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Final report

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1 Acknowledgments

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2 Executive summary

A number of significant economic and environmental forces are driving changes in rice planting techniques and weed management in the Philippines and Asia generally. These forces include reduced water availability and costs, and higher labour costs. This has resulted in an increase in direct-seeding of rice. Concomitant with this shift, however, is a more complex weed problem faced by farmers, and an increasing reliance on herbicides for weed control. In this project, knowledge and expertise developed in Australia in understanding weed management development, weed management extension, herbicide resistance and resistance management was applied in a region in the early stages of cropping intensification and potential development of herbicide resistance.

The objectives of the project were:

1. To sample and document farmers' current weed practices, perceptions (including HR and health risks due to herbicides) and information sources in relation to direct-seeded rice in the Philippines.

2. To test, evaluate and adapt a promising (low herbicide use) direct-seeded rice production method in farmers' fields in the Philippines.

3. To assess the status of herbicide resistance in rice weeds in the Philippines.

4. To develop an economic framework for policy analysis of herbicide resistance and weed management issues in the Philippines and Australia.

A survey of 400 rice growers in two major rice-growing regions, Nueva Ecija and Iloilo, established baseline weed management practices used by farmers, and scoped farmer perceptions of weed issues and weed management options. Farmers were highly dependent on herbicides (spraying from one to three times per season) and were using herbicides with a high risk of developing herbicide resistance.

Field sites for on-farm trials of Integrated Weed Management (IWM) versus Farmer's Practice were established in four sites initially, and expanded to four additional sites. Reduced weed weights, increased yields, higher profits and reduced number of herbicide applications were obtained with the use of IWM as an approach to control weeds in all the study sites, compared to farmers' practice. Results were consistent over six seasons of on-farm trials.

An evaluation after two-three seasons indicated that the majority (80 percent) of the farmer co-operators in Iloilo and Nueva Ecija rated the overall effectiveness of the IWM technology as either very good or good, and that many of the co-operators (75 percent) and some neighbouring farmers (10 percent) were adopting IWM on their farms. A final project workshop to plan for a post-project strategy resulted in draft plans for on-going IWM activities in Nueva Ecija and Iloilo in 2008-09 after the completion of the ACIAR project.

Herbicide resistance screening found the first cases of herbicide resistance in *Echinochloa* spp. to herbicides butachlor, propanil and pretilachlor in the Philippines and greatly increased awareness of resistance risks and the ongoing capacity within PhilRice to confirm and characterise further cases. Further, weedy rice infestations in the regions were mapped and samples collected, and weedy rice has been confirmed by the project research to be highly prevalent and potentially a major threat to sustainable direct-seeded rice cropping. Valuable international research linkages have been initiated in this area with the expectation of future research activities.

Results from economic analyses demonstrated that there is reduced incentive for investment in resistance prevention when gaining resistance from a neighbour is likely, and emphasised the importance of research to determine actual resistance risks and the economic benefits of preventing herbicide resistance mobility.

3 Background

A number of significant economic and environmental forces are driving changes in rice planting techniques and weed management in the Philippines and Asia generally. These forces include reduced water availability and costs, and higher labour costs. As a consequence, direct seeding as a method of crop establishment in rice is increasingly common in the Philippines. Direct seeding uses less labour by as much as 50%.

Concomitant with this shift, however, is a more complex weed problem faced by farmers. With direct seeding, there is less use of flooding and manual weeding for weed control and direct seeding is contributing to a rapid increase in the reliance on herbicides and thus adds to the likelihood of herbicide resistance developing in the Philippines. There are two to three rice seasons in the Philippines and hence, farmers spray herbicides up to a maximum of six times per year. This intensive and prolonged herbicide application can cause shifts in weed populations and the development of herbicide resistance is a potential problem associated with prolonged usage of a single type of herbicide. However, there are limited data available in the Philippines regarding herbicide use, weed shifts and herbicide resistance.

When this project commenced, concern about looming weed management problems had already been expressed by IRRI researchers (Bouman, 2003). It was considered that the availability of efficient weed control techniques would be the key to the success of direct-seeded rice (Pandey et al., 2002). Together with the health and environmental concerns regarding increased herbicide use, experience in other rice growing countries had demonstrated that the weed management demands of direct-seeding could set rice growers on a path to herbicide resistance problems (Valverde and Itoh, 2001).

With awareness of herbicide resistance risks there is the opportunity for pre-emptive action to reduce the risk and costs of herbicide resistance. The availability and promotion of rigorous testing for resistance can work to demonstrate to growers and advisors that herbicide resistance has actually developed and identify which herbicides remain effective. This is necessary in the early stages of a herbicide resistance problem where application and herbicide quality problems are usually assumed to be the cause of poor weed control. This can be particularly important in markets, such as in the Philippines, where herbicide products can be of inconsistent quality and content, and where application methods can be unreliable.

In this project, knowledge and expertise developed in Australia in understanding weed management development, weed management extension, herbicide resistance and resistance management was applied in a region in the early stages of cropping intensification and potential development of herbicide resistance. Grain growers in the Australian cropping belt face what is often referred to as the most serious herbicide resistance problem in the world. This evolution of herbicide resistance in major cropping weeds (such as *Lolium rigidum*) threatens the sustainability of the herbicide-dependent cropping systems that have been developed, such as no-till systems (Powles et al., 1997).

In many major grain growing regions the majority of fields contain a weed population resistant to multiple major herbicide classes. In Western Australia, for example, over 70% of paddocks contain a resistant weed population (Llewellyn & Powles, 2001). Although resistance to some herbicides is already widespread, most grain growers have several herbicide options still available to control weed infestations in crops. Increasingly, however, these important alternative options are being lost due to herbicide resistance, for example, resistance to glyphosate. Therefore, the decision problem of conservation of the herbicide resource versus exploitation is as relevant in Australia as it is in regions where herbicide resistance risks have emerged more recently. Through large research and extension initiatives, Australian growers are being encouraged to invest in integrated weed management practices to reduce selection pressure for further herbicide resistance.

In the Philippines, a priority issue is to develop economic weed management practices that can become part of a cost-effective and sustainable weed management system. The need for this is being driven by the following factors previously mentioned, and as indicated in Figure 1:

- the declining role of hand weeding and transplanting due to labour costs
- reduced water management options for weed control
- a move to more intensive cropping
- more direct seeding that favours major weeds.

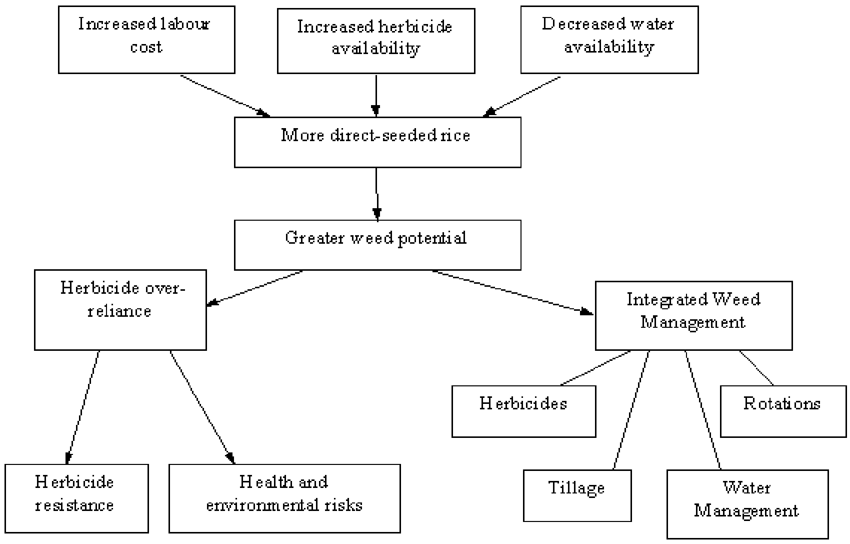

Figure 1. Factors influencing weed management in rice in the Philippines and possible responses

Rice growing is the major agricultural enterprise in the Philippines. Rice is grown on 4.2 million hectares by two million farmers. Rice production in 2003 was 13.5 million metric tonnes, which was about one million metric tonnes short of supplying the requirement of the Philippine population. The population of the Philippines is increasing at an accelerated rate and domestic demand is increasing faster than local rice production. Intensification of rice production is seen as necessary for Filipino farmers to increase income from rice farming and for the country to attain rice self-sufficiency. Cost-saving and yield enhancing technologies, including greater use of direct seeding and less hand weeding, are needed to boost yields and improve the productivity of rice farmers. The proportion of farmers using direct seeding was 25% in 1993 (Cruz et al., 1996), with the proportion of rice area established using direct seeded being estimated more recently as approximately 42% (Pandey and Velasco, 2002).

Weeds are among the major problems constraining the production of high yields by farmers in the country. Depending on rice culture, yield loss caused by uncontrolled weeds in the Philippines range from 44 to 96% (Ampong-Nyarko and De Datta, 1991). The higher yield loss is often observed in dry seeded rice under upland conditions. Weed management is a major and increasing cost in rice production, particularly in direct-seeded systems (Pandey et al., 2002). Cost-effective strategies that reduce current and future herbicide reliance have the potential to benefit growers in the short and long term. Such strategies will allow growers to respond to threats such as the ‘water crisis’ (Bouman, 2003) in a sustainable way.

This project examined a number of aspects of the interaction between direct-seeded rice and herbicide use in the Philippines, as outlined in the objectives which follow this section.

4 Objectives

The project had four main objectives incorporating weed science and social science. There were:

1. To sample and document farmers’ current weed practices, perceptions (including HR and health risks due to herbicides) and information sources in relation to direct-seeded rice in the Philippines. This information will be used to identify risks to the sustainability of current weed management systems. Implications of social trends such as declining rural labour availability on rice production systems will also be investigated.
2. To test, evaluate and adapt a promising (low herbicide use) direct-seeded rice production method in farmers’ fields in the Philippines. Apparently cost-effective weed management options that use herbicides less intensively than current practices will be further tested and extended.
3. To assess the status of herbicide resistance in rice weeds in the Philippines. The first major survey of herbicide resistance in the Philippines will be used to raise awareness of the current status and future risks.
4. To develop an economic framework for policy analysis of herbicide resistance and weed management issues in the Philippines and Australia.

5 Methodology

5.1 Objective 1. To sample and document farmers' current weed practices, perceptions and information sources in relation to direct-seeded rice in the Philippines

A survey of rice growers in two major rice-growing regions was conducted. Prior to developing the survey three activities to inform the survey development were conducted:

- A review of existing economic, adoption and sociological literature relating to rice grower behaviour (including studies conducted by IRRI and past studies by Philrice) was undertaken.
- A preliminary analysis of existing survey data (e.g. BAS/PhilRice 5 yearly survey of 2000 rice-based farm households) was conducted to gather background information on farmer use of direct-seeding and herbicides.
- Participatory Rural Appraisals (PRA) were conducted in four locations in Nueva Ecija (Rizal and Aliaga) and Iloilo (Barotac Nuevo and Dingle) to:
  - gain farmer perspectives on weed issues
  - gain farmer perspectives and information on weed control practice use.

Following these initial activities, the farm survey was jointly developed by the research partners from August to November 2004, and was designed to capture both current and planned weed management practices, and also perceptions about herbicide use and other weed issues. An electronic copy of the survey is attached to this report (Appendix 1). The survey was pre-tested in October 2004 and then implemented by the socio-economic and survey staff of PhilRice in the local languages over December 2004 - February 2005 in two major rice growing regions where direct-seeding is commonly practiced.

The specific study areas selected were Iloilo and Nueva Ecija, the rice bowls of the Western Visayas and Central Luzon, respectively (Figure 2). These two regions were identified by the analysis of existing BAS/PhilRice survey data to be those regions with the largest percentage of farmers using direct seeding. A total of 200 farmers for each province, equally distributed among the sample municipalities, were interviewed using a quantitative approach with fully specified questionnaires. The data gathered were analysed and frequencies, means and ranks were obtained. The final report was done in consultation with the Australian counterpart scientists.

The third output (farmer information sources – see section 6) was scoped in four Participatory Rural Appraisals (PRAs) conducted in August 2004. Questions on information sources were not included in the survey because the length of the survey had become a problem.

PhilRice staff Karen Barroga was successful in obtaining an ACIAR John Allwright scholarship and commenced study at UWA in June 2006. She is investigating the learning and adoption of multi-component and preventive agricultural innovations in the Philippines, using Integrated Weed Management (IWM) and Integrated Crop Management (ICM) as examples of multi-component and preventive innovations. This work has potential to contribute significantly to Objective 1 following project completion.

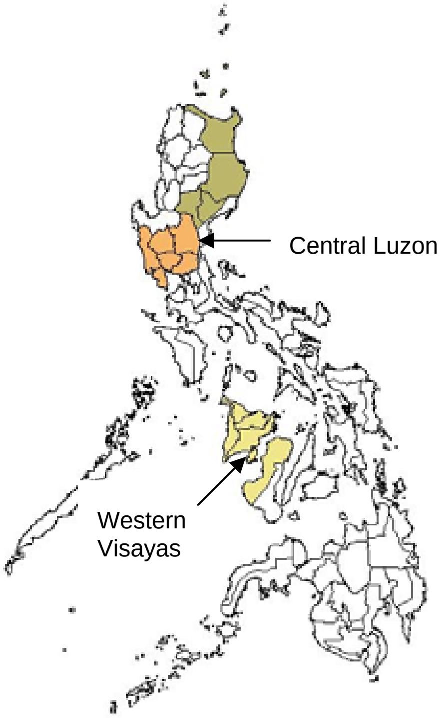

Figure 2 Map of the Philippines showing the study areas: Central Luzon and Western Visayas

5.2 Objective 2. To test, evaluate and adapt a promising (low herbicide use) rice production method in farmers' fields

The on-farm testing and adaptation of a set of weed management practices for direct seeded rice involved farmers, but still aimed to maintain sufficient scientific rigour to enable results to be communicated with confidence to other regions. The new practices to be tested, evaluated and adapted had been developed through on-station research at PhilRice (Casimero and Juliano, 2004) and these were tested in the more realistic farmer environment. The approach used was village-level integration: farmer participatory research which takes account of traditional or best farming practices of farmers in their village context and also involves the active participation of farmers in managing simple experiments on-farm (Figure 3). The process involved the following stages:

5.2.1 Workshop and benchmarking

Before embarking on the full implementation of the activity, workshops (or PRAs) of stakeholders in four selected barangays were conducted. The barangays were selected in the target areas of Nueva Ecija and Iloilo, and also to represent two distinct sites (farms located at the head end and tail end areas of the irrigation system) for the trials to be established. The sites selected were in Rizal and Aliaga municipalities in Nueva Ecija, and in Dingle and Barotac Nuevo municipalities in Iloilo. Participants in the workshop included researchers, local government units, extension agents, farmers, women and other interested parties. The workshops served as the avenue for scoping weed issues in the area (see section 5.1) and introducing the proposed project on integrated weed management. The workshop served as the first step of initiating participation of stakeholders in the project, and had the specific aim of involving farmers and local leaders at project inception.

Other relevant information to establish the baseline data for the trial site areas was gathered using small focused group discussions with key informants in the village including local government leaders, farmer leaders, herbicide company personnel, local traders and other stakeholders in the community.

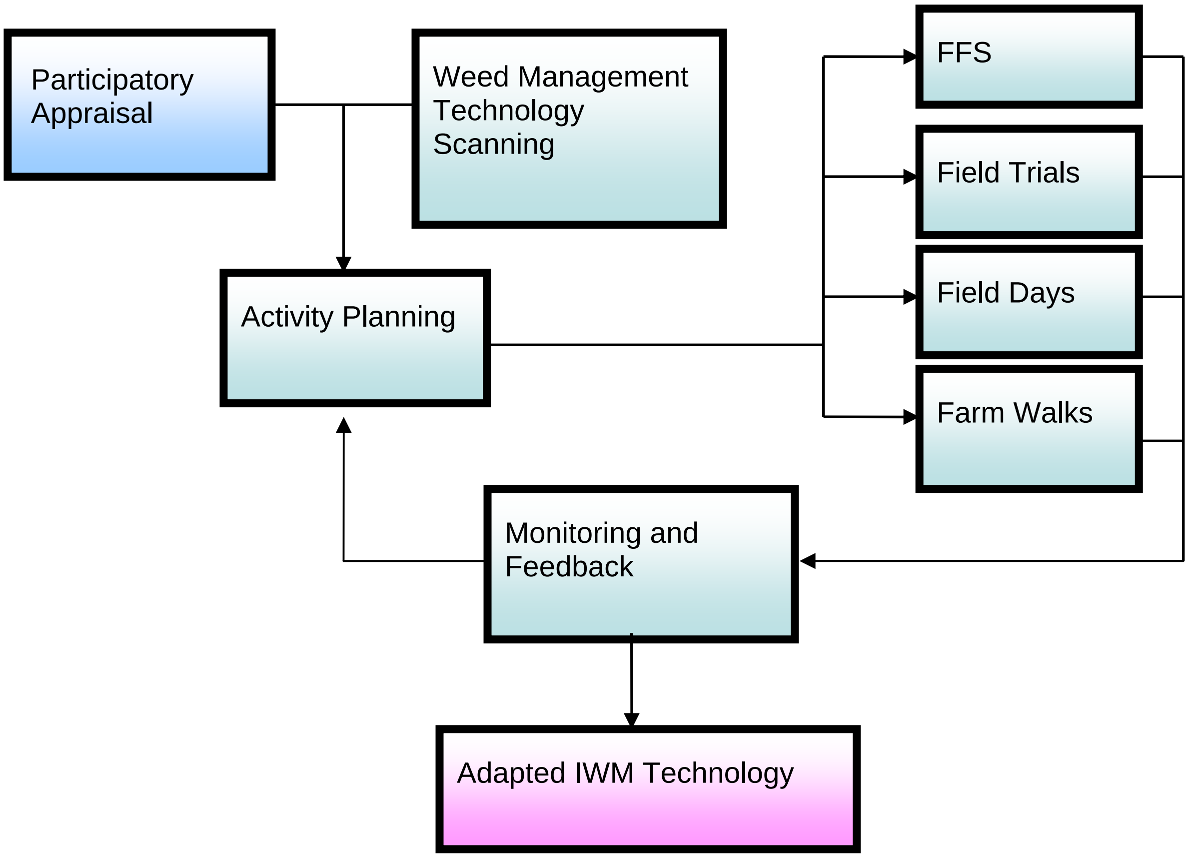

Figure 3 Schematic diagram of the Village Level Integration approach used for implementing IWM into village farming systems

5.2.2 On-farm research

Following the PRAs and discussions with local extension workers and community leaders, farmer co-operators for the field trials were identified. At each of the four sites, ten farmers were selected to serve as farmer-partners in the implementation of the on-farm trial. Their fields had to be strategically located and accessible as they served as radial points for technology dissemination. Farmer-partners were selected based on the following criteria: 1) farming at least one hectare direct seeded rice, 2) having the resources and manpower to shoulder the costs not supported by the project, 3) farmer leader in the community, and 4) willing to cooperate in the project and serve as a farmer extensionist in disseminating integrated weed management to other farmers. The co-operators represented a good spread of farmers: some progressive, some average, and some poor managers. The first field trials commenced for the dry-season crops in Oct/Nov 2004 in Iloilo and January 2005 in Nueva Ecija.

The initial on-farm trials involved two treatments, integrated weed management and conventional weed management (Base Farmers' Practice). During the first year, the package of weed management practices that was implemented was based on research results from on-station experiments at PhilRice, with some modifications to fit in the best weed control practices of the farmers. The IWM treatment was a combination of cultural management practice, tactical use of intermittent irrigation involving reduced use of continuous flooding, plus minimal herbicide use.

Use of the weed control action indicator (WCAI) was also included and farmers were trained in the use of this tool. WCAI is a tool that helps farmers to decide subsequent weed control measures after the application of the first herbicide. It makes use of visual assessment of weed cover (WC) and relative weed height (RWH) in relation to rice plant height to determine if post-emergence herbicide application or hand weeding needs to be done at 30 and 45 DAS. Control action will be done at 15 DAS if RWH and WC are >15% and >5%, respectively. At 30 or 45 DAS, additional weed control measure is needed if RWH and WC are > 30% and >5%, respectively. Otherwise, no control is undertaken.

The integrated weed management package consisted of good land preparation (3 weeks to one month period that includes ploughing, two harrowings at one week interval each and land levelling one day before seeding), water management (irrigating the field at 8-10 days after seeding (DAS) and when possible, followed by intermittent irrigation until maximum tillering stage) and one herbicide application (pre-emergence or early post-emergence) at 1-15 DAS. At 15, 30 and 45 DAS, the farmer used the WCAI to determine if additional herbicide application or handweeding should be done based on the relative weed height and weed cover in the rice field.

