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1 Acknowledgments

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2 Executive summary

BACKGROUND: Rice is a major field crop of paramount importance for global food security. In Asia, the world's largest and most important rice-producing region, pressure on water resources, increased labour costs, climatic variability and the need to increase cropping intensity have led to major changes from transplanted to direct-seeded rice systems (DSR). However, this increased adoption of more profitable and resource-efficient DSR systems have caused greater weed problems including severe infestation of weedy rice as one of the main constraints to productive DSR systems. The greater availability of herbicide technology has not prevented weedy rice from becoming a serious global constraint of rice production.

This work has aimed to identify the challenges posed by current weedy rice infestation levels in the Philippines and Vietnam, two major Asian rice producers, develop novel solutions for weed management in rice, identify research gaps and support stewardship for the adoption of new technologies (i.e. Clearfield technology) for effective control of weedy rice in Asia.

AIM: In this **small research activity (SRA)** we aimed to:

1) Establish the extent of the weedy rice problems in relevant locations of the Mekong Delta region, Vietnam and in the Philippines.
2) Design and test a novel proof-of-concept approach for safe herbicide control of weedy rice.
3) Review previous ACIAR-funded projects to gain insights into established weed management strategies in Asian rice systems.
4) Organize a workshop involving prominent Asian scientists to capture their views on weed challenges and evolution of rice systems in Asia.

OUTCOMES:

1) Recent surveys in Vietnam and Philippines indicated the urgent need to increase awareness on weedy rice among Asian growers to allow implementation of a number of region-specific effective weed management strategies. We have surveyed three locations Batangas (Luzon), North Cotabato and Sultan Kudarat (Mindanao) in the Philippines (see Appendix 1) and four locations in the Mekong Delta region of Vietnam (districts of Cho Moi, Phu Tan, Thoai Son and Vinh Long) (see Appendix 2). Results confirm that weedy rice and grass weed species cause major problems to rice farmers in both the Philippines and Vietnam. There seem a sufficient level of awareness among surveyed farmers of the damaging effects of weedy rice. As weedy rice and other weeds are a major evolving challenge of DSR systems there is need for continuous monitoring programs. It will be a priority to minimize infestations of weedy rice and other co-evolving weed issues in rice systems in Asia to sustain food production and protect the income of small-hold Asian farmers. Thus, a global dedicated endeavour is required to identify and test for control solutions based on improved understanding of weedy rice biology and physiological and biochemical herbicide-weed interactions.

2) A conceptually novel proof-of-concept method for selective herbicide control of weedy rice was developed and tested under controlled glasshouse conditions at the University of Western Australia. We found that the organo-phosphate insecticide phorate applied to rice seeds can safen and protect rice against the herbicides clomazone or triallate. Thus, with a safener selective herbicide control of weedy rice can be achieved with high doses of clomazone or triallate (not currently registered in rice). This methodology improves the level of control of other weeds as such as *Echinochloa* or *Leptochloa*, identified as major

damaging weeds in the location surveyed in the Philippines and Vietnam. This practice can enable selective weedy rice control without rice damage and call for herbicide discovery programs to identify candidate safener and herbicide combinations to alleviate weed infestations in global rice crops. A paper has been submitted to the international peer-reviewed journal, *Pest Management Science* (see Abstract in Appendix 3).

3) The review of previous ACIAR funded project provided ideas, insights and topics of discussion which were included in the presentation delivered by Roberto Busi in a workshop organized in India in 2015 with prominent Asian and International leading scientists with extensive experience on weed management in rice. Some common themes emerged from the review of those research projects focused on weed management in DSR versus puddle (wet tillage) transplanted rice:
    a. DSR has the potential to reduce irrigation water usage up to 53%;
    b. Weeds and weedy rice infestations confirmed as a major threat to DSR. DSR requires high reliance on herbicides for weed control which can result in rapid evolution of herbicide resistant weeds;
    c. Weed shifts are evident in DSR systems with grass weeds such as *Leptochloa or Echinochloa* or *Cyperus* that can become dominant;
    d. Integrated Weed Management (IWM) shows potential to reduce herbicide usage, minimize weed problems and increase yields and profits;
    e. IWM adoption from farmers not directly involved in a research project is generally low (only 10%).

4) A successful satellite symposium "*The weedy rice threat to food security in Asia: global insights into managemen*t" was organized at the XXV Asian Pacific Weed Science Society (APWSS) Conference, Hyderabad, India, 13 - 16th October, 2015 and a total of 12 expert weed scientists from India, Vietnam, Australia, Malaysia, Philippines, Sri Lanka, Japan, Italy and USA were invited and participated to present their research on weedy rice. Discussions occurred on agronomic challenges, extent of rice weedy rice infestations, biological features of weedy rice and evolution of rice systems in Asia towards an increasing adoption of DSR together with new technologies (i.e. Clearfield™ vs. Provisia™ herbicide tolerant rice varieties). A summary was written and published in the newsletter of APWSS (see Appendix 4). Another multi-author abstract was written, submitted and accepted as key note oral presentation at the upcoming International Weed Science Society Congress (Prague, Czech Republic, 19-24th June 2016) (see Appendix 5).

5) In synergy with the ACIAR investment, a successful Crawford Fund grant has allowed a scientific collaborator from Vietnam, Dr Nghia, to spend 2 months of intensive training at the Australian Herbicide Resistance Initiative and conduct research. These activities undertaken at UWA allowed the candidate to gain valuable knowledge in weed science research (i.e. specific methodologies on geographical surveys, seed germination test, herbicide efficacy tests, herbicide dose-response statistical analysis). This improved knowledge will help Dr Nghia, via extension centres in the Mekong Delta, to raise awareness in rice farmers and local agronomists in Vietnam of the damaging effects of weedy rice, the threat of herbicide resistance in rice weeds and illustrate possible future options for effective weed control in rice.

CONCLUSIONS: This study confirms that weedy rice is a widespread problem in surveyed geographical areas of the Philippines and in the Mekong Delta in Vietnam. Our work calls for collaborative efforts between the private and the public sector to identify candidate safener and herbicide combinations to achieve herbicidal weedy rice control and alleviate weed infestations in global rice crops. The Crawford Fund has contributed to training and capacity building in Vietnam providing fundamental knowledge in weed science research that will foster future research collaborations between the University of Western Australia, University of Queensland and Cantho University on sustainable rice production systems in Asia. Thus, we envisage future collaborations in multi-year research projects mutually beneficial to Australia and Asia to raise awareness of weed challenges in relevant Asian and Australian cropping regions, discover novel solutions to major weed problems and promote stewardship in weed management practices. Our work will aim towards greater productivity, profitability and sustainability, contribute to economic growth of those regions, help Asian smallholder vs Australian profit-oriented farmers to sustainable agricultural production and foster overall resilience in agriculture in Asia and Australia promoting climate change adaptation.

3 Introduction

It is universally acknowledged that rice is the world's most important food source and staple food for more than half of the world population. Asia is the world's largest rice-producing region (approx. 134 million hectares in Asia of a total of 153 million hectares globally). Pressure on water resources, increased labour costs, agricultural system intensification and urbanization have led to a major change from transplanted to direct-seeded rice (DSR). DSR offers many advantages, however, weeds, including weedy rice are the main constraint to productive DSR systems. Weedy rices are unwanted plants of *Oryza sativa* that compete with rice. Weedy rice increases production costs and reduces growers' profit through yield reduction. The major traits of weedy rice are early shattering of the grain and variable seed dormancy (Azmi and Karim, 2008; Delouche *et al*, 2007b). In Asia, weedy rice infestations are increasingly reported in DSR systems in different countries including Malaysia, Sri Lanka, Thailand, India, Korea, Philippines and Vietnam (Table 1).

Table 1. Rice area (M ha) in selected Asian countries, Europe and USA, adoption of direct-seeded rice and year of first detection of weedy rice.

Country	Rice ha (10^6)	DSR (%)	Weedy rice
China	30	10	1960s
India	44	30	1997
Indonesia	12	20	
Japan	1.6	1.6	2003
Malaysia	0.7	70	1987
Philippines	4.5	40	1991
Sri Lanka	0.9	80	1992
Thailand	10	35	2001
Vietnam	8	50	1994
EU	0.6	100	Early 1900
USA	1.4	100	1846

(Adapted from Gealy et al, 2015; Gressel and Valverde, 2009; Matloob et al, 2014; Rao et al, 2007; Vidotto and Ferrero, 2005).

The weedy rice challenge in Asia

Weedy rices are broadly defined as plants from the genus *Oryza* that mimic, infest and compete with rice (Delouche *et al*, 2007a). Weedy rice is reported as a serious pest of DSR systems. Weedy rice can spread rapidly, is highly competitive and can dramatically reduce rice yield and quality (Fischer and Ramirez, 1993). The particular problem is that seeds of weedy rice species mature and shatter before rice, injecting large seed numbers into the soil seedbank which will perpetuate the infestations in the following growing seasons. The shift to DSR accompanied by widespread, often exclusive, use of herbicides for weed control in rice can rapidly result in major problems with weedy *Oryza* species. Due to many morphological and physiological similarities between weedy rice and rice plants, the control of weedy rice is a difficult and complex long term endeavour.

In India, awareness about the problem amongst farmers and management of weedy rice are the major concerns as Indian growers tend to categorize weedy rice as harmless 'off-types' and manage it by occasional manual rouging of panicles only. Farmers tend to abandon rice cultivation once fields are heavily infested with weedy rice. With no selective herbicide available, land preparation practices are the sole method of its management. In a recent survey in Vietnam, weedy rice infestation was the worst problem encountered in wet direct-seeded rice; however, most growers were aware of the presence of weedy rice in their fields and the damage it does to the crop (Chauhan *et al*, 2015). In a previous survey in the Philippines, about 40% of the growers did not know that seeds of weedy rice have dormancy (Tanzo *et al*, 2013). In the same survey, cutting the weedy rice panicles at harvest was practiced by a majority of the respondents (82%). Both of these studies suggested a need to increase awareness about weedy rice among Asian growers. In this study we conducted surveys in regions of the Philippines and Vietnam know to be infested by weedy rice and quantified such infestations and assessed the perceptions and farmers' knowledge on this damaging weed.

As the use of contaminated crop seed is primarily contributing to the spread of weedy rice we aimed to survey the extent of saved seed used by local farmers for the subsequent crop and also quantified the contamination levels from weedy rice of these seed stocks.

Can we reduce the negative impact of weedy rice in Asia?

Weedy rice control tactics are based on multiple tactics embracing combinations of preventative, cultural, mechanical, chemical and genetic tools. In the face of the threat to rice production from weedy rice issues with DSR systems a number of management strategies have been established to be effective in rice ecosystems in the America's and Europe.

One of the most convincing method for weedy rice management is the prevention of its further spread. For example, those strategies have been deployed in Californian rice monoculture where weedy rice, accidentally introduced through contaminated seed, has been almost eradicated by the combination of water-seeding and the use of certified crop seed free of weedy rice seed (Fischer, 1999).

Pre-plant herbicides generally provide effective weed control of a major proportion of the soil weed seed bank. However, despite the greater availability of herbicides, weedy rice is difficult to eradicate with herbicidal strategies and thus remains a serious global constraint. Post-emergence weedy rice control can be achieved with the use of herbicide-tolerant rice varieties otherwise selective in-crop control of weedy rice with post-emergence herbicide would be extremely difficult as rice and weedy rice respond identically to herbicides.

There are potential innovative solutions to achieve safe and selective weedy rice control in rice crops by strategic and sequential application of the two components (the herbicide active ingredient + a herbicide safener) of commercially available herbicide formulations. Some herbicides can be toxic to germinating rice seedlings unless a specific herbicide safener is mixed with the herbicide compound in commercially available formulated products. Thus, we hypothesized that the dissociated use of herbicide and specific safener could allow effective weedy rice control without causing injury to the rice crop (see also Shen *et al*, 2013). We hypothesize little damage or mortality in rice seeds exposed to the safener versus significant phyto-toxicity and mortality in rice seeds treated with the herbicide only. Thus, we tested whether the use of a safener applied directly to rice crop seeds before seeding could safen germinating rice seedlings against a herbicide applied post-seeding pre-emergence. The herbicide would be lethal to germinating weedy rice seedlings but not to safened rice seedlings. Here, we present the results of this proof of concept study.

Minimizing the negative impact of weedy rice, would significantly contribute to more profitable and sustainable rice cultivation in Asia. Thus, we envisaged the organization of a ‘weedy rice workshop’ with prominent Asian rice weed scientists to collects their views and opinions on the rising challenges of weedy rice following adoption of DSR and issues related to cultivation of imidazolinone-resistant varieties in Asia and worldwide. The workshop focused on topical issues of rapidly changing rice systems thourghout Asia, established preventative/management strategies (e.g. use of clean seed, herbicides currently used, use of machinery, farm hygiene) and recent introduction of herbicide-related technologies in some Asian countries (eg Clearfield or Provisia herbicide-tolerant rice varieties).

4 Methodology

1. **Establish the extent of the weedy rice problems in localities of the Southern Mekong Delta region in Vietnam and the North (Luzon) and South Island (Mindanao) in the Philippines by surveying contamination levels of saved crop seed and determine the current practice adopted by local farmers to mitigate the problem.**

In 2015 surveys were conducted during the dry season in three different locations of Batangas (Luzon island), North Cotabato and Sultan Kudarat (Mindanao island) in the Philippines (see Appendix 1) and in four districts of the Mekong Delta region in Vietnam (districts of Cho Moi, Phu Tan, Thoai Son and Vinh Long). A survey questionnaire was developed and pretested in previous survey studies in the same countries [Tanzo, I. R., et al. (2013); Chauhan, B. S., et al. (2015)]. The survey aimed at obtaining information on social characteristics and farm types, farmers' cultural and farm management practices such as the use of DSR, seedling establishment, land preparation, irrigation, general crop management (eg fertilizer and pesticide usage). We also developed a series of weedy rice focused questions to understand farmers' perceptions of weedy rice infestations on their farms, control options and crop and weed management tactics adopted by farmers.

In the Philippines the surveys were conducted on the most affected villages and the results were collated in a total of 33 tables including socio-demographic profile of respondents, distribution of area affected by weedy rice (%), distribution of the number of weedy rice density (plants / m^2), duration of land preparation, harvesting/threshing method, common rice varieties, seed classes, seed sources, seeding rate, method of crop establishement, herbicide use, yield, weedy rice characteristics, weedy rice control and management, weedy rice features (true/false choices), cost of weedy rice control operations and cropping year in which weedy rice was first noticed as a major problem (Appendix 1).

In Vietnam the survey questionnaires included similar aspects and the results were collected in a total of 19 tables (Appendix 2). Overall we investigated the socio-economic profile of respondent farmers and farm characteristics, reasons for direct-seeded rice adoption, rice varieties, crop seeding rate, types and source of rice crop seed, practices of seed treatment, varieties, crop nutrition and fertilizer rates, water and field leveling management, crop pests and disease, attributes and characteristics of weedy rice, weedy rice control and management, dominant weed species, herbicide knowledge and use, damage caused by weedy rice, gross return, costs and farm profit. Frequency values are expressed as percentages.

We surveyed the proportion of farmers in the Philippines and Vietnam that used their own seed to establish the following crop. We collected 500 g rice seed samples and separated the off-types rice seeds based on seed morphology and color (i.e. pigmented hulls, awned, etc.). Those rice seeds with particular morphological characteristics (putatively weedy rice) were separated and quantified before being de-hulled. The proportion of those off-type de-hulled seeds were visually inspected and separated into different types. We considerered weedy rice only as the proportions of seeds that had pigmented pericarp (on average 1% of the proportion of seeds with distinct morphological characteristics), whereas seeds with normal pericarp were not considered weedy rice contaminants.

2. **Design and test a novel proof-of-concept approach for simple herbicide control of weedy rice.**

Dose-response studies with the herbicides clomazone and triallate

In this study a medium grain Australian rice variety (Reiziq) and a population of the globally distributed grass weed Echinochloa colona (L.) Link collected in Western

Australia (Goh *et al*, 2016) were subjected to herbicide dose-response assays. Plants were grown during the Australian summer season (December – February) in a glasshouse environment with warm temperatures ranging from 16C (night) – 32C (day) and mean temperatures 18C (night) – 25C (day). Rice seeds were imbibed and pre-germinated on solidified 0.6% (w/v) agar medium for three days and planted at the eruption of the primordial root at 0.5 cm depth in 17 cm-diameter pots in commercial potting soil (50% peat, 25% sand and 25% pine bark). Fifteen rice seeds were placed in each individual pot. The pots were treated immediately after seed transplanting with 0, 125, 250, 500, 750, 1,000 and 2,000 g ha^{-1} of either clomazone (2-[(2-chlorophenyl)methyl]-4,4-dimethyl-1,2-oxazolidin-3-one; Command, 48% clomazone, FMC, PO BOX 526, Cannon Hill QLD 4170) or triallate [S-(2,3,3-trichloroprop-2-enyl) N,N-di(propan-2-yl)carbamothioate, Avadex Xtra, 50% triallate, Nufarm 103-105 Pipe Road Laverton, North, Victoria 3026]. The clomazone recommended label dose for rice ranges between 240 and 290 g ha^{-1}, whereas the labelled dose of triallate is between 800 and 1500 g ha^{-1} depending on target weeds. The putative safener, the insecticide phorate (diethoxy-(ethylsulfanylmethylsulfanyl)-sulfanylidene-l(5)-phosphane; Thimet, Barmac Industries, 82 Christensen Road, Stapylton QLD 4207, Queensland), was applied to the soil surface at 0.1 g per pot corresponding to 10 kg phorate a.i. ha-1 just prior to the herbicide treatments (treatment “Soil 10” versus no phorate “Seed 0” indicating herbicide treatments only), or added with the germinating rice seeds on agar via a 10mL aqueous solution at rates of a) 0.66% wt/wt phorate/rice seed (treatment “Seed 5” corresponding to 5 kg phorate ha-1 at a seeding rate of 150kg rice seed ha-1) b) 1.3% wt/wt (treatment “Seed 10” corresponding to 10 kg phorate ha-1) c) 2.0 % (treatment “Seed 15” corresponding to 15 kg phorate ha-1) or d) 2.66% (treatment “Seed 20” corresponding to 20 kg phorate ha-1). Plants were grown in optimal conditions and regularly watered to achieve >90% field capacity. There were four replicated pots per herbicide dose and the individual pot represented the experimental unit. Approximately 33 *E. colona* seeds in admixture with 5 rice seeds were scattered in 17cm-pots prior to herbicide application to understand whether the rice seeds imbibed with the highest tested phorate dose (20 kg ha^{-1}) could potentially lower the herbicide efficacy on weeds (i.e preventing the bioactivation of the herbicide clomazone or triallate). There were three replicated pots per herbicide dose and the individual pot represented the experimental unit. Following appropriate statistical investigation LD50 and GR50 values were estimated allowing calculation of a Crop Selectivity Index (CSI) comparing dose – response curves in the presence relative to dose – responses in the absence of phorate (e.g. CSI = ratio between LD50 values for “Seed 10” / LD50 for “Seed 0” responses).

