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Australian Centre for International Agricultural Research

Final report

Small research and development activity

project	**Understanding Drill Seeding of Rice (DSR) techniques and business models in southern Lao PDR for sustaining adoption**
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Contents

1 Acknowledgments

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- The farmers and other stakeholders who engaged with the process. They committed time and displayed faith to participate, which we hope will be rewarded beyond the results they received at the feedback sessions.
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- Tamara Jackson, whose previous work in Savannakhet played a part in the rise of DSR. Tamara gave early guidance to this SRA.
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2 Executive summary

Direct-seeded rice (DSR) offers benefits to rice farming households by increasing labour productivity: more rice from existing labour, or freeing time from rice farming for other activities (Clarke *et al.*, 2018). In recent years, DSR has been adopted by more farmers in lowland Lao rice systems. More adoption will lead to more households benefitting, but the pattern of DSR adoption across time has not been linear. Area planted using DSR seems to have stalled, and even declined as some farmers have disadopted. This begs the question; why has adoption not continued to increase if the benefits are clear? This project was designed to address this question in the Savannakhet region of Lao PDR.

The objectives of the study were to:

1. Develop a greater understanding of drivers of, and barriers to, successful DSR and consequent rural livelihood enhancement.
2. Identify both technical and policy insights and recommendations.
3. Identify further interventions and research needed to respond to opportunities and challenges from adoption of DSR (e.g. management practices, information systems, supply and value chains, policy instruments, technical including machinery refinement, etc)

This project used a mix of qualitative and quantitative approaches to understand farmers' experiences with DSR, and the innovation process around adoption and use of DSR. Field observations were combined with individual interviews and focus group discussions. A participatory feedback approach was included, out of respect for the time committed by participants, to enable co-learning by all stakeholders and participants, and to refine the outputs for usefulness.

Two key documents have been produced from the results of this project: a technical brief, outlining the main technical findings and recommendations, and a policy brief, outlining the main policy context and recommendations. These documents formed the basis of our feedback process and any subsequent technical or policy dialogue.

The additional four farmer videos were developed to contribute to and encourage, farmer knowledge sharing on DSR approaches and applications.

A summary of the findings from the study includes the following points **:**

- Those farmers using direct-seeded rice (DSR) as a means to save labour (especially for women and girls), generally used the saved labour to diversify their livelihoods away from rice.
- Farmers are choosing different methods of DSR, combined with transplanting, to adapt to their different needs, different field conditions and variable rainfall patterns.
- Participants reported that weed control is the big determinant of success with DSR:
    - Weed-infestation was the most commonly cited reason for dissatisfaction with DSR
    - Better weed control was the most common way suggested by farmers to improve DSR
    - Weed-infested DSR can have very low yield and/or consume more labour in hand-weeding than saved from avoiding transplanting
    - Weed infestation was the most common reason cited for disadopting DSR
    - Weed competition generally increases with DSR, particularly where standing water is less reliable, like in higher toposequence fields.

- Participants reported that the fields/contexts that sustain DSR generally have a good ability to maintain standing water for weed control.
- Farmers are independently innovating to apply DSR in their context; most of this innovation is taking place independent of the government extension system.
- There has been DSR adoption, and disadoption, with disadoption occurring in response to weed infestation. Of those interviewed that use DSR, most farmers were satisfied with it, even if yields are typically a little less than with transplanting.

Recommendations:

Policy

- Given that some farmers have innovated and succeeded with DSR, good, open, accessible sharing of knowledge and experience between farmers seems the best way to expand successful DSR.
- Given the reported central role of standing water in sustainable DSR, any initiative that enhances standing water, by extending its duration or area will greatly aid the success of DSR. Conversely, contexts that are rarely able to achieve standing water will likely be retired from rice production in favour of non-rice crops or other uses.

Technical

- Improved weed identification skills amongst farmers and other stakeholders should aid weed management for sustainable DSR.
- Given the often-described story of increased weed competition leading to DSR disadoption, managing the weed seedbank seems to be both important for sustainable DSR, and under-appreciated to this point in time.
- Given that standing water was often cited as central to sustainable weed management, techniques to increase the extent and/or duration of standing water during the growing season will aid DSR uptake.

3 Summary of terms, abbreviations and acronyms

ADS	Lao PDR's Agricultural Development Strategy to 2025 and Vision to 2030
DoPLA	Department of Planning and Legal Affairs
DSR	Direct seeding of rice, including a range of techniques where producing seedlings and transplanting is not used (see below)
DDS	dry-drill seeding
WB	wet broadcasting, which broadcasts pre-germinated seed into a puddled soil
DB	dry broadcasting, which broadcasts dry seed onto dry soil and then incorporates the seed with harrows
Drum seeding	drum seeding places pre-germinated seed in rows onto a puddled soil
MAFF	Ministry of Agriculture, Forestry and Fisheries
NAFRI	National Agriculture and Forestry Research Institute
NUoL	National University of Laos
poor	Decree No. 201/PM :Definition of Poverty in Laos—Poverty is the deprivation of basic needs for the daily livelihood such as shortage of food that cannot provide the energy of 2100 Kcal/day/person, deprivation of clothes, durable shelter, inability to afford health care in case of sickness, inability to afford elementary education, inability to access public services.
SME	Small to medium enterprise

4 Introduction

The direct seeding of rice (DSR), whilst present in Lao PDR since at least the early 1990s, has been a focus of rice research in Lao PDR since about 2006. DSR includes dry-drill seeding (DDS) which places the seed in the soil with a seeder, wet broadcasting (WB) which broadcasts pre-germinated seed into a puddled soil, dry broadcasting (DB) which broadcasts dry seed onto dry soil and then incorporates the seed with harrows, and drum seeding which places pre-germinated seed in rows onto a puddled soil. Several recent ACIAR projects (CIM-2006-041, CSE-2009-004, SMCN-2012-071, LWR 2008-019, LWR-2012-110) have explored it; both broadcast-seeding, and the application of dry drill-seeding (DDS) in southern provinces. The 2009 ADB-IFAD SNRMPEP project sought to promote it in four districts of Savannakhet.

Following the widespread and rapid adoption of DSR in the Savannakhet province, Clarke & Jackson et al. (2018) showed that the rapid adoption was the result of a “perfect storm” of opportunities and challenges. They also showed the complexity of the adoption process and the importance of co-production of knowledge and engaging with stakeholders to foster innovation. Two years after their study, there is evidence that the innovation system around DSR is still evolving. This current project was designed to explore the ongoing innovation processes, including the further adaptation of DSR techniques and farming practices as well as new business models, diversification and social innovation.

Recent observations raise a series of questions about rice-system social innovation.

1. What DSR land preparation, seeding, and crop management is (or is not) working for Savannakhet lowland farmers and in what contexts? What might work in future?
    a. How are weeds being managed successfully? How could they be managed in the future?
2. What business models are (or are not) working to provide seeding services for rice and non-rice crops? What might work in the future?
    a. Can poorer households access DSR and will it improve their livelihood?
    b. What other implications does DSR have for poorer households?
3. For both of the above questions, what policy implications might this have? What implications for machinery specifications might this have?

Starting in 2014-15 in Savannakhet Province, there has been rapid uptake of DDS. The area of DDS in the province increased from only trial plots up to 2013, 80 ha in 2014, to an estimated 17,000 ha in 2016 (Clarke et al., 2018). Many seeders were purchased, and initial results were encouraging (yields were similar, labour input less). Since 2017, the area of DSR has stagnated or fallen in most rice-producing districts; some farmers have even returned to transplanting. This decline has been attributed partly to two high-rainfall wet seasons (reportedly causing difficulty in implementing DDS), but also to difficulties in managing increasing weed infestation. The uptake of DSR in Savannakhet has so far not been straightforward, and recent assumptions about large-scale uptake of DSR in lowland Lao PDR (Mullen et al, 2019) may not be valid.

As of 2018, DSR has been adopted in less than 5% of total rice production areas in 15 districts of Savannakhet province. Preliminary field observations and PAFO data indicate that the closer to the Mekong River, the greater the adoption of direct seeding practices; DDS adoption in the lowland areas close to the Mekong River is 10.2%, while away from the Mekong is only 1.7% of the total rice production areas, even less in mountainous areas (Table 1). Songkhone district has by far the largest DSR area with 7,750 ha.

Table 1: DDS adoption in rice production of Savannakhet province, wet season 2018

Area	Total Area of Rice (ha)	DDS (ha)	Percentage of Total Rice Production area
Mountainous Area	26,800	33.6	0.12
Lowland (far from Mekong River)	97,050	1,618	1.67
Lowland (near the Mekong river)	80,600	8,211.3	10.18
Total	204,500	9,862.9	4.82

Source: Savannakhet PAFO

Previous ACIAR research has shown that successful DSR can deliver substantial labour savings. There is no need to create a nursery, pull and transplant seedlings. Vial and Newby (2014) showed that DSR can save 30 percent of labour, but that saving can be lessened or even lost by greater labour required for weeding. Combine harvesting can save an additional 48 percent of labour compared to manual harvest (Table 2).

Table 2: The seasonal labour requirement (days.ha^{-1}) for transplanting, broadcast and drill-seeding.

	Transplanting	Broadcast	Drill-seeding
Land preparation	4	4	2
Nursery	3	-	-
Transplant	30	-	-
Seed	-	1	1
Fertilize	2	2	2
Maintenance	12	12	12
Weeding	0-10	0-40	0-30
Harvest (manual)	56	56	56
(Combine Harvest)	(5)	(5)	(5)
Total (for manual harvesting)	**107-117**	**75-115**	**73-103**

Data sourced from Vial and Newby (2014).

This labour reduction doubles the return to labour of combine-harvested rice from about 65,000 LAK/day to about 125,000 LAK/day, *provided both yield and weeding time is similar*.

Both Laing et al (2019) and Dalgliesh et al (2016) showed that DDS can lower yield variability between years in comparison to transplanting, as the rice can be established earlier before standing water is achieved. This allows earlier flowering and grain-fill, which reduces the chance of terminal drought stress and associated yield loss. This can be of great value to Lao rainfed systems, where terminal drought often reduces yield and quality, but early drought can greatly delay the achievement of standing water required for transplanting.

The aim of this SRA is to document the experience of direct-seeded rice (DSR) in Savannakhet to date, within the broader farming and social system. It aims to understand which approaches are more/less successful, the reasons for adoption, non-adoption and disadoption, and possible technical and policy insights and recommendations.

Key objectives of this study are to:

1. Develop a greater understanding of drivers of, and barriers to, successful DSR and consequent rural livelihood enhancement.
2. Identify both technical and policy insights and recommendations.
3. Identify further interventions and research needed to respond to opportunities and challenges from adoption of DSR (e.g. management practices, information systems, supply and value chains, policy instruments, technical including machinery refinement etc.)

5 Methodology

5.1 Research design

We used a qualitative, social-constructivist approach to explore the experiences, insights and perceptions of some farming households and communities in the DSR innovation system and the nature of innovation in DSR. This study builds on a previous study in Savannakhet, which used the innovation systems approach providing input to further develop innovation and livelihoods improvement in rice systems (Clarke *et al.*, 2018).

A participatory feedback approach was adopted to enable co-learning by all stakeholders and participants, increase the transparency of the research and make the outputs as useful as possible.

Because of the complexity of farming systems and the multiple cultural, economic, policy and biophysical influences on them, we adopted a broad approach, which takes account of the range of stakeholders, and their influence and experiences.

Participants for the research were drawn from three key groups:

a. Rice-based system farmers in Savannakhet Province
b. Policy and business stakeholders in Savannakhet Province
c. Policy and government stakeholders in the Lao National Government in Vientiane

We did aim to engage with poor farmers during our participatory feedback approach but only engaged with a few; we discuss this below.

5.2 Data collection and fieldwork methods

There were five strands to the data collection:

1. DSR field observations
2. Individual farmer interviews
3. Village-based focus groups
4. Interviews with policy and business stakeholders in Savannakhet province
5. Brief desk research and document analysis – particularly the Lao Agricultural Development Strategy to 2025 and Vision to 2030 (ADS), as it was based on a number of listed policy documents.

5.2.1 DSR field observations and interviews

A total of 35 farmers' fields, from 13 villages in 10 districts were chosen for field weed observations under the guidance of Dr. Deirdre Lemerle. Observations focused on the weed density and weed composition across a geographically very broad cross-section of DSR fields. The associated interviews with the farmers of those fields sought information on DSR practices and attitudes (Table 3, Figure 1). A subsequent 97 farmers, from 12 villages in 7 districts were chosen for the same interviews, but without field observations as widespread flooding precluded further field observations. We asked that poorer farmers be included in the sample set, but found that only one respondent identified as poor. The questions for both sets of interviews are listed in Appendix 5.

Upon realising that the poor farming households were under-represented in the process, we conducted interviews in two villages that were officially categorised as poor, in Phin district (the Lao government definition of poor appears in section 3). We interviewed a further 8 farmers, half of whom were rice insufficient.

Table 3: A list of the districts and villages for field observations with interviews, and solely interviews, with the number of participants (n).