The 'conventional' method followed that of the local farmers' weed management practices and was decided by consensus of the co-operators at each site. It commonly involved just one ploughing, one harrowing and levelling over a period of just one week. This results in relatively poor land preparation, and it was followed by a largely pre-established program of pre-emergence herbicide application or early post-emergence herbicide (1-8 DAS) application followed by post-emergence herbicide application or handweeding at 30 to 45 DAS. Conventional practice involved greater use of flooding for longer periods and therefore greater water use. The IWM and BFP treatments are summarised in Table 1.

Table 1 Integrated Weed Management and Base Farmers' Practice weed control treatments

Activities	Base Farmers' Practice	Integrated Weed Management
Land Preparation	1-2 weeks period (1 ploughing, 1 harrowing, and levelling)	At least 2-3 weeks period (1 ploughing, 2 harrowings, and levelling)
Herbicide Application	Pre- or early post- and late post-emergence or handweeding at 30 to 45 DAS	Pre- or early post-emergence
Water Management	Greater use of flooding for longer periods	Alternate wetting and drying (AWD)
Weed Control Action Indicator (WCAI)	Not used	Used at 15, 30 and 45 DAS

In the initial season of on-farm trials 10 x 10 m^2 plots were constructed side-by-side in the farmers' fields for the IWM and BFP treatments. The farmer co-operator implemented both weed management practices for the on-farm trial with guidance from the project staff. During the application of IWM practices in the plot, the researcher worked in the field with the farmer. Local government agricultural technicians were also closely involved with the implementation of the trials. This procedure served as hands-on training for both the farmers and the technicians on the IWM package. The farmer implemented the local agreed "common" weed management practice in the conventional treatment plot. Except for the weed management, all other cultural management practices recommended for wet direct-seeded rice were followed.

Following a direct request from farmers at the PRAs, season-long training in rice crop management took place in the four sites. Training took place at the four sites before the field trials commenced and farmers were taught the "stale-seedbed" technique in preparation for practising it in their own fields. The follow up workplan involved weekly training/meetings in the barangays, and a close working relationship with the Local Government Units at the four sites. Training on Integrated Crop Management (ICM) in rice was conducted simultaneously with the on-farm trials, following the participatory approach of the FAO-IPM Farmer Field School (FFS). This training aimed to educate farmers on how to manage their crop well, including good weed control, so they could grow a healthy rice crop for better yields. The training was based around monitoring the growth and production of the field trial crops and was conducted by PhilRice staff and local government agricultural technicians. In Iloilo, training was also conducted by staff of the Western Visayas Agricultural Research Centre (WESVIARC) who were project collaborators in Ilolilo. Field days were held in conjunction with the trials and were attended by the co-operators and other farmers in the barangay. In each province, farmers from both barangays involved in the IWM trials attended the field days at each site.

Data were collected to assess the effectiveness of the weed control treatments, including:

- Percent crop phytotoxicity rating (visual assessment of % phytotoxicity/ phytoinjury index (1-9) such as yellowing, thinning, curling, stunting, onion-leafing) was taken at 7 and 15 days after herbicide application.
- Percent weed control/ weed control index (1-9) by visual assessment was taken at 15 days after herbicide application. Percent weed control for each individual weed species at 30 and 45 DAS was taken from the actual weed count in the 2 sampling quadrats.
- Weed count, and weight for each weed species was taken at 30 and 45 DAS from a 0.5 m^2 sampling area using two 0.5 m x 0.5 m quadrats per plot.
- Number of productive tillers/$m^{2.}$ The number of productive tillers/m^2 was counted at harvest from a separate 1 m^2 area outside of the yield area.
- Yield will be taken on 10 m^2 at the centre of each plot (and converted to tons/ha), and the weight adjusted at 14% moisture content.

5.2.3 Cost and return analysis based on on-farm research

A cost and return analysis was done on a continuous basis (at the end of each season) to demonstrate the economic benefits of the low herbicide use weed management package and compared to that of the farmer's practice. This included monitoring of inputs (herbicide, water, labour, etc.) and other costs and benefits associated with rice production. Costs were monitored by farmer co-operators using a farm record diary.

5.2.4 On-going review and adaption of the IWM practice

At the end of each season a post-season evaluation session was held with the farmer co-operators and local extension workers to discuss the implementation of the trials and any issues that had arisen, the weed control and economic results achieved, and their ideas for the next season. In this way, the IWM treatment for the next season was continuously assessed and adapted to local situations in consultation with farmers and extension workers. The farmer's practice treatment was the same as that implemented during the first year of the on-farm trial. The adaptations made to the IWM treatment in the various sites are reported in the results section 7.2.3.

After two years (in the second half of 2006) a survey was conducted by the PhilRice team to assess the uptake of the IWM techniques among farmer co-operators and neighbouring villagers. The aim of the survey was to:

- determine the farmer co-operators' perception of the effectiveness of IWM technology for weed management
- determine the uptake of the IWM technology in the farmer co-operators' fields
- assess diffusion of the IWM technology to other farmers' fields at the midterm of project implementation.

The data were gathered from both IWM farmer co-operators and other farmers in the project sites in Iloilo and Nueva Ecija. Focus group discussions were held with all IWM farmer co-operators in each project site, and a survey was implemented with the other farmers. Forty farmers from each province whose farms are adjacent to the farmer co-operators' trial plots were randomly selected and interviewed using a fully structured questionnaire.

5.2.5 Expansion of the research sites

During the project, the on-farm trials expanded to villages nearby the original sites in Nueva Ecija and Iloilo. In 2006 -2007, the number of sites increased from four to eight (with a total of eighty farmer co-operators) because of the demand from farmers to be involved in the project and learn about IWM.

A review of the project was conducted in September 2007 and it was recommended that the last dry season crop (2008) should focus on demonstrating IWM in large plots (0.5 to 1.0 ha/farmer). This establishment of demonstration plots aimed to show the workability and feasibility of implementing IWM in large plots. Field days were held in conjunction with the demonstration plots.

5.3 Objective 3. To assess the status of herbicide resistance in rice weeds in the Philippines

The aim of this objective was to develop and document a reliable herbicide resistance testing process suited to the local environment and infrastructure, and use this to assess the status of herbicide resistance in rice fields in the Philippines. The development of the most appropriate protocols and formalising the testing method enabled confidence in communicating resistance testing results, something that it is particularly necessary when familiarity with resistance risk is low among growers and advisors. It was envisaged that results from initial testing would be used to raise awareness of resistance and the availability and need for testing. The following methodological stages were followed:

5.3.1 Appraisal of awareness of herbicide resistance and collection of weed samples

The PRAs and survey of farmers in target areas in Iloilo and Nueva Ecija (as part of the questionnaire for Objective 1) enquired about experience with herbicide failure and awareness of herbicide resistance. To further scope the perceived incidence of herbicide resistance, Dr Casimero and Mr Martin discussed herbicide resistance issues at meetings of agricultural technicians and at a meeting of the Philippine Weed Science Society in 2004, and also asked about field observations of herbicide resistance, with the aim of using existing networks of field staff throughout Philippines for identification of areas and populations with possible occurrences of herbicide resistance.

From the information gathered during the participatory appraisals and baseline survey, it was learnt that farmers in Iloilo and Nueva Ecija provinces had little or no knowledge of herbicide resistance, although some farmers reported loss of herbicide efficacy. In 2005, a follow-up survey was done in the project sites by Mrs Juliano, to learn about the history of herbicide application and rice cultivation in the project study areas. It was found that farmers at these sites had a long history of using butachlor + propanil herbicide to control weeds in direct-seeded rice. Based on this follow-up survey, weed samples were taken from suspect fields at the project sites.

5.3.2 Development of herbicide resistance testing protocols

As only a very limited amount of resistance testing has been conducted in the Philippines and at PhilRice, an important methodological stage was the refinement of testing procedures to suit local conditions, weed species and the available facilities. PhilRice scientists had some resistance testing experience but only with relatively simple testing procedures. Confirming new and emerging levels of resistance required more sophisticated approaches.

Dr Casimero visited both WAHRI and Charles Sturt University resistance testing centres in September 2004, reviewing testing protocols and meeting with Dr John Broster, Professor Steve Powles and other WAHRI research staff. Following the identification of

Echinochloa spp. as a suspect weed in the project field sites, a literature search on herbicide resistance (HR) testing protocols that would be suitable for testing HR in *Echinochloa* was undertaken and that was the basis of the methodology used for the reported work. Some modifications were made for the germination and establishment of weeds in pots. Some documentation of the protocols used for testing HR on 2, 4-D in *Sphenoclea* in the Philippines used by Sy and Mercado (1983) was done.

Simultaneous with testing of the samples was the continued development or optimization of protocols for testing HR weeds in rice. Two protocols to screen for herbicide resistance with single or cross resistance for propanil, butachlor, pretilachlor, and butachlor + propanil were developed at PhilRice. Three protocols to screen for the evolution of resistance from susceptible biotype using whole plant assays; screening of cross- or multiple resistances using whole plant assays but two different herbicides with one experimental set up; and quick tests to cover weeds that emerge/escape after control has been applied at the time of field application (farmers' fields) were adapted by PhilRice staff after Mrs Juliano undertook hands-on training at the Western Australia Herbicide Resistance Initiative (WAHRI) laboratory at the University of Western Australia from April-July 2008. The protocols that were developed during the project are attached as Appendix 2.

5.3.3 Herbicide resistance testing of suspect weed populations at PhilRice research facilities

Initial samples of *Echinochloa crusgalli* and *Echinochloa glabrescens* were obtained from the suspect fields in the project sites in Nueva Ecija and Iloilo provinces (see section 5.3.1). Eight populations from the two provinces were the first samples to be subjected to resistance screening. Control populations were weed samples taken from the Banuae rice terraces where no herbicides are used. All populations were initially tested against butachlor + propanil. Dose response assays were done for all populations for butachlor + propanil together, and for butachlor and propanil separately.

In 2006-2007, after the completion of the initial HR screenings, three greenhouse trials were set up to screen for:

- pretilachlor cross-resistance in barnyard grass (*Echinochloa* spp.)
- heritability of resistance in the F2 generation of butachlor + propanil resistant barnyard grass populations
- resistance screening for cyhalofop in *Leptochloa chinensis*.

The survey conducted in 2005 by Mrs Juliano on herbicide use in Nueva Ecija and Iloilo had revealed a shift of herbicide use from butachlor+propanil to pretilachlor with the latter being used for an average of four years. Thus, identifying cross-resistance, where previously identified butachlor+propanil resistant populations are also resistant to pretilachlor (also a Group K herbicide), would be significant. For the cyhalofop screening, four populations of *Leptochloa chinensis* were collected from two villages in Barotac Nuevo, Iloilo (where several populations of *Echinochloa* spp. Used in the previous experiments had been collected), and were screened for possible resistance. A susceptible population collected from PhilRice Central Experiment Station served as the check.

As the project finished, work towards screening for resistance of *E. crusgalli* and *E. glabrescens* to bispyribac sodium and *L. chinensis* on cyhalofop-butyl was continuing, and several different screening techniques were being conducted as a result of the training program undertaken at WAHRI by Mrs Juliano in April-July 2008.

5.3.4 Collection of weedy rices and study of their morphological characteristics

Following discussions with Professor Powles at WAHRI in 2004, it was decided to expand the investigation of herbicide resistant weeds to include weedy rice infestations in direct-seeded rice fields. In other parts of Asia, weedy (or wild) rice has become a major weed problem in direct–seeded rice (e.g. Chin and Mortimer 2002, Ferrero 2003). Weedy rice cannot be sprayed out of rice crops as it is a rice species, and hence the weed problem caused by weedy rice mimics that of herbicide resistant weeds. Discussion with farmers indicated that they were aware of weedy rices but did consider them as a weed problem. In 2005, weedy rices were collected from farmers' fields in Nueva Ecija, where in some cases crops had a 60% (visual assessment) infestation of weedy rice. In 2006, weedy rices were collected from farmer's fields in Iloilo.

During the reproductive stage, different rice field areas of Nueva Ecija and Iloilo were surveyed for possible occurrence of weedy rice. Fields alongside the road were randomly surveyed for the presence of weedy rice. If weedy rice was present, the height of weedy rice and cultivated rice plant samples were measured. Type of rice establishment, number of panicles per plant plant and number of hills per metre were also recorded. A global positioning system (GPS) was used to map the distribution and to track the position of the areas where weedy rice was first spotted. Collection of samples was made for morphological characterization in the laboratory.

Twenty seeds each of weedy rice biotypes and cultivated rice (PSB Rc82 and IR64) were sown in Petri dishes lined with moist filter paper and properly maintained under alternating light and dark conditions in the laboratory. Number of seeds that germinated daily was recorded for 5 days. Water was provided as needed.

In the screenhouse, seeds of different weedy rice biotypes and cultivated rice varieties were planted in 8-in diameter clay pots filled previously with soil (Maligaya clay loam). The plants were maintained and allowed to grow until maturity. The study was conducted for two seasons (2005 dry and wet seasons for Nueva Ecija samples, and 2006 wet and dry seasons for Iloilo samples) with ten replications. One pot served as one replicate. Fertilizer at the rate of 120-60-60 kg (DS) or 90-30-30 (WS) NPK/ ha was also provided at 15, 30 and 45 days after seeding to maintain growth and development of the plants. Plant height, number of leaves and tillers were gathered weekly while the rest of the agronomic characteristics were gathered after harvest.

5.4 Objective 4. To develop an economic framework for policy analysis of herbicide resistance and weed management issues in the Philippines and Australia

Pesticide economics is an emerging field; there have been very relatively few empirical applications of economic theory to the analysis of economically efficient use of herbicide resources. On the direction of the ACIAR Program Manager, Dr Ken Menz, this objective was given a lower priority than originally planned, in favour of more emphasis on Objectives 1 and 2. The methodology used included literature reviews and modelling work on the economics of herbicide use. The aim of the work was to produce recommendations for weed management and herbicide use strategies including policy options to improve herbicide use for optimal farmer and social benefit.

5.4.1 Herbicide use and resistance risks in the Philippines and Australia

A review of literature and existing data on direct seeding, herbicide use and resistance risks in the Philippines was carried out. Data from previous five-yearly surveys of 2000 rice-based households throughout the Philippines, collected by the Philippines Bureau of Agricultural Statistics in conjunction with PhilRice, was used to assess trends in direct seeding and herbicide use. The survey of 400 rice-based households in the study areas in Nueva Ecija and Iloilo elicited some of the data necessary for modelling of weed and herbicide parameters in Philippines rice growing: e.g. current and future herbicide use patterns, mobility of weeds, information sources, costs, etc. Similar data from Australian cropping regions was collected from existing sources and previous surveys.

5.4.2 Literature review and modelling of the economics of herbicide use

An initial literature review of issues related to conservation of the herbicide resource (particularly from a public good aspect), and modelling approaches that have been used in previous work was conducted (e.g. Llewellyn et al. 2001, Pannell and Zilberman 2001, Laxminarayan 2003). As a result of this review (see Marsh et al. 2006) it was considered that a fairly strong case existed to argue that conservation of glyphosate as a herbicide resource has a public-good component, particularly because of the possible loss of conservation tillage (e.g. in Australia), and the spread of resistance though weed mobility (e.g. by irrigation water such as in rice-based systems in the Philippines). Further work then focussed on modelling the optimal use of glyphosate, and assessing the changes that incorporating weed mobility would make to the economics of conserving the herbicide resource.

Optimal use of glyphosate

Economic analysis was used to determine the optimal use of glyphosate over time for individual farm situations. The economics of pest resistance is a developing and increasingly important field (Laxminarayan 2003). This work has applications in the Philippines where resistance levels are currently very low and in developed countries where glyphosate resistance is becoming an increasing area of concern (e.g. Powles 2003). In each case, there is the decision problem of how much to invest in conserving the remaining herbicide options. There have been very few studies which have considered the trade-offs between the competing demands of short-term usage versus long-term sustainability of a highly-valued agrichemical. For certain highly-valued herbicide classes there are clear public-good advantages in maintaining the ‘biological capital’ of susceptibility to the herbicides. For example the recent shifts to erosion-preventing conservation tillage in dryland cropping (e.g. D’Emden et al 2006) and the more water-efficient rice growing practices will be difficult to sustain unless herbicide options remain available.

Herbicide resistance mobility

The economics of managing herbicide resistance in weeds has focused on cost-effective responses by individual growers to the development of resistance at the individual field level, and the risk of resistance spread through weed mobility has been treated in economic analyses as if it were negligible. The survey of growers in the Philippines highlighted the real and perceived likelihood of weed mobility across and between properties. Work by Busi et al. (2008) highlights the potential for gene flow from resistant rigid ryegrass in Australia, and in the USA the mobility of glyphosate resistant *Conyza canadensis* is causing concern (e.g. Dauer et al. 2007). Together with the increasing level of costly forms of resistance in Australian and USA grain growing, this has made research into the economics of herbicide resistance management in the presence of weed (and resistance) mobility a priority.

The model developed to determine optimal farm-based glyphosate use (Weersink et al. 2005) was adapted to investigate a hypothetical situation where herbicide resistance mobility could occur.

Optimal weed management practices to control Echinochloa spp. in rice

In 2007, John Allwright PhD scholar from PhilRice, Jesusa Beltran, commenced work to adapt the Ryegrass Integrated Management model (RIM) to investigate weed management options for *Echinochloa* spp. in rice in the Philippines. This will involve on-going collaboration with socio-economists and weed researchers at PhilRice and IRRI to ensure realistic and relevant data and output is achieved. The model will use a wide range of weed control alternatives including: various pre- and post-emergent herbicides, cultivation and water control techniques. The methods used in the model will identify options for achieving optimal farm level herbicide management of *Echinochloa* spp. in rice in the Philippines.

6 Achievements against activities and outputs/milestones

Objective 1: To sample and document farmers' current weed practices, perceptions and information sources in relation to direct-seeded rice in the Philippines

no.	activity	outputs/ milestones	completion date	comments
1.1	Literature review and study of existing survey data	Literature review and background completed (A/PC)	November 2004	The review of literature and existing survey data was completed and a paper outlining the findings was presented at the Australian Agricultural and Resource Economics Society Conference in 2005 (see Section 10.2). Further work on analysis of herbicide use trends using BAS/PhilRice five-yearly survey data is currently being undertaken by PhilRice John Allwright scholar, Jessie Beltran, as part of her PhD studies.
1.2	Develop and conduct a survey of growers in target areas	Survey completed (PC)	February 2005	400 farmers in two major rice growing regions in the Philippines (Nueva Ecija and Iloilo) were surveyed on their current and planned weed management practices and herbicide use, and perceptions of weed control issues.
1.3	Conduct analysis and report on survey	Report and recommendations based on survey completed (A/PC): - a comparison of weed control practices between direct-seeded rice and transplanted rice - identification of perceptions regarding weed management held by farmers that are amenable to change - farmers' sources of information documented, including influence of herbicide companies	July 2005	The results from the survey were analysed, and results used to inform the implementation of the on-farm trials and the season-long training associated with these. The results from the survey work were written up and presented at two conferences (see Section 10.2)

PC = partner country, A = Australia

Objective 2: To test, evaluate and adapt a promising (low herbicide use) rice production method in farmers' fields through farmer participation in the Philippines

no.	activity	outputs/ milestones	completion date	comments
2.1	Select sites and initiate participatio n of farmer groups	Sites and participation established (PC)	September 2004	Discussions with local government authorities were held to select suitable sites in Iloilo and Nueva Ecija. PRAs were held to scope local issues and establish participation.
2.2	Establish on-farm developme nt sites	On-farm sites established (PC/A)	January 2005	Four field sites were initially established in Aliaga and Rizal (Nueva Ecija), and Dingle and Barotac Nuevo (Iloilo). In 2006-07 the number of sites increased to eight with the inclusion of four extra sties in villages nearby the original sites.

2.3	Develop practices with farmer participatio n	Practices developed and adopted (PC) - adapted weed management technologies - a socio-economic analysis of the adapted weed manage-ment practices	June 2008	Season-end evaluations held with farmers and local government agricultural technicians discussed possible adaption of the technologies based on the previous season's results and experiences. This process was written up in papers to various local and international conferences (see Section 10.2).

PC = partner country, A = Australia

Objective 3: To assess the status of herbicide resistance of rice weeds in the Philippines

no.	activity	outputs/ milestones	completion date	comments
3.1	Raise alertness in regions and seek suspect samples for testing	Weed (seed) samples collected (PC)	June 2005	Initial collections of *Echinochloa crus-galli* were completed. Following discussion with Professor Powles (WAHRI) initial collections of weedy rices were also commenced.
3.2	Establish and document testing protocols	Testing protocols documented and extended (PC/A) - an appropriate protocol for testing HR weeds in the Philippines	June 2006	Initial testing protocols were developed from the literature and in consultation with Professor Powles and other experts. A final protocol was documented at the end of the project, based on the initial protocol, training of PhilRice staff conducted at WAHRI, and experience gained while conducting the testing (see Appendix 2).
3.3	Complete testing of submitted samples	Confirmation of resistance status of rice field weeds (PC/A)	June 2007	HR testing confirmed resistance of a number of samples of *Echinochloa crus-galli* to herbicides butachlor and propanil, and cross-resistance to pretilachlor. These findings are publicised on the International Survey of Herbicide Resistant Weeds website (www. weedscience.org/in.asp) and also in a journal article (see Section 10.2).
3.4	Continue testing of samples	Up-to-date record of resistance status (PC/A) - a list of weeds x location where herbicide resistance has been confirmed and the corresponding herbicides	June 2008	Samples of both weedy rices and other rice weeds for resistance testing are continuing to be collected, and HR testing is continuing. A list of resistance status of samples collected is attached as Appendix 3.