3. Review previous ACIAR projects focused on rice systems to gain insights into established weed management strategies.

We conducted a review of ACIAR-funded projects that supported research on rice systems in Asia and summarized relevant outcomes and results in the introductory presentation of the satellite symposium focused on weedy rice. Eight previous ACIAR-were considered funded projects including:

-Three annual reports:

- (Diversification and intensification of rice-based cropping systems in lower Myanmar - SMCN/2011/046;
- Climate Change Affecting Land Use in the Mekong Delta: Adaptation of Rice-based Cropping Systems (CLUES): SMCN/2009/021);
- Improved irrigation water management to increase rice productivity in Cambodia: LWR/2009/046;

-Four final reports:

- Herbicide use strategies and weed management options in Filipino and Australian cropping focused on rice systems to gain insights into established weed management strategies: SMCN/2003/011;

- Zero-tillage rice establishment and crop-weed dynamics in rice and wheat cropping systems in India and Australia: CSE/2004/033;
- Growing More Rice with Less Water: Increasing Water Productivity In Rice-based Systems: LWR/2000/030;
- Increased productivity of rice-based cropping systems in Lao PDR: CSE/2006/041;

-One literature review:

- Agriculture, Irrigation and Poverty Reduction in Cambodia: Policy narratives and Ground realities compared (2013).

4. Organize a workshop involving prominent Asian scientists to capture their views on rice weed issues and evolution of rice systems

A successful satellite symposium "*The weedy rice threat to food security in Asia: global insights into managemen*t" was organized at the XXV Asian Pacific Weed Science Society (APWSS) Conference, Hyderabad, India, 13 - 16th October, 2015 and a total of 12 expert weed scientists from India, Vietnam, Australia, Malaysia, Philippines, Sri Lanka, Japan, Italy and USA were invited and participated to present their research work on weedy rice. Nine extended abstracts were published in the APWSS Conference Proceedings (Vol. 2, pp. 4 – 15; accessed on-line on May 30th 2016 at http://apwss.org/apwss-publications.htm). A workshop summary was written to collect expert opinions of Asian rice weed scientists and raise awareness of rice weed issues to relevant stakeholders and farmers.

5 Objectives or terms of reference

1) Establish the extent of the weedy rice problem weeds in relevant rice systems, quantify levels of rice crop seed contamination and determine the constraints to adoption by farmers of mitigating practices.

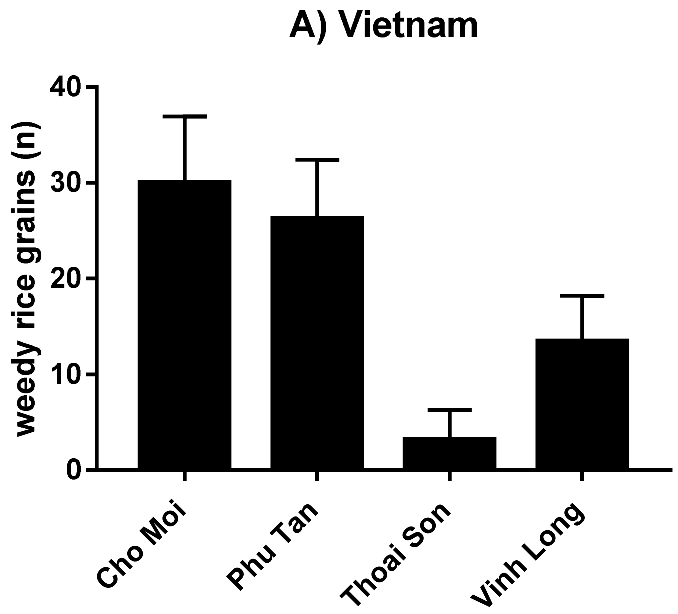
A total of 211 farmers in the Philippines and 124 in Vietnam were randomly selected and interviewed by experienced and trained personnel. DSR was adopted by the great majority (generally >90%) of the farmers in the Philippines, especially in the two locations of Mindanao, and in the Mekong Delta region of Vietnam. in Vietnam the most important reason to adopt DSR relates to time constraints to establish the crop by tranplanting, greater costs of transplanting and diminished labour availabilty. By contrast, in the location of Luzon (Philippines) a good proportion of farmers (>50%) continue to establish crops by manually transplanting rice seedlings. In Batangas weedy rice was first noticed as a significant problem in the year 2000 and this may have in part influenced the choices of crop establishment to minimize subsequent weedy rice infestations. Weedy rice appears to be an expanding problem in North Cotabato and Sultan Kudarat, the two surveyed localities of the southern island Mindanao. Approximately 70% of interviewed farmers noticed weedy rice presence in their farms between 2013 and 2015. In these two locations the survey reveals high level of DSR adoption and also high level of mechanisation at harvest in Sultan Kudarat. Our survey reveals that in the Philippines at least 35% of farmers have weedy rice infesting 10-30% of their farms at densities up to 20 plants / m^2 in both rice growing seasons.

In both countries the majority of farmers are aware of the presence of weedy rice in their farms and also they have sufficient knowledge of the biological characteristics of weedy rice (eg plant height, early maturity and shattering, awns and colored pericarp). Importantly farmers understand the damaging effects of weedy rice to the rice crop and the adoption of DSR can lead to more severe weedy rice infestations. Sometimes it appeared that a wrong perception of farmers on weedy rice could be influenced by the operator conducting the survey. Thus, there is scope to correct wrong farmer perceptions on weedy rice with extension, training and field day demonstrations.
In both countries weedy rice is ranked among the dominant and most damaging weeds together with globally distributed grass weeds such as *Echinochloa* spp., *Leptochloa* spp. and sedges such as *Cyperus* spp. In the Philippines the mean cost of weeding remains low (approx 1%) but rice yield in the presence of weedy rice infestations can be reduced of 20% with subsequent impact on household budget. In both countries the survey confirms there is the widespread adoption of herbicides for weed control but there is greater reliance on pre-emergence herbicide with a limited number of herbicide modes of action which could lead to selection for resistant populations. Hand weeding and panicle cutting to minimize weedy rice infestations remain important control tools for weedy rice in both countries.

One of the most imoprtant and effective management measures for weedy rice is to prevent the accidental or recurrent introduction of weedy rice in farmers' fields. Thus, we surveyed the portion of farmers in the Philippines and Vietnam using saved seed to establish the next crop and quantified the weed contaminations levels. With some variablity depending on the geographical area surveyed, a large proportion of Filipino and Vietnamese farmers used saved crop seed to establish the following rice crops. In 500g samples of saved rice seed we have identified rice grains with pigmented hulls or distinct morphological features such as presence of awns indicating presence of putative weedy rice seeds. The quantified levels of rice grains with pigmented hulls contaminating saved rice crop seed samples was high and equal to 5% and 9% in the Philippines and Vietnam, respectively. Those off-types were separted from the more uniform crop type and subjected to further inpections. After these pigmented seeds were de-hulled an average 85% of those grains had normal pericarp and only 1% pigmented pericarp. Thus, consistently with an extensive literature indicating red pericarp for the majority of weedy rices, we classified weedy rice contaminants only those seeds with both pigmented hulls and pericap (Figure 1). In the seed samples collected in the Philippines, the local trained rice experts found up to five off-type rice seeds and suggested those were morphological variants of weedy rice. Sometimes up to five weedy rice types were contaminating a single sample of saved rice seed.

Thus, there is much scope to continue this work to define more accurately the morphological variability in local rice germplasm. A more accurate characterization of the local rice varieties and the definition of morphological variabilty of weedy rice types can help understand how to exploit those morphological characteristics of weedy rice (eg presence / absence of awns) to 1) educate farmers to identify weedy rice features and 2) define potential methods to remove mechanically awned weedy rice from saved rice crop seeds.

In DSR, hand-weeding operations of weedy rice are much less efficient because it is nearly impossible to distinguish weedy rice from rice at the seedling stage. As a result weedy rice, a de-domesticated competitive form of rice is becoming an acute problem in Asia. In Vietnam recent surveys indicate weedy rice can cause up to 70% yield loss in the most severely infested rice fields (Chin and Thi 2010). Our survey corroborates this result and suggests farmers are facing a significant weedy rice problem infesting their crops. There is a urgent need to conduct awareness campaigns to educate farmers about the risk of further spreading weedy rice in new fields and how to minimize weedy rice infestations to sustain an increased rice yield. Follow-up research should establish the long term benefits of using certified seeds not contaminated with weedy rice seeds to minimize weedy rice infestations.



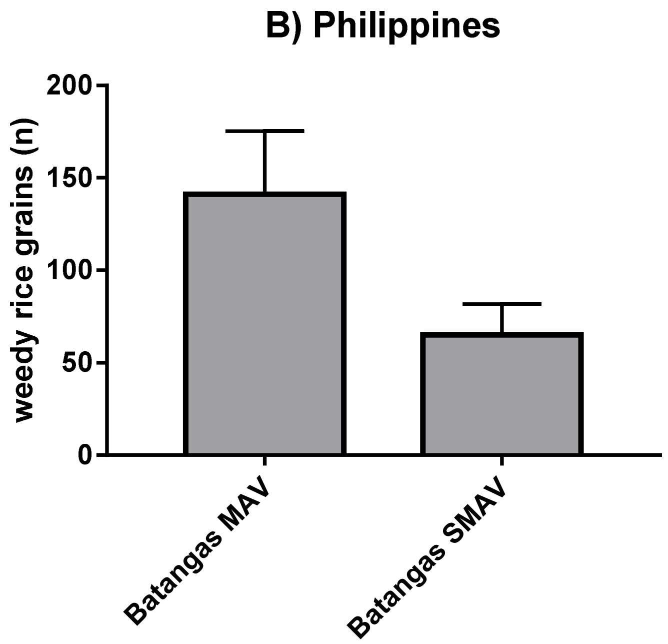


Figure 1. Number of (weedy) rice seeds with pigmented hulls and pericarp found in 500g of rice crop saved seed. Seed samples were collected from farmers' household during the 2015/16 survey in different locations of A) Vietnam and B) Philippines. MAV = most affected village SMAV = second most affected village.

2) Design and assess novel technologies for weedy rice control in rice crops.

In this study we have developed a proof-of-concept methodology by applying a safener to rice seeds to protect rice plants against a herbicide lethal to weedy rice thus, enabling selective weedy rice control in a rice field.

Weedy rice is one of the most damaging global weeds and a major threat of DSR systems. Rice response to a range of clomazone or triallate doses in combination with phorate applied to rice seeds or to the soil surface is shown in Figure 2 and Figure 3, respectively. The level of clomazone or triallate control of the major weed *Echinochloa colona* in the presence of phorate-treated versus phorate-untreated rice seeds is displayed in Figure 4.

Clomazone is used as a global rice herbicide for weed control, but only effective against weedy rice at high dosages (Figure 1). Here, we report protection of rice against clomazone by treatment of rice seed with the organo-phosphate insecticide phorate. Thus the phorate is acting as a safener to the rice seed against injury from the subsequent herbicide treatment. Similarly, substantial weedy rice control was achieved with triallate plus phorate with minimal rice damage (Figure 2). To the best of our knowledge such selective herbicide control of weedy rice in rice crops (herbicide ± safener) has very rarely been achieved in commercial rice crops. In one study, Shen et al. (2013) showed that the safener fenclorim applied to rice seeds followed by pre-emergence application of the chloroacetamide herbicide pretilachlor achieve selective control of weedy rice in rice crops. However, subsequent commercial and large-scale field validation research has not been reported. Here, we attempted to calibrate an effective dose of phorate to be applied as herbicide safener to rice crop seeds prior to crop seeding and identify the most discriminative herbicide dose applied in pre-emergence post seeding to enable rice crop safening and effective weedy rice control. Therefore, our demonstration of phorate safening of rice is a “proof of concept” of a rice safener enabling selective herbicidal control of weedy rice infesting rice crops. A chemical discovery program could identify rice safeners considerably more effective than phorate and with a more suitable toxicological profile. Research is warranted to explore the potential for herbicide and rice safeners to provide selective weedy rice control in rice field crops.

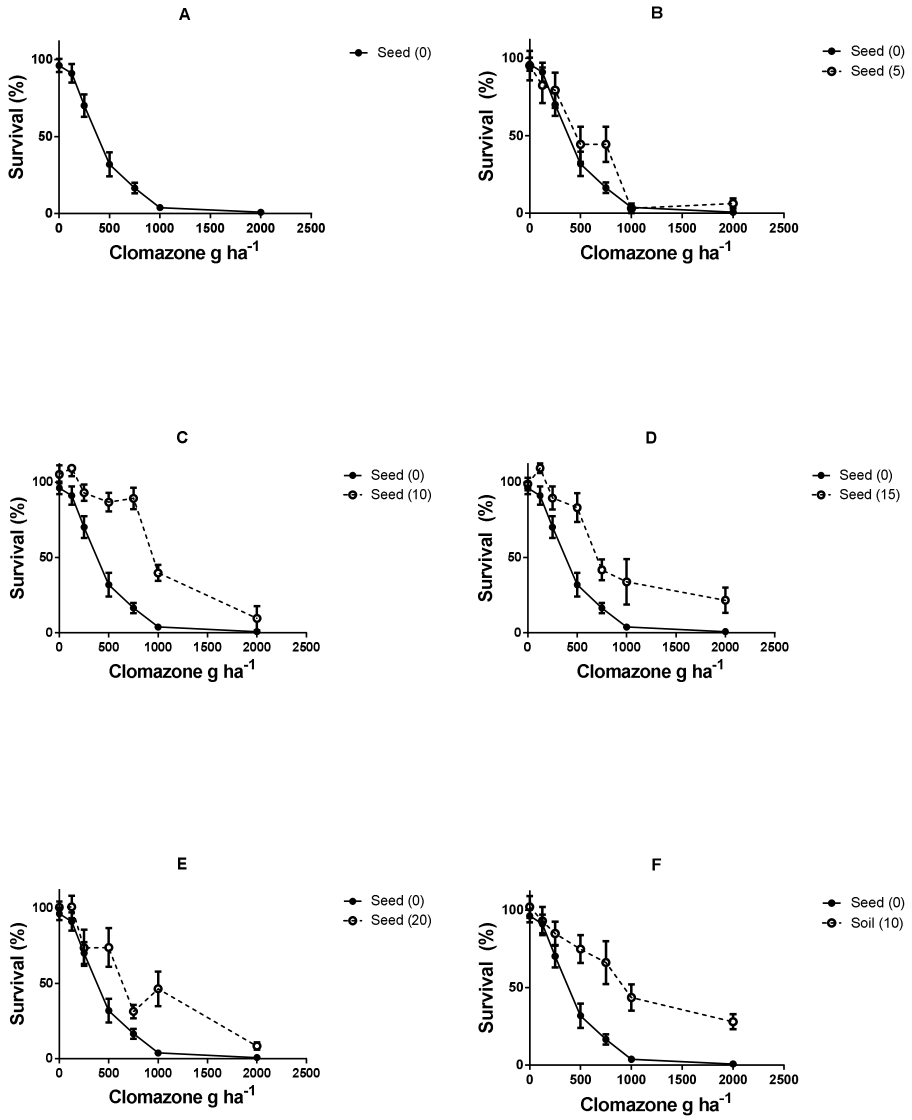


Figure 2. Mean plant survival (emergence as % of untreated control) ± standard errors in clomazone dose-response of rice plants. A) Filled circles and solid lines refer to clomazone dose-response alone with seeds not previously exposed to phorate (Seed 0); B) open circles and dashed line refer to clomazone dose-response with seed treated with 5 kg phorate ha^{-1} (Seed 5); C) open circles and dashed line refer to clomazone dose-response with seed treated with 10 kg phorate ha^{-1} (Seed 10); open squares and dashed line refer to clomazone dose-response with seed treated with 15 kg phorate ha^{-1} (Seed 15); open squares and dashed line refer to clomazone dose-response with seed treated with 20 kg phorate ha^{-1} (Seed 20); open squares and dashed line refer to clomazone dose-response with untreated seed and phorate at 10 kg phorate ha^{-1} applied to the soil surface of pots prior to triallate treatments (Soil 10); Symbols are observed means ± SE (n = 12).