District	Field observation + interview	n	Interview only	n
Near to Mekong:				
Songkhone	Muang Kai	6	Nonesomboun	8
			Nakhamnone	7
Champhone	Wattana	6	Nakhu	10
	Phaikhong	1	Phai	7
Outumphone	Naxaithong	3	Nahouakhoua	9
			Maet	7
Xaibuli	Nongsaphang	1	Thakham	7
			Dongnangam	1
			Berngse	6
Xaiphouthong	Dongmakfai	3	Thapho	14
Far from Mekong:				
Phalanxai	Phanomxai	4	-	
Sonbuli	Xienghom	2	-	
	Nonesavang	1		
Atsaphone	Vanghai	2	Pakkhayar	10
	Dongnangam	1		
Atsaphanthong	Jaeramong	2	Phongna	11
Mountainous area:				
Phin	Nathomkao	3	Nathomkao	4
			Nathomkhok	4

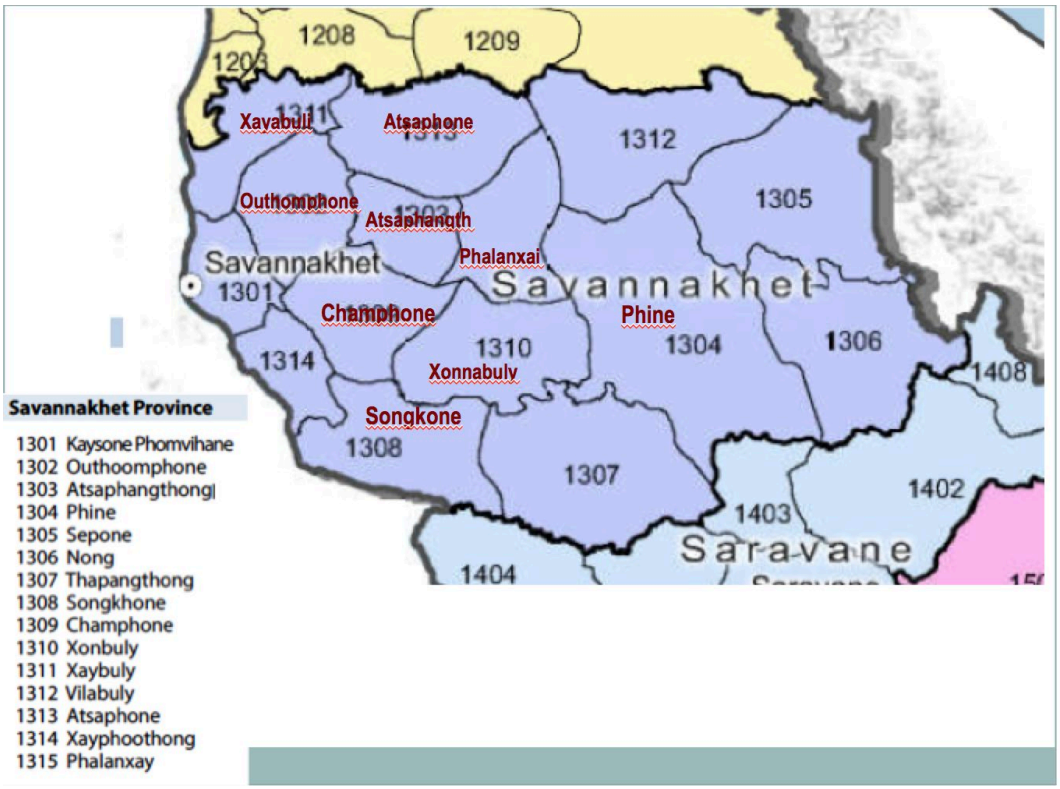


Figure 1: distribution of districts sampled for the focus group interviews in August 2018 (map from Laos atlas)

5.2.2 Focus group discussions

A total of 16 villages were chosen from five districts for focus group discussions, with representative villages from each of the three key areas (close to Mekong, far from Mekong and mountainous area) (Table 4). Village sampling was decided by the Lao researchers in consultation with the PAFO staff:

District data was looked at (from the last 3 to 4 years). Villages were selected that either:

- Had a relatively long history with DSR,
- Had changed techniques back to transplanting, at least some, and/or
- PAFO had not worked there before.

The focus group discussions included six to eight farmers including a mix of genders, farmers that still use at least some traditional transplanting, DSR adopters, and disadopters (Table 4). We did not specifically stipulate that poor farmers be included in these groups (the consequences of this are discussed below). Two villages (Lahanam and Muang Kai) were combined to allow the exchange of ideas and views between the farmer groups and to allow a greater opportunity for learning and exposure to new ideas among the group. Teams of three researchers worked with the groups. Two researchers acted as interviewers and the third recorded notes. No audio and video recordings were made.

After each focus group discussion, the interviewers developed a combined transcript of the discussion that was translated into English for the analysis stage. Indicative questions were prepared in an interview protocol (Appendix 4); the exact questions depended on the direction of the specific focus group discussion.

Table 4: List of villages, and interviewees per village included in the focus group discussions. M=male, F=female, DDS = dry drill seeding, WB = wet broadcast, DB = dry broadcast, TP = transplanted.

		Participants		Planting techniques used			
District	**Village**	**M**	**F**	**DDS**	**WB**	**DB**	**TP**
Near Mekong:							
Songkhone	Lahanam	6	5		x		x
	Muang Kai	2	1	x			x
	Nakala	6	3	x	x	x	x
Champhone	Phaikhong	4	3	x	x		x
	Wattana	6	3	x	x	x	x
Outumphone	Phonyanang	4	1	x			x
	Naxai	1	4	x		x	x
Xaibouli	Nadeng	5	1	x	x		x
Far from Mekong:							
Atsaphangthong	Lienxay	5	1	x			x
Atsaphone	Vanghay	4	2	x			x
	Nahungnoi	5	4	x	x		x
Xonnabouli	Xienghom	3	2	x	x	x	x
Mountainous area:							
Phin	Napor	2	2	x			x
	Nathomkao	2	3	x			x
	Chaeramong	3	11	x			x
Phalanxai	Phanomxai	3	3	x			x

5.2.3 Policy and business stakeholders in Savannakhet province

Semi-structured interviews were carried out with policy and business stakeholders involved in rice-based farming systems:

- Machinery suppliers
  - one in Savannakhet and one in Xeno
- Asian Development Partners (ADP), which has large mills in Savannakhet and Champassak
- Policy
  - Head of Department of Commerce and Industry
  - Department of Planning, Savannakhet
  - Head of PAFO, Savannakhet
  - Deputy Head of Irrigation department, Savannakhet PAFO
- Technical and extension
  - Director General of DAFO, Atsaphone
  - Deputy Director General of DAFO, Phine
  - Deputy head of the DAFO, Atsaphangthong
  - Head of Thassano Seed Production Center, Savannakhet
  - Head of Farmers' Group, Ban Tuat, Mr Bounsu

Interview protocol with indicative questions is in Appendix 4. The exact questions depended on the direction of the specific interview.

5.2.4 Desk research and document analysis

The primary desktop analysis was undertaken on the Lao Agricultural Development Strategy to 2025 and Vision to 2030. We focussed on this document had input from a range of other listed policy documents; both Lao and international, so we considered how our findings compared to the goals within it.

Other documents reviewed/considered during the SRA include:

DSR extension materials created and used in Savannakhet in the past eight years. Leigh Vial has both utilised and contributed to the creation of much of this material.

Keoka, K (2018) Advantages and Challenges of the Agro-ecology Development in Lao PDR, CIRAD

Bartlett, A (2015) Sustainable Farmer Organisations: DAEC Framework for Capacity-Building

A draft of 'Embedding green and sustainable agriculture in the Lao PDR policy agenda: A discussion paper' (2018), by National Agriculture and Forestry Research Institute (NAFRI), Department of Policy and Legal Affairs (DoPLA), The Agro-Biodiversity Initiative (TABI), Stockholm Environment Institute (SEI), Asia and Strengthening Policy Research for Agriculture Policy Development Project (SRAPD)

5.3 Analysis

5.3.1 DSR field observations and interviews

A list of the observed weed species (by scientific name) was generated. Across all the observed fields, both the frequency of the presence of each weed species and the frequency of overall weed density were analysed. The relative importance of each weed species was also analyzed, as ranked by the farmers of the observed fields.

The data from both the interviews conducted concurrently with field observations, and interviews conducted in isolation from field observations, were combined for the analysis. Both the tangible data (choice of seeding techniques, access to equipment, land

preparation, etc.) and the views of the interviewees were analysed by considering the frequency of each category. The views of interviewees were stratified according to their expressed satisfaction with DSR, as compared to transplanting.

5.3.2 Farmer focus group discussions and other stakeholder interviews

Transcripts were produced and translated into English (from Lao language) for analysis. The data analytical framework was the social innovation system framework that focuses on innovation systems and networks (Clarke & Jackson et al, 2018; The World Bank 2011), explore the actors, networks, and connections that foster and support ongoing change towards improved livelihoods.

The four key aspects (or categories) were:

1. Actors, the roles they play and the activities in which they are involved

2. Attitudes and practices of the actors

3. Patterns of interaction between the actors

4. The enabling environment.

The data was organised through narrative development, emergent themes, orienting concepts (based on the four aspects of the innovation framework) (Cresswell 2009; Jupp 2006; Patton 2002).

5.4 Feedback process

A feedback process was held to ensure that findings were appropriately shared, relevant stakeholders were consulted and the response to our findings was noted. This was conducted in three stages.

1. Policy dialogue with key stakeholders in Vientiane
2. Policy engagement process with key government stakeholders in Savannakhet.
3. Feedback and discussion with farmers and DAFO staff

5.4.1 Policy dialogue with key national stakeholders in Vientiane

Input and feedback from the policy group were through a policy dialogue workshop held in May 2019. During the policy dialogue workshop, the participants were presented with the preliminary analysis from the first two stakeholder groups (individual responses were made anonymous). Their response was then invited in a small group format, and incorporated into the consequent technical and policy briefs. In addition to the four SRA researchers, the notable participants were:

National participants:

- Dr Vanthong Phengvichith, NAFRI
- Dr Thavone Inthavong, NAFRI
- Dr Vongphaphane Manivong, DoPLA (Policy)
- Dr Phanxay Ingxay, DoPLA (Legal)
- Dr Somkhit Boulidam, NUOL Social Sciences Division
- Ms Dulce Simmanivong, ACIAR
- Mr Andrew Bartlett, Helvetas/SNV

Savannakhet participants:

- Mr Sisavanh Xayavong, Savannakhet PAFO
- Ms Ketsana Chantakhuamane, Savannakhet PAFO
- Mr Phetsamone Simali, Savannakhet PAFO
- Mrs. Korlakan Phesaisy, Songkhone DAFO
- Mrs. Veomany Thepvongsa, Champhone DAFO

Subsequent drafts of the policy brief have been shared with Drs Manivong and Ingxay from DoPLA, to ensure its greater relevance.

5.4.2 Policy engagement process with key government stakeholders in Savannakhet

Researchers presented results to provincial authorities, inviting their feedback on our technical and policy findings. We challenged them to respond to our findings, including what initiatives may be possible in the current context

- Deputy Director of Savannakhet PAFO
- Head of Agriculture Division, Savannakhet PAFO
- Representative of Planning and Investment Department, Savannakhet
- Representative of Industry and Commerce Department, Savannakhet
- Representative of Nanyobai Bank, Savannakhet

5.4.3 Feedback and discussion with farmers and DAFO staff

Researchers returned to each village that had hosted a focus group discussion. Both our technical and policy findings (from draft technical and policy briefs) were presented, and comments invited. In this process, DAFO staff were also informed of our findings.

In particular, researchers sought farmers' responses to the concepts of the weed seedbank, strategies for managing more weed prone contexts and vehicles for increasing farmer knowledge sharing.

6 Achievements against project activities and outputs/milestones

6.1 Achievements

Objective 1: To conduct focus group discussions in 15 villages, with complementary farmer and field surveys, and report the results

No.	Activity	Outputs/ Milestones	Completion date	Comments
1.1	Conduct the FGDs	FGDs conducted	August 2018	The FGDs worked well, and drew out good quantitative information.
1.2	Conduct field weed surveys	Field weed surveys conducted	August 2018	Field weed surveys were done under the guidance of Dr Deirdre Lemerle, Crawford Fund.
1.3	Conduct farmer interviews on DSR	Interviews conducted	March 2019	Done in two parts: during field surveys and stand-alone.
1.4	Report on the FGDs	Report written	February 2019	Report attached
1.5	Report on the field weed surveys	Report written	January 2019	Report attached
1.6	Report on farmer interviews	Report written	April 2019	Report attached

PC = partner country, A = Australia

Objective 2: To conduct a policy dialogue, then provide technical and policy briefs to both national and provincial government

No.	Activity	Outputs/ Milestones	Completion date	Comments
2.1	Conduct Policy Dialogue	Policy Dialogue conducted	May 2019	A wide range of relevant stakeholders attended, including policy actors from MAFF, senior officials from NAFRI, development actors etc .
2.2	Write Technical Brief	Technical Brief written	June 2019	Technical Brief attached. This has been shared with senior NAFRI staff, as well as senior Savannakhet stakeholders during the feedback process
2.3	Write Policy Brief	Policy Brief written	June 2019	Policy Brief attached. Two drafts of the policy brief have been shared with DoPLA and their feedback incorporated.
2.4	Conduct feedback sessions in all 15 FGD villages	Feedback sessions conducted	September 2019	
2.5	Adjust technical or policy briefs due to feedback	Adjustments made	October 2019	-

PC = partner country, A = Australia

7 Findings and discussion

7.1 Findings

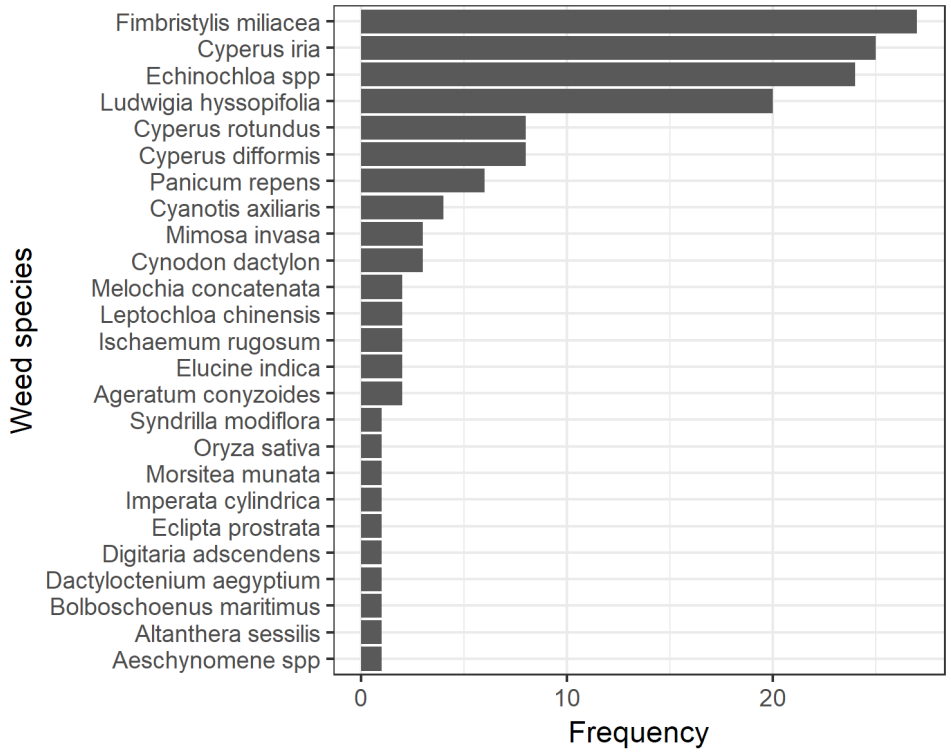
7.1.1 Weed status and management in observed fields

From the 35 DSR fields sampled we found the following:

- The most frequently encountered weeds were sedges, *Fimbristylis miliacea*, *Cyperus* spp. *iria*, *difformis* and *rotundus*, and the dominant grass genus identified was *Echinochloa* ssp. (differentiation between species was not possible) (Figure 2).
- High weed densities of more than 50 plants/m^2 were observed prior to hand-weeding in 21 of the 35 fields (60%).
- In 83% of the fields, farmers used only hand-weeding, 11% do nothing, and only 6% used some herbicide.
- 53% of the fields were dry-drill seeded, 28% dry broadcast and 14% wet broadcast.