PC = partner country, A = Australia

Objective 4: To develop and economic framework for policy analysis of herbicide resistance and weed management issues in the Philippines and Australia

no.	activity	outputs/ milestones	completion date	comments
4.1	Develop economic analysis approach for herbicide management	Model for herbicide resource management developed (A)	June 2006	Literature reviews and conference papers reviewing herbicide use in the Philippines and the economics of herbicide use were completed (Marsh *et al.* 2005, 2006; Casimero *et al.* 2005). A model to investigate optimal glyphosate use was developed (Weersink *et al.* 2005).

4.2	Analyse herbicide use scenarios	Optimal herbicide use strategies identified (A) - economic analysis of benefits of weed manage-ment strategies for achieving optimal value from herbicide resources from a broad societal viewpoint	June 2007 and ongoing	The Weersink *et al.* (2005) model used to investigate optimal use of glyphosate was adapted to account for weed mobility (Marsh *et al.* 2006). Work commenced to adapt Ryegrass Integrated Management (RIM) model to management of *Echinochloa* spp. in rice in the Philippines (John Allwright PhD scholar Jesusa Beltran).
4.3	Recommenda tions for policy and planning	Recommendations on optimal long-term use patterns for herbicides (A/PC)	June 2008 and ongoing	Policy briefs written for managing herbicide resistance and weedy rice in the Philippines.

PC = partner country, A = Australia

7 Key results and discussion

7.1 Objective 1. To sample and document farmers' current weed practices, perceptions and information sources in relation to direct-seeded rice in the Philippines

7.1.1 Literature review and study of existing data

Data from the BAS/PhilRice 2002 survey indicated a high use of direct seeding in the dry season in both Central Luzon (57 percent of respondents) and the Visayas (99% of respondents) where the study regions of Nueva Ecija and Iloilo are located. The data also showed evidence of increased herbicide use in direct-seeded compared to transplanted crops (Figure 4). More than 80 percent of respondents in all regions who established crops using direct-seeding reported using herbicides on the standing crop in the dry season of 2001, compared to around 50 percent of respondents who established crops by transplanting.

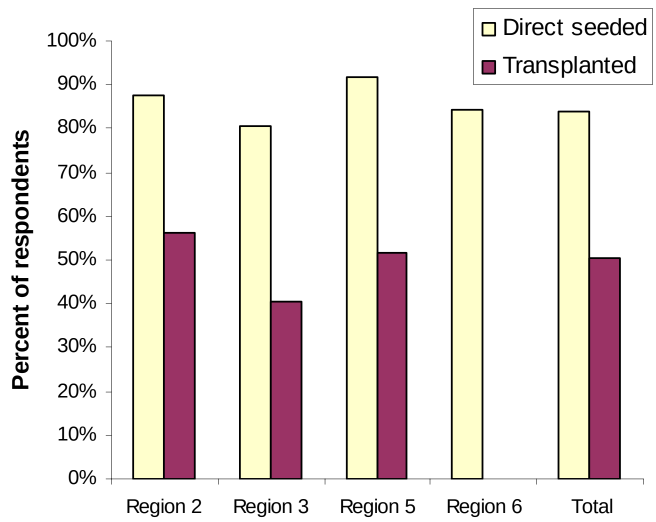

Figure 5 Proportion of farmers using herbicide on standing dry season direct-seeded and transplanted rice crops by region: where Region 2 is North-eastern Luzon (n = 24 for direct-seeding and n = 165 for transplanted); Region 3 is Central Luzon (n = 138 for direct-seeding and n = 106 for transplanted); Region 5 is Southern Luzon (n = 37 for direct-seeding and n = 118 for transplanted); and Region 6 is the Visayas (n = 89 for direct-seeding and n = 1 for transplanted). Source: Data from BAS/PhilRice survey of rice-based households, 2002.

For the dry season crop, the use of pre- and post- emergent herbicides was common and a wide range of herbicides were used (28 different brand names were mentioned by respondents). Figure 6 shows the percentage of different herbicide types applied to standing dry season rice crops in 2001. In 2001, when these data were collected, the use of ALS- (Group B) and ACCase- (Group A) inhibiting herbicides on rice crops in these regions of the Philippines appears to be low, with the main herbicides used being 2,4-D (Group O), butachlor and pretilachlor (Group K3), and some use of butachlor plus propanil mixes (Groups K3 and C2), oxadiazon (Group E) and bispyribac sodium (Group B).

The findings of the literature review and study of existing data, along with findings of the PRAs focussed on weed issues in the study regions, were used to inform the development of the farm survey. The results were also written up as conference papers: Marsh et al. (2005) "Direct-seeding of rice and herbicide use in the Philippines: implications for weed management" and Casimero et al. (2005) "Direct seeding of rice and shifts in herbicide use in the Philippines". Further work on the trends in herbicide use on rice in the Philippines is being undertaken by PhD scholar Jesusa Beltran, using the data from the 2007 BAS/PhilRice survey of rice-based households.

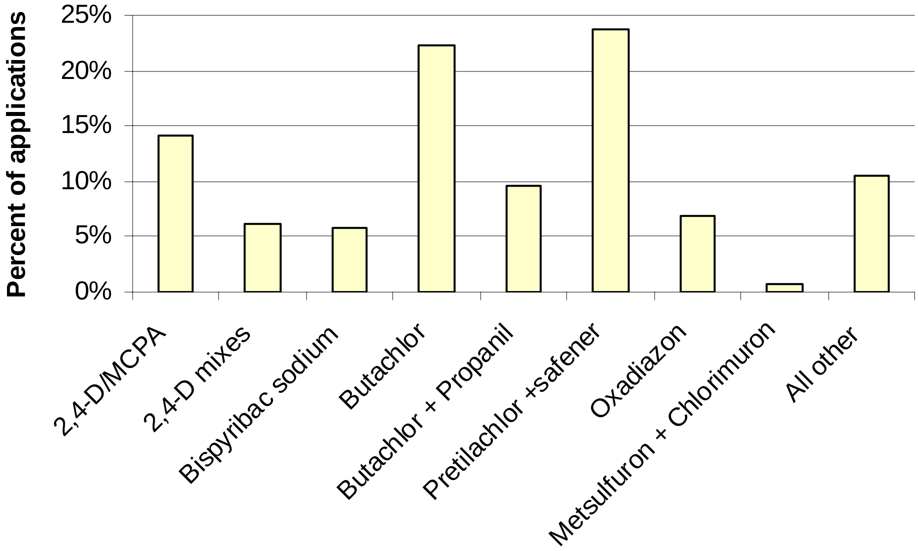

Figure 6 Percent of herbicide applications (n = 425) to standing dry season rice crops in 2001 classified by specific herbicide types. Source: Data from BAS/PhilRice survey of rice-based households, 2002.

7.1.2 Survey of farmers in the study areas

The survey of 400 rice growers, jointly developed by the research partners from August to November 2004, and implemented from December 2004 to March 2005 in the two study regions of Nueva Ecija and Iloilo, was designed to capture both current and planned weed management practices, and also perceptions about herbicide use and other weed issues. The results highlighted the trend towards greater herbicide reliance and important factors to consider in the research, development and extension for integrated weed management.

Results showed that almost all of farmers' current weed management practices involved a combination of cultural practices and herbicide use (Table 2). Thorough land levelling, water management, and herbicide application were the most preferred and commonly used practices in response to weed problems in direct-seeded rice. These practices were perceived to be the most effective and simple means of weed control and farmers indicated that they were satisfied with the level of weed control that these practices were providing.

But, if water availability became a problem, farmers failed to do good land preparation and tended to use more herbicides to control weeds. Farmers were highly dependent on herbicides (spraying from one to three times per season) and were using herbicides with a high risk of developing herbicide resistance (Table 3). The most common brands of herbicides applied were Advance EC (butachlor + propanil), Nominee (bispyribac sodium), Clincher (cyhalofop butyl), Sofit (safened pretilachlor), Rice Star (fenoxaprop ethyl), 2, 4-D Ester, and Tornado (butachlor + propanil). It is interesting to note that post-emergence herbicides belonging to high risk herbicide-resistant groups like bispyribac sodium and cyhalofop butyl ranked next to butachlor + propanil as the most commonly used herbicides. Intensive and continuous use of these groups of herbicides will increase the risk of developing herbicide resistance in these areas. Farmer-respondents were not aware and/or not concerned about this issue. In fact, three of the most popular herbicides (Nominee, Clincher and Ricestar) used by farmers in Iloilo belong to the ALS and AOPPs herbicide groups. These results are strikingly different to the herbicide use reported from the 2002 BAS/PhilRice survey (see Section 7.1.1).

Table 2 Number of respondents reporting use of specific weed management practices in Neuva Ecija and Iloilo, 2004

	Nueva Ecija (n = 200)				**Iloilo (n = 200)**			
	Used for the past 2 years		Intend to use next season		Used for the past 2 years		Intend to use next season	
Practices	Freq	%	Freq	%	Freq	%	Freq	%
Burning stubble from previous crop	106	53	107	54	134	67	116	58
1st cultivation only < 1 week before DS[a]	81	41	64	32	55	28	52	27
1st cultivation at least 3 weeks before DS	133	67	135	65	151	76	149	75
At least 2 harrowings following cultivation	158	79	158	79	183	93	181	92
Through levelling before DS	177	89	176	88	192	96	189	95
Pre-emergence herbicide application	90	45	75	38	176	89	172	87
Post-emergence herbicide application	165	83	164	82	145	73	145	73
High seeding rate	94	47	80	40	132	66	127	64
Water management for weed control	175	88	174	87	176	88	176	88
Manual weeding	137	69	136	68	116	61	108	55

[a] *DS is direct seeding*

Table 3 Number of respondents reporting using specific herbicides on rice crops, 2004

	Nueva Ecija (n = 200)		**Iloilo (n = 200)**	
Brand Name	Freq	%	Freq	%
24 D Ester	18	9.0	13	6.5
Advance EC	80	40.0	74	37.0
Agroxon	11	5.5	5	2.5
Cleanser/Clincher	20	10.0	40	20.0
Machete	7	3.5	1	0.5
Ronstar	0	0.0	15	7.5
Sofit	25	12.5	17	8.5
Direk	9	4.5	11	5.5
Nominee	77	38.5	38	19.0
Rice Star	6	3.0	20	10.0
Tornado	0	0.0	23	11.5
Toro	8	4.0	0	0.0
No herbicide used	9	4.5	4	2.0

About 15% of the farmers considered that they would increase their frequency of herbicide application in the next four years, though the majority thought that they would not change. Most of the farmers were concerned about the environmental and health hazards associated with herbicide use, but none were aware of the possibility of herbicide resistance development. Most farmers sourced their information on weed management and herbicides from agricultural government extension officers, chemical companies' extension staff and other farmers.

Perceptions regarding weed management were gathered. A significant number of farmers in both provinces had observed changes in problem weeds associated with direct-seeded rice, and perceived that shifts in weed populations were brought about by climatic changes, from animals/birds/rats, from the weeds blown by air/wind, and from chemical use. The majority said they planned to continue using their current weed management methods but that they were willing to try new methods that can provide better weed control.

Farmer-respondents were also asked to rate the effectiveness of various weed management options (Table 4). Strategies which included the shorter land preparation times were rated as much less effective. These results are encouraging as it shows that farmers are aware of the most effective/ideal weed management strategies. However, in reality farmers are constrained in following these practices mainly because of uncertainty of water supply. Although farmers thought that longer land preparation time was a good practice, they were not confident that longer preparation could effectively control weeds without herbicides, rating it the least effective strategy in Nueva Ecija (2.76), and second least effective strategy in Iloilo (3.26). This suggests that farmers perceive that herbicides are crucial for good weed control, even when good land preparation practices are used. It can also be seen that farmers, especially in Nueva Ecija, perceive that pre- and post-emergence herbicide use can substitute for poor land preparation and give relatively good weed control results. Herbicide application was a dominant weed control strategy and farmers thought that application of pre- and post-emergence herbicides provides for a good control of weeds with poor land preparation, rating this option quite highly.

Table 4 Mean ratings by respondents of weed management strategies (ratings from 1 to 5 where 1 = very poor practice and 5 = very good practice)

Weed Management Strategy	**Mean Rating**	
	Nueva Ecija (n=200)	Iloilo (n=200)
First cultivation only 1 week or less before DS, followed by pre-emergence herbicide only	2.86	2.58
First cultivation at least 3 weeks before DS, followed by at least 2 harrowings, levelling and no herbicide	2.76	3.26
First cultivation only 1 week or less before DS, followed by pre-emergence and then post-emergence herbicides as needed	3.25	3.43
First cultivation at least 3 weeks before DS, followed by at least 2 harrowings, levelling and pre-emergence herbicide	3.51	4.18
First cultivation at least 3 weeks before DS, followed by at least 2 harrowings, levelling and pre-emergence and post emergence herbicides	3.78	4.30

The survey results gave the project team a good idea of weed management issues throughout Nueva Ecija and Iloilo that could potentially affect the adoption of an IWM strategy. The survey results also indicated that there was a need for training and extension work targeted at raising awareness about weeds, herbicide use, herbicide resistance, and integrated weed management in direct seeded rice. Results from the survey were written up as a report and also presented at the Pest Management Council of the Philippines conference in Davao in 2006 (Beltran et al. 2006 "A review of the current weed management practices of farmers adopting direct seeding in Iloilo and Nueva Ecija").

7.2 Objective 2. To test, evaluate and adapt a promising (low herbicide use) rice production method in farmers' fields through farmer participation in the Philippines

7.2.1 Selection of sites and farmer co-operators

Initial sites and training established

Field sites were confirmed in 4 barangays: Barotac Nuevo and Dingle in Iloilo; Aliaga and Rizal in Nueva Ecija. Participatory Rural Appraisals (PRAs) were conducted in Nueva Ecija and Iloilo in August 2004 to scope weed management practices and weed management issues in the survey sites. Key findings from the PRAs included:

- Weed control was identified as a major problem for farmers

- Farmers relied on herbicides to control weeds, but also used cultural and water management
- Farmers can identify weeds, but have poor knowledge about which herbicides should be used to control specific weeds
- Farmers have observed shifts in weed populations.

Towards the end of each PRA the proposed weed control technology and associated ACIAR project was explained and discussed.

Following the PRAs and discussions with local extension workers and community leaders, farmer co-operators for the field trials were identified and the initial plan for eight farmer trials (four in each of Iloilo and Neuva Ecija) was expanded to 40 (10 in each of the four barangays). The first field trials commenced for the dry-season crops in Oct/Nov 2004 in Iloilo and January 2005 in Nueva Ecija.

Training took place in the four municipalities before the field trials commenced and farmers were taught the “stale-seedbed” technique in preparation for practising it in their own fields. The follow-up workplan involved weekly training/meetings in the barangays and frequent visits from PhilRice staff and LGU co-operators. Following a request from the farmer co-operators to learn more about rice crop production, season-long Farmer Field Schools were held at each site. The training was based around monitoring the growth and production of the field trial crops, and field days were held in conjunction with the trials. In each province, farmers from both barangays involved in the IWM trials attended the field days at each site. Extension and workshops on IWM were part of the training.

Additional sites established

Only 3 farmers in Aliaga participated in the trials for the wet season in 2005 as many growers prefer to transplant their crops under the wetter seasonal conditions. In the wet season of 2005, on-farm trials in Aliaga commenced at another site in the same village 2 km away where farmers were keen to participate and wish to direct seed both the dry and wet season crops. Original farmer co-operators in Aliaga who wished to continue with the on-farm IWM trials were still supported.

In 2006-07 the on-farm trials expanded to villages nearby the original sites in Nueva Ecija and Iloilo. The number of sites increased from four to eight because of the demand from farmers to be involved in the project and learn about IWM.

7.2.2 Results from the on-farm weed management trial sites

Results from the first season of on-farm trials

Results from the first season of trials indicated that good weed control was obtained in all the trial sites in both IWM and FP plots (Table 5). Yields were generally higher in barangays located at the head (Dingle and Rizal), rather than tail (Barotac Nuevo and Aliaga), of the irrigation system (Table 6). Comparing the grain yields obtained from the IWM and FP plots, a minimum of 0.3 t/ha was added to the yield with the use of IWM in areas where water supply was limiting (Table 6). With readily available water as in Dingle and Rizal, the yield advantage obtained was 0.7 t/ha. With the application of IWM, farmers in both sites in Nueva Ecija and Iloilo increased their yields by 10% and 15%, respectively. The cost and return analysis showed that with IWM, farmers could get increased profit ranging from US$117/ha to US$227/ha (Table 7). Overall, results obtained from these four on-farm trial sites were consistent in indicating a better weed control, increased yields, and higher profits with the use of integrated weed management as an approach to control weeds.

Table 5 Average weed dry weight at 45 DAS during the 2004-05 dry season in the four on-farm trial sites (10 trials per site at Dingle, Barotac Nuevo, Aliaga and Rizal) as affected by weed management practice

Site	**Weed Management**	**Weed dry weight (g/m2)**		
		Grasses	Broadleaves	Sedges
Dingle	IWM	1.42*	1.42	1.72
	FP	3.26	3.28	2.30
Barotac Nuevo	IWM	1.42*	1.42*	1.42*
	FP	3.72	2.98	5.86
Aliaga	IWM	2.68	1.42	2.04*
	FP	1.88	1.42	8.28
Rizal	IWM	6.58*	3.76	2.16
	FP	13.84	3.76	1.42

** Significant difference between IWM and FP at P = 0.05*

Table 6 Average grain yield of rice during the 2004-05 wet and dry seasons in the four on-farm trial sites (10 trials per site Dingle, Barotac Nuevo, Aliaga and Rizal) as affected by weed management practice

Site	**Weed Management**	**Grain yield (t/ha)**	
		Dry season	Wet season
Dingle	IWM	4.04*	4.53*
	FP	3.47	3.83
Barotac Nuevo	IWM	3.43*	4.06
	FP	2.99	3.26
Aliaga	IWM	3.69*	5.36*
	FP	3.35	4.99
Rizal	IWM	6.76	4.37
	FP	6.08	4.14

** Significant difference between IWM and FP at P = 0.05*

After one season of on-farm trials the project team assessed that:

- learning on weed management techniques needs to be encompassed within a farming systems framework
- good weed control can be obtained using IWM techniques
- both external and internal constraints to the use of IWM exist and affect farmers' use of IWM techniques for weed control.

However, the initial results encouraged farmer co-operators and participating LGUs to continue with the on-farm trials.

Table 7 Cost and return analysis (in $US) of weed management practices implemented in the on-farm trials (average of ten farmers for each site in Barotac Nuevo, Dingle, Aliaga and Rizal) in 2004-05 dry season

Weed Management Site	**Gross Income**	**Production Cost**	**Net Return**	**Increase in Net Return (%)**
Barotac Nuevo: IWM	1,407	849	556	54
FP	1,156	796	360	
Dingle: IWM	1,784	769	1,015	29
FP	1,525	737	788	
Aliaga: IWM	2,025	921	1,104	15
FP	1,896	934	961	
Rizal: IWM	2,382	992	1,391	9
FP	2,269	995	1,274	

Results from the second and third years of on-farm trials

Results from the second and third years of the trials were consistent in indicating that good weed control was attained in the IWM plots in all trial sites.

In the 2005-06 season, grain yield increased in the IWM plot from 0.2 to 0.8 t/ha (7 to 33%) during the 2005 wet season and 0.2 to 0.9 t/ha (4 to 17%) during the 2006 dry season compared to the Farmer's Practice plot. Farmers in Rizal obtained the highest yield increase of 0.9 t/ha during the 2006 dry season. Higher yield increases were seen in Iloilo during the 2005 wet season with net return increased by 54 and 28% in Barotac Nuevo and Dingle, respectively. Although yields obtained in Iloilo were lower than in Nueva Ecija in the dry season, higher net returns accrued to the farmer because of the lower total cost of production. In Nueva Ecija, net return increased by 9% in Rizal and 17% in Aliaga, whereas the net return obtained by farmers in Barotac Nuevo was 39% and 41% in Dingle.