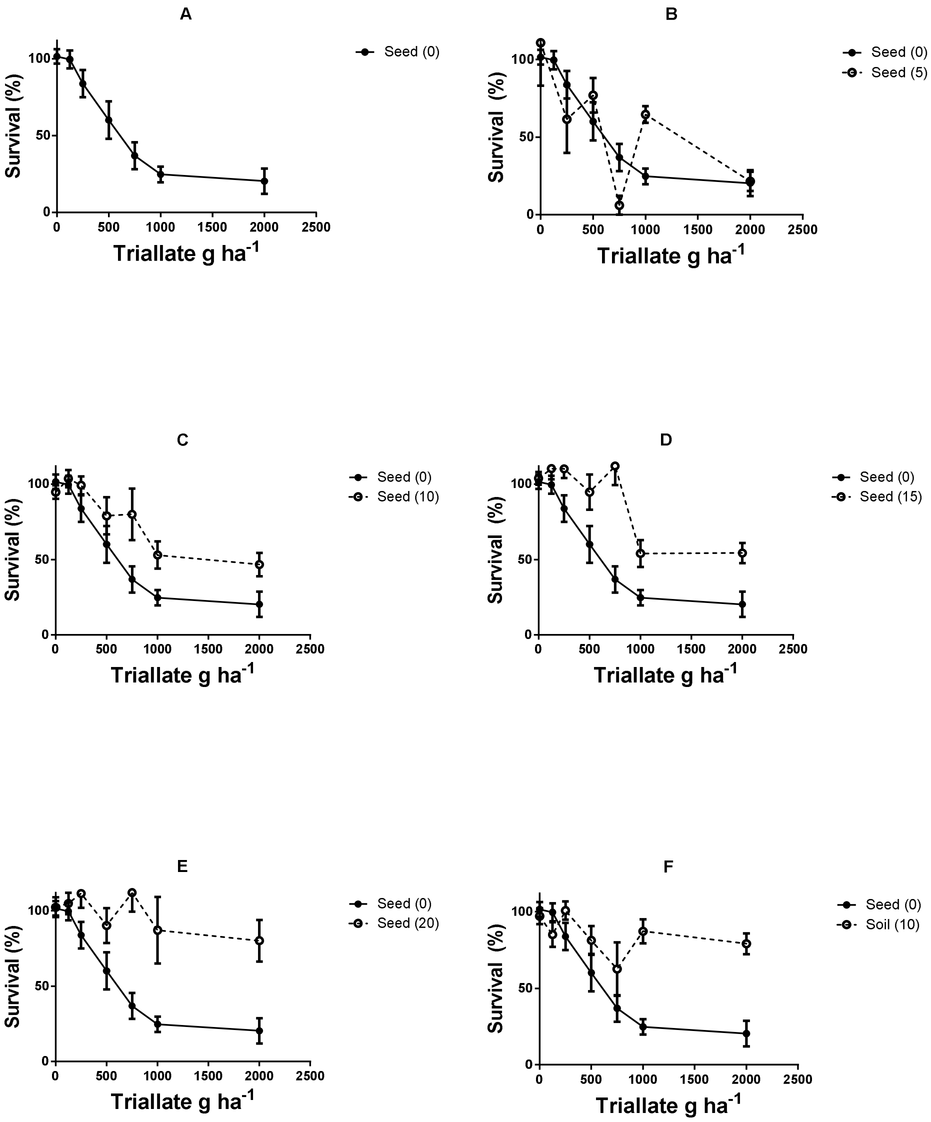


Figure 3. Mean plant survival (emergence as % of untreated control) ± standard errors in triallate dose-response of rice plants. A) Filled circles and solid lines refer to triallate dose-response alone with seeds not previously exposed to phorate (Seed 0); B) open circles and dashed line refer to clomazone dose-response with seed treated with 5 kg phorate ha^{-1} (Seed 5); C) open circles and dashed line refer to clomazone dose-response with seed treated with 10 kg phorate ha^{-1} (Seed 10); D) open circles and dashed line refer to clomazone dose-response with seed treated with 15 kg phorate ha^{-1} (Seed 15); E) open circles and dashed line refer to clomazone dose-response with seed treated with 20 kg phorate ha^{-1} (Seed 20); F) open circles and dashed line refer to clomazone dose-response with untreated seed and phorate at 10 kg phorate ha^{-1} applied to the soil surface of pots prior to triallate treatments (Soil 10); Symbols are observed means ± SE (n = 12).

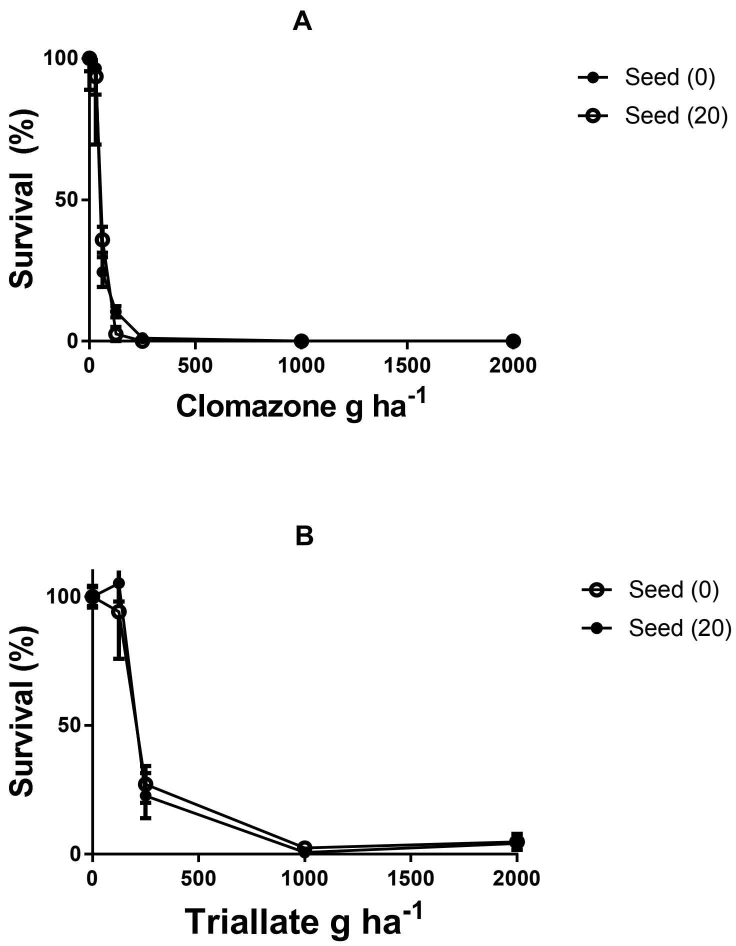


Figure 4. Mean plant survival (emergence as % of untreated control) ± standard errors of the grass weed *Echinochloa colona* treated plants in clomazone dose-response studies in admixture with the rice crop.

A) Open circles and solid lines refer to clomazone dose-response of *E. colona* seeds in admixture with rice seeds (five seeds per pot = 220 rice crop plants m^{-2}) not previously exposed to phorate (Seed 0); Filled circles and dashed line refer to clomazone dose-response of *E. colona* seeds in admixture with rice seed previously treated with 20 kg phorate ha^{-1} (Seed 20);

B) Open circles and solid lines refer to triallate dose-response of *E. colona* seeds in admixture with rice seeds (five seeds per pot = 220 rice crop plants m^{-2}) not previously exposed to phorate (Seed 0); Filled circles squares and dashed line refer to triallate dose-response of *E. colona* seeds in admixture with rice seed previously treated with 20 kg phorate ha^{-1} (Seed 20).

3) Review of ACIAR projects focused on rice system establishment and weed management strategies.

Challenges related to weedy rice infestations or other major weed genera such as *Cyperus, Echinochloa* and *Leptochloa* was described and had been anticipated by previous ACIAR-funded projects focused on rice systems in Asia. We found some common themes of weed management practices in DSR vs transplanted puddled (wet tillage) rice that are summarized in a few bullet points:

- As DSR is more resource efficient (e.g. can reduce water usage by 53%) it will continue to grow in adoption in Asia;
- Weeds and weedy rice infestations are a threat to DSR. The evolution of multiple herbicide resistant weeds has been documented globally in several areas where rice is intensively grown in DSR systems [e.g. *Echinochloa* species resistant to several mode of herbicide action].
- DSR causes evident weed shifts in the weed flora with grass weeds such as *Leptochloa or Echinochloa* and others dominating.
- Integrated Weed Management (IWM) shows potential to reduce herbicide usage, minimize weed problems and increase rice yields and profit.
- Economics and environment drive changes in rice planting techniques and weed management.
- As IWM is a relatively complex innovation with high learning requirements, uptake by non-cooperator farmers (not directly involved in ACIAR funded projects) is slower and adoption low (up to 10%).

4) Survey of the expert opinion of Asian scientists to capture their views on: future socio-economic trends, extent of rice weed issues and evolution of rice systems.

- Discussions occurred on agronomic challenges with weedy rice infestations, biological features of weedy rice and evolution of rice systems in Asia towards an increasing adoption of DSR together with new technologies (i.e. Clearfield™ vs. Provisia™ rice varieties) (see Appendix 4 and 5 for summaries of the satellite symposium "*The weedy rice threat to food security in Asia: global insights into managemen*t". Weed scientists in Asia are knowledgeable and well understand the principles of best weed management practices (i.e. plant into clean fields, use clean seed, diversify the herbicide program, follow label; appropriate water management, prevent seed set from escaped weeds, control weeds at harvest and clean machinery).
- However, we have identified that an important and much needed step towards improved weed management in DSR in Asia would be a study that integrates effective management strategies that have been deployed in global rice ecosystems (Americas, Asia and Europe) and quantify the success of management strategies. Thus far, no study has quantified the efficacy of different weed management strategies on weedy rice and weed control in rice. For example, a statistical meta-analysis could be used to calculate average responses to the various weed management strategies and estimate their variability response/efficacy. As, weed management is based on multiple tactics to incorporate appropriate combinations of preventative, cultural, mechanical, chemical and genetic tools we believe that a meta-analysis review of field experiments would be very useful. Such a study has never been conducted and should relate weed management techniques and weedy rice infestations in DSR rice. Farmers are likely to adopt integrated measures if there is a solidified knowledge and prediction of likely efficacy in their fields.

6 Future investments needs

The results of this and other ACIAR-funded projects suggest that the adoption of DSR is likely to expand and those systems will likely dominate the rice cultivation landscape in major rice-producing Asian countries. Weeds have the potential of causing crop damage greater than any other crop pest (Oerke, 2006). Similarly in DSR systems weeding operations are an absolute requirement to safeguard crop yields. In DSR hand-weeding operations of weedy rice and other aggressive weed species (*Cyperus*, *Echinochloa*, *Leptochloa*, etc.) are problematic as it is difficult to distinguish weeds from rice seedlings at such a young stage. As a result weedy rice, a de-domesticated competitive form of rice is becoming an acute problem in Asia. In Vietnam recent surveys indicate weedy rice can cause up to 70% yield loss in the most severely infested rice fields (Chin and Thi 2010). Our survey study corroborates that Filipino and Vietnamese farmers are facing a significant problem infesting their crops.

We suggest that in the Mekong Delta vietnamese farmers are facing a greater challenge to manage rice weeds as the adoption of DSR is nearly 100% and weedy rice infestations are epidemic (more explicit recommendations are also at paragraph 7.2 below). Here below we suggest a list of studies or components that could be included in future research proposals aimed at reducing the impact of rice weeds in Asia:

a) – meta-analysis review study to quantify the efficacy of Integrated Weed Management (IWM) on weedy rice and driver weeds of DSR in a particular Asian region (eg Mekong Delta, Vietnam);

b) – modelling simulations calibrated to a particular East Asian conditions region (eg Mekong Delta, Vietnam) to infer the population dynamics of weedy rice in response to management practices or agro-climatic conditions: DSR vs transplanting, crop nutrition, water management, use of herbicide-tolerant varieties varieties, herbicide use or other non-chemical weed management tactics;

c) – large scale demonstration of current management options and novel proof-of-concept control techniques, technologies and improved control tools (e.g. new herbicides, new crop safeners, new herbicide tolerant varieties for selective weedy rice control);

d) – risk, awareness and response campaigns to educate farmers about the biological features and damaging effects of weedy rice;

e) – crop and weed management practices to foster adaptation to climatic changes constraining yields and farmer returns in the short term.

7 Conclusions and recommendations

This work has aimed to raise awareness on currently documented weedy rice infestation levels in two important rice producing countries in Asia and proactively anticipate issues related to the adoption of new technologies such as herbicide-resistant rice varieties (Clearfield™ or Provisia™). This survey confirms weedy rice is a widespread problem in surveyed geographical areas of the Philippines and Mekong Delta in Vietnam.

Our proof-of-concept research work has allowed us to call for close collaborative efforts with major chemical corporations and establishment of international herbicide discovery programs to identify candidate safener and herbicide combinations to achieve herbicidal weedy rice control and alleviate weed infestations in global rice crops.

The support provided by ACIAR and the Crawford Fund has allowed the training of Dr Nghia, a young mid-career research leader in Vietnam to increase fundamental knowledge in weed science research principles which will provide common ground to foster future possible collaborations between the University of Western Australia, the University of Queensland and Cantho University. Thus, significant outcomes have been delivered for both Australian and collaborating scientists in Philippines and Vietnam.

7.1 Conclusions

Rice (*Oryza sativa* L.) is the most important staple food in Asia, where it is traditionally grown by manual transplanting of seedlings into puddled soil.

DSR continues to expand in Asia and this will cause more severe infestations of weedy rice and grass weed species shift which will cause major problems to rice farmers. As weedy rice and other weeds are a major evolving challenge of DSR systems there is need for continuous monitoring programs and surveillance of this threat.

Labour unavailability, increasing labour costs, increased pressure on water resources and the need to maintain profit will increase the use of herbicides for weed control. Economics and environment will drive changes in rice planting techniques, crop management and subsequent weed problems.

Minimizing infestations of weedy rice and the co-evolving issues of herbicide-resistant weeds, will significantly contribute to sustain global food production and protect the income of small-holder Asian farmers. The spread of herbicide resistant populations may have a great future impact on Asian farmers and may become a very severe issue in areas where the extent of the problem is overlooked. The intensive rice cropping systems with multiple growing season per year is likely to exacerbate the evolution of herbicide resistant populations.

New technologies will be available to farmers to minimize crop pests but good agronomic principles and best crop and weed management practices will need to be promoted with sound stewardship programs or these technologies will be short-lived.

Adoption and implementation of best management practices from neighbouring farmers will be necessary to achieve sustainable crop production and minimize weeds and pest problems. Sustainability will require extensive collaboration across all sectors.

Extension and communication strategies should be developed to ensure that major research discoveries and improved solutions are presented to stakeholder and end users. This will ensure farmers will be implementing IWM on their farms long after the study is completed.

7.2 Recommendations

Minimizing infestations of weedy rice and the co-evolving issues of herbicide-resistant rice weeds, will significantly contribute to sustain global food production and protect the income of small-holder Asian farmers. Weeds in DSR represent an evolving challenge that will require global and collaborative efforts to develop and improve strategies for their control. An important component of research should foster overall resilience in agriculture in Asia and Australia and promote adaptation to anticipated future climatic changes.

Thus, we strongly believe that a three-year research study should be conducted in the Mekong Delta region of Vietnam as one of the most representative rice growing area in East Asia. We have identified some research priorities as the most logical expansion from a fruitful one-year study conducted within the SRA in 2015/16. We have identified reseach areas that should be considered in a possible three-year research project focused on integrated weed and crop management:

a) INTEGRATED WEED MANAGEMENT FOCUS: A meta-analysis review aimed at ranking weed control efficacy of techniques currently used in DSR systems in East Asia (chemical vs non-chemical) and provide critical insight into the most appropriate weed management program. IWM is highly advocated as the most robust approach to minimize weedy rice infestations globally but there is no study that has quantified the efficacy of specific techniques for weedy rice control in Asia. This initial study would provide critical and quantitative information on most effective IWM techniques for a specific region (eg use of certified in Vietnam) before research is conducted and provide insights techniques that need improvement and new technologies that are available elsewhere but yet to be released in Asia [herbicide-tolerant varieties such as Clearfield™ or Provisia™ rices]. No data exist in Asia on the long-term benefits of using certified seeds to minimize weedy rice infestations and we could establish those long-term field trials.

b) GEOGRAPHICAL WEED SURVEYS: This SRA reports on significant weed contamination in crop seed samples collected from Vietnamese farmers, a major geographical survey should assess the distribution of major dominant weeds and weedy rice infesting farmers' fields in established DSR systems in Vietnam. This survey should be followed by an assessment of weed response to the most commonly used herbicides. In Asia there is little information regarding the extent of herbicide resistant weeds but there is increasing anecdotal evidence of weeds escaping herbicide treatments and herbicide failures. This would promote awareness and build knowledge on herbicide use and technology. This study would much contribute to capacity building of Vietnamese scientists, farmers and extension personnel.

c) CLIMATE CHANGE, WATER MANAGEMENT & CROP NUTRITION: Glasshouse, field plots research and large demonstration field trials to assess best crop and weed management strategies that can improve farmers' adaptation to predicted water shortages and soil moisture delicnes as consequence of climatic changes. For example a study should explore the interaction of water management tactics that can reduce water consumption but also minimize competition between rice and weedy rice or other weeds (ie alternate wetting and drying vs continuous flooding) and how these water management strategies interact with crop nutrition and fertiliser application strategies [ie deep fertilizer placement of phosphorus (P) and nitrogen (N)] to restrict access of weeds to fertilisers and favour the crop against weed competition.

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8.2 List of publications produced by project

R Busi ACIAR investments to improve weed control in rice in Asia and current focus on weedy rice. *APWSS Conference Proceedings* (Vol. 2, pp. 4 – 15; available at http://apwss.org/apwss-publications.htm).

R Busi NK Nguyen BS Chauhan F Vidotto M Tabacchi and SB Powles. Can Safeners Allow Selective Control of Weedy Rice Infesting Rice Crops? *Under review in Pest management Science.* (Appendix 3).

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R Busi F Vidotto M Tabacchi BS Chauhan NR Burgos and S Powles. The weedy rice threat to food security in Asia: global insights into management. Keynote talk at IWSC Congress in Prague 19-24 June 2016 (Appendix 5).

9 Appendixes

9.1 Appendix 1:

Farmer survey to quantify perception, management practices and weedy rice infestation levels in the North (Luzon) and South Island (Mindanao) in the Philippines.

