soil erosion and therefore deliver economic benefits in the future (Kelley, 1983).

Table 3 Effect of substitution of the second cultivation with pre-sowing glyphosate on yield, input costs and gross margin per hectare

2nd ploughing	Glyphosate	No. of farms	Yield (kg/ha)	Input cost	Gross margin
No	No	21	3,986	0.00	400.75
Yes	No	38	4,181	34.69	453.39
Yes	Yes	14	4,309	47.22	355.72
No	Yes	15	4,032	19.95	451.65
SE			317	1.31	59.80
5%LSD			892	3.69	168.17
Significance			NS	0.01	NS

A total of 9 households (10%) practiced hand weeding only (Table 4) and the average cost of weed control for hand weeding only was USD 35.19/ha. Twenty two households used both hand weeding and herbicide at a cost of USD 53.71/ha. The majority of households (57) used herbicide only for weed control at a cost of USD 36.53/ha. Although there was a higher yield (NS) for hand-weeding plus herbicide, the cost was significantly greater than for hand-weeding or herbicide alone. Although not significant, the gross margin for herbicide alone was the highest.

Table 4 Effect of replacing hand-weeding with in-crop herbicides on yield, input costs and gross margin per hectare

Hand-weeding	Herbicide	No. of farms	Yield (kg/ha)	Input cost	Gross margin
Yes	No	9	3,596	35.19	369.73
Yes	Yes	22	4,343	53.71	412.22
No	Yes	57	4,132	36.53	438.65
SE			273	5.10	52.09
5%LSD			767	14.33	146.46
Significance			NS	0.01	NS

Table 5 Regression of gross margin on the components of variable costs

Term	Coef.	SDEV	F-value	P
Constant	-729.36	61.7903	139.3280	0.0000
Yield (kg/ha)	0.1625	0.0060	723.3630	0.0000
1st ploughing	-1.1686	0.5693	4.2140	0.0420
2nd ploughing	-1.1747	0.4769	6.0680	0.0160
Seed	-0.5087	0.6000	0.7190	NS
Hand planting	-0.3599	0.4443	0.6560	NS
Machine planting	-0.9734	0.4219	5.3220	0.0230
1st hand-weeding	-1.2092	0.5910	4.1860	0.0420
2nd hand-weeding	-0.0681	1.9154	0.0010	NS
Atrazine	2.1125	5.6101	0.1420	NS
2,4-D	-8.6845	6.4735	1.8000	NS
Paraquat	-0.6807	0.7991	0.7260	NS
Glyphosate	-0.1541	1.6790	0.0080	NS
1st spraying	-4.4487	3.1909	1.9440	NS
2nd spraying	0.6463	2.4113	0.0720	NS
3rd spraying	-3.6185	1.4081	6.6030	0.0120
Harvest	-0.4189	0.3968	1.1140	NS
Threshing	-0.3736	2.2482	0.0280	NS
Transport	-0.5507	0.5227	1.1100	NS
Price per tone	4.0713	0.1633	621.7920	0.0000

Multiple regression analysis (Anon., 2011) was used to determine if individual variable cost and income components had an effect on the gross margin (Table 5). The cost of ploughing, machine planting, hand-weeding once and the third spraying all had a significant negative effect on

gross margin. Therefore the farmers should concentrate on reducing these costs to improve profitability.

Grain yields ranged from 900 to 8,333 kg/ha with an average of 4,130 kg/ha. The regression of gross margin on maize yield shows that, on average, for every extra tonne of yield the gross margin increased by USD 130. The price received for maize varied between USD 70 and USD 250 per tonne with an average of USD 172 per tonne.

93% of farmers used herbicides and 68% of these were satisfied with this method because their fields were mostly large and they had insufficient labour for hand-weeding. 87% of herbicide users reported good herbicide efficacy and quick action, 11% reported ineffective control, and 3% were concerned that herbicide application could have negative effects on soil and human health. There were three main reasons that led farmers to apply herbicide: less costly than hand-weeding; convenience and fast action; and labour shortage.

CONCLUSION

This study documented trends in practices for weed management in Pailin Province Cambodia. The main drivers for change appear to have been the cost and availability of hand labour. This has led to mechanization of land preparation, and sowing and to the replacement of in-crop hand weeding with selective herbicides.

Although the current herbicide-based system for maize is working well, it is not likely to be sustainable without crop rotations and use of a wider range of herbicides. Maize crops in Pailin are being invaded by *Sorghum bicolor* (Shattercane) and *S. halepense* (Johnson grass) that are not controlled by atrazine. Rotation of crops and herbicides will be necessary to prevent a build up of naturally resistant weeds and development of genetic herbicide resistance.

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