Results of 2006 wet season (July-October 2006) and 2006-2007 dry season (December 2006-March 2007) field trials in Nueva Ecija and Iloilo were also consistent with results from previous seasons in that good weed control was attained in the IWM plots in all sites. Weed weights at 45 days after seeding were significantly reduced in all sites, particularly during the dry season, indicating that IWM provided a season-long control of weeds. Also, significantly higher productive tiller number was observed in the IWM plot compared to the farmer practice plot. Grain yield in the IWM plots during the wet season in Aliaga and Rizal, Nueva Ecija, was increased by 8% and 15% respectively, compared to the FP plots. In Dingle and Barotac Nuevo, Iloilo, grain yield was increased by 13% and 11% respectively. During the dry season, there was an 11% increase in yield in Aliaga and 10% increase in Rizal, while in Dingle and Barotac Nuevo, 17% and 7% yield increases were observed, respectively. Higher net returns were seen in Nueva Ecija during the wet season. The net returns from the IWM plots in Aliaga and Rizal was 39% and 30% more than the FP plot. In Iloilo, net returns from the IWM plots during the wet season, were increased by 24% and 18% in Dingle and Barotac Nuevo, respectively. During the dry season, the net return obtained by farmers in Barotac Nuevo was increased by 14% and 38% in Dingle while in Aliaga and Rizal, the net returns were increased by 25% and 20%, respectively, over the FP plots.

Results of the 2007-08 wet season on-farm trial showed a dominance of the broadleaf and sedge weeds associated with direct–seeded rice because of the abundance of water during the rainy season. Consistent with the results of the previous years, weed density and weights were significantly lower in the IWM plots compared to the farmer's practice. Similar trends were seen in the percent weed control effect of the two treatments. The use of WCAI was helpful in reducing the frequency of herbicide application and weed control costs. These positive effects of the IWM resulted in higher productive tiller number and grain yield. In Rizal, Nueva Ecija, productive tiller number increased by 7% and grain yield significantly increased by 17%. In Aliaga, an 8% and 12% increase in the productive tiller number and grain yield were observed, respectively. As a consequence of the savings in weed control costs and increase in grain yields, net income of farmers increased by 41% in Rizal and 35% in Aliaga. In Iloilo, grain yield also increased by 7% in Barotac Nuevo, 20% in Pandan, Dingle and 7% in Sinibaan, Dingle. The net income of farmers similarly increased by 16% in Barotac Nuevo, 29% in Pandan, Dingle and 18% in Sinibaan, Dingle.

Overall results after six seasons of on-farm trials

Weed control and herbicide use

Figures 7, 8 and 9 are examples of the weed data that were collected. These graphs are for Main Bucot barangay, which was the initial site in Aliaga, Nueva Ecija (at the tail of the system). The data show that IWM maintained good control of grass weeds, and better control of sedges and broadleaves over the four seasons (in this barangay the farmer co-operators opted to transplant rather than direct seed in the wet seasons of 2006 and 2007). Of interest is the increasing problem with sedge weeds in this area.

Figures 10, 11 and 12 show the same data for Aglipay barangay, which was the initial site in Rizal, Nueva Ecija (the head of the system). Again, better weed control was obtained with IWM, except for grasses in the 2005 dry season. Grass and broadleaf weed burden was generally higher in all plots in this area. Similar data for all the study sites showed that the IWM plots in almost all seasons had less grass, sedge and broadleaf weed weights at 45 DAS compared to the FP plots. The differences were often, but not always, significant.

Figure 13 shows an example of the reduction in herbicide application and handweeding that occurred in IWM plots. These data are for Aglipay barangay, Nueva Ecija. IWM plots had less number of post-emergence sprays and handweedings compared to FP plots. Similar data were obtained from sites in Iloilo.

Rice yield

Consistent yield increases were obtained in IWM plots compared to FP plots. Figure 14 gives an example for Pandan barangay in Dingle, Iloilo. In this area, grain yields were always higher in the IWM plots. Note that there were three crops in 2006. The yield in DS 05 was significantly difference at p=0.05, and yields for 2006 (1) and 2006 (2) were significantly different at p=0.01. Increased yield in IWM plots also occurred in all seasons in Acuit barangay in Barotac Nuevo.

Net returns per hectare

Net returns were also consistently higher in IWM plots compared to FP plots. Tables 8 and 9 show data for net income per hectare for six seasons of IWM on-farm trials in Iloilo and Nueva Ecija, respectively. In Iloilo (Table 8), net income/ha was always higher in IWM plots, with the percent increase in net income/ha for IWM plots compared to FP plots ranging from 3 to 70 percent. Generally, percent increase in net income/ha for IWM plots was higher in the dry season than the wet season (with an exception of the 2005 wet season in Barotac Nuevo). The percent increase in income in IWM plots exceeded 20 percent in 60 percent of the trial data results over the six seasons.

In Nueva Ecija (Table 9) net income/ha was again always higher in IWM plots, with the percent increase in net income/ha for IWM plots compared to FP plots ranging from 5 to 41 percent. In contrast to the results from Iloilo, the percent increase in net income/ha tended to be higher in the wet season, but the seasonal difference was not as marked as in Iloilo. The percent increase in IWM exceeded 20 percent in 50 percent of the trial data results over the six seasons

In summary:

Reduced weed weights, increased yields, higher profits and reduced usage of herbicide were realized with the use of integrated weed management as an approach to control weeds in both the study sites. Results were consistent over six seasons of on-farm trials.

Building upon the experience of farmers trained in IPM FFS, our experience showed that it is easier for farmers to understand the principles of weed dynamics and management when coupled with the “learning while doing approach” followed in the participatory on-farm adaptation trial. With the FFS on Rice ICM, farmers learnt the other available weed management options and the basic weed concepts that enable them to make science-based decisions on weed management.

The results of the participatory on-farm trial work was written up and presented at several workshops and conferences in Australia, Canada and the Philippines:

- Marsh et al., 2006 “Working with farmers to develop practical weed management techniques for direct-seeded rice in the Philippines”, Australasian Pacific Extension Network 2006 International Conference, Beechworth, Australia.

- Casimero et al., 2006. Participatory adaptation of an Integrated Weed Management strategy for wet direct-seeded rice in the Philippines", 15th Australian Weeds Conference, Adelaide.
- Martin et al., 2006. "On-farm adaptation of an integrated weed management strategy for wet direct-seeded rice in Nueva Ecija province", 37th Annual Scientific Meeting of the Pest Management Council of the Philippines, Davao City, Philippines.
- Marsh et al., 2008. "Achieving high adoption of IWM in direct-seeded rice in the Philippines", 5th International Weed Science Conference, Vancouver, Canada.

Further details of these publications are given in Section 10.2.3.

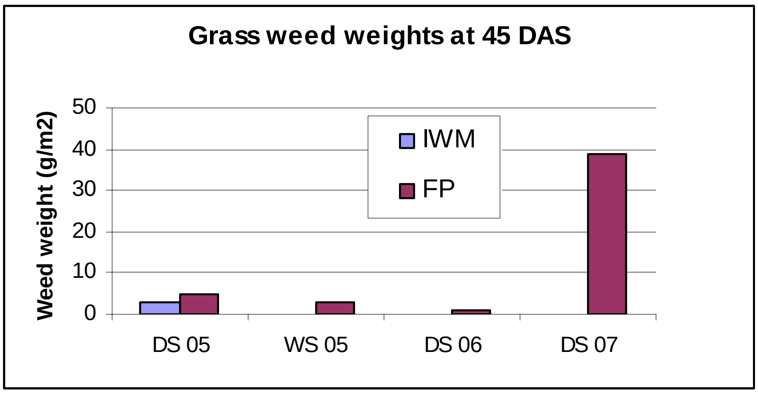

Figure 7 Fresh weed weights (g/m^2) for grasses at 45 DAS in IWM and Farmer's Practice Plots in Main Bucot barangay, Nueva Ecija (DS 05, n=10; WS 05, n=3; DS 06, n=5; DS 07, n=9; in WS 06 and WS 07 rice was transplanted)

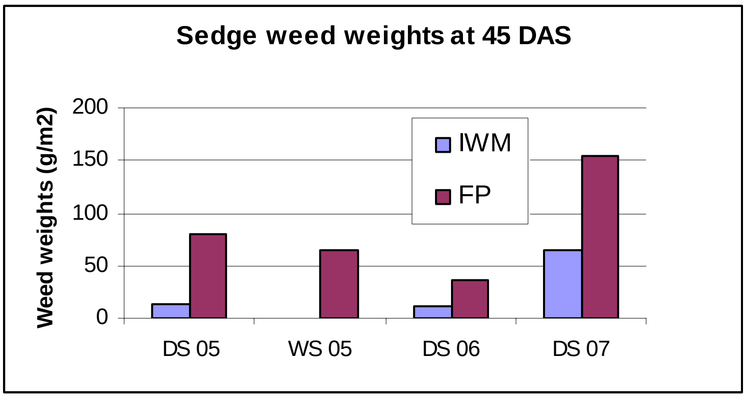

Figure 8 Fresh weed weights (g/m^2) for sedges at 45 DAS in IWM and Farmer's Practice Plots in Main Bucot barangay, Nueva Ecija (DS 05, n=10; WS 05, n=3; DS 06, n=5; DS 07, n=9; in WS 06 and WS 07 rice was transplanted)

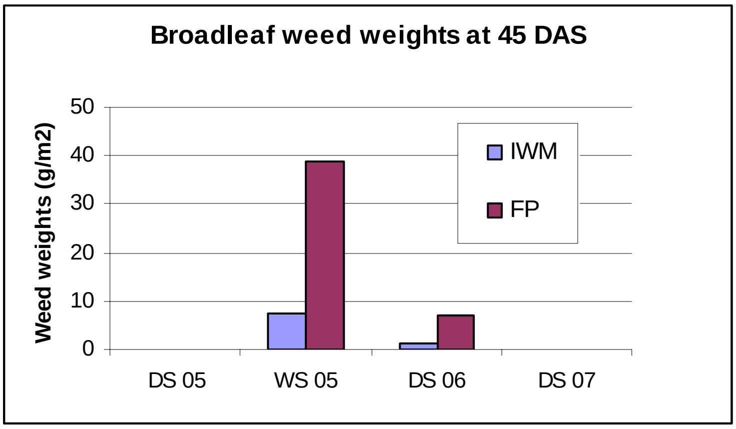

Figure 9 Fresh weed weights (g/m^2) for broadleaves at 45 DAS in IWM and Farmer's Practice Plots in Main Bucot barangay, Nueva Ecija (DS 05, n=10; WS 05, n=3; DS 06, n=5; DS 07, n=9; in WS 06 and WS 07 rice was transplanted)

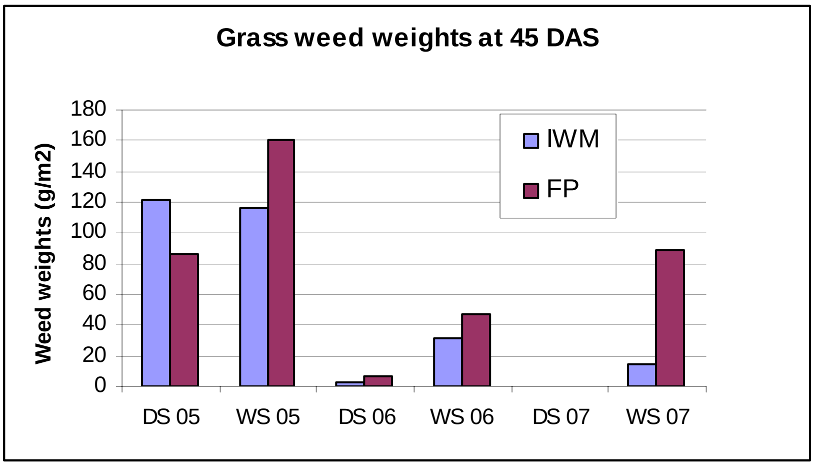

Figure 10 Fresh weed weights (g/m^2) for grasses at 45 DAS in IWM and Farmer's Practice Plots in Aglipay barangay, Nueva Ecija (DS 05, n=10; WS 05, n=8; DS 06, n=10; WS 06, n=7; DS 07, n=10; WS 07, n=10)

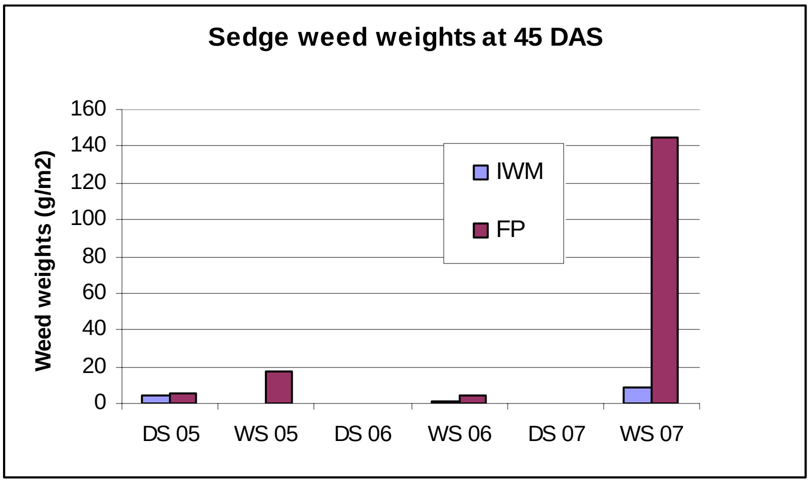

Figure 11 Fresh weed weights (g/m^2) for sedges at 45 DAS in IWM and Farmer's Practice Plots in Aglipay barangay, Nueva Ecija (DS 05, n=10; WS 05, n=8; DS 06, n=10; WS 06, n=7; DS 07, n=10; WS 07, n=10)

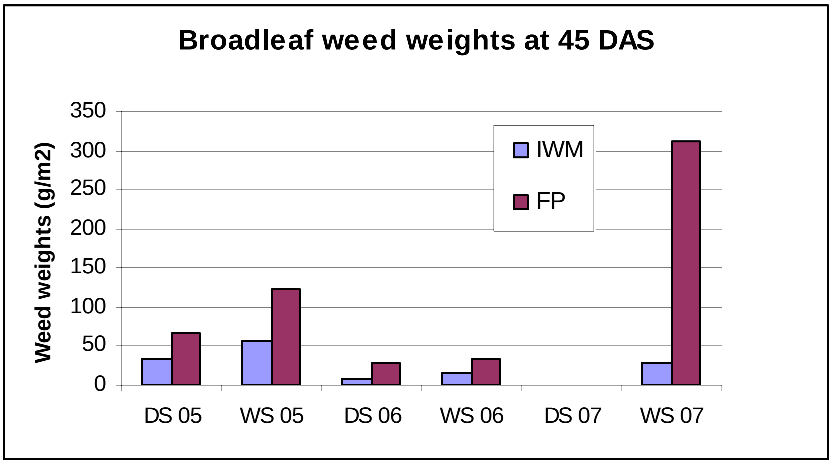

Figure 12 Fresh weed weights (g/m^2) for broadleaves at 45 DAS in IWM and Farmer's Practice Plots in Aglipay barangay, Nueva Ecija (DS 05, n=10; WS 05, n=8; DS 06, n=10; WS 06, n=7; DS 07, n=10; WS 07, n=10)

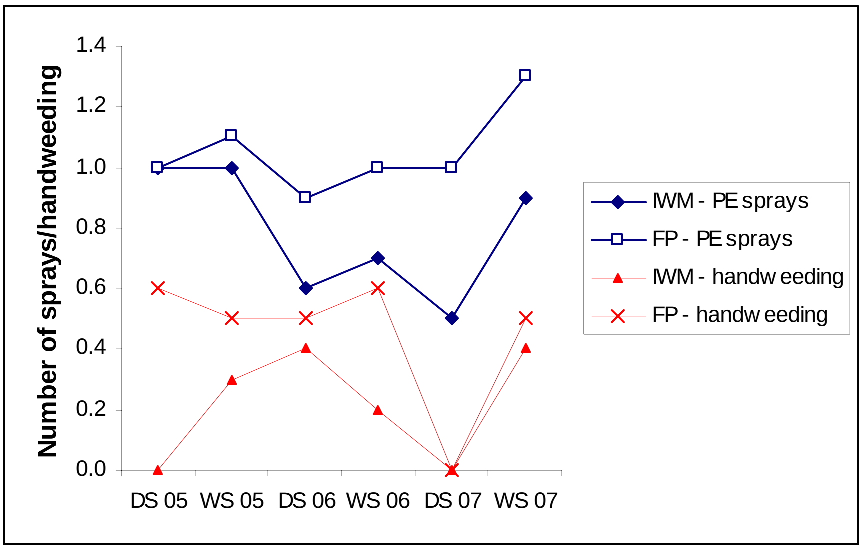

Figure 13 Number of post emergence sprays and handweedings in IWM and FP plots in Aglipay, barangay, Nueva Ecija ((DS 05, n=10; WS 05, n=8; DS 06, n=10; WS 06, n=7; DS 07, n=10; WS 07, n=10)

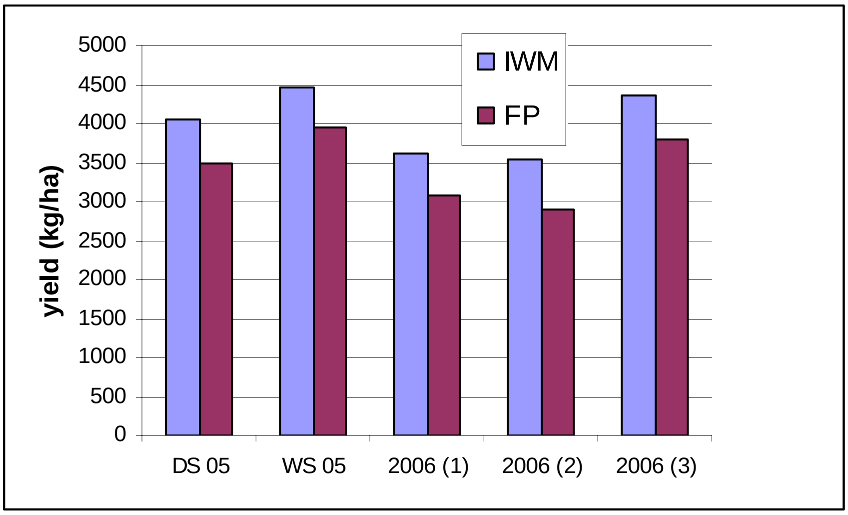

Figure 14 Grain yield for IWM and FP plots in Pandan, Dingle (average of 10 plots in all seasons).

Table 8 Average Net Income (US$/ha) for farms from 3 sites in Iloilo for six seasons of IWM and FP on-farm trials

Sites	Practice	Net Income (US$/ha)					
		DS 05	DS 06	DS 07	WS 05	WS 06	WS 07
Barotac Nuevo	IWM	228	275	344	271	283	461
	FP	170	197	295	160	240	399
	% increase	34	40	17	70	18	16
Pandan, Dingle	IWM	477	297	376	381	335	445
	FP	377	183	228	370	255	344
	% increase	27	62	65	3	32	29
Sinibaan, Dingle	IWM			326		328	403
	FP			226		288	341
	% increase			44		14	18

Table 9 Average Net Income (US$/ha) for farms from 2 sites in Nueva Ecija for six seasons of IWM and FP on-farm trials

Sites	Practice	Net Income (US$/ha)					
		DS 05	DS 06	DS 07	WS 05	WS 06	WS 07
Rizal	IWM	829	1131	892	483	574	483
	FP	760	979	746	442	442	343
	% increase	9	16	20	9	30	35
Aliaga	IWM	431	649	682	610	306	473
	FP	366	620	547	531	220	351
	% increase	18	5	25	15	39	41

Establishment of large demonstration trials in the 2007-08 dry season

A review was conducted in September 2007 and it was recommended that the last dry season crop should focus on demonstrating IWM in large plots (0.5 to 1.0 ha/farmer). During the 2007-08 dry season, the on-farm trials were converted into demonstration plots for the adapted integrated weed management. A total of 80 farmer co-operators were involved in the on-farm demonstration trials which aimed to show the workability and feasibility of implementing IWM in large plots. Higher productive tiller number and grain yield were seen, which were consistent with the results of the on-farm trials. Productive tiller in IWM plots were higher by 6% in Rizal and 5% in Aliaga, Nueva Ecija. Grain yield also increased by 12% and 3% in Rizal and Aliaga. Higher net income was obtained by farmers in Rizal and Aliaga. The results of the demonstration of IWM in Iloilo also showed the beneficial effect of implementing IWM on rice production and farmers' income. In Barotac Nuevo, grain yield was improved by 42 percent, 17 percent in Pandan and 20 percent in Sinibaan, Dingle. Farmers' net income was increased by 44 percent in Barotac Nuevo, 40 percent in Sinibaan and 80 percent in Pandan, Dingle.

Before crop harvest, field days and farm walks were conducted to showcase the results of the demonstration trials to other farmers and extension workers in other villages in Nueva Ecija and Iloilo.

7.2.3 Adaptation and development of IWM practices with farmer participation

Following each season, evaluation meetings were held when results and problems were discussed with the participating farmers. As a result of these discussions the IWM technology was adapted to local situations in consultation with farmers and extension workers, and trialled in the following seasons.