Prepared by: LM Juliano, EC Martin, DKE Donayre, and JC Beltran

Area coverage and sample size

Province	Municipality	Village	No. of samples
Batangas	Nasugbu	MAV	34
		SMAV	35
North Cotabato	Libungan	MAV	37
		SMAV	35
Sultan Kudarat	Lambayong	MAV	35
		SMAV	35

Note: WR-MAV - weedy rice- most affected village

WR-SMAV - weedy rice- second most affected village

Tab. 1 Socio-demographic profile of respondents

Item	Batangas				North Cotabato				Sultan Kudarat			
	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	freq	%	freq	%	freq	%	freq	%	freq	%		
Age (mean)	59		55		57		51		43		54	
Age of farmer (range)												
25-35	0	0	3	9	2	5	3	9	10	29	4	11
36-50	9	26	12	34	8	22	15	43	18	51	9	26
51-65	12	35	13	37	18	49	14	40	7	20	17	49
>60	13	38	7	20	9	24	3	9	0	0	5	14
Sex												
Male	21	62	23	66	20	54	12	34	25	71	26	74
Female	13	38	12	34	17	46	23	66	10	29	9	26
Education (ave. no. of years)	8		9		9		9		10		8	
Educational Level												
None	1	3	0	0	1	3	0	0	0	0	0	0
Elementary	16	47	9	26	8	22	9	26	3	9	17	49
Secondary	9	26	14	40	15	41	17	49	21	60	14	40
Tertiary	8	24	12	34	13	35	9	26	11	31	4	11
Farming experience (no. of years)	28		23		33		23		19		26	
Farming experience (range)												
1-10	6	18	6	17	4	11	7	20	13	37	6	17
11-20	8	24	11	31	3	8	9	26	8	23	9	26
21-30	8	24	13	37	9	24	9	26	11	31	10	29
>30	12	35	5	14	21	57	10	29	3	9	10	29
Total rice area (mean ha)	2		3		1		3		2		2	
Total farm area (ha)												
<0.5	1	3	0	0	7	19	0	0	1	3	0	0
0.5-1.0	8	24	10	29	17	46	18	51	12	34	14	40
1.1-2.0	12	35	12	34	12	32	6	17	8	23	15	43
>2.0	13	38	13	37	1	3	11	31	14	40	6	17
Tenurial status												
Owner	12	35	16	46	24	65	15	43	17	49	22	63

[1] - *weedy rice most affected villages*

[2] - *weedy rice second most affected villages*

Tab. 2 Distribution of seed treatment, method of crop establishment, and method of irrigation

Item	Batangas				North Cotabato				Sultan Kudarat			
	MAV¹		SMAV²		MAV¹		SMAV²		MAV¹		SMAV²	
	freq	%	freq	%	freq	%	freq	%	freq	%	freq	%
Seed Treatment:												
Jan-Jun harvest												
Yes	2	6	9	26	1	3	7	20	3	9	1	3
No	32	94	26	74	36	97	28	80	32	91	34	97
Jul-Dec harvest												
Yes	3	9	6	17	2	5	9	26	3	9	1	3
No	31	91	29	83	35	95	26	74	32	91	34	97
Method of crop establishment:												
Jan-Jun harvest												
Transplanting	15	44	5	14	4	11	0	0	2	6	3	9
Direct-seeding	19	56	30	86	33	89	35	100	33	94	32	91
Jul-Dec harvest												
Transplanting	24	71	21	60	2	5	0	0	2	6	5	14
Direct-seeding	10	29	14	40	35	95	35	100	33	94	30	86
Method of transplanting:												
Jan-Jun harvest												
Manual	15	100	5	100	4	100	0	0	2	100	3	100
Jul-Dec harvest												
Manual	24	100	21	100	2	100	0	0	2	100	5	100
Method of direct-seeding:												
Jan-Jun harvest												
Manual	11	62	11	39	31	94	34	97	33	100	31	97
Mechanical	8	38	19	61	2	6	1	3	0	0	1	3
Jul-Dec harvest												
Manual	7	70	11	79	34	97	34	97	33	100	29	97
Mechanical	3	30	3	21	1	3	1	3	0	0	1	3
Method of irrigation:												
Jan-Jun harvest												
Continous	15	44	7	20	20	54	22	63	11	31	10	29
Wet-Dry	19	56	28	80	17	46	13	37	24	69	25	71
Jul-Dec harvest												
Continous	16	47	10	29	20	54	22	63	11	31	10	29

Wet-Dry	18	53	25	71	17	46	13	37	24	69	25	71

[1] - *weedy rice most affected villages*

[2] - *weedy rice second most affected villages*

Tab. 3. Distribution of percentage of area affected by weedy rice

% of Area Affected	Batangas				North Cotabato				Sultan Kudarat			
	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Jan-June harvest												
< 10%	5	15	5	14	5	14	12	34	3	9	5	14
10-30%	17	50	10	29	14	38	14	40	17	49	18	51
31-20%	7	21	18	51	12	32	5	14	13	37	9	26
> 50%	5	15	2	6	6	16	4	11	2	6	3	9
July-Dec harvest												
< 10%	5	15	6	17	9	24	18	51	4	11	5	14
10-30%	22	65	13	37	13	35	14	40	19	54	19	54
31-20%	2	6	14	40	10	27	0	0	8	23	8	23
> 50%	5	15	2	6	5	14	3	9	4	11	3	9

[1] - *weedy rice most affected villages*

[2] - *weedy rice second most affected villages*

Tab. 4 Distribution of the number of weedy rice plants per square meter reported by farmers

	Batangas				North Cotabato				Sultan Kudarat			
	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Jan-Jun harvest												
< 5	12	35	6	17	1	3	9	26	2	6	0	0
5-10	14	41	17	49	19	51	18	51	4	11	2	6
11-20	8	24	8	23	9	24	5	14	7	20	12	34
> 20	0	0	4	11	8	22	3	9	22	63	21	60
Jul-Dec harvest												
< 5	13	38	5	14	9	24	15	43	2	6	0	0
5-10	17	50	19	54	13	35	13	37	3	9	3	9
11-20	4	12	7	20	9	24	5	14	7	20	12	34
> 20	0	0	4	11	6	16	2	6	23	66	20	57

[1] - *weedy rice most affected villages*

[2] - *weedy rice second most affected villages*

Tab. 5 Distribution of duration of land preparation (no. of days) reported by farmers

	Batangas				North Cotabato				Sultan Kudarat			
No. of days	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Jan-Jun harvest												
1-7	3	9	2	6	3	8	4	11	21	60	9	26
8-14	3	9	7	20	9	24	13	37	6	17	8	23
15-21	12	35	4	11	17	46	10	29	4	11	9	26
> 21	16	47	22	63	8	22	8	23	4	11	9	26
Jul-Dec harvest												
1-7	4	12	2	6	3	8	4	11	20	57	5	14
8-14	3	9	5	14	10	27	14	40	8	23	10	29
15-21	11	32	5	14	15	41	11	31	3	9	9	26
> 21	16	47	23	66	9	24	6	17	4	11	11	31

[1] - *weedy rice most affected villages*

[2] - *weedy rice second most affected villages*

Tab. 6 Distribution of harvesting/threshing method by farmers.

Item	Batangas				North Cotabato				Sultan Kudarat			
	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Jan-Jun harvest												
Manual	34	100	35	100	32	86	35	100	1	3	2	6
Combine harvester	0	0	0	0	5	14	0	0	34	97	33	94
Jul-Dec harvest												
Manual	34	100	35	100	32	86	35	100	2	6	1	3
Combine harvester	0	0	0	0	5	14	0	0	33	94	34	97

[1] - *weedy rice most affected villages*

[2] - *weedy rice second most affected villages*

Tab. 7 Distribution of common variety planted by farmers, January-June harvest

Jan-Jun harvest	Batangas				North Cotabato				Sultan Kudarat			
	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
300 series	0	0	0	0	0	0	1	3	0	0	0	0
BR-II	1	3	0	0	0	0	0	0	0	0	0	0
Basmate (Senador)	0	0	1	3	0	0	0	0	0	0	0	0
Black rice	0	0	0	0	1	3	0	0	0	0	0	0
Destiny (traditional)	0	0	0	0	0	0	0	0	0	0	1	3
Diamond X (traditional)	0	0	0	0	0	0	0	0	0	0	1	3
GSR	1	3	0	0	0	0	0	0	0	0	0	0
II-60	0	0	0	0	0	0	0	0	0	0	1	3
M-3 line	0	0	0	0	10	27	4	11	1	3	0	0
Masipag	0	0	0	0	1	3	1	3	0	0	0	0
Masipag (Red)	0	0	0	0	1	3	0	0	0	0	0	0
NSIC Rc 128	0	0	1	3	0	0	0	0	0	0	0	0
NSIC Rc11	0	0	1	3	0	0	0	0	0	0	0	0
NSIC Rc120	0	0	2	6	0	0	0	0	0	0	0	0
NSIC Rc122	0	0	0	0	0	0	0	0	1	3	0	0
NSIC Rc128	1	3	5	14	2	5	2	6	7	20	2	6
NSIC Rc138	1	3	0	0	0	0	0	0	0	0	0	0
NSIC Rc158	0	0	0	0	12	32	10	29	0	0	0	0
NSIC Rc160	8	24	7	20	4	11	2	6	18	51	4	11
NSIC Rc160, PSB Rc82	0	0	1	3	0	0	0	0	0	0	0	0
NSIC Rc160, Piling David	1	3	0	0	0	0	0	0	0	0	0	0
NSIC Rc168	1	3	0	0	0	0	0	0	0	0	0	0
NSIC Rc194	1	3	1	3	0	0	0	0	0	0	0	0
NSIC Rc216	2	6	2	6	0	0	0	0	0	0	0	0
NSIC Rc218	0	0	0	0	0	0	0	0	0	0	1	3
NSIC Rc222	0	0	0	0	1	3	6	17	0	0	17	49
NSIC Rc224	0	0	0	0	1	3	1	3	0	0	5	14
NSIC Rc226	0	0	0	0	1	3	0	0	1	3	0	0
NSIC Rc228	0	0	1	3	0	0	1	3	0	0	0	0
NSIC Rc238	3	9	2	6	0	0	1	3	1	3	0	0
NSIC Rc240	0	0	1	3	0	0	1	3	0	0	0	0
NSIC Rc298	1	3	6	17	0	0	1	3	0	0	0	0

NSIC Rc298, PSB Rc82	1	3	0	0	0	0	0	0	0	0	0	0
NSIC Rc30	2	6	0	0	0	0	0	0	0	0	0	0
NSIC Rc328	0	0	0	0	0	0	1	3	0	0	0	0
NSIC Rc34 (Burdagol)	1	3	0	0	0	0	0	0	0	0	0	0
PSB Rc10	1	3	0	0	0	0	0	0	0	0	0	0
PSB Rc128	0	0	0	0	1	3	0	0	0	0	0	0
PSB Rc18	5	15	0	0	0	0	0	0	0	0	0	0
PSB Rc64	0	0	0	0	1	3	0	0	0	0	0	0
PSB Rc82	1	3	3	9	1	3	0	0	5	14	3	9
Pedro (traditional)	0	0	0	0	0	0	1	3	0	0	0	0
Piling David	1	3	0	0	0	0	0	0	0	0	0	0
R-30	0	0	1	3	0	0	0	0	0	0	0	0
Senador	1	3	0	0	0	0	0	0	0	0	0	0
Texas (local variety)	0	0	0	0	0	0	0	0	1	3	0	0
unknown	0	0	0	0	0	0	2	6	0	0	0	0
Total	34	100	35	100	37	100	35	100	35	100	35	100

[1] - *weedy rice most affected villages*

[2] - *weedy rice second most affected villages*

Tab. 8 Distribution of common variety planted by farmers, July-December harvest

Jul-Dec harvest	Batangas				North Cotabato				Sultan Kudarat			
	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Agila	0	0	0	0	0	0	1	3	0	0	0	0
Angelica	2	6	0	0	0	0	0	0	0	0	0	0
BR-11	0	0	3	9	0	0	0	0	0	0	0	0
Basmate (Senador)	0	0	1	3	0	0	0	0	0	0	0	0
Burdagol (traditional)	0	0	0	0	0	0	1	3	0	0	0	0
Don’t know	1	3	0	0	0	0	0	0	0	0	0	0
Ginanda	0	0	1	3	0	0	0	0	0	0	0	0
Green varieties	0	0	1	3	0	0	0	0	0	0	0	0
M-3 line	0	0	0	0	7	19	2	6	0	0	0	0
M3, NSIC Rc160	0	0	0	0	1	3	0	0	0	0	0	0
Masipag	0	0	0	0	2	5	1	3	0	0	0	0
Masipag (Red)	0	0	0	0	1	3	0	0	0	0	0	0

NSIC Rc122	0	0	0	0	0	0	0	0	3	9	0	0
NSIC Rc128	4	12	4	11	4	11	1	3	3	9	0	0
NSIC Rc138	1	3	0	0	0	0	0	0	0	0	0	0
NSIC Rc158	0	0	0	0	8	22	3	9	0	0	0	0
NSIC Rc160	5	15	6	17	1	3	6	18	17	49	7	20
NSIC Rc168	2	6	0	0	0	0	0	0	0	0	0	0
NSIC Rc193	0	0	0	0	1	3	0	0	0	0	0	0
NSIC Rc194	1	3	1	3	0	0	0	0	0	0	0	0
NSIC Rc198, Pulang David	1	3	0	0	0	0	0	0	0	0	0	0
NSIC Rc206	0	0	0	0	0	0	0	0	1	3	0	0
NSIC Rc212	0	0	0	0	0	0	1	3	0	0	0	0
NSIC Rc214	0	0	0	0	1	3	0	0	0	0	0	0
NSIC Rc216	4	12	4	11	0	0	0	0	0	0	0	0
NSIC Rc218	0	0	1	3	0	0	0	0	0	0	2	6
NSIC Rc222	0	0	0	0	0	0	7	21	1	3	9	26
NSIC Rc224	0	0	0	0	1	3	0	0	0	0	0	0
NSIC Rc226	0	0	1	3	2	5	1	3	0	0	0	0
NSIC Rc238	1	3	0	0	1	3	2	6	0	0	0	0
NSIC Rc240	0	0	2	6	0	0	1	3	0	0	0	0
NSIC Rc28	1	3	0	0	0	0	0	0	0	0	0	0
NSIC Rc282	0	0	0	0	0	0	0	0	0	0	1	3
NSIC Rc298	0	0	6	17	3	8	2	6	0	0	0	0
NSIC Rc30	1	3	0	0	0	0	0	0	0	0	0	0
NSIC Rc300	0	0	0	0	0	0	0	0	0	0	2	6
NSIC Rc302	0	0	0	0	1	3	0	0	0	0	0	0
NSIC rc160	0	0	0	0	0	0	0	0	1	3	0	0
NSIc Rc128	0	0	0	0	0	0	0	0	0	0	1	3
NSIc Rc160	0	0	1	3	0	0	0	0	2	6	0	0
NSIc Rc222	0	0	0	0	0	0	1	3	0	0	0	0
PSB Rc10	1	3	0	0	0	0	0	0	0	0	0	0
PSB Rc18	3	9	0	0	0	0	0	0	0	0	2	6
PSB Rc22	1	3	0	0	0	0	0	0	0	0	0	0
PSB Rc82	1	3	2	6	0	0	0	0	6	17	11	31
PSB Rc218, NSIC Rc216	0	0	1	3	0	0	0	0	0	0	0	0
Pedro	0	0	0	0	2	5	0	0	0	0	0	0
Piling David	2	6	0	0	0	0	0	0	0	0	0	0
Red rice	0	0	0	0	1	3	0	0	0	0	0	0
SL8	1	3	0	0	0	0	1	3	0	0	0	0

Senador	1	3	0	0	0	0	0	0	0	0	0	0
Texas (local variety)	0	0	0	0	0	0	0	0	1	3	0	0
Toner	0	0	0	0	0	0	1	3	0	0	0	0
unknown	0	0	0	0	0	0	2	6	0	0	0	0
Total	34	100	35	100	37	100	34	100	35	100	35	100

[1] - weedy rice most affected villages

[2] - weedy rice second most affected villages

Tab. 9 Distribution of major seed class used by farmers

	Batangas				North Cotabato				Sultan Kudarat			
	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Seed class, Jan-Jun harvest												
farmers seeds	23	68	24	69	28	76	19	54	5	14	5	14
registered	1	3	0	0	1	3	7	20	3	9	2	6
certified	10	29	11	31	8	22	9	26	27	77	28	80
Seed class, July-Dec harvest												
farmers seeds	28	82	28	80	29	78	20	57	6	17	5	14
registered	0	0	0	0	0	0	5	14	3	9	3	9
certified	5	15	7	20	8	22	9	26	26	74	27	77
hybrid	1	3	0	0	0	0	1	3	0	0	0	0

[1] - weedy rice most affected villages

[2] - weedy rice second most affected villages

Tab. 10 Distribution of seed source by farmers, January-June harvest

Source	Batangas				North Cotabato				Sultan Kudarat			
	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	No.	%	No.	%	No.	%	No.	%	No.	%		%
Department of Agriculture	11	33	12	34	4	11	6	17	0	0	0	0
National Irrigation Administration	0	0	0	0	0	0	1	3	0	0	0	0
PhilRice	1	3	0	0	1	3	4	11	0	0	0	0
Pesticide Company (Agent)	0	0	0	0	0	0	1	3	0	0	0	0
farmer/exchange/own produce	21	64	23	66	25	68	17	49	4	12	4	13
seed grower/producer	0	0	0	0	5	14	5	14	29	88	28	88
palay/input trader	0	0	0	0	2	5	1	3	0	0	0	0
Total	33	100	35	100	37	100	35	100	33	100	32	100

[1] - *weedy rice most affected villages*

[2] - *weedy rice second most affected villages*

Tab. 11 Distribution of seed source by farmers, July-December harvest

Source	Batangas				North Cotabato				Sultan Kudarat			
	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Department of Agriculture	5	15	7	20	4	11	5	14	0	0	0	0
National Irrigation Administration	0	0	0	0	0	0	1	3	0	0	0	0
PhilRice	1	3	0	0	2	5	5	14	0	0	0	0
Pesticide Company	1	3	0	0	0	0	0	0	0	0	0	0
farmer/exchange/own produce	26	79	28	80	25	68	19	54	5	15	4	13
seed grower/producer	0	0	0	0	3	8	4	11	28	85	28	88
palay/input trader	0	0	0	0	3	8	1	3	0	0	0	0
Total	33	100	35	100	37	100	35	100	33	100	32	100

[1] - *weedy rice most affected villages*

[2] - *weedy rice second most affected villages*

Tab. 12 Average seeding rate (kg/ha) reported by farmers.