The complete findings of this survey, including survey questions presented to farmers, can be found in Appendix 6.

Figure 2: Incidence of weed species observed in 35 rice fields in Savannakhet Province, Lao PDR. All fields were established using a direct seeding method.



7.1.2 DSR methods

Information generated during farmer interviews and discussion groups indicated that the choice of planting technique (including transplanting) is determined by a range of factors:

- Wet season rainfall pattern
- Labour availability
- Weed infestation
- Availability of machinery
- Soil type
- Toposequence position
- Ability of the field to retain standing water
- The household's tolerance to a reduction of grain yield that is assumed to occur with DSR, compared to transplanting

This suggests that the choice of planting method is, and will remain, diverse spatially and temporally and is an integral and useful aspect of the agricultural innovation system and farmer decision-making. Different establishment methods are used in different fields in the same year, and in the same field over different years.

DDS and dry broadcasting were by far the most popular DSR methods in the villages sampled for the 2018 wet season, comprising 54% and 22% of responses respectively. Another 8% used DDS only in some fields. Only 4 of the 132 interviewed farmers used wet broadcast seeding in the 2018 wet season, although we do know that wet broadcast seeding is common in the dry season irrigated areas, such as Songkhone and Champhone districts. Only 2 of the 132 interviewed farmers used drum seeding in 2018, in addition to one farmer in a focus group discussion, and another in a video interview.

There were several references in the focus group discussions to using different rice establishment methods in different contexts, and even sequentially in one field in one season. In particular, farmers reported that DDS or dry broadcast is typically used early in the season. If early heavy rain or drought causes that establishment to fail, then it may be followed with the same or another DSR method or transplanting. The sequential use of rice establishment methods, whilst still achieving timely establishment, is aided by the ability to use DDS earlier than traditional planting times.

"The DDS technique is easy and save time for me. In case when the soil is too wet caused by early rain, I will easily switch to the rice transplanting technique without any problem."

7.1.3 DSR yields, relative to transplanting

Farmers in the focus group discussions and the farmer interviews reported that yields were generally slightly less than that of transplanting (in fields with reasonable weed control), or greatly less yield (where weed competition is greater). Some farmers indicated superior DSR yields (especially with DDS or drum seeding) in some fields in some seasons, but the general pattern observed by the farmers was a slight yield penalty.

There were several references in the focus group discussions to weed-induced crop failures. High densities of weeds are very difficult to control with the typical hand-weeding methods. Farmers felt yields in fields with high weed burdens were typically less than half that of the transplanted rice field and could be close to zero. In addition to low yield, additional time spent hand-weeding can cost up to three times the labour originally saved using DSR. Some respondents reported ceasing weed control (a 'let-it-be' approach), and therefore accepting a very low yield.

7.1.4 Technical innovation

Farmers interviewed indicated significant motivation to use DSR, and a willingness and ability to innovate. Examples of DSR innovations farmers have developed or accessed include:

- Soaking seed before DDS;
- Placing fertilizer with the seed when using DDS;
- Home manufacture of 'extracted micro-organisms' (EM) for weed control;
- Selecting rice establishment method according to toposequence position;
- Selecting fields for DSR with a small weed seedbank;
- Sequential application of establishment technique with changing weather during the season, or with excessive weed infestation;
- Installing larger wheels on a drum seeder to make it easier to roll across the field;
- Khao Koo: growing volunteer wet season rice in the residue from irrigated dry season rice. Very few weeds emerge;
- Cutting the rice crop (and weeds) at 30-45 days after seeding, to achieve weed control;
- No-till drill-seeding of clay soil to avoid the need for (difficult, for some clay soils) land preparation.

It is worth noting that only the first and second listed innovation can be found in materials and messages in formal extension programs, be they regular or project-based. The other innovations have been undertaken using knowledge and experience gained outside the extension system.

7.1.5 Information sources

Farmers reported that they sourced information from a variety of channels and sources. While some of them reported learning from development projects and extension efforts, many others reported learning from neighbours and neighbouring villages, extended family, YouTube videos, and in one case a visit to rice farmers in Thailand. Only a very limited number of farmers reported engaging with the traditional extension system (which was reported to be mostly project-based); opportunities to engage with the extension system appear to be limited:

'…all information [from extension staff] seems to be transferred to farmers in a rushing and inappropriate manner that makes people confuse and practice the [DSR] technique wrongly.'

Some of the interviewees talked about being part of a 'coffee club' ('Sapha Café'), a traditional village forum. Farmers gathered in the local café to drink coffee and to share ideas about rice farming, amongst other things. In some villages, however, there appears to be little sharing of ideas, at least about DSR. In Jaeramong Village, for example, during the discussion of our presented findings during the feedback session, one farmer commented that they had never heard DSR issues discussed openly like that in the village, in a group setting or otherwise.

7.1.6 Adoption, disadoption and 'satisfaction'

In the focus group discussion, there was frequent mention of adoption of DSR, but also disadoption of DSR, usually necessitated by weeds. DSR was either disadopted in specific (usually weedy) fields or whole farms. Of those who had disadopted DDS in particular, some farmers had sold their seeders, but others are keeping it in the expectation/hope of re-adopting DDS in the future.

'Three out of the 14 interviewees continue their rice production with the DDS technique and the remaining 8 have switched back to the hand transplanting technique. All have tried for one or two years with the DDS and have confronted with high weed infestation

and yield decreasing. In the first year farmers are very happy with the DDS technique. They consider that the DDS is the promising technique for solving the labour shortage in the family even rice yield per hectare is equal or a little less than the yield of the transplanting technique. They observe that weeds are abundant in the second and subsequent years, which are one of the main causes leading to abandon the DDS technique of most [village named] farmers.'

Regardless of adoption and disadoption patterns, many farmers mentioned a uniform desire to use DSR, to gain the cost and labour savings.

"…once we know the method to deal with weeds we will practice the DDS technique again."

Of the 132 farmers interviewed who had adopted some form of DSR, most used either DDS or dry broadcast (Table 5). Wet seeding methods are not commonly used. Only six of the interviewees used wet seeding techniques in 2018 (Table 5), and wet seeding was only rarely mentioned in the focus group discussions, and once in the farmer video interviews. Wet broadcasting and some drum seeding are used in the dry season (when water can be controlled), especially in Songkhone and Champhone Districts.

Table 5: The Direct-seeded Rice (DSR) techniques used by interviewed farmers in Savannakhet province, Lao PDR.

Seeding technique	Frequency	%
Dry drill seeding (DDS)	79	55
Dry broadcast	30	23
'Broadcast'/'Seeding by hand'	5	4
Transplanting*	9	5
DDS and Dry broadcast	4	3
DDS, Dry broadcast and transplant	3	2
DDS and transplant	4	3
Wet Broadcast	4	3
Drum seeding	2	2
Total	**140**	**100**

*The farmers were selected as DSR farmers, so these interviewees solely using transplanting were not included in subsequent analysis.

Of the DDS farmer interviewed, 74% were satisfied with this technique, and 83% of the dry broadcast farmers were satisfied, almost all citing cost, time or labour savings. Almost all the dissatisfied farmers cited weed infestation or yield loss as the reason. 50% of DDS farmers and 71% of dry broadcast farmers interviewed cited weed control as the best improvement that could be made to the technique. 22% of DDS farmers cited better training on DDS as the best improvement that could be made.

7.1.7 Weed management in direct seeding of rice

Whilst there is some understanding of weed species and behaviour, there seems to be insufficient ability to consistently identify weed species for subsequent consideration of weed competitiveness, density, and consequent management. For example, in our discussion group and interviews a 'weed that looks like rice' could refer to *Echinachloa spp* or to weedy rice (*Oryza sativa*). However, these species have different behaviours and different consequences for DSR.

The observed DSR fields had high weed density in 2018; 60% of the direct-seeded fields sampled had a high weed density before weeding (more than 50 weeds/m^2). Farmers in the focus group discussions consistently described the process of weed build-up in their fields with progressive seasons of direct seeding:

'…if farmers apply continuously the DDS technique for rice production on a same plot for a period of three years weeds have more chance to grow. In the first year weed was not

much or even less comparing to the rice transplanting technique. He concluded that weeds are invaded in the second and third year if you cultivate rice on the same plot for 3 consecutive years.'

When asked the source of increasing weed density in DSR in the feedback process, participants had a range of views (e.g. weeds came from fertiliser, from manure or from the forest). Few appreciated that increasing weed pressure is most likely caused by the previous season's weeds seeding-down in situ to increase the weed seedbank.

Standing water still seems the most common form of weed control and limiting the weed seedbank. Low toposequence fields are favoured for DSR where standing water is more reliably achieved. DSR is generally not persistently used on many higher toposequence positions where standing water is less often achieved; increasing weed density leads to weed-induced crop failure and/or disadoption of DSR.

'The technique is suitable for the low-lying land areas with sufficient standing water in the rice field to effectively manage weeds.'

'Farmers who have been using DDS, but stop: they have problems with weeds and their fields higher and not suitable for this technique.'

'With irrigation water farmers can well manage weed and the DDS will be used again.'

'The upper part of the rice field does not have water when it has no rain for two or three days. Once the rice field lacks of standing water weeds are growing. [name withheld] said DDS technique is not suitable for sandy soil, which does not retain water and therefore weed germinates.'

During our feedback process, we identified three farmers in three different villages (Lienxay, Phine and Muangkai) who supplement their fields with pond water when necessary, to more reliably achieve standing water for weed control. The former two farmers appear on the interview videos featured below.

For DDS at least, farmers said that current equipment and techniques are more suited to prepare soil and seed the higher toposequence positions (sandier soils and better surface drainage); they are not so well suited to the low toposequence (clay soils and less surface drainage) where weed management is easier.

Herbicide use is not common; our small survey found only 6% of farmers using herbicides. Along with the desire to improve weed control, there is currently substantial resistance to using herbicide:

"We bought a bag of herbicide from a mobile Thai trader, who told us "organic herbicide". The smell is very bad when we open the bag. We decided not to use it and kept at the corner of our house said [the farmer]. We will throw it away, but we are afraid of destroying the environment."

7.1.8 Poor farmers adopting DSR

We did not engage deliberately with a large number of poor farmers, despite some attempt to. But, there was some mention of poor farmers in the process:

Poor farmers generally do not appear to interact with the extension system. This was demonstrated by their lack of engagement with this SRA, which was conducted within the extension system.

One interviewed poor farmer described how other villages donated both land preparation and seeding services to him to conduct DSR in the 2018 wet season. The one 'poor village' we managed to engage in follow-up interviews were very motivated to use DSR, as they believed it would allow them to better embrace their existing non-farm opportunities (work on an adjacent rubber plantation and textile production).

Of the only nine poor farmers interviewed:

Most had tried DSR (although the sample was likely biased to that), and all wished to try or continue using DSR. There was a mixture of rice-sufficient and rice-insufficient respondents, but their rice status did not seem to affect their enthusiasm for DSR. They generally learned of DSR, and accessed skills and experience, from within the village or a nearby village; the village head facilitated this in one village. Only two of the respondents had accessed DSR via a project. The respondents either hired a seeder (one had seeding services donated by the village), or borrowed a project seeder that was with the DAFO office. All respondents in one village claimed that access to a drill-seeder restricted their adoption of DSR; dry broadcast seeding (which does not require a seeder) was not mentioned in their response. There was frequent mention of the need for standing water for weed control, so fields with better standing water (can 'carry' water) were chosen for DSR.

7.2 Discussion:

7.2.1 Policy engagement process

The policy engagement process was complex and non-linear. Persistence was required, as the key individuals were not always available and one event or publication does not seem sufficient to progress a policy initiative. This points to the need to develop a communication process, rather than a one-off engagement over one piece of research.

Our iterative approach, with initial data collection followed by at least one feedback process, has been helpful in this respect. Provincial authorities, for example, were verbally/informally updated with initial findings, then participated in a subsequent small workshop where they were challenged for what actions were possible. Whilst no policy initiative has resulted, we have likely got closer to one by engaging in this way. Likewise, DoPLA has been consulted on three occasions; in the policy dialogue, and with two drafts of the policy brief. We did get good feedback on the first draft, but none to the second.

The process of two-way feedback in the policy dialogue held in Vientiane demonstrated the value of two-way dialogue. As a consequence of advice at the policy dialogue, we split our communications tools into two: one for policy and one for technical. For example, we identified two key audiences and documents: 1) a policy brief for the policy division in MAFF (Department of Policy and Legal Affairs, DoPLA); and 2) a technical brief for NAFRI and PAFO. This approach tailored the communication output to the audience.