Adaptations to manage limited water supply

After the first season of on-farm trials it became obvious that water supply was a key issue, affecting both crop growth and consequent yield, and also the ability to apply water management methods (e.g. intermittent irrigation) for weed control. Problems with water availability in barangays at the end of the irrigation system (e.g. Barotac Nuevo in Iloilo and Aliaga in Nueva Ecija) was a problem for the length of the land preparation period required for the IWM plot. The constraint faced by farmers in these villages at the tail of the irrigation system is the delay in release of irrigation water, which hampered the longer land preparation time needed for IWM. Trials in the 2005-06 seasons compromised on the land preparation time which was shortened from 3 to 2 weeks to accommodate water shortage problems and the "short turn around time" between seasons.

Larger trial plot areas

After the first season of trials plot seasons were increased to 500m^2 at the request of farmers who thought that the 200m^2 plot size used initially was too small.

Row seeding with a drum seeder

Row seeding was suggested by farmers as an adaptation to the broadcast method employed in the trial. Row seeding allowed farmers to adopt mechanical weeding as another alternative method of weed control and to remove weeds that survived herbicide treatments. In 2006-07, row seeding with a drum seeder as a method of seed establishment was used by some farmer cooperators in Nueva Ecija to test if there were differences in weed weights and yield compared with hand broadcasting.

Variable results were obtained for weed weight. In Aliaga, higher grass weed weight was observed in hand broadcasted rice than in the drum seeded rice. In Rizal, higher weed weight was seen in the drum-seeded plots. More weeds were observed in the hand-broadcasted FP plots compared to both the drumseeded and hand-broadcasted IWM plots. Yields were increased by more than 11 percent when drumseeding was used with IWM, compared to hand-broadcasting with the Farmer's Practice weed control. Net income increased by more than 25 percent with the use of drumseeding combined with IWM, while hand-broadcasting combined with IWM increased the net income by 15 percent. Contrary to the notion that drumseeding allows more weeds to grow in the wider space left between rows, it was shown that with IWM the weeds are not able to establish and hence unable to compete with the rice. These results indicate the compatibility of drumseeding with IWM. Particularly in areas with good water supply, more benefits are obtained by farmers with drumseeding as indicated by superior yields and higher income of farmers.

A field trial was also conducted in PhilRice Central Experiment Station in Nueva Ecija during 2006-07 Dry Season to determine the effect of establishment method and herbicide used on growth of weeds in wet direct-seeded rice. In both seeding methods 40 kg/ha seeding rate was used. The seeding method (row seeding vs hand broadcasting) did not affect the density of common weeds present in the area. However, weeds species were affected by different herbicides used. Initial results from one season showed higher populations of *Leptochloa chinensis* in plots treated with bispyribac sodium. In terms of grain yield, highest grain yield of 5.7 t/ha was recorded in plots treated with bispyribac-sodium and using the hand broadcasting method of sowing.

7.2.4 Survey of farmers' adoption and perceptions of the IWM technology

A survey was conducted in 2006 after two-three seasons of on-farm trials to gain further insights into farmers' perceptions of IWM and assess the adoption and diffusion of the IWM practices by farmer co-operators and neighbouring farmers. Focus group discussions were held with all IWM farmer co-operators in each project site for both provinces, and a survey was implemented with the other farmers. Forty farmers from each province with farms adjacent to the farmer co-operators' trial plots were randomly selected and interviewed using a fully structured questionnaire.

Evaluation of IWM effectiveness

The majority (80%) of the farmer co-operators in Iloilo and Nueva Ecija rated the overall effectiveness of IWM technology as either very good or good. A similar rating was given to the effectiveness of IWM in managing weeds in both provinces. The major reasons given for the effectiveness of IWM in the field were: reduced weed problems, good crop stand, reduced herbicide and fertilizer applications, reduced cost of production, well levelled field, reduced seeding rate, and improved yield.

IWM plot vs farmer's practice plot

Farmer co-operators have IWM trial and farmer's practice plots in their fields. Based on the results from two seasons of farm trials, the majority of the farmer co-operators observed differences in their two plots. They said that their IWM plots have less weed problems compared to their farmer's practice plot. All of them mentioned that their costs of production were less because of reduced herbicide and labour usage in the trial plot. Farmer co-operators also observed that they have higher yield in their trial plots. However, most of them want to see if this yield advantage is sustainable over larger areas.

IWM extent of use on farmer co-operators' farms

Most (75%) of the farmer co-operators said they were now using all the components of the IWM technology on their whole farm area. On average, most of them used IWM on their whole farm area after 2-3 seasons of farm trials. The adoption of the IWM technology by the farmer co-operators appears to be quite fast.

All farmer co-operators were also asked if they discussed the IWM technology with other farmers. All of them reported that they have discussed it with their co-farmers but they observed that only few followed the new practice. The factors they think that limit diffusion are that other farmers lack IWM information, water problems, and the "to see is to believe" attitude of farmers.

IWM diffusion on non co-operators' farms

Forty five percent of non farmer co-operators were generally aware about the IWM technology. This percentage includes all farmers who categorised their awareness of the technology as little awareness, some awareness, quite aware and very aware. In general, the top sources of information for these farmers about the technology were LGU agricultural technicians, PhilRice staff, technodemo sites, and fellow farmers (co-operators and non co-operators). In Nueva Ecija, 14 percent of the respondents reported that they have learnt the IWM technology through their own experiences. This is probably true because a number of them already knew some of the IWM components such as water management, application of pre-emergence herbicides, and longer land preparation. Of the IWM components, the weed control action indicator (WCAI) and use of post emergence herbicides were the components that were identified as needing more promotion or awareness in both provinces.

Moreover, almost 10 percent of the non farmer co-operators had tried to use all the IWM components on their farms. Lack of knowledge (particularly on WCAI), needing the cooperation of other farmers, and not being able to see clear benefits were the top reasons cited by the farmers for not using the IWM technology. Farmer respondents were also asked for factors that will make them adopt the IWM technology. Main factors given were attendance at training, seeing a successful IWM farmer in the community, and being convinced of the clear benefits of IWM.

7.2.5 Plans to scale out the IWM technology

Final project workshop to plan the scale-out of IWM activities

The final project workshop "Planning workshop for the post-project adoption of Integrated Weed Management" was held on June 3 2008 at PhilRice with farmers and local government representatives from Iloilo and Nueva Ecija provinces. The workshop was attended by around 25 participants – farmers and provincial and municipal agricultural LGU staff from Iloilo and Nueva Ecija, WESVIARC staff Cora Arroyo and Jesusa Argumento, PhilRice project staff (Dr Casimero, Mr King, Mr Martin and Ms Marsh), and ACIAR Philippines manager Cecilia Honrado.

Five papers reviewing the results of the project work were presented in the morning – including an overview of the project, results of on-farm trials of IWM in Nueva Ecija, results of on-farm trials of IWM in Iloilo, survey and characterization of weedy rice, and herbicide resistance in the Philippines.

During the afternoon the participants worked in two groups (Nueva Ecija and Iloilo) to plan and budget IWM activities in their region in 2008-09. The groups came up with two very different proposals: the Nueva Ecija group wanting to conduct demonstration trials (including method demonstrations) in 22 sites throughout the municipality- “IWM Techno-Demo for Irrigated Lowland Rice in Nueva Ecija Province” ; the Iloilo group wanting to expand the FFS (PalayCheck incorporating IWM) and on-farm trials to 4 new barangays in both Dingle and Barotac Nuevo (80 new farmer co-operators) in 2008-09, and then continue to add 2 municipalities per year to the program – “Village Integration of IWM on Irrigated Areas (Province Wide)”.

The implementing agencies were proposed to be PhilRice, Office of the Provincial Agriculturalist – Nueva Ecija Provincial Government and LGUs for Nueva Ecija; and PhilRice, Provincial and Municipal LGUs, Department of Agriculture WESVIARC, NIA and farmer groups (Irrigators’ Associations) for Iloilo.

PhilRice staff indicated that they would work with these groups to fine tune their plans and budgets prior to implementing these projects. It appears likely that the work will be jointly funded by PhilRice, Provincial and Municipal LGUs and PCARRD (who have committed one million PHPs for this work).

Incorporation of IWM within Palay-Check

Plans have also been made to integrate IWM within PalayCheck, PhilRice’s primary rice production extension program, which is to be applied nationally. This was a government initiative in response to the “rice crisis” in 2008. The “training-of-trainers” was undertaken by PhilRice and IRRI in the second half of 2008. This move will embed the results from the ACIAR project within PhilRice’s rice extension program.

7.3 Objective 3. To assess the status of herbicide resistance in rice weeds in the Philippines

7.3.1 Survey of farmers’ herbicide use in the study regions

Prior to commencing herbicide resistance screening, farmers in the study regions were surveyed in 2005 to assess their weed problems and herbicide usage. Farmers had been using the direct-seeded rice technology for an average of 14.5 years in Iloilo and 16.4 years in Nueva Ecija. These farmers practiced intensive rice mono-cropping with Iloilo averaging 2.5 crops per year, with a maximum of 3 crops per year. In Nueva Ecija, they usually had 2 crops per year. Farmers had used herbicides for 2–15 years in Iloilo and for 2–20 years in Nueva Ecija. Most of the farmers in the two areas started using herbicides when they started to practice the direct seeding method of rice production.

The first herbicide used by farmers in direct seeded rice was butachlor which was used by 67 percent of Iloilo farmers and 60 percent of Nueva Ecija farmers for an average of 8.3 and 8.7 years, respectively. According to the farmers, they had observed that “the formulation of the herbicide was no longer strong to effectively control the weeds” and have shifted to other herbicides due to poor weed control.

Because of this, most of the farmers in the two areas shifted to butachlor+propanil, with three brands used in Nueva Ecija to control diverse populations of weeds. In Iloilo, 80 percent of the farmers had been using butachlor+propanil for an average of 9 years while 87 percent of farmers used this herbicide in Nueva Ecija for an average of 7.1 years. Ten percent of the total farmers interviewed in Nueva Ecija had been using butachlor+propanil for 15-20 years. In Nueva Ecija, some farmers do a follow up application of the same butachlor+propanil herbicide, but using a different brand at 15 days after seeding (DAS) or mixed with another brand of butachlor+propanil applied at 15 DAS.

Some farmers after using butachlor+propanil for an average of 5 years had shifted to other herbicides such as pretilachlor. This herbicide had been used by 53 percent of farmers in Iloilo for 4.1 years and 33 percent of Nueva Ecija farmers for an average of 4.3 years. A newer herbicide, bispyribac sodium, was used by 27 percent of farmers in both areas for an average of 3 years.

For follow-up application, herbicides such as piperophos were used at 8-15 DAS by 13 percent and 10 percent of Iloilo and Nueva Ecija farmers, respectively, usually following the application of pretilachlor or butachlor+propanil. Farmers (27 percent in Iloilo and 13 percent in Nueva Ecija) had also been using cyhalofop-butyl. Fenoxaprop-p-ethyl on the other hand was used by only 7 percent of farmers in both areas. These herbicides belong to a newer herbicide family, AOPPs, and were used for follow-up herbicide applications at 30 DAS. MCPA was used by 20 percent and 10 percent of farmers in Iloilo and Nueva Ecija, respectively, as a follow-up herbicide at 45 DAS.

Metsulfuron+chlorimuron was used in Nueva Ecija to control *Cyperus rotundus* with 10 percent of the farmers using this herbicide mixed with 2,4-D and applied pre-plant. It was also mixed with MCPA for follow-up application at 35 DAS. Farmers also said that 2,4-D was heavily used 15 - 20 years ago but now it is only used for broadleaf or tank-mixed with other herbicides for weeds that are hard to control, such as *Hydrolea zeylanica* in Nueva Ecija. It is also tank-mixed with MCPA to control *C. rotundus* in Nueva Ecija at 30 DAS, and as a follow-up application at 15 DAS. Farmers in Iloilo have not been using this herbicide for the last 5 years due to poor weed control and the availability of new herbicides in the market for use in direct-seeded rice.

Farmers in the surveyed areas observed that the same weed species still grew with direct seeded rice, but the population density has become more intense in the past five years. Major weeds were dominated by *Echinochloa spp., Leptochloa chinensis, Ischaemum rugosum,* the broadleaf weeds *Sphenoclea zeylanica* and *Hydrolea zeylanica,* and the sedges *Cyperus iria, Fimbristylis miliacea,* and *Cyperus rotundus.*

7.3.2 Herbicide resistance screening

Results of resistance screening to commonly used herbicides, butachlor and propanil

Findings from the survey were used to inform the selection of weed species and herbicides for herbicide resistance screening. Initial samples of *Echinochloa crusgalli* and *Echinochloa glabrescens* were obtained from the suspected fields in the project sites in Nueva Ecija and Iloilo province. Eight populations from the two provinces were the first samples to be subjected to resistance screening. Control populations were weed samples taken from the Banuae rice terraces where no herbicides are used. All populations were tested against butachlor + propanil. Three seedlings, grown in size#10 clay pots until 6 DAS were sprayed with the recommended rate of the herbicide using a hand-held sprayer. Ten pots represented each weed population. The total number of weed seedlings surviving the herbicide treatment were counted and ranked following the rating used by Llewellyn and Powles (2001). Plants surviving the herbicide treatment are rated as resistant when the percent survival is more than 20 percent. The preliminary results indicate that the percent survival of the weed seedlings ranged from 37 to 73 percent, indicating possible resistance of the population to butachlor + propanil. These populations were subjected to another testing to confirm the initial observation, and the results are shown in Table 10. Seventeen of the 19 populations of *Echinochloa* species collected and screened exhibited resistance to butachlor+propanil, one population of *E. glabrescens* was rated as developing resistance to this herbicide, and one susceptible population collected from General Santos City, Cotabato was used as the check.

Table 10 Survival and resistance rating of *Echinochloa* species collected from farmers' fields screened for herbicide resistance using butachlor+propanil at 1 l/ha (0.7 kg ai/ha).

Species	Place of collection	No of plants survived (21 DAT)	% Survival	Resistance Rating[a]
E. crusgalli	Bucot, Aliaga, Nueva Ecija	15	50	Resistant
E. crusgalli	Bertrese, Quezon, Nueva Ecija	15	50	Resistant
E. crusgalli	Lusok, Bongabon, Nueva Ecija	15	50	Resistant

E. crusgalli	Soledad, Sta. Rosa, Nueva Ecija	17	57	Resistant
E. crusgalli	Acuit, Barotac Nuevo, Iloilo	17	57	Resistant
E. crusgalli	Monpon, Barotac Nuevo, Iloilo	12	40	Resistant
E. glabrescens	Bucot, Aliaga, Nueva Ecija	18	60	Resistant
E. glabrescens	Aglipay, Rizal, Nueva Ecija	20	67	Resistant
E. glabrescens	Baluga, Talavera, Nueva Ecija	16	53	Resistant
E. glabrescens	Rang-ayan, Munoz, Nueva Ecija	12	40	Resistant
E. glabrescens	La Purisima, Aliaga, Nueva Ecija	15	50	Resistant
E. glabrescens (1)[b]	Acuit, Barotac Nuevo, Iloilo	21	70	Resistant
E. glabrescens (2)	Acuit, Barotac Nuevo, Iloilo	20	67	Resistant
E. glabrescens (3)	Acuit, Barotac Nuevo, Iloilo	20	67	Resistant
E. glabrescens	Monpon, Barotac Nuevo, Iloilo	15	30	Resistant
E. glabrescens	Dapitan, Pototan, Iloilo	10	33	Resistant
E. glabrescens	Hamabalud, Pototan, Iloilo	5	17	Developing resistance
E. glabrescens	Sinibaan, Dingle, Iloilo	10	33	Resistant
E. glabrescens	Gen. Santos City, Cotabato	0	0	Susceptible

[a] *Resistance rating – resistant (>20% survivors), developing resistance (1-20% survivors), susceptible (zero survivors)*
[b] *Species or populations followed by numbers in ( ) were collected in different fields in the same barangay.*

A response dose assay (following the procedure of Valverde et al. 2000) was also conducted on these populations with treatments of zero, one, two and four times the recommended rate of field application. Table 11 shows the LD50 values indicating the differences in herbicide resistance between biotypes of the test Echinochloa species. Of the 19 populations, four biotypes had high LD50 ranging from 1.8 l/ha (1.26 kg ai) to 2.9 l/ha (2.03 kg ai) of butachlor+propanil. Minimum and maximum resistance ratios of the biotypes indicated that these four highly resistant biotypes were 5.6 to 9 times less sensitive to butachlor+propanil than the susceptible biotype. The same trend could be established with LD50 values obtained in response dose assays using butachlor alone and propanil alone.

Results of further resistance screening

In 2006-2007, after the completion of the initial screenings, three greenhouse trials were set up to screen for pretilachlor cross-resistance in barnyard grass, heritability of resistance in butachlor+propanil resistant barnyard grass populations, and resistance screening for cyhalofop in Leptochloa chinensis. The screening and response dose assays for herbicide resistance in Echinochloa spp. was expanded to test resistance to pretilachlor. Seven populations of previously identified butachlor+propanil resistant barnyard grass were found resistant to pretilachlor. Resistance screening showed that all populations except one exhibited resistance and one population rated as developing resistance to the herbicide. Response dose assays showed that only two populations did not survive a pretilachlor dose of 4 L/ha which is four times the recommended rate for field application. LD50 values ranged from 0.65 l/ha (0.20 kg ai) to 0.90 l/ha (0.27 kg ai) which indicate that these resistant biotypes are 3-4 times less sensitive than the susceptible check. Further, the results revealed that 90 percent control of barnyard grass needs more than 2 l/ha but less than 4 l/ha of pretilachlor.

No resistance was found for Leptochloa chinensis and Ischaemum rugosum to cyhalofop. Also, no resistance was observed for E. crusgalli and E. glabrescens to bispyribac sodium.

Table 11 Butachlor + propanil concentration required to reduce by 50 percent (LD_{50}) the number of survivors of resistant *Echinochloa* biotypes

Species	Place of collection	LD_{50} (l/ha)	LD_{50} (kg ai)	Resistance Index[a]
E. crusgalli	Bucot, Aliaga, Nueva Ecija	1.00	0.70	3.1
E. crusgalli	Bertrese, Quezon, Nueva Ecija	1.00	0.70	3.1
E. crusgalli	Lusok, Bongabon, Nueva Ecija	1.00	0.70	3.1
E. crusgalli	Soledad, Sta. Rosa, Nueva Ecija	1.15	0.81	3.6
E. crusgalli	Acuit, Barotac Nuevo, Iloilo	1.25	0.88	3.9
E. crusgalli	Monpon, Barotac Nuevo, Iloilo	0.80	0.56	2.5
E. glabrescens	Bucot, Aliaga, Nueva Ecija	1.30	0.91	4.1
E. glabrescens	Aglipay, Rizal, Nueva Ecija	2.90	2.03	9.1
E. glabrescens	Baluga, Talavera, Nueva Ecija	1.10	0.77	3.4
E. glabrescens	Rang-ayan, Munoz, Nueva Ecija	0.80	0.56	2.5
E. glabrescens	La Purisima, Aliaga, Nueva Ecija	1.00	0.70	3.1
E. glabrescens (1)[b]	Acuit, Barotac Nuevo, Iloilo	2.15	1.51	6.7
E. glabrescens (2)	Acuit, Barotac Nuevo, Iloilo	1.05	0.74	3.3
E. glabrescens (3)	Acuit, Barotac Nuevo, Iloilo	1.80	1.26	5.6
E. glabrescens	Monpon, Barotac Nuevo, Iloilo	1.00	0.70	3.1
E. glabrescens	Dapitan, Pototan, Iloilo	0.75	0.53	2.3
E. glabrescens	Hamabalud, Pototan, Iloilo	0.60	0.42	1.9
E. glabrescens	Sinibaan, Dingle, Iloilo	0.75	0.53	2.3
E. glabrescens	Gen. Santos City, Cotabato	0.32	0.22	-

[a] *Resistance Index = LD_{50} resistant population/LD_{50} susceptible reference*
[b] *Species or populations followed by numbers in ( ) were collected in different fields in the same barangay.*

Complete results from the resistance testing carried out on weed populations during the project are attached as Appendix 3. The continuous use of a single herbicide for several years (nine and seven years in Iloilo and Nueva Ecija respectively) in monocropped areas (three crops/year in Iloilo and two crops/year in Nueva Ecija) provided selection for resistant populations of *Echinochloa* spp. This finding of resistant weed populations explained why farmers in these areas have been using higher doses of herbicides and increasing the number of applications per season. What was perceived by farmers to be a result of reduced herbicide efficacy was actually found to be herbicide resistance of the weeds to butachlor, to butachlor+propanil, and to pretilachlor.

The herbicide resistance screening work was written up and presented at conferences in the Philippines and SE Asia.