	Batangas		North Cotabato		Sultan Kudarat	
	MAV[1]	SMAV[2]	MAV[1]	SMAV[2]	MAV[1]	SMAV[2]
Jan-Jun harvest						
mean	94	94	97	100	89	79
min	40	20	20	20	40	60
max	250	250	150	250	240	110
Jul-Dec harvest						
mean	96	101	95	102	90	76
min	18	20	20	20	2	40
max	250	250	150	250	240	110

[1] - *weedy rice most affected villages*

[2] - *weedy rice second most affected villages*

Tab. 13 Common herbicide use in the farm, January-June harvest

Brand	Batangas				North Cotabato				Sultan Kudarat			
	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
2,4-D ester	13	20	8	12	6	13	7	10	5	7	6	8
2,4-D + Hero	0	0	2	3	0	0	0	0	0	0	0	0
2,4-D + Nominee	2	3	1	1	0	0	0	0	0	0	0	0
2,4-D + Ricestar	1	2	1	1	0	0	0	0	0	0	0	0
Advance	2	3	0	0	11	23	9	13	0	0	0	0
Agrobonds	0	0	0	0	1	2	3	4	0	0	9	13
Agroxone	0	0	3	4	0	0	0	0	0	0	0	0
Asodril + Cypermethrin	0	0	0	0	1	2	0	0	0	0	0	0
Barbers	0	0	0	0	1	2	0	0	0	0	0	0
Basagran	0	0	0	0	0	0	0	0	1	1	0	0
Brodan	0	0	0	0	1	2	0	0	0	0	0	0
Choice	0	0	0	0	1	2	2	3	14	19	1	1
Clear out	0	0	0	0	0	0	0	0	1	1	3	4
Clincher	0	0	0	0	0	0	6	9	4	5	0	0
Cone	0	0	1	1	0	0	0	0	0	0	0	0
Cypermethrin	0	0	0	0	1	2	2	3	0	0	0	0
Direct	1	2	0	0	1	2	0	0	0	0	0	0
Guarantee	0	0	0	0	14	29	9	13	0	0	3	4
Gramoxone	0	0	1	1	0	0	0	0	0	0	0	0
Grasstop	1	2	0	0	0	0	0	0	0	0	0	0
Ground plus	0	0	0	0	0	0	0	0	3	4	0	0
Hero	3	5	6	9	0	0	0	0	0	0	0	0
Machete	11	17	4	6	0	0	2	3	3	4	4	6
Magnum	0	0	0	0	2	4	3	4	0	0	0	0
Nominee	21	32	19	28	2	4	7	10	17	23	22	31
Padan	0	0	0	0	0	0	2	3	0	0	0	0
Power	0	0	0	0	0	0	0	0	1	1	0	0
Pre-emergence	0	0	0	0	0	0	1	1	0	0	0	0
Prevathon	0	0	0	0	0	0	0	0	0	0	1	1
Pyanchor	0	0	0	0	2	4	0	0	0	0	0	0
Quadro 8	0	0	0	0	0	0	0	0	0	0	2	3
Ricestar	2	3	1	1	0	0	1	1	22	29	10	14

Ronstar	0	0	0	0	0	0	1	1	2	3	10	14
Ronstar + clear out	0	0	0	0	0	0	0	0	1	1	0	0
Round-up	0	0	0	0	0	0	0	0	1	1	0	0
Siga	0	0	0	0	1	2	0	0	0	0	0	0
Sniper	0	0	0	0	2	4	0	0	0	0	0	0
Sofit	9	14	20	30	1	2	12	18	0	0	0	0
Total	66	100	67	100	48	100	67	100	75	100	71	100

[1] - weedy rice most affected villages

[2] - weedy rice second most affected villages

Tab. 14. Common herbicide use, July-December harvest

Brand	Batangas				North Cotabato				Sultan Kudarat			
	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
17 DAS	0	0	0	0	0	0	0	0	1	1	0	0
2,4-D	12	19	9	14	6	12	6	10	5	7	5	7
2,4-D + Hero	0	0	2	3	0	0	0	0	0	0	0	0
2,4-D + Nominee	3	5	0	0	0	0	0	0	0	0	0	0
2,4-D + Ricestar	1	2	1	2	0	0	0	0	0	0	0	0
Advance	4	6	0	0	14	28	6	10	0	0	0	0
Agroxone	0	0	2	3	0	0	0	0	0	0	0	0
Agrobonds	0	0	0	0	1	2	2	3	0	0	9	13
Agrowell	0	0	0	0	0	0	2	3	0	0	0	0
Asodril	0	0	0	0	1	2	0	0	0	0	0	0
Asodril + cypermethrin	0	0	0	0	1	2	0	0	0	0	0	0
Basagran	0	0	0	0	0	0	0	0	1	1	0	0
Brodan	0	0	0	0	1	2	0	0	0	0	0	0
Chice	0	0	0	0	0	0	0	0	1	1	0	0
Choice	0	0	0	0	0	0	2	3	13	18	1	1
Clincher	0	0	0	0	0	0	9	15	3	4	0	0
Cone	0	0	1	2	0	0	0	0	0	0	0	0
Cypermethrin	0	0	0	0	1	2	1	2	0	0	0	0
Gramoxone	0	0	1	2	0	0	0	0	0	0	0	0
Ground plus	0	0	0	0	0	0	0	0	2	3	0	0
Guarantee	0	0	0	0	14	28	10	16	0	0	2	3
Hero	1	2	5	8	0	0	0	0	0	0	0	0

Machete	11	17	12	18	0	0	1	2	3	4	9	13
Magnum	0	0	0	0	2	4	3	5	0	0	0	0
Nominee	21	33	20	30	3	6	6	10	17	23	18	26
Power	0	0	0	0	0	0	0	0	2	3	0	0
Prevathon	0	0	0	0	0	0	0	0	0	0	1	1
Pyanchor	0	0	0	0	3	6	0	0	0	0	0	0
Quadro 8	0	0	0	0	0	0	0	0	0	0	1	1
Ricestar	1	2	0	0	0	0	1	2	21	28	12	18
Ronstar	0	0	0	0	0	0	2	3	3	4	8	12
Ronstar + clear out	0	0	0	0	0	0	0	0	1	1	0	0
Round-up	0	0	0	0	0	0	0	0	1	1	0	0
Sniper	0	0	0	0	3	6	0	0	0	0	0	0
Sofit	9	14	13	20	0	0	11	18	0	0	0	0
Sonic	0	0	0	0	0	0	0	0	0	0	1	1
Vertako	0	0	0	0	0	0	0	0	0	0	1	1
Total	63	100	66	100	50	100	62	100	74	100	68	100

[1] - *weedy rice most affected villages*

[2] - *weedy rice second most affected villages*

Tab. 15 Average number of weeding operations, herbicide application, normal yield and yield with weedy rice problem, Batangas

Item	WR- MAV			WR-SMAV		
	mean	min	max	mean	min	max
Manual weeding jan-june harvest (no.)	4	0	22	3	0	24
Manual weeding jul-dec harvest (no.)	4	0	44	2	0	24
Herbicide application jan-june harvest (no.)	2	0	3	2	1	3
Herbicide application jul-dec harvest (no.)	2	0	3	2	1	3
Average normal yield jan-june harvest (kg/ha)	4758	1000	12500	4686	1300	9000
Average normal yield jul-dec harvest (kg/ha)	4731	1000	12500	4532	2120	11960
Yield with weedy rice problem jan-june harvest (kg/ha)	3576	650	8750	3592	1000	9880
Yield with weedy rice problem jul-dec harvest (kg/ha)	3751	650	8750	3393	750	8840

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 16 Average number of weeding operations, herbicide application, normal yield and yield with weedy rice problem, North Cotabato

Item	WR- MAV			WR-SMAV		
	mean	min	max	mean	min	max
Manual weeding jan-june harvest (no.)	1	0	5	1	0	6
Manual weeding jul-dec harvest (no.)	1	0	6	1	0	6
Herbicide application jan-june harvest (no.)	1	0	3	2	1	3
Herbicide application jul-dec harvest (no.)	1	0	3	2	0	3
Average normal yield jan-june harvest (kg/ha)	5015	1800	10710	4575	1290	6800
Average normal yield jul-dec harvest (kg/ha)	4960	1600	11220	4898	1140	14400
Yield with weedy rice problem jan-june harvest (kg/ha)	3585	1200	7910	3686	1140	6051
Yield with weedy rice problem jul-dec harvest (kg/ha)	3449	900	9600	3989	1280	10000

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 17 Average number of weeding operations, herbicide application, normal yield and yield with weedy rice problem, Sultan Kudarat

Item	WR- MAV			WR-SMAV		
	mean	min	max	mean	min	max
Manual weeding jan-june harvest (no.)	1	0	3	1	0	4
Manual weeding jul-dec harvest (no.)	1	0	3	1	0	3
Herbicide application jan-june harvest (no.)	2	0	3	2	0	3
Herbicide application jul-dec harvest (no.)	2	0	3	2	0	3
Average normal yield jan-june harvest (kg/ha)	4995	1600	8500	5180	2600	9000
Average normal yield jul-dec harvest (kg/ha)	4324	1000	8960	4236	1125	6380
Yield with weedy rice problem jan-june harvest (kg/ha)	3759	1100	6300	3437	700	6540
Yield with weedy rice problem jul-dec harvest (kg/ha)	3208	400	7425	2960	1500	5540

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 18 Distribution of the knowledge of the attributes of weedy rice by farmers

Item	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
	WR-MAV		WR-SMAV		WR-MAV		WR-SMAV		WR-MAV		WR-SMAV	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Weedy rice s more common in diret-seeding												
TRUE	31	91	32	91	26	70	28	80	32	91	33	94
FALSE	1	3	1	3	7	19	4	11	3	9	2	6
Do not know	2	6	2	6	4	11	3	9	0	0	0	0
Weedy rice has only one kind of panicle												
TRUE	15	44	17	49	16	43	16	46	22	63	15	43
FALSE	19	56	17	49	20	54	18	51	13	37	19	54
Do not know	0	0	1	3	1	3	1	3	0	0	1	3
Seeds of weedy rice have dormancy												
TRUE	22	65	21	60	29	78	27	77	33	94	33	94
FALSE	9	26	9	26	4	11	4	11	2	6	1	3
Do not know	3	9	5	14	4	11	4	11	0	0	1	3
Panicle seeds or grains of weedy rice shatter easily												
TRUE	30	88	32	91	37	100	32	91	33	94	35	100
FALSE	4	12	3	9	0	0	2	6	2	6	0	0
Do not know	0	0	0	0	0	0	1	3	0	0	0	0
Weedy rice can be taller than cultivated rice												
TRUE	34	100	33	94	37	100	34	97	35	100	32	91
FALSE	0	0	2	6	0	0	0	0	0	0	3	9
Do not know	0	0	0	0	0	0	1	3	0	0	0	0
Flag leaves of weedy rice are always drooping												
TRUE	26	76	28	80	30	81	19	54	25	71	27	77
FALSE	3	9	4	11	6	16	16	46	9	26	8	23
Do not know	5	15	3	9	1	3	0	0	1	3	0	0
Weedy rice is a type of weed in rice												
TRUE	29	85	31	89	28	76	27	77	27	77	22	63

FALSE	4	12	2	6	5	14	8	23	8	23	13	37
Do not know	1	3	2	6	4	11	0	0	0	0	0	0
Awns can be absent in some weedy rice												
TRUE	13	38	17	49	19	51	21	60	21	60	17	49
FALSE	19	56	16	46	18	49	13	37	14	40	17	49
Do not know	2	6	2	6	0	0	1	3	0	0	1	3
Weedy rice have only closed panicles												
TRUE	15	44	14	40	26	70	29	83	27	77	25	71
FALSE	16	47	18	51	9	24	4	11	8	23	9	26
Do not know	3	9	3	9	2	5	2	6	0	0	1	3
Weedy rice seeds left on the soil surface at harvest easily germinate												
TRUE	34	100	34	97	28	76	29	83	29	83	30	86
FALSE	0	0	1	3	5	14	4	11	6	17	3	9
Do not know	0	0	0	0	4	11	2	6	0	0	2	6
Grains of weedy rice are all color red												
TRUE	8	24	2	6	15	41	25	71	23	66	22	63
FALSE	25	74	32	91	19	51	10	29	12	34	13	37
Do not know	1	3	1	3	3	8	0	0	0	0	0	0
Weedy rice is late-maturing												
TRUE	5	15	7	20	9	24	8	23	10	29	9	26
FALSE	27	79	28	80	27	73	23	66	25	71	25	71
Do not know	2	6	0	0	1	3	4	11	0	0	1	3
The grain (pericarp) color of weedy rice after milling is always red												
TRUE	16	47	15	43	18	49	22	63	23	66	30	86
FALSE	18	53	19	54	15	41	8	23	11	31	5	14
Do not know	0	0	1	3	4	11	5	14	1	3	0	0
It is possible to eat weedy rice												
TRUE	30	88	27	77	20	54	20	57	33	94	32	91
FALSE	4	12	8	23	11	30	10	29	0	0	2	6
Do not know	0	0	0	0	6	16	5	14	2	6	1	3
Weedy rice can be harvested with cultivated rice												
TRUE	25	74	26	74	24	65	23	66	31	89	28	80
FALSE	9	26	9	26	13	35	11	31	3	9	7	20

	Do not know	0	0	0	0	0	0	1	3	1	3	0	0
Longevity of weedy rice seeds in soil may last more than one cropping													
	TRUE	33	97	34	97	36	97	29	83	35	100	34	97
	FALSE	0	0	0	0	0	0	6	17	0	0	1	3
	Do not know	1	3	1	3	1	3	0	0	0	0	0	0
Weedy rice consumes more fertilizer than cultivated rice													
	TRUE	31	91	28	80	28	76	22	63	28	80	26	74
	FALSE	2	6	6	17	5	14	13	37	5	14	6	17
	Do not know	1	3	1	3	4	11	0	0	2	6	3	9
There is only one type/kind of weedy rice													
	TRUE	8	24	3	9	21	57	19	54	9	26	10	29
	FALSE	26	76	32	91	15	41	14	40	26	74	25	71
	Do not know	0	0	0	0	1	3	2	6	0	0	0	0

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 19 Distribution of knowledge of management/control of weedy rice by farmers

Item	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
	WR-MAV		WR-SMAV		WR-MAV		WR-SMAV		WR-MAV		WR-SMAV	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Weedy rice problem will increase if seeds are exchanged with other rice farmers												
TRUE	33	97	30	86	28	76	27	77	31	89	31	89
FALSE	1	3	3	9	7	19	7	20	3	9	2	6
Do not know	0	0	2	6	2	5	1	3	1	3	2	6
Available herbicides may reduce the weedy rice problem											0	
TRUE	17	50	15	43	10	27	12	34	17	49	16	46
FALSE	16	47	19	54	21	57	23	66	18	51	18	51
Do not know	1	3	1	3	6	16	0	0	0	0	1	3
The best way to reduce weedy rice is by cutting the panicles at harvest												
TRUE	31	91	27	77	28	76	30	86	27	77	26	74
FALSE	3	9	8	23	9	24	5	14	8	23	9	26
Do not know		0		0		0		0		0		0
Preparing the land properly can reduce weedy rice												
TRUE	30	88	31	89	31	84	29	83	25	71	29	83
FALSE	4	12	4	11	6	16	6	17	10	29	6	17
Do not know	0	0		0		0		0		0		0
Rotary weeder/cultivation can reduce weedy rice												
TRUE	30	88	32	91	23	62	16	46	11	31	19	54
FALSE	3	9	3	9	8	22	17	49	15	43	11	31
Do not know	1	3	0	0	6	16	2	6	9	26	5	14
Deep plowing will reduce weedy rice												
TRUE	21	62	18	51	26	70	22	63	14	40	21	60

	FALSE	10	29	16	46	8	22	11	31	21	60	13	37
	Do not know	3	9	1	3	3	8	2	6	0	0	1	3
Early flooding has no effect on weedy rice infestation													
	TRUE	17	50	16	46	19	51	19	54	21	60	21	60
	FALSE	16	47	19	54	15	41	15	43	14	40	13	37
	Do not know	1	3	0	0	3	8	1	3	0	0	1	3
A high seeding rate will reduce weedy rice													
	TRUE	17	50	18	51	13	35	16	46	15	43	19	54
	FALSE	12	35	16	46	22	59	19	54	19	54	15	43
	Do not know	5	15	1	3	2	5	0	0	1	3	1	3
Thoroughly cleaning farm machinery like the thresher/harvester or tractor will help limit infestation of weedy rice													
	TRUE	25	74	19	54	24	65	30	86	21	60	24	69
	FALSE	9	26	14	40	13	35	5	14	14	40	11	31
	Do not know	0	0	2	6	0	0	0	0	0	0	0	0
Field or irrigation canals should be cleared of weedy rice to limit infestation													
	TRUE	30	88	28	80	26	70	33	94	20	57	22	63
	FALSE	4	12	6	17	10	27	2	6	15	43	13	37
	Do not know		0	1	3	1	3	0	0	0	0	0	0
Repeated plowing during fallow period can reduce weedy rice													
	TRUE	32	94	32	91	28	76	21	60	25	71	26	74
	FALSE	2	6	3	9	7	19	11	31	10	29	9	26
	Do not know	0	0	0	0	2	5	3	9	0	0	0	0
Manual weeding is recommended/effective during serious infestation of weedy rice													

TRUE	31	91	31	89	33	89	29	83	33	94	33	94
FALSE	3	9	4	11	3	8	5	14	2	6	2	6
Do not know	1	3	0	0	1	3	1	3	0	0	0	0

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 20 Distribution of farmers' knowledge on the problems caused or effects of weedy rice

Item	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
	WR-MAV		WR-SMAV		WR-MAV		WR-SMAV		WR-MAV		WR-SMAV	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Weedy rice decreases the yield of cultivated rice as it competes with sunlight, fertilizer and other nutrients												
TRUE	34	100	35	100	34	92	29	83	33	94	35	100
FALSE	0	0	0	0	1	3	6	17	2	6	0	0
Do not know	0	0	0	0	2	5	0	0	0	0	0	0
Weedy rice reduces quality of rice/crop yield												
TRUE	33	97	35	100	34	92	34	97	34	97	34	97
FALSE	1	3	0	0	3	8	1	3	1	3	1	3
Do not know	0	0		0		0		0		0		0
Weedy rice does not affect the yield of cultivated rice												
TRUE	5	15	3	9	9	24	14	40	11	31	9	26
FALSE	29	85	31	89	26	70	21	60	24	69	26	74
Do not know	0	0	1	3	2	5	0	0	0	0	0	0
Weedy rice decreases the number of tillers of cultivated rice												
TRUE	33	97	35	100	25	68	26	74	31	89	33	94
FALSE	1	3	0	0	11	30	8	23	4	11	2	6
Do not know	0	0	0	0	1	3	1	3	0	0	0	0
Weedy rice can reduce the market value of the harvested rice												
TRUE	34	100	33	94	30	81	27	77	33	94	34	97
FALSE	0	0	2	6	5	14	7	20	2	6	1	3
Do not know	0	0	0	0	2	5	1	3	0	0	0	0
Weedy rice mixture increases the milling cost												
TRUE	21	62	19	54	24	65	20	57	16	46	13	37
FALSE	13	38	15	43	10	27	13	37	18	51	22	63
Do not know	0	0	1	3	3	8	2	6	1	3	0	0

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 21 Distribution of farmers who use herbicides for weedy rice

Item	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
	WR-MAV		WR-SMAV		WR-MAV		WR-SMAV		WR-MAV		WR-SMAV	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
User	15	44	19	54	16	43	23	66	13	37	13	37
Non-user	19	56	16	46	21	57	12	34	22	63	22	63
Total	34	100	35	100	37	100	35	100	35	100	35	100

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Distribution of farmers' reasons for not using herbicide on weedy rice

Reason	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
	WR-MAV		WR-SMAV		WR-MAV		WR-SMAV		WR-MAV		WR-SMAV	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Herbicide is not effective to control WR	18	95	15	100	5	25	8	67	17	71	20	95
Do not know what herbicide to use	0	0	0	0	6	30	0	0	4	17	0	0
Rice crop were also killed in herbicide	1	5	0	0	9	45	4	33	3	13	1	5
Total	19	100	15	100	20	100	12	100	24	100	21	100

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 22 Distribution of other management/control practices for weedy rice by farmers.