Likewise, the feedback process to the participating villages gained us respect and goodwill, and several extra insights. Generally, our findings were vindicated. We found extra insights on the presence or absence of information-sharing opportunities, and also found several examples of longer-term successful DSR farmers, upon whom the farmer interview videos were centered. Farmers saw the feedback sessions as very useful for them and expected to often organize such similar activity in the future to share technical information and knowledge at the community level.

7.2.2 Policy implications

National rice production

The adoption of DSR will not be the mechanism to fulfill the desired rice production increase in the ADS. DSR in itself is unlikely to increase yields. DSR may well be a part of a reduction in rice area, as some high-weed-competition fields are retired from rice, and farmers use the time freed from rice farming to pursue other opportunities.

'Due to the difficulty of the weeding management for rice plantation, many of the farmers have turned their paddy fields into sugar cane plantation with the company.'

DSR can have an important role in stabilising rice production especially if rainfall variability continues or increases in the future. Using the different forms of DSR, rice crops can be successfully established with early onset of rains, late onset of rains, or re-established after crop failure from early drought or flooding. This aligns with the ADS's objective of providing options for adaptation to climate change, and providing more food stability with variable rainfall.

Currently, farmers using DSR do not appear to be able to readily link to the rice value chain options, including any consequent rice export that is an objective of the ADS. We were told by a large miller in Savannakhet that currently, DSR paddy is generally of inadequate quality for commercial purposes, as it is too often contaminated with excessive amounts of weed seed that make commercially milling and processing unviable.

Sustaining adoption of DSR

The adoption of DSR is neither linear nor simple. Approaches, perspectives, and experience of DSR vary widely. In addition, the interviews also show that the pathways to adoption are also very varied; some adopt after interaction with extension programs or projects, others adopt on their own initiative, others adopt (or do not adopt) after seeing local examples. Promotion of DSR adoption as a simple, linear process, and any planning based on this (eg extension, infrastructure, other promotion schemes), is likely to be incorrect.

Given standing water is still a central part of sustainable weed control in the absence of herbicides, any policy initiative that improves the extent and duration of standing water will likely help DSR adoption. This could mean establishing or improving irrigation facilities to providing standing water early in the wet season:

'They expect to have irrigation facilities for producing food in the dry season and with the irrigation they can better manage weeds in their rice fields.'

'Another challenge is that there is no irrigation system that is available in this community. Therefore, they have less ability to control water supply for their paddy rice and weeding is over controllable.'

It could mean facilitating the construction of farm ponds for water supply and drainage. A technique that two of our video-interviewed farmers already employ.

Livelihood diversification

In cases where DSR was successfully adopted, interviewees reported using the additional time (especially women's time) for diversification of livelihoods rather than to grow more rice. A range of other on-farm, off-farm (including transplanting for others) and non-farm options was mentioned. Many of the interviewees reported growing other crops rather than increasing rice production. For example, farmers reported growing vegetables, mushrooms, or sugar cane for the factory. This aligns with the Lao Government's Agricultural Development Strategy's objectives of increasing non-rice crops and livestock production. It also aligns with its objective of increasing the economic activity of SMEs and rural development, where non-farm opportunities are taken.

DSR particularly freed up the time of women, some of whom reported spending more time on weaving for commercial purposes or starting a retail business.

'DDS technique is very easy and requires only two men. So, women have time to do other work.'

'The women have time to join social work happening in the village'

Conversely, where DSR is being disadopted — due to weed-induced crop failure or otherwise — the livelihood diversification benefits are relinquished until DSR can be re-adopted.

Support for DSR innovation and adoption

DSR as a technique has less margin for error; yield declines from imperfect management are reported as greater than with transplanting. This is why some farmers disadopt DSR and return to transplanting. As such, the support systems around it need to be more substantial than with transplanting. Research, and especially extension and training will need to improve to support sustainable DSR adoption.

Most of the innovation with DSR to date has occurred outside of the formal extension system. It is understandable that resources for extension in Lao PDR are limited, so extension systems are limited in their ability to physically engage with farmers. Modern communication technologies, like YouTube, Facebook and other social media, give the extension systems the opportunity to engage a wider, receptive audience. This has already been done for some endeavours at NAFRI. Secondly, farmer-to-farmer knowledge and information sharing, either face-to-face or by other means, has facilitated most of the innovation to date. Viable, sustainable platforms for farmer-to-farmer knowledge sharing will do much to promote innovation and successful adoption of DSR. The Lao government's Agricultural Development Strategy has goals for the formation and use of farmer learning groups, supported by technicians. Farmer knowledge-sharing groups are a legitimate format for this — farmers generally gain knowledge and experience from each other, rather than solely from a technician.

The poor adopting DSR

Whilst this SRA was not successful in engaging with many poor farmers, we did observe that poor farmers are currently generally not engaged with the extension system more broadly. Farmer-based knowledge-sharing groups may give new opportunity for the poor to engage with DSR, these groups may be a better way of engaging poor farmers in an appropriate context. Any knowledge-sharing format should hence have accessibility of the poor in mind; it should not require much travel, access to technology or financial resources. A localised, inclusive format is likely best, perhaps aligned with the village temple or village head.

Some intervention to aid access to seeders might be more appropriate for poor farmers than for other farmers. We had not heard equipment access as being an issue in the interviews and focus group discussions with regular farmers, particularly with dry broadcast seeding being regarded as a realistic option. For farmers in general, free or subsidised equipment provision very rarely helps sustainable adoption of mechanisation (Martin Gummert, IRRI, pers.comm.). But, as part of an accessible knowledge-sharing group, aligned with existing village institutions, equipment provision should be more likely to help than usually.

Poor farmers are likely to be less tolerant of any decline in yield moving from transplanting to DSR. They generally have less paddy area and more likely to be rice insufficient. A yield decline is more undesirable; a sharp yield decline like a weed-induced crop failure could be catastrophic. Continued research, or guidance on DSR technique, that reduces or eliminates the yield decline associated with DSR compared to transplanting, will aid the poor in adopting and benefitting from DSR.

Poor families are also seeking and engaging particularly with non-farm and off-farm opportunities; their livelihood benefitting similarly or perhaps even more than other farmers. Extra time away from rice production activities, that successful DSR allows, may allow them to better embrace these opportunities.

7.2.3 Technical implications

Rice productivity

DSR seems a constructive way to deal with variable rainfall patterns between and within years. Dry broadcast or especially DDS are well suited to low-rainfall seasons, provided

weeds are controllable. Transplanting still seems to have a place in higher rainfall years. Wet broadcast and drum seeding can have a place in higher rainfall years (and/or where supplementary water is available), but research into techniques to reduce the risk of establishment failure from water-logging will help this. This could include anaerobic germination germplasm, or field choice and design to aid surface drainage.

Weed management

The weed seedbank (the quantity and composition of weed seed in the soil and consequent possible weed infestation in a crop) appears to be a central issue for DSR, and rice-growing in general. Any subsequent research needs to consider the role of the weed seedbank, and farmers' ability to manage weed seeds in their environment. In the absence of herbicides, it is very difficult to manage weeds once the weed seedbank is high, and this is a key factor in DSR disadoption.

There currently appears to be a limited understanding of the weed seedbank as a central driver of in-crop weed competition. Many farmers, researchers and extension agents focus on in-crop weed competition in any one season, rather than considering how that level of potential weed competition arose. Sustainable weed management will highlight the importance of maintaining a low weed seedbank over years to aid weed control. Some farmers do understand the weed seedbank dynamic (like our fourth video-interviewed farmer in Alan Wattana village).

The identification of weeds, and a subsequent understanding of their behaviour in DSR systems, is a central ability that farmers must have to sustainably adopt DSR. There is quite a bit of experience and understanding of some weed types and their behaviour, but it needs to be more thorough and complete. Some written material exists, but its scope is not complete or up-to-date. A hard copy or web-based Lao weed identification tool, that is accessible at the village level, will be enormously valuable.

Standing water still seems to be the primary method to both limit the weed seedbank and control weeds in-crop. Any agronomic innovation that increases the extent or duration of standing water will aid weed control.

'Some of them learn to use water to control weeds and they are effective [for DSR].'

This could include:

- Using supplementary water sources to enhance standing water
- Improving DSR on lower toposequence fields that have better standing water
- Better levelling to ensure uniform standing water
- Devising techniques to seed later in the season, when standing water is more reliable. Late seeding also allows prolonged land preparation for better weed control, and/or repeat seeding after a failed seeding event. Techniques could include:
    - Anaerobic germplasm to reduce the risk of crop loss from water-logging immediately after seeding (the vulnerable stage)
    - Field design, and field access to surface drainage, to enhance the ability to drain water from the field immediately after seeding for successful establishment
    - Short-season and/or photoperiod-sensitive germplasm to suit a late seeding time

In the village feedback sessions, participants' views were sought on deliberate late planting, to aid weed control, even if this reduced potential yield. Whilst we need to be wary that the concept may not have been fully understood as it was presented, the general response was that late-seeding seems a sensible option to have, if suitable germplasm was available to moderate yield decline.

8 Other outputs

8.1 Videos

Four short video interviews were made of successful DDS farmers in Savannakhet:

- Mr Vanxay, Lhienxay Village
- Mr Sisomnyon, Phine Village, Outumphone District
- Mr Daphandone, Vanghay Village, Atsaphone District
- Mr Don, Alan Wattana Village, Champhone District

These videos were made (somewhat spur-of-the-moment for the first one!) both as a specific record of successful DSR farmers to share with others, and as an example of using electronic means to reach a wider audience.

Links, in same order:

https://www.youtube.com/watch?v=VOyQSETcWx0&t=21s

https://www.youtube.com/watch?v=cy86HLUqA1s

https://www.youtube.com/watch?v=BOrRI-P-tCY

https://www.youtube.com/watch?v=3WVFt-Q2Fxo

8.2 Field trials

Limited field trials and demonstrations were pursued in four villages in the 2019 wet season, and are reported in Appendix 3. These trials featured:

- Placement of basal fertiliser with the seed
- Cutting the crop at about 60 DAS for weed control
- Inter-row cultivation with a powered implement (a whipper snipper)

The results from these trials were modest; primarily due to unhelpful weather. Rains came very late at most sites, and then flooding followed shortly after!

The main conclusions were:

- Placing basal fertiliser with the seed, compared to broadcasting it 14 DAS, increased early vigour but this effect did not necessarily persist later in the season nor increase grain yield.
- Inter-row cultivation with a tyned implement failed, due to the inability to accurately guide the implement and the poor structure (tilth) of the soil.
- Inter-row cutting of individual inter-rows with a powered implement was quite successful
    - Small and/or more sparse weeds were easier to cut
    - The rice plants need to be about 60 DAS to be large enough for good guidance in the inter-row and less risk of damage (this increases the risk of weeds growing to a larger size in this time, causing larger yield loss and needing more power and torque to cut)
    - Cutting larger weeds requires substantial power and torque from the inter-row cutter, particularly at high weed density. It may well wear out the cutter prematurely.
- Cutting the rice and weeds at about 60 DAS did not control weeds
    - This may have been due to the cut material being removed for animal fodder, so not forming a mulch for weed control.

9 Impacts

9.1 Scientific impacts

The primary scientific impact to date has been to introduce the concept of the weed seedbank to Lao scientists and policymakers. Whilst the presence of weeds in-crop is always referred to, and the phenomenon of increasing weeds after changing to DSR is acknowledged, the direct connection with weed seedbank behaviour has not been made. The introduction of this concept allows consideration of what can be done within the rice system over years, rather than just the one season.

No papers have been published as yet, but a presentation of our findings from the weed survey was presented at the annual APWSS conference September 3-6, 2019.

9.2 Capacity impacts

Capacity was developed primarily in Savannakhet; staff of the provincial and district agriculture offices.

1. The staff at the PAFO Agriculture Land and Management Division (Sisavanh Xayavong, Ketsana Chantakoumane and Phetsamone Simali) learned about the design and application of qualitative and participatory research methods. This included preparation of discussion questions, selection of villages and participants, conduct of the focus group discussions, analysis of the data and the feedback process (Figure 3). The method of the first half of the focus group discussions being led by the two Lao consultants and PAFO staff leading the remaining half, allowed PAFO staff to learn the method and then apply it. Judging by the summary report, they successfully applied the method unsupervised. All three staff appreciated the insights gained on the current status of DSR and views on it by application of these methods; we were seeking unknown unknowns!

Figure 3: Mr Phetsamone Simali engaging with farmers from Phin District during the feedback sessions.

2. The DAFO staff at five district offices gained by seeing the application of qualitative and participatory methods. Whilst they were not involved in the design or analysis, they were integral to the village and participant selection and conduct of the focus group discussions and feedback sessions. Some of them frankly

expressed that they had opportunity to learn for the first time on how the DSR technique is applied in the field.

3. The PAFO staff learned how to prepare and record interviews with successful DSR farmers. Modern communication technologies offer many opportunities for extension staff to engage with a larger number of farmers.
4. The two AVI volunteers, Matt Champness in particular, have benefitted by engaging with our activities after his arrival in Savannakhet in March 2019. In particular, he joined the feedback sessions and the design and conduct of the field trials/demonstrations. Matt has rewarded us with the concoction of a powered inter-row weeder; a clever attachment to a whipper-snipper. This has been a helpful step. Inter-row cultivators are not new, but this one — by only partially engaging with the soil — seems best adapted to the challenging Acrisols we find in Savannakhet.
5. The PAFO staff learned weed identification techniques whilst conducting the weed survey under the guidance of Deirdre Lemerle.
6. PAFO, DAFO and NAFRI staff learnt the necessity of policy level intervention and private sector engagement in promoting the DSR technique and without it it is difficult to increase the adoption rate.

9.3 Community impacts

The community impacts will only come if the success of DSR as a technique increases in southern Lao PDR, and the associated socio-economic impacts are felt. We are unable to credit this SRA for an increment of DSR adoption, that would represent an impact.

9.3.1 Economic impacts

Successful DSR contributes to household livelihoods and rural economic development primarily by allowing farmers to diversify their livelihood; on-farm, off-farm or non-farm. A greater area of successful DSR will increase the benefits of this livelihood diversification and increased returns to labour especially. But, weed-induced DSR failure can be quite damaging to household livelihood.

9.3.2 Social impacts

Many of the social impacts will be a consequence of the aforementioned economic impacts: farming households using time freed from rice farming to diversify their livelihoods on-farm, off-farm and non-farm. This will likely accelerate out-migration from rural areas, to better non-farm options and provide more opportunities for young people to continue their education with minimum interruption during the rice growing season.

A second social impact observed in our study is a changed social dynamic in places, where (younger) farmers undertake an innovation with respect to DSR (learned independently or from others) without necessarily seeking approval from elders, which is usually the case. Likewise, some social norms around time for transplanting are being put aside to accommodate the different seeding times with DSR. Village livestock management needs to do the same!

9.3.3 Environmental impacts

If DSR can be adopted broadly, *without widespread use of herbicides*, this would be a beneficial environment and human health and safety outcome. Most, if not all, DSR systems elsewhere are reliant on herbicides, usually in the context of poor product regulation and poor application safety. Lao PDR seems to be different. Most farmers and certainly all policymakers would prefer to avoid herbicides; it appears that farmers will disadopt DSR rather than using herbicides. This will be fascinating to watch.

10 Conclusions and recommendations

10.1 Conclusions

Our research findings re-affirm the benefits that flow from the adoption of DSR. However, the challenges faced by farmers as they transition from traditional planting techniques to DSR should not be underestimated. At this stage, in this region of Lao PDR, sustained adoption of DSR with successful outcomes for the farm household is restricted to farmers who:

- Have fields that have some ability to maintain standing water in the growing season;
- Have some ability to adapt different DSR methods to suit their needs and field conditions;
- Have the capacity to absorb the risk associated with crop failures due to weed infestation;
- Have fields with low weed infestation and some ability to manage weeds through a combination of hand-weeding and managing standing water. Hand weeding is inadequate in the absence of reliable standing water.

Farmers who are not in this position are unlikely to be successful over multiple seasons. This will lead to disadoption of DSR. We have suggested a range of policy and technical solutions to help farmers overcome these challenges and adapt DSR to suit their situation and needs.

Any mechanism which enhances the duration or extent of standing water in the growing season will aid DSR. That may involve supplementing standing water, it may involve choosing a growing season that has better standing water.

Farmer-based knowledge sharing is very likely the means to wider DSR adoption. Enough innovation, knowledge and experience already exists amongst farmers but it needs to be shared better. Longer-term successful DSR practitioners exist now. The current extension methods will not suffice; its penetration is inadequate and its uniform recommendations will not service the wide array of situations to which DSR can be applied.

Poor farmers can likewise gain from DSR, perhaps moreso than others, but DSR yields need to be similar to transplanting. The techniques need to be refined with research, and guidance on DSR (farmer-based knowledge sharing) needs to be accessible to the poor. Some equipment provision, whilst not usually advisable, may be appropriate as part of a farmer-based knowledge-sharing group.

10.2 Recommendations

As a result of the qualitative and quantitative approaches used in this study to understand and document farmers' experiences with DSR we developed a series of technical and policy recommendations that are listed in Appendices 1 and 2. Our broader recommendations are:

There is a research gap in relation to weed management in DSR systems that has not been adequately addressed in the Lao context. Understanding the weed seedbank is at the centre of it. Whilst herbicides are used successfully in other countries, there is a need to develop non-chemical solutions for Lao farmers. Lao farmers and leaders alike wish to avoid widespread herbicide use.

Some farmers have been able to succeed with sustainable DSR in their own context. The sharing of knowledge and experience between farmers appears to be the best way to facilitate the sustained adoption of DSR by individual farmers. Whilst many farmers are

trialing DSR techniques, unless they are supported to adapt and change the techniques to suit their needs and contexts they may not sustainably adopt DSR.

Poor farmers can gain from DSR; it can enable them to grasp other livelihood opportunities. But, DSR must be a reliable option for them; the yield must be similar to transplanting, and weed-induced crop failures must be avoided. An inclusive form of farmer-based knowledge sharing can likely achieve this, provided it is genuinely accessible to the poor. There may be a place for a pilot trial — in conjunction with a farmer-based knowledge sharing group and perhaps an NGO — where some insurance is offered against large yield decline, and access to basic equipment is facilitated, until they are sufficiently experienced with DSR. In future DSR research should stratify for poor farmers, to interrogate the conclusions we have made.

The participatory approach in the SRA seemed to work well, although it did consume time. Engaging openly with participants on DSR issues gave ample opportunity for them to share their views. Following up with feedback to the participants allowed plenty of opportunity to test and refine those insights particularly as goodwill was built. Future projects should consider feedback of findings to participants, above and beyond the written form, as part of M&E activities.

11 References

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11.2 List of publications produced by project

No publications have been produced as yet

12 Appendices

12.1 Appendix 1: Technical brief

Technical Brief for SRA CIM-2018-113: Innovation, adoption and disadoption of DSR in Savannakhet, Lao PDR

Leigh Vial, Khamlouang Keoka, Amphone Vongsouphanh, Elizabeth Clarke and Sisavanh Xayavong

1. Background

This technical brief has been developed as a product of a Small Research Activity commissioned and funded by the Australian Centre for International Agricultural Research (ACIAR) in collaboration with NAFRI and the Savannakhet PAFO.

The direct seeding of rice (DSR), whilst present in Lao PDR since at least the early 1990s, has been a focus of rice research since about 2006. DSR includes dry-drill seeding (DDS) which places the seed in the soil with a seeder, wet broadcasting (WB) which broadcasts pre-germinated seed into a puddled soil, dry broadcasting (DB) which broadcasts dry seed onto dry soil and then incorporates the seed with harrows, and drum seeding which places pre-germinated seed in rows onto a puddled soil. Several recent ACIAR projects (CIM-2006-041, CSE-2009-004, SMCN-2012-071, LWR 2008-019, LWR-2012-110) have explored it; both broadcast-seeding, and particularly the application of dry drill-seeding (DDS) in southern provinces. The 2009 ADB-IFAD SNRMPEP project sought to promote it in four districts of Savannakhet.

From about 2014-15 in Savannakhet Province in particular, there was a rapid uptake of DDS. The area of DDS in the province increased from only trial plots up to 2013, 80 ha in 2014, to more than 17,000 ha in 2016 (Clarke et al., 2018). Many seeders were purchased, and initial results encouraging (yields were similar, labour input less). Since 2017, the area of DSR has stagnated or fallen in most rice-producing districts; some farmers/fields have even returned to transplanting. Farmers interviewed attributed the decline partly to two high-rainfall wet seasons (hence difficulty in doing DDS), but also to difficulties in managing increasing weed infestation.

Two short follow-up small research activities have been commissioned by ACIAR and NAFRI to review the adoption and innovation process and assess ongoing needs for farmers implementing DSR in Savannakhet, one in 2015 (Clarke et al., 2018) and the 2018-19 study, both of which are qualitative studies of farmer experiences and perspectives. The focus of the 2015 study was to better understand the drivers and obstacles underpinning the rapid adoption of DSR.

The second, 2018-19, research activity is focused on ongoing developments in the adoption of direct seeding of rice. The data is drawn from small group discussions in 16 villages across 9 districts, complemented by brief one-on-one interviews in 12 villages across 7 districts. The villages chosen for group discussions have seen significant adoption of DSR. Only farmers who have adopted some form of DSR either currently or previously were interviewed. The aim of this study was to understand the current situation with respect to DSR, both technically and with respect to the innovation system that

supports its adoption. It also aimed to broadly understand if DSR was achieving livelihood changes from its adoption.

2. Direct seeding of rice in Savannakhet

2.1 DSR yields

Whilst this qualitative study did not measure yields *per se*, the focus group discussions and the farmer interviews indicated that yields were generally slightly less than that of transplanting. Some farmers indicated superior DSR yields — particularly with DDS or drum seeding — in some fields in some seasons, but the general acceptance was a slight yield penalty. Given that weed competition was consistently mentioned as a challenge, even by those farmers satisfied with DSR, it is fair to say that weed competition is a significant cause of that yield decline.

There were several references in the focus group discussions to weed-induced crop failures. High densities of weeds can prove too much to control with the typical hand-weeding methods. Yields are typically less than half that of transplanted rice, and can be close to zero. These weed-induced crop failures can be very damaging for a farming household, and generally lead to disadoption, at least in those contexts where many weeds are expected.

2.2 DSR methods

Farmers interviewed indicated that choice of planting technique (including transplanting) is determined by a range of factors (such as rainfall, labour availability, expected weed infestation, toposequence position, soil type and sensitivity to a change in yield). This suggests that the choice of planting method is, and will remain, diverse spatially and temporally and is an integral and useful aspect of the agricultural innovation system and farmer decision-making. Different establishment methods are used in different fields in the same year, and in the same field over different years. Tradition and cultural beliefs, such as ceremonies for planting time, seem to have little effect on DSR innovation.

DDS and dry broadcasting were by far the most popular DSR methods. Presumably the limited ability to control water supply to most fields is part of the reason for that, although perhaps our sample set was somewhat biased to DDS and dry broadcast. Little reference was made to wet broadcast seeding in our study, although we do know that wet broadcast seeding is common in the dry season irrigated areas, such as Songkhone and Champhone districts. Only the occasional farmer has yet used drum seeding, although one farmer recorded a substantially higher yield with drum seeding than with transplanting.

There were several references in the focus group discussions to using different rice establishment methods in different contexts, and even sequentially in the one field in one season. In particular, DDS or dry broadcast is typically used early in the season. If early heavy rain or drought causes that establishment to fail, then it may be followed with the same or another DSR method, or transplanting. This seems a constructive way to deal with variable rainfall patterns between and within years. Sequential use of rice establishment methods, whilst still achieving timely establishment, is aided by the ability to use DDS earlier than traditional planting times.

2.3 Technical innovation

Farmers interviewed indicated significant motivation to use DSR, and a willingness and ability to innovate. Examples of DSR innovations and associated decision-making farmers have developed or accessed include:

- Soaking seed before DDS;
- Placing fertilizer with the seed when using DDS;
- Home manufacture of 'extracted micro-organisms' (EM) for weed control;
- Selecting rice establishment method according to toposequence position;
- Selecting fields for DSR with a small weed seedbank;
- Sequential application of establishment technique with changing weather during the season, or with excessive weed infestation;
- Installing larger wheels on a drum seeder to make it easier to roll across the field;
- Khao Koo: growing volunteer wet season rice in the residue from irrigated dry season rice. Very few weeds emerge;
- Cutting the rice crop (and weeds) at 30-45 days after seeding, to achieve weed control;
- No-till drill-seeding of clay soil to avoid the need for (difficult, for some clay soils) land preparation.

DSR seems to provide farmers with options to adapt to variable rainfall patterns such as late onset of the monsoon. For example, DDS is allowing seeding before the establishment of standing water, provided weeds can be managed.

2.4 Weed management in direct seeding of rice

Whilst there is some understanding of weed species and behaviour, there is insufficient ability to consistently identify weed species for subsequent consideration of weed competitiveness, density, behaviour and consequent management. For example, in our discussion group and interviews a 'weed that looks like rice' can refer to *Echinachloa spp* or to weedy rice (*Oryza sativa*); they are different weeds with different behaviour and different consequences for DSR.

The weed seedbank (the quantity and composition of weed seed in the soil and consequent possible weed infestation in a crop) is a central issue for DSR, and rice-growing in general. The change to direct seeding, in particular, has generally caused an increase in the weed seedbank; 60% of the direct-seeded fields sampled had a high weed density before weeding (more than 50 weeds/m^2). Farmers consistently described the process of weed buildup in their fields with progressive seasons of direct seeding. However, there appears to be limited understanding of the weed seedbank as a central driver of in-crop weed competition, the importance of maintaining a low weed seedbank over years to aid weed control, and longer-term strategies to manage it.

Standing water is still the most common form of weed control and limiting the weed seedbank. Hence, low toposequence fields are favoured for DSR where standing water is more reliably achieved, and DSR is generally not used on many higher toposequence positions where standing water is less often achieved. For DDS at least, current equipment and techniques are more suited to prepare soil and seed the higher toposequence positions (sandier soils and better surface drainage); they are not so well suited to the low toposequence (clay soils and less surface drainage). During our field activities, we identified three farmers in three different villages who supplement their fields with pond water to reliably achieve standing water for weed control. There may also be an opportunity for some irrigation schemes to consider supplying water early in the wet season to enhance standing water for weed control.

In situations where the weed seedbank is greater, there is a temptation to use herbicides in order to continue using DSR. Herbicides are close to the only viable weed control

option once the weed seedbank reaches a certain level. Our small survey found 6% of farmers using herbicides.

3. Recommendations

1. The identification of weeds, and a subsequent understanding of their behaviour — particularly in DSR systems — is a central ability that farmers must have access to, to sustainably adopt DSR. There is quite a bit of experience and understanding about some weed types and their behaviour, but it needs to be more thorough and complete. Some written material also exists, but its scope is not complete or up-to-date. A hard copy or web-based Lao weed identification tool, that is accessible at the village level, will be enormously valuable.
2. Awareness and understanding of the weed seedbank — including weed density, species composition, changes in both and how to manage it over time — will be central to sustaining DSR without extensive reliance on herbicides. The weed seedbank needs to be a central concept and topic of research, extension and training.
3. One of the best strategies for managing weeds in rice is better control of standing water. Water needs to be drained immediately after seeding for small seedling survival, but then standing water kept afterwards to control weeds. Any ability to expand the area of reliable standing water will aid weed management. Even small, localized movements of water (typically from farmer-owned and operated systems) can aid both drainage and standing water. Conversely, fields that have little or no chance of achieving standing water are likely not suited to DSR and may cease growing rice.

   Technical innovations that could enhance the extent or duration of standing water for weed control include:

   - Using lower toposequence fields that have better standing water
   - Better levelling to ensure uniform standing water
   - Use of irrigation systems to supplement standing water
   - Use of stored water in ponds to supplement standing water
   - Later seeding, in the main wet season, when standing water is more reliable. Varieties, seeding and management techniques may have to change to achieve this.

In those contexts where the weed seedbank cannot be limited, either herbicides or improved versions of inter-row cultivation may become a management option to retain the smallholder livelihood benefits of DSR. If herbicides are conceded as an option, careful thought and policy mechanisms need to be put in place to ensure farm, food and environmental safety including an appropriate regulatory environment. There are a range of inter-row cultivation devices, often powered for greater field productivity, that demand investigation of their place in a Lao DSR system.

12.2 Appendix 2: Policy brief

Policy Brief: Innovation systems approach to the adoption of direct-seeded rice (DSR) in Savannakhet Province.

Leigh Vial, Khamlouang Keoka, Elizabeth Clarke, Amphone Vongsouphanh, Sisavanh Xayavong

1. Background

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From about 2014-15 in Savannakhet Province in particular, there was a rapid uptake of DDS in particular. The area of DDS in the province increased from only trial plots up to 2013, 80 ha in 2014, to more than 17,000 ha in 2016 (Clarke et al., 2018). Many seeders were purchased, and initial results encouraging (yields were similar, labour input less). Since 2017, the area of DSR has stagnated or fallen in most rice-producing districts; some farmers/fields have even returned to transplanting. Farmers interviewed attributed the decline partly to two high-rainfall wet seasons (hence difficulty in doing DDS), but also to difficulties in managing increasing weed infestation.

Two short follow-up small research activities were commissioned by ACIAR and NAFRI to review the adoption and innovation process and assess ongoing needs for farmers implementing DSR in Savannakhet, one in 2015 (Clarke et al., 2018) and the 2018-19 study, both of which are qualitative studies of farmer experiences and perspectives. The focus of the 2015 study was to better understand the drivers and obstacles underpinning the rapid adoption of DSR.

The second, 2018-19 research activity is focused on ongoing developments in the adoption of direct seeding of rice. The data is drawn from small group discussions in 16 villages across 9 districts, complemented by brief one-on-one interviews in 12 villages across 7 districts. The villages chosen for group discussions have seen significant adoption of DSR. Only farmers who have adopted some form of DSR either currently or previously were interviewed. The aim of this study was to understand the current situation with respect to DSR, both technically and with respect to the innovation system that supports its adoption. It also aimed to broadly understand if DSR was achieving livelihood changes from its adoption.

This policy brief is done with close reference to the *Agricultural Development Strategy to the year 2025 and Vision to 2030*. This strategy is itself based on a range of Lao national government strategies and the Millennium Development Goals.

2. What is DSR?

Direct-seeded rice (DSR) is the establishment of rice by distributing seed in the field, as opposed to transplanting seedlings from a nursery. There are four different DSR techniques:

- Dry drill seeding (DDS), where the seed is placed in rows into dry or moist soil. Access to a seeding machine is required for this. DDS can be used earlier in some years, as standing water is not required in the field to seed.
- Dry broadcast seeding, where the seed is spread by hand onto prepared soil, then mixed into the soil. Dry broadcast seeding can be used earlier in some years, as standing water is not required in the field to seed.
- Wet broadcast seeding, where the seed is spread by hand onto soil that has been prepared with standing water. Standing water is required in the field, from rainfall or irrigation.
- Wet drum seeding, where the seed is dropped in rows onto soil that has been prepared with standing water. A drum-seeding machine is required for this, and standing water is required in the field, from rainfall or irrigation.

3. Why use DSR?

DSR allows the farmer to save a lot of labour that would have been required to pull the seedlings from the nursery and transplant them in the field (about 30 days.ha^{-1}). This can be very helpful, as much family labour has now left for off-farm or non-farm opportunities and this increases the returns to the remaining labour.

Our data from Savannakhet found farmers generally wish/intend to use DSR, or to return to DSR. We were told that the time saved from nurseries and transplanting is being used for other on-farm activities (other crops and livestock, sometimes more rice), off-farm activities (eg on plantations, or transplanting for others) and non-farm activities (transport, textiles, retail business). DSR will likely become more common in future.

Both recent experimental evidence (Xangsayasane et al., 2018) and our data show that even with good management, DSR generally does not increase on-farm yield; it tends to reduce yield a little, particularly due to greater weed competition.

A common issue for farmers in our surveys for all forms of DSR was increasing challenges controlling weeds since changing from transplanting. Like in rice systems across Asia, the weed seedbank (weed seeds in the soil) and consequent weed competition tends to increase under DSR, especially in fields that do not have reliable standing water (Kumar and Ladha, 2011). Farmers reported costly weed-induced crop failures (much lower yields and much more time for hand-weeding), and consequent disadoption of DSR in some fields. They also reported achieving more sustainable weed control in areas with more reliable standing water — typically in the low toposequence or fields with reliable access to irrigation. It is in these fields that DSR has persisted.

After a recent surge in the area of DSR in Savannakhet to more than 17,000 ha in 2016, DSR area has declined to 9,300 ha in 2018.

4. What does DSR offer the Agricultural Development Strategy to 2025 and Vision to 2030?

Provided weed density is not too great, DSR decreases the labour required for rice (Table 1). DSR generally does not increase yield (although it can avoid low yield due to variations in weather during a season). Hence, successful DSR increases labour productivity (and consequent returns to labour, Table 2), but not land productivity.

Table 1: The seasonal labour requirement (days.ha^{-1}) for transplanting, broadcast and drill-seeding.

	Transplanting	Broadcast	Drill-seeding
Land preparation	4	4	2
Nursery	3	-	-
Transplant	30	-	-
Seed	-	1	1
Fertilize	2	2	2
Maintenance	12	12	12
Weeding	0-10	0-120	0-120
Harvest (manual)	56	56	56
(Combine Harvest)	(5)	(5)	(5)
Total	**107-117**	**75-195**	**73-193**

Data sourced from Vial and Newby (2014). Weeding time has been altered according to our data.

Table 2: The labour requirements and net income per day, for transplanted, successful DSR and failed DSR.

	Transplanting	**Successful DSR**	**Failed DSR**
Labour required (days.ha^{-1})	**66**	**34**	**84**
Income	7,500	7,500	3,750
Costs	3,180	3,240	2,070
Net income ('000 kip.ha^{-1})	4,320	4,260	1,680
Net income ('000 kip.day^{-1})	**65**	**125**	**20**

Labour and input costs sourced from Vial and Newby (2014)

A combine harvest is assumed.

A failed DSR crop is assumed to have half the yield, and twice the labour savings from crop establishment are used for hand weeding.

The different methods of DSR allow rice crop establishment in drier, intermediate and wetter seasons, hence have the ability to stabilize yield somewhat with variable rainfall.

Consequently, successful DSR:

- Increases rice productivity (labour, not land). Hence, it fits with the Food Crops Action Plan.
- Can provide an adaptation to climate change, providing more food stability with variable rainfall. Hence, it fits with the Food Crops Action Plan.
- Does not generally need substantial extra investment, so does not necessarily need extra provision for credit for equipment
- DSR allows for more time for non-rice crops and livestock production by freeing time from rice farming, aiding to achieve the planned increase in non-rice crop and livestock production for food diversity. Hence, it fits with the Food Crops Action Plan
- Aids more economic activity and SMEs by freeing time from rice farming, hence promoting rural development and consequent national development
- Will ***not*** aid the planned increase in national rice production. DSR could stabilize rice production with some variations in rainfall, but yields will not increase under DSR. In fact, more weed-prone fields will likely cease rice production under DSR and as farmers seek better livelihoods, so rice area may well decline.
- Appears unlikely to provide paddy of sufficient quality (varietal purity and free from weed seeds) to satisfy the goals for commercial production with current seed supply and weed management practices.

DSR appears a good technique to satisfy many — but not all — goals in Agricultural Development Strategy to 2025 and Vision to 2030.

5. What is the policy issue?

There are three policy issues:

1. DSR will not fulfill the desired production increase in the Agricultural Development Strategy to 2025 and vision to 2030. DSR will not increase yields (although it may stabilize yields compared to transplanting in dry years). DSR may well be a part of a reduction in rice area, as some high weed competition fields are retired from rice, and farmers use time freed from rice farming to grow more non-rice crops and livestock.

2. The labour productivity and yield stability benefits of DSR adoption are being compromised by heavy weed infestation in many contexts. With heavy weed infestation ('Failed DSR'), yields decline sharply, and the extra labour requirement for weeding increases above and beyond that saved from transplanting (Table 2). This vastly decreases both the return to labour and the opportunity to use the freed labour for other activities. Additionally, we were told by a large miller in Savannakhet that weed-seed contaminated paddy is inadequate for commercial purposes. Consequently DSR is not being adopted, or is being dis-adopted in some contexts, particularly where weed burdens are high.

3. DSR as a technique has less margin for error; yield declines from imperfect management are often greater than with transplanting. As such, the support systems around it need to be more substantial than with transplanting. Research, and especially extension and training will need to improve to support sustainable DSR.

6. What are the policy options?

1. Improve the function and the scope of farmer groups, to enable them to become a vehicle for learning and information and knowledge exchange between farmers, to aid the innovation process for DSR and other techniques. It is similar to the intervention of establishing learning groups, but does not rely on technicians for all technical input. Resources should be made available to DAFO and DAFO staff trained for this, and any other extension and training resources focused on these groups.
2. Increasing the extent and duration of standing water is a very effective means of limiting weeds in DSR, in the absence of herbicides. There are three actions that policy could consider, given the effectiveness of standing water for weed control:
    a. Use of irrigation systems (including groundwater supplies) to supplement standing water early in the wet season. The provision of this irrigation service could be made a higher priority for planned new or existing irrigation systems.
    b. Use of stored water in ponds to supplement standing water. Policy could aid farmers to construct, maintain and use ponds or low-lying areas to catch, store then use water, one use being to supplement standing water in a small-scale irrigation system (eg Johnston et al., 2014).
    c. Rice paddy areas that are consistently-poor at maintaining standing water will likely cease growing rice in future as better livelihoods are sought. This should be acknowledged in rice crop area and production goals, and other agricultural or non-agricultural uses should be researched and prioritized.

7. References

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12.3 Appendix 3: Field trials report

1. Introduction

The 2019 wet season experiments and demonstrations aimed to trial and demonstrate some techniques likely to help manage weeds, in the absence of herbicides:

- Placing basal fertilizer with the seed during seeding, to increase seedling vigour and consequent weed competitiveness.
- Inter-row cultivation to kill/suppress weeds
- Cutting the crop to control weeds in-crop.

2. Methodology

The experiments and demonstrations were done in drill-seeded fields at 4 locations: Alan Wattana, Tuat and Thapho and Muang Kai villages.

The experiment at each site had two treatments: placing basal fertilizer (~60 kg/ha of 15-15-15) with the seed at seeding, and broadcasting the same rate of basal fertilizer 14 DAS. There were four replicates in a blocked design. Land preparation and crop management was as per farmer practice at each village. Due to drought and then flood, only the experiment at Alan Wattana was harvested for a grain yield measurement.

The first demonstration was inter-row cultivation. At about 45-50 DAS, an implement was used to cultivate the inter-row. The original intention was to use a tyned implement on dry soil, but the chosen tyned implement, when first applied at Alan Wattana, quickly proved unsuitable to this context. Thankfully Matt Champness led an innovation process that developed a powered 'inter-row cutter', fitted to a whipper-snipper. This is used in standing water, and proved much more appropriate to this context. Inter-row cutting was successfully done at Alan Wattana and Thapho.

The second demonstration was of cutting both the rice and weeds at about 50-60 DAS. For best effect, this is best done when there is substantial biomass of rice (and weeds) to form a mulch, and standing water to suppress weeds. This was successfully done at Alan Wattana and Muang Kai.

3. Results

All experiments and demonstrations were affected by adverse weather; Thapho and Tuat in particular received very little early rain in June and July, so seedlings were affected by water stress. Heavy rain fell in August, that caused widespread flooding. Consequently grain yield was only measured at Ban Alan Wattana.

The results were also affected by substantial variation within the fields. Some parts of the field had standing water more readily than others, which increased the variability in some of the measurements.

3.1 Placing fertilizer with the seed

There was visual evidence of increased seedling vigour at both Alan Wattana and Tuat (Figure 1). Ban Tuat showed a significant increase in seedling vigour score, whilst Alan Wattana showed a difference at p=0.13 (Table 1). The effect was not evident at Alan Wattana by 47 DAS.

Table 1: Rice seedling vigour score (1-10) at two sites, at two different timings, for two fertilizer treatments (fertilizer with the seed and fertilizer broadcast)

Location	Timing	Fertilizer with seed	Fertilizer broadcast
Ban Alan Wattana	14 DAS	6.3a*	4.3a*
	47 DAS	6.5a	6.5a
Ban Tuat	13 DAS	8.0a	4.7b

Row entries followed by different letters are significantly different ($p<0.05$)

*These row entries different at a $p=0.13$

(a) **(b)**

Figure 1 Photographs of one replicate of the fertilizer with the seed experiment. (a) Ban Tuat 14 DAS 12/6/19. (b) Ban Alan Wattana 14 DAS. Left side is fertilizer with seed, right side is fertiliser broadcast (applied immediately after photograph taken)

Placing fertilizer with the seed did not affect grain yield; both treatments had a grain yield of 3.4 t/ha.

3.2 Inter-row cultivation

Inter-row cultivation with a tyned implement was unsuccessful. Too many rice seedlings were displaced and consequently the co-operating farmer did not wish to continue the treatment. In the absence of precision guidance, it was too difficult to guide the implement with sufficient precision. This was particularly so given the poor soil structure in this field (typical of soils in Savannakhet with a history of puddling). The large soil aggregates did not flow well past the tynes, which increased displacement of seedlings.

Figure 2: The unsuccessful attempt at inter-row cultivation with a tyned implement in relatively dry soil conditions.

Inter-row cultivation with a powered single-row inter-row cultivator ('inter-row cutting') was much more successful. It was conducted with standing water, so rice was quickly able to grow into the inter-row. The hooded design allowed easy guidance in the inter-row, cutting almost all of the weeds and doing little damage to the rice seedlings. Both the ease and efficacy of the cutting process depended on the presence of water. In the absence of water, a lot more torque and power was required to cut the weeds, and guidance was more difficult. This is particularly so for the typical Savannakhet paddy soils which become quite hard without standing water, even if they are still moist. Whilst the inter-row cutter can cultivate and kill relatively large weeds, this is slower and does put greater strain on the motor and drive-train of the implement; maybe too much. Inter-row cutting with young weeds, sparse weeds, or both may be a more realistic approach.

Early inter-row cutting is easiest to do, and likely best for preserving yield potential. However, early inter-row cutting will involve younger rice seedlings. Younger seedlings provide less of a 'boundary' for the implement's hood to contact for guidance to stay in the inter-row, so there is greater risk of seedlings damage with earlier inter-row cutting. What is the preferred timing? A small weed burden in the crop would be very helpful, allowing inter-row cutting to be delayed until the rice seedlings are big enough, without losing excessive yield potential, or making the cutting task too difficult.

At Ban Thapho, inter-row cutting successfully removed most of the weeds in the inter-row (Figure 3). The ground cover was greatly reduced, from 95% before cutting, to 34% after. The vast bulk of this reduction in ground cover was generally weeds.

Figure 3: Overhead photographs of the experiment field at Ban Thapho, before (left) and after (right) inter-row cutting.

At Ban Alan Wattana, inter-row cutting was also successful (Figure 4). Weed competition was not as great, however, so ground cover (measured 13 days after cutting) was only reduced from 92% to 65%. The cutting process was easy, presumably as standing water was present, and weed biomass was modest.

Figure 4: Inter-row cutting at Ban Alan Wattana, 30/7/19. The left side of the field was inter-row cut, the right side was not.

Participating farmers were enthused by the inter-row cutter, as it is precise, done with standing water (so subsequent weeds are suppressed) and the implement seems well-adapted to their soils.

3.3 Crop cutting

Cutting both rice and weeds at about 50-60 DAS did not reduce weed competition. No yield measurements were taken, but visual observation was that weeds recovered similarly to the rice. At Alan Wattana there were two weed species present: *Cyperus difformis* and *Fimbristylis miliacea*. At Ban Muang Kai there were four weed species present: *Cyperus rotundus, Fimbristylis miliacea, Cyperus iria* and *Cyperus difformis. Echinachloa spp.* were not present. All weed species responded in a similar way. At both villages, standing water was present, but cut material was removed immediately after cutting for forage. This likely compromised weed suppression after cutting.

Figure 5: Cutting half the field at Ban Alan Wattana. Unfortunately the farmer cut the other half of the field 5 days later.

Figure 6: A field at Ban Alan Wattana. The left side of the photo was cut 14 days previous, and the right side 9 days previous.

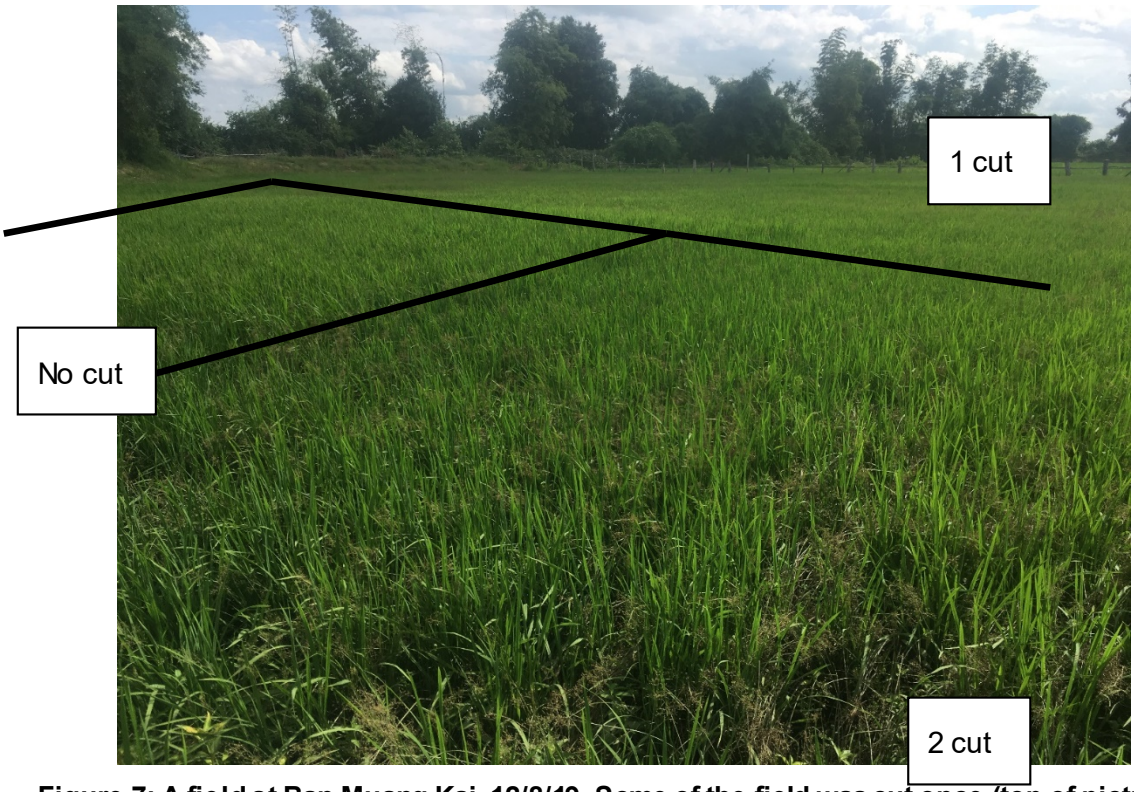

Figure 7: A field at Ban Muang Kai, 12/8/19. Some of the field was cut once (top of picture), some cut twice (bottom of picture) and some left uncut (left side of picture).

Conclusions

In the experiments, placing fertilizer with the seed gave an early visual response in the field, and made some difference to early vigour scores, but did not change grain yield where it was measured.

Crop cutting did not control weeds in our demonstrations.

Tyned inter-row cultivation was not suited to the dry soil conditions we encountered. But, inter-row cutting shows potential for in-crop weed control.

12.4 Appendix 4: Interview and focus group discussion questions

12.4.1 Farmer interviews

Field-specific questions:

1. How was the field prepared? ມີການກຽມດິນຈັກຄັ້ງ
    a. Number of ploughings ໄຖຈັກເທື່ອ
    b. Time between ploughings ໄລຍະຫ່າງຂອງການໄຖ
    c. Number of harrowings ຄາດຈັກເທື່ອ

2. What basal fertilizer was used? What rate (kg/rai or kg/ha)? ໃຊ້ຝຸ່ນຫຍັງແດ່ ອັດຕາເທົ່າໃດ

3. How did you get the equipment to prepare the field? ເຄື່ອງມືທີ່ໃຊ້ໃນການກຽມດິນແມ່ນໄດ້ມາແນວໃດ
    a. Owned equipment ຂອງຕົວເອງບໍ
    b. Borrowed equipment ຢືມ
    c. Hired equipment ເຊົ່າ
    d. Contractor ຜູ້ປະກອບການມາຊ່ວຍ
    e. Other? ອື່ນໆ

4. How was the crop sown? ມີວິທີການແນວໃດໃນການປູກເຂົ້າ
    a. Dry broadcast ຫວ່ານແຫ້ງ
    b. Wet broadcast ຫວ່ານປຽກ
    c. Drill ຢອດ
    d. Timeliness of sowing (early, no-time or late) ຊ່ວງເວລາໃນການປູກເຂົ້າ

5. How did you get the equipment to sow the field? ເຈົ້າໄດ້ເຄື່ອງມືໃນການປູກເຂົ້າມາແນໃດ
    a. Owned equipment ຂອງຕົວເອງ
    b. Borrowed equipment ຢືມ
    c. Hired equipment ເຊົ່າ
    d. Contractor ຜູ້ປະກອບການ
    e. Other? ອື່ນໆ
    f.
6. Was the seeding equipment suitable enough? ເຄື່ອງມື ຫຼື ເຕັກນິກທີ່ໃຊ້ແມ່ນດີແລ້ວບໍ

7. How was the weeding done? ມີວິທີແນວໃດໃນການຄວບຄຸມຫຍ້າ
    a. Manually pulling ຖອນດ້ວຍມື
    b. Herbicide ຢາຂ້າຫຍ້າ
    c. None ບໍ່ໄດ້ຮັດຫຍັງ
    d. Other ອື່ນໆ

8. Did you use herbicide, insecticide or fungicides in your direct-seeded fields? (for rice)

Other questions

9. How much does your household rely on farming for livelihood? (A little, some, a lot) ມີລາຍຮັບຈາກການກະສິກຳເທົ່າໃດ ໃນ 1 ປີ

10. Were you satisfied with the decision to sow this way? Why/why not? ພໍໃຈບໍທີ່ໄດ້ນຳໃຊ້ເຕັກນິກດັ່ງກ່າວ ຍ້ອນຫັຍງ

11. Is there anything else you think is important, in your experience, to improve seeding technique? ຕາມປະສົບການຂອງເຈົ້າມີຍັງບໍທີ່ຄວນປັບປຸງຕື່ມອີກກ່ຽວກັບເຕັກນິກດັ່ງກ່າວ. How can you make that improvement?

12.4.2 Focus group discussions

1. crop management

a. why did you adopt/not adopt/disadopt DDS?
b. Ask about the alternative – wet and dry broadcasting
c. Key issues they have experienced
d. How they solve these issues
e. Where they learned these skills
f. What they have learned from solving these issues
g. Has the area you plant to rice increased?
h. Do you think you can apply these new skills (from other villages) to their own situation? (in the case of mixing villages)

2. changes in livelihoods

a. what has changed in your lives/business/ farm (do the gender roles change?)
b. are there particular changes in women's role in the rice production? Are they moving out of agriculture/staying in/taking different roles?
c. what opportunities/or challenges have arisen
d. how is the labour situation – how has this changed what is the impact on the labour service?
e. Culture and social capital – what impact on this?
f. What impact on decision-making and gender roles?

3. background information

a. ethnicity and culture
b. economic status nad employment
c. farm size and has planted with DDS
d. land
e. soil type
f. irrigation (village maps)
g. village population
h. where did you get information about the new techniques = who provided it and how
i. who are the people that you get most information from

approach to group interview

- group discussion – each participant is asked to contribute to answering the questions posed to the group
- encourage discussion about the answers

12.4.3 Business and provincial policy stakeholders

1. changes in rice production and value chain

a. has (or will) the introduction of DDS create changes in the rice production, milling and trading – present and future
b. how has this affected you? (eg quality of rice, availability for purchace etc)
c. What do you think about these changes?
d. What impact does this have on your business?
e. Does this create future opportunities?
f. What changes have you made or plan to make yourself in response?
g. what markets are you focusing on? Which varieties?

2. policy implications

a. what is your role and your organisation's role in guiding policy for rice-based farming
b. what are the key policies influencing rice production and trade in SVK province
c. how do these policies influence the adoption of direct seeding of rice
d. what are the implications of adoption of direct seeding for the Province
e. Do the national and provincial policies complement each other and how or how not?
f. What is the impact of direct seeding on poor farmers?
g. How are you engaging with farmers – particularly poor farmers (eg, farmer groups, etc)
h. What will be the benefit for women of the adoption of direct seeding of rice?

3. next steps?

a. What do you see as the next opportunity for innovation in rice-based system?
b. What opportunities are there to support poor farmers in improving livelihoods
c. Do you see a need for policy change? If so what?
d. What plans are there for expansion of direct seeding (scaling out)? And other future changes?
e. How will these be implemented?
f. What about the mountainous areas? Other provinces?

12.5 Appendix 6: Report of the field observations

A survey of farmers' experiences using drill-seeding compared with broadcasting of rice crops in Savannakhet Province in Lao PDR

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Summary

- There is considerable evidence in SE Asia that when farmers change from transplanting to *direct-seeding of rice (Oryza sativa* L.*), weeds become more of a problem.*
- *This study combined field observations and a questionnaire of farmers to understand techniques used, farmer satisfaction with the rice establishment methods used and reasons for it, and to identify the type of weeds found in the rice fields in Savannakhet Province of southern Laos in direct-seeded rice crops.*
- Weeds were identified as the main problem using direct seeding as it was the main reason for farmers to not try, or even abandon the technique. It was also shown that the farmers know little about the impact of weeds on their rice yields.
- *The major weeds were mainly sedges, Fimbristylis miliacea, Cyperus* spp. *iria, difformis* and *rotundus, and the dominant grass genus identified was Echinochloa ssp. (differentiation between species was not possible).* High weed densities of more than 50 plants/m^2 were observed prior to hand-weeding in 21 of the 35 fields (60%).
- 83% of farmers use hand-weeding, 11% do nothing, and only 6% use some herbicide.
- 53% of respondents used DDS, 28% dry broadcast, 14% wet broadcast
- 78% of the users of DDS were happy with the techniques, but only 40% of those using dry broadcast and 20% of those using wet broadcast
- The main stated motivation for using direct-seeding methods was saving labour.
- Knowledge needs identified to assist drill seeding were: 60% wanted more information on weed management, 40% want more information on fertiliser, variety choice, and commented on the importance of seedbed levelling and early soil preparation.
- T*he study indicated a significant need for supporting farmers and advisers with weed management techniques and providing assistance with weed recognition.*

Introduction

Savannakhet is the largest province in the Lao PDR and the biggest producer of rice. Much of the population depends on agriculture for their livelihoods (mainly rice), using many different techniques such as transplanting, dry or wet broadcast, dry or wet direct seedling and others. While their rice production is affected by some problems (labour,

climate changes, weed, pets and diseases), direct-seeding of rice (DSR) and particularly dry drill seeding (DDS) is being adopted quickly in southern Lao PDR as it helps farmers save labour, time and reduce drought and flooding risks in some areas of Savannakhet Province.