- Juliano and Casimero 2006. “Herbicide resistance in *Echinochloa* spp: The case of Nueva Ecija and Iloilo”, 37th Annual Scientific Meeting of the Pest Management Council of the Philippines, Davao City, Philippines. (Awarded Best Paper in Weed Science for the Conference).
- Juliano and Casimero, 2007. Herbicide resistance in *Echinochloa* spp: The case of Nueva Ecija and Iloilo, Philippines, 21st Asian Pacific Weed Science Society Conference, Colombo, Sri Lanka.

The work confirming resistance of *Echinochloa* spp. to butachlor and propanil is recorded on the IWSS herbicide resistance website.

Development of protocols for herbicide resistance screening

During the course of the project two protocols to screen for herbicide resistance with single or cross resistance for propanil, butachlor, pretilachlor, and butachlor+propanil were developed at PhilRice. Three protocols to screen for the evolution of resistance from susceptible biotype using whole plant assays; screening of cross- or multiples resistances using whole plant assays for two different herbicides but with one experimental set up; and quick tests to cover weeds that emerged/escape after control has been applied at the time of field application (farmers' fields) were adapted by PhilRice staff after Mrs Juliano undertook three months hands-on training at the Western Australia Herbicide Resistance Initiative Laboratory at the University of Western Australia from April-June 2008.

Details of the protocols developed are attached as Appendix 2.

7.3.3 Results of weedy rice studies

Following discussions with Professor Powles at WAHRI in 2004, it was decided to expand the investigation of herbicide resistant weeds to include weedy rice infestations in direct-seeded rice fields. In 2005, weedy rices were collected from farmers' fields in Nueva Ecija, where in some cases crops had a 60 percent (visual assessment) infestation of weedy rice. In 2006, weedy rices were collected from farmer's fields in Iloilo. These weedy rices were grown out in the glasshouse for morphological characterisation.

Occurrence, distribution and morphological characteristics of weedy rice (Oryza sativa L.) in Nueva Ecija

Five weedy rice biotypes were found associated with cultivated rice around rice fields in 32 municipalities of Nueva Ecija. Among these, WR-NE 1 was found to be the most common biotype in many rice fields. The percentage occurrence in the different municipalities ranged from 12.5 to 25%[1] while the severity of infestation in the field ranged from 8 to 19%. The five weedy rice biotypes had variable grain characteristics. Dark red coloration in the stem was also observed in some biotypes. The biotypes were found to be associated with both direct-seeded and transplanted rice with a population density of 0.5 to 2.4 plants per m^2.

All weedy rice biotypes germinated earlier than rice varieties PSB Rc82 and IR64 under laboratory conditions. Consistent with field observations, all biotypes were taller than cultivated rice varieties. They also produced more tillers and leaves, had larger leaves, heavier shoot biomass and matured earlier than cultivated rice. However, no shattering of grains was observed in all biotypes. Moreover, the five biotypes also produced more panicles although no significant differences were observed except for WR-NE 3. Seed characteristics of the five biotypes are illustrated in Figure 15.

Eight weedy rice biotypes were found associated with cultivated rice around rice fields in five municipalities of Iloilo. Of these, WR-ILO 1, WR-ILO 3 and WR-ILO 5 were the most common biotypes. The percentage occurrence in the different municipalities ranged from 3 to 75% while the severity of infestation in the field ranged from 5 to 60%. The different weedy rice biotypes were often mixed together in the one field.

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[1] *Percentage occurrence = fields where weedy rice was found over the total number of fields surveyed.*

WR-NE1 WR-NE2 WR-NE3 WE-NE4 WR-NE5

Figure 15 Seed characteristics of 5 weedy rice biotypes collected in Nueva Ecija

Similar to the Nueva Ecija biotypes, the Iloilo weedy rice biotypes when grown in the screenhouse generally were taller, had more grains per panicle, emerged earlier, produced more tillers and leaves, had larger leaves, heavier shoot biomass and matured earlier than cultivated rice. An example of the data collected for both Nueva Ecija and Iloilo weedy rice biotypes is shown for the Iloilo biotypes in Table 12.

Dr Casimero presented the initial results of the survey of distribution and occurrence and characterization of weedy rice in a pre-conference workshop during the 20th Asian Pacific Weed Science Society conference in Vietnam in November 2005. It was observed at this workshop that there is a huge problem with weedy rice in Southeast and South Asia. Dr Casimero visited Thailand after this conference and met with Dr Chanya Maneechote, weed scientist from the Department of Agriculture Thailand, to discuss weedy rice management and their extension activities with farmers. She also travelled to the provinces to observe and discuss with Thai farmers how they manage weedy rice in their fields.

In June 2008, Dr Casimero presented the results from the weedy rice studies at a pre-conference workshop on weedy rice at the 5th International Weed Science Conference in Vancouver, Canada. At this workshop plans were made for the development of a FAO weedy rice initiative in South and Southeast Asia, and Dr Casimero and Mr Martin attended the regional workshop in October 2008 in Bangkok, Thailand.

Table 12 Selected agronomic characteristics of cultivated rices PSB Rc82 and PSB Rc14 compared to weedy rice biotypes collected in Iloilo, grown in the screenhouse at PhilRice, Nueva Ecija, during the 2006 dry season

Weedy rices/ cultivated rices	Growth duration (days)	Leaf area (cm2)	Panicle per plant	Grains per panicle	1000-grain weight (g)
PSB Rc82	105.9	16.7	14.2	74.7	22.5
PSB Rc14	103.8	19.4	15.0	103.4	18.2
WR-ILO 1	95.6	21.7	8.1	87.6	19.4
WR-ILO 2	74.5	30.3	9.5	149.3	24.7
WR-ILO 3	86.6	20.1	11.9	78.4	19.4
WR-ILO 4	86.3	23.9	14.6	115.6	19.1
WR-ILO 5	94.8	18.4	8.0	90.6	16.5
WR-ILO 6	72.8	21.2	12.6	93.8	17.1
WR-ILO 7	84.9	25.3	11.4	93.1	21.3
WR-ILO 8	74.1	25.5	8.7	136.5	24.9

Results from the weedy rice studies were written up and presented at two conferences.

- Donayre et al. 2006. "Occurrence, distribution and morphological characteristics of weedy rice (*Oryza sativa* L.) in Nueva Ecija", 37th Annual Scientific Meeting of the Pest Management Council of the Philippines, Davao City.
- Casimero et al. 2008. "Distribution and morphologic characterization of weedy rice in the two major rice growing areas in the Philippines" 5th International Weed Science Conference, Vancouver, Canada.

7.4 Objective 4. To develop an economic framework for policy analysis of herbicide resistance and weed management issues in the Philippines and Australia

7.4.1 Development of an economic analysis approach for herbicide management

The survey of growers in the Philippines highlighted the real likelihood of weed mobility between properties (Table 13). The increasing level of costly forms of resistance in Australian grain growing, and perceptions of herbicide resistance mobility in Australia (e.g. Llewellyn and Allen 2006) suggested that research into the economics of herbicide resistance management in the presence of weed (and resistance) mobility was a priority.

An initial paper was completed (Weersink et al. 2005) on the economics of pre-emptive management by farmers to conserve glyphosate and published in Crop Protection. This paper deals with the economics of conserving the herbicide resource from the farmer's perspective, and provides the first empirical evidence that optimal use of glyphosate can involve some conservation strategies on the part of the farmer. This was in contrast to previous work for other herbicides that had suggested that it was not economic to conserve herbicide use to prevent resistance. However, the Weersink et al. model did not consider the possibility of movement between farms of herbicide resistant weeds.

An initial literature review of issues related to conservation of the herbicide resource (particularly from a public good aspect) and modeling approaches that had been used in previous work was completed. From this review it was argued that a fairly strong case exists to argue that conservation of glyphosate as a herbicide resource has a public-good component, particularly because of the possible loss of conservation tillage, and the spread of resistance though weed mobility.

This work was written up and presented at the 26th Conference of the International Association of Agricultural Economists in August 2006 (Marsh et al. 2006, "Social costs of herbicide resistance: the case of resistance to glyphosate").

Table 13 Mean ratings by respondents of farmers' perceptions of weed seed sources (ratings from 1 to 7 where 1 = top source and 7 = least source)

Perceived source of weeds	**Mean Rating**	
	Nueva Ecija (n=200)	Iloilo (n=200)
Seeds in the ground from pervious crops/years	2.30	2.79
Seeds carried in by irrigation water	2.88	2.57
Seeds brought in by animals/people	2.35	4.12
Seeds blown in	4.85	3.56
Seeds brought in by machinery	4.67	4.14
Weeds seeds in the crop seeds	4.67	4.14

7.4.2 Analysis of herbicide use scenarios

A simulation model to investigate the effect of weed mobility on the economics of herbicide use was developed. The model (based on the Weersink et al. 2005 model), incorporated hypothetical data for the probability of resistance spread. A paper containing the methodology and results from a number of simulation runs investigating various herbicide resistance spread scenarios was presented at the 15th Australian Weeds Conference in Adelaide in September 2006 (Marsh et al. 2006, "Weed and pollen mobility and social costs of herbicide mobility").

Simulation results suggested that:

- resistance mobility will reduce the time to expected resistance development, especially the expected delay in resistance development when a 'preventive' strategy is used
- resistance mobility increases the expected cost of weed control, and could make the use of preventive strategies less cost-effective, especially in the short term.

The hypothetical model has been useful in identifying key parameter areas where data is lacking. A better understanding is needed of:

- the actual mobility of resistance for different weeds
- the ability of preventative strategies to reduce resistance mobility risks
- the costs of weed control after resistance onset.

It is envisaged that work on the model will continue, focussing on the affect of weed mobility on herbicide use and costs, and the incorporation of real data.

Further work on optimal weed management strategies is being undertaken by John Allwright PhD scholar, Ms Beltran. She is adapting the Ryegrass Integrated Management (RIM) model, currently used in Australia to assess weed management options in broadacre cereal cropping, for use with rice in the Philippines.

8 Impacts

8.1 Scientific impacts – now and in 5 years

Now

- Herbicide resistance in *Echinochloa* spp. to important rice herbicides butachlor and propanil has been confirmed through the work of this project. This is the first reported case of resistance in *Echinochloa* spp. in the Philippines, and is recorded on the IWSS herbicide resistance website.
- The high survival rate of the F2 generation of highly resistant populations to butachlor + propanil confirmed heritability of resistance to this herbicide.
- Seven populations of Echinochloa spp. which were previously found to be resistant to butachlor + propanil also showed resistance to pretilachlor. This indicates that these populations have developed cross (or multiple) resistance.
- Morphological studies and mapping of weedy rice populations in Nueva Ecija and Iloilo have documented the emerging problem posed by weedy rice in these major rice growing areas. This is the first time that weedy rice had been investigated in the Philippines.

In five years

- Initial work on weedy rice done by the project team will be progressed through collaboration with a major FAO initiative on weedy rice in SE Asia.
- There is potential for the research on the social and economic costs of herbicide resistance and issues associated with potential herbicide resistance mobility to contribute to the research debate on the need to conserve glyphosate as a herbicide resource.

8.2 Capacity impacts – now and in 5 years

Now

- Farmers that participated in the on-farm trial and the 8-week follow-up training enhanced their skills in managing weeds and were encouraged to think of other strategies to improve further their rice production management skills. Farmers suggested integrating other establishment practices, like row seeding using the plastic drumseeder and reducing the duration of land preparation to 15 days instead of 21 days, and helped design the experiments to test their ideas.
- Farmers in these communities (both co-operators and other farmers nearby the sites) are now implementing new IWM practices in their own fields.
- The herbicide resistance screening resulted in the first reported case of resistance in *Echinochloa* spp. in the Philippines, and this result has raised awareness of herbicide resistance among the rice-growing industry.
- A number of PhilRice project members undertook ACIAR-sponsored training courses during the duration of the project, which contributed directly to their research, extension and project management capabilities:
  - Dr Casimero participated in the “Training Course on Research Management for Agriculture” held at IRRI and conducted by ACIAR and the University of New England in 2005.

  - Edwin Martin participated in training on the “Application of Participatory Approaches to Agricultural Research and Extension” at the International Rice Research Institute in November 2005.
  - Mrs Corazon Arroyo, project collaborator from the Western Visayas Integrated Agricultural Research Centre, participated in the “Training Workshop on Application of Participatory Approaches to Agricultural Research and Extension” at IRRI in August 2006.
  - Dr Casimero and Glen Ylar (staff of PhilRice) participated in training on “Research and Development Project Management and Commercialization Skills” in October 2006 and June 2007 in the Philippines. The training was funded by ACIAR for Philippine collaborators.
  - Dr Casimero was successful in obtaining an ACIAR John Dillon Fellowship and attended the “New Managers Development Program 55” at the Mt Eliza Business School, and also a training course on “Leading Successful Research Projects and Teams” at the University of Melbourne in February 2007.
  - Edwin Martin attended training on “Financial and Economic Research Methods for Agricultural Research Managers” in September 2007.
- PhilRice and Australian project team members have written up research results from the project and presented them at a number of conferences in the Philippines, Australia and elsewhere.

In five years

- Plans to scale-out the IWM technology through a program devised jointly by local LGUs, farmer co-operators in the two districts and PhilRice, with 1M Peso funding from PCCARD, will contribute to building capacity on rice production and weed management among rice farmers over a larger area.
- The IWM technology will be incorporated within PhilRice’s Palay Check program, ensuring that the results of and lessons learnt from this project become a component of PhilRice’s major extension program to improve the capacity of Filipino rice growers.
- During the project, a set of resistance testing protocols has been developed, and Mrs Juliano has developed experience in resistance screening and undergone 3 months hands-on training at the Western Australian Herbicide Resistance Initiative (WAHRI) at UWA under the guidance of Professor Powles. This will enable PhilRice to play an on-going leading role in monitoring herbicide resistance in the Philippines.
- Researchers at PhilRice are now doing further testing of weed populations and are able to advise field workers that PhilRice researchers should be alerted to suspect weed populations so that resistance status can be confirmed.
- As a direct result of the ACIAR project, two senior PhilRice staff are undertaking PhD projects on highly relevant topics - “Farmers’ perceptions, learning and adoption of multi-component and preventive rice technologies in Nueva Ecija, Philippines” and “Economic analysis of weed management options in rice production in the Philippines”. This will greatly increase the capacity of PhilRice to address weed management challenges in the future.
- Training undertaken by PhilRice project team members (detailed in the previous section) will contribute to their research, extension and management capability in the future.

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

Now

- The participatory on-farm trials, together with the field days conducted created awareness on the importance of IWM as a strategy to increase farmer's productivity. It also raised awareness on herbicide resistance as this topic was introduced to the farmers during the training.
- The confirmation of herbicide resistance in *Echinochloa* spp. in the Philippines raised awareness of herbicide resistance among the rice-growing industry.

In five years

- Plans to scale-out the IWM technology, with PCCARD funding, will contribute to better weed management and improved rice productivity over a larger area.
- The IWM technology will be incorporated within PhilRice's Palay Check program, ensuring that the results of this project become a component of PhilRice's major extension program to rice growers.

8.3.2 Social impacts

Now and in five years

- PhilRice project members Dr Casimero, Mr Martin and Mrs Juliano were invited to talk about integrated weed management, weedy rice and herbicide resistance in local and national radio and programs and various farmer's fora. Dr Casimero and Mr Martin were also requested to lecture to the technical and sales staff of Syngenta Philippines about weedy rice and herbicide resistance. This has reinforced PhilRice's reputation as a leading source of technical and extension information about weed management in the Philippines.
- The farmer co-operators of the PhilRice-ACIAR project were featured in a story about integrated weed management in the PhilRice website in June 2007 (http:www.philrice.gov.ph) and in one agriculture magazine. This has reinforced to co-operators the importance of their participation and local knowledge in the adaptation of technologies.
- Farmer co-operators benefited from the cross-visits made to other project sites for field days associated with the on-farm trials. In Iloilo, farmers from Dingle and Barotac Nuevo discussed together the problem of water availability at the end of the system (i.e. in Barotac Nuevo), and this resulted in the districts making a joint approach to the irrigation authorities about irrigation issues.
- Many women were involved as farmer co-operators and as participants in the training courses. This reinforced their position as farmers with valuable contributions to make to the adaptation of technologies.

8.3.3 Environmental impacts

In five years

- The participatory on-farm trials, together with the season-long training on Rice ICM and associated field days raised awareness in the four communities about the importance of Integrated Weed Management to reduce dependence on herbicides to control weeds. Reduced dependence on herbicides has the potential have a positive effect on environmental pollution caused by herbicides, and also reduce health concerns from inappropriate use of herbicides.

8.4 Communication and dissemination activities

8.4.1 Formal communications

A range of formal communication activities have occurred, with the aim of sharing information and raising awareness of the research that was undertaken in the ACIAR project.

Communications with weed scientists: in Australia, the Philippines and internationally

- September 2004: Dr Casimero presented a seminar to the Western Australian Herbicide Resistance Initiative (WAHRI) group at UWA on “Rice production in the Philippines and weed challenges”.
- November 2004: Ms Marsh presented a seminar to the WAHRI group at UWA on “Direct seeding and herbicide use in the Philippines: implications for weed management”.
- The project team visited IRRI in February 2005 and had meetings with Dr Bas Bouman, Dr David Johnston, Mr Joel Janiya and Dr Sushil Pandey to seek information on work in this area being undertaken by IRRI scientists and to inform them of work being done in the ACIAR project.
- In September 2005, Dr Casimero and Mrs Beltran visited UWA to progress project research work. Dr Casimero presented a seminar to the WAHRI group on the preliminary results of the work being done on screening *Echinochloa* spp. for herbicide resistance. As a result of this seminar Professor Powles made a commitment to attend the 37th Annual Scientific Meeting of the Pest Management Council of the Philippines in Davao City in May 2006, and present a plenary session paper on herbicide resistance.
- November 2005: Following the Asian-Pacific Weeds Conference in Ho Chi Minh City, Dr Casimero travelled on to Thailand and met with Dr Chanya Maneechote, weed scientist of the Department of Agriculture Thailand, to discuss weedy rice management and their extension activities with farmers. She also travelled to the provinces to observe and discuss with Thai farmers how they manage weedy rice in their fields.
- February 2006: Ms Marsh met with Dr Fay Rola-Rubzen (at the AARES conference) and discussed progress on the respective ACIAR projects. This meeting confirmed that weed management had not been identified as an issue by participants in the “immigration and women’s needs” project.

- During the project, Dr. Rick Llewellyn chaired the national Glyphosate Sustainability Working Group, an initiative with the objective of promoting research & industry collaboration and encouraging sustainable herbicide use. This group served as an avenue to disseminate findings from this project. http://www.weedscrc.org.au/glyphosate/index.html.
- The confirmation of herbicide resistance in *Echinochloa crus-galli* (barnyard grass) in direct-seeded rice fields in the Philippines was entered in the International Survey of Herbicide Resistant Weeds (http://www.weedscience.org/in.asp). This website is funded and supported by the Herbicide Resistance Action Committee (HRAC), the North American Herbicide Resistance Action Committee (NAHRAC), and the Weed Science Society of America (WSSA). The specific URL for the Philippine findings from research conducted by the ACIAR project team is: http://www.weedscience.org/Case/Case.asp?ResistID=5272#Contacts.

Communications with extension personnel and farmers in the Philippines

- April 2005: Dr Casimero delivered a lecture entitled “Weed management in rice: science and technology updates” to extension personnel of the different local government units (LGUs) of Regions I and III during the Rice Science and Technology Updates for Extension Workers at PhilRice, Maligaya, Munoz, Nueva Ecija.
- October 2006: Dr Casimero delivered a lecture on “Weedy rice and the problems it causes to farmers” during the Farmers’ Forum in Dingle, Iloilo.
- March 2007: PhilRice launched the poster “Damong Palay (Weedy Rice)” during the 20th National Rice R&D Conference held at PhilRice, Maligaya, Munoz, Nueva Ecija. Three thousand copies of the poster were printed. Some of these were distributed to the participants during the Rice R&D conference.
- In 2007, PhilRice cooperated with the International Rice Research Institute to produce a weedy rice brochure: “Alamin and damong palay sa Asya”.
- March, April and May, 2008: Dr Casimero and Mr Martin served as trainers in a series of training for the technical and sales staff of Syngenta Philippines on identification and management of weedy rice.
- March 2008: Dr Martin served as lecturer on Integrated Weed Management in rice and rice-based cropping systems during the two-week training-of-trainers for the implementation of the Philippine Rice Self-sufficiency Program.
- March 2008: Dr Casimero and Mrs Juliano served as lecturers on Integrated Weed Management in rice and rice-based cropping systems during the season-long training of extension workers and rice self-sufficiency officers for the implementation of the Philippine Rice Self-sufficiency Program.