Management/control	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
	WR-MAV		WR-SMAV		WR-MAV		WR-SMAV		WR-MAV		WR-SMAV	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Field soaking	0	0	1	3	1	2	0	0	0	0	0	0
Manual weeding	27	66	27	68	23	41	17	28	29	56	23	59
Use of clean seeds	0	0	0	0	0	0	4	7	1	2	0	0
Use of transplanting method	0	0	0	0	3	5	1	2	2	4	1	3
Thorough plowing	1	2	0	0	1	2	3	5	0	0	0	0
Thorough land preparation	1	2	1	3	7	13	3	5	3	6	6	15
Good water management	3	7	5	13	5	9	9	15	8	15	6	15
Replace seed variety used	0	0	0	0	3	5	3	5	0	0	0	0
Herding of ducks	0	0	0	0	1	2	0	0	0	0	0	0
Cutting of panicles	9	22	6	15	10	18	20	33	8	15	3	8
Rice straw burning	0	0	0	0	2	4	0	0	1	2	0	0
Total	41	100	40	100	56	100	60	100	52	100	39	100

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 23 Distribution of common herbicide use by farmers to control weedy rice, January-June harvest

Brand	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
	WR-MAV		WR-SMAV		WR-MAV		WR-SMAV		WR-MAV		WR-SMAV	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
2,4-D	6	26	5	20	0	0	1	4	0	0	0	0
Advance	0	0	0	0	2	13	4	15	0	0	0	0
Agrobonds	0	0	0	0	0	0	2	8	0	0	0	0
Clearout	0	0	0	0	0	0	1	4	2	17	3	23
Clincher	0	0	0	0	0	0	3	12	0	0	0	0
Gramaxon	0	0	1	4	0	0	0	0	0	0	0	0
Ground plus	0	0	0	0	0	0	0	0	3	25	0	0
Guarantee	0	0	0	0	11	69	4	15	0	0	1	8
Hero	0	0	4	16	0	0	0	0	0	0	0	0
Machete	6	26	2	8	0	0	2	8	0	0	1	8
Nominee	4	17	5	20	1	6	1	4	1	8	3	23
Power	0	0	0	0	0	0	0	0	1	8	0	0
Pyanchor	0	0	0	0	2	13	0	0	0	0	0	0
Ricestar	1	4	1	4	0	0	1	4	3	25	2	15
Ronstar	0	0	0	0	0	0	2	8	1	8	2	15
Roundup	0	0	0	0	0	0	0	0	1	8	1	8
Sofit	6	26	7	28	0	0	5	19	0	0	0	0
Total	23	100	25	100	16	100	26	100	12	100	13	100

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 24 Distribution of common herbicide use by farmers to control weedy rice, July-December harvest

Brand	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
	WR-MAV		WR-SMAV		WR-MAV		WR-SMAV		WR-MAV		WR-SMAV	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
2,4-D	8	36	4	15	0	0	2	7	0	0	0	0
Advance	1	5	0	0	5	31	2	7	0	0	0	0
Agrobonds	0	0	0	0	0	0	2	7	0	0	0	0
Agroxon	0	0	1	4	0	0	0	0	0	0	0	0
Clearout	0	0	0	0	0	0	0	0	3	25	1	9
Clincher	0	0	0	0	0	0	5	19	0	0	0	0
Ground plus	0	0	0	0	0	0	0	0	2	17	0	0
Guarantee	0	0	0	0	9	56	6	22	0	0	1	9
Hero	0	0	4	15	0	0	0	0	0	0	0	0
Machete	2	9	7	27	0	0	1	4	0	0	2	18
Nominee	8	36	7	27	0	0	2	7	1	8	3	27
Power	0	0	0	0	0	0	0	0	1	8	0	0
Pyanchor	0	0	0	0	2	13	0	0	0	0	0	0
Ricestar	0	0	1	4	0	0	1	4	3	25	1	9
Ronstar	0	0	0	0	0	0	0	0	1	8	1	9
Roundup	0	0	0	0	0	0	0	0	1	8	1	9
Sofit	3	14	2	8	0	0	6	22	0	0	0	0
Sonic	0	0	0	0	0	0	0	0	0	0	1	9
Total	22	100	26	100	16	100	27	100	12	100	11	100

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 25 Distribution of type of sprayer and nozzle used by farmers

Type	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
	WR-MAV		WR-SMAV		WR-MAV		WR-SMAV		WR-MAV		WR-SMAV	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
January-June harvest												
Knapsack	15	100	19	100	16	100	21	100	11	100	13	100
July-December harvest												
Knapsack	15	100	19	100	16	100	20	100	11	100	13	100
January-June harvest												
Butterfly	0	0	0	0	8	50	3	14	0	0	1	8
Cone	12	80	15	79	0	0	0	0	0	0	0	0
Round	0	0	0	0	6	38	9	43	5	45	12	92
flat	3	20	4	21	2	13	9	43	6	55	0	0
July-December harvest												
Butterfly	0	0	0	0	8	50	3	14	0	0	1	8
Cone	12	80	15	79	0	0	0	0	0	0	0	0
Round	0	0	0	0	6	38	9	43	5	45	12	92
flat	3	20	4	21	2	13	9	43	6	55	0	0

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 26 Average herbicide cost (Php/ha) spent for weedy rice

Province		mean	min	max
Batangas				
MAV	January-June harvest	565.88	0.00	4050.00
	July-December harvest	621.18	0.00	4050.00
SMAV	January-June harvest	663.71	0.00	3500.00
	July-December harvest	669.71	0.00	4150.00
North Cotabato				
MAV	January-June harvest	479.46	0.00	1700.00
	July-December harvest	427.57	0.00	1280.00
SMAV	January-June harvest	638.57	0.00	2400.00
	July-December harvest	616.46	0.00	2400.00
Sultan Kudarat				
MAV	January-June harvest	361.50	0.00	1800.00
	July-December harvest	281.50	0.00	1800.00
SMAV	January-June harvest	348.89	0.00	1701.00
	July-December harvest	296.03	0.00	1701.00
Average	January-June harvest	509.12	0.00	4050.00
	July-December harvest	484.22	0.00	4150.00

Note: WR-MAV - weedy rice- most affected village
WR-SMAV - weedy rice- second most affected village

Tab. 27 Distribution of cropping year the weedy rice is first observed in the farm

Type	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
	WR-MAV		WR-SMAV		WR-MAV		WR-SMAV		WR-MAV		WR-SMAV	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1979	0	0	1	3	0	0	0	0	0	0	0	0
1982	0	0	1	3	0	0	0	0	0	0	0	0
1986	0	0	1	3	0	0	0	0	0	0	0	0
1987	1	3	0	0	0	0	0	0	0	0	0	0
1990	0	0	2	6	0	0	0	0	1	3	1	3
1995	2	6	2	6	0	0	0	0	0	0	0	0
1998	0	0	1	3	0	0	0	0	0	0	0	0
2000	11	32	9	26	0	0	0	0	2	6	3	9
2001	4	12	0	0	0	0	0	0	0	0	0	0
2002	0	0	1	3	0	0	0	0	0	0	1	3
2003	1	3	0	0	0	0	0	0	0	0	0	0
2004	1	3	0	0	0	0	0	0	0	0	0	0
2005	3	9	4	11	0	0	0	0	2	6	2	6
2007	0	0	1	3	0	0	0	0	1	3	0	0
2008	1	3	1	3	0	0	0	0	2	6	2	6
2009	1	3	2	6	0	0	0	0	1	3	0	0
2010	3	9	3	9	0	0	1	3	3	9	8	23
2011	0	0	1	3	1	3	0	0	1	3	1	3
2012	2	6	1	3	0	0	0	0	4	11	5	14
2013	2	6	0	0	6	16	8	23	8	23	4	11
2014	2	6	1	3	21	57	12	34	4	11	5	14
2015	0	0	3	9	9	24	14	40	6	17	3	9
Total	34	100	35	100	37	100	35	100	35	100	35	100

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 28 Distribution of cropping year the weedy rice is considered a problem in farm

Type	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
	WR-MAV		WR-SMAV		WR-MAV		WR-SMAV		WR-MAV		WR-SMAV	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1979	0	0	1	3	0	0	0	0	0	0	0	0
1987	1	3	0	0	0	0	0	0	0	0	0	0
1990	0	0	1	3	0	0	0	0	1	3	0	0
1995	1	3	1	3	0	0	0	0	0	0	0	0
1998	0	0	1	3	0	0	0	0	0	0	0	0
2000	3	9	2	6	0	0	0	0	1	3	2	6
2001	3	9	1	3	0	0	0	0	0	0	0	0
2004	1	3	0	0	0	0	0	0	0	0	0	0
2005	1	3	3	9	0	0	0	0	2	6	2	6
2006	0	0	1	3	0	0	0	0	0	0	0	0
2007	0	0	2	6	0	0	0	0	1	3	0	0
2008	0	0	2	6	0	0	0	0	2	6	1	3
2009	1	3	1	3	0	0	0	0	0	0	0	0
2010	6	18	2	6	0	0	0	0	2	6	5	14
2011	0	0	1	3	0	0	0	0	1	3	0	0
2012	3	9	1	3	0	0	0	0	1	3	1	3
2013	5	15	2	6	4	11	5	15	7	21	5	14
2014	5	15	6	17	20	57	14	42	5	15	11	31
2015	3	9	7	20	11	31	14	42	11	32	7	20
2016	0	0	0	0	0	0	0	0	0	0	1	3
Total	33	100	35	100	35	100	33	100	34	100	35	100

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 29 Cropping season the weedy rice is first observed in the farm

Type	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
	WR-MAV		WR-SMAV		WR-MAV		WR-SMAV		WR-MAV		WR-SMAV	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
DS	19	56	24	69	25	68	25	71	10	29	7	20
WS	15	44	11	31	12	32	10	29	25	71	28	80
Total	34	100	35	100	37	100	35	100	35	100	35	100

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 30 Perception of farmers considering weedy rice as a problem in the farm

	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
Type	**WR-MAV**		**WR-SMAV**		**WR-MAV**		**WR-SMAV**		**WR-MAV**		**WR-SMAV**	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
No	1	3	0	0	2	5	2	6	1	3	0	0
Yes	33	97	35	100	35	95	33	94	34	97	35	100
Total	34	100	35	100	37	100	35	100	35	100	35	100

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 31 Cropping season where the weedy rice is considered a problem in the farm

	BATANGAS				NORTH COTABATO				SULTAN KUDARAT			
Type	**WR-MAV**		**WR-SMAV**		**WR-MAV**		**WR-SMAV**		**WR-MAV**		**WR-SMAV**	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
DS	20	61	26	74	25	71	17	52	16	47	19	54
WS	13	39	9	26	10	29	16	48	18	53	16	46
Total	33	100	35	100	35	100	33	100	34	100	35	100

Note: WR-MAV - weedy rice- most affected village; WR-SMAV - weedy rice- second most affected village

Tab. 32 Opinion on how weedy rice reached the farm or community

Opinion	Batangas				North Cotabato				Sultan Kudarat			
	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Due to weather condition	0	0	1	2	2	4	0	0	2	5	0	0
Brought by the wind	0	0	1	2	3	6	1	2	2	5	0	0
Carried by man	2	4	0	0	0	0	0	0	1	3	0	0
Carried through irrigation/water	10	22	9	20	3	6	12	23	5	13	6	15
From the pesticides used	0	0	0	0	1	2	0	0	0	0	0	0
From the soil	6	13	7	16	2	4	6	12	6	15	4	10
Fom uncleaned farm machineries	1	2	1	2	6	12	6	12	16	40	3	7
No idea	7	16	3	7	6	12	3	6	2	5	6	15
Brought by animals	1	2	0	0	4	8	0	0	0	0	1	2
Through seeds bought	18	40	22	50	24	47	24	46	5	13	20	49
	0	0	0	0	0	0	0	0	1	3	1	2
Total	45	100	44	100	51	100	52	100	40	100	41	100

[1] - *weedy rice most affected villages*

[2] - *weedy rice second most affected villages*

Tab. 33 Distribution of common weed problems reported by farmers

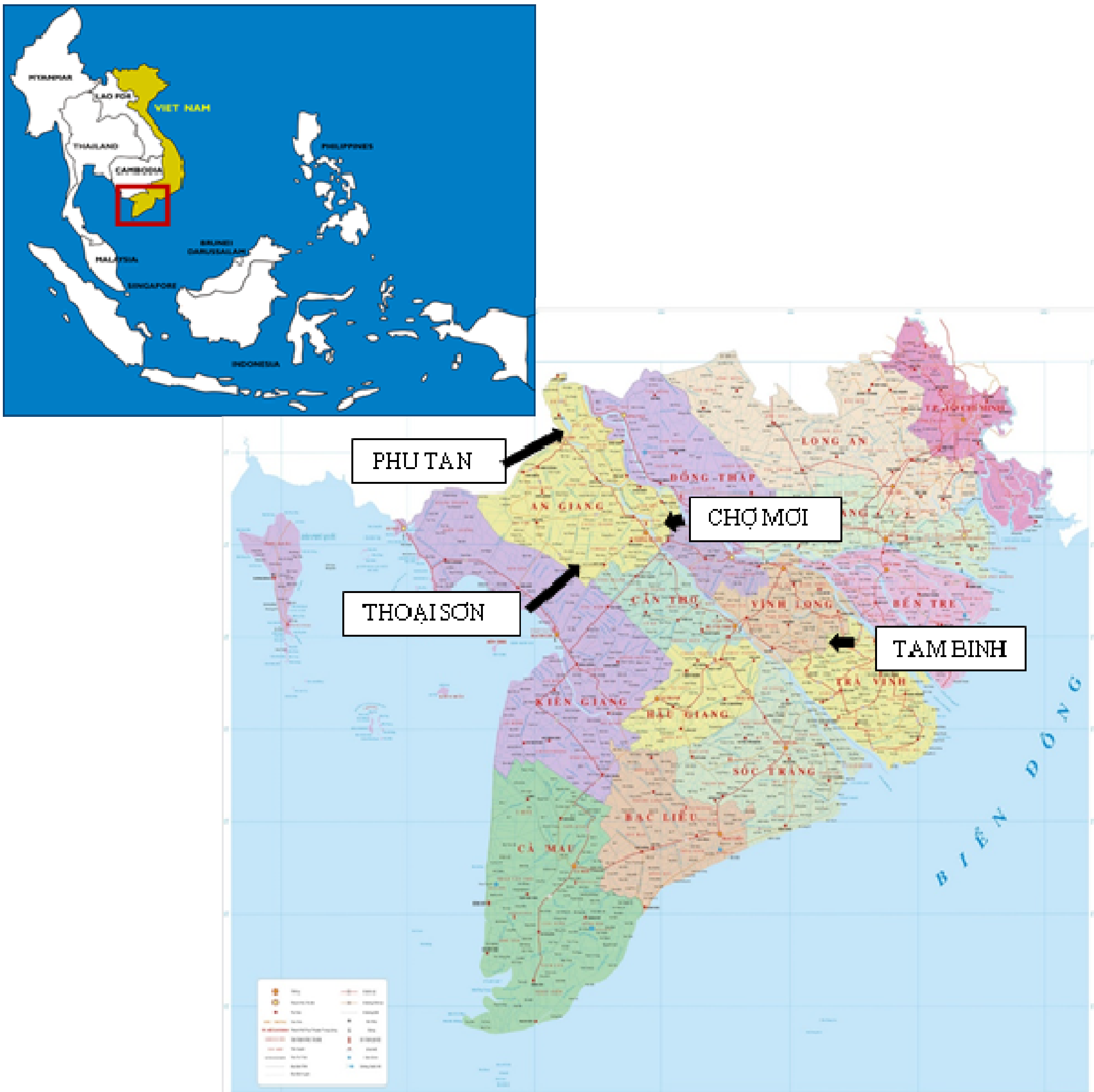
Weeds	Batangas				North Cotabato				Sultan Kudarat			
	MAV[1]		SMAV[2]		MAV[1]		SMAV[2]		MAV[1]		SMAV[2]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Echinochloa crus-galli	32	23	30	23	19	11	15	9	20	12	20	14
Oryza sativa	0	0	0	0	30	17	26	16	28	17	19	13
Echinochloa colona	0	0	0	0	25	14	22	13	32	19	24	17
Cyperus difformis	25	18	27	20	16	9	12	7	9	5	9	6
Leptochloa chinensis	2	1	2	2	8	5	16	10	31	18	27	19
Cyperus iria	1	1	0	0	18	10	24	15	23	14	16	11
Fimbristylis miliacea	6	4	7	5	18	10	17	10	7	4	6	4
Ischaemum rogusum	14	10	11	8	5	3	5	3	12	7	10	7
Monochoria vaginalis	21	15	21	16	2	1	0	0	1	1	0	0
Ludwigia hyssopyfolia	0	0	0	0	15	9	13	8	3	2	5	3
Eclipta prostrata	0	0	0	0	12	7	11	7	2	1	4	3
Sphenoclea zeylanica	6	4	5	4	4	2	4	2	1	1	2	1
Pistia stratiotes	7	5	7	5	0	0	0	0	0	0	0	0
Dactyloctenium aegyptium	9	7	5	4	0	0	0	0	0	0	0	0
Cynodon dactylon	5	4	7	5	1	1	0	0	0	0	0	0
Scirpus juncoides	5	4	6	5	0	0	0	0	0	0	0	0
Eichhornia crassipes	2	1	2	2	0	0	0	0	0	0	0	0
Paspalum distichum	1	1	1	1	0	0	0	0	0	0	0	0
Macroptillum lathyroides	0	0	1	1	0	0	0	0	0	0	0	0
Phyllantus debilis	1	1	0	0	0	0	0	0	0	0	0	0
None	0	0	0	0	0	0	0	0	0	0	1	1
Total	137	100	132	100	173	100	165	100	169	100	143	100

[1] - weedy rice most affected villages

[2] - weedy rice second most affected villages

9.2 Appendix 2:

Farmer survey to quantify perception, management practices and weedy rice infestation levels in the Southern Mekong Delta, Vietnam.