ACIAR SRA CIM-2018-113 aims to understand the innovation process around changes in rice establishment techniques in Savannakhet. It aims to understand the rice establishment methods being used and changes in recent years, the techniques used with it, the role of government, private industry and others in supporting the changes, and farmers' perceptions of their requirements to succeed with these methods.

The objective of these field observations was to describe the ways farmers are managing their crops this season, their satisfaction with these methods and their perceived needs for future success. It also aims to identify the main weed species present and to determine current weed control tactics used by farmers in mainly dry direct seeding and broadcast rice. This also allows a future extension and training program on weed management to be scoped, which will be supported by the Australian Volunteer Program. This would support an assignment for a weed agronomist to demonstrate weed control methods on farm using community-based learning.

Direct-seeded rice (DSR) describes all non-transplanted rice. It includes:

- Dry-drill seeding (DDS) where the seed is placed into dry or moist soil;
- Dry broadcast seeding, where the seed is broadcast on dry soil, then usually incorporated into the soil with a light cultivation;
- Wet broadcast seeding, where the seed is broadcast into wet soil, that has usually been prepared with puddling;
- Wet direct seeding (or drum seeding) where the seed is dropped onto wet soil in rows with a drum-seeder. The soil has usually been prepared with puddling.

Methods

A survey was undertaken in July/August 2018 (wet season) at the end of tillering of rice and prior to hand-weeding to determine farmers' experiences in this season with drill-seeded and broadcast crops. This involved a questionnaire of farmers, as well as field observations. The questionnaire was presented by PAFO and DAFO staff to 35 farmers from 13 villages across 10 districts. The farmers were asked a number of questions about their crop sowing and weed management methods and experiences. Farmers were shown pictures of weed species for weed identification to determine the most important species. The locations are shown in Figure 1. Field observations were made of the crop condition (good or poor, based on uniformity of crop colour, height, and patchiness). The crop and the weed densities were estimated by farmers and DAFO staff using a 1m^2 quadrat placed in an area representative of overall field. The weed species were identified and recorded. Weeds that were not flowering were difficult to recognise. Drill seeding was by machine and broadcasting was by hand.

Results

Overall conditions and practices used by farmers

The growing conditions for the wet-season rice in 2018 were wet; the rains started early (in May) and continued very wet with widespread flooding in some districts. Crop and weed densities ranged from <50-300 plants/m^2 with no clear relationship between seeding method and crop or weed density. Crop condition was roughly 50% 'poor' and 50% 'good'. Many of the poor crops looked yellow or pale green and were patchy with differences in height. The main pests and diseases identified by farmers were leaf blast, gall midge, stem borer, white plant hopper, rice bug and leaf spot. No pesticides (insecticides or fungicides) were used.

Below is a summary of the results of the farmers surveyed:

- Gender: 71% men, 29% women
- Number of pre-seeding ploughings: 20% once, 71% twice and 9% thrice, usually 7-14 days between ploughing, while 91% of all farmers also did one cultivation immediately prior to seeding
- Ownership of tillage equipment: 86% owned, 14% hired (contract tillage seems to have been described as hired)
- Time of seeding: 3% in April, 34% in May and 63% in June
- Ownership of drill seeder (of those who did DDS): 74% owned, 26% hired or borrowed (contract seeding seems to have been described as hired)
- Weed control: 83% hand-weeding, 11% do nothing, 6% use some herbicide
- Do farmers sell their rice: 63% sell their rice, between 0.5 to 3 t/year
- 53% of respondents used DDS, 28% dry broadcast, 14% wet broadcast (Table 1)
- 78% of the users of DDS were happy with the techniques, but only 40% of those using dry broadcast and 20% of those using wet broadcast (Table 1)

Table 1: The number of respondents using each direct-seeding (DSR) technique, and the proportion (%) of those using each technique that were happy, not happy or neutral about the results they achieved.

Seeding method	Not happy (%)	Neutral (%)	Happy (%)	Number of respondents
Dry drill-seeding	11	11	78	19
Dry broadcast	60	0	40	10
Wet broadcast	40	40	20	5
Wet direct-seeding (drum seeder?)	0	0	100	1
Dibbling	0	0	100	1

- The reasons for happiness with any of the DSR techniques (although not consistently recorded) were almost all the ability to save labour (13 respondents). Only 1 respondent cited a similar yield as the main reason for their satisfaction with the technique.
- When asked what was important for the success of their chosen technique, 22 of the 35 respondents highlighted weed management or aspects of it. One respondent wanted to change to a more suitable variety, two highlighted the need for better field levelling and two respondents felt fertilizer management was important. One respondent felt that quality seasonal weather forecasting to help best use DSR
- Knowledge needs to assist drill seeding: 60% wanted more information on weed management, 40% want more information on fertiliser, variety choice, and commented on the importance of seedbed levelling and early soil preparation.

Fertilizer management

Farmers applied up to three fertiliser treatments: 89% applied one (basal), 55% applied two and 14% applied three applications. Farmers type of basal fertiliser varied

considerably: 45% used 16.20.00, 29% used either 15.15.15 or 16.8.8, 11% used nothing, 9% used rice husk and 6% used manure. For farmers using a second application, 26% used 41.00.00, 11% used 16.20.00, while 17% used another (15.15.15, 16.8.8, 10.8.8). It appears that a broad range of fertilisers are used. No relationship was found between seeding method and fertiliser used.

Weed issues

The questionnaire found that 83% of farmers use hand-weeding, 11% do nothing, and only 6% use some herbicide. Two farmers cut weeds early for animal feed, and a whippa snipper was also used by some (this could be used for weed cutting on the bunds).

The main weed species observed in the field are shown in Figure 2, while the most important species identified by the farmers are in Figure 3. The most frequently observed species and those considered the most important by the farmers were: *Fibristylis miliacea* (sedge), *Cyperus iria* (sedge), *Echinochloa* spp. (grasses), *Ludwigia hyssopifolia* (broadleaf), and *Cyperus difformis* and *rotundus* (sedges). Other important grass species were *Leptochola chinensis, Cynodon dactylon, Ischaemum rugosum* and *Dactyloctenium aegyptium*. Many of these species have resistance to herbicides in SE Asian countries which have wide adoption of herbicides.

Many farmers and some advisers had difficulty identifying weed species and wanted help with this. There were no consistent patterns between weed species and method of seeding the crop by either broadcast or drill-seeding. Wild rice was observed at only two sites, and this will require future attention as it is now considered the worst weed of rice in SE Asia, because of limited herbicidal options.

The weed densities were counted by the farmers using only one 1 m^2 quadrat per field prior to hand-weeding. High weed densities of more than 50 plants/m^2 were observed in 21 of the 35 fields (60%) (Table 2).

Table 2: The number of fields observed with each range of weed densities.

Weed density (plants/m²)	**0-25**	**25-50**	**50-100**	**100-200**	**200+**
Number of fields	6	3	5	9	7

There was no relationship between incidence of weed numbers recorded in the field and seeding methods. Imprecise sampling and errors due to low sampling numbers make the differences in crop and weed population densities difficult to predict.

Conclusions and future needs

The farmers who have adopted direct-seeded rice, have done so predominantly to save costs of labour, although a similar or better rice yield is desirable. Weeds are clearly a major cost and constraint to adoption of successful direct-seeded rice crops and farmers need more information to address this problem. The impacts of pest and diseases is less clear but obviously important. In addition, choice of rice variety, and fertiliser type, frequency and timing, are also important information needs. Farmers are keen to minimise herbicide and pesticide use, and they identified the importance of pre-seeding weed control techniques.

More than half of the surveyed farmers (all who had used a form of DSR) had used DDS. Surveyed farmers were generally satisfied with the results from DDS, but less so for dry and wet broadcast. Weeds and consequent low yields were the main reason for dissatisfaction where a reason was given. Saving labour — presumably without much loss of yield — was the primary reason given for satisfaction with the technique. The rice yield *per se*, was rarely mentioned as the primary criteria for satisfaction.

There was generally a high weed density in the surveyed fields, prior to any hand-weeding, but some fields had very low weed density.

Experience is other countries in SE Asia indicates an increase in weeds in direct-seeded rice creates greater demand for and dependence on herbicides leading to effects on farmer health (given often primitive application techniques), ecosystem health and often rapid development of resistance. Resistance to herbicides has been identified in other countries in the sedge and grass species identified as important in this study. Lao farmers and the Lao government have consistently expressed the desire to use non-herbicide weed control techniques. Can we reduce the risk of resistance by introducing integrated weed control techniques from pre-sowing and throughout the crop/weed growing cycles. Farmers need more cost-effective control options, and training assistance in weed identification.

Acknowledgements

We thank the Australian Centre for International Agricultural Research (SRA CIM 2018-113) and the Crawford Fund of Australia for funding this survey. Thanks to PAFO, DAFO staff and farmers for participating.

Figure 1: Village locations based on GPS readings

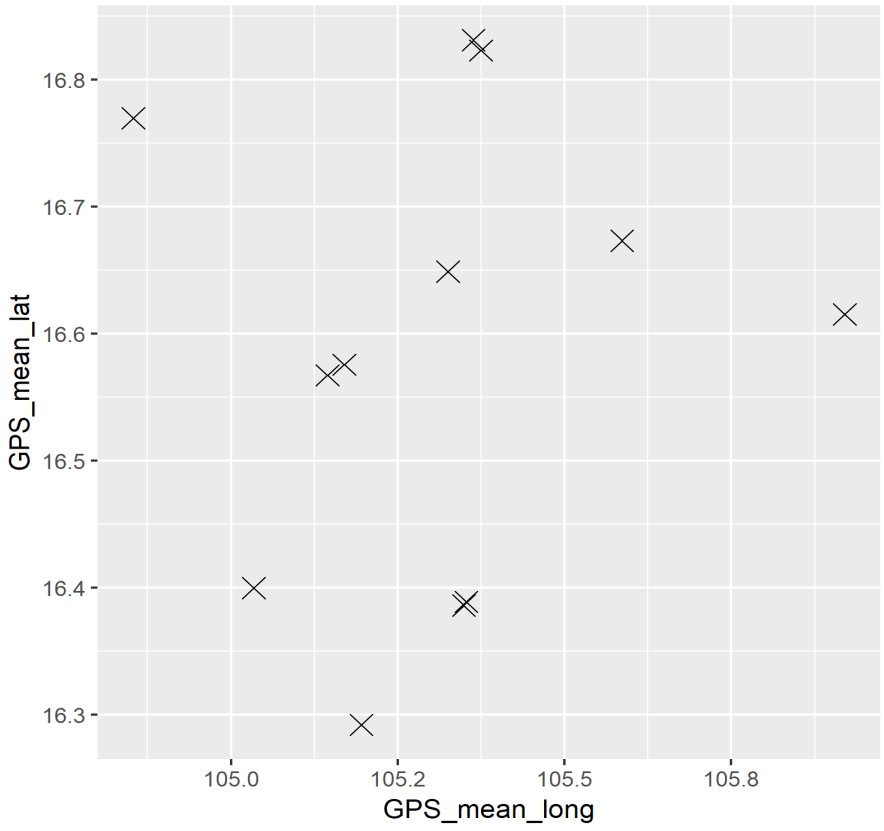

Figure 2: Incidence of weed species observed at each field

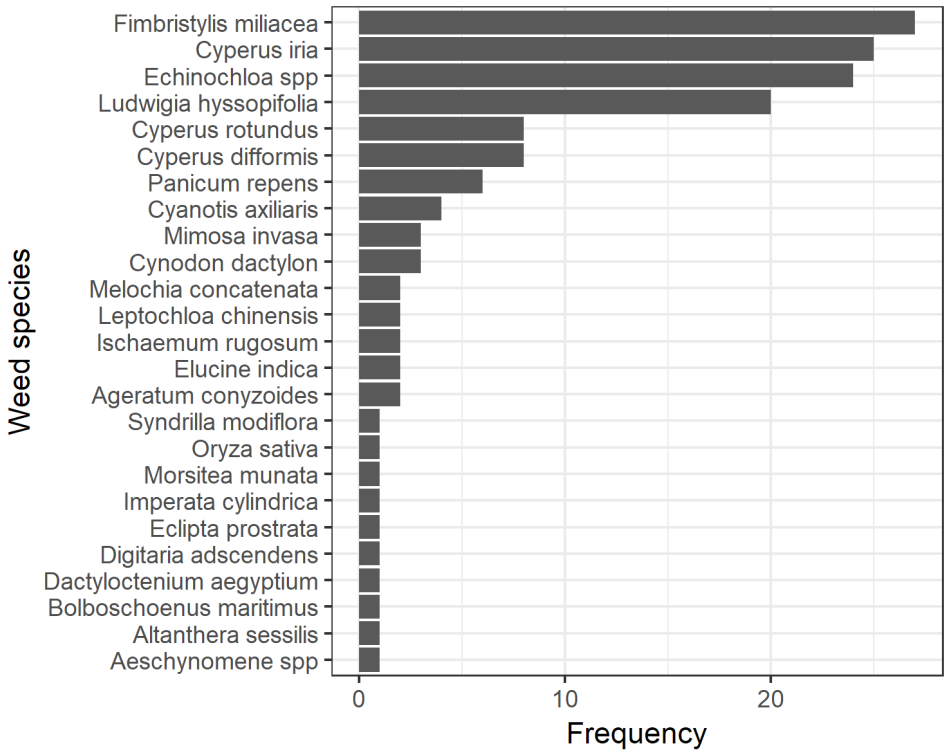

Figure 3: Most important weed species as identified by the 35 farmers (1-7 priority weighted)