Visits to project sites by senior program managers in PhilRice and ACIAR

- Dr Leocadio Sebastion, PhilRice Executive Director, visited the Iloilo on-farm trial sites (with Dr Casimero) and talked to farmers in August 2005.
- March 2006: Dr Ken Menz, ACIAR Program Manager, attended a field day conducted in Rizal, Nueva Ecija to showcase the results of the on-farm trial. This field day was also attended by about 80 farmers from the adjacent villages.

Communications through conferences attendances and presentations

Members of the Philippines and Australian project team attended a number of conferences over the duration of the project, presenting results of the research work from the project. ACIAR funds were used to support attendance at some of these conferences.

Dr Rick Llewellyn attended:

- 13th Australian Society of Agronomy Conference, Perth, Australia, in September 2006, presenting an invited paper entitled: “Achieving rapid adoption: information value and the role of grower groups”.
- 5th International Weed Science Conference, Vancouver, Canada, in June 2008, presenting a paper entitled: “Has herbicide resistance led to higher weed densities?” and co-organised a session on socio-economic aspects of weed management.

Ms Sally Marsh attended:

- 14th Australian Weeds Conference, Wagga Wagga, Australia, in September 2004.
- 49th Australian Agricultural and Resource Economics Society Conference, Coffs Harbour, Australia, in February 2005, presenting an oral paper entitled: “Direct-seeding of rice and herbicide use in the Philippines: implications for weed management”.
- 50th Australian Agricultural and Resource Economics Society Conference, Sydney, Australia, in February 2006, presenting an oral paper entitled: “Social costs of herbicide resistance: the case of resistance to glyphosate”.
- 37th Annual Scientific Meeting of the Pest Management Council of the Philippines in Davao City, Philippines, in May 2006.
- Australasian Pacific Extension Network 2006 International Conference, Beechworth, Australia, in March 2006, presenting an oral paper entitled: “Working with farmers to develop practical weed management techniques for direct-seeded rice in the Philippines”.
- 26th Conference of the International Association of Agricultural Economists, Gold Coast, Australia, in August 2006, presenting a poster paper entitled: “Social costs of herbicide resistance: the case of resistance to glyphosate”.
- 15th Australian Weeds Conference, Adelaide, Australia, in September 2006, presenting an oral paper entitled: “Weed and pollen mobility and social costs of herbicide resistance”.
- 5th International Weed Science Conference, Vancouver, Canada, in June 2008, presenting an oral paper entitled: “Achieving high adoption of IWM in direct-seeded rice in the Philippines”.

Professor Steve Powles attended:

- 37th Annual Scientific Meeting of the Pest Management Council of the Philippines in Davao City, Philippines, in May 2006, presenting an invited plenary session powerpoint presentation entitled: ”Herbicide resistance”.

Dr Donna Casimero attended:

- 14th Australian Weeds Conference, Wagga Wagga, Australia, in September 2004, presenting an oral paper entitled: “Agro-ecological approaches to managing weeds in wet direct-seeded rice”.
- 36th Pest Management Council of the Philippines Annual Scientific Meeting, Munoz, Philippines, in May 2005, presenting an oral powerpoint presentation entitled: “Herbicide resistance in the Philippines: To be or not to be”.
- 20th Asian Pacific Weed Science Society Conference, Ho Chi Minh City, Vietnam, in November 2005, presenting an oral paper entitled: “Direct seeding of rice and shifts in herbicide use in the Philippines”.

- 37th Annual Scientific Meeting of the Pest Management Council of the Philippines in Davao City, Philippines, in May 2006, presenting an oral powerpoint presentation entitled: “Bringing the science of weeds to farmers: The PhilRice-ACIAR experience”.
- 15th Australian Weeds Conference, Adelaide, Australia, in September 2006, presenting an oral paper entitled: “Participatory adaptation of an Integrated Weed Management strategy for wet direct-seeded rice in the Philippines”.
- 38th Annual Scientific Meeting of the Pest Management Council of the Philippines in Tagbilaran City, Philippines in March 2007.
- 21st Asian Pacific Weed Society Conference, Colombo, Sri Lanka in October 2007, presenting an oral paper entitled: “Herbicide resistance in *Echinochloa* spp: The case of Nueva Ecija and Iloilo, Philippines”.
- 39th Pest Management Council of the Philippines, Puerto Princesa City, Philippines, in May 2008, presenting an invited plenary paper entitled: “Sustainable weed management in rice in Asia”.
- 5th International Weed Science Conference, Vancouver, Canada, in June 2008, presenting an oral paper entitled: “Distribution and morphologic characterization of weedy rice in the two major rice growing areas in the Philippines”.

Mrs Leylani Juliano attended:

- 37th Annual Scientific Meeting of the Pest Management Council of the Philippines in Davao City, Philippines, in May 2006, presenting an oral paper entitled: “Herbicide resistance in *Echinochloa* spp: The case of Nueva Ecija and Iloilo”.
- 38th Annual Scientific Meeting of the Pest Management Council of the Philippines in Tagbilaran City, Philippines in March 2007, presenting an oral powerpoint presentation entitled: “Pretilachlor cross-resistance in butachlor + propanil resistant biotypes of *Echinochloa* species”.
- 20th National Rice R&D Conference, Munoz, Philippines in March 2007, presenting an oral paper entitled: “Herbicide resistance in *Echinochloa* species: the case of Nueva Ecija and Iloilo provinces”.

Mrs Jessie Beltran attended:

- 37th Annual Scientific Meeting of the Pest Management Council of the Philippines in Davao City, Philippines, in May 2006, presenting an oral paper entitled: “A review of the current weed management practices of farmers adopting direct seeding in Iloilo and Nueva Ecija”.
- 38th Annual Scientific Meeting of the Pest Management Council of the Philippines in Tagbilaran City, Philippines in March 2007, presenting an oral powerpoint presentation entitled: “Diffusion of the IWM technology: a quick review”.

Mr Edwin Martin attended:

- 20th Asian Pacific Weed Science Society Conference, Ho Chi Minh City, Vietnam, in November 2005.
- 18th National Rice R&D Conference, Munoz, Philippines, in April 2006, presenting a poster entitled: “Morphological characteristics of weedy rice in Nueva Ecija”.
- 37th Annual Scientific Meeting of the Pest Management Council of the Philippines in Davao City, Philippines, in May 2006, presenting an oral paper entitled: “On-farm adaptation of an integrated weed management strategy for wet direct-seeded rice in Nueva Ecija province”.

- 38th Annual Scientific Meeting of the Pest Management Council of the Philippines in Tagbilaran City, Philippines in March 2007, presenting an oral powerpoint presentation entitled: "Occurrence, distribution and farmers' management practices for *Cyperus rotundus* in irrigated lowland rice".
- 20th National Rice R&D Conference, Munoz, Philippines in March 2007, presenting an oral powerpoint presentation entitled: "Weedy rice: the silent menace in direct-seeded rice".

Mr Dindo King attended:

- 18th National Rice R&D Conference, Munoz, Philippines, in April 2006, presenting a poster entitled: "Distribution and occurrence of weedy rice in Nueva Ecija."
- 37th Annual Scientific Meeting of the Pest Management Council of the Philippines in Davao City, Philippines, in May 2006, presenting an oral paper entitled: " Occurrence, distribution and morphological characteristics of weedy rice (*Oryza sativa* L.) in Nueva Ecija".
- 38th Annual Scientific Meeting of the Pest Management Council of the Philippines in Tagbilaran City, Philippines in March 2007, presenting an oral powerpoint presentation entitled: "Occurrence, distribution and morphological characteristics of weedy rice (*Oryza sativa* L.) in Iloilo".
- 20th National Rice R&D Conference, Munoz, Philippines in March 2007, presenting a poster entitled: "Lowland ecotypes of *Cyperus rotundus* in ricefields of Aliaga, Nueva Ecija".
- 39th Pest Management Council of the Philippines, Puerto Princesa City, Philippines, in May 2008, presenting an oral powerpoint presentation entitled: "Participatory research on integrated weed management in direct-seeded rice".

Mrs Cora Arroya, WESVIARC collaborator, attended:

- 37th Annual Scientific Meeting of the Pest Management Council of the Philippines in Davao City, Philippines, in May 2006, presenting an oral powerpoint presentation entitled: "On-farm adaptation of an integrated weed management strategy for wet direct-seeded rice in Iloilo province".

Mrs Jesusa Argumento, WESVIARC collaborator, attended:

- 37th Annual Scientific Meeting of the Pest Management Council of the Philippines in Davao City, Philippines, in May 2006.

Communications through mass media

- August 2005: Dr Casimero served as a resource person on weed management in a radio program "Ang Progresibong Magsasaka (The progressive farmer)" at DZNE. In this program, Donna shared information about integrated weed management and the on-going on-farm trials being conducted in Rizal and Aliaga, Nueva Ecija.
- December 2005: Dr Casimero served as a resource person in a morning TV program "Lakas Magsasaka (Farmer Power)" in agriculture in collaboration with Syngenta Philippines, PhilRice and a TV station (ABS-CBN) to discuss weedy rice, its characteristics, distribution and problems associated with it.
- May 2006: Dr Casimero served as a resource person on herbicides and management of weeds in direct seeded rice in the radio program "Ang progresibong magsasaka". In this program, Donna shared the results of the on-going on-farm trial on IWM and introduced herbicide resistance as new problem in the field. Possible HR management alternatives were discussed.

- Following the 37th Annual Scientific Meeting of the Pest Management Council of the Philippines in May 2006 when project team researchers reported herbicide resistance in *Echinochloa* species, a number of newspaper articles were published alerting farmers to these research findings:
  - "R&D notes: 2 weed species develop resistance to herbicides", Philippines Star, Aug 6 2006, p. 4.
  - "PhilRice weed researchers shine in PMCP confab", Ilocos Times, Aug 21-27 2006, p. 20.
  - "Agri-news: Careful with herbicides", Ilocos Times, Aug 21-27, p. 21.
  - "Harvest Time: Careful with herbicides", Sunday Punch, Aug 27 2006, p. 6.
- August 2006: Dr Casimero served as a resource person to discuss weedy rice and integrated weed management on the local radio program "Progresibong Magsasaka" aired every Monday at 4 pm over radio DWNE.
- During the second half of the project PhilRice was active in disseminating the project results in magazines and newspapers in the Philippines, and on the PhilRice website.
  - Pablico, S. Ma. 2006. Careful now with herbicides. Agriculture Magazine Vol. X No. 8. Sept. 2006. pp. 22-24.
  - Pablico, S. Ma. 2006. Weed or rice?: Farmers warned to watch out for weedy rice. Philippine Star. March 11, p. B-4
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  - Pablico, S Ma. 2007. Integrated weed management reduces recurring low income. 16 June 2007. http:www.philrice.gov.ph
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  - Pablico, S. Ma. 2007. How Iloilo farmers get more income. Agriculture Magazine. Vol. XI No. 5. May, pp. 8-10.
  - Pablico, S. Ma. 2007. Prevent weedy rice. Agriculture Magazine Vol. XI No. 3. March 2007. pp. 54-55.
  - Pablico, S. Ma. 2007. Integrated weed management. Philippine Star. June 10, 2007. p. B-4
- June 2007: Dr Casimero was a resource person in "Ating Alamin", an early morning agriculture FM radio program to discuss weedy rice and its impact on rice production.

8.4.2 Informal communications

Throughout the project the Philippine and Australian team engaged in many less formal communications about project activities with weed scientists, agricultural technicians, extension personnel and farmers in the Philippines and Australia.

9 Conclusions and recommendations

9.1 Conclusions

9.1.1 Objective 1. To sample and document farmers' current weed practices, perceptions and information sources in relation to direct-seeded rice in the Philippines

Almost all farmers in Nueva Ecija and Iloilo used weed management practices involving a combination of cultural practices and herbicide use. However, if water availability became a problem, farmers failed to do good land preparation and tended to use more herbicides to control weeds. Farmers were highly dependent on herbicides (spraying from one to three times per season) and were using herbicides with a high risk of developing herbicide resistance. As direct seeding increases, water constraints increase and hand weeding decreases, there is a growing need for training and extension work targeted at raising awareness about weeds, herbicide use, herbicide resistance, and integrated weed management in direct seeded rice.

9.1.2 Objective 2. To test, evaluate and adapt a promising (low herbicide use) rice production method in farmers' fields through farmer participation in the Philippines

On-farm trials of Integrated Weed Management (IWM) versus Farmer's Practice across major rice-growing districts over 6 seasons showed reduced weed weights, increased yields, higher profits and reduced number of herbicide applications using an IWM strategy.

There is a need to locally adapt the IWM practices and strategy, particularly where water availability and reliability is limiting. Adaptations included a shorter land preparation period in areas with poorer water availability, use of a drum seeder to facilitate manual weeding, and larger trial plot areas.

The use of IWM generated positive learning and communication. Eighty percent of the farmer co-operators in Iloilo and Nueva Ecija rated the overall effectiveness of the IWM technology as either very good or good. The adoption of the IWM technology by the farmer co-operators was fast, with most (75%) using IWM on their whole farm area, typically after 2-3 seasons of farm trials. As IWM is a relatively complex innovation with high learning requirements, uptake by non-co-operator neighbour farmers was slower (10%).

9.1.3 Objective 3. To assess the status of herbicide resistance in rice weeds in the Philippines

Herbicide resistance

The first cases of herbicide resistance in *Echinochloa* spp. to herbicides butachlor, propanil and pretilachlor in the Philippines have been confirmed. The resistance status was tested in multiple populations using the testing capacity and procedures established at PhilRice. There have been major increases in awareness of resistance risks and the capacity to confirm, characterise and communicate further cases.

Weedy rice

Weedy rice is more widespread than previously realised. Weedy rice biotypes surveyed in Nueva Ecija and Iloilo possessed morphologic and agronomic characteristics that were potentially advantageous over cultivated rice in terms of growth and development. Farmers were largely unaware of the potential impact of weedy rices on rice yield, and a poster and brochure (in collaboration with IRRI) were developed and distributed. On-going efforts are required, such as the collaboration with a regional FAO weedy rice initiative.

9.1.4 Objective 4. To develop an economic framework for policy analysis of herbicide resistance and weed management issues in the Philippines and Australia.

The potential public benefit gained through the availability of safe cost-effective herbicides has been demonstrated in results showing the significant positive effect of glyphosate cost on the adoption of erosion-reducing conservation farming practices in Australia (D'Emden et al. 2006). Further, economic analysis focussed on investigating the potential impact of herbicide resistance mobility through weed and pollen movement. There is likely to be reduced incentive for investment in resistance prevention when gaining resistance from a neighbour is likely (as would be common in irrigated rice districts). It will be important to determine actual resistance risks and the economic benefits of preventing herbicide resistance mobility.

9.2 Recommendations

Herbicide resistance

ACIAR should consider funding more work to fully understand the current and future extent of herbicide resistance and the implications. Further research is needed to:

- better understand the mechanism of resistance, its mobility and future risks
- determine herbicide group and IWM recommendations for farmers
- extend testing to other areas and other major weed species in direct-seeded rice
- develop herbicide resistance awareness and management strategies using a participatory approach with farmers.

Further, there could be a need to establish PhilRice testing facilities if warranted by the extent of herbicide resistance, and provide opportunities to further build the human capacity at PhilRice for herbicide resistance screening and management.

Weedy rice

Valuable international research linkages have been initiated in this area with the expectation of future research activities. Potential exists for ACIAR to work with PhilRice in responding to the finding that weedy rice is highly prevalent and potentially a major threat to sustainable direct-seeded rice cropping. One possible response is a national approach to weedy rice management. Research that is needed includes:

- further work to determine the extent and source of weedy rice infestation in the Philippines
- research work on weedy rice (yield loss assessment, invasiveness of weedy rice, seed bank studies, rate of return, longevity, management of weedy rice, etc.)
- testing and applying participatory approaches to develop new farming system options for weedy rice in the Philippines.

Integrated Weed Management

IWM strategies have been shown to be effective and profitable; however there is a need for further work to develop IWM options where water availability and reliability is problematic. It is recommended that efforts be made to incorporate IWM training into broader crop and pest management 'systems' training programs.

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11 Appendixes

11.1 Appendix 1. Baseline survey of rice farm households in Nueva Ecija and Iloilo provinces

PHILIPPINE RICE RESEARCH INSTITUTE
Maligaya, Science City of Muñoz, Nueva Ecija

Ctrl No:
Season/Yr: ______

ACIAR
Australian Centre for International Agricultural Research

BASELINE QUESTIONNAIRE

Name of Respondent: ______________________	Date of Interview:
Relationship to the Sample Farmer: ______________	Interviewer:

A. Farmer Profile

1. **Barangay:**	11. **Membership in Organization**
2. **Municipality:**	*01* Irrigators' association
3. **Province:**	*02* Farmers' association
4. **Name of Farmer:**	*03* Cooperative
5. **Age:**	*04* Others (specify) ______________
6. **Sex:** *01* Male *02* Female	11.1 **Reasons for not joining:**
7. **Household size:**	12. **Rice training (past 3 yrs)**
8. **No. of years residing in the community:**	*01* FFS
9. **No. of years in school:**	*02* IPM
10. **No. of years in rice farming:**	*03* Others (specify) ______________
	12.1 **Reasons for not attending training/s:**

B. Household Profile

13. **Number of household members by age group**

Age group	Number: *Male*	Number: *Female*
less than 1 yr-old	____	____
1-3 yr-old	____	____
4-9 yr-old	____	____
10-15 yr-old	____	____
16-49 yr-old	____	____
50 and above	____	____

14. **Rice consumption per wk (kg)** __________

15. **Sources of rice consumed in a year**

Source	Percent
01 Own production	____
02 Bought	____
03 Others (specify)	____

16. **Sources of Agricultural Income**

Source	Earnings per Month
01 Rice farming	P ________
02 Other crops farming	P ________
03 Livestock/Poultry	P ________
04 Fish	P ________
05 Off-farm	P ________

17. **Sources of Non-Agricultural Income**

Source	Earnings per Month
06 Salaried employment	P ________
07 Self-employment/business	P ________
08 OCW remittances	P ________
09 Others (specify)	P ________

18. **Total farm area (ha)** ________

	Hectares
18.1 **Rice farm**	
01 Lowland irrigated	________
02 Lowland rainfed	________
03 Upland	________
18.2 **Other farms not planted with rice**	
04 Annual crops	________
05 Perennial crops	________

19. **Tenurial status**

	Hectares
01 owner	________
02 amortizing owner	________
03 renter/lessee	________
04 mortgage owner	________
05 tenant/shareholder	________
06 Others (specify)	________

20. **Labor participation of household members in farming**

Household Member	Number	Activity: Rice	Other Crops	Livestock/Poultry	Fish	Off-farm
19.1 Husband		*01*	*02*	*03*	*04*	*05*
19.2 Wife		*01*	*02*	*03*	*04*	*05*
19.3 less than 15 yr-old children	____	*01*	*02*	*03*	*04*	*05*
19.4 15 to 20 yr-old children	____	*01*	*02*	*03*	*04*	*05*
19.5 21 and above children	____	*01*	*02*	*03*	*04*	*05*
19.6 Other adult relatives	____	*01*	*02*	*03*	*04*	*05*

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C. Farming Profile

21. Road structure from farm to market
01 concrete 03 gravel 05 trail
02 asphalt 04 earth 06 water

22. Distance of market from farm (km): ______

23. Rice Farm Financing
23.1 Source of farm financing
01 borrowed 02 own 03 both
23.2 If both, percent by source
___% borrowed ___%own
23.3 If borrowed, from whom and interest rate:

Source	Amt. Borrowed	%/mo
01 bank	____	____
02 cooperative	____	____
03 input dealer	____	____
04 trader	____	____
05 relatives/friends	____	____
06 Others (specify) ______	____	____

23.4 In what forms were your credit availed?
01 cash 02 pesticides
03 fertilizer 04 seeds
05 others (specify) ________

24. Sources of farm inputs
01 coop
02 input dealer
03 traders
04 government

25. Sources of seeds
01 coop
02 seed grower
03 traders
04 government
05 own/exchange

26. Cropping pattern (lowland irrigated)

	Crop	Planting Date: Earliest (Wk/Mo)	Planting Date: Latest (Wk/Mo)
1st			
2nd			
3rd			

27. Irrigation Facilities (lowland irrigated)

27.1 Type	27.2 Source	27.3 Condition
01 NIS	01 canal	01 Good
02 CIS	02 deepwell	02 Average
03 private	03 shallow tube well	03 Poor
	04 open well	
	05 river/stream	
	06 spring	

28. Soil type
01 light 02 medium 03 heavy

29. Problems in rice farming
29.1 Insects
01 leafhopper
02 stem borer
03 black bug
04 rice bug
05 army worm
06 others (specify) ________
29.2 Diseases
01 tungro
02 bacterial leaf blight
03 blast
04 others (specify) ________
29.3 Other pests
01 Rats 03 others (specify) ________
02 Golden snail
29.4 Weeds
01 light (infestation: 10% and below)
02 moderate (between 10 and 50% infestation)
03 severe (50% and above infestation)
29.5 Soil/Nutrient
01 Zinc
02 Saline
03 others (specify) ________
29.6 Irrigation water — *Problem Months*
01 Insufficient ________
02 Average ________
03 Excessive ________

30. Rice varieties preferred for planting
30.1 Preferred variety
30.2 Reason of preference
01 High yielding 06 Nonlodging
02 Resistant to pest/diseases 07 Commands better price
03 High tillering ability 08 Easy to harvest
04 Early maturing 09 Good eating quality
05 Short stature 10 Others (specify) ________

31. Total irrigated planted to rice (in hectares) during the last season? ________

32. Method of crop establishment
32.1 Wet Season 01 *Direct seeded* 02 *Transplanted*
32.2 Dry Season 01 *Direct seeded* 02 *Transplanted*

33. Month Planted ________

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D. Material Inputs

Area Planted:______________ Dry / Wet Season CY____________

ITEM	Variety	Quantity	Unit	Weight/Volume per unit [1]	Price per unit (Pesos)	Transport cost (per bag)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
34. Seeds/Planting Materials						
01 Purchased						
02 Own produce						
03 Received from others						
35. Seed Classification 01 Registered 02 Certified seeds 03 Good seeds 04 Farmer's seeds 05 Hybrid						
36. Fertilizers						
36.1 Inorganic						
01 Urea (45-0-0)						
02 Urea (46-0-0)						
03 Ammonium sulfate (21-0-0)						
04 Ammonium phospate (16-20-0)						
05 Complete (14-14-14)						
06 Complete (16-16-16)						
07 Others (specify)						
1.						
2.						
36.2 Organic						
01 Farm residues						
02 Guano						
03 Sagana 100						
04 Others (specify) ________						
37. Farm Chemicals						
37.1 Insecticide (specify)						
1.						
2.						
3.						
4.						
37.2 Weedicide/Herbicide						
1.						
2.						
3						
37.3 Rodenticide						
1.						
2.						
37.4 Fungicide						
1.						
2.						
37.5 Molluscicide						
1.						
2.						
38. Fuel & Oil						
01 Gasoline						
02 Diesel						
03 Oil						
39. Other inputs						
1. Sacks						
2. Twine						
3. Others (specify) ________						

[1] Example: 1liter/bottle
50 kg/sack

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E. Labor Requirements

Area Planted:_____________

Dry / Wet Season CY ____________

FARM OPERATION	TIMING (DBS/ DAS)	WORKER CODE [a]	OPERATOR, FAMILY & EXCHANGE				PERMANENT			HIRED LABOR				FOOD COST (P)	FUEL COST (P)
			No. of Workers	No. of Days	Ave. No. of hrs/day	Prev. Wage Rate (P) [b]	No. of Workers	No. of Days	Ave. No. of hrs/day	No. of Workers	No. of Days	Ave. No. of hrs/day	Total Payment (P)		
(1)		(2)		(3)	(4)	(5)				(12)	(13)	(14)	(15)		(16)
40. **Seedbed preparation**															
41. **Seed Sowing**															
42. **Seedling Care and Maintenance**															
43. **Land Preparation**															
43.1 Plowing															
43.2 Harrowing															
43.3 Rotavating															
43.4 Levelling															
43.5 Cleaning and repair of dikes															
44. **Planting/Transplanting**															
44.1 Pulling of seedlings															
44.2 Transplanting/Direct Seeding															
44.3 Irrigation/watering															
45. **Fertilizer Application**															
1st															
2nd															
3rd															
46. **Herbicide Application**															
1st															
2nd															
47. **Insecticide/fungicide/molluscide/ rodenticide application**															
1st															
2nd															
3rd															
4th															
48. **Weeding**															
1st															
2nd															
3rd															
49. **Field Monitoring/IPM**															
50. **Harvesting**															
51. **Threshing**															
52. **Cleaning/Drying**															
53. **Hauling**															

[a] O- Operator, F - Family, E - Exchange

[b] indicate prevailing wage rate per day in the locality (for imputation purposes)

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F. Other Rice Production Expenses

Area Planted:________________ Dry / Wet Season CY ________________

ITEM	CASH PAYMENT (P/season)	PAID IN KIND (Quantity/season)		
		No. of Sacks	Kg/Sack	Equivalent Value
(1)	(2)	(3)	(4)	(5)
54. Rental fee				
01 Tractor				
02 Turtle				
03 Thresher				
04 Animal				
05 Drying Pavement/Mechanical Dryer				
55. Interest payment of crop loan				
56. Land rent/share (if lessee or tenant)				
57. Irrigation fee				
58. Others (specify)				
1.				
2.				

G. Rice Production and Disposal

ITEM	QUANTITY (kg)	Price (P/kg)
59. Total amount harvested		
60. Harvester's share		
61. Thresher's share		
62. Landlord's share/amortization fee		
63. Paid to creditor		
64. Paid to hired laborer (maintainer)		
65. Operator's share		
66. Kept for home consumption		
67. Kept for seeds		
68. Given away		
69. Sold		
70. Price of palay		

H. Farm Investments

ITEM (1)			Area/ No. of Units (2)	Acquisition Cost (Peso/unit) (3)	Year Acquired (4)	Repairs/Maintenance (Peso/unit/season) (5)
10.1 Rice farm land owned						
10.2 Work animals	1. Carabao					
	2. Others (Specify)	1.				
		2.				
10.3 Farm buildings and other structures	1. Farm house					
	2. Warehouse					
	3. Others (Specify)	1.				
		2.				
10.4 Farm machinery	1. Two wheel tractor					
	2. Four wheel tractor					
	3. Grain Dryer					
	4. Thresher					
	5. Engine					
	6. Turtle					
	7. Water pump					
	8. Blower/Cleaner					
	9. Others (Specify)	1.				
		2.				
10.5 Farm tools, equipments and other supplies	1. Plow					
	2. Harrow					
	3. Sprayer					
	4. Weeder					
	5. Shovel/Spade					
	6. Bolo					
	7. Scythe					
	8. Hoe					
	9. Spading fork					
	10. Others (Specify)	1.				
		2.				
10.6 Other farm investments (Specify)	1.					
	2.					
	3.					

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I. Other Information

Farmer's Current Farming Problems

81. What are the five most important problems you face in rice farming? *(enumerate)*

Rank	Problem
1	
2	
3	
4	
5	

82. Main types of weeds growing in your rice crops

NOW	5 YEARS AGO
1	1
2	2
3	3
4	4
5	5

82.1 What do you think are the cause/s of changing weeds in your rice crops?

82.2 Given a scale of 1-10 and 10 being the highest, how confident are you in identifying weeds? ________

83. Current weed management practices

83.1 Weed management practices

Practice	Have you used this practice in the past 2 years?		Do you intend to use the practice in your crops next year?	
Dry season crop	**Yes**	**No**	**Yes**	**No**
Direct-seed crop				
Burning stubble from previous crop				
First cultivation only 1 week or less before direct seeding				
First cultivation at least 3 weeks before direct seeding				
At least 2 harrowings following initial cultivation				
Thorough levelling before seeding				
Pre-emergent herbicide application				
Post-emergent herbicide application				
High seeding rate				
Water mgt for weed control				
Manual weeding				
Other weed management strategy- please state:				

84.2. Reason/(s) for choosing the weed management strategy you currently use

1.
2.
3.
4.

84.3. Problems in weed management

1.
2.
3.
4.

84.4 Perceptions about effectiveness of weed management strategies/techniques

a) How do you decide if you need to use weed control management intervention on your crop?

b) If you used the following weed control practices on a typical rice field, how effective do you think it would be in controlling weed?

PRACTICE	Very poor 1	2	3	4	Very Good 5		Easiness rating
First cultivation only 1 week or less before direct seeding, followed by pre-emergent herbicide only							
First cultivation only 1 week or less before direct seeding, followed by pre-emergent herbicide and then post-emergent herbicides as needed							
First cultivation at least 3 weeks before direct seeding, followed by at least 2 harrowings, levelling- no herbicides							
First cultivation at least 3 weeks before direct seeding, followed by at least 2 harrowings, levelling and pre-emergent herbicide							
First cultivation at least 3 weeks before direct seeding, followed by at least 2 harrowings, levelling, pre-emergent herbicide & post-emergent herbicide							

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I. Continuation...

Opinion on herbicide and its applications

85. What do you think of herbicide prices?

01 Expensive 02 Cheap 03 Average

86. Are you planning to use other weed management practices aside from you currently use?

86.1 *If yes, what practices?* ______

86.2 *If no, why not?* ______

87. Herbicide use

87.1 Applications of herbicides **of any type**

	Dry season crop	Wet season crop	3rd crop
a) Ave number of applications now			
b) What do you think this figure was 4 years ago?			
c) What do you think it might be in 4 years time?			

87.2 Applications **of ALS inhibitors and AOPP** (Riestar, Nominee, Drago, Almix, Clincher,etc)

	Dry season crop	Wet season crop	3rd crop
a) Ave number of applications now			
b) What do you think this figure was 4 years ago?			
c) What do you think it might be in 4 years time?			

87.3 Do you have any concerns about the use of herbicides in your farm? 01 Yes 02 No 03 Unsure

If yes or unsure what are those? ______

88. In your opinion, what are the major sources of weeds germinating in your crops?

(Please rank according to importance) Rank

	Rank
Seeds in the ground from previous crops/years	______
Seeds carried in by irrigation water	______
Seeds brought in by animals/people	______
Seeds blown in	______
Seeds brought in by machinery	______
Weed seeds in the crop seeds	______
Other	______

89.1 Do you have access to adequate information about how to control weeds in your rice crops?
(Please mark how you think about your access to information on the scale of 1 to 7)

No access to information	1	2	3	4	5	6	7	Access to enough information

89.2 Contact with information sources about weed management
In the past 12 months, how many times did you talk/attend to the following information sources on weed management?

a) local chemical dealers ______ c) field day on weed management ______

b) agricultural technician ______ d) field day on other rice cropping issues ______

90. Opinions about current and future water availability

90.1 Do you have access to adequate irrigation water in the growing season for the dry season crop?
(Please mark how you think about your access to water irrigation on the scale of 1 to 7)

Very poor access to irrigation	1	2	3	4	5	6	7	Very good access to irrigation

90.2 How do you think your access to irrigation water for the dry season crop will change in the future?
(Please mark how you think about your access to water irrigation on the scale of 1 to 7)

A lot less irrigation will be available	1	2	3	4	5	6	7	A lot more irrigation will be available

91. Seeding rates used for direct seeding

91.1 What will be your average rice seeding rate for the dry season crop this year? ______ kg/ha

91.2 What was your average rice seeding rate about 5 years ago ? ______ kg/ha

If different from 91.1, what is the reason for change? ______

91.3 What do you think it will be in 4 years time? ______ kg/ha

If different from 91.1, what is the reason for the expected change? ______

92. Future farming intentions

92.1 For how many more years do you expect to be working on this farm? ______ years

92.2 Will a member of your family continue farming on this property after you leave or retire? Use the scale below:

Certainty Yes	1	2	3	4	5	6	7	Certainty No

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11.2 Appendix 2. Protocols used for herbicide resistance screening and dose response assays

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11.2.1 Protocol 1. Whole plant assays for early post emergence herbicides (butachlor+propanil and propanil)

A. Screening for resistance

Seedlings are screened using the recommended rate at 1 L/ha or 0.7 kg ai/ha (192 L/ha spray volume) and application time of 6-8 days after seeding (DAS) of butachlor + propanil herbicide.

Size # 10 clay pots, large enough to provide adequate space for uniform growth of the seedlings, are filled with Maligaya clay loam soil (*fine montmorillonitic isohyperthermic Ustic Epiaquerts)* obtained from lowland ricefield at the PhilRice Central Experiment Station. The soil-filled pots are placed in the screenhouse prior to use, watered, and kept moist before transplanting.

The procedure of Valverde et al. (2000) is used in the screening. Seeds of resistant weed species are soaked in water for 24 hours and placed in petri dishes lined with moist filter paper. At 1-2 days after incubation in the petri dishes, when 1 mm of the radicle protruded from the seed coat or one leaf is emerging, the seedlings are transferred to the pot.

Transplanting is usually done late in the afternoon to avoid injury caused by high light intensity. About 5-6 seedlings are transferred to each pot. Pots are placed where there is plenty of bright light but not on full sun to allow normal growth without the soil drying out rapidly. The seedlings are watered and fertilized to encourage healthy and vigorous seedlings until the desired growth stage before herbicide treatments.

At 6 days after transplanting, the plants are thinned to three uniform seedlings per pot. A total of 30 plants at 3 plants per pot (equivalent to 10 replications) of similar size and growth stage (at 2-leaf stage) of each population are selected for herbicide treatment. All plants are treated at 6 days after transplanting (which is about 6 days after emergence). This corresponded to the 6-8 DAS application time for field conditions as recommended in the herbicide label.

A manual hand sprayer is calibrated to deliver 1 ml of water in every pull of the lever and used entirely in the experiment. A 1 m^2 area is measured where the 10 pots for each population are placed for treatment. Two passing of the sprayer on the pots is done for each treatment.

The number of survived seedlings is recorded at 7, 14, and 21 days after treatment (DAT). Percentage survival was calculated based on the formula:

$$\% \text{ survival} = \frac{\text{number of survived seedlings}}{\text{total number of seedlings}} \times 100$$

The experiment is repeated once. Data are presented as average of two experiments.

Populations are classified resistant, developing resistance, or susceptible based on the number of plants that survived in each population (Llewellyn and Powles, 2001). Populations are classified as resistant if more than 20% of the plants survived the herbicide treatment. This is recorded as unaffected and expressed as percentage of the controls. Populations in which 1-20% of the plants survived are classified as developing resistance. Where all plants are killed by the herbicide treatment, the population is classified as susceptible.

B. Dose response assay

The procedure of Valverde et al. (2000) is also followed in the response dose assay of the resistant populations.

Treatments:

T1 – control (no herbicide applied)

T2 – recommended rate (1 L/ha or 0.7 kg ai/ha)

T3 – two times the recommended rate (2 L/ha or 1.4 kg ai/ha)

T4 – four times the recommended rate (4 L/ha or 2.8 kg ai/ha)

The number of survivors are counted three times during a 3-week period (at 7, 14, 21 DAT) where data are expressed as percentage of the controls. Percentage survival is calculated based on the formula:

$$\% \text{ survival} = \frac{\text{number of survived seedlings}}{\text{total number of seedlings}} \times 100$$

All experiments were repeated once. Data are presented as average of two experiments.

A susceptible check is also subjected to response dose assay using butachlor + propanil at the following rates:

T1 – control (no herbicide spray)

T2 – 250 ml/ ha (0.175 kg ai/ha)

T3 – 500 ml/ha (0.350 kg ai/ha)

T4 – 750 ml/ha (0.525 kg ai/ha)

This dose response assay on the susceptible check is done to determine the LD_{50} value of the population. The LD_{50} value is the herbicide rate required to reduce the number of survivors of the population by 50% from the untreated plants. Since all the plants were killed at the recommended rate (1 L/ha) of the herbicide for field application, the lower concentrations of the herbicide were used to enable the plants to survive treatments and determine the LD_{50} value.

11.2.2 Protocol 2. Whole plant assays for pre-emergence herbicides (butachlor, pretilachlor)

The procedure used in the response dose assay for early post emergence herbicides is also used in this protocol with some modifications. The spray volume is also 192 L/ha and the treatments include:

T1 – control (no herbicide applied)

T2 – recommended rate (1 L/ha or 0.6 kg ai/ha)

T3 – two times the recommended rate (2 L/ha or 1.2 kg ai/ha)

T4 – four times the recommended rate (4 L/ha or 2.4 kg ai/ha)

Maligaya clay loam soil is heated at 80-100^{o}C for four hours to kill all weed seeds that may be present in the soil medium allowing only the seeds of the test populations to germinate.

Seeds are soaked for 24 hours before they are sown. There are three seeds in each pot. Treatments are applied at three days after seeding.

The number of germinated and surviving seedlings are counted at 7, 14, and 21 DAT. Data are expressed as percentage of the controls. Percentage survival is calculated based on the formula:

$$\%\ \text{survival} = \frac{\text{number of survived seedlings}}{\text{total number of seeds sown}} \times 100$$

11.2.3 Other protocols/techniques (new trials)

Evolution of resistance from susceptible biotype using whole plant assays through recurrent selections (Neve and Powles 2005a, 2005b).

The procedure covers using low dose herbicide rate and then increase the dose with the progenies. (Experimental set up will follow Protocol 1.) This will provide good background information on how biotypes develop resistance with continuous application of the same herbicide. A known susceptible population of *Echinochloa crusgalli* will be used in the study. Initial herbicide dose will be 100 ml/ha (0.1x of the recommended rate). All survivors will be allowed to mature and seeds will be collected. The succeeding progenies will be subjected to increasing dose of herbicides (200 ml/ha, 400 ml/ha and so on).

Screening of cross- or multiple resistances using whole plant assays but two different herbicides with one experimental set up.

The screening will follow Protocol 1 but will be modified. The procedure follows that to determine the resistance in one biotype, the first herbicide is sprayed and then after the 21-day evaluation period, the shoots of surviving plants are cut to soil level and allowed to regrow to 2-leaf stage and then the second herbicide is sprayed. Then survivors are then determined after 21 days. Essentially, this procedure is a quick screening procedure that allows for the screening of two herbicides with just one plant. This will lessen labor and costs of doing two experimental set ups with the same objective.

Quick tests will cover weeds that emerged/escape after control has been applied at the time of field application (farmers' fields). This quick screening will immediately determine if these surviving weeds are due to resistance or delayed germination.

Weed seedlings (whole plants) are collected from the field and immediately brought to the screenhouse. The roots are cut to only 2 inches and the shoot is also cut to about an inch. The seedlings are planted in size #10 pots previously filled with Maligaya clay loam soil. The seedlings are allowed to regrow until 2-leaf stage for the application of herbicide. Evaluation for survivors will be done at 3 weeks after herbicide treatment.

11.3 Appendix 3. Summary of weed populations tested for herbicide resistance

Species	Place of collection	No. of populations	Herbicides	Remarks
	Nueva Ecija			
E. crusgalli	Rizal	2	but, but+prop, prop, pret*	
	Quezon	1	but, but+prop, prop	
	Sta. Rosa	1	but, but+prop, prop	
	Bongabon	1	but, but+prop, prop	
E. glabrescens	Rizal	2	but, but+prop, prop, pret	only 1 pop'n resistant to pret
	Aliaga	2	but, but+prop, prop, pret	only 1 pop'n resistant to pret
	Munoz	1	but, but+prop, prop	
	Pantabangan	1	But+prop	
	San Jose	1	but+prop	
	Sto. Domingo	1	but+prop	
	Llanera	1	but+prop	
	Cabanatuan	1	but+prop	
	Zaragosa	1	but+prop	
	Jaen	1	but+prop	
	San Isidro	1	but+prop	
	Laur	1	but+prop	developing resistance
	Gabaldon	1	but+prop	developing resistance
	San Leonardo	1	but+prop	
	Penaranda	1	but+prop	
L. chinensis	Aliaga, NE	1	cyhalofop	No resistance
	San Isidro, NE	1	cyhalofop	No resistance
	Quezon, NE	1	cyhalofop	No resistance
I. rugosum	Aliaga, NE	1	bispyribac sodium	No resistance
	Rizal, NE	1	bispyribac sodium	No resistance
	Iloilo			
E. crusgalli	Barotac Nuevo	2	but, but+prop, prop, pret	
	Pototan	2	but, but+prop, prop, pret	
	Dingle	1	but, but+prop, prop	
E. glabrescens	Barotac Nuevo	4	but, but+prop, prop, pret	2 pop'ns resistant to pret
	Pototan	2	but, but+prop, prop	1 developing resistance
	Dingle	2	but, but+prop, prop	
	Ajuy	1	but, but+prop, prop	
	Passi	1	but+prop	
	Banate	1	but+prop	developing resistance
	San Rafael	1	but+prop	
	Lambunao	1	but+prop	
	Janiuay	1	but+prop	
E. glabrescens	Anilao	1	but+prop	
	San Enrique	1	but+prop	
	Cabatuan	1	but+prop	developing resistance
	Dumalag	1	but+prop	developing resistance
	New Lucena	1	but+prop	

Species	Place of collection	No. of populations	Herbicides	Remarks
	Tigbauan	1	but+prop	developing resistance
	Iloilo City	1	but+prop	
	Zarraga	1	but, but+prop, prop	
	Iloilo			
	San Miguel	1	but+prop	
	Pavia	1	but+prop	
	Sta. Barbara	1	but, but+prop, prop	
L. chinensis	Dingle, Iloilo	1	cyhalofop	No resistance/susceptible
	Barotac Nuevo	2	cyhalofop	No resistance
I. rugosum	Dingle, Iloilo	1	bispyribac sodium	No resistance
	Pototan	1	bispyribac sodium	No resistance
TOTAL		62		

but = butachlor; but+prop = butachlor + propanil; prop = propanil; prep = pretilachlor