Prepared by:

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1.1. Annual cropping season schedule at Cho Moi site (An Giang province): (1): The Winter-Spring crop is established from November to January; (2) The Summer-Fall crop is lasted from April to July; (3) The Fall-Winter crop is established from August to November. Land preparation: 15 days before seeding time, by using a small ploughing machine to plough soil one time then plough soil is leveled from 1 to 2 times by other small soil leveling machine. Rice seed is soaked with clean water for 24 hours, then germinated seeds are broadcasted on the leveled land covered by 3-5 cm of water depth for 3 days then water is drained. The purpose of keep that water level in rice field is to control the weeds at this stage of rice.

1.2. Annual cropping season schedule at Phu Tan site (An Giang province): (1): The Winter-Spring crop is established from November to January; (2) The Summer-Fall crop is lasted from April to July; (3) The Fall-Winter crop is established from August to November. Land preparation: 5-15 days prior to seeding time, by using a small ploughing machine to plough soil one time then ploughed soil is leveled from 1 to 2 times by other small soil leveling machine. Rice seed is soaked with clean water for 24 hours, then germinated seeds are broadcasted on the leveled land which water is drained out. The water level in the rice field will be filled up after 3-6 seeding days.

1.3. Annual cropping season schedule at Thoai Son site (An Giang province): (1): The Winter-Spring crop is established from December to February; (2) The Summer-Fall crop is lasted from May to August; (3) The Fall-Winter crop is established from August to November. Land preparation: 5-15 days prior to seeding time, by using a small ploughing machine to plough soil one time then ploughed soil is leveled from 1 to 2 times by other small soil leveling machine. Rice seed is soaked with clean water for 24 hours, then germinated seeds are broadcasted on the leveled land which water is drained out. Then the rice field will be rewetted with water after 3-6 seeding days.

1.4. Annual cropping season schedule at Vinh Long province: (1): The Winter-Spring crop is established from end of November to February; (2) The Summer-Fall crop is lasted from April to July; (3) The Fall-Winter crop is established from August to November. Land preparation: 5-15 days prior to seeding time, by using a small ploughing machine to plough soil one time then ploughed soil is leveled from 1 to 2 times by other small soil leveling machine. Rice seed is soaked with clean water for 24 hours, then germinated seeds are broadcasted on the leveled land which water is drained out. Then the rice field will be rewetted with water after 3-6 seeding days.

Tab 1. Socio and farm characteristics of rice farmer-respondents affected by weedy rice (WR) in some areas of the Mekong Delta, 2015.

	Farmer Household (%)			
Socio-demographic characteristic	**Cho Moi (n = 31)**	**Phu Tan (n = 30)**	**Vinh Long (n = 34)**	**Thoai Son (n = 29)**
Age of head house hold				
20-35 years old	29	16.7	8.8	24
36-50 years old	38.7	60	32.4	20.7
51-65 years old	22.5	20	55.9	55.3
Over 66 years old	9.6	3.3	2.9	0
Sex (%)				
Female	0	0	8.8	6.9
Male	100	100	91.2	93.1
Educational level				
Elementary school	45.3	26.6	53	44.8
Secondary school	45.1	36.7	38.2	41.4
High school	9.6	36.7	8.8	13.8
Landholding				
Less than 0.5 ha	22.5	0	14.7	3.5
0.5 -1ha	35.4	33.3	58.8	44.8
More than 1 ha	41.9	66.7	26.5	51.7
Source of irrigation (%)				
NIS/CIS	100	100	0	100
STW/etc	0	0	0	0
Rain	0	0	0	0
River	0	0	100	0
Others	0	0	0	0
Crop establishment (%)				
Transplanting	0	6.7	2.9	0
Direct seeding	100	100	100	100

Tab 2. Adoption of direct-seeded rice (DSR) by farmer households (FH) in Cho Moi, Phu Tan, Thoai Son districts, An Giang province and Tam Binh district, Vinh Long province, 2015.

Reasons for adopting DSR	Farmer Household (%)			
	Cho Moi (n = 31)	Phu Tan (n = 30)	Vinh Long (n = 34)	Thoai Son (n = 29)
Higher cost of transplanting	79.4	86.7	61.8	89.7
Less time to establish DSR crop	93.5	96.7	100	96.6
Lower profit from transplanting	38.7	26.7	35.3	24
Lower labour requirement in DSR	64.5	70	97	55.2
Lower labour availability for transplanting	77.4	83.3	88.2	55.2
Similar profit from both transplanting and DSR	64.5	46.7	17.6	51.7
Low water availability	25.8	10	0	10.3
Lower water requirement in DSR	32.3	23.3	29.4	37.9
Others	0	0	0	0

Tab 3. Rice varieties, seeding rates, type of seed, seed soaking, seed treatment, and rice establishment practiced by farmer households (FH) in Cho Moi, Phu Tan, and Thoai Son districts, An Giang province and Tam Binh district, Vinh Long province, Vietnam, 2015.

Description	Farmer Household (%)			
	Cho Moi (n = 31)	Phu Tan (n = 30)	Vinh Long (n = 34)	Thoai Son (n = 29)
Rice variety				
IR50404	0	-	-	100
OM 6976	100	-	-	-
CK 92 (nếp)	-	83.4	-	-
CK 2003 (nếp)	-	13.3	-	-
AG 13 (nếp)	-	3.3	-	-
OM 5451			100	-
Seed rate (kg ha_1)				
Lower than 100	0	6.7	2.9	0
100-150	0	13.3	55.9	17.2
180-200	67.7	70	44.1	31
210-240	32.3	16.7	0	20.8
250-300	0	0	0	31
Type of seed				
Registered seeds	0	0	0	0
Certified seeds	0	0	100	48.3
Own seed stock	100	100	0	37.9
Farmer exchange	0	0	0	10.3
Time of seed soaking and incubation (h)				
24	35.5	14.3	44.1	13.7
36	19.4	7.1	23.5	27.6
48	3.2	46.4	26.5	48.3
72	41.9	32.2	5.9	10.3
Rice establishment				
Broadcasting	100	90	56	55.2
Row seeding	0	10	44	44.8
Transplanting	0	6.7	2.9	0

Tab 4. Reasons for selecting a variety for direct seeding by farmer households (FH) in Cho Moi, Phu Tan, and Thoai Son districts, An Giang province and Tam Binh district, Vinh Long province, Vietnam, 2015.

Reasons for selecting a particular variety	FH (%)			
	Cho Moi (n = 31)	**Phu Tan (n = 30)**	**Vinh Long (n = 34)**	**Thoai Son (n = 29)**
High yield	80.6	86.7	82.4	79.3
High price	64.5	60	29.4	10.3
More number of panicles	77.4	86.7	61.8	75.9
Low/high straw biomass	51.6	10	11.8	6.9
Bigger grains	74.2	53.3	47	75.9
Good eating quality	64.5	53.3	64.7	20.7
Good cooking quality	61.3	56.7	76.5	27.6
Seed availability	83.8	90	88.2	89.7
Suitable for soil type	87.1	100	79.4	82.8
Suitable for DSR	71	83.3	94	69
Suitable for transplanting	0	6.7	11.8	3.4
Resistant to insects	64.5	26.7	73.5	6.9
Resistant to diseases	83.8	43.3	70.6	13.8
Resistant to lodging	32.3	0	11.8	0
Tolerant to salt	0	0	2.9	0
Weed competitive	38.7	6.7	14.7	27.6
Easy to sell	74.2	83.3	88.2	82.8
Others	0	3.3	0	0

Tab 5. Timing of nutrient application in rice cultivation in Cho Moi, Phu Tan, and Thoai Son districts, An Giang province and Tam Binh district, Vinh Long province, Vietnam, 2015.

Timing of nutrient application (day after sowing (DAS))	Farmer Household (%)											
	Cho Moi (n = 31)			Phu Tan (n = 30)			Vinh Long (n = 34)			Thoai Son (n = 29)		
	N	**P_2O_5**	**K_2O**	**N**	**P_2O_5**	**K_2O**	**N**	**P_2O_5**	**K_2O**	**N**	**P_2O_5**	**K_2O**
7 – 10	83.9	19.4	3.2	96.7	13.3	10	64.7	64.7	64.7	100	82.8	20.7
15 – 24	100	90.3	6.5	83.3	63.3	20	91.2	88.2	91.2	79.3	79.3	51.7
25 – 35	93.5	87.1	64.5	70	66.7	56.7	50	47	50	72.4	82.8	69
36 – 45	48.4	38.7	93.5	63.3	60	70	97	97	97	34.5	31	37.9
60 – 65	0	0	0	20	20	26.7	0	0	0	3.4	0	3.4

Tab 6. Fertilizer rates of application used by farmers in rice cultivation in some areas of the Mekong Delta, 2015.

Parameter	Details	Farmer Household (%)			
		Cho Moi (n = 31)	Phu Tan (n = 30)	Vinh Long (n = 34)	Thoai Son (n = 29)
Nitrogen (N)	Recommended (100 kg N ha^{-1})	3.2	0	0	3.5
	Less than recommended	9.7	0	47	37.9
	More than recommended	87.1	100	53	58.6
Phosphorus (P_2O_5)	Recommended (60 kg P_2O_5 ha^{-1})	0	0	0	0
	Less than recommended	35.5	33.3	35.3	10.3
	More than recommended	64.5	66.7	64.7	89.7
Potassium (K_2O)	Recommended (30 kg K_2O ha^{-1})	22.6	3.3	11.8	17.2
	Less than recommended	12.9	16.7	0	13.8
	More than recommended	64.5	80	88.2	69
Total average dose		140N – 67.1 P_2O_5 – 51.9 K_2O kg.ha^{-1}	176N – 83.6 P_2O_5 – 65.4 K_2O kg.ha^{-1}	104N – 106 P_2O_5 – 54.3 K_2O kg.ha^{-1}	109N – 84 P_2O_5 – 52 K_2O kg.ha^{-1}

Tab 7. Water management in rice cultivation in some areas of the Mekong Delta, 2015.

Irrigation		Farmer Household (%)			
		Cho Moi (n = 31)	Phu Tan (n = 30)	Vinh Long (n = 34)	Thoai Son (n = 29)
First irrigation: (DAS)	0-5	3.2	3.3	29.4	6.9
	6-10	96.8	96.7	70.6	93.1
Number of times irrigation (times)	Less than 5 times	0	0	23.5	17.2
	5-6 times	0	0	0	44.8
	7 times	41.9	33.3	50	31
	9 times	19.4	16.7	11.8	0
	10 times	38.7	50	14.7	7
Water level (cm)	3-4 cm	25.8	10	8.8	31
	5 cm	41.9	83.3	58.8	55.2
	7-10 cm	32.3	6.7	32.4	13.8

Tab 8. Field levelling by farmer household in direct-seeded rice (DSR) in the Vietnam, 2015

Parameter	Farmer Household (%)			
	Cho Moi (n = 31)	Phu Tan (n = 30)	Vinh Long (n = 34)	Thoai Son (n = 29)
Do you level your field?	96.8	100	100	100
Benefits perceived from field levelling	96.8	100	100	100
Better water use	93.6	93.3	100	100
Better crop emergence	100	100	100	100
Better nutrient utilization	96.8	100	100	100
Better yield	100	96.7	100	100
Source of sufficient water	100	100	100	100
Gravity	100	96.7	0	100
Own well	0	0	0	0
Other sources	0	0	100 river	0

Tab 9. Major insect pests of rice of direct – seeded rice (DSR) as reported by farmers in some areas of the Mekong Delta, Vietnam, 2015.

No.	Insect type	Farmer Household (%)			
		Cho Moi (n = 31)	Phu Tan (n = 30)	Vinh Long (n = 34)	Thoai Son (n = 29)
1	*Steneostarsonemus spinki Smiley (nhện gié)*	3.2	73.3	61.8	69
2	*Spodoptera mauritia (Sâu keo)*	9.7	6.7	2.9	31
3	*Orseolia oryzae (Wood-Mason) (Muỗi hành)*	12.9	23.3	29.4	13.8
4	*Spodoptera mauritia (Sâu cánh chẻn)*	12.9	0	16.7	3.4
5	*Cnaphalocrocis medinalis (sâu cuốn lá)*	100	93.3	100	96.6
6	*Nymphula depunctalis (sâu phao, đục bẹ)*	32.3	6.7	17.6	27.6
7	*Scirpophaga incertulas (sâu đục thân-sâu óng)*	100	86.7	94	86.2
8	*Nivaparvata lugen (rầy nâu)*	32.3	93.3	91	62
9	*Baliothips biformis (bù lạch-bọ trĩ)*	19.4	80	44.1	55.2
10	*Others: Aleurolobus barodensis Maskell (bọ phấn trắng), spider mite (nhện đỏ), Spodoptera exigua Hübne (sâu xanh da láng)*	0	13.3	0	6.9

Tab 10. Predominant disease problems in rice production in some areas of the Mekong Delta, Vietnam, 2015.

No.	Disease type	Farmer Household (%)			
		Cho Moi (n = 31)	Phu Tan (n = 30)	Vinh Long (n = 34)	Thoai Son (n = 29)
1	Rotten neck blast (Thối cổ gié)	16.1	10	23.5	10.3
2	Leaf blast (đạo ôn lá)	87.1	93.3	85.3	96.6
3	Brown leaf spot (đốm nâu)	6.5	6.7	0	3.4
4	Mottled spot (đốm vằn)	16.1	53.3	56	65.5
5	Dark particular / grain *(lem lép hạt)*	29	90	82.4	51.7
6	Early ripening yellow leaf (vàng lá chin sớm)	32.3	70	14.7	62
7	Bacterial leaf blight (vi khuẩn)	58.1	76.7	85.3	75.9
8	Other blast	22.6	23.3	23.5	31
9	others	0	0	11.8	0

Tab 11. Knowledge of the Attributes of weedy rice of farmers in Viet Nam, 2015.

Attributes of weedy rice	Farmer Household (%)			
	Cho Moi (n = 31)	Phu Tan (n = 30)	Vinh Long (n = 34)	Thoai Son (n = 29)
1. Weedy rice is more common in direct-seeding.	77.4	46.7	94	58.6
2. Seeds of weedy rice have dormancy.	67.7	76.7	88.2	86.2
3. Grains of weedy rice shatter easily.	16.1	13.3	11.8	10.3
4. Weedy rice can be taller than cultivated rice.	90.3	93.3	91.2	96.6
5. Weedy rice is a type of weed in rice.	67.7	70	76.5	86.2
6. Awns can be absent in some weedy rice.	45.2	20	41.2	48.3
7. Weedy rice seeds left on the soil surface at harvest easily germinate.	93.6	100	88.2	100
8. Grains of weedy rice are all colored	83.9	93.3	100	89.7
9. The grain color of weedy rice after milling is always colored	74.2	80	97	86.2
10. It is possible to eat weedy rice.	67.7	93.3	85.3	89.7
11. Weedy rice can be harvested with cultivated rice.	41.9	73.3	86.7	55.2
12. Longevity of weedy rice seeds in soil is more than one year	80.7	90	91	100

Tab 12. Farmer-respondents knowledge of the incorrect attributes of weedy rice (WR) in the some areas of the Mekong Delta, Vietnam.

	Farmer Household (%)											
Attributes of weedy rice	**Cho Moi (n = 31)**			**Phu Tan (n = 30)**			**Vinh Long (n = 34)**			**Thoai Son (n = 29)**		
	True	**False**	**Not Sure**	**True**	**False**	**Not Sure**	**True**	**False**	**Not Sure**	**True**	**False**	**Not Sure**
WR is late-maturing	-	93.6	6.4	-	93.3	6.7	11.8	88.2	-	-	100	-
WR is only found in Vinh Long	32.3	58.1	9.6	16.7	66.7	16.6	5.9	85.3	8.8	20.7	62	17.3
WR has only one kind of panicle	35.5	54.8	9.7	16.7	80	3.3	5.9	91	3.1	20.7	65.5	13.8
WR have only closed panicles	51.6	22.6	25.8	33.3	53.3	13.4	38.2	55.9	5.9	31	48.3	20.7
WR can be harvested with cultivated rice	35.5	51.6	12.9	66.7	30	3.3	61.8	29.4	8.8	65.5	31	3.5
There is only one type/kind of WR	9.7	80.7	9.6	6.7	86.7	6.6	2.9	91.2	5.9	6.9	82.8	10.3
The grain (pericarp) color of WR after milling is always red	87.1	12.9	-	73.3	23.3	3.4	64.7	35.3	-	62	31	7
Grains of WR are all color red	51.6	22.6	25.8	33.3	63.3	3.4	29.4	70.6	-	65.5	27.6	6.9
Flag leaves of WR are always drooping	80.7	12.9	6.4	53.3	26.7	20	17.6	73.5	8.9	27.6	44.8	27.6

Tab 13. Knowledge of Management/Control of Weedy Rice of farmers in Viet Nam, 2015.

