Australian Government

Australian Centre for International Agricultural Research

Annual report

project	Sustainable intensification and diversification in the lowland rice system in Northwest Cambodia
project number	CSE/2015/044
period of report	1st July 2018 to 30th June 2019
date due	15th July 2019
date submitted	
prepared by	A/Prof. Daniel Tan, Dr Bob Martin, Dr Yorn Try, Dr Rebecca Cross, Herve Thieblemont, Dr Som Bunna
co-authors/ contributors/ collaborators	Dr Van Touch, Dr Floris Van Ogtrop, A/Prof Rosanne Quinnell, Adj/Prof Bill Rathmell, Dr Clemens Grünbühel, Prof Lingling Li, Dr Pao Srean, Dr Peter Ampt, Dr Petr Matous
approved by	Dr Eric Huttner / Dr Sarina MacFadyen

Contents

1 Progress summary

Introduction

CSE/2015/044 commenced in November 2016 and runs for five years. It is focused on Banteay Meanchey, Battambang and Pursat provinces in northwestern Cambodia. In 2010, Battambang and Banteay Meanchey were Cambodia's largest rice producing provinces and the three provinces account for 27% of Cambodia's wet season rice production. The project aims to work with local communities to enhance sustainable intensification and diversification to improve productivity and livelihood security for farmers. The project objectives are to:

1. Identify the local socio-economic and agronomic trends, constraints and opportunities for sustainable intensification and diversification;
2. Establish participatory on-farm trials to test sustainable intensification options;
3. Comparative evaluation of different scaling models for sustainable intensification and diversification;
4. Build the capacity of local farming communities and tertiary agricultural educational institutions.

Collaborating Agreements

Collaborating agreements have been signed with Ockenden in Banteay Meanchey (27th July 2017) and Voluntary Service Overseas (VSO) in Battambang to facilitate concurrent scaling out of project innovations. The project is also working closely with the Cambodian Agricultural Value Chain Program (CAVAC) on improvement of rice seed quality, introduction of dry and wet drill seeders to replace hand broadcasting.

Project management and communications

(1) Daniel Tan maintains regular day to day communication with project staff via email and Skype

(2) Daniel Tan arranges and chairs regular Skype/Zoom meetings with field staff and managers usually each fortnight

(3) Management team meeting in February 2019 (i.e. every 6 months) at which trials and demos were discussed and agreed to.

Establishment of on-farm experiments and demonstrations

Farmers are interested in machine planters to replace hand broadcasting rice and transplanting for pure seed production. Two options are available for wet seeded rice: the drum seeder and the Cambodian-invented Eli air seeder. Large scale demonstrations for mechanised planting for seed production have been established at Svay Cheat village and Don Bosco farm in Battambang and a large-scale demonstration for mechanised planting for paddy rice production has been established in Kouk Tonlaop village, Banteay Neang Commune, Mungkul Borei district, Banteay Meanchey province in the early and main wet season as well as the dry season in 2018 and 2019. We also had great parallel field demonstrations conducted by CARDI in Phnom Penh and Pursat in 2018 and 2019.

Cambodia Agricultural Research and Development Institute (CARDI)

This report covers the research and demonstration conducted by Agricultural Engineering Division of Cambodia Agricultural Research and Development Institute from January –December 2018 main wet season and for dry season 2019.

Objective 2

Activity 2.4, Output 2.4.2. Performance of drum seeder and weed control for dry and wet season 2018: Partners: CARDI, RUA-Students, UniSA (Australia), University of Sydney (Australia),

The drum seeder prototyped by the MAFF Department of Agricultural Engineering (DAE) and small scale irrigation, through the research and extension option to select the appropriate direct seeding tools that can be worked with dry and wet seeding as suggested from the CamSID meeting, for CARDI-agricultural engineering to undertake these activities. DAE have agreed to loan the drum seeder fitted to 4WT (4 wheel tractor) to test at CARDI (Figure 1).

Figure 1. Prototype 4-WT drum seeder on loan from Department of Agricultural Engineering (DAE)

Objectives

1. Evaluate the performance of drum seeder fitted with 4-WT and drum seeder pulled by hand;
2. Determine the effects of establishment method and cropping sequence on weed populations and species shifts.
3. Economic analysis

Methods

The machinery evaluation was conducted for crops at the CARDI research station during 2018 under two rice crop sequences, where the first rice crop was grown from 15th February to 30th May and the second rice crop is from 9th July to 14th November 2018. The soil type was Prateah Lang.

The experiment was carried out to test two drum seeder treatments under four weed management options with three replicates (Figure 2). A split plot design was used with the drum seeder treatment as the main plot and weed management options as sub-plots. Main plots were: drum seeder fitted with 4WT; and drum seeder pulled by hand. Sub-plots were: W0. No weeding; W1. Hand weeding; W2. Herbicide – EXPERT; W3. Herbicide - ABLE Kill.

Figure 2. Field layout for the seeder * herbicide experiment

The fertilizer application rate varied depending on variety: Urea at 63 kg/ha, DAP at 50 kg/ha and KCl at 50 kg/ha was applied to early maturity rice. Fifty percent of urea was applied at sowing and 50% at panicle initiation (PI). For medium rice maturity, we applied 30% of urea at sowing, 40% at 40 days after planting and 30% at PI.

The field was ploughed twice by 4-WT, then harrowed by 2 wheel tractor (2-WT) before planting. The seed was soaked and pre-germinated 12 hours before planting at 70 kg/ha. The variety used was CAR 14 for the dry season and Phka Rumduol at 60 kg/ha in the wet season.

Weed control treatments were:

1. No-weeding, we kept the plot free of weed growth until harvesting time,
2. Hand weeding; we weeded twice for whole crop cycle, the first weeding on 11th March and second on 9th April 2019 when the rice was 30 days and 60 days old, respectively;
3. Herbicide, EXPERT (quinclorac 50% +pyrazosulfuron 7% +fenoxaprop-P-ethyl 13% applied at 30 and 60 days after sowing (DAS), and
4. Able Kill (bensulfuron 6% +quinclorac 34%) applied at 30 and 60 DAS.

The paddy was irrigated during land preparation, then at 15 days after sowing and four times altogether.

Data collected included: establishment at 15 and 35 DAS (plant/m^2), plant density (plant/m^2), plant height (cm), weed biomass at 60 DAS (kg/ha), panicle length (mm), rice biomass (kg/ha) and rice grain yield (kg/ha).

All data were entered and analysed using CropStat 7.2 to determine main effects of planting method and weed management and the interaction of planting method and weed control.

Results and Discussion

The 3.1 m wide 4-WT drum seeder was able to plant at 1 ha/hour whereas the hand-pulled seeder 2.4 m drum seeder took 2-3 hours/ha. The 4-WT drum seeder also saved seed dropped at headland and made the soil surface level.

Table 1. Summary of ANOVA model for effects of treatments in the dry season 2018

Variate	ES15	ES35	PD	PTH	WB60	PL	RGY
Planting method (PM)	ns	ns	ns	ns	ns	ns	ns
Weed management (WM)	ns	*	ns	ns	**	ns	*
(PM)*(WM)	ns	ns	ns	ns	ns	ns	ns
MEAN	47	84	376	82	305	28	4
C of V	7	4	8	2	16	3	7

Note: 1. ES15-35-Establisment at 15 days and 35 days (plant/m^2), 2. PD-plant density (plant/m^2), 3. PLH- Plant height (cm), 4. WB60- Weed biomass at 60 days (kg/ha), 5.PL- Panicle length (mm) and 6. RGY- Rice grain yield (tonnes/ha).

There were no significant differences between for establishment at 15 days for the seeder treatments. and also not significant for weed management. The crop established at 35 days was not significantly different for planting method but was significant different ($P<0.05$) for weed control; hence, establishing a crop without controlling weeds will cause poor establishment. The plant density was not significantly different for planting method and weed management.

Table 2. The effect of planting method and weed management on rice establishment at 15 30 DAS and plant density for DS 2018

(PM)/(WM)	Establishment 15 DAS		Mean	Establishment at 35day		Mean	Plant density		Mean
	DS-4WDT	DS-HM		DS-4WDT	DS-HM		DS-4WDT	DS-HM	
NW	47	50	48	79	78	78	379	378	378
HW	45	49	47	87	88	88	397	388	392
Expert	46	46	46	86	84	85	362	344	353
ADK	46	47	46	86	83	85	371	387	379
Mean	46	48	47	85	83	84	377	374	376
5% LSD (PM)	3 ns			3 ns			26 ns		

5%LSD (WM)			4ns			4 *			37ns
5%LSD (PM)*(WM)	5ns			5ns			52ns		
CV		7			4			8	

There were no significant differences between planting methods and weed management on plant height (p >0.05). Weed biomass was significantly affected by different weed management, while the nil weeding treatment showed a higher dry weed biomass than by manual weeding and the two other herbicide. Weed biomass was not affected by planting method. The rice grain yield was not affected by planting method. Rice grain yield was 3.948 t/ha in the presence of weeds, whereas rice grain yield was 4.541 t/ha with weed control. The rice grain loss due to weeds was 593 kg/ha (16%).

Table 3. The effects of planting method with weed management on rice establishment at plant height (cm), weed biomass (kg/ha) and rice grain yield for DS 2018

(PM)/(WM)	Plant height		Mean	Weed biomass		Mean	Rice grain yield		Mean
	DS-4WDT	DS-HM		DS-4WDT	DS-HM		DS-4WDT	DS-HM	
NW	81	82	82	718	790	754	3.903	3.993	3.948
HW	84	82	83	168	146	157	4.473	4.437	4.455
Expert	82	82	82	171	137	154	4.543	4.637	4.590
ADK	83	83	83	163	146	155	4.513	4.643	4.578
Mean	82	82	82	305	305	305	4.358	4.428	4.393
5%LSD (PM)	1ns			43ns			0.280 ns		
5%LSD (WM)			2ns			61**			0.396*
5%LSD (PM)*(WM)	3 ns			87 ns			0.559 ns		
CV	2			16			7		

Results from main wet season 2018

There was a significant difference between the two planting methods for plant density, for rice planted using the 4-WT machine was 6 plants/m^2 greater than drum pulled by hand, and plant density was highly significantly different between planting method; the poor plant density was the non-weeded treatment. Weed biomass was not significantly different between rice planted by 4-WT and drum pulled by hand, but there was high significant difference among weed management with a high weed biomass for non-weeded treatment. This year, good tillage resulted in fewer weeds in the whole paddy field. Rice grain yield received from drum pulled by hand was 134 kg/ha higher than 4-WT. Weed management increased rice grain yield by 1,463 kg/ha compared with unweeded control.

Table 4. The effects of planting method with weed management on rice establishment at plant tall(cm), weed biomass(kg/ha) and rice grain yield for MWS 2018

(PM)/(WM)	Plant density		Mean	Weed biomass		Mean	Rice grain yield		Mean
	4-WT	HM		4-WT	HM		4-WT	HM	
NW	130	112	121	351	300	326	2615	2740	2678
HW	165	161	163	0	0	0	3836	4117	3977
Expert	161	163	162	101	96	98	4191	4281	4236
ADK	167	163	165	98	99	98	4190	4230	4210
Mean	156	150	153	137	124	131	3708	3842	3775

5%LSD (PM)	3.7 *	34.2 ns	111.8 *
5%LSD (WM)	5.2 **	48.4 **	158.1 **
5%LSD (PM)* (WM)	7.4 *	68.5 ns	223.6 ns
CV	2.8	30	3.4

Activity 2.4, Output 2.4.1. Options to reduce rice seeding rates below 80 kg/ha for dry-drill seeders

The overall objective was to determine the effects that planting method with seed rate below 80 kg/ha and weed management on weed burden and crop yield in main wet season (MWS) 2018. Individual aims were to:

1. determine the best seed rate and plant density to reduce time, labour, as well as to increase grain yield;
2. determine the effect of seeding rate and plant density on weed biomass and rice grain yield;
3. quantify the cost saving effects (time and labour) of new technologies for improving crop yield.

Methods

The experiment was conducted at CARDI. Variety Phka Rumdoul was used in the main wet season. In the following dry season and it is planned to grow: 1. Dry season rice, 2. Mungbean, 3. Maize and 4. Watermelon. The experiment is designed as a Randomised Complete Block (RCB) with three replications, the main plot was weed control and sub-plot was planting methods with different seed rate, the plot size was 15 m^2 (2 m x 5 m) with a total of 60 plots.

Table 5. Treatments, main and sub treatment for the main trial conducted in CARDI

Treatment	Main plots	Sub-plots (seeding rate kg/ha)
1	Non-Weedy	40
2	Non-Weedy	60
3	Non-Weedy	80
4	Non-Weedy	180 (broadcast)
5	Weedy	40
6	Weedy	60
7	Weedy	80
8	Weedy	180 (broadcast)

Figure 3. Site location

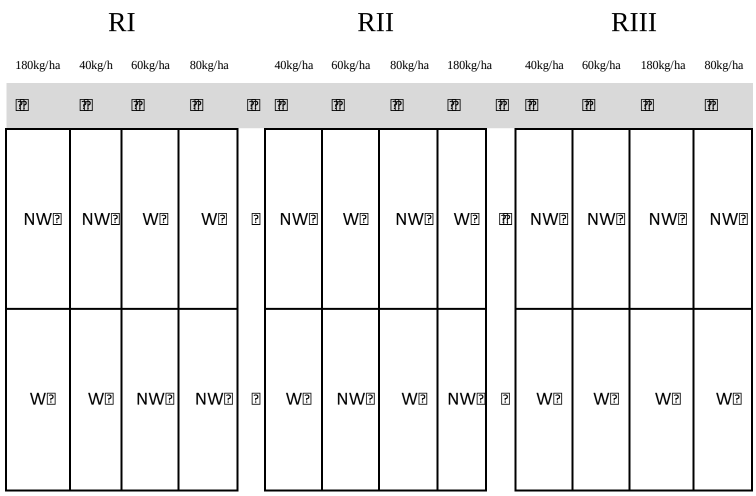


Figure 4. Field layout

The treatments are in 3 replicates with a total area of 15 m^2 (3 m x 5 m) per plot. The main plot was ploughed 2 times, levelled and harrowed before planting. Seeding rates of 40, 60 and 80 kg/ha were sown into dry soil than irrigated with water standing in the field for 48 hours and then drained. Fertilizer was applied using CARDI recommendation and applied at sowing, tillering and PI. The seed rate for the broadcast treatment was 150 kg/ha and seed was pre-germinated before broadcast.

There were two methods for weed control: the nil-weeding treatment was kept weed-free from planting time until the trial was finished, for weed control we used CHHREKDEY herbicide (pretilachlor 26% + bensulfuron-methy l4% WP, which was applied on 15th August 2018

The dates for all above-mentioned operations will be recorded. All the inputs for land operation such as time labour and cost to be recorded. Fresh weeds will be harvested approx. a week before PI in 50 × 50 cm squares following the scheme below. After that, the weed from each plot will be dried separately for 2 days at 70°C. The dried weeds will be weighed and their biomass determined on a unit basic. The plant density and grain yield for all each treatment will be determined by harvesting the correspondent plot. All analysed data will be recorded in the table below: The trial was planted on 16th July 2018 and harvested on 14th November 2018.

Result and discussion

It was not possible to adjust the Cambodian Seed Drill to deliver a seed rate of 20 kg/ha, so we were only able to use three seed rates (40, 60 and 80 kg/ha) compared with hand broadcast at 180 kg/ha.

Table 6. Summary ANOVA model for mother trial

VARIATE	Plant density (plant/m^2)	Weed biomass (kg/ha)	Rice grain yield (kg/ha)
Planting method(PM)	**	ns	ns
Weed management(WM)	ns	**	*
(PM)*(WM)	ns	ns	ns
MEAN	166	72	4194
C OF V	16	64	12

Rice planted with good weed management resulted in a higher plant density, better than nil-weeding by approximately 19 plants/m^2 (Table 7). The seed rate also had an impact on plant density where hand broadcasting provided higher plant density, while seed rate 40, 60 and 80 kg/ha were not significantly different for plant density. Weed management was had a highly significant effect between weeding and non-weeded on plant density, weed biomass and rice grain yield. Poor weed management reduced rice grain yield by approximately 709 kg/ha (equal to 16.4%). Planting rice with seed rates (<80 kg/ha) had no significant effect on rice grain yields.

Table 7. The effect of weed management and seed rate on plant density (plant/m^2), weed biomass (kg/ha) and rice grain yield (kg/ha)

(WM /(PM)	PD		Mean	WB		Mean	RGY		Mean
	NW	WM		NW	WM		NW	WC	
HB(180/kg-ha)	208	253	230	138	0	69	4,204	4,696	4,450
SD 40kg/ha	115	133	124	165	0	82	3,412	4,122	3,767
SD 60kg/ha	133	138	136	132	0	66	3,857	4,960	4,409
SD 80kg/ha	167	178	172	140	0	70	3,887	4,416	4,151
Mean	156	175	166	144	0	72	3,840	4,549	4,194
LSD at5%(WM)	23.4 **			40.4 **			447.8 *		
LSD at5%(PM)			33.2 *			57.1 ns			633.3 ns
(PM)*(WM)	46.9 ns			80.8 ns			895.6 ns		
CV	16.2			64.3			12.2		

Activity 2.7, Output 2.7.1. Pre-emergence herbicide options for rice

The main study on weed management techniques on rainfed lowland direct seeding method rice is for the following objectives:

1. Identify weed biomass and yield losses by weed competition at rainfed lowland area;
2. Find out best weed control practices in rainfed lowland direct seeding with seed rates below 80 kg/ha in rice production

Materials and Methods

The photoperiod sensitive rice variety, Phka Rumduol was used. CARDI's fertiliser recommendation for Bakan soil type was applied.

Herbicides:

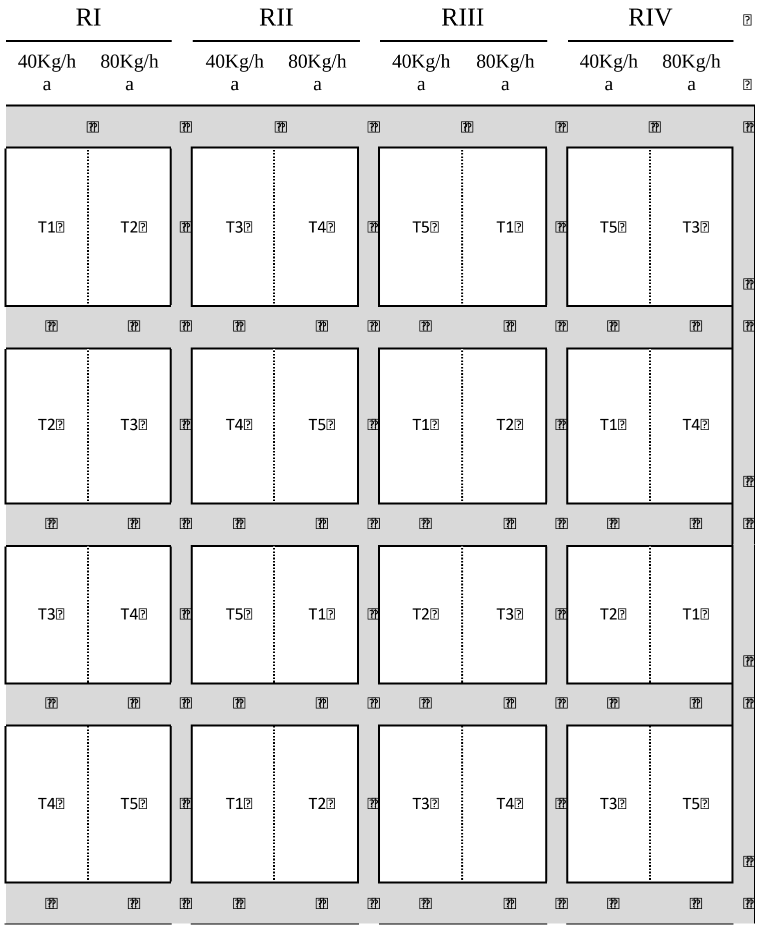
1. Chreyk Dey (pretilachlor 26% + bensulfuron-methyl 4%wp);
2. Sunamy (pyrazosulfuron – ethyl 10%wp);
3. Super Malice (bispyribac-sodium 20wp);
4. Naruto (2,4-D; butyl ester 72% SL); and
5. Sasuke (fenoxaprop-P-ethyl 13% + Quinclorac 50% + Pyrazosulfuron-ethyl 7%WP

The experiment was conducted in the rainfed transplanting and direct seeded rice areas, located in Sorya Krom village, Roleap commune, Pursat town, Pursat province on Bakan soil type and fertilizer applied three times: at sowing urea (25 kg/ha), DAP (25 kg/ha) and KCl (25 kg/ha). For topdressing 1 we used Urea (50 kg/ha) and for topdressing 2 we used Urea (25 kg/ha).

The trial was laid out in a split plot design where the Cambodia Seed drill with 40 kg/ha and 80 kg/ha (planting method) were the main plots and weed management were the sub-plots.

Table 8. The treatment, main and sub treatment for trial conducted in Pursat province

Trt	Main Treatment	Sub-Treatment
1	Seed Drill with 40kg/ha	pretilachlor + bensulfuron-methyl
2	Seed Drill with 40kg/ha	pyrazosulfuron-ethyl
3	Seed Drill with 40kg/ha	bispyribac-sodium
4	Seed Drill with 40kg/ha	2,4-D;butyl ester
5	Seed Drill with 40kg/ha	fenoxaprop-P-ethyl + quinclorac + pyrazosulfuron
6	Seed Drill with 80kg/ha	pretilachlor + bensulfuron-methyl
7	Seed Drill with 80kg/ha	pyrazosulfuron-ethyl
8	Seed Drill with 80kg/ha	bispyribac-sodium
9	Seed Drill with 80kg/ha	2,4-D;butyl ester
10	Seed Drill with 80kg/ha	fenoxaprop-P-ethyl + quinclorac + pyrazosulfuron



All plots were ploughed twice and harrowed by 4-WT, then all plots were levelled by 2-WT before planted by Cambodian seed drill. The planting date was 26th June 2018 and it was harvested on 7th November 2018.

Results and discussion

Table 9. Summary AVOVA model effects of trial conducted in Pursat province

Variate	Establishment 21 DAS (plants/m^2)	Plant density (Plants/m^2)	Rice grain yield (kg/ha)
Seed rate (SR)	**	**	ns
Weed management (WM)	ns	ns	ns
(SR)*(WM)	ns	ns	ns
MEAN	127	201	3,773
C of V	17	6	19

The plant density in the rice crop planted by Cambodia Seed Drill with seed rate 80 kg/ha was 274 plants/m^2 compared with seed rate 40 kg/ha which had a plant density of 142 plants/m^2 only. However, plant density was not significant different among the five herbicides. The rice grain yield was similar for the five herbicides and rice planted by 40-80 kg/ha (Table 10).

Table 10. The effects of weed control and seed rate on plant density and rice grain yield in main wet season /Pursat province.

seed rate (SR)/weed management (WM)	Plant density(plant/m2)		Mean	Grain yield (kg/ha)		Mean
	Seed 40 kg/ha	Seed 80 kg/ha		Seed 40 kg/ha	Seed 80 kg/ha	
Chreyk Dey	139	259	199	3,459	3,652	3,555
Sunamy	141	256	199	3,794	3,672	3,733
Super Mailce	139	261	200	3,698	3,770	3,734
Naruto 2,4 D	143	260	202	3,699	4,663	4,181
Sasuke	142	272	207	3,612	3,715	3,663
Mean	142	272	207	3,612	3,715	3,663
LSD at5%(W)	7.5 **			473.8 ns		
LSD at 5%(SR)			11.8 ns			749.1 ns
(W)*(SR)	16.7 ns			1059.4 ns		
CV	5.7			19.4		

Results from dry season 2019

Objective 2

The results from the dry season 2019 included the following activities

1. Options to reduce rice seeding rates below 80 kg/ha for dry-drill with dry season
2. Evaluation of the water irrigation and mulching methods for watermelon production,
3. Evaluation the performance of differences in Chinese radish variety growth performance in the paddy field after harvested wet season rice
4. Evaluation the mungbean production

This section covered the research and demonstration conducted by Agricultural Engineering Division of Cambodia Agricultural Research and Development Institute from January – May 2019 for dry season 2019.

Activity 2.4, Output 2.4.2 Option to reduce rice seeding rates below 80 kg/ha dry-drill with dry season in CARDI/crop 2 (long term experiment)

Introduction

The field experiment conducted with a split plot design in which the seeding rate was the main plot and weed management was the sub-plot with three replications.

The main treatment was three different seed rates such as T1 = 80 kg/ha, T2 = 100 kg/ha and T3 = 120 kg/ha. The sub-plot was weed management such as NW=no weeding, W0- We used herbicide, "O-stop "containing bensulfuron methyl 8% + quinclorac 27% WP and W1- flooding method.

Land preparation

The paddy field was ploughed twice time by 4 Wheel Drive tractor (4WDT), then harrowed by 2 wheel tractor (2WT) before planting.

Rice variety and seed preparation

The rice seed variety Senkraob, we cleaned before planting with seed rate

T_1= 80, T_2=100 and T_3=120 kg/ha with Cambodian Seed Drill

Fertilizer application:

The fertilizer application used CARDI's recommendation: Fertilizer application: Urea=63 kg/ha, DAP=50 and KCL=50 kg/ha for early rice maturity duration, we applied Urea at basal:50% and PI:50%.

Planting method

The trial plots were planted by Cambodian Seed Drill with four rows, row space 18 cm and planted on 22nd January 2019.

Weed management

The weed control treatments were

1. No weeding, we let weeds grow until harvesting time,

2. Weeding; we used herbicide (O-stop) twice for whole crop cycle and we sprayed on first at 4th February 2019 and second at 3rd April 2019.

Irrigation

The paddy was irrigated during the land preparation, then at 15 days after sowing and were irrigated 3 times altogether, except sub-treatment flooding we kept water standing in permanence and we regularly pumped to maintained level in the field.

Data collection

The data collected were: 1. Plant density (plant/m^2), plant height (cm), weed biomass at 60 days (kg/ha), panicle length (mm), weed biomass (kg/ha) and rice grain yield (kg/ha).

Analysis method

All data has entries and analysis using Crop Star7.2 application, the method for analysis was identifying the effect on:

- Planting method on grain yield;
- Weed management
- Interaction effect planting method with Weed control.

Results and Discussion

The summary of ANOVA model of statistical analysis on seeding rate with weed management presented in the Table 11, rice planted with seeding rates 80, 100 and 120kg/ha showed no significant differences in plant density, but there was a significant difference in weed biomass and high significant difference in rice grain yield. Two weeding controls (no weeding & weeding) have significant differences on seeding rate and a highly significant difference in weed biomass, there were significant difference in interaction effects between seeding rate with weed management on weed biomass, but significant interactions on grain yield.

Table 11. Summary ANOVA model for statistical analysis of seeding rate and weed management

VARIATE	Plant density (%)	Weed biomass(kg/ha)	Grain yield(kg/ha)
Seeding Rate (SR)	ns	*	**
Weed Management (WM)	**	**	**
SR*WM	ns	*	ns
MEAN	262	169	4,698
C OF V	5.3	22.2	3.6

There were no significant differences in plant density among the three seeding rates - the average plant density was an average 262 plants/m^2, but weeding method had higher plant density by 30 plant/m^2 (12%) compared with no weeding method (Table 12).

Table 12. The effects of seeding rate and weed management on plant density

Seeding rate (SR)/Weed management (WM)	Plant density(plant/m^2)		Mean
	No weeding	Weeded	
T1=80 kg/ha	243	271	257
T2=100 kg/ha	251	271	261
T3=120 kg/ha	248	289	269
Mean	247	277	262
LSD at 5%(SR)			18 ns
LSD at 5%(WM)	14 **		
(SR)*(WM)		25 ns	
CV		5	

The seed rate 80 kg/ha had the highest weed biomass (kg/ha) compared with seed rates 100 kg/ha and 120 kg/ha (Table 13). The weed management, such as no weeding method provided the highest weed biomass (337kg/ha) compared with control using herbicide.

Table 13. The effect of seeding rate and weed management on weed biomass (kg/ha)

Seeding rate (SR)/Weed management (WM)	Weed biomass (kg/ha)		Mean
	No weeding	Weeded (herbicide)	
T1=80 kg/ha	428	0	214
T2=100 kg/ha	322	0	161
T3=120 kg/ha	262	0	131
Mean	337	0	169
LSD at 5%(SR)			48*
LSD at 5%(WM)	39 **		
(SR)*(WM)		68 *	
CV		22	

Seed rate 100 kg/ha received rice yield of 4,673 kg/ha and seeding rate 120kg/ha received 5,090 kg/ha both higher than rice planted by seeding rate 80 kg/ha with grain yield of 4,332kg/ha only (Table 14). Two weeding methods showed that, well weeded herbicide control increased rice grain yield by 2,357 kg/ha (40.1% higher) than no weeding, while the average rice grain yield for no weeding was 3,520 kg/ha.

Table 14. Effects of seeding rate and weed management on rice grain yield (kg/ha)

Seeding rate (SR)/Weed management (WM)	Rice grain yield (kg/ha)		Mean
	No weeding	Weeded	
T1=80 kg/ha	3,230	5,434	4,332
T2=100 kg/ha	3,568	5,778	4,673
T3=120 kg/ha	3,763	6,418	5,090
Mean	3,520	5,877	4,698
LSD at 5%(SR)			219**
LSD at 5%(WM)	179 **		
(SR)*(WM)		310* *	
CV		4	

Table 15. Economic analysis for seeding rate and weed management for dry season with Senkraob variety

Item		Seeding rate 80 kg/ha					Seeding rate 100 kg/ha					Seeding rate 120 kg/ha				
	Unit	Qty	Unit Cost (US$)		Total Cost (US$)		Qly	Unit Cost (US$)		Total Cost (US$)		Qly	Unit Cost (US$)		Total Cost (US$)	
I- Operation			WD	NW	WD	NW		WD	NW	WD	NW		WD	NW	WD	NW
1-Land Preparation																
First land preparation/ha	ha	1	35.0	35.0	35.0	35.0	1	35.0	35.0	35.0	35.0	1.0	35.0	35.0	35.0	35.0
Second land preparation/ha	ha	1	35.0	35.0	35.0	35.0	1	35.0	35.0	35.0	35.0	1.0	35.0	35.0	35.0	35.0
2-Planting	ha	1	30.0	30.0	30.0	30.0	1	30.0	30.0	30.0	30.0	1.0	30.0	30.0	30.0	30.0
3-Labour Fertilizer	Man/day	2	5.0	5.0	10.0	10.0	2	5.0	5.0	10.0	10.0	2.0	5.0	5.0	10.0	10.0
4-Crop care	Man/day	5	5.0	5.0	25.0	25.0	5	5.0	5.0	25.0	25.0	5.0	5.0	5.0	25.0	25.0
5-Labour Insecticide	Man/day	1	10.0	-	10.0	-	1	10.0	-	10.0	-	1.0	10.0	-	10.0	-
6-Labour Herbicide	Man/day	1	10.0	-	10.0	-	1	10.0	-	10.0	-	1.0	10.0	-	10.0	-
6-Harvesting	ha	1	90.0	90.0	90.0	90.0	1	90.0	90.0	90.0	90.0	1.0	90.0	90.0	90.0	90.0
TOTAL (A)					**245.0**	**225.0**				**245.0**	**225.0**				**245.0**	**225.0**
II- Material																
1-Seed	Kg/ha	80	0.6	0.6	48	48	100	0.6	0.6	60.0	60.0	120.0	0.6	0.6	72.0	72.0
2-Chemical fertilizer																
Urea	Kg/ha	75	0.6	0.6	41.3	41.3	75	0.6	0.6	41.3	41.3	75.0	0.6	0.6	41.3	41.3
DAP	Kg/ha	50	0.5	0.5	25.0	25.0	50	0.5	0.6	25.0	25.0	50.0	0.5	0.5	25.0	25.0
KCL	Kg/ha	50	0.5	0.5	26.0	26.0	50	0.5	0.5	26.0	26.0	50.0	0.5	0.5	26.0	26.0
3-Insecticide	Pack	20	0.8	-	15.0	-	20	0.8	-	15.0	-	20.0	0.8	-	15.0	-
4-Pesticide/Mulucide 6GB	Pack	3	4.0	4.0	12.0	12.0	3	4.0	4.0	12.0	12.0	3.0	4.0	4.0	12.0	12.0
5-Herbicide	Pack	20	0.8	-	15.0	-	20	0.8	-	15.0	-	20.0	0.8	-	15.0	-
TOTAL (B)					**182.3**	**152.3**				**134.3**	**164.3**				**134.3**	**176.3**

Grand Total Input (A+B)		**427.3** **377.3**		**379.3** **389.3**		**379.3** **401.3**
Varietal name	Weeding (herbicide)	No Weeding	Weeding (herbicide)	No Weeding	Weeding (herbicide)	No Weeding
Rice yield (Kg/ha)	5,434	3,230	5,778	3,568	6,418	3,763
Income (Rice price US$0.30/Kg)	1,630	969	1,733	1,070	1,925	1,129
Gross margin (US$/ha)	1,203	592	1,354	681	1,546	728

The economic summary of three seeding rates with weeding (herbicide) (WD) and no weeding (NW) control are presented in Table 16 below. The weeding method across seed rates received a higher rice grain yield than no weeding method. Seed rate 80 kg/ha showed that weeding method received benefit of US$1,203/ha, while rice planted without weeding received benefit of US$592/ha only. For rice planted with seed rate 100 kg/ha, good weed control received benefit of US$1,354/ha and no weeding received benefit of US$681/ha and seeding rate 120 kg/ha received benefit of US$1,546/ha for weeding and no weeding received benefit of US$728/ha only.

Table 16. Summary of rice yield, input and income cost and gross margin for three seeding rate and weed management in dry season.

Item	Seed rate 80kg/ha			Seeding rate 100kg/ha			Seeding rate120kg/ha		
	WD	NW	Mean	WD	NW	Mean	WD	NW	Mean
Rice yield(kg/ha)	5,434	3,230	4,332	5,778	3,568	4,673	6,418	3,763	5,090
Input cost (US$/ha)	427	377	402	379	389	384	379	401	390
Income cost (US$/ha)	1,630	969	1,300	1,733	1,070	1,402	1,925	1,129	1,527
Gross margin (US$/ha)	1,203	592	897	1,354	681	1,018	1,546	728	1,137

Activity 2.5, Output 2.5.1. Evaluating the performance of Chinese radish varieties grown in paddy field after harvesting wet season crop.

Introduction

Chinese radish is a root and leaf vegetable that is grown and cook daily for pickled food. The supply of Chinese radish is currently not enough to support the capacity of Cambodian population growth, so improved quantity and quality of Chinese radish is a priority. Selecting the right variety to plant is a very important thing for the farmer. To solve this complex problem, we selected four radish varieties to test in the paddy field after harvesting wet season rice in 2018.

Objectives:

- Identify the best performance of radish with good yield and market acceptability, at rain-fed lowland areas
- Study the input cost and economic benefit and investment return for radish

Materials and Research Methodology

Materials

The long-term rotation research trial was conducted with Prateah Lang soil type in CARDI. The experiment was carried out by using a Randomized Complete Block Design (RCBD) in factorial arrangement with four replications and four treatments; each plot was 2 m long and 1 m wide with a total of 16 plots with area 32 m^2.

Land preparation

Land was prepared by 4WDT with 7-disc plough and 30 cm depth, then harrowed before bed making (light till) with 2 m length x 1 m wide and 30 cm high. Each bed was planted with 10 rows and each row 4 hills.

Varieties

The 4 variety names and sources:

I. Chinese radish sold by C. P. Group Thailand,

II. Choke Kasikorn - seed source from Thailand,

I. Ural - sourced from India sale buy East –West Seed,

II. Chia Tai sourced from Thailand, this company established since 1921 sale by C.P. Group,

Duration from planting to harvest approximately 45-50 days.

Fertilizer application

Fertilizer application and time applied (ACIAR project –SMC-71),

Time	Date	Fertilizer Type	Quantity kg/ha)	Quantity (g/16 beds)
Basal	1st February 2019	15-15-15	200	640
1st top-dress (10 DAS)	11 February 2019	Urea	30	96
		15-15-15	200	640
2nd top-dress (25-30 DAS)	2nd March 2019	Urea	80	256
		KCL	50	160

Irrigation

The crop was irrigated by using sprinkler every day at 4 pm based on soil moisture availability.

Data collection

The measurement was tuber root length, diameter, individual root weight, total yield and good yield production.

Data analysis

All data was entry and analysed using CROP START 7.2 application. To identifying the yield performance and cross margin.

Result and discussion

The result of performance of 4 varieties with tuber length, diameter, tuber weight, total yield and good yield is presented in Table 17 below. There was no significant difference in the tuber length, diameter, tuber weight among four varieties, but the best quality yield was Chinese radish variety=45,000 tonnes/ha follow by Choke Kasikorn=41,825 tonnes/ha, Ural =36,000 tonnes/ha and the lowest yield was 34,250 tonnes/ha for Chia Tai variety, it also the best yield performance for four variety was Chinese radish=39,375 tonnes/ha, Choke Kasikorn=37,450 tonnes/ha, Ural =30,500 tonnes /ha and Chia Tai=29,000 tonnes/ha.

Table 17. Each varietal performance on tuber length, diameter, total yield and good quality yield

Varieties	Tuber length (cm)	Diameter (mm)	Tuber weight(g)	Total yield(kg/ha)	Good yield(kg/ha)
Chinese Radish	20	9	150	45,000	39,375
Choke Kasikorn	21	10	150	41,825	37,450
Ural	19	10	143	36,000	30,500
Chia Tai	23	9	138	34,250	29,000
Mean	20	10	148	40,942	35,775
5%LSD	3 ns	2 ns	0.4 ns	4187 *	5782 *
CV	9	16	17	7	11

The result of economic analysis for four radish varieties is presented in the Table 18 below. It costs approximately US$1459/ha for input cost for whole process and material, but all varieties differ in radish yield, in terms of gross margin, Chinese radish gets benefit US$4,448/ha, Choke Kasikorn =US$4,159/ha, Ural=US$3,117/ha and Chia Tai=US$2,891/ha.

Table 18. Economic analysis for Chinese radish production on input cost and income with 4 radish variety grown in rainfed lowland after harvested wet season rice.

INPUT	Inputs			
	Unit	Quantity	Unit Cost	Total Cost (US$)
I- Operation	Person/day		US$	
1- Land Preparation				
First land preparation	ha	1	35.00	35.00
Second land preparation	ha	1	35.00	35.00
Harrow	ha	1	30.00	30.00
Bed making	ha	1	40.00	40.00
2- Planting/day	Person/day	25	5	125.00
3- Fertilizer				
Urea (Kg/ha)	Kg	101	0.55	55.55
KCL (Kg/ha)	Kg	78	0.52	40.56
DAP (Kg/ha)	Kg	19	0.50	9.50
4- Crop care				
Labor Fertilizer/day	Man/day	5	5.00	25.00
insecticide/day	Man/day	4	10	40.00
Hand weeding/day	Man/day	10	5	50.00
Watering	Man/day	45	5	225.00
5- Harvesting				
Pulled /harvested/day	man/day	20	5	100.00
TOTAL (A)				810.61
ll- Material				
1- Seed (Kg/ha)				
Chinese Radish	kg	9	18	162.00
Choke Kasikorn Seed	kg	9	18	162.00
Ural	kg	9	18	162.00
Chia Tai	kg	9	18	162.00
5- Insecticide	Bottle	3	5	15.00
Total (B)				648.00
Grand Total Input (A+B)				1,458.61
Varietal name	Chinese Radish	Choke Kasikorn	Ural	Chia Tai
Radish Yield (Kg/ha)/	39,375	37,450	30,500	29,000
Income (Radish price US$0.15/Kg)	5,906	5,618	4,575	4,350
Gross margin (US$/ha)	4,448	4,159	3,116	2,891
Investment ratio	3.0	2.9	2.1	2.0

Activity 2.6, Output 2.6.2. Evaluation of the irrigation and mulching methods on watermelon production in the paddy field after harvesting wet season rice 2018.

Introduction

It is less practical for Cambodian farmers to grow any kind of cash crop after rice, except in some areas where farmers have existing sources of supplementary irrigation water and they have access to rice stubble for mulch. However, there has been successfully the experiments in India and Indonesia to using mulching to cover the soil to grow wheat and soybean to increase productivity. We try to demonstrate options that Cambodian farmers may adopt appropriate technologies for their conditions.

Optimising the efficiency of irrigation water under condition of scarcity is common concern of farmers that plant cash crops, also for growing areas within the Mekong and Basac river basins. Generally, the Cambodian farmer in upland area grow the crop depending on rainfall, but when growing lowland crops along the Mekong and Basac river, they use supplementary irrigation water from underground wells and river. They use spray, channel flow and other different irrigation methods, but when we look at the economic or agriculture input, irrigation is the other cost included in the production cost, sufficient and appropriate of water use may save some money and time for them. A wide technology gap exists between currently available irrigation technology and specific water needs of rural poor. Simple pump, appropriate drip irrigation technology and plastic water bucket are examples of household-level irrigation that need small irrigation systems for low entry cost, high rate of return and easy maintenance.

Objective

- Identify the appropriate irrigation method (furrow and drip) on watermelon yield

- Identify the effectiveness of different mulching method (rice straw and plastic) on watermelon yield and its economic return.

Material and Methodology

The research trial was conducted in the rainfed condition, with Prateah Lang soil type in CARDI. The experiment was carried out by using a split plot with randomised design in factorial arrangement with three replications, two main plots and three sub-plots, each plot was 9 m length and 2.5 m wide, with a total of 18 plots with area 405 m^2.

Main and sub treatment

Rep	Main-treatment Irrigation method	Sub-treatment Mulching	Rep	Main-treatment Irrigation method	Sub-treatment Mulching
1	Furrow irrigated	Plastic mulch	1	Drip irrigated	Plastic mulch
1	Furrow irrigated	Rice straw mulch	1	Drip irrigated	Rice straw mulch
1	Furrow irrigated	Bare bed	1	Drip irrigated	Bare bed
2	Furrow irrigated	Plastic mulch	2	Drip irrigated	Plastic mulch
2	Furrow irrigated	Rice straw mulch	2	Drip irrigated	Rice straw mulch
2	Furrow irrigated	Bare bed	2	Drip irrigated	Bare bed
3	Furrow irrigated	Plastic mulch	3	Drip irrigated	Plastic mulch

3	Furrow irrigated	Rice straw mulch	3	Drip irrigated	Rice straw mulch
3	Furrow irrigated	Bare bed	3	Drip irrigated	Bare bed

Land preparation

Land was prepared by 4WDT with 7-disc plough and depth 20 cm, then harrowed before bed making (light till) with 9 m length x 2.5 m wide and 25 cm high.

Varietal and seedling preparation

The Reach Cheany variety was selected to trial; the seedling was prepared by plastic tray and transplanted when 12 days old.

Three mulching methods were used, 1- plastic mulch to cover the bed with holes for transplanting melon seedlings, 2 -rice straw - 2.5 tonnes/ha was spread on soil surface and 3- bare bed (with no cover).

Fertilizer application

Fertilizer application and time applied (ACIAR project –SMC-71),

Time	Date	Fertilizer Type	Qty (kg/ha)
Basal	31 January 2019	DAP	25
		KCL	25
		UREA	25
1st top-dress (7 DAS)	8 February 2019	DAP	50
		KCL	100
		UREA	100
2nd top-dress (20 DAS)	23 February 2019	DAP	50
		KCL	50
		UREA	100
3rd top-dress (40 DAS)	10 March 2019	DAP	50
		KCL	50
		UREA	50

Irrigation

The crop was irrigated using sprinkler every day at 4 pm, the amount of water applied depended on soil moisture content

Data collection

The measurement was fruit length, diameter, individual fruit weight, total yield and good quality yield production. First harvested on 01st April 3019 and second batch harvested on 5th April 2019.

Data analysis

All data was entered and analysed using CROP START 7.2 application. Yield performance and gross margin were calculated.

Results and discussion

The result of irrigation and mulching method is shown the summary in Table 19 below. Irrigation methods did not have a significant difference on plant survival and total yield. Mulching did not have a significant difference on plant survival but had a significant difference in melon yield.

Table 19. Summary ANOVA model for statistical analysis of mulching and irrigation methods on melon production

VARIATE	Survive plant at harvested (hill/ha)	Total yield (kg/ha)
Irrigation Method (IM)	ns	ns
Mulching (ML)	ns	*
(IM)*(ML)	ns	ns
MEAN	7,440	13,518
C of V	6	16

The watermelon was planted at approximately 8000 plant/ha, but from first to second harvest, there were no significant differences between watermelon plants planted in bed covered by plastic mulch, bare bed and rice straw mulch on plant establishment, and irrigation method (furrow irrigated or drip irrigated) was also not significantly different (Table 20).

Table 20. The effect of irrigation method and mulching on plant establishment (plant/m^2)

Irrigation Method	Plant establishment at harvesting (hill/ha)			Mean
	Plastic mulch	Bared bed	Rice straw mulch	
Furrow	7,496	7,793	7,541	7,610
Drip irrigated	7,170	7,526	7,111	7,269
Mean	7,333	7,659	7,326	7,440
LSD at 5%(IR)				ns
LSD at 5%(ML)		ns		
(IR)*(ML)			ns	
CV			6	

The result of watermelon received by irrigation method and mulching technique is presented in Table 21 below. Plastic mulch had 15,620 tonnes/ha yield and followed by rice straw mulch with 13,857 tonnes/ha and the bare bed had the lowest yield at 11,076tonnes/ha. The lower yield was due to watermelon fruit damage by insect and fruit diseases. Watermelon yield was similar for furrow and drip irrigation, with average yield of 13,518 kg/ha. The water use efficiency was better with drip irrigation method which saved water (approximately 4.790m^3/ha or 40.1%) compared with furrow irrigation method.

Table 21. The effects of irrigation method and mulching technique on total yield watermelon

Irrigation Method	Total watermelon yield (kg/ha)			Mean	Water (litre/ha)
	Plastic mulch	Bare bed	Rice straw mulch		
Furrow	13,910	10,933	14,354	13,066	11,767
Drip irrigated	17,330	11,219	13,360	13,970	6,969
Mean	15,620	11,076	13,857	13,518	9,368
LSD at 5%(IR)				ns	2,337 *
LSD at 5%(ML)		2,855 *			
(IR)*(ML)			ns		
CV			16		7

Activity 2.5, Output 2.6. Mungbean production in the paddy field after harvested wet season rice

The mungbean variety, CARDI Chey was used to test in the paddy field, the paddy field was ploughed twice times then harrowed, and the mungbean was planted using the Cambodian Seed Drill with 4 rows, seeding rate was 35 kg/ha, row spacing - 20 cm, plot size – 20 m length and 21 m wide, with total area - 420m^2. Date of planting was 22nd January 2019, Fertilizer application (Urea=50 kg/ha, DAP=100kg/ha and KCL=50kg/ha), We applied: 1.basal Urea=20 kg/ha, DAP=40 kg/ha and KCL=15 kg/ha, 2. First top-dressing Urea=15 kg/ha, DAP=30 kg/ha and KCL=15 kg/ha, 3. Second top-dressing Urea=15 kg/ha, DAP=30 kg/ha and KCL=15 kg/ha. Water irrigated by using sprinkler at morning and afternoon. The first harvested on 22nd March 2019 and second on 28th March 2019. The total yield= 29.358 kg/420m^2 equal 700 kg/ha.

Several options for production and productivities

The main wet season rice plus other option crops with the same area, option1: Main wet season (Phka Rumdoul)+ Dry season (Senkraob) profit=US$2,569, 2. Main wet season (Phka Rumdoul)+Dry season (Chinese radish) profit=US$5,492, 3. Main wet season (Phka Rumdoul)+Dry season (Watermelon) profit=US$1,322 and 4.Main wet season (Phka Rumdoul)+Dry season(Mungbean) profit=US$1,375 (Table 22).

Table 22. The economic analysis for main wet season rice and second crop such as dry season rice, Chinese radish, watermelon and mungbean in the same land.

Item	Crop				
	Phka Rumduol	Sen Kraob	Chinese Radish	Watermelon	Mungbean
Yield (Kg/ha)	4,549	6,418	39,375	15,620	700
Input cost (US$/ha)	320	401	1,459	1,285	720
Income (US$/ha)	1,365	1,925	5,906	1,562	1,050
Gross margin (US$/ha)	1,045	1,524	4,448	277	330
Investment ratio	3	4	3	0.2	0.5
Option (US$/2crops)	Wet season (WS)	Dry Season (DS)			
2,569	1,045	1,524			
5,492	1,045		4,448		
1,322	1,045			277	
1,375	1,045				330

Summary and conclusions

Machinery testing

1. The 4-WT drum seeder can be used on larger paddy fields, it can replace hand seeders and it is suitable for service providers (contractors).
2. For dry season (CAR 14 variety) produced similar yields for rice planted by drum seeder with 4-WT or drum seeder pulled by hand.
3. Small amount of rice grain yield increase in drum seeder pulled by hand.
4. Rice growth in dry and main wet season increased rice grain yield for best weed control, either by hand weeding or herbicide application compared to nil weed control.
5. For dry season (SKO variety) produce similar yields for rice planted by CARDI drill (dry seeding) for seeding rates 80-120 kg/ha.

Options to reduce rice seeding rates below 80 kg/ha for dry-drill seeders

1. Good weed management provided the best plant density, lowest weed biomass and received high rice grain yield
2. Seeding with seed rate 40, 60 and 80 kg/ha produced similar rice grain yield for rice planting by hand broadcasted with seed rate 180 kg/ha.
3. In 2019 dry season, seeding with seed rates 80, 100, 120 kg/ha produced similar rice grain yield.

Pre-emergence herbicide options for rice

1. Plant density for rice planted with seed rate 40 kg/ha produced lower plant density than rice planted with seed rate 80 kg/ha.
2. Rice grain yield was similar for rice growth with seed rate 40 or 80 kg/ha (wet seeding rate).
3. Five different herbicides were not significantly different for plant density and rice grain yield.

Options for dry season non-rice crops

1. Chinese radish is more profitable than mungbean, watermelon and rice in the dry season.
2. Mulching with rice straw or plastic produces higher watermelon yields than bare soil.

Battambang

Objective 1

Activity 1.3, Outputs 1.3.4, 1.3.5: The role of social networks for the adoption of agricultural innovations in rural Cambodia. Key implementation team: Aaron Junjian Zhang (USYD honours student), Petr Matous, Bob Martin, Daniel Tan, Sophea Yous.

This activity resulted in a thesis submitted by Aaron Junjian Zhang in partial fulfilment of the requirements for the Degree of Bachelor of Engineering in Civil Engineering at the University of Sydney.

The correlations between social network properties and technology diffusion in rural Cambodian settings were explored. Quantitative data were collected from January to February 2018 in Angsangsak village, Battambang Province, Cambodia. Data were analysed using three statistical tools: Pearson's product-moment correlation; independent sample t-test; and the Ordinary Least Square regression model.

It was found that the betweenness centrality of farmers is positively correlated with technology diffusion. However, the position in social networks alone does not tell the full story. The analysis also suggested that exposure to mass media and agricultural associations was negatively correlated with adoption of new technologies. Additionally, the larger the annual net profit earned, the more likely a farmer will adopt new technologies.

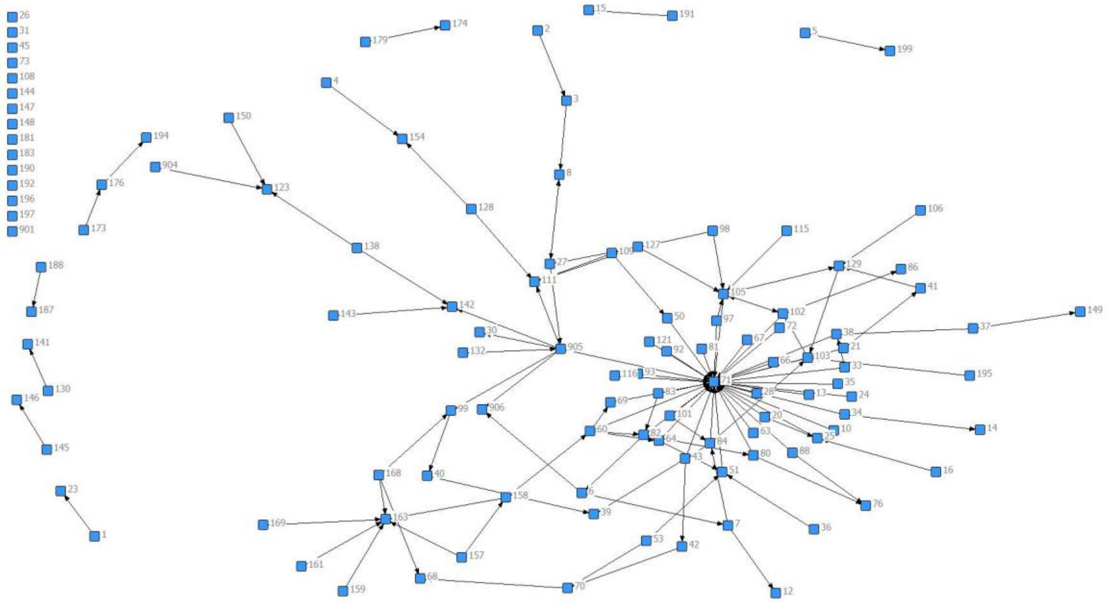


Figure 5. Sociogram of Angsangsak Village Based on Advice-seeking Networks

Conclusions

- The higher betweenness centrality of a farmer, the earlier this farmer may adopt technology. Farmers with high betweenness centrality have access to diverse cliques within the local social networks and therefore have the best access to diverse sources of information. Moreover, due to the brokerage opportunities possessed by farmers with high betweenness centrality in their networks, most agricultural technologies will go through them, giving rise to the possibility of technology adoption.

- Trust among farmers contributes to the significant role of word-of-mouth information from other farmers in adoption behaviour. It can be attributed to the traditional Cambodian society which is organised around kinship, and family relations play a dominant role in Cambodian farmers' social lives.
- The more annual net profit earned, the more likely for a farmer to adopt new technologies. Wealth implies a higher ability of farmers to bear a risk; thus, farmers who have high risk-taking ability are more likely to adopt new technologies.

Implications

- In rural Cambodian settings, focus should be put on identifying and training information brokers, farmers with high betweenness centrality in their networks, rather than the common approach of the generally popular farmers who possess high degree centrality.
- The key to an effective diffusion strategy is to conduct a social network analysis in the target community, and precisely locate the actors who bridge two or more different cliques prior to any technology promotion program.
- More links between different actors, and more importantly, clusters, should be created to make up for the structural holes. Effective relationships between producers and users of innovations and their smooth working links where there is a huge gap between them should be developed.
- Therefore, network brokerage can be done by providing innovation platforms where players of innovation can meet frequently. It aims not simply to strengthen the pre-existing informal networks, but also to promote social interactions and form social proximity.

Directions for future research

- Network constraint is a great perspective to study technology diffusion.
- Inter-village networks play a considerably important role in analysing famers' behaviour on technology adoption. Future research could focus on the information flows between villages and observe how social networks affect technology adoption from a macro level.
- Due to the unexpected negative association between technology diffusion and exposure to mass media and agricultural associations, more effort should be put to investigate the roots of this relationship in rural Cambodia settings.

Activity 1.4, Output 1.4.3: Analysis of gender roles in farming activities. Key implementation team: Rebecca Cross, Van Touch, Flavia Ciribello (VSO)

Where women are more involved in the activity (their involvement is at least 50%), then they play a bigger role in the decision making; they discuss with their husband and make the decision in agreement. Women are reported to be involved at 50% in the decision making related to, for example, *Transplanting in the gaps, Weeding, Making the rice levee, Drying, packaging and storing rice, Hiring Laborers and Contractors.* Exceptions are related to *Buying pesticide and fertilizer* and *Buying bags and strings* – probably due to their limited knowledge regarding inputs and harvesting needs. They are the best negotiators within the family but in this case their action is informed and influenced by the husband's opinion. On the other hand, it is worthy to note that the farmers reported that the women play a bigger role than men in the decision making related to *Selling Rice* (60% vs

40%). This was the only activity in which women had control over the decision-making process. Similarly, when women are less involved in an activity *e.g. buying seed; land preparation; broadcasting* then their opinion is less likely to influence the final decision. For instance, for the decisions concerning land preparation, the farmers reported that women are involved in decision-making at 12.5%. Also interesting to note are the instances when women play less of a role in the activity but more of a role in decision-making. This is usually related to inputs; women were not very involved in applications, but when to apply inputs – fertiliser, pesticide/insecticide and herbicide, was a decision often made by checking the field as a partnership, although the man ultimately had more say in these decisions (Figure 6).

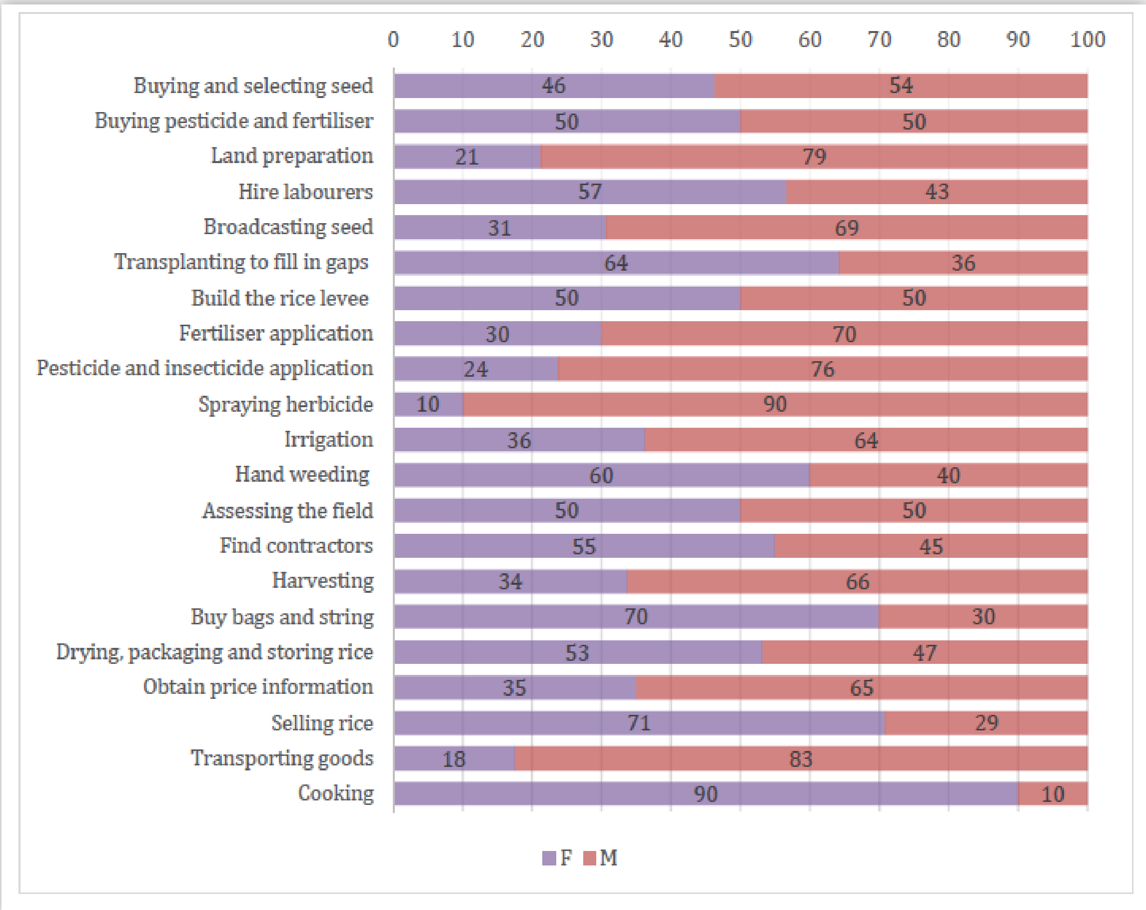


Figure 6. **Male and female % of involvement in each activity listed by respondents in the rice value chain**

The opportunities for women to lead the way in innovation and farm improvement are extensive. There are a number of key skills women have and roles women could fulfill which could increase their participation in the rice value chain without requiring a ‘gender reversal’ or a drastic shift in gender roles. These potential services include women as financial managers for households, investments, local businesses and ACs. Women as record keepers (monitoring key aspects of production) and farm planners (generating and using data to identify trends and opportunities for practice change). Women as quality control experts (to find efficiencies and potential improvements/innovations or new markets). Women as local extensionists – acting as conduits for bringing outside knowledge of innovation into villages and households. Women as entrepreneurs – exploring potential for developing businesses and generating off-farm income via collective groups of women. Women as citizen scientists – trialing and monitoring new practices or approaches on a small scale, for example Integrated Pest Management. In these positions, women could become facilitators of not only increased equity, but increased sustainability in their villages, by improving environmental, economic, socio-cultural and personal outcomes for all.

Activity 1.4, Output 1.4.3: Analysis of gender roles in vegetable production. Key implementation team: Rebecca Fong (USYD honours student), Daniel Tan, Rebecca Cross, Bob Martin, Sophea Yous, Ratha Rien

For centuries, the backbone of Cambodia's economy and agriculture sector has been the cultivation of rice. However, recent market trends have seen changing dietary patterns and a decline in the global price of rice for the foreseeable future, leaving small-scale rice farmers without a sustainable income.

An option that farmers in North-west Cambodia have is to diversify into vegetable production. Vegetable demand has been on the rise in the past 10 years due to their nutritious qualities. Additionally, vegetables are a useful form of crop rotation for minimising the spread of diseases and improving the quality of soil and are suitable for growing in post-wet-season Cambodian soils.

This project aims to analyse the scalability of vegetable production, by conducting a value chain analysis (VCA) to map and evaluate each actor in the chain of Cambodian vegetables, including farmers, collectors and wholesalers. In addition, this report will also be addressing the degree of gender equality in vegetable production to determine if there has been progress in women empowerment.

The VCA was conducted using the mixed method approach in collaboration with the ACIAR which included interviews with 524 household farmers in the provinces of Battambang and Banteay Meanchey. There is a great demand for Cambodian vegetables as they are recognised to be of high quality relative to those imported from neighbouring countries. Challenges that actors in the VCA face are the lack of resource-base and technical knowledge. Once these issues have been resolved and proper post-harvest storage has been implemented, vegetables may be a positive diversification option for improved livelihoods. Women play a key role in vegetable production and integrated models that realise women's potential to capitalise on and value-add to vegetable products will advance the vegetable industry in Cambodia.

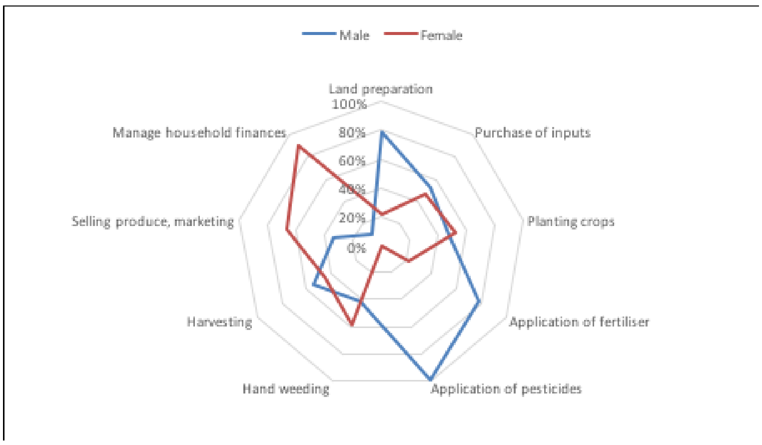


Figure 7. Distribution of gender roles in vegetable production in NW Cambodia.

The distribution of gender roles in vegetable production was analysed via the 70 vegetable surveys conducted (Figure 7). The main difference between the genders indicates that men do most of the hard labour activities such as land preparation and application of pesticides and herbicides while women are more predominantly involved in monetary decision making such as managing the household finances and selling the produce. However, the survey revealed that an equal workload is shared among males and females in farming roles where hard labour is not required (for example, planting crops). During surveys, some women stated that they are out in the field for only a few hours a day while the children are at school. Women are seen to participate in crop planting, harvesting and hand weeding as these were tasks, which were not as time sensitive nor perceived to be as ‘unsafe’ as pesticide and herbicide application.

Directions for future research

Women were identified as the primary manager of household finances, selling of produce and equally involved in purchase of inputs. Proposed activities include:

- Training for women in household financial management, farm investments, local businesses and leadership of Agricultural Cooperatives;
- Sustainable intensification and diversification requires significant changes in the types of inputs required (seed, fertiliser, pesticide) and engagement of women as well as input sellers will be sought.

Objective 2

Activity 2.4, Output 2.4.2: Options to reduce rice seeding rates below 80 kg/ha for dry-drill seeders, Svay Cheat village, early wet season 2018. Key implementation team: Bob Martin, Ratha Rien, Sophea Yous

Figure 8. The Kid seed drill for dry-seeding rice and other crops

Most growers of certified rice seed have replaced transplanting with broadcasting because of cost and are now interested in machine row planting as a low-cost alternative. A field experiment was therefore conducted with a seed producer in Svay Cheat village, Battambang province to compare different sowing rates under dry-seeded conditions using the KID seeder with regard to agronomic and economic considerations. An experiment, in four replicates, was conducted to compare drill seeding rates of 20, 40, 60 and 80 kg ha^{-1} with hand broadcasting at 180 kg ha^{-1} with and without herbicide.

The weed population was low and there was no effect of herbicide. Although the seeding rate response curve was relatively flat, paddy yields for 20 and 40 kg ha^{-1} seeding rates were significantly less than for the higher seeding rates. Furthermore, the hand broadcasting treatment was favoured by the farmer's seedbed preparation which was too soft for machine planting.

The results (Figure 9) confirm previous research (Martin et al. in press) which suggests that reducing rice seeding rates below 60-80 kg ha^{-1} might not be currently feasible considering yield constraints within the existing agro-ecological system of rice production in NW Cambodia.

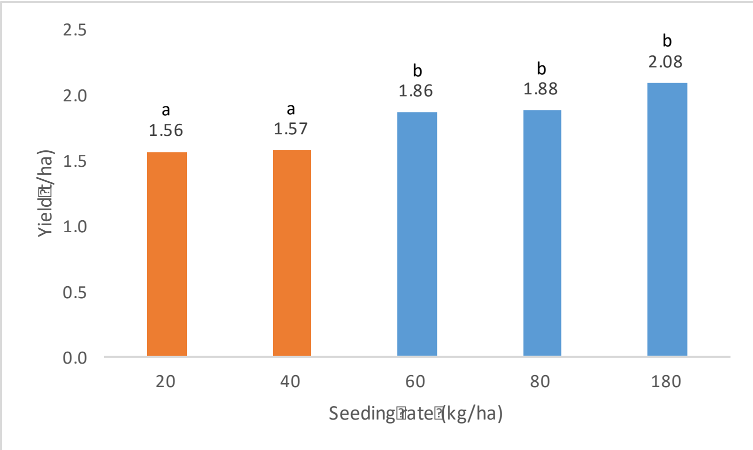


Figure 9. Effect of seeding rate on rice paddy yield at Svay Cheat in the EWS 2018

Activity 2.5, Output 2.5.1: Evaluation of mungbean varieties for short duration and drought tolerance. Key implementation team: Harry Campbell-Ross (USYD honours student), Bob Martin, Sophea Yous, Ratha Rien.

Figure 10. CARDI Chey and Cambodian Mungbean-3 (CMB-3) were the best mungbean varieties but are yet to be commercially released

There is considerable scope for expansion of mungbean as a diversification crop in the lowland rice system considering the profitability (\$500-\$1,000 ha^{-1}) and potential export market. Mungbean can be grown on residual soil water after the main wet season rice crop on active flood plain soils in north-western Cambodia. With the cost of labour for harvesting at \$200-250 ha^{-1}, farmers are looking to reduce the number of pickings by choosing short-duration varieties with reduced pod shattering.

The objective of this study was to evaluate 10 existing commercial mungbean varieties from Cambodia (2), Thailand (4) and Vietnam (4) for short duration and determinate flowering. The 10 varieties were evaluated under adequate soil water at the University of Battambang (13°05’05” N; 103°13’11” E) and limited soil water at Don Bosco School Farm (13°04’37” N 103°10’24” E). The experimental design was a randomized complete block with four replicates. The varieties were assessed for emergence, vegetative biomass, early flowering, grain yield, seed size, height, resistance to powdery mildew, lodging and marketability.

The Cambodian varieties (CARDI Chey and CMB-3) best satisfied these criteria and resulted in significantly greater income per hectare compared to varieties in the local market (DX-208 and KPS-2) (Figure 11). None of the Thai or Vietnamese varieties were superior to the Cambodian varieties. It is therefore proposed that options for commercial release of CARDI Chey and CMB-3 are pursued. Quick maturing non-shattering ecotypes are required by farmers and the market requires bright shiny large seeds.

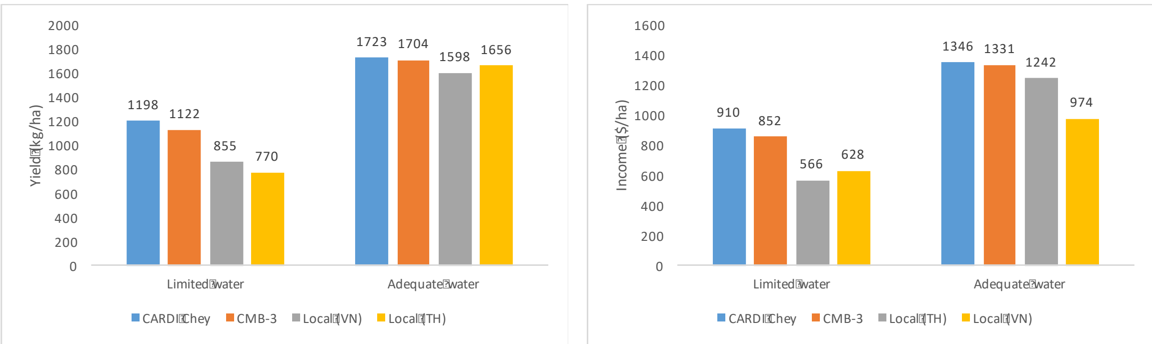


Figure 11. Yield (left) and income (right) from mungbean varieties under adequate and limited soil water conditions in 2018

Further mungbean genotype evaluation in 2019 will include Australian non-PBR genotypes which are likely to possess these qualities. The varieties from Cambodia, CMB-3 and CARDI-Chey, had superior agronomic and quality characteristics compared with Vietnamese and Thai varieties. This was reflected in the price estimate and income of each variety as both were found to have the most lucrative gross margins. These findings showed that the varieties available to farmers are unsuitable for continued production in the local farming systems. This study could also lead to the creation of a certified mungbean seed production business by a local village agricultural cooperative as a means of value-adding.

Evaluation of mungbean varieties (2019 dry season)

Activity 2.2: On-farm field experiments and demonstrations on rice and other rotation crops [e.g. mungbean, waxy maize, and vegetable crops] conducted to refine and adapt successful SID innovations

Figure 122. Mungbean varieties during the podding stage

In lowland rice systems, mungbean is commonly grown as a low-cost opportunity crop in the early dry season between December and March using residual soil water after the main wet season rice crop or after receding floodwaters. The average yield of mungbean in lowland districts is 819 kg ha^{-1} but Angsangsak-Prek Trab village farmers claim they can achieve yields up to 1,500 kg ha^{-1} and if true, this would give a potential exploitable yield gap of 681 kg ha^{-1}. Farmers are therefore achieving only 50-60% of obtainable yield. Farmers in Angsangsak-Prek Trab plant two varieties (DX-208 and KPS-2) and pick two times with the second pick 15-20 days after the first. Under this regime, pod shattering is a problem with DX-208 but not with KPS-2. However, DX-208 is preferred for seed quality and price.

This work is being conducted with support from Ms Caitlin Cavanagh as part of her University of Sydney 4th year thesis project.

1. Objectives

1. Evaluate a selection of Australian mungbean varieties for short-duration and synchronous flowering in comparison with Cambodian registered and varieties available in the local market (KPS-2, Thailand and DX-208, Vietnam).
2. Identify varieties most suited to Cambodian soils and early dry season climatic conditions through validation and simulation of scenarios using APSIM.
3. Engage with farmers, input suppliers, traders, and Agricultural Cooperatives, to identify mungbean varieties suitable for registration as Quality Declared Seed (QDS);
4. Develop a pilot mungbean Quality Declared Seed (QDS) business model in collaboration with Voluntary Service Overseas (VSO) and the Angsangsak Agricultural Cooperative (AAC).

An experiment was carried out during January-April 2019 to evaluate a selection of 11 Australian mungbean varieties for short-duration, synchronous flowering and non-shattering in comparison with Cambodian registered varieties and varieties available in the local market (KPS-2, Thailand and DX-208, Vietnam).

No shattering was observed for Australian varieties Berken, Delta, Emerald, Green Diamond, King, Satin or Shantung. There was more shattering in Celera, Putland and CMB-3 compared to DX-208. However, farmer observation was that shattering was less for CMB-3 compared to DX-208.

The average final grain yield at 101 days after sowing (DAS) was 2,258 kg ha^{-1} and ranged from 1,205 (Yellow Shn) to 2,917 kg ha^{-1} (Shantung). The average cumulative grain yields (kg ha^{-1}) were: 836 at 58 DAS; 1,240 at 63 DAS; 1,437 at 73 DAS; 1,820 at 83 DAS, and 2,258 at 101 DAS (13).

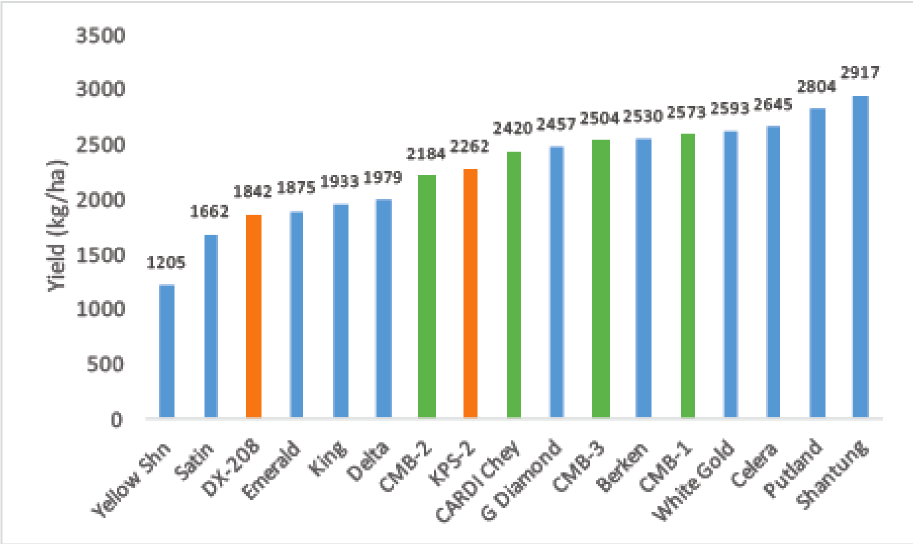


Figure 13. Yield of 17 mungbean varieties (kg/ha)

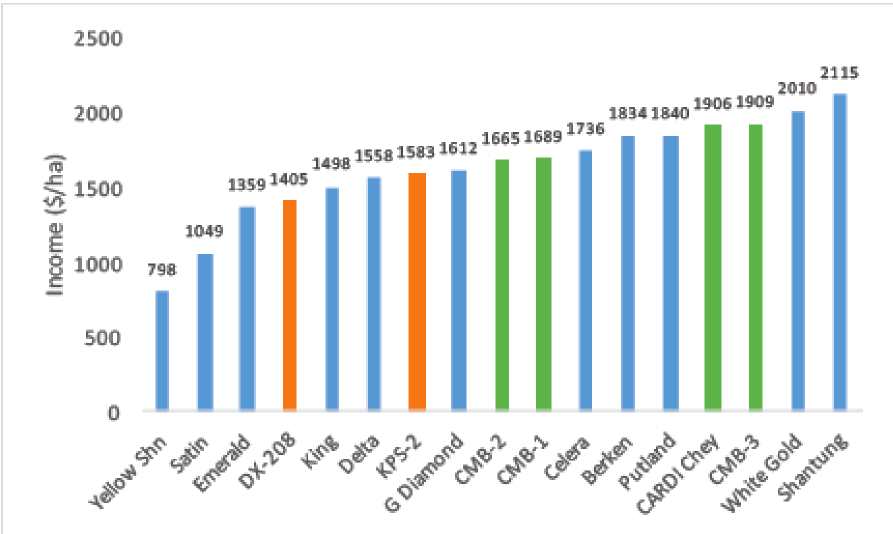


Figure 14. Income from 17 mungbean varieties ($/ha)

In farmer and buyer quality assessments, Berken, Green Diamond and Putland were downgraded because of small seed size. Celera, KPS-2, Satin and Emerald were marginal for seed size. The rest of the varieties were satisfactory for seed size. Satin, Yellow Shn, Berken, KPS-2, CMB-1, DX-208 were downgraded for colour. Satin, CMB-1, Berken and KPS-2 were downgraded because of lack of lustre. Satin and CMB-1 received particularly low scores. For overall quality, CARDI Chey, CMB-2, CMB-3, Delta and White Gold received the best scores. Satin, Berken, KPS-2, CMB-1 and Green Diamond were the lowest scoring group for overall quality. Delta, CARDI Chey and White Gold received the highest estimated price (3,500 riel kg^{-1}). King, CMB-2 and CMB-3 were given 3,300 kg^{-1}. However, several varieties (Emerald, KPS-2, Green Diamond, Berken, CMB-1, Celera, Putland, Shantung and DX-208) were quoted at 3,000 riel kg^{-1}. Yellow Shn (2,500 riel kg^{-1}) and Satin (2,800 riel kg^{-1}) were heavily downgraded.

The gross margin, based on the average of farmer and buyer valuations, varied widely from \$340 ha^{-1} for Yellow Shn to \$1,657 ha^{-1} for Shantung. The best Cambodian varieties were

CMB-3 ($1,451 ha^{-1}) and CARDI Chey ($1,447 ha^{-1}). The overall assessment of varieties against selection criteria indicated that further comparison of Shantung and White Gold with CMB-3 and CARDI Chey was warranted.

Table 23. Options for increasing mungbean yields.

Problem	Current practice	Improved practice
Pod-shattering	Limited choice of varieties	Varieties with synchronized flowering
Lack of soil water	Two passes of a disc plough, two harrowings	Crop residue retention, minimum or no tillage
Poor crop nutrition	No basal fertiliser, foliar fertiliser application	Basal NPK+TE fertiliser + rhizobial inoculation
Poor weed control	Post-emergence herbicide on stressed weeds	Pre-emergence herbicide is more effective
Insect pests	Broad-spectrum insecticides applied in vegetative stage cause flaring of secondary pests (e.g. aphids)	Seed dressing with systemic insecticide + IPM with a priority to manage pests attacking pods
Diseases	Application of fungicide	Resistant varieties, seed treatment
Suspected K deficiency	Limited use of foliar fertilisers to promote flowering	Test strips of KCl in farmers' fields in 2019-20

The mungbean on-farm research activity commenced in October 2017 and has progressed rapidly to the scaling out stage (15). Options for scaling out of the improved package for mungbean under Objective 3.2 will be explored in 2019 and 2020.

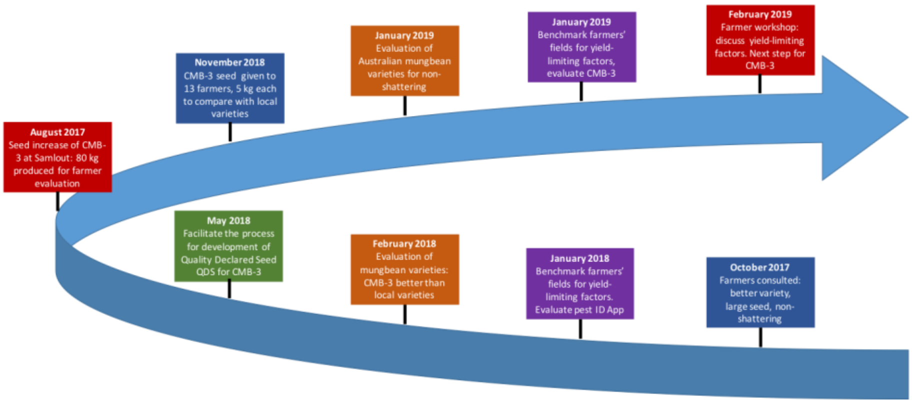


Figure 15. Development of mungbean as a diversification crop: timeline of activities at Angsangsak/Prek Trab

Comparison with farmer practice at Angsangsak-Prek Trab in 2019

Data were collected from five mungbean growing households at Angsangsok-Prek Trab villages in 2019 (Table 114). The average planting date was 22nd December and the average area of mungbean was 1.9 hectares. The average for first pick was 75 DAS and 92 DAS for second pick and the average number of days between picks was 17 days.

Table 114. Farmer-practice mungbean production at Angsangsak-Prek Trab in 2019

Description	Min	Max	Ave
Planting date	29-Nov	5-Jan	22-Dec
Area (hectares)	0.6	4.5	1.9
First pick (days after sowing)	59	84	75
Second pick (days after sowing)	71	105	92
Yield (kg ha^{-1})	893	1,111	951
Price (Riel kg^{-1})	3,190	3,567	3,379
Income (USD ha^{-1})	583	889	760
Variable costs (USD ha^{-1})	216	326	282
Gross margin (USD ha^{-1})	452	1,263	812

The average farm mungbean yield was 951 kg ha^{-1} which was only 42% of the average yield in the experiment (2,258 kg ha^{-1}). A lot of this difference is due to the difference in water availability. However, farmers can improve water-use efficiency by retaining crop residues, reducing tillage and drill seeding.

The average price for the first pick is 3,567 riel kg^{-1} compared to the average for the second pick of 3,190 riel kg^{-1}. This suggests there might be some options for storage and collective marketing. The average variable costs for farmer-practice was \$282 ha^{-1} compared to the variable costs of the experiment which were \$458 ha^{-1}. Consequently, the best farmer gross margin (1,263 ha^{-1}) was better than the average for the experiment (1,164 ha^{-1}). This reinforces the importance of minimizing costs in opportunity cropping situations.

Plans for 2019-20

Output	Planned work
2.3.1	Cropping calendar planting windows established and validated for mungbean on 3 soil types
2.3.3	Complete a value-chain description for mungbean from farm to end-users
2.4.3	On-farm demonstration of reduced tillage, machine seeding, improved varieties, Integrated Pest Management and Site-Specific Nutrient Management
2.5.3	Farmer/buyer quality assessment of mungbean lines
	Options for CMB-3 seed production explored in the Angsangsak Value Chain Network
	QDS options for CMB-3 and other lines explored with CARDI, GDA, private sector
2.6.3	ACIAR mungbean production guide for Cambodian conditions (MN162) updated to incorporate CamSID findings for lowland mungbean after flood/rice
2.7.3	Complete and upload an integrated mungbean IPM App (disease, insect and weeds combined)
3.1.2	Scaling options explored for mungbean using APSIM and IAT modelling

3.2.3	Provide training to input sellers on appropriate pesticides for use in Mungbean IPM and engage them as extension agents to scale-out mungbean technologies
3.3.2	Identify potential mungbean seed producers and provide business planning support

Activity 2.5, Output 2.5.3: feasibility of commercialisation of Cambodian mungbean varieties under the Quality Declared Seed (QDS) protocol. Key implementation team: Bob Martin in collaboration with GDA, CAVAC, IRRI, JICA, VSO, Angsangsak AC.

This initiative addresses CamSID output 2.5.3: supply chain network (seed producers, input suppliers, farmers and markets) for high quality seed and varieties of high value linked up with the local value chain network (VCN).

Despite the enactment of the Law on Seed Management and Plant Breeder's Rights in 2008, a certified seeds industry has so far not ensued in Cambodia, including for rice. With regard to mungbean, the superior varieties CARDI Chey, CMB-1, CMB-2, CMB-3 were registered after an extensive series of ACIAR-supported trials between 2004 and 2006. Small seed samples can be obtained from CARDI for research purposes but none of these varieties have been commercially released.

This is not an uncommon situation in developing countries and the Quality Declared Seed (QDS) system was created by FAO to facilitate mobilization of the resources and expertise of government regulators and seed production organizations. QDS is designed to manage seed quality through existing community-based seed producers and local seed businesses to enable marketing of quality seed at the local scale.

In mid 2018, the General Directorate of Agriculture (GDA), Ministry of Agriculture, Forestry and Fisheries (MAFF) convened a working party to establish and implement the QDS standard in accordance with the Cambodian Law on Seed Management and Plant Breeder's Rights. GDA is the designated National Authority to implement QDS. Bob Martin was invited to join the QDS working party on the basis of his expertise on weed seed contamination in rice done under CamSID. CAVAC, IRRI and JICA are also represented on the GDA QDS working party. In 2019, CamSID will work with VSO and the Angsangsak Agricultural Cooperative to establish a QDS program for registered Cambodian mungbean varieties.

Activity 2.6, Output 2.6.2: Site-specific nutrient management (SSNM) in rice: Svay Cheat, early wet season 2018. Key implementation team: Chinaza Onwuchekwa-Henry (USYD PhD student), Bob Martin, Sokunroth Chhun, Sophea Yous, Ratha Rien.

Time of application of fertiliser topdressing for rice

Figure 16. Chinaza measuring canopy cover using digital App (Canopeo) at 48 DAS

A survey was conducted in 2017 to document current farmer fertiliser practices in lowland rice systems and to identify key research questions to help small-holder farmers increase rice yield and economic returns. A total of 100 farmers were interviewed using a structured survey questionnaire with 25 farmers randomly selected from each of four communes: Ou Mal; Phnum Sampov; Preaek Norint; and Ta Kream in Battambang province (Chhun et al. 2019).

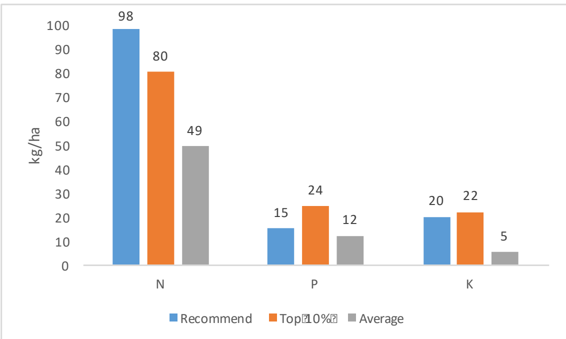


Figure 17. Fertiliser use on rice in Battambang compared to recommended for Toul Samrong soil

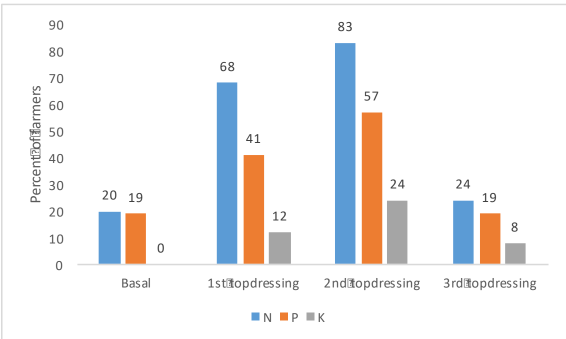


Figure 18. Timing of fertiliser application (percent of farmers)

The average paddy yield was 3.29 t ha^{-1}. Ninety-five percent of farmers used fertilizer on rice in the 2017 wet season. Urea (82%) was the most commonly used fertilizer, followed by di-ammonium phosphate (DAP, 52%), ammonium phosphate (27%), N:P:K fertilizers (12%), and muriate of potash (8%). Overall, 91% of farmers applied N, 86% applied P and only 30% applied K.

The predominant soil type in Battambang province is Toul Samroung (White et al., 1997). This soil is characterized by brown or gray clayey or loamy topsoil that develops moderate to large cracks on drying. The fertilizer recommendation for rice for this soil type is N:P:K: 86:30:10 kg ha^{-1} (Blair and Blair, 2014). Fertilizer used by farmers in the wet season was below the recommended rate: 50% of recommended N, 81% of recommended P and 26% of recommended K (Figure 17).

The IRRI recommendation for N application to rice is to apply in 2-3 splits with more splits for longer duration cultivars. The first top dressing should be applied at the onset of tillering, 21 days after seeding (DAS) and just after first weeding. The second top dressing should be applied at about panicle initiation, between 45–50 DAS. More than 30-35 kg N ha^{-1} should not be applied in a single split to minimize loss. Basal N should be applied only when it is necessary.

The average time for fertiliser top-dressing applications in this study were 27, 59, and 86 DAS and appear to be much later than recommended (Figure 18). The timing of N application was in accordance with recommendations with the bulk applied as topdressing (Figure 18). However, P is normally applied as a basal application but in Battambang, only 16% of P is applied at sowing. It is also customary to apply 50% of K at sowing and 50% at panicle initiation but in Battambang, no farmers applied K at sowing.

Key findings from this work are as follows. Although 95% of Battambang rice farmers apply fertiliser, the application rates are around 50% of those recommended. Fertiliser topdressings are applied later than recommended, especially for the second topdressing which is 59 DAS when it should be 45-50 DAS. Phosphorus is normally applied at sowing but only 19% of farmers applied P at sowing. Likewise, 50% of K should be applied at sowing but no farmers applied K at sowing. There is a need to demonstrate to farmers the importance of correct rate and timing of N:P:K but with special emphasis on P and K.

Ms Chinaza Onwuchekwa-Henry, University of Sydney PhD student, is working with CamSID to identify farming system constraints with farmers, determine optimum dry and wet seeding rates for rice, develop an N-topdressing App in field experimentation and validation of N-rich test strips using Normalized Difference Vegetation Index (NDVI).

Objectives

1. Establish a network of nutrient-omission plots in farmers’ fields to determine the extent of N:P:K deficiencies in lowland rice in NW Cambodia;
2. Conduct replicated experiments to determine optimal timing of N:P:K fertiliser in rice and to establish a Site Specific Nutrient Management (SSNM) protocol for rice in NW Cambodia;
3. Conduct field days and engage with farmers to understand agronomic, economic and social constraints to adoption of SSNM fertiliser application practices;
4. Produce and disseminate best-practice guidelines and communication strategies for SSNM in rice.

Methods

An experiment was conducted at Svay Cheat (12.9244 N, 103.2476 E) in the main wet season (MWS) 2018 to determine optimal timing of N:P:K fertiliser in rice and to establish a SSNM protocol for rice in NW Cambodia. The experiment was in a split plot design with four replicates. The treatments were:

1. Basal application of DAP at 75 kg/ha + K20 at 25 kg/ha;
2. First topdressing with urea at 25 kg/ha;
3. Second topdressing with urea at 75 kg/ha and K2O at 25 kg/ha;
4. Third topdressing with urea at 50 kg/ha.

Block 1	Block 2	Block 3	Block 4
Plot 1 B+, T1-, T2-, T3-	Plot 9 B+, T1-, T2-, T3-	Plot 17 B-, T1-, T2-, T3-	Plot 25 B-, T1-, T2-, T3-
Plot 2 B+, T1+, T2-, T3-	Plot 10 B+, T1+, T2-, T3-	Plot 18 B-, T1+, T2-, T3-	Plot 26 B-, T1+, T2-, T3-
Plot 3 B+, T1+, T2+, T3-	Plot 11 B+, T1+, T2+, T3-	Plot 19 B-, T1+, T2+, T3-	Plot 27 B-, T1+, T2+, T3-
Plot 4 B+, T1+, T2+, T3+	Plot 12 B+, T1+, T2+, T3+	Plot 20 B-, T1+, T2+, T3+	Plot 28 B-, T1+, T2+, T3+
Plot 5 B-, T1-, T2-, T3-	Plot 13 B-, T1-, T2-, T3-	Plot 21 B+, T1-, T2-, T3-	Plot 29 B+, T1-, T2-, T3-
Plot 6 B-, T1+, T2-, T3-	Plot 14 B-, T1+, T2-, T3-	Plot 22 B+, T1+, T2-, T3-	Plot 30 B+, T1+, T2-, T3-
Plot 7 B-, T1+, T2+, T3-	Plot 15 B-, T1+, T2+, T3-	Plot 23 B+, T1+, T2+, T3-	Plot 31 B+, T1+, T2+, T3-
Plot 8 B-, T1+, T2+, T3+	Plot 16 B-, T1+, T2+, T3+	Plot 24 B+, T1+, T2+, T3+	Plot 32 B+, T1+, T2+, T3+

Figure 19. Plot plan for the fertiliser topdressing experiment at Svay Cheat

The experiment was sown with Sen Kra Oub variety at 70 kg/ha using a Kid seed drill on September 26th 2018. The seed was treated with Cruiser Plus 312.5 FS at 50 mL/100 kg of seed. Pre-emergence herbicide, pretilachlor + fenclorim 300 SL was applied at 1.5 L/ha on 27th September.

Results

The average paddy yield for the experiment was 4,550 kg/ha. There were no significant effects of fertiliser treatments on yield components, yield or net benefit. Net benefit was calculated on the assumption of $250/t for rice paddy, $0.63/kg for DAP and $0.41/kg for Urea and K_2O.

Table 25. Effect of basal and topdressing fertiliser applications on rice yield components.

Topdressing	**Spikelets**	**Panicles**	**100 grain weight (g)**	**Yield (kg/ha)**	**Net benefit**
Nil	104	186	2.78	4173	$1,020
Tillering	113	197	2.78	4763	$1,157
Panicle initiation	111	182	2.83	4456	$1,044
Pre-heading	116	188	2.82	4808	$1,158
LSD	NS	NS	NS	NS	NS
Basal	**Spikelets**	**Panicles**	**100 grain weight (g)**	**Yield (kg/ha)**	
Nil	109	195	2.80	4477	$1,101
Plus	113	180	2.81	4623	$1,080
LSD	NS	NS	NS	NS	NS

Plans for 2019-20

The experiment will be repeated with modifications at the same site during the MWS in 2019.

Activity 2.6, Output 2.6.2: Strategic agronomic options for a sustainable lowland rice-based farming system in NW Cambodia. Key implementation team: Chinaza Onwuchekwa-Henry (USYD PhD student), Daniel Tan, Floris van Ogtrop, Bob Martin, Rose Brodrick (CSIRO), Sophea Yous, Ratha Rien.

The general aim of this work is to improve approach in quantifying N uptake, rice biomass and weed distribution cover for a sustainable lowland rice-based farming system in NW Cambodia. The general research question is: can the use of key agronomic options optimise nutrient use increase and sustain yield in lowland rice-based farming systems in northwest Cambodia?

Sub-questions:

1. What is the optimal rate for dry and wet seeding of rice in northwest Cambodia?
2. Which of the spectral sensors - Canopeo app and GS-NDVI can best estimate rice biomass and population densities?
3. Can spectral sensors (GS-NDVI and SPAD) monitor N status and predict N topdressing at panicle stage?
4. Can spectral sensors quantify weed interference/distribution and estimate crop injury under varying herbicide application.
5. Can introduction of minimum tillage improve mungbean yield after double cropping rice?

Early wet season 2018

Two different experiments were conducted in the early wet season and a nutrient benchmarking study in the farmers' field. This experiment involved the dry seeding experiment. Different seeding rates were conducted at Kork Tonloab and Svay Cheat Villages that are located in Banteay Meanchey and Battambang provinces, respectively. The objectives will address optimum seeding rates for dry seeding, estimate plant population densities using digital image from Canopeo and compare the effectiveness of using spectral sensors to monitor plant biomass.

The seeding rates used were 20, 40, 60, 80 and 180 kg and were the same across locations while the management practices were slightly different. Kork Tonloab used a nitrogen reference plots to determine the nitrogen application rates to be applied to the various plot while Svay Cheat used farmer practice.

Field activities

The key field activities included the use of GreenSeeker and digital app Canopeo to take measurements of canopy cover at different crop growth stages to aid in estimation of plant biomass and collection of components data (**Error! Reference source not found.**). So far, his experiment has been concluded and the results of the statistical analysis will address the research objectives as well as estimate the yield gaps due to under various agronomic practices.

Herbicide experiment at Don Bosco School farm

The common practice by the Cambodian farmers is the use of herbicides without the prior knowledge of the damage some of the herbicides can cause on the rice plants, thus affecting the final yield. Hence, the second experiment involved the use of different pre-emergence herbicides: butachlor, oxadiazon, pendimethalin, pretilachlor + fenclorim and no application (control) and two seeding rates; 40 and 80 kg/ha. This experiment was conducted at Don Bosco school farm, Sala Balat village, Battambang province. The objectives include; to study the relationship of using GreenSeeker NDVI and Canopeo to quantify weed distribution cover and estimate crop injury from herbicide application drift.

Figure 20. Visual observation on herbicide effects on rice plants at Don Bosco

Field activities

Samples of plant height, number of tillers, canopy cover and leaf nitrogen content collected after post herbicide – glyphosate applied at 30 days after sowing to monitor herbicide injury on rice plants. Weed biomass and weed density were sampled to quantify the weed distribution cover. From this study, we can recommend the best herbicide that pose less risk on rice crop and yield to farmers.

Farmers field benchmarking nitrogen application

This is the third research study for early wet season. Cambodian farmers still apply nitrogen fertilizer at rates lower than the recommended rate of 50 kg/ha N by CARDI. Site-specific nutrient management is important to understand the nutrient dynamics and requirement for rice production in the selected areas. Field benchmarking of N application was carried out in four farmers' fields at Svay Cheat village. This will inform our decision to conduct future experiments on N top dressing to improve nutrient use efficiency for rice productivity in northwest Cambodia.

Field activities

Composite soil samples were collected from each field at a depth of 15 cm using soil cores. Information on the various agronomic practices carried out by these farmers were collected and their fields were benchmarked. The layout of the benchmarked field consisted of a 5 m x 25 m with is treatment; control, Urea, Urea + K (potassuim), Urea + DAP (Di-ammonium phosphate) and NPK. Data on soil, N uptake and yield components were taken.

Table 26. Locations of farmer benchmarked fields

Field No.	GPS of each field		Variety
1	12° 54' 2" N	103° 13' 27" E	Srongae
2	12° 14' 23"N	103° 13' 33" E	Srongae
3	12° 55' 4" N	103° 14' 4" E	Kais
4	12° 55' 11" N	103° 14' 49" E	Senkraob

Main wet season

For the main wet season, two experiments only were planted in the month of September. The first experiment at Kork Tonloap village is a wet seeding experiment with different seeding rates similar to the dry seeding experiment. Every other activity remains the same and data collection is still on going.

In order to address challenge of low fertilizer application by Cambodian farmers, an experiment was conducted at Svay Cheat village which focuses on N management for N uptake optimisation and N use efficiency in rice plant. The second experiment involves a study on urea top dressing and different time of application, which include; Basal application, 20 – 25, 40 – 45, 60 – 65 days.

Field activities

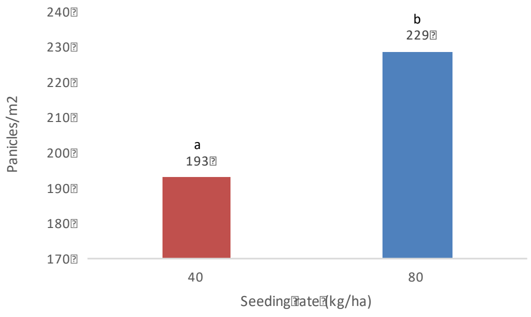
This involves the use of spectral sensors to monitor N uptake at different growth stages. The experiment is on - going and so far, data collected will address the research objectives. More updates will be unravelled as we analyse the data for the concluded experiments.

Activity 2.7, Output 2.7.1: Pre-emergence herbicide options for dry direct-seeded rice, Don Bosco demonstration farm, early wet season 2018. Key implementation team: Bob Martin, Chinaza Onwuchekwa-Henry (USYD PhD student), Mr Bora Ung (UBB masters student), Ratha Rien

Figure 21. Common weed species at the site, *Cyanotis axillaris* (left), *Echinochloa colona* (centre) and *Leptochloa chinensis* (right) were indicators of lack of water in the paddy

In NW Cambodia, the predominant method of seeding rice in the early wet season is hand broadcasting onto a dry seedbed and only post-emergence herbicides are used. Drill seeding offers the opportunity to introduce post-sowing pre-emergence herbicides for more timely and effective weed control. Post-sowing pre-emergence herbicides (butachlor, oxadiazon, pendimethalin and pretilachlor + fenclorim) were compared with nil-herbicide at rice seeding rates of 40 and 80 kg ha^{-1} in a split plot design with four replicates.

There were no significant interactions between herbicide treatment and seeding rate for panicles per m^2, seeds per panicle, 1000 seed weight, or grain yield at 14% moisture content. Rice seeding rate affected the number of fertile panicles per m^2 which was significantly lower at 40 kg ha^{-1} compared to 80 kg ha^{-1} (Figure22). The paddy yield for the high seeding rate was significantly greater than for the lower seeding rate (Figure23). There were no significant effects of seeding rate on spikelets per panicle or for 1000 grain weight.



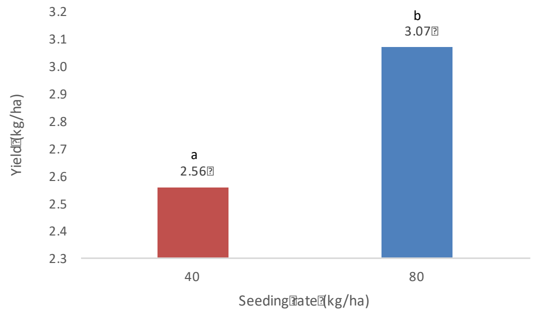
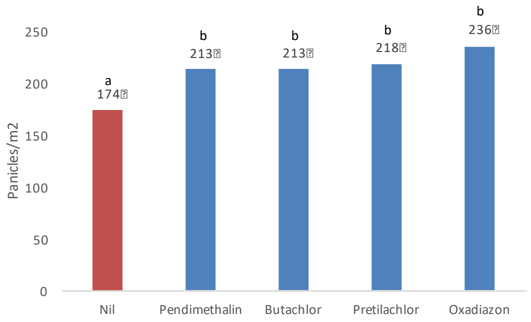


Figure 22. Effect of seeding rate on the number of fertile panicles.

Figure 23. Effect of seeding rate on rice paddy yield.

All herbicide treatments resulted in a significant increase in the numbers of fertile rice panicles per m^2 compared to the nil herbicide control (Figure 24) and paddy yield was highly correlated with panicles per m^2 ($R^2 = 0.95$).



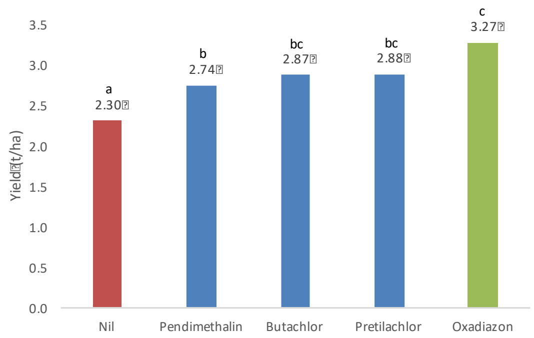


Figure 24. Effect of post-sowing pre-emergence herbicide treatments on the number of fertile panicles.

Figure 25. Effect of post-sowing pre-emergence herbicide treatments on rice paddy yield.

In terms of paddy yield adjusted to 14% moisture content, oxadiazon was the best pre-emergence herbicide treatment (Figure 25). Pretilachlor + fenclorim safener was the second-best treatment but it should be noted it was not possible to obtain butachlor and pendimethalin with the fenclorim safener. It is planned to repeat the experiment at Don Bosco in EWS 2019, hopefully with butachlor and pendimethalin with fenclorim safener.

Pre-emergence herbicide options for dry drill-seeded rice (2019 – Early Wet Season)

Activity 2.7. Evaluate available chemical and non-chemical protocols and options for integrated weed, insect and disease management in the crop sequence.

Figure 26. Planting the pre-emergence experiment at Don Bosco

In NW Cambodia, the predominant method of seeding rice in the early wet season is hand broadcasting onto a dry seedbed and only post-emergence herbicides are used. Drill seeding offers the opportunity to introduce post-sowing pre-emergence herbicides for more timely and effective weed control.

In an experiment at Don Bosco Agro Technical School farm (13.078 N, 103.176 E) in 2018, oxadiazon was the best pre-emergence herbicide treatment and pretilachlor + fenclorim was the second-best treatment. However, all herbicide treatments were significantly better than nil control for weed biomass and rice paddy yield. The experiment is being repeated in field W1 (13.077 N, 103.173 E) at Don Bosco Agro Technical School farm in 2019.

Post-sowing pre-emergence herbicides (butachlor, oxadiazon, pendimethalin and pretilachlor + fenclorim) are being compared with nil-herbicide in a split plot design with +/- bispyribac-sodium post-emergence herbicide as main plots in four replicates.

Table 27. Pre-emergence herbicides for drill-seeded rice

Chemical name	Product name	Concentration	Rate (L/ha)
Butachlor	Kago 62 EC	620 g/L	1.5
Oxadiazon	Ronstar 25 EC	250 g/L	1.0
Pendimethalin	Kmean Smau 330 EC	330 g/L	1.5
Pretilachlor + Fenclorim	Sofit 300 EC	300 g/L	1.5
Bispyribac-sodium	Nominee 10 SC	10 g/L	0.2

The experiment was sown on 24th June 2019 with Sen Kra Oub at 80 kg/ha, treated with Cruiser Plus 312.5 FS and sown with the Don Bosco Kid seed drill in 25 cm row spacing.

Pre-emergence herbicides were applied to the soil surface on 25th June after 5 mm rainfall overnight. Weed seeds were broadcast at 1.85 kg per block = 74 kg/ha. Weeds included *Oryza sativa, Ischaemum rugosum*, and *Melochia corchorifolia*.

Plans for 2019-20

Depending on the results of the experiment, we will work with input sellers in Activity 3.2 to promote the most appropriate pre-emergence herbicides. Butachlor, oxadiazon and pretilachlor are available in one large input store. Although pendimethalin is registered, it is not available in Battambang.

Networking a way to sustainable integrated pest management (IPM) for rice in NW Cambodia.

Activity 2.7. Evaluate available chemical and non-chemical protocols and options for integrated weed, insect and disease management in the crop sequence.

Figure 27. IPM social analysis at Ou Ta Nhea village. From L to R, Lucinda Dunn, Sophea Yous, Ratha Rien and farmer

The aim of this work is to develop a suitable integrated pest management (IPM) regime for rice farmers in Cambodia by analysing current rice insect and ecosystem networks, in conjunction with social (knowledge, attitudes and practices [KAPs] and social network) analysis of rice farmers and input sellers' knowledge and practices of rice pest management in low, medium and high cropping intensity villages. Research questions include:

1. What are the ecological and social factors that are influencing current insect pest control for smallholder rice farmers in Cambodia?
2. What knowledge, attitudes and practices (KAPs) do rice farmers, and input sellers have and use towards insect pests, pest control and pesticide use, and how can these be harnessed to improve sustainable pest management?
3. How do landscape composition and variations in cropping intensity impact farm input/ management practices and the pest/predator-prey networks?
4. What other methods of pest control aside from chemical use could be integrated into the pest management system and how?

Table 28. The four target villages and their respective levels of cropping intensification

Village	Cropping System	Location	Soil group	Irrigation	Rice crops/year
Prey Toteung	Low intensification	12.943 N, 103.192 E	Luvisol	Nil	1
Svay Cheat	Medium Intensification	12.918 N, 103.245 E	Luvisol	WS	1 to 2
Boeng Pring	Medium Intensification	13.373 N, 103.033 E	Vertosol	WS	1 to 2
Ou Ta Nhea	High Intensification	13.095 N, 102.999 E	Vertosol	WS/DS	2 to 3

University of Sydney PhD student, Lucinda Dunn aims to monitor beneficial and pest insects, assessing the rice agroecosystem landscapes and surveying farmers and input sellers in four different villages of high, medium and low cropping intensity (Table 28). In doing this, the effect of cropping intensity on pests and pest management can be determined and will lead to the development of a sustainable pest management regime for farmers suitable for their cropping scenarios using a holistic ecosystem approach.

Lucinda established 17 rice fields belonging to farmers within Svay Cheat Village in 2018 and will continue sampling in the early wet season from June- August in 2019. The field sampling procedure is to sweep net the field for insects along three transects: one on the bund of the field, one transect bund parallel and one transect in the middle of the field. Random quadrat sampling for eggs and larvae and aquatic sampling were also used. This experiment is being repeated in 2019 and will collect data from the other target villages as well.

The insects caught are currently being identified so mixed variate analysis can be performed. Lucinda will also use the Vegan package in R to perform ecological network and food web analysis once all insects are sorted and identified. So far, sixteen species of beneficial arthropods from five Orders have been found in rice fields in Svay Cheat village: Arachnida (3); Coleoptera (2); Hemiptera (1); Hymenoptera (6); and Odonata (4). Sixteen arthropod pest species from five Orders were identified: Diptera (2); Coleoptera (4); Hemiptera (4); Lepidoptera (4); and Orthoptera (2).

Social analysis sampling

The first social analysis Lucinda have begun is the farmer rice insect pest and management survey which has been uploaded onto CommCare (https://www.dimagi.com/commcare/) and is performed by the CamSID staff on android tablets. The target, to obtain data from a minimum of 120 households (30 in each of the target villages), has been reached and analysis of the data has commenced.

From these surveys, Lucinda has identified what insect pests farmers think are most prominent, how many farmers can differentiate insect pests from beneficial insects, what their opinions are towards beneficial insects, how farmers manage insect pests, where they get their insect pest management information from, their attitudes towards the use of pesticides, and their knowledge and attitudes towards alternative insect pest control practices.

Insecticide use in low and medium intensification systems (Prey Toteung, Svay Cheat) is low with around one application per crop cycle. However, in the high intensification system (Ou Ta Nhea), 5-6 applications are made per crop cycle. Insecticides used are broad spectrum and the risk of outbreaks of secondary pests such as brown plant hopper (*Nilaparvata lugens*) is likely to be high.

A survey of input sellers within each village commenced in June 2019. This survey will determine the training, knowledge, extension, attitudes and practices they have and have access to and support available from the primary chemical supply companies.

CamSID is promoting seed dressing with insecticide/fungicide as part of the rice IPM protocol. Although seed dressing chemicals are stocked by some input sellers, very few farmers apply them. During July-August 2019, seed dressing workshops will be conducted with input sellers and their farmer clients in the four target villages.

Activity 2.7, Output 2.7.2: The potential for silicon (Si) fertilization to reduce the impact of blast fungal disease caused by *Magnaporthe oryzae* in rice. Key implementation team: Daniel Howell (USYD honours student), Rosanne Quinnell, Bob Martin, Daniel Tan and Ratha Rien.

Figure 28. Rice blast fungal disease caused by *Magnaporthe oryzae*

Dan Howell (Honours in Biology, School of Life and Environmental Sciences) undertook part of his experimental work in Cambodia. Dan's project aimed to assess the impact of the application of soil-applied silicon fertiliser treatments for reducing the impact of rice blast in the early wet season 2018. Largely this part of Dan's project delivered base-line data for subsequent experiments for the late wet season, which is when blast is considered to be more of an issue. We were able to borrow hand-held X-ray fluorescence analysers (hhXRF) for a pilot study and to undertake a validation of the accuracy of hh-XRF for measuring Si. Dan used the XRF for his a glasshouse experiment (device: Sci-Ap, see https://www.axt.com.au/silicon-in-plants-handheld-xrf/), and for the fieldwork in Cambodia (device: Niton).

Optimising rice production is critical for food and economic security in Cambodia. Rice blast disease caused by the pathogenic fungus *Magnaporthe oryzae*, significantly hinders rice productivity by reducing the yield and quality of crops. Cambodia recently banned the use of tricyclazole, a fungicide commonly used to control blast, so sustainable, non-toxic strategies to manage blast disease, such as silica application, need to be explored. Silicon, enhances the physical and biochemical plant defenses of rice against fungal infection.

Two field trials in Cambodia were run in parallel with a glasshouse experiment in Sydney to assess the efficacy of two types of silica treatment, rice husk ash (RHA - a silica-rich by-product of rice milling) and commercially-available fused magnesium phosphate (FMP), to reduce rice blast severity. Two field experiments were conducted to evaluate the effects of silica treatment and dose rate (RHA: 0 - 4000 kg/ha; FMP 0 - 1000 kg/ha) on the severity of rice blast. No significant effects of these treatments were observed in the field experiments because there was no incidence of blast disease. Furthermore, it was discovered that the Si in RHA is in the crystalline form not the amorphous form and therefore not able to be taken up by the rice plant. This is because the RHA is produced at temperatures above 900°C. Attention in 2019 will focus on FMP as a source of Si for management of blast.

The glasshouse trial assessed the silicon content of rice shoots applied with RHA and FMP at dose rates between 0 and 2000 kg/ha. A novel technique to measure silicon content in plants was implemented and results indicated that it is feasible to use handheld X-ray fluorescence (HHXRF) analysers to measure Si in fresh rice leaves. There was no significant effect on Si content of glasshouse rice shoots as a result of the type (RHA or FMP) or dosage rate of silica treatment. Single applications of silicon treatments in the field had no significant effect on rice blast severity, most likely because the overall severity at the time of the experiments (early wet season) was low. Two types of HHXRF devices (Niton and Sci-Aps) gave precise relative measures of Si content; however, future development of the methodology should improve the accuracy of these devices for use on fresh plant material.

It is proposed to continue field experiments in 2019 to determine the potential of using fused magnesium phosphate as a management tool for rice blast in Northwest Cambodia.

Activity 2.7, Output 2.7.3: Development of an insect ID App for mungbean. Key implementation team: Isabel Hinchcliffe (USYD honours student), Rosanne Quinnell, Tanya Latty, Bob Martin, Daniel Tan and Sophea Yous

Figure 29. Isabel Hinchcliffe and Sophea Yous demonstrating the mungbean Insect Pest ID App to a farmer in Angsangsak village

In response to the need for crop diversity, Cambodian farmers have begun including mungbean into rice cropping systems. However, mungbean is facing significant yield loss due to direct impacts of insect and disease pests. Improper pest management has worsened the issue, causing economic losses to farmers and environmental disruption through ill-informed chemical use.

Use of broad-spectrum insecticides as a solution to all observed insect pests is common place in mungbean fields of lowland Cambodia and can be linked to unsuitable sources of agricultural information. This is particularly concerning when considering insecticide chemicals with different modes of action produce varied effects on different insect species, and existing populations of natural enemies can be destroyed by non-specific insecticides.

Species specific control mechanisms are therefore indicated. The majority of farmers included in this study were unable to distinguish between beneficial and pest insect species. The importance of accurate species identification (ID) in providing the most appropriate insect pest treatment is clear, as is the need to transfer information on the roles of beneficial insects in insect pest management. This project aimed to discover the insect pest and beneficial species most common in mungbean fields of lowland Cambodia, and to use this information to develop an informative image-rich mobile phone application to aid Cambodian farmers with insect and disease identification, and so provide specific management recommendations applicable to the Cambodian context.

This study evaluated the feasibility of the proposed App through a survey with potential users and these responses were incorporated into developing the Insect Pest ID App prototype, which was trialed with farmers and subsequently refined. The Insect Pest ID App has been well received by farmers with users seeing its potential to support crop management decisions. This App holds potential as an important agricultural education tool and may be applied to a broader range of mungbean farmers in the future (Figure 30).

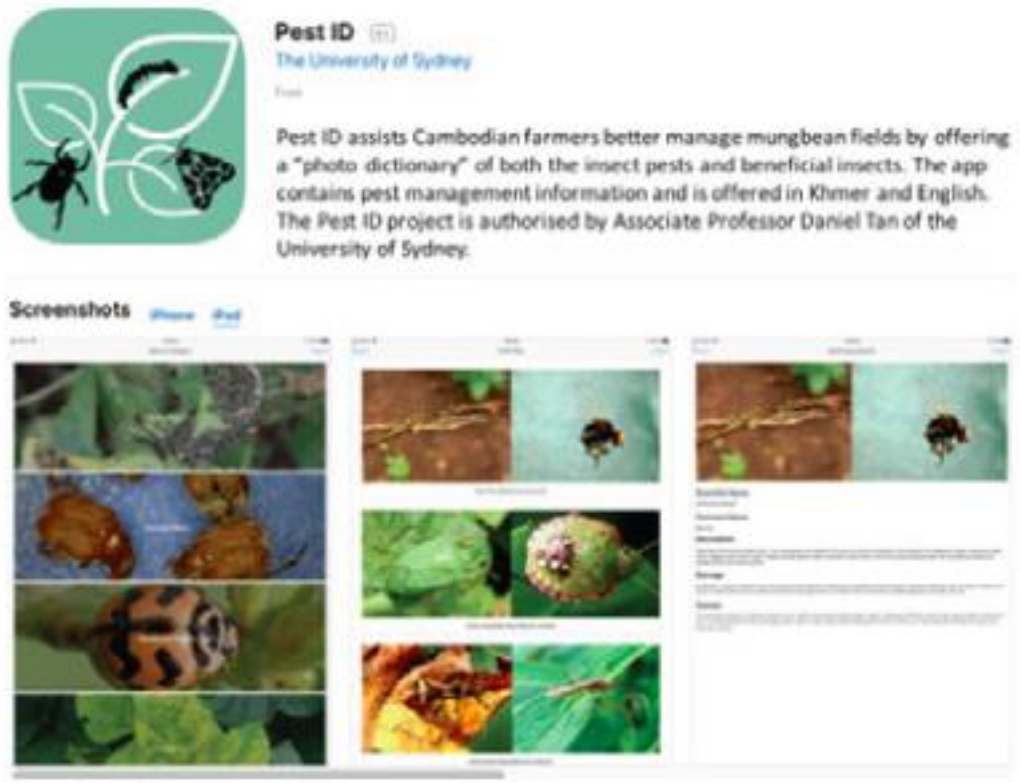


Figure 30. Screen shot of the mungbean Insect Pest ID App (https://itunes.apple.com/gr/app/pest-id/id1328731895?mt=8)

Activity 2.7, Output 2.7.3: Managing plant species on rice field perimeters and bunds to improve IPM. Key implementation team: Bob Martin, Sokunroth Chhun, Rica Flor (IRRI).

Figure 31. Potentially beneficial plant species such as *Mimosa pudica* (left) and *Desmodium triflorum* (right) are found on almost all rice bunds

Cultural weed control is a part of integrated weed management which involves the integrated use of cultural, manual, and/or mechanical control methods. Rice field perimeters and bunds are a source of weed entry into fields. The plant species growing along the margins of rice fields are also potential alternative hosts to rice diseases and insect pests. On the positive side, some of these plants can harbour beneficial insects and predators of rice pests.

Figure 32. Typical perimeters to rice fields in NW Cambodia

Rice fields are typically adjoined by roadsides, canals, ponds and “bunds” of varying trafficability. Most commonly, bunds are suitable for foot traffic only and vehicle access from field to field, including 2-WT is often through the paddies (regardless of who owns them). This in itself, imposes an important limitation on crop diversification options in the rice system.

The objectives of this activity are to:

1. Document the plant species occurring on perimeters and bunds surrounding the CamSID benchmarking rice fields;
2. Attempt to correlate species incidence with causal factors such as water access, soil fertility, local landuse management etc;

3. Assess options to alter floristic composition of bunds as an IPM tool to reduce incidence of alternative pest hosts and to provide harbour for beneficial agents.

On the 20 rice bunds sampled so far, 126 plant species have been recorded with the most prolific families being Poaceae (28 species), Fabaceae (27 species) and Cyperaceae (11 species). The average number of species found on individual bunds was 37. Floristic differences are emerging between the Toul Samrong and Kampong Siem soil groups. It is expected that species favoured by higher soil fertility and soil pH might occur more frequently on Kampong Siem soil (Figure 33).

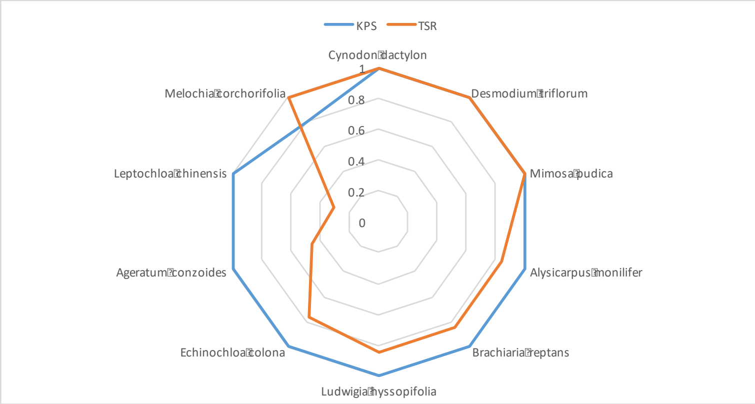


Figure 33. Frequency of the 10 most common plant species on rice bunds as affected by soil type

Traffic-tolerant prostrate legume species such as *Desmodium triflorum*, *Mimosa pudica* and *Alysicarpus monilifer* occur on almost all rice bunds. Selective management to favour these species might be a way to reduce the occurrence of alternative hosts of rice pests, especially members of the family Poaceae.

Objective 3

Scale-out models for adoption of diversification crop technologies

Activity 3.1: Evaluate most successful farmer-led prototype groups and community-led VCN communication models to scale up SID through local VCNs.

Figure 34. Sophea Yous interviewing a cucumber grower

Diversification and intensification of the farming system in the rainfed lowland through increasing crop yield, including an additional crop per year and production of high value crops such as vegetables, could potentially lift the average family's farming income from approx. 500 to 2,500 per annum on an average smallholder farm size of 1 ha. There has been limited uptake of diversification possibilities (e.g. higher value non-rice crops such as mungbean, vegetables and mushrooms) due to lack of training and knowledge of the available options.

Where supplementary irrigation water is available, the strategy is to test the feasibility of a vegetable crop such as longbean, water convolvulus and tomatoes. If these crops are planted on residual soil water after rice, in November-December, they require minimal supplementary irrigation. Cambodia imports 40-60% of its fresh vegetables (Newman et al. 2014) and there is a growing demand for vegetables in Siem Reap. In addition, diversifying into vegetables improves nutritional food security.

From the baseline survey in HARVEST (2013), the proportion of farm income from crop production in Battambang province is 78% from rice, 4% from vegetables and 18% from other crops (e.g. mung bean) (Table 29).

Table 29. Annual household total income and expenditure and proportion of sales from crop production (%) in Battambang Province (HARVEST 2013)

Annual Household Total Income (USD)		Annual Household Total Expenditure (USD)		Sales from crop production (%)	
Farm	416	Food	304	Rice	78%
Off-farm	153	Non-food	217	Vegetables	4%
Other	51	Housing	41	Other crops	18%
Total	621	Total	562	Total	100%

The vision for diversified cropping for this project is to reduce the proportion of cropping income from rice to 60% and increase the proportion of farm income from vegetables and other crops to 40%. Diversification and intensification of the farming system in the rainfed lowland by increasing crop yield, including an additional crop per year and producing crops of higher value such as vegetables, could potentially lift the average family income from farming from approximately $500 to $2,500 per annum.

Table 30. Plausible target cropping systems: gross margin (USD/ha/year) for Northwest Cambodia (based on the Toul Samrong soil system).

System	Dry Season	Early Wet Season	Main Wet Season	Total
Traditional farmer practice (low input)			473	473
SID Option 1 (Two rice crops)		719	805	1,523
SID Option 2 (Two rice crops + mung bean)	974	719	805	2,498
SID Option 3 (One rice crop + two vegetable crops*)	1,077	719	1,077	2,873

Before commencing experiments or demonstrations, it is essential to engage with local farmers to take on board indigenous knowledge and to clearly understand the research questions. With VSO winding down in 2019, we have begun partnerships with other scale out partners such as Agriance, Agribuddy CE-SAIN, East West Seeds and USAID HARVEST II.

This work is being conducted with support from Ms Stella Lay as part of her University of Sydney 4th year thesis project.

2. Vegetable grower survey in 2019

The purpose of this survey is to better understand the issues relating to the production of crops other than rice on small-holder farms. The survey is made up of several components:

1. An initial interview to obtain production details about the main diversification crop that you are currently growing (this should take about 30 minutes);
2. Having identified a particular field, we then record details of the cropping calendar for that field;
3. This includes details and costs of land preparation, costs of seed, fertiliser, pesticide inputs, and costs of harvesting. Yield and price information is recorded at harvest and this will enable an economic analysis to be done;
4. Data collection in the selected crop field on the farm. This includes: physical and chemical analysis of the soil; crop growth; and incidence of nutrient disorders, diseases, insect pests, and weeds.

3. Preliminary results

One hundred vegetable grower surveys have been completed in 2019 in four districts, 14 communes and 19 villages in Battambang province. The data are still being analysed.

Most vegetables are grown on small upland plots near the house but some specialist vegetable growers have plots of one hectare or more where 2-3 crops are grown per year. Diversification crops are not generally grown in rice fields except for active floodplain where mungbean, rice cucumber and watermelon are grown after flood waters recede.

Upland vegetable plots generally have access to irrigation and these crops are grown using high-input technologies (Table) with gross margins from $2-3,000/ha. Diversification crops grown in rice fields generally have no access to irrigation and rely on residual soil water after the flood water recedes.

Table 31. Gross margin analysis for high and low input vegetables (USD/ha)

	High input vegetable plot			Low input rice field		
	Cucumber	Cucumber	Cucumber	Watermelon	Rice cucumber	Rice cucumber
Income	5,000	4,923	4,781	2,605	539	1,275
Variable costs						
Land preparation	119	63	63	120	105	125
Bed preparation	361	396	358	0	0	0
Irrigation	75	336	344	42	238	102
Planting	203	137	216	80	72	188
Fertiliser	386	378	258	122	127	82
Weed control	30	11	17	6	50	63
Insect control	72	18	18	73	18	20
Disease control	74	16	18	31	0	0
Harvesting	664	1,250	664	113	1,000	1,875
Total	1,984	2,604	1,955	585	1,610	2,455
Gross margin	3,016	2,319	2,826	2,020	(1,071)	(1,180)

Low yields and high cost of harvesting of rice cucumber suggest that this crop is not profitable if the cost of farm labour is considered. Watermelon appears to be a more profitable option (Table 31).

Options for CamSID in 2019-20

1. Promotion of straw mulching and permanent beds to replace plastic in high-input vegetable systems;
2. Work with input sellers to promote IPM in vegetables, especially with regard to broad-spectrum insecticide products;
3. In low-input systems, promote reduced tillage and crop residue retention to conserve soil water.

CamSID field day Svay Cheat, 5th June 2019

Activity 3.1: Evaluate most successful farmer-led prototype groups and community-led VCN communication models to scale up SID through local VCNs.

Figure 35. Farmer co-operator, Mr Makara explaining the Eli sown field to field day participants

The field day was held on 5th June 2019 and was organised by Ms Sophea Yous with support from Mr Sokunroth Chhun, Ms Charyia Korn and Mr Santik Kheav. Nine farmers completed a questionnaire and all were invited by the host farmer, Mr Makara. The majority of farmers attended because they were very interested in machine seeders. There was also interest in more specific information about whether machine seeders would work on their farm and trying machine seeders on their farm. Regarding other topics of interest, rice disease management was top of the list followed by seeding rates, fertiliser choices and weed management.

Mr Makara and three other farmers have adopted use of the Eli seeder in Svay Cheat village. The Eli seeder they are using is a community resource purchased with support from the Cambodia Agricultural Value Chain Program (CAVAC) in the form of a 30% subsidy. These farmers have adopted the Eli and the CamSID role is now monitoring and providing advice when required. Farmers inspected Mr Makara's field which was planted with Sen Kra Oub with the Eli seeder at 100 kg/ha on 11th May. He used organic fertiliser, applied at 150 kg/ha to the whole field on 29th May. He applied herbicide Bispyribac-sodium 40% W/V SC 25 days after sowing and the field was irrigated on 31st May.

This field is also one of four fields (4.2 ha) in Svay Cheat that have been laser-levelled as part of a CamSID demonstration under Activity 3.2.

Service provider for Kid seeder and laser-levelling by Mr Yang Thy

Mr Yang Thy, machinery service provider from Kampong Preang, 10 km from Svay Cheat, agreed to bring his Kid seeder and laser-leveller to the field day. Mr Thy has planted 164 ha with his Kid seeder in Kg Preang in 2019. He has one Kid machine but planning to buy one more. He is charging $37.50 per hectare at the moment but this is down from $42.50 in 2018.

Videos were also shown of the CamSID Kid seeder in operation at Tahen village (13.078 N, 103.288 E). There were videos of two different planting scenarios. An important lesson that we are trying to teach is the folly of unnecessary cultivation before seeding that delays seeding until further rain is received. This delays planting and adds to the risk and cost of planting. Each rotavation costs $25/ha. Follow-up field days are planned for Tahen to look at the comparison of options 1 and 2.

Farmer observations on machine seeders and costs

Question 1: What do you think about these machines?

No.	Eli seeder	Kid seeder	Laser-levelling
1	Nice	Don't know	Nice
2	Uses less seed and easy to take care	Good, low seeding rate, good crop ventilation	Good
3	Nice, I can use it well	Nice, modern, faster	Nice, I want to practice in the field
4		Good, healthy plants	
5			
6	Available, good result	Row planting, low seeding rate	Need extra ploughing before levelling
7	Good, reduced time to plant	Good, reduced labour	Interested, water control, weed control, higher yield
8	It looks nice	It's easy to use, no need for extra labour, easier than Eli	I would do laser-levelling but I can't afford it
9	Good	It is better than hand-broadcast	I have no idea

Summary of farmer observations on the machines:

- **Eli seeder**: Nice, available, I can use, reduced time to plant;
- **Kid seeder**: Compared to broadcasting, Kid seeder was described as nice, modern, faster, easy to use, reduced seeding rate, reduced labour cost;
- **Laser-levelling**: Positive - nice, results in improved water and weed control resulting in higher yield. Negative - needs extra ploughing to prepare and is expensive.

Question 2: Are you interested to use these machines? ☑ yes, ☐ No

Number	Yes	No
1	✓	
2	✓	
3	✓	
4	✓	
5	✓	
6	✓	
7	✓	
8	✓	
9	✓	

Question 3: What contracting rate would you accept per hectare (USD/ha)?

No.	Eli seeder	Kid seeder	Laser-levelling
1		37.50	250
2		37.50	250
3		37.50	250
4		37.50	
5		37.50	
6	17.50	17.50	
7		32.50	200
8		Yes, if got subsidy from CamSID	
9		37.50	

The greatest farmer interest was in the Kid seeder and least in Eli. Most farmers accepted the contract rate for Kid but two farmers expected a lower rate or subsidy from CamSID.

Plans for 2019-20

There are now 10 Kid drill seeders in Battambang province and more on the way. CamSID will work with CAVAC to connect with these service providers to scale out CamSID outputs such as reduced tillage, seeding rates, seed treatments, IPM and appropriate basal fertiliser rates.

Scaling out rice crop establishment technologies: Tahen case study

Activity 3.1: Evaluate most successful farmer-led prototype groups and community-led VCN communication models to scale out SID through local VCNs.

Figure 36. Roth, Sophea and Chariya doing establishment counts in broadcast rice at Tahen

CamSID is collaborating with the Catholic Mission (https://www.catholicmission.org.au/) Tahen project, funded by Rural Funds Management, Australia (https://ruralfunds.com.au/) to demonstrate drill seeding and improved practices for rice. CamSID has loaned a Kid drill seeder to the Tahen project and the Tahen farmers are doing the planting. The Cambodia Agricultural Value Chain Program (CAVAC, https://cavackh.org/) provided a 30% subsidy for purchase of the Kid seeder.

CamSID activities at Tahen are related to the project's Objective 3: Comparative evaluation of scale-up and scale-out models for Sustainable Intensification and Diversification (SID) adoption at village and community level. Activity 3.2 supports private sector input and machinery service suppliers, Non-Government Organisations (NGOs) and traders to promote SID methods to their farmer clients through local Value Chain Networks (VCNs) including analysis of components of input prices and credit provision.

There are 10 key farmers affiliated with the Tahen project and so far, they have received training from CamSID on:

- Reduced tillage and soil moisture conservation;
- Seed cleaning, seed dressing and seeding rate;
- No-till fallow management and pre-emergence herbicides;
- Operation of the Kid seed drill with support from Mr Thy, the nearest Kid Service Provider.

The farmers are implementing the technologies themselves and the response has been positive. They doubted the need for seed cleaning and reduced tillage initially but, step-by-step, they are coming on board.

Figure 37. Demonstrations of rice seeding methods at Tahen village, Roka commune, Sangkae district Battambang province Cambodia (13.080 N, 103.272 E).

The Kid seeder demonstrations at Tahen occupy 11 fields with a total area of 14.75 hectares (Figure 37), (Table 32).

Table 32. Demonstrations of rice seeding methods at Tahen village, treatment descriptions

Area	Field	Area (ha)	Seeding method	Seed dressing	Tillage
1	E,G	3.53	Broadcast by machine	Yes	Rotavator before/after seeding
1	R	0.91	Broadcast by machine	No	Rotavator before/after seeding
1	F	0.45	Kid seed drill	Yes	Rotavator before seeding
1	I,J,K	3.47	Kid seed drill	Yes	No rotavation – no-tillage
1	L	0.9	Kid seed drill	Yes	Rotavator before seeding
1	M	1.41	Kid seed drill	No	Rotavator before seeding
1	S,P,O	4.42	Kid seed drill	No	Rotavator before seeding
2	A1	0.5	Kid seed drill	Yes	No rotavation
2	B	0.5	Kid seed drill	Yes	Rotavator before seeding
2	C	0.8	Kid seed drill	Yes	Rotavator before seeding
2	D	0.3	Kid seed drill	Yes	Rotavator before seeding
2	I	0.5	Kid seed drill	Yes	Rotavator before seeding
2	J	1.5	Kid seed drill	Yes	Rotavator before seeding
2	A2	0.1	Broadcast by hand	Yes	Rotavator after seeding
2	E	0.8	Broadcast by hand	No	Rotavator before/after seeding
2	F	0.7	Broadcast by hand	No	Rotavator before/after seeding
2	G	0.8	Broadcast by hand	No	Rotavator before/after seeding
2	H	0.3	Broadcast by hand	No	Rotavator before/after seeding

Land preparation began in the Area 2 fields on April 22nd and then received 220 mm of rain before planting on 4th and 5th June. The rain had broken down most of the clods and the remaining ones were relatively soft. The wet soil was at 5 cm depth. The farmers said the field needed Rotavating before planting. However, they agreed to give it a try. The machine broke down the clods giving a fine seedbed and the seed was planted into good soil moisture.

The remaining fields were rotavated as per farmer practice. The clods were made smaller but they were hard and the seeder could not produce a fine seedbed. In addition, the rotavator had dried the soil to a depth of 8-10 cm and the seed could not be placed in contact with soil moisture.

Figure 38. Kid seeding with no rotavation (left) and with rotavation (right). Rotavation dried out the soil to 8-10 cm compared to soil moisture at 4-5 cm with no rotavation. Rotavation also produced a cloddy seedbed.

Preliminary results for Area 2

Rice establishment, 13 DAS

Rice establishment was recorded on 17th June, 12-13 DAS for the drill seeded fields. It was assumed that 100 seed weight of Sen Kra Oub was 2 g. The amount sown was assumed to be 75 kg/ha for drill seeding and 150 kg/ha for broadcast seeding. The calculated amount of seed sown was 350 seeds/m^2 for drill seeding and 750 seeds/m^2 for broadcast seeding.

Table 33. Rice establishment for drill seeded vs broadcast 13 DAS in Area 2.1.

Seeding method	Plants/m^2	Assumed sown/m^2	Establishment
Broadcast	429	643	67%
Kid drill	344	375	92%

On average, estimated rice establishment was better for drill seeding compared to broadcast. However, establishment varied from 40–100% for drill seeding and the main cause of this is variation in seedbed moisture. The decision to rotavate before seeding is critical if seedbed moisture is lost from the operation. In some cases, rice cannot be sown after rotavation until further rain has fallen.

GreenSeeker NDVI

NDVI readings for the drill-seeded rice sown on 4-5th June averaged 0.15. There was a lower reading in field B due to poor establishment and slower plant growth due to lack of seedbed moisture. Rotavation of field B before sowing is assumed to have dried out the seedbed. The reading for broadcast rice in field A2 was 0.17 which reflects higher plant density.

NDVI readings in the four farmer-broadcast fields averaged 0.44, ranging from 0.40 to 0.47. These fields were sown before the drill seeded fields. However, NDVI readings were high also in these broadcast fields because of heavy weed biomass.

Weed density

Broadleaf weeds were the most prevalent, followed by grasses and sedges (Table 34). Compared to broadcast, drill seeding reduced broadleaf weeds by 66% compared with 34% for grasses.

Table 34. Weed density (plants/m^2) for drill seeded and broadcast rice 13 DAS.

Seeding method	Broadleaf	Grass	Sedge	Total weeds
Broadcast	46	22	3	71
Kid drill	16	15	2	32

So far we have identified 9 broadleaf weed species, 7 grasses, 2 other monocots and 1 sedge species in seed for sowing and in the fields.

Insect pests and diseases

Some rice leaves had yellow streaks or patches, leaves curled from the margin to the middle and withered leaf tips. Although none were seen, these symptoms are consistent with damage by the rice thrip (*Stenchaetothrips biformis*). Leaf curling and withered tips are also symptoms of drought stress. Leaf chewing insects (caterpillars, grass hoppers) were present in small numbers.

Plans for 2019-20

1. Continue providing SID training and support to the Tahen project key farmers through the rice production cycle and demonstrate dry season diversification crop options;
2. Conduct a survey in the local VCN to collect data on scaling-out positive and negative issues.

Scaling out CamSID outputs via the service provider network

Activity 3.1: Evaluate most successful farmer-led prototype groups and community-led VCN communication models to scale out SID through local VCNs.

Figure 39. Mr Chhoeun Sarith (Kid seeder owner) inspecting a rice crop sown by his Kid seeder on 15th June.

The Australian aid project, Cambodia Agricultural Value Chain Program (CAVAC) is promoting the adoption of the Kid and Eli seeders by providing a 30% subsidy for purchase of the machines. CamSID is working alongside CAVAC to provide technical support to the service providers. Ten of the 15 Kid seed drills operating in Cambodia are in Battambang province (Table 35).

Table 35. Details of Kid seed drill service providers in Battambang province

Name	Phone	Village	Commune	District	Ha sown in 2019
Chhorm Cheanin	097 721 2345	Anlong Ta Mei	Chheu Teal	Banan	
Don Bosco	092 527 330	Sala Balat	Ou Mal	Battambang	11
Mr. Peng Vuthea	092 559 199	Boeng Riang	Ou Mal	Battambang	
Chhoeun Sarith	017 364 191	Voat Roka	Ou Mal	Battambang	23
Mr. Hul Kloem (AC)	012 675 589	Prey Sangha	Khnach Romeas	Bavel	
CamSID project	017 605 784	Ta Haen Muoy	Roka	Sangkae	15
Mr. Yang Thy (AC)	078 713 445	Os Tuk	Kampong Prieng	Sangkae	150
Mr. Khov Chhignly	012 732 333	Kampong Preah	Kampong Preah	Sangkae	6
Mr. Prak Sim	012 216 593				
Mr. Chea Sarann	012 413 901				

Mr Chhoeun Sarith

Mr Chhoeun Sarith has planted 23 ha of rice with his Kid seeder this season. This Sen Kra Oub crop (Figure 39) was planted on 15th June at 80 kg/ha with 50 kg/ha DAP. Mr Sarith pays his tractor driver 100 baht/ha ($3.30) and the assistant is paid 30,000 riel/day ($7.50). They can plant one hectare in just over one hour. So if they plant 7 ha in a day, the labour cost is $4.37/ha.

He is using quinclorac + pyrazosulfuron-ethyl herbicide but it is not controlling *Echinochloa colona* or *E. crus galli* and he also uses the broad-spectrum insecticide abamectin which is risky for the flaring of secondary insect pests such as brown planthopper.

Mr Sarith is also an input seller in Voat Roka village on the outskirts of Battambang city. So he is both a key farmer and an input seller and an ideal scale-out agent for CamSID.

Mr Yang Thy

Mr Thy is a machinery service provider from Kampong Preang and is also president of the Kampong Preang Agricultural Cooperative. There are 244 farmers in the AC and a total area of 1,500 ha of rice (6.15 ha per farmer). 1,350 broadcast and Kid seeding on 150 hectares. The plan is for 400 ha drill seeding next year. Mr Thy has one Kid machine but planning to buy one more. He is charging $37.50 per hectare at the moment but this is down from $42.50 in 2018. Mr Thy was asked if there was farmer interest in machine broadcasting of rice. The majority of farmers are interested in the Kid seeder and machine broadcasting might be used on very large fields.

Practices:

- Seeding rates: Sen Kra Oub at 100-130 kg/ha and Phka Rumduol 75-80 kg/ha.
- Starter fertiliser: DAP 50 kg/ha plus organic 6:3:3 at 25 kg/ha (from Thailand).
- Water arrives in 10 days – mid-July, they top-dress after water arrives.
- Herbicides: 2,4-D sodium mixed with bispyribac-sodium applied when soil is moist. Will apply this evening. What weeds are the biggest problem? *Echinochloa crus galli*, *Fimbristylis miliacea*.
- Fertiliser topdressing rates at tillering stage: DAP (50 kg/ha) + Urea (25 kg/ha) split for 2 times of application. At PI, 15:15:15 at 50 – 75 kg/ha and some farmers add Urea at 25 kg/ha.
- Yield potential for the fields: average is 4 t/ha for SKO and 2.5-3.0 t/ha for Phka Rumduol. Best yield is 6 t/ha for SKO and 4.5 t/ha for PKR. This year, because of drought, he expects the yield be 800-1,000 less than average (3.0-3.2 t/ha for SKO). His fertiliser topdressing rate will be reduced to the low end of the range (50 kg/ha DAP).

Chinaza has selected four fields in Kg Preang for field evaluation of NDVI in rice to optimise N-topdressing rate.

Plans for 2019-20

Conduct case-studies of the 10 Kid seeder owners in Battambang province to determine opportunities to include CamSID outputs into their operations (reduced tillage, seed treatment, seeding rate, pre-emergence herbicides, optimal fertilisers etc)

CamSID can also provide training to seed drill service providers on:

- No-till fallow management and pre-emergence herbicides;

- Reduced tillage and soil moisture conservation;
- Seed cleaning, seed dressing and seeding rate;
- Pre-emergence and alternative herbicide options; and
- Optimal basal fertiliser mixtures and rates.

Convene a Battambang “Expo” of rice direct-seeding options in collaboration with MAFF, CARDI, CAVAC, CIRAD and other parties engaged in dry/wet seeding machines for rice.

Scaling out CamSID outputs via the input seller network: case study

Activity 3.2: Support private sector input and machinery service suppliers, NGOs and traders to promote SID methods to their farmer clients through local VCNs including analysis of components of input prices and credit provision.

Figure 40. Input sellers being interviewed by Mr Chhun Sokunroth

During our project so far, we have discovered that the majority of farmers rely on input sellers for advice on pesticide and fertiliser use. Our aim is therefore to support private sector input and machinery service suppliers to promote sustainable intensification and diversification (SID) methods to their farmer clients through local Value Chain Networks (VCNs).

According to the Battambang PDAFF, there are 402 input sellers in the province. However, there are 166 input sellers in CamSID target districts (Table 36). Assuming that the average input seller has a clientele of 150 rice farming households, they have potential to deliver CamSID outputs directly to 40% of rice farming households.

Table 36. Input sellers and potential households reached in CamSID target villages in Battambang province.

District	No. of Input sellers	Estimated No. of Farmers reached	No. of rice farming Households*	Estimated percent households reached
Aek Phnum	33	4,950	9,181	54%
Banan	34	5,100	15,189	34%
Battamban g	26	3,900	7,772	50%
Sangkae	41	6,150	17,631	35%
Thma Koul	32	4,800	17,620	27%
Total	166	24,900	67,393	40%

*** NCDD, 2010**

Activity 3.2 is being implemented in collaboration with the Provincial Department of Agriculture, Forestry and Fisheries (PDAFF), Battambang. An initial questionnaire was "road-tested" by CamSID staff and refined during June 2019. A case study for the Input Seller in Svay Cheat village has been completed. The business is owned and operated by husband and wife and they are the only input seller in the village (Figure 40).

The purpose of this activity is to assist CamSID to scale-out its outputs of more appropriate products and improved practices. Our research has identified options to improve fertiliser and pesticide use through Site-Specific Nutrient Management (SSNM) and Integrated Pest Management (IPM). Delivery of these outputs requires engagement with fertiliser and pesticide input sellers.

We are hoping to provide help and support for existing input seller activities and providing new business opportunities. CamSID is seeking to promote more suitable products such as:

- pre-emergence herbicides for rice and diversification crops;
- selective insecticides that don't harm beneficial organisms;
- more appropriate NPK fertiliser mixes that are suitable for basal fertiliser application in rice and diversification crops.

This case-study shop is located in Svay Cheat village (13.929 N, 103.254 E). According to NCDD (2010), Svay Cheat village has a population of 1,227 persons, or approximately 272 households. Eighty-four percent of these households grow rice and this input seller has around 100 clients, therefore this input seller supposedly reaches almost 50% of the rice farming population in the village. This input seller sells fertiliser, pesticides, spraying equipment and livestock feed.

Project staff require a significant amount of training to ensure they record accurate information on pesticides (Figure 41, Figure 42).

Figure 41. Details on the pesticide box

Figure 42. Details on the pesticide label

Urea and DAP were by far the most commonly used fertilisers (Table 37) and assuming the average rice area per farm is 3.6 ha, the estimated total amount of fertiliser applied to rice is 166 kg/ha in this village which is consistent with the findings of Chhun et al. (2019). The proportions of nutrients sold were: N (19.1); P_2O_5 (10.4); and K_2O (1.4). The average profit margin on fertiliser sales was 3%.

Table 37. Quantities, prices and margins for fertilisers sold

Fertiliser type	Amount sold (t)	Buying price (riel)	Selling price (riel)	Selling price (USD/kg)	Margin (%)
46-0-0	30	80,000	82,000	0.41	3%
18-46-0	20	120,000	125,000	0.63	4%
16-20-0	2	75,000	77,000	0.39	3%
20-20-15+TE*	2	100,000	102,000	0.51	2%
21-7-18 + TE	2	100,000	102,000	0.51	2%
27-12-6 + TE	2	100,000	102,000	0.51	2%
0-0-60	1	80,000	82,000	0.41	3%
Total/Average	59	93,571	96,000	0.48	3%

*** TE = trace elements**

Herbicides were the most commonly used pesticides. And bispyribac-sodium was by far the most commonly used herbicide (Table 38), followed by 2,4-D and fenoxaprop-P-ethyl + ethoxysulfuron. The profit margin on pesticides averaged 12% but varied widely. It is important to note the heavy reliance on one particular herbicide and mode of action (MoA) groups 1 and 2 (WSSA, 2018). These practices have a potential for development of herbicide resistance. No pre-emergence herbicides were on sale despite being registered and available at other outlets.

Table 38. Herbicides sold

Active ingredient	Trade name	Manufacturer	Boxes
Bispyribac-sodium	Bisken 40 EC	Kenvos	30
2,4-D dimethyl amine	Zico 720 SL	Saigon Plant Protection	5
Fenoxaprop-P-Ethyl + Ethoxysulfuron	Ricestar Xtra 89 OD	Bayer	5
Glyphosate	Lyphoxim 48 SL	Saigon Plant Protection	1
Pyrazosulfuron-ethyl	Sunami 10 WP	Nanjing Essence	1
Quinclorac + Pyrazosulfuron + Fenoxaprop	Xpert 70 WP	Zhejiang Rayfull	1

Sales indicated that minimal insecticides, fungicides and seed dressings were used (Table 39).

Table 39. Insecticides, fungicides and seed treatments sold

Pesticide	Active ingredient	Trade name	Boxes
Insecticide	Alpha Cypermethrin	Deco Alpha 5 EC	3
Insecticide	Chlorantraniliprole	Prevathon 5 EC	2
Insecticide	Dinotefuran	Not known	1
Fungicide	Fenoxanil + Kasugamycin	Nileda	2
Seed treatment	Thiamethoxam + Difenoconazole + Fludioxonil	K-Seed 312.5 FS	0

Although seed dressing was on sale, no farmers were buying it. Therefore, workshops on seed dressing would be appropriate.

The input seller's opinion was that 70% of farmers knew what pesticide to select and 30% asked for advice. The input sellers were asked if they were interested in receiving training on any of the following: fertiliser product use; improved seed varieties, herbicides, insecticides, fungicides, molluscicides, effective product use, pesticide health and safety, agro input marketing, agronomic training, crop marketing & processing, business planning, sales promotion, customer relationships, financial management, pesticide register details. This input seller was mainly interested in training on product use and safety. This is an important issue because farmer pesticide application methods are dangerous to operator health (Chhun, et al. 2019, Figure 43).

Figure 43. Pesticides are currently applied in a way that the operator is severely exposed (left). 2-WT spray machines can significantly reduce the exposure (right)

Apart from lack of funds, there were no major constraints to running the business. The input seller provides credit to 80% of farmers buying fertiliser and to 40% of farmers buying pesticides.

Plans for 2019-20

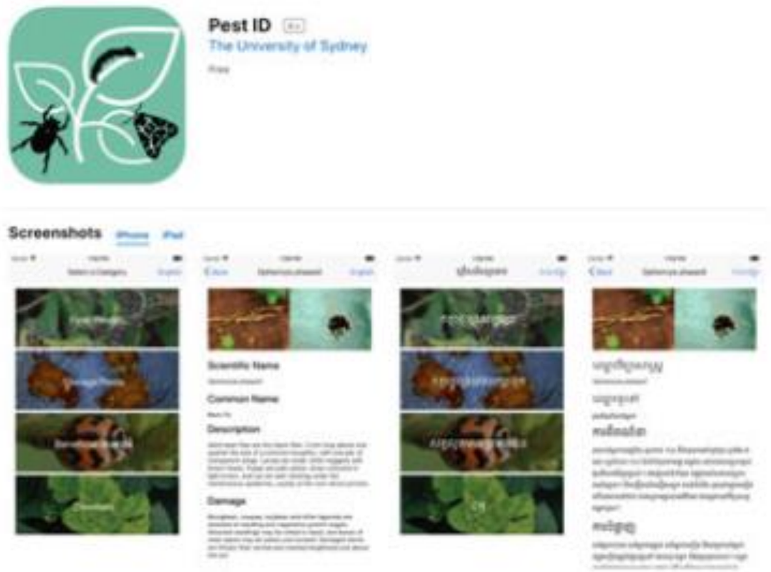
1. Case studies will be completed for key input sellers in the remaining CamSID focus villages in Battambang: Angsangsak-Prek Trab; Boeng Pring; Ou Ta Nhea; and Prey Toteung.
2. Training materials for key CamSID outputs will be prepared. For example, in this case study, we found that pre-emergence herbicides were not in stock and that seed treatments were stocked but farmers were not buying them.
3. Farmer-training workshops on CamSID outputs will be convened at key input seller locations in CamSID target villages.
4. Opportunities for scaling-out will be explored through engagement with the five large input sellers in Battambang City.

Objective 4

Development of information tools

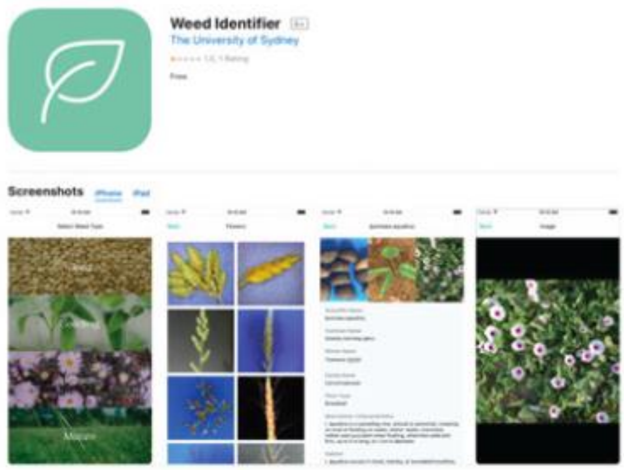
Activity 4.2: Develop and disseminate information tools and messages using extension support materials (e.g. radio/TV programs) and information and communications technology for local communities.

Pest-ID app (https://apps.apple.com/us/app/pest-id/id1328731895)



This study, led by University of Sydney honours student Isabel Hinchcliffe, evaluated the feasibility of the Pest-ID App through a survey with potential users and these responses were incorporated into developing the Insect Pest ID App prototype, which was trialed with farmers and subsequently refined. The Insect Pest ID App has been well received by farmers with users seeing its potential to support crop management decisions. The App has been downloaded 1,147 times on iOS and 727 times on Android.

Weed-ID app (https://apps.apple.com/us/app/weed-identifier/id1165963850?ls=1)



A mobile phone app is helping Cambodian rice farmers manage the spread of weeds at various stages of rice production, and will ultimately improve yields, increase financial gains and build knowledge of crop management in farming communities.

WeedID for iOS and WeedID for android, developed by Master of Agriculture and Environment student, Yehezkiel Henson and a small team of researchers, has been patented, and is already in use in Cambodia.

Weed-ID contains a photo dictionary of the most common weeds in northwest Cambodian rice fields at different stages of growth. The app has images of seeds, seedlings, mature plants and flowers that will all help to identify the most important weeds in rice.

Capacity building to implement SID technologies

Activity 4.3: Increase the supply of practically trained university, PDA, private sector suppliers/trader staff to provide support and sustainability for SID adoption by farmers (USYD, MCU)

Figure 44. Project Officer, Sophea Yous, is writing her masters thesis on mungbean varietal evaluation.

Ms Lucinda Dunn

Lucinda is a University of Sydney PhD candidate working on IPM for stemborers, pest and beneficial organisms in rice in NW Cambodia. She is supervised by A/Prof Daniel Tan, Dr Tanya Latty and Dr Bob Martin.

Ms Chinaza Onwuchekwa-Henry

Chinaza is a University of Sydney PhD candidate working to optimize agronomy for rice-mungbean systems in northwest Cambodia. She is supervised by A/Prof Daniel Tan and Dr Bob Martin.

Ms Stella Lay

Stella is a University of Sydney 4th year student who is working on her thesis “Potential for vegetable diversification in a rice-based cropping system” with support from CamSID.

Ms Caitlin Cavanagh

Caitlin is a University of Sydney 4th year student who is working on her thesis “Benchmarking Mungbean Production with Smallholder Cambodian Farmers” with support from CamSID.

Ms Sophea Yous

Sophea is enrolled in the Master of Science in Sustainable Agriculture course at the University of Battambang (UBB). Her thesis topic is evaluating mungbean varieties for northwest Cambodia. She is supervised by Dr Pao Srean and Dr Bob Martin.

Mr Ratha Rien

Ratha is enrolled in the Master of Science in Sustainable Agriculture course at the University of Battambang (UBB). His thesis topic is weed seed contamination in rice paddy and seed for sowing. He is supervised by Dr Pao Srean and Dr Bob Martin.

Ratha is currently on leave from January-August 2019 to study at the Department of Life, Health and Environmental Sciences, University of La'Aquila, Italy.

Ms Chariya Korn

Chariya is enrolled in the Master of Science in Sustainable Agriculture course at the University of Battambang (UBB). Her thesis topic is evaluating Australian mungbean varieties for northwest Cambodia. She is supervised by Dr Pao Srean and Dr Bob Martin.

References

Blair, G., Blair, N., 2014. Nutrient status of Cambodian soils, rationalisation of fertiliser recommendations and the challenges ahead for Cambodian soil science. Curr. Agric. Res. J. 2, 5–13.

Chhun S, Kumar V, Martin RJ, Srean P, Hadi BAR. 2019. Weed management practices of smallholder rice farmers in Northwest Cambodia. Crop Protection. https://doi.org/10.1016/j.cropro.2019.04.017.

CIMMYT. 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico. D.F.

MAFF, 2017. Annual Report of Agriculture, Forestry and Fisheries 2016-2017 and Directions 2017-2018. Ministry of Agriculture Forestry and Fisheries, Kingdom of Cambodia.

NCDD, 2010. National Committee for Sub-National Democratic Development, 2010. Commune Database Online. General Planning Department, Ministry of Planning: www.ncdd.gov.kh.

Ouk M., Sokhom S., Khun L.H., Sieng L.H. and Orn C. 2009. Varietal improvement increases mung bean yields in Cambodia. *Cambodian Journal of Agriculture* **9**, 1–7.

Robertson, M.J., Carberry, P.S., Huth, N.I., Turpin, J.E., Probert, M.E., Poulton, P.L., Bell, M., Wright, G.C., Yeates, S.J., and Brinsmead, R.B. 2002. Simulation of growth and development of diverse legume species in APSIM, Australian Journal of Agricultural Research 53:429-446.

Som B, Pao S, Ouk M, Mitchell J, 2011. Effects of straw mulch on mungbean yield in rice fields with strongly compacted soils. *Field Crops Research* **124**, 295–301.

Stuart, A.M., Pame, A.R. P, Silva, J.V., Dikitanan, R.C., Rutsaert, P., Malabayabas, A.J.B., Lampayan, R.M., Radanielson, A.M., Singleton, G.R. 2016. Yield gaps in rice-based farming systems: Insights from local studies and prospects for future analysis. Field Crops Research 194, 43-56.

White PF, Oberthür T, Sovuthy P, eds. 1997. The soils used for rice production in Cambodia. A manual for their identification and management. International Rice Research Institute, P.O. Box 933. Manila, Philippines.

WSSA 2018. Weed Science Society of America - Herbicide Site of Action (SOA) Classification List. Date last modified: 5 December 2018. http://wssa.net/wssa/weed/herbicides/.

Banteay Meanchey

Objective 2

Part 1 – July to December 2018 (Early and Main wet season 2018)

Activity 2.4, Output 2.4.2. Kuok Tonlaop (EWS) – Dry seeding using Kid Seeder (Seed Rate Experiment) – 2018: Key Project implement team: Dr Yorn Try, Mr Nheb Khim, Ms Ngann Seyma, Mr Chhan Tekhong

This experiment was sown on 25th April 2018 and harvested on 17th August 2018.

Purpose: Determine the effect of different seeding rate and weed management on yield, yield components, insect damage and disease infection, and economical effect for dry seeding during early wet season 2018.

The experiment was in a split plot design with weed management as the main plots, and different seeding rates were sub-plots, and three replications. Weed management was divided into two levels: Weeding (W) and Non-Weeding (NW). The sub-plot was divided into five different levels including 20 kg/ha, 40 kg/ha, 60 kg/ha, 80 kg/ha, and 180 kg/ha (hand broadcast). Sowing method was operated by Thai Kid Seeder.

Figure 45. Kid seeder for dry seeding

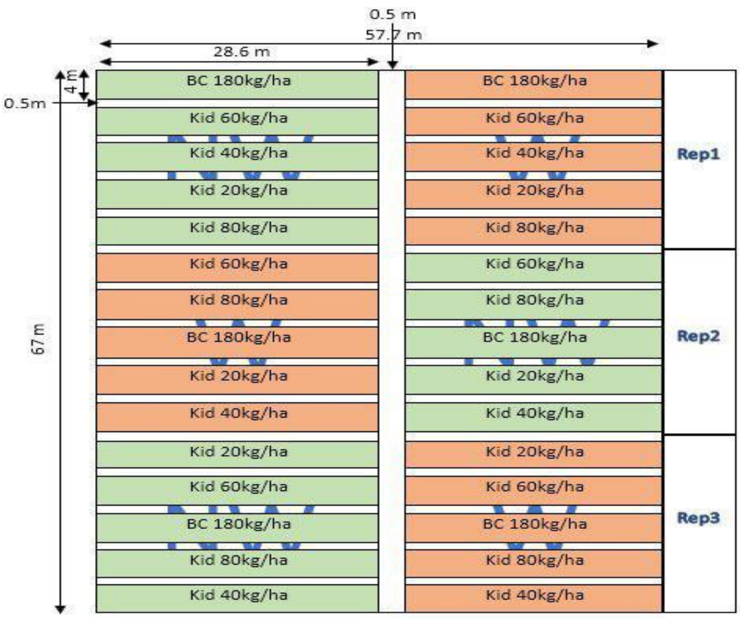


Figure 46. Experimental layout for the seeding rate experiment at KTL

Through data collection and analysis, we have concluded important messages from the experiment for scaling up to farmers.

Table 40. Economic analysis for paddy rice production with selling at fresh yield

Seeding rates (kg/ha)	Fresh yield (t/ha)	Input cost ($/ha)	Labour cost ($/ha)	Income ($/ha)	Gross Margin ($/ha)
20	4.7	281	165	1,097	652
40	6.3	298	165	1,464	1,001
60	6.4	316	165	1,481	1,001
80	7.1	334	165	1,652	1,153
180	7.2	383	165	1,657	1,110

There are more than 95% of farmers in the Northwest selling their rice at farm gate as fresh paddy rice; Mr Chiv Sarith is a leading farmer who his fresh paddy rice at farm gate. Our experiment was harvested on 20th August 2018, after recording fresh yield; we continued to dry to record dry yield. At the same time, Mr Sarith sold his rice straight way with the price of 10,000 Baht/ton; equivalent to 232 USD/t. When all costs were calculated including input costs and labour cost against total incomes based on the above price, the highest profit (gross margin) is 80 kg/ha seeding rate (1153 USD/ha), the second highest profit is farmer practice, 180 kg/ha seeding rate (1,110 USD/ha); and the lowest profit is 20 kg/ha seeding rate (652 USD/ha).

Table 41. Economic analysis for paddy rice production with selling at dry yield

Seeding rate (kg/ha)	Dry yield (t/ha)	Input cost ($/ha)	Labor cost ($/ha)	Income ($/ha)	Gross margin ($/ha)
20	4123	281	247	1146	618
40	5624	298	277	1563	988
60	5769	316	280	1603	1007
80	6439	334	293	1790	1163
180	6367	383	292	1769	1093

In general, there are lot of hypotheses claiming that selling paddy rice at dry yield could get more profit compared with selling at fresh yield. In response to those hypothesis, we did a calculation on the expenses on the drying fee, normally the rice miller in BMC charges 20 USD/t. The unit price for dry yield is 12,000 Baht/t equivalent to 278 USD/t based on the exchange rate on 30th August 2018. When all costs were calculated including input costs, labour cost, and drying cost against total incomes based on the above price, the highest profit (gross margin) is 80 kg/ha seeding rate (1163 USD/ha), the second highest profit is farmer practice, 180 kg/ha seeding rate (1,093 USD/ha); and the lowest profit is 20 kg/ha seeding rate (618 USD/ha).

With 80 kg/ha seeding, the margin between selling at fresh yield and selling dry yield are 10 USD/ton which is not a big difference (1153 USD/ton and 1163 USD/ton). This not including the interest for 10 days and transport paddy rice from farm gate to rice milling shed. Because of low profit from selling at dry yield, most of the farmers just sell their fresh paddy rice without drying at the farm gate.

Conclusion

1. During early wet season between 25th April and 17th August 2018, disease (especially rice blast) and insect pests were not yield limiting issues. Disease and insects were at very low

density and did not significantly reduce rice yield. Birds and rats did not cause any substantial damage.

2. Lodging rate was recorded as a very big issue in Sen Kraob variety during early wet season; the highest seeding rate had the highest lodging rate and vice versa.
3. With KTL early wet season, non-weeding and weeding method was non-significant in determining yield; therefore weed management at KTL was not a major issue.
4. There was a significant difference in fresh yield and dry yield between different seeding rates; with dry seeding method, and 80 kg/ha was the optimum dry seeding rate (using Kid seeder) for Sen Kraob in early wet season at KTL.
5. With the seeding rate at 80 kg/ha, the margin between selling with fresh yield and dry yield was not large (1153 $/ha and 1163 $/ha); it was less than 10 $/ha (not enough to cover the drying charges of 20 $/ha).

Activity 2.7, Output 2.7.1. Banteay Meanchey - Integrated pest management in rice (with two University of Battambang [UBB] Masters students)

To build IPM program for rice, the important step is to identify key insect pests and their natural enemies and recognise which species is the main insect pest and their important predators and parasites. Moreover, the study of biological characteristics of the key insect pest and their natural enemies is needed. Then the monitoring and recording of insect pest population dynamics in the rice field is very useful for IPM program. During six-month implementation of the IPM proposal, we found important information (Table 42)

Table 42. Presence of rice pests at KTL

No	Species	Family	Order	Frequency	Damaged stage
1	Rice stem borer *Tryporiza incertulas*	Noctuidae	Lepidoptera	++	Tillering - flowering
2	Rice leaf folder *Cnaphalocrosis medinalis*	Pyralidae	Lepidoptera	+	Tillering - flowering
3	Rice skipper *Parnara guttata*	Hesperiidae	Lepidoptera	-	Maximum tillering
4	Black bug *Scotinophora lurida*	Pentatomidae	Hemiptera	+	Early tillering - maximum tillering
5	Rice bug *Leptocorisa acuta*	Coreidae	Hemiptera	-	Flowering
6	Brown plant hopper *Nylaparvata lugen*	Delphacidae	Homoptera	-	Tillering - flowering

Rice stem borer is the most important insect pest, then rice leaf folder appears to be important when rice is at the flowering stage. The other species occur with low density and do not cause heavy damage.

Table 43. Parasitoid species in rice leaf folder and rice stem borer

No.	Parasitic species	Family	Parasitism	Host	Distribution
1	*Apanteles cypris* Nixon (2♀)	Braconidae	Larva	*Cnaphalocrocis medinalis*	Eastern Palaearctic & Oriental: Bangladesh, China, India; Indonesia, Japan, Malaysia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka Vietnam
2	*Bracon onukii* Watanabe (2♀+2♂)	Braconidae	Larva	*Cnaphalocrocis medinalis*	Eastern Palaearctic & Oriental: China, Japan, Korea, Vietnam
3	*Casinaria colacae* Sonan (1♀)	Ichneumonidae	Larva	*Parnara guttata; Pelopidas mathias*	Eastern Palaearctic & Oriental: China
4	*Dolochogenidea agilis* Ashmead (2♀)	Braconidae	Larva	*Pelopidas mathias*	Oriental: India, Indonesia, Philippines, Vietnam
5	*Telenomus rowani* Gahan (a few)	Scelionidae	Egg	*Scirpophaga incertulas*	
6	*Tropobracon luteus* Cameron (1♀+1♂)	Braconidae	larva	*Chilo suppressalis; Scirpophaga incertulas, Sesamia inferens*	Oriental: Bangladesh, China, India, Indonesia, Malaysia, Pakistan, Philippines, Sri Lanka, Thailand, Vietnam
7	*Xanthopimla flavolineata* Cameron	Ichneumonidae	Pupa	*Chilo suppressalis, Cnaphalocrocis medinalis, Parnara guttata, Sesamia inferens*	Australasian, Oceanic, Oriental: Australia, Bangladesh, Indonesia, Japan, Laos, Malaysia, Nepal, Pakistan, Papua New Guinea; Philippines, Sri Lanka, Vietnam
8	*Orientohormius* sp. (1♀)		Unknown	Unknown	New genus, new species
9	*Taiwanhormius* sp. (1♀)		Unknown	Unknown	New species

Activity 2.4, Output 2.4.2. Mechanization (mechanized drum seeder) in direct seeded rice at NW, Cambodia. (Led by Dr Cuong, SFSA)

Mechanization in farming is one of focus activities under project CamSID that helps farmers reduce a huge of burden work to rice farmers. Large farm size plus scarce farm labour are main drivers for farmers to adopt direct seeded rice in NW Cambodia as well as in Banteay Meanchey.

Under project CamSID, in October, 2017 SFSA in collaboration with MCU imported a mechanized drum seeder made in Vietnam (version. 1) to demonstrate to farmers in BMC & BTB. In comparison to hand broadcast or manual drum seeder made by IRRI the machine proved a great advantage. This helped farmers to increase significantly in sowing capacity with safety in herbicide application. Hundreds of ha were quickly adopted by farmers in BMC & BTB.

However, during field demonstration and practical adoption in the first year, the mechanized drum seeder still showed some disadvantages such as small wheels, low engine power, heavy herbicide tank load. These led to instances that the machine, sometimes got stuck in field of deep soil layer. In addition to that due to the sowing hole diameter being too large and made at close distance resulted in more seed being dropped and took time to manage in calibration for low seed rate sown.

To overcome these issues, during August – September, 2018, SFSA have worked closely with the Vietnam manufacturer to improve functions of the machine and practically tested in Vietnam field. Finally, two mechanized drum seeder – version. 2 were successfully made in Vietnam then exported to CamSID project in this October 2018. The version. 2 showed more advantages compared to the version. 1

Specification	Version. 1	Version. 2	Benefit
Wheel height	90 cm diameter	110 cm diameter	Avoid being stuck in deep soil field
Engine power	0.95 HP	1.25 HP	Increase sowing capacity
Herbicide tank volume	200 L	160 L	Avoid being stuck & easy driving
Sowing hole large	12 mm diameter	10 mm diameter	Less seed dropped
Line to line distance	10 cm	20 cm	Easily sown in optimal spacing
Hole to hole distance	3.5 cm	7.0 cm	Saving time in calibration.
Wheel & support pole	Not in one line	In one line	Reduce disturbance on field surface

Figure 47. Vietnamese mechanised drum seeder, version 1

The improved machine – Version. 2 has been adopted in KTL by Mr. Chiv Sarith without the problems as what happened in his field in last year with version. 1

Figure 48. SFSA will provide to Ockenden one of this machine the – version 2.0 for use in seed production.

Activity 2.2, Output 2.2.2. Banteay Meanchey – Fish Production

Figure 49. Tilapia fish production

Fish raising is an important enterprise for smallholders in North West Cambodia. Every household has small pond in front of the house or behind the house.

Therefore, raising fish in this small pond to increase household income is very important. Mr Yann Sakhon has been growing fish for 10 years but he is still thinking that he has not enough experience to grow fish more economically. In response to this problem, we have set up the fish experiment at Mr Sakhon's pond with three different densities of fingerling including 25, 50, 75, and 100 fingerling per cage (5 x 5 x 5 m). The experiment has been implemented since 11th July 2018, now it is 5 months, at this time the density of 25 fingerling per cage seems to be the optimal stocking rate; Mr Yann Sakhon is very happy with this result; he is planning to enlarge his pond to grow more fish if our fish experiment is successful. We shall harvest in one month later (during February). Then the comparison between the different stocking rates will also be analysed and the enterprise compared with rice production.

Part 2 - **July to December 2018 (Early and Main wet season 2018)**

Project implement team: Dr Yorn Try**,** Mr Nheb Khim**,** Ms Ngann Seyma**,** Mr Chhan Tekhong**,** Saing Sophath

Based on the result of annual meeting in Battambang on 13th February 2019, we have done most of these activities as follows:

1. Completed the experiment on main wet season seeding rate (wet seeding) and weed management on 24th September 2018 at Kork Tonlaob village, Mungkulborei district;

2. Completed the experiment on dry season rice seeding rate (wet seeding) and weed management on 28th March 2019 at Oambel Sereisopon city;

3. Completed the watermelon dry season experiment on different techniques on 14th January 20189 at Botrong village, Botrong commune, Ochrouv district;

4. Experiment on early wet season seeding rate (dry seeding) and fertilizer level (in progress) on 1st May 2019 at KTL, Mung Kulborei district;

5. First rice demonstration on CamSID technical package scaling on 31 May 2019 at Botrong village, Botrong commune, Ochrouv district, and

6. First rice demonstration on CamSID technical package scaling on 21st June 2019 at Spean Sraeng village, Phnom Srok district.

Activity 2.4, Output 2.4.2. Completed the experiment on seeding rates and weed management on 24th September 2018 at Kork Tonlaob village, Mungkulborei district

Purpose: To determine the effect of different seeding rate and weed management on yield, yield components, insect damage and disease infection, and economics for dry seeding during early wet season 2018.

The experiment was designed in a two factorial layout (split plot design) with weed management as the main plot, and different seeding rates were sub-plot, and three replications. Weed management was divided into two levels: Weeding (W) and Non-Weeding (NW). The sub-plot was divided into five different levels including 20 kg/ha, 40 kg/ha, 60 kg/ha, 80 kg/ha, and 180 kg/ha (hand broadcast). Sowing method was operated by Mechanized Drum Seeder.

Figure 50. Mechanized drum seeder operating for wet seeding

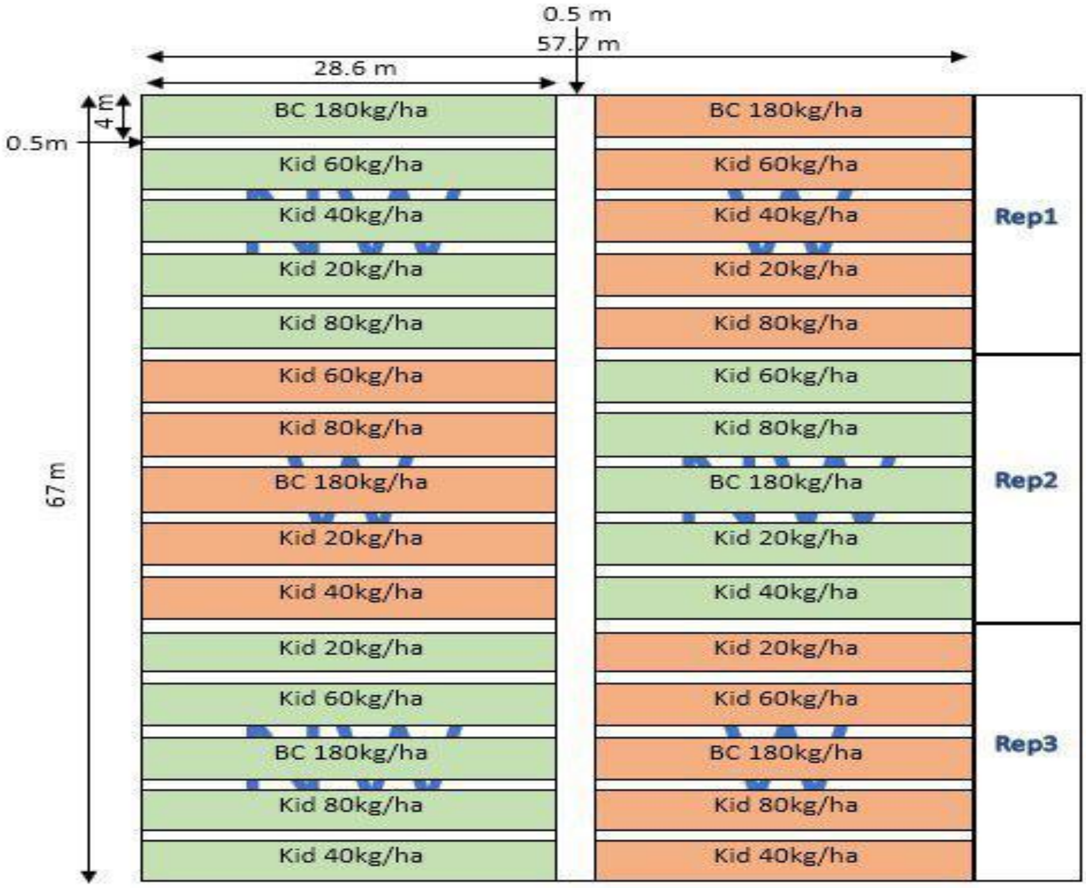


Figure 51. Experimental layout for split-plot design with two factors and three replicates

Through data collection and analysis, we have concluded important messages from the experiment for scaling up to farmers.

Activity result

Wet seeding-main wet season

It is similar to early wet season, there were three main disease found during main wet season rice at KTL including rice blast (*Pyricularia oryzae*), brown spot (*Bipolaris oryzae*), and bacteria leaf blight *(Xanthomonas oryzae* pv. *oryzae*). These three diseases occurred from15 days after sowing until maturing stage. Rice blast infected the field from early stage and reached its peak during 30 to 45 days after sowing and then decreased at the end of harvest. Brown spot infect the rice field with low damage (0.21%) at 15 days after sowing and then reached its peak at 45 and 60 days after sowing at around 4%. Bacteria leaf blight infected the crop at a low incidence at the beginning, then increased at 45 days after sowing. In general, blast infected the field from early stage of rice and the damage did not exceed 5% until the end; then brown spot and bacteria leaf blight infected the field later but infection increased at 45 day after sowing but its damage did not exceed 6%. In conclusion, during the main wet season the three diseases found in Sen Kraop rice at KTL did not cause any serious damage.

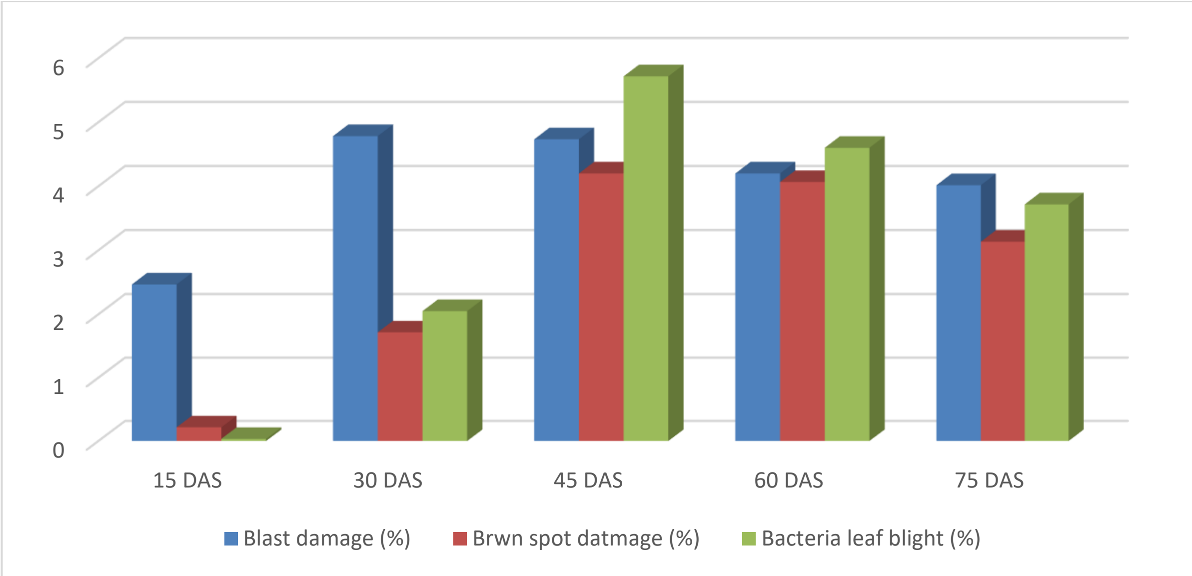


Figure 52. Incidence of rice blast, brown spot, and bacterial leaf blight from 14 days after sowing until 100 days after sowing

Insect pests

During experimental implementation, insect pests were recorded every two weeks. Eight species of rice insect pests were found during early wet season; rice stem borer and brown planthopper were the most important insect pest with (++). Rice leaf folder, black bug, and thrips were the second insect pest during main wet season; they occurred with (+) presence. Rice bug and rice skipper occurred with (-) and were not very important insect pests.

Table 44. Insect pest composition in rice during early wet season at Kork Tonlaop

No	Species	Family	Order	Frequency	Damaged stage
1	Rice stem borer *Tryporiza incertulas*	Noctuidae	Lepidoptera	++	From Tillering flowering
2	Rice leaf folder *Cnaphalocrosis medinalis*	Pyralidae	Lepidoptera	+	From Tillering to flowering
3	Rice skipper *Parnara guttata*	Hesperiidae	Lepidoptera	-	Maximm Tillering
4	Black bug *Scotinophora lurida*	Pentatomidae	Hemiptera	+	Early tillering to maximum tillering
5	Rice bug *Leptocorisa acuta*	Coreidae	Hemiptera	-	Flowering
6	Brown plant hopper *Nylaparvata lugen*	Delphacidae	Homoptera	++	From Tillering to flowering
7	*Thrips oryzae*	Thripidae	Thysanoptera	+	Tilering stage
8	Green leafhopper *Nephoettix nigropictus*	Cicadellidae	Hemipter	+	From tilering to flowering

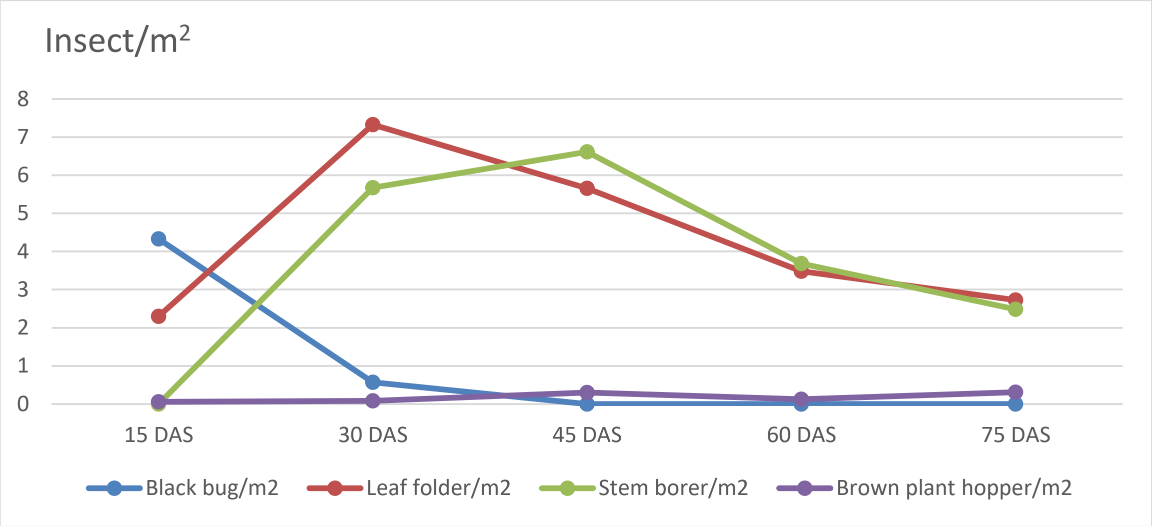


Figure 53. Population dynamics of four important insect pests in rice during main wet season at Kork Tonlaop, Mungkul Borei, Banteay Meanchey

There are 8 species of insect pests found during main wet season 2018 at KTL but four species were more common compared with other species. Therefore our project staff sampled these four species at two week intervals. Black bug occurred early at 15 days after sowing then disappeared at 45 days after sowing. Brown plant hopper occurred at very low density from 15 days after sowing to harvest time. The two species, rice stem borer and rice leaf folder occurred with high density between 30 days after sowing and 45 day after sowing, then decreased gradually until the end of season.

Plant establishment

Plant establishment was sampled at 10 days after sowing; the density was significantly different between seeding treatments. There were no-significant differences between seeding rates (20 kg/ha, 40 kg/ha).

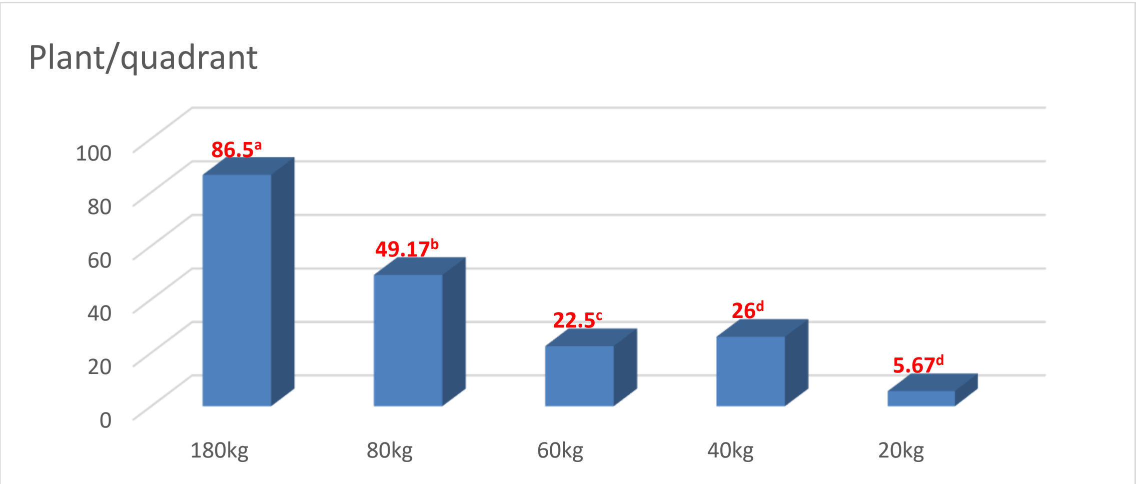


Figure 54. Plant establishment of in paddy rice during main wet season at Kork Tonlaop, Mungkul Borei, Banteay Meanchey

Lodging rate

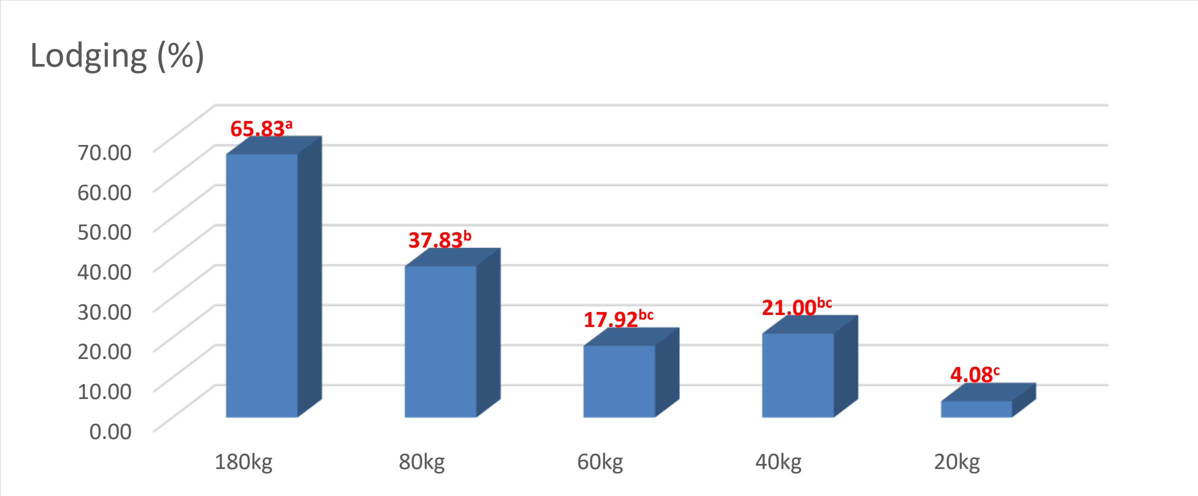


Figure 55. Lodging rate from different seeding rate during main wet season at Kork Tonlaop, Mungkul Borei, Banteay Meanchey

During main wet season, Sen Kraob still dominates rice production areas in the North West Cambodia. It was planted in about 70% of the area at KTL. Lodging is also one of the factors causing yield losses. During experiment, we evaluated the lodging rate at one week before harvesting. There were significant differences between the five seeding rates. The highest seeding 180 kg/ha had the highest lodging (65.83%), followed by the lower seeding 80 kg/ha at 37% lodging; the lowest seeding 20 kg/ha had the lowest lodging rate of 4.08%.

Figure 56. On the left side is 20 kg/ha, on the right side is 180 kg/ha, and in the middle is 80 kg/ha

Table 45. Agronomic characteristics of rice from two factor experiment during main wet season

Seeding rate	Panicle/quadrant	No. grain/ panicle	1000 grain weight (g)	Fresh yield (kg/plot)	Dry yield (kg/plot)
180kg/ha	136.83^{a}	78.06^{c}	27.14^{c}	36.33^{c}	28.33^{c}
80kg/ha	117.83^{ab}	93.94^{bc}	27.37^{b}	40.33^{bc}	32.75^{bc}
60kg/ha	101.25^{bc}	111.39^{ab}	27.43^{b}	42^{ab}	33.65^{ab}
40kg/ha	94.17^{cd}	118.94^{a}	27.41^{b}	40.33^{a}	34.33^{ab}
20ha/ha	78^{d}	123.61^{a}	28.03^{a}	43.33^{a}	36.42^{a}

Based on ANOVA two factors analysis and Duncan multiple range test (DMRT) for number of panicles per quadrant, number of grain per panicle, 1000 grain weight, fresh yield and dried yield; Table 2 indicates that the number of panicle is significantly different between seeding rates; 20kg/ha seeding rate had the lowest panicle per quadrant (78^{d}) and 180 kg/ha seeding rate is the highest panicle per quadrant (136.83^{a}). The number of grain per panicle were significantly different between seeding rates. The 180 kg/ha seeding rate had the lowest grain per panicle (78.06^{c}) and the 20 kg/ha of seeding had the highest grain per panicle (123.61^{a}). The 1000 grain weight was significantly different between seeding rates; 20 kg seeding rate had the heaviest grain (28.03[a]) and the 180 kg seeding rate had the lowest grain (27.14[c]). The seeding rates of 40 kg, 60 kg, and 80 kg were not significantly different in 1000 grain weight (27.41[b], 27.43[b], and 27.37[b]; respectively). The dry yield between seeding rates are significant different. The 20 kg seeding rate had the highest yield (36.42[a] kg/plot) and the 180 kg/ha seeding rate had the lowest yield (28.33[c] kg/plot). The dry yield was not significantly different the seeding rates; 20, 40 and 60 kg/ha confirming that the yield response in the range of 20 to 60 kg/ha seeding rates is quite flat.

Economic analysis

Table 46. Table of economic analysis for paddy rice production sold at fresh paddy yield

Seeding rates (kg/ha)	Fresh yield (t/ha)	Input cost ($/ha)	Labor cost ($/ha)	Income ($/ha)	Profit (Gross Margin) ($/ha)
20	4.33	324	270	1,276	681
40	4.15	342	270	1,222	610
60	4.20	359	270	1,236	607
80	4.03	373	270	1,187	544
180	3.63	464	270	1,070	335

There are more than 95% of farmers in the Northwest selling their rice at farm gate as fresh paddy rice; Mr Chiv Sarith is one of them who sold his fresh paddy rice at farm gate. Our experiment was harvested on 28th December 2018, after recording all fresh yield data; we continued to dry to record dry yield. At the same time, Mr Sarith just sold his rice straight way with the price of 9,500 Baht/ton; equivalent to 294 USD/ton. When all costs were calculated including input costs and labor cost against total income based on the above price, the highest profit (gross margin) is at 20 kg/ha seeding rate (681 USD/ha), the second highest profit is 40kg/ha of seeding rate (610 USD/ha); and the lowest profit is 180 kg/ha seeding rate (335 USD/ha).

Table 47. Economic analysis for paddy rice production sold at dry yield

Seeding rate (kg/ha)	**Dry yield (t/ha)**	**Input cost ($/ha)**	**Labor cost ($/ha)**	**Income ($/ha)**	**Profit (Gross margin) ($/ha)**
20	**3.64**	**324**	**357**	**1329**	**648**
40	**3.43**	**342**	**353**	**1253**	**558**
60	**3.37**	**359**	**354**	**1228**	**515**
80	**3.28**	**373**	**351**	**1195**	**472**
180	**2.83**	**464**	**343**	**1034**	**227**

In general, there are lot of hypotheses that selling paddy rice at dry yield could get more profit compared with selling at fresh yield. In response to this hypothesis, we did a calculation on the expenses on the drying fee, normally the rice miller in BMC charges 20USD/ton. If the farmer dries by themselves the cost is cheaper; one ton of paddy rice costs 15 USD to dry. The unit price for dry yield is 11,800 Baht/ton equivalent to 365USD/ton based on exchange rate 30th December 2018. When all costs were calculated including input costs, labor cost, and drying cost against total incomes based on the above price, the highest profit is 20 kg/ha seeding rate (648 USD/ha), the second highest profit is 40 kg/ha (558 USD/ha); and the lowest profit is 180 kg/ha seeding rate (227 USD/ha).

Conclusions

1. During wet season between 24th September and 28th December 2018, disease (especially blast) and insect pests were not yield limiting issues. Disease and insects were found with very low density and did not significantly reduce the rice yield. Bird and rat did not cause any substantial damage.
2. Lodging rate was recorded as a very big issue in Sen Kraob variety during main wet season; the highest seeding rate had the highest lodging rate and vice versa.
3. With KTL main wet season, non-weeding and weeding method was non-significant in determining yield; therefore, weed management at KTL was not a major issue.
4. There was a significant difference in fresh yield and dry yield between different seeding rates; with wet seeding method, and 20 kg/ha was the optimum wet seeding rate (using Mechanized drum seeder) for Sen Kraob in main wet season at KTL.
5.With the seeding rate at 20 kg/ha, the margin between selling with fresh yield and dry yield was not large (681$/ha and 648$/ha); selling at fresh yield is more economical than selling at dry yield (35 USD profit per hectare).

Activity 2.4, Output 2.4.2. Completed the experiment on seeding rates and weed management (dry season rice with wet seeding method) on 28th March 2019 at Oambel Sereisopon city

The aim was to determine the effect of seeding rate (20, 40, 60, 80, 180 kg/ha) on dry season rice (and weed incidence) with wet seeding method.

Plant establishment

Plant establishment was collected at 14 days after sowing; each plot was sampled for 0.25 cm^2 and the number of plants was counted.

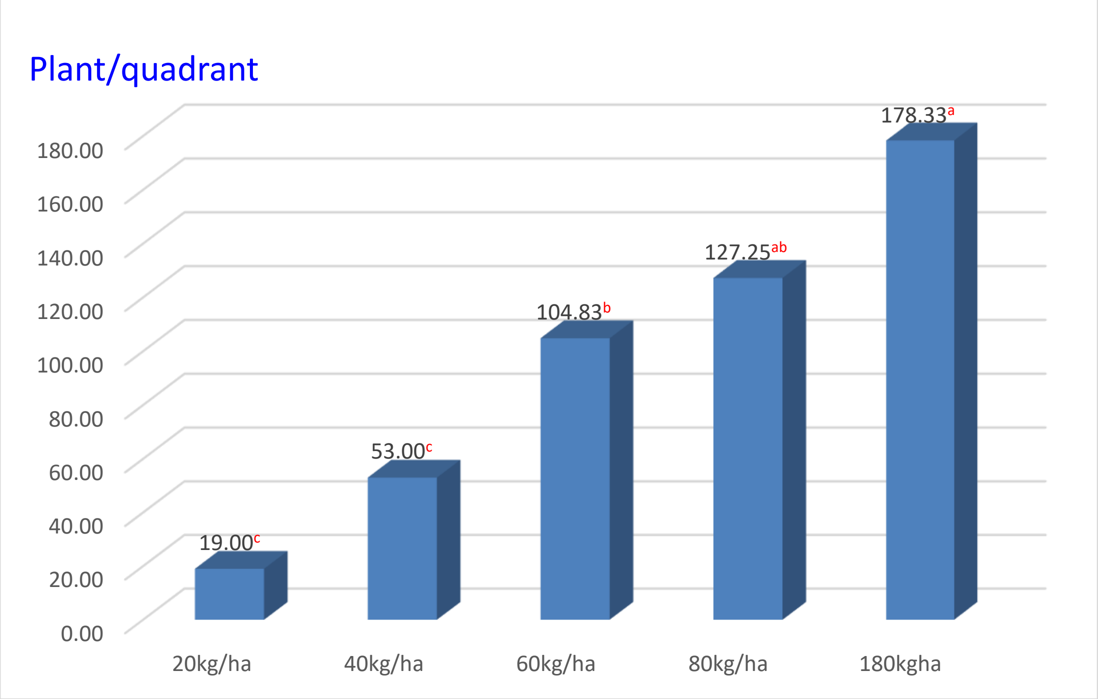


Figure 57. Plant establishment recorded collected at 14 days after sowing

The plant density at 14 days after sowing was significant different at 5% level; 20 kg/ha seeding rate was the lowest density (19.00^{c} plant/quadrant) and the highest density was 180 kg/ha seeding rate (178.33^{a} plant/quadrant). There were no significant differences in plant establishment between 80 kg/ha rate and 60 kg/ha of seeding rates (127.25^{ab} and 104.83^{b}). There were also no significant differences in plant establishment between 40 kg/ha and 20 kg/ha seeding rates (53.00^{c} and 19.00^{c}).

Disease infection

Similar to the wet season, the same three main diseases are found during the dry season rice as at KTL-Banteay Meanchey including rice blast (*Pyricularia oryzae*), brown spot (*Bipolaris oryzae*), and bacterial leaf blight *(Xanthomonas oryzae* pv. *oryzae*). These three diseases occurred from 15 days after sowing until maturing stage.

In general, rice blast was the main disease which infected the field from early stage at 15 days after sowing and reached its peak at 60 days after sowing and then decreased at the end of harvest.

With five seeding rates, the disease severity (%) in each seeding rate were recorded and analysed at different stages of rice development including 15 DAS, 30 DAS, 45 DAS, 60 DAS, and 75 DAS.

There were significant differences in disease severity caused by blast during all stages of rice development (see Table 48). At 15 DAS, disease severity caused by blast was significantly different between different seeding rates but there were no significant differences between 80 kg/ha, 60 kg/ha, and 40 kg/ha (3.67^{b}, 3.58^{b}, and 3.33^{b}, respectively).

At 30 DAS, there were significant differences in disease severity between the five different seeding rates; the highest seeding rate (180 kg/ha) had the highest infection (8.58^{a}), the lowest seeding rates (20kg/ha) had the lowest infection (2.67^{e}).

Figure 58. Picture of blast symptom at 45 days after sowing during dry season

Table 48. Incidence of disease severity (%) of rice blast recorded by different stage of rice

Seeding rate	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**
20 kg/ha	2.08^{c}	2.67^{e}	3.08^{c}	3.67^{c}	3.58^{d}
40 kg/ha	3.33^{b}	4.00^{d}	4.83^{b}	4.25^{c}	4.08^{cd}
60 kg/ha	3.58^{b}	5.25^{c}	5.75^{b}	4.33^{c}	4.58^{c}
80 kg/ha	3.67^{b}	7.33^{b}	7.50^{a}	5.83^{b}	5.42^{b}
180 kg/ha	4.42^{a}	8.58^{a}	8.25^{a}	8.50^{a}	6.83^{a}
Average	3.42	5.57	5.88	5.32	4.90

**Least significant at 5% level*

At 45 DAS, the disease infection reached its peak for all seeding rates; there were significant differences in disease infection between seeding rates but there were not significant differences between 180 kg/ha and 80 kg/ha (8.25^{a} and 7.50^{a}); and there were no significant differences in disease infection between 60 kg/ha and 40 kg/ha (5.75^{b} and 4.83^{b}).

At 60 DAS, the infection was slightly reduced compared to at 45 DAS; there were significant differences in disease severity between treatments; but there were no significant differences between 60 kg/ha, 40 kg/ha, and 20 kg/ha (4.33^{c}, 4.25^{c}, and 3.67^{c}, respectively).

At 75 DAS, there were significant differences in disease severity between seeding rates but there were no significant differences in disease severity between 60 kg/ha (4.58^{c}) and 40 kg/ha (4.08^{cd}); and there were no significant differences in disease infection between 40 kg/ha (4.08^{cd}) and 20 kg/ha (3.58^{d}).

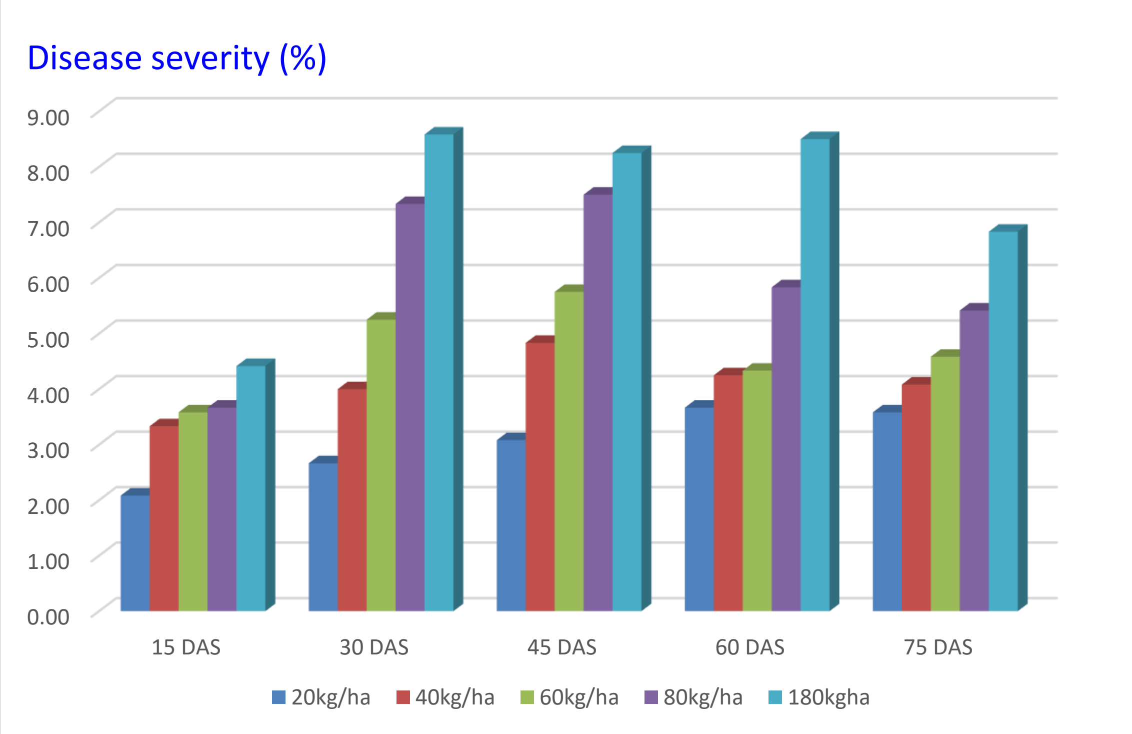


Figure 59. Incidence of blast during dry season-2019 at BMC

Insect pests

During dry season experimental implementation, insect pests were recorded every two weeks. Fifteen species of rice insect pests were found during dry season in 2019; Among those species, three species were Lepidoptera, four species were Hemiptera, three species were Diptera, two species were Homoptera, one species was Coleoptera, one species was Orthoptera, and one species was Thysanoptera. Rice stem borer (*Tryporiza incertulas*) and rice leaf folders (*Cnaphalocrosis medinalis*) were the most important insect pest in dry season rice; these two species occurred with very high density (++++ and +++). The other species occurred with low density and did not reduce rice yield significantly.

Table 49. Insect pest composition in rice during early wet season at Ou Ambil Village

No	Species	Family	Order	Frequency	Damaged stage
1	Rice stem borer *Tryporiza incertulas*	Noctuidae	Lepidoptera	++++	From Tillering flowering
2	Rice leaf folder *Cnaphalocrosis medinalis*	Pyralidae	Lepidoptera	+++	From Tillering to flowering
3	Rice skipper *Parnara guttata*	Hesperiidae	Lepidoptera	-	Maximm Tillering
4	Rice gall midge *Orseolia oryzae*	Cecidomyiidae	Diptera	++	Tillering stage
5	Rice leaf beetles *Oulema oryzae*	Chrysomelidae	Coleoptera	-	Tillering stage
6	Black bug *Scotinophora lurida*	Pentatomidae	Hemiptera	+	Early tillering to maximum tillering
7	Rice bug *Leptocorisa acuta*	Coreidae	Hemiptera	++	Flowering
8	Seedling maggots *Atherigona oryzae*	Muscidae	Diptera	+	Early tillering
9	Brown plant hopper	Delphacidae	Homoptera	++	From Tillering to

	Nylaparvata lugen				flowering
10	Green leafhopper *Nephotettix nigropictus*	Cicadellidae	Homoptera	+	From Tillering to flowering
11	*Thrips oryzae*	Thripidae	Thysanoptera	+	Tilering stage
12	Green leafhopper *Nephoettix nigropictus*	Cicadellidae	Hemipter	+	From tilering to flowering
13	Rice whorl maggots *Hydrellia philippina*	Ephydridae	Diptera	+	Early tillering
14	Grasshopper *Oxya chinensis*	Acrididae	Orthoptera	++	Maximum tillering
15	Green stink bug *Nezera viridula*	Pentatomidae	Hemiptera	-	Maximum tillering

Note: - occurred with < 10%, + occurred with <25%, ++ occurred with <40%, +++ occurred with <60%, and ++++ occurred with > 60%.

Rice stem borer (*Tryporiza incertulas*) is the most important species occurred with high density (++++) from 30 DAS to 75 DAS. The insect pests infected the rice field from 30 day after sowing (DAS) until 76 DAS; 45 DAS is the heaviest infection for Sen Kraob varieties during dry season. Therefore we recorded and analysed the incidence this insect pest in different seeding rates (20 kg/ha, 40 kg/ha, 60 kg/ha, 80 kg/ha, and 180 kg/ha) at four developmental stages (30 DAS, 45 DAS, 60 DAS, and 76 DAS), There were significant differences in insect pest populations between different seeding rates for four developmental stages of rice (see Table 50).

Table 50. Population dynamic of rice stem borer (*Tryporiza incertulas*) in rice during early wet season at Ou Ambil Village

Seeding rate	30 DAS	45 DAS	60 DAS	75 DAS
20 kg/ha	3.67^{d}	3.50^{d}	2.00^{c}	1.17^{b}
40 kg/ha	6.00^{c}	6.83^{c}	4.17^{b}	3.17^{a}
60 kg/ha	7.67^{bc}	8.50^{bc}	4.83^{ab}	3.50^{a}
80 kg/ha	9.33^{ab}	10.17^{ab}	4.67^{ab}	4.00^{a}
180 kgha	10.67^{a}	11.33^{a}	5.17^{a}	3.67^{a}

At 30 DAS, there were significant differences between all treatments but there were no significant differences between 180 kg/ha (10.67^{a}) and 80 kg/ha (9.33^{ab}); and there were no significant differences between 80 kg/ha ($9/33^{ab}$) and 60 kg/ha (7.67^{bc}); there were also no significant differences between 60 kg/ha (7.67^{bc}) and 40 kg/ha (6.00^{c}).

At 45 DAS, the stem borer density reached its peak, causing very heavy damage in rice; there were significant differences in insect pest density between all seeding rates but there were no significant differences between 180 kg/ha and 80 kg/ha, 80 kg/ha and 60 kg/ha, and 60 kg/ha and 40 kg/ha.

At 60 DAS, the stem borer density decreased compare with at 45 DAS; there were significant differences in density between all treatments but there were not significant differences between 180 kg/ha, 80 kg/ha, and 60 kg/ha; and there were no significant differences in density between 80 kg/ha, 60 kg/ha, and 40 kg/ha (4.67^{ab}, 4.83^{ab}, and 4.17^{b}, respectively).

At 75 DAS, the insect pest density decreased very quickly; there was a significantly lower stem borer density in 20 kg/ha seeding rate (1.17^{b}); but there were no significant differences in density between 180 kg/ha, 80 kg/ha, 60 kg/ha, and 40 kg/ha (3.67^{a}, 4.00^{a}, 3.50^{a}, and 3.17^{a}).

In conclusion, the different seeding rates were variably affected by rice stem borer (*Tryporiza* *incertulas*) damage. The highest seeding rate had the heaviest damage from rice stem borer and the lowest seeding rate application the lowest damage from rice stem borer. The application of 20 kg/ha had the lowest stem borer density for all developmental stages of rice. Therefore 20 kg/ha seeding rate could be applied for integrated pest management (IPM) for rice against insect pest.

Lodging rate

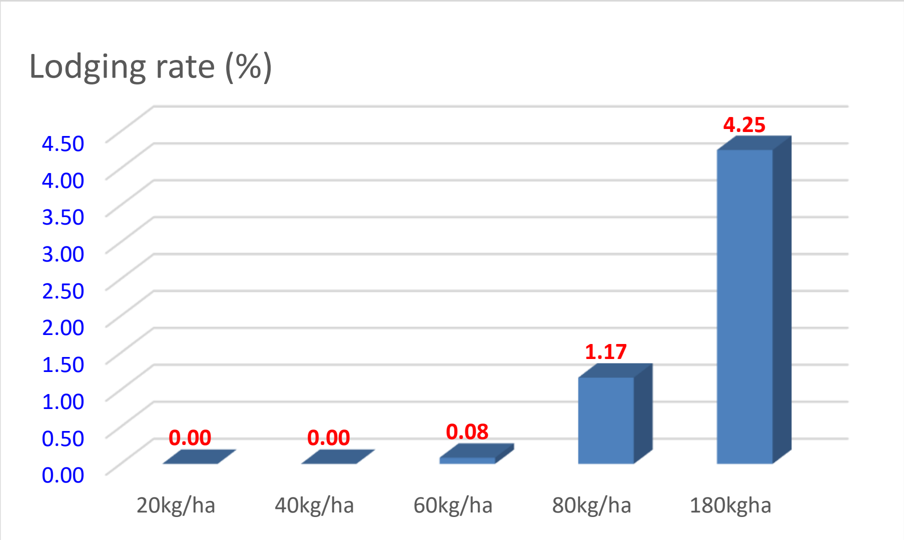


Figure 60. Lodging rate from different seeding rates during dry season at Kork Tonlaop, Mungkul Borei, Banteay Meanchey

During dry season, Sen Kraob is still the dominant rice variety in the North West Cambodia. Dry season rice was cultivated only at the area which is close to the available irrigation system; therefore dry season area in BMC is not very big area and most of dry season rice are Sen Kraob variety. Only few areas are using 504 variety (3%). From the previous experiment at KTL during early wet season and main wet season, lodging is one of the main issues reducing rice yield. Lodging was recorded two times at 100 DAS and 107 DAS during the dry season. The result of lodging rates showed that 20 kg/ha, 40 kg/ha, and 60 kg/ha had the lowest lodging rates (0.00%, 0.0%, and 0.08%; respectively). The highest seeding rate (180 kg/ha) had the highest lodging with 4.25%, followed by the second highest lodging rate at 80 kg/ha seeding rate with 1.17%. Compared with main wet season and early wet season, lodging issue during dry season is not a major problem.

Agronomic characteristics of rice from two factor experiment during dry season

Based on ANOVA two factor analysis and Duncan multiple range test (DMRT) for number of panicle per quadrant, number of grain per panicle, 1000 grain weight, fresh yield and dried yield, Table 51 indicates that the number of panicle per quadrant is significantly different between different seeding rates; 20 kg/ha of seeding rate had the lowest panicle number per quadrant (52.50^{e}) and 180 kg/ha seeding rate had the highest panicle per quadrant (118.58^{a}); there were no significant differences in number of panicles per quadrant between 180 kg/ha and 80kg/ha of seeding rates (118.58 and 113.08).

Table 51. Agronomic characteristics of rice from two factor experiment during main wet season

Seeding rate	Panicle/quadrant	No. grain/ panicle	1000 grain weight (g)	Fresh yield (kg/plot)	Dry yield (kg/plot)
180 kg/ha	118.58^{a*}	80.72^{c}	26.69^{c}	42.33^{d}	37.67^{c}
80 kg/ha	113.08^{b*}	84.67^{c}	26.82^{b}	46.67^{cd}	41.00^{c}
60 kg/ha	102.25^{c}	89.72^{c}	26.82^{b}	50.33^{bc}	45.67^{b}
40 kg/ha	86.17^{d}	112.978^{b}	26.90^{b}	53.83^{ab}	48.67^{ab}
20 ha/ha	52.50^{e}	126.94^{a}	27.10^{a}	57.00^{a}	51.33^{a}

In contrast with number of panicles per quadrant, the highest number of grain per panicle appeared in the lowest seeding rates 20 kg/ha (126.94 grain/panicle) and the lowest grain per panicle is 180 kg/ha seeding with 80.72 grain/panicle. There were no significant differences in number of grain per panicle between 180 kg/ha, 80 kg/ha, and 60 kg/ha (80.72, 84.67, and 89.72; respectively). The 180 kg/ha seeding rate had the lowest grain per panicle (80.72^{c}/panicle) and the 20 kg/ha seeding rate had the highest grain per panicle (126.94^{a}). The 1000 grain weight is significant differences between seeding rates; 20 kg seeding rate had the heaviest grain (27.10^{a}) and 180 kg seeding rate had the lightest grain (26.69^{c}). The seeding rates of 40 kg, 60 kg, and 80 kg are not significantly different in 1000 grain weight (26.90^{b}, 26.82^{b}, and 26.82^{b}; respectively). There were significant differences in fresh yield between seeding rates; the 20 kg seeding rate had the highest yield (57.00^{a} kg per plot) and 180 kg seeding rate had the lowest yield (43.33^{c} kg per plot); there were no significant differences in yield between 20 kg/ha and 40 kg/ha (57.00^{a} and 53.83^{ab}). The yield response was relatively flat over the seeding rates 20 to 60 kg/ha.

Economic analysis

Table 52. Economic analysis for paddy rice production sold at fresh yield

Seeding rates (kg/ha)	Fresh yield (t/ha)	Input cost ($/ha)	Labor cost ($/ha)	Income ($/ha)	Profit (Gross Margin) ($/ha)
20	5.7	347	280	1,254	627
40	5.38	350	280	1,184	554
60	5.03	367	280	1,107	460
80	4.67	373	280	1,027	374
180	4.23	472	275	931	184

There are more than 95% of farmers in the Northwest selling their rice at farm gate as fresh paddy rice; Mrs Leang Nhor and other farmers at Ou Ambel village, Ou Ambel commune, Sisophon city usually sell their fresh paddy rice at the farm gate. Our experiment was harvested on 28th March 2019, after recorded all data of fresh yield. At the same time, Mrs Leang Nhor just sold her paddy rice straight way with the price of 7.00 Baht/kg (1 USD equal to 31.98 Thai Baht); equivalent to 220 USD/ton. When all costs were calculated including input costs and labor cost against total incomes based on the above price, the highest profit (gross margin) is 20 kg/ha of seeding rate (627 USD/ha), the second highest profit is 40 kg/ha of seeding rate (554 USD/ha); and the lowest profit is 180 kg/ha of seeding rate (184 USD/ha).

Conclusion

1. During dry season between 12th December 2018 and 28th March 2019, disease (especially blast) and insect pests were key limitations to yield. Disease and insects were found with very high density; Insecticide application and fungicide application are more frequently used. Bird and rat caused more damage when compared to wet season.
2. Lodging rate was not an issue in Sen Kraob variety during dry season; the percentage lodging ranged from 0.00 to 4.25%; the highest lodging rate was in 180kg/ha seeding rate (4.25%) and the lowest lodging was 20 kg/ha and 40 kg/ha of seeding rate.
3. At Ou Ambel village during dry season, non-weeding and weeding method was non-significant in determining yield; therefore, weed management at Ou Ambel, Sisophon city was not a major issue.
4. There was a significant difference in fresh yield between different seeding rates; with wet seeding for dry season, 20 kg/ha was the optimum rate for wet seeding-dry season (using Mechanized drum seeder) for Sen Kraob in wet seeding-dry season at Ou Ambel village, Ou Ambel commne, Banteay Meanchey province. The 20 kg/ha of seeding rate provided the highest profit (627$/ha), followed by the 40 kg/ha seeding rate (554$/ha); and the lowest profit was the 180kg/ha seeding rate (184$/ha).

Activity 2.2, Output 2.2.2. Completed the watermelon experiment in dry season on different techniques on 14th January 2019 at Botrong village, Botrong commune, Ochrouv district

According to our monitoring from germination to harvest, the important diseases found in our watermelon field were as follows. Damping-off (*Rhizoctonia* sp.) occurred at early stage at seven days after transplanting, then downy mildew (*Pseudoperonospora cubensis*) occurred at all developmental stage of watermelon but this disease caused less damage in watermelon. Therefore, only damping-off disease severity was recorded at seven days after transplanting.

Disease severity (%)

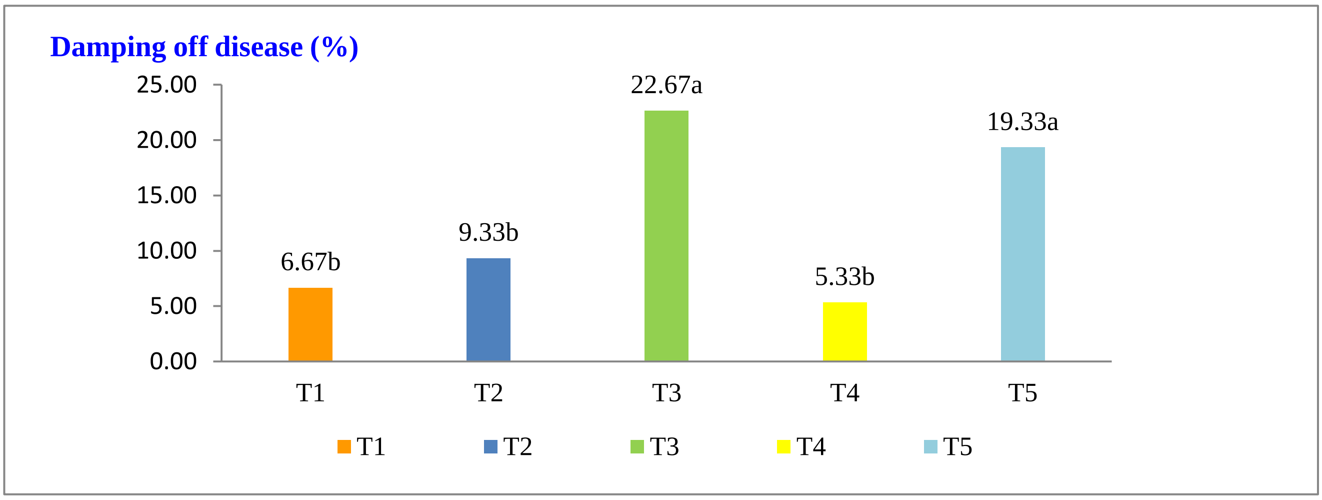


Figure 61. Disease severity sampling at seven days after planting

Damping-off disease attacked mostly the young plants and seedlings are most susceptible to damping-off prior to emergence or within the first week after emergence (Ruiter, 2015, p. 30). In our experiment we collected data only at one time at 7 days after planting (DAP) in all treatments (T1: direct seeding into hole (no till; T2: ploughing and direct planting; T3: ploughing, raised seedbed - bare soil; T4: ploughing, raised seedbed - straw mulch and T5: ploughing, raised seedbed – plastic mulching (black and silver).

Figure 62. Disease sampling activity at seedbed (damping off is easily spread as the seedlings were grown on the ground).

There were significant differences in disease severity between five growing techniques; T3 had the most severe damage from disease (22.67[a]%), then followed by T5 (19.33[a]%); and T4 was the least damage from disease (5.33[b]%). In pairwise comparison, there were no significant differences between T3 (22.67[a]) and T5 (19.33[a]). There were no significant differences between T1 (6.67[b]), T2 (9.33[b]) and T4 (5.33[b]). In conclusion, the techniques on ploughing the field together with raising seedbed and mulching by rice straw was the most effective method to control damping-off in watermelon in the dry season; followed by the direct seeding into the hole (farmer practice) which was the second effective method.

Insect pests

Watermelon has been a fruit crop grown in Cambodia for a long time and is attacked by many insect pests which can cause significant yield loss. In our experiment, ten species of insect pests were found in watermelon including red and yellow pumpkin beetles (*Raphidophalpa* sp. and *Aulacophora* sp.), fruit.

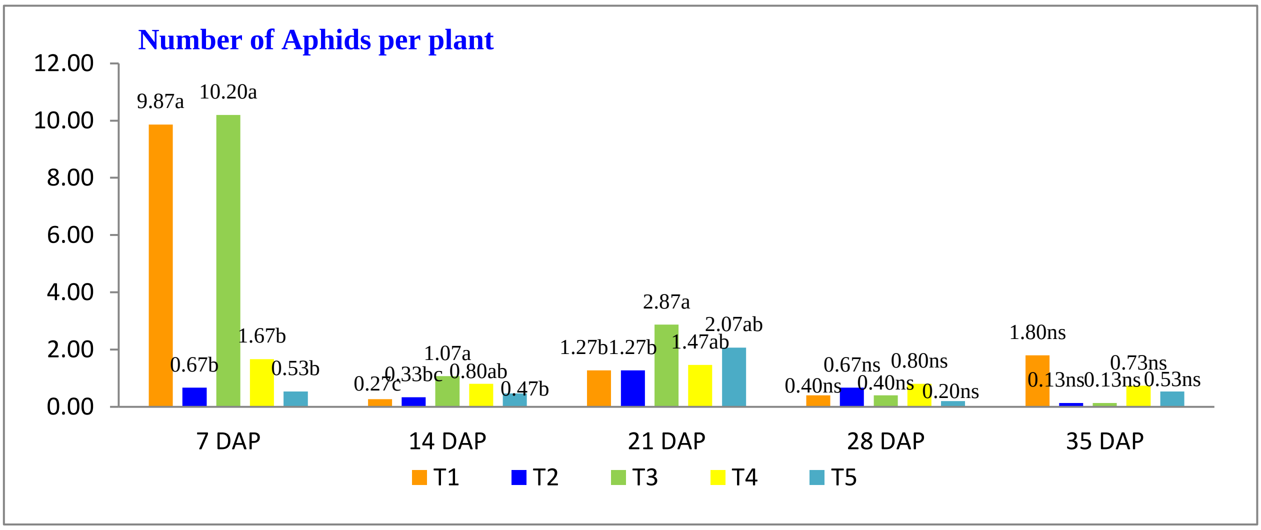


Figure 63. Population dynamics of *Aphis gossypii* from 7 DAP to 35 DAP

fly (*Bactrocera cucurbitae*), thrips (*Thrips tabacci*), *Thrips* sp., whitefly (*Bemisia tabacci*), aphids (*Aphis gossypii*), leaf-eating caterpillar (*Diaphania* sp.), leaf miner (*Liriomyza trifolii*), red spider mite (*Tetranychus urticae*). Among these ten species found in watermelon, two insect species were the most important: *Aphis gossypii* and *Thrips tabacci*. The population dynamics of these two species were recorded weekly.

Figure 64. ***Thrips tabacci*** **damage symptoms** **Figure 65.** ***Aphis gossypii*** **damage symptoms**

Aphis gossypii Glover, commonly known as cotton aphids or melon aphid, was reported causing damage to watermelon and cucumber (Goff and Tissot, 1932). It can cause serious damage to watermelon early in growing season when plants are small (Johnson and Webb, 1992).

During our experiment, we observed that aphids appeared and were present from 7 days after planting until 35 days after planting in all treatments (T1: direct seeding into hole (no till); T2: ploughing and direct planting; T3: ploughing, raised seedbed - bare soil; T4: ploughing, raised seedbed - straw mulch and T5: ploughing, raised seedbed – plastic mulching (black and silver). In 7 DAP, number of aphids on T1 (9.87^{a} insects/plant) and T3 ($10,20^{a}$ insects/plant) are not significantly different, while T2 (0.67^{b} insects/plant), T4 (1.67^{b} insects/plant), T5 (0.53^{b} insects/plant) were not significantly different. T1&T3 had significantly more aphids than T2, T4, and T5. At 14 DAP, T3 (1.07^{a} insects/plant) & T4 (0.80^{ab} insects/plant) are not significantly different, T4 (0.80^{ab} insects/plant) were not significantly different to T5 (0.47^{b} insects/plant), T5 (0.47^{bc}) &T2 (0.33^{bc} insects/plant) were not significantly different, and T2 was not significantly different to T1 (0.27^{c} insects/plant). T3 (1.07^{a} insects/plant) had more aphids than T5 (0.53^{b} insects/plant) and T1 (0.27^{c} insects/plant). At 21, 28 and 35 DAP, there are no significant differences between treatments.

In conclusion, aphids invaded the watermelon field during seven days after planting with highest densities in treatment-1 (farmer practices-direct seed into hole) and treatment-3 plough, raised seedbed - bare soil; then the population decreased in all treatments due to insecticide application.

Apart from aphids sampling, *Thrips tabacci* population dynamics were recorded at the same time (see Figure 66); *Thrips tabacci* occurred from early stage to the end of harvesting stage.

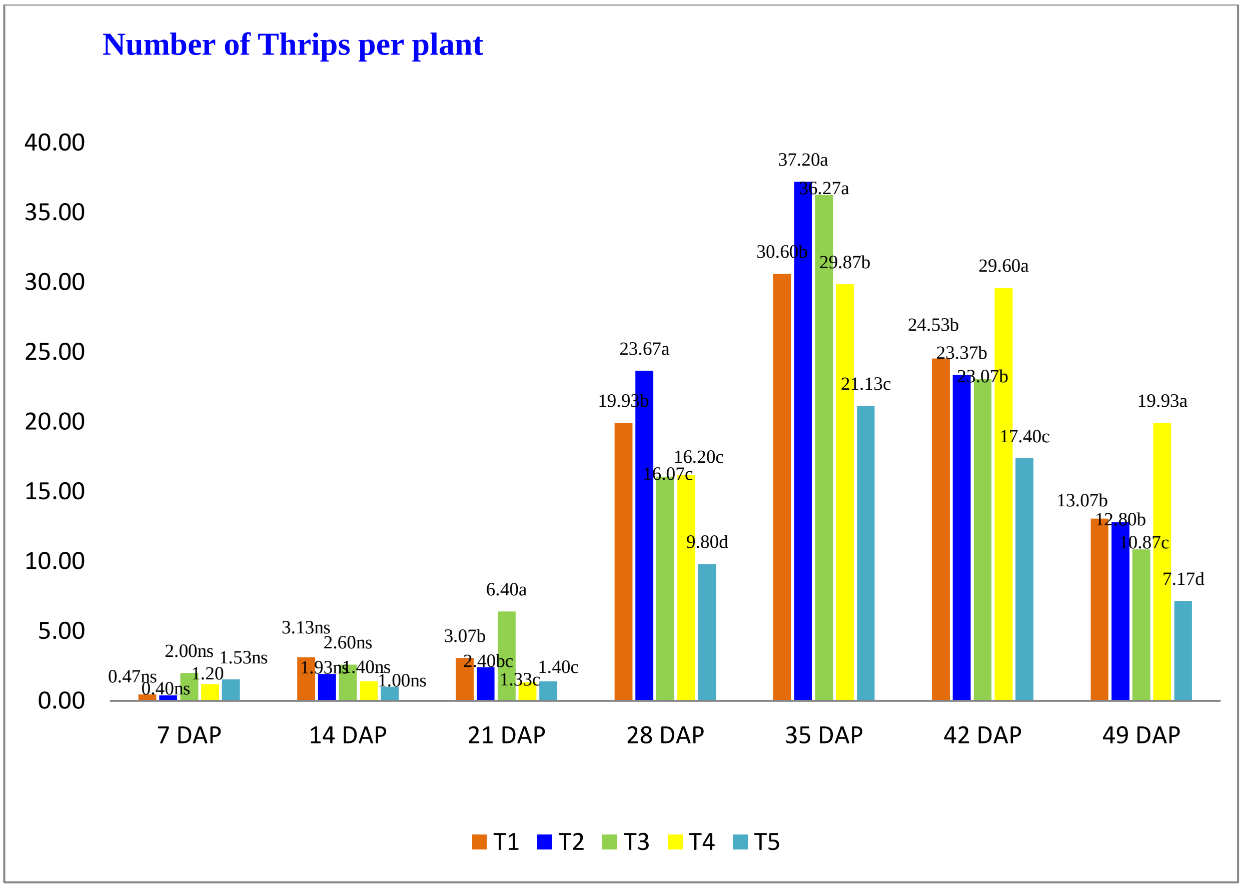


Figure 66. Population dynamics of *Thrips tabacci* from 7 DAP to 49 DAP

Figure 67. Sugar testing for ripe fruits

Thrips are able to multiply during any season that crops are cultivated but are favoured by warm weather. When crops mature, their suitability for thrips declines, so this thrips growth rate diminishes even in the presence of warm weather. In our experiment all treatment had a small increase in the number of thrips between 7 DAP and 14 DAP. Then thrip numbers increased very quickly from 21 DAP, 28 DAP and 35 DAP, and then it decreased when watermelon plants got old. Treatments T1, T2, T3, T4 and T5 were not significantly different between 7 DAP and 14 DAP. At 21 DAP, trip numbers were highest in T3 (6.40^{a} insect/plant) and the lowest in T2 (2.40^{bc} insect/plant), T5 (1.40^{c} insect/plant) and T4 (1.33^{c} insect/plant). At 28 DAP, the highest trip numbers were in T2 (23.67^{a} insect/plant) and the lowest in T5 (9.80^{d} insect/plant). At 35 DAP, the highest trip numbers were in T2 (37.20^{a} insect/plant), T3 (36.27^{a} insect/plant) and the lowest in T5 (21.13^{c} insect/plant). At 42 DAP, the highest trip numbers were in T4 (29.60^{a} insect/plant) and the lowest in T5 (17.40^{d} insect/plant). At 49 DAP, the highest trip numbers were in T4 (19.93^{a} insect/plant) and lowest in T5 (7.17^{d} insect/plant).

In conclusion, *Thrips tabacci* infected the field from an early stage and reached its peak at 35 days after planting, then thrip density decreased gradually until the end of harvest. To reduce thrip density, it is necessary to spray at 21 days after planting (based on trip monitoring) plus plastic mulching and make a seedbed for the field.

Table 53: Yield and yield components of watermelon for each treatment

Treatment	Number of fruits per plant (Average)			Total fruit per treatment	Fruit weight (Kg)
	21 DAP	28 DAP	35 DAP	55 DAP (Harvest time)	55 DAP (Harvest time)
T1 - Direct seeding into hole	0.20^{ns}	0.93^{ns}	1.60^{ns}	79.67^{ns}	1.72^{d}
T2 - Plough, flat planting	0.07^{ns}	1.13^{ns}	1.67^{ns}	82.00^{ns}	1.80^{cd}
T3 - Plough, raised seedbed - bare soil	0.00^{ns}	1.47^{ns}	1.53^{ns}	75.33^{ns}	2.02^{bc}
T4 - Plough, raised seedbed - straw mulch	0.00^{ns}	0.80^{ns}	1.67^{ns}	81.00^{ns}	2.21^{ab}
T5 - Plough, raised seedbed – plastic covering (black and silver)	0.13^{ns}	1.33^{ns}	1.87^{ns}	91.67^{ns}	2.29^{a}

Our experiment showed that the number of fruit per plant that we collected during 21, 28, 35, and 55 days after planting from all treatments were not significantly different. However, the fruit weight for each treatment was significantly different. There were no significant differences between treatment T5 (2.29 kg/fruit) and T4 (2.21 kg/fruit) and the heaviest weight/fruit was T-5 with 2.29 kg/kg; followed by T-4 with 2.21 kg/fruit; and the third heaviest fruit was T3 with 2.02 kg/fruit). There were no significant differences between T-1 and T-2.

With number of fruit and fruit weight, T-5 was the best (2.29 kg/fruit), then followed by T-4 (2.21 kg/fruit). T-1 and T-2 were not very effective in fruit weight (1.72 kg/fruit and 1.80 kg/fruit).

Table 54: Actual yield and economic effective analysis for each treatment

Treatment	Number of fruits (fruit/ha)	Fruit weight (kg/ha)	Production cost (USD/ha)	Income (USD/ha)	Profit (USD/ha)	Return on invest (ROI)
T1 - Direct seeding into hole	15,133^{ns}	26,029.33^{d*}	1,285.30	2080.83	795.53	0.62
T2 - Plough, flat planting	16,000^{ns}	28,853.33^{cd}	1,301.50	2400.00	1098.50	0.84
T3 - Plough, raised seedbed - bare soil	15,267^{ns}	30,838.67^{c}	1,395.30	2480.83	1085.53	0.78
T4 - Plough, raised seedbed - straw mulch	16,067^{ns}	35,507.33^{b}	1,645.30	2928.33	1283.03	0.78
T5 - Plough, raised seedbed – plastic covering (black and silver)	17467^{ns}	41,312.44^{a}	1,742.20	3056.67	1314.47	0.75

There were no significant differences in number of fruits between all treatments but there were significant differences in total fruit weight/ha between all treatments; T-5 had the highest yield with 41312.44 kg/ha, followed by T-2 with 35507.33 kg/ha; and the lowest yield was T-1 with 26029.33 kg/ha. Production cost was highest in T-5 with 1742.20 usd/ha, followed by T-4 with 1645.30 usd/ha; T-1 (1285.30 usd/ha) and T-2 (1301.50 usd/ha) which had very low cost compared with T-5 and T-4.

The fruits were harvested at the same time on 10th March 2019 for all treatment; the price was based on visual counting and evaluation by the buyer at the farm gate. The price of treatment-1 was 550 riel/fruit (0.1375$/fruit), treatment-2 was 600 riel/fruit (0.15$/fruit), treatment-3 was 650 riel/fruit (0.1625$/fruit), treatment-4 and treatment-5 were 700 riel/fruit (0.175$/fruit). Based on the price provided by the buyer, the profits from T-1, T-2, T-3, T-4, and T-5 are 795.53$, 1098.50$, 1085.53$, 1283.03$, and 1314.47, respectively. Regarding to the return on investment, T-2 was most effective method for watermelon growing with 84% return on investment, follow by treatment-3 and treatment-4 with 78% of return on investment.

Conclusion

1. During the dry season experiment on watermelon from 14th January to 10th March 2019, damping-off (*Rhizoctonia* sp.) was the main disease which infected watermelon plants at early stage; direct seeding into a hole (zero till) and ploughing-raised seedbed with rice straw covering could significantly reduce disease infection.
2. Two main insect pest species found in watermelon are *Aphis gossypii* and *Thrips tabacci*; Aphids infected the field with high population at early stage (7 DAP) whereas thrips infected the field at a later stage (28 DAP until harvest) in the field. Direct seeding into a hole (T2) and ploughing the field and raised seedbed together with plastic covering (T5) could significantly reduce aphid population. Ploughing the field plus raised seedbed with plastic covering appeared to be the most effective method to control *Thrips tabacci* in watermelon
3. There were no significant differences in number of fruits per hectare between all treatments but there were significant differences in fruit weight per hectare between different planting techniques. Treatment-5 had the highest yield with 41,312 kg/ha, treatment-4 had the second highest yield with 35,507 kg/ha, treatment-3 was the third highest yield with 30,839 kg/ha, followed by treatment-2 with 28,853 kg/ha, and the

lowest yield was treatment-1 with 26,029 kg/ha.

4. With economic analysis (return on investment), treatment-2 (ploughing with flat planting) was the most effective investment with return investment of 84% (spend 1$ get back 0.84$ of profit); treatment-3 (ploughing with raised seedbed and bare soil) and treatment-4 (ploughing with raised seedbed and straw mulching were the second effective investment with 78% of investment. Treatment-5 was not the most effective investment compared with other treatments.

Activity 2.4, Output 2.4.2. Experiment on seeding rates and fertilizer level on 1st May 2019 at Kuok Tonloap (KTL), Mung Kulborei district (dry seeded rice)

The experiment aims to determine the optimal seeding rates, fertiliser levels and the optimal interaction between seeding rates and fertiliser rates on yield, yield components, agronomic characteristics and economics.

The experiment was conducted on 1st May 2019 at KTL, where the previous experiments on seeding rates took place, with dry seeding method using Thai Kid seeder. Sen Kraop variety was selected for the experiment. Data collection will be made on plant establishment, disease infection, major insect pest, number of panicle per plot, number of grain per panicle (counting 10 panicle per plot), 100 hundred grain weight, fresh yield per plot, and dry yield per plot. Lodging rate will be recorded one week before harvested. More importantly, the economic analysis will be analyzed based on recently price of rice and the calculation of all expenses (input cost and labor cost). Plant establishment will be done based on crop development and real situation; if the rain comes after sowing, plant establishment will be done two weeks after sowing; if not the sampling date will be delayed. The record on disease infection was based IRRI method and will sampled at one week interval from early tillering stage until one week before harvesting.

Since the experiment was set up, there was little rain and the field lacked water for rice development; heavy rain came during the second week of June; it was nearly two months from planting now but plant is just at early tillering stage. With visual observation, the highest seeding rate plot appeared to be at a lower density compared to others sown by the Thai Kid Seeder. The big difference between Thai Kid Seeder and farmer practice were, in the Thai Kid Seeder plots, rice seed could stay in the soil for a while (for our experiment there was no rain for one month and a half). Even there is no rain rice seed still remain there and could germinate later whereas in the farmer plot with sown by hand, rice seed just stay somewhat in the surface; exposed directly to sunlight, and heat; if there was no rain after sowing, the rice seed will die very soon; more importantly, rice seed could be eaten by birds, rats, and other pests. Then the first fertilizer application was done on 11th June 2019. Therefore plant establishment data collection cannot be done as scheduled (normally two weeks after planting). Plant establishment data collection was done on 25th and 26th June 2019. Below is a data analysis on plant establishment by ANOVA two factors with three replications design.

The plant establishment is not significant difference between fertilizer application levels low, medium, and high (173.73^{a} plant/m^2, 194.6^{a} plant/m^2, and 170.37^{a} plant/m^2), respectively. The plant establishment in the medium plot appeared to highest density and there were similar density between low fertilizer application plot and high fertilizer application plot.

The plant establishment were significantly different between seeding rates (20 kg/ha, 40 kg/ha, 60 kg/ha, 80 kg/ha, and 180 kg/ha). In visual observation, the highest density appeared to be in 80 kg/ha of seeding rate with 227.78^{a} plant/m^2, followed by 60 kg seeding rate/ha with 204.22^{ab} plants/m^2, next is 180 kg/ha seeding rate and 40 kg/ha seeding rate with 195.78^{b} plants/m^2 and 181.78^{b} plants/m^2. Plant establishment in the 20 kg/ha seeding rate had the lowest density with 88.28b plant/m^2. With pair comparison, there were no significant differences between 60 kg/ha and 80kg/ha seeding rate, and there were significant differences between 180 kg/ha, 60 kg/ha and 40 kg/ha seeding rates. In conclusion, 60 kg/ha of seeding rate was the best plant density and 20 kg/ha seeding rate had the lowest density.