No	Management/Control of Weedy Rice	Farmer Household (%)			
		Cho Moi (n = 31)	Phu Tan (n = 30)	Vinh Long (n = 34)	Thoai Son (n = 29)
1	The best way to minimize WR is to use certified seed to prevent its infestations	100	100	97	72.4
2	Weedy rice problem will increase if seeds are exchanged with other rice farmers	87.1	73.3	91.2	62
3	Shifting from DSR to TR rice for two years can help minimize weedy rice infestations	64.5	76.7	88.2	72.4
4	Available herbicides may reduce the weedy rice problem	61.3	20	82.4	62
5	The best way to reduce weedy rice is by cutting the panicles	80.7	60	88.2	82.8
6	Good land preparation (repeated tillage) can reduce weedy rice	93.6	96.7	91.2	72.4
7	Early flooding has no effect on weedy rice infestation	58.1	26.7	44	44.8
8	A high seeding rate will reduce weedy rice.	45.2	60	20.6	34.5
9	Thoroughly cleaning of farm machinery like the thresher/harvester or tractor will help limit infestation of weedy rice.	61.3	76.7	91.2	51.7
10	Field or irrigation canals should be cleared of weedy rice to limit infestation.	93.6	86.7	82.4	89.7
11	Deep ploughing will reduce WR	35.5	23.3	38.2	75.9
12	Rotary weeder/cultivation can reduce WR	16.1	10	11.8	17.2
13	Repeated plowing during fallow period can reduce weedy rice.	35.5	63.3	82.4	55.2
14	Manual weeding is effective during serious infestation of weedy rice.	48.4	80	94	69
15	Weedy rice is hard to control in broadcast crop	71	86.7	97	79.3
16	Weedy rice problem can be reduce by row seeding (drum seeder)	51.6	33.3	76.5	51.7
17	Use of transplanting can reduce weedy rice problem	77.4	76.7	85.3	62
18	Use of clean seed can reduce weedy rice problem	96.8	96.7	100	96.6
19	Use of water seeding can reduce weedy rice problem	96.8	90	50	79.3
20	Use of crop rotation can reduce weedy rice problem	38.7	66.7	73.5	20.7
21	Continuous rice cropping can reduce weedy rice problem	22.6	23.3	58.8	6.9

Tab 14. Farmer-respondents knowledge of incorrect management practices for weedy rice (WR) in Viet Nam, 2015.

	Farmer Household (%)											
Management of weedy rice	**Cho Moi (n = 31)**			**Phu Tan (n = 30)**			**Vinh Long (n = 34)**			**Thoai Son (n = 29)**		
	True	**False**	**Not Sure**	**True**	**False**	**Not Sure**	**True**	**False**	**Not Sure**	**True**	**False**	**Not Sure**
Available herbicides may reduce the WR problem	61.3	32.3	6.4	20	73.3	6.7	82.4	17.6	-	62	31	7
Not preparing the land can reduce WR.	3.2	90.3	6.5	96.7	3.3	-	91.2	5.9	2.9	72.4	20.7	6.9
A high seeding rate will completely eliminate WR	45.2	45.2	9.6	60	33.3	6.7	20.6	73.5	5.9	34.5	51.7	13.8

Tab 15. Dominant weed species in rice fields in An Giang and Vinh Long, Viet Nam, 2015.

	Farmer Household (%)			
Weed species	**Cho Moi (n = 31)**	**Phu Tan (n = 30)**	**Vinh Long (n = 34)**	**Thoai Son (n = 29)**
Leptochloa chinensis (L.) Nees	90.3	56.7	88.2	65.5
Echinochloa crus-galli (L.) P. Beauv	83.9	63.3	94	58.6
Fimbristylis spp	93.5	63.3	88.2	20.7
Cyperus rotundus L	22.6	53.3	47	13.8
Oryza sativa (contamination)	93.5	70	97	37.9
Ludwigia octovalvis (Jacq.) Raven	19.4	0	20.6	0
Echinochloa colona (L.) Link	32.3	3.3	64.7	0
Ipomoea aquatic L	3.2	0	20.6	0
Paspalum distichum L	0	0	8.8	0
Marsilea minuta L	3.2	0	14.7	0
Cyperus nutans Vahl	67.7	26.7	47	10.3
Cyperus iria L	29	0	23.5	0
Cyperus elatus L	67.7	26.7	47	10.3
Cynodon dactylon (L.) Pers	3.2	0	0	0
Others	0	0	0	0

Tab 16. Herbicides used and herbicide spray techniques used by farmers in An Giang and Vinh Long, Viet Nam, 2015.

		Farmer Household (%)			
Parameter	**Details**	**Cho Moi (n = 31)**	**Phu Tan (n = 30)**	**Vinh Long (n = 34)**	**Thoai Son (n = 29)**
Herbicides	Only pre-emergence	90.3	76.7	94	58.6
	Only post-emergence	51.6	70	11.8	51.7
	Both pre- and post emergence	29	6.7	0	3.4
	Herbicides plus hand weeding	93.5	83.3	97	75.9
Pre-emergence application time	Immediately after sowing	22.6	50	85.3	34.5
	2 d after sowing	16.1	10	5.9	6.9
	3 - 4 d after sowing	51.6	26.7	5.9	62
Post-emergence application time	7- 10 d after sowing	32.3	40	8.8	10.3
	10 -15 d after sowing	12.9	6.7	0	10.3
	15 -20 d after sowing	16.1	20	0	3.4
Type of sprayer/ nozzle	Knapsack sprayer, 1 nozzle, spray	0	0	0	0
	Knapsack sprayer, 3 nozzles, spray	0	0	0	0
	Knapsack sprayer, 4 nozzles, spray	0	0	0	0
	Knapsack sprayer, 6 nozzles, spray	0	0	0	0
	Power sprayer, spray	100	100	100	100

Tab 17. Weed problem and improvement of weed management in direct-seeded rice in Cho Moi, Phu Tan, Thoai Son districts, An Giang and Tam Binh district, Vinh Long, Vietnam, 2015.

	Farmer Household (%)			
Description	**Cho Moi (n = 31)**	**Phu Tan (n = 30)**	**Vinh Long (n = 34)**	**Thoai Son (n = 29)**
Are weeds the main problem in DSR?	80.6	63.3	85.3	82.8
Are ‘other weeds’ a greater problem than weedy rice?	3.2	20	17.6	17.2
Weed management can be improved by:				
Discovering new molecules	71	60	55.9	62
Using weed-competitive varieties	77.4	50	32.4	31
Developing new implements	71	73.3	38.2	41.4
Using high seed rate	35.5	43.3	23.5	24
Using row spacing	29	16.7	79.4	44.8
Broadcasting with high seed rate	32.3	20	26.5	31
Using clean seeds	90.3	93.3	100	79.3
Using transplanting	32.3	63.3	94	6.9
Using good and pure seeds	93.6	90	100	79.3
Using clean machines	64.5	66.7	88.2	13.8
Keeping bunds and water channels clean	90.3	90	97	93
Taking out few survival plant in the field	54.8	90	100	58.6
Using appropriate herbicide	90.3	96.7	100	96.6
Using the correct dose of herbicide	90.3	90	100	72.4
Correct timing of herbicide application	96.8	93.3	100	100

Tab 18. Knowledge on the problems caused by weedy rice of farmers in Vinh Long site, 2015 (n=34).

Attributes of weedy rice	True		False		Don't know	
	No. of household	(%)	No. of household	(%)	No. of household	(%)
1. Weedy rice decreases the yield of cultivated rice as it competes with sunlight. fertilizer and other nutrients.	30	88.2	2	5.9	1	2.9
2. Weedy rice reduces quality of rice	29	85.3	3	8.8	1	2.9
3. Weedy rice does not affect the yield of cultivated rice.	2	5.9	26	76.5	2	5.9
4. Weedy rice decreases the number of tillers of cultivated rice.	30	88.2	3	8.8	1	2.9
5. Weedy rice can reduce the market value of the harvested rice.	30	88.2	2	5.9	1	2.9
6. Weedy rice cause lodging in cultivated rice	18	52.9	10	29.4	4	11.8
7. Weedy rice mixture increases the milling cost	12	35.3	17	50	4	11.8

Tab 19. Cost (US $ ha $^{-1}$) of rice production as reported by surveyed farmers in Viet Nam, 2015.

Items	Farmer Household (%)			
	Cho Moi (n = 31)	Phu Tan (n = 30)	Vinh Long (n = 34)	Thoai Son (n = 29)
Labor	197	240.3	194.5	264.4
Materials Inputs	588	695.4	489.3	639.1
Grain yield (Ton.ha^{-1})	7	7.5	6.3	7.2
Price (USD/rice ton)	209	219.2	206.2	191.7
Gross return	1518	1652.7	1291.7	1385.7
Profit	733	716.9	607.9	482.2
Cost of production (USD.ha^{-1})	785	935.8	683.8	903.5

9.3 Appendix 3:

Can Safeners Allow Selective Control of Weedy Rice Infesting Rice Crops?

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ABSTRACT

Rice is a major field crop of paramount importance for global food security. However, the increased adoption of more profitable and resource-efficient direct-seeded rice systems (DSR) has contributed to greater weed infestations including weedy rice that has become a severe problem in several Asian regions. In this study we have developed a conceptually novel method for selective herbicide control of weedy rice.

The insecticide phorate applied to rice seeds provided substantial level of protection against the herbicides clomazone or triallate. Fifteen kg phorate ha^{-1} significantly increased the LD_{50} values >2-fold greater than rice plants treated only with clomazone. Twenty kg phorate ha^{-1} in combination with 2,000 g triallate ha^{-1} safened rice plants (80% survival) with LD_{50} >3.4-fold greater than in phorate-untreated rice. Weed control efficacy was not lowered by the presence of phorate-treated rice seeds.

Weedy rice is one of the most damaging global weeds and a major threat of DSR systems. In this study we have developed a proof-of-concept method to allow selective weedy rice control in rice crops. We call for herbicide discovery programs to identify candidate safener and herbicide combinations to achieve herbicidal weedy rice control and alleviate weed infestations in global rice crops.

Keywords: Agricultural pesticides, Pest management systems, Rice, Seed physiology, Seed treatment, Weed management.

9.4 Appendix 4:

The weedy rice threat to food security in Asia: global insights into management

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Asia is the world's largest and most important rice-producing region. Pressure on water resources and increased labour costs have led to a major change from transplanted to direct-seeded rice (DSR). For example, weedy rice infestations are increasingly reported in DSR systems in different countries including Malaysia, Sri Lanka, Thailand, India, Korea, Philippines and Vietnam.

Table 1. Rice area (M ha) in selected Asian countries, Europe and USA, adoption of direct-seeded rice and year of first detection of weedy rice.

Country	Rice ha (10^6)	DSR (%)	Weedy rice
China	30	10	1960s
India	44	30	
Indonesia	12	20	
Japan	1.6	1.6	
Malaysia	0.7	70	1987
Philippines	4.5	40	1991
Sri Lanka	0.9	80	
Thailand	10	35	2001
Vietnam	8	50	1994
EU	0.5	100	Early 1900
USA	1.4	100	1846

(Adapted from Gealy *et al*, 2015; Gressel and Valverde, 2009; Matloob *et al*, 2014; Rao *et al*, 2007; Vidotto and Ferrero, 2005).

DSR offers many advantages, however, weeds, including weedy rice are the main constraint to productive DSR systems. Weedy rices are unwanted plants of *Oryza sativa* that compete with rice. Weedy rice increases production costs and reduces growers' profit through yield reduction. The major traits of weedy rice are early shattering of the grain and variable seed dormancy (Azmi and Karim, 2008; Delouche *et al*, 2007b). In Asia, weedy rice was reported to have greater nitrogen-use efficiency for shoot biomass than cultivated rice (Chauhan and Johnson, 2011). The use of contaminated planting seeds and weedy rice-infested equipment has helped in spreading weedy rice in several countries. In India, Awareness about the problem amongst farmers and management of weedy rice are the major concerns in India growers tend to categorize weedy rice as harmless 'off-types' and manage it by occasional manual rouging of panicles only. Farmers tend to abandon the land once it is heavily infested with weedy rice. With no selective herbicide available, land preparation practices are the sole method of its management.

Despite the greater availability of herbicides weeds and weedy rice remain a serious global constraint. This work has aimed to raise awareness on currently documented weedy rice infestation levels in Asia rice fields and proactively anticipate issues related to the adoption of new and highly effective technologies such as herbicide-resistant rice varieties (Clearfield™). In a recent survey in Vietnam, weedy rice infestation was the worst problem encountered in wet direct-seeded rice; however, most growers were aware of the presence of weedy rice in their fields and the damage it does to the crop (Chauhan *et al*, 2015). In a previous survey in the Philippines, about 40% of the growers did not know that seeds of weedy rice have dormancy (Tanzo *et al*, 2013). In the same survey, cutting the weedy rice panicles at harvest was practiced by majority of the respondents (82%). Both of these studies suggested a need to increase awareness about weedy rice among Asian growers.

Clearfield rice^{TM} is nontransgenic, herbicide-resistant rice, produced by mutagenesis and classical breeding (Croughan 1998). After 13 years since Clearfield rice^{TM} was commercialized, primarily to control weedy rice with imidazolinone herbicides, there are several reports of failure of the technology. It was launched almost simultaneously in the southern US, Latin America and South America, offering a novel opportunity to control weedy rice selectively in rice. In 2006, Clearfield rice^{TM} was commercialized in Italy, the largest rice-producing country in Europe (Sudianto et al. 2013). In 2010, Clearfield rice^{TM} was launched in Malaysia. 13 years since Clearfield^{TM} rice commercialization, crop-to-weed gene flow has led to hybridization between weedy rice and the crop and ALS-resistant weedy rice plants have invaded fields where Clearfield rice was grown. The greatest challenge with herbicide-resistant rice technology is the evolution of herbicide-resistant weedy rice via gene flow. No herbicide program can control all weeds all the time because of several mitigating factors (biotic or abiotic) – herbicide application parameters, weather; variability in weed emergence and growth stage; ecotypic diversity; seedbank size; farming practices; edaphic factors; and others. Therefore, some weedy rice are bound to escape some time, some place, and potentially hybridize with the herbicide-resistant crop. Such rare outcrosses are then selected by the herbicide (in this case, the imidazolinones), in succeeding seasons of planting Clearfield^{TM} rice, and will produce progenies carrying the herbicide-resistant trait that will gradually dominate the soil seedbank. This is documented in all regions where Clearfield^{TM} rice is grown; in some cases, after three cropping seasons.

The efficacy of a number of management strategies, established to be effective in rice ecosystems in the Americas and Europe, were reviewed and presented. Modeling simulations, parametrized on rice crops grown in temperate European conditions, showed the importance of weedy rice biological traits and the interaction with several cultural practices such as soil tillage, water management, herbicide treatment efficacy and crop rotation affecting the population dynamics of weedy rice. Importantly, new tactics, based on improved understanding of weedy rice biology and herbicide-weed physiological and biochemical interactions, towards safe and selective chemical weedy rice control in rice crops were discussed.

Some herbicides are toxic to germinating rice seedlings unless a specific herbicide safener is mixed with the herbicide compound in commercially available formulated products. Thus, we hypothesize the dissociated use of herbicide and specific safener will allow effective weedy rice control without causing injury to the rice crop (see also Shen *et al*, 2013). We hypothesize little damage or mortality in rice seeds exposed to the safener versus significant phyto-toxicity and mortality in rice seeds treated with the herbicide only. If our hypothesis will be confirmed we will be able to implement novel techniques for selective weedy rice control. It is important to emphasize that such a selective herbicide control of weedy rice in rice crops (herbicide ± safener) has never been achieved in commercial rice crops. Some preliminary results were presented and their relevance discussed.

We aimed towards a helpful and proficient satellite workshop on weedy rice as an important step towards increased awareness of weedy rice in Asia rice fields and possible control solutions based on improved understanding of weedy rice biology, physiology and biochemistry of the herbicide-weed interactions. As weeds in DSR remain an evolving challenge a continuous effort will be required as a global and dedicated endeavour.

Minimizing infestations of weedy rice and the co-evolving issues of herbicide-resistant rice weeds, will significantly contribute to sustain global food production and protect the income of small-hold Asian farmers.

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9.5 Appendix 5:

The weedy rice threat to food security in Asia: global insights into management

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Asia is the world's largest and most important rice-producing region. Pressure on water resources and increased labour costs have led to a major change from transplanted to direct-seeded rice (DSR). DSR offers many advantages, however, weeds, including weedy rice are the main constraint to productive DSR systems. Despite the greater availability of herbicides weeds and weedy rice remain a serious global constraint. This work aims to raise awareness on currently documented weedy rice infestation levels in Asia rice fields and proactively anticipate issues related to the adoption of new and highly effective technologies such as herbicide-resistant rice varieties (Clearfield™). Recent surveys in Vietnam and Philippines indicate the urgent need to increase awareness on weedy rice among Asian growers. After 13 years since Clearfield™ rice commercialization, crop-to-weed gene flow has led to hybridization between weedy rice and the crop and ALS-resistant weedy rice plants have invaded fields where Clearfield rice was grown. The efficacy of a number of management strategies, established to be effective in rice ecosystems in the Americas and Europe, are reviewed and will be presented. Modeling simulations, parametrized on rice crops grown in temperate European conditions, show the importance of weedy rice biological traits and the interaction with several cultural practices such as soil tillage, water management, herbicide treatment efficacy and crop rotation affecting the population dynamics of weedy rice. Importantly, new tactics, based on improved understanding of weedy rice biology and herbicide-weed physiological and biochemical interactions, towards safe and selective chemical weedy rice control in rice crops wil be discussed. Weeds in DSR represent an evolving challenge that will require a global and dedicated effort. Minimizing infestations of weedy rice and the co-evolving issues of herbicide-resistant rice weeds, will significantly contribute to sustain global food production and protect the income of small-hold Asian farmers.

9.6 Appendix 6:

Figure a). Weedy rice infesting Filipino rice fields.

Figure b). Weedy rice types infesting Filipino rice fields.

Figure c). Weedy rice types and grass weeds infesting Filipino rice fields.

Figure d). Weedy rice types and grass weeds infesting Vietnamese rice fields.

. Figure e). Weedy rice types and grass weeds infesting Vietnamese rice fields.

Figure f). Weedy rice types and grass weeds infesting Vietnamese rice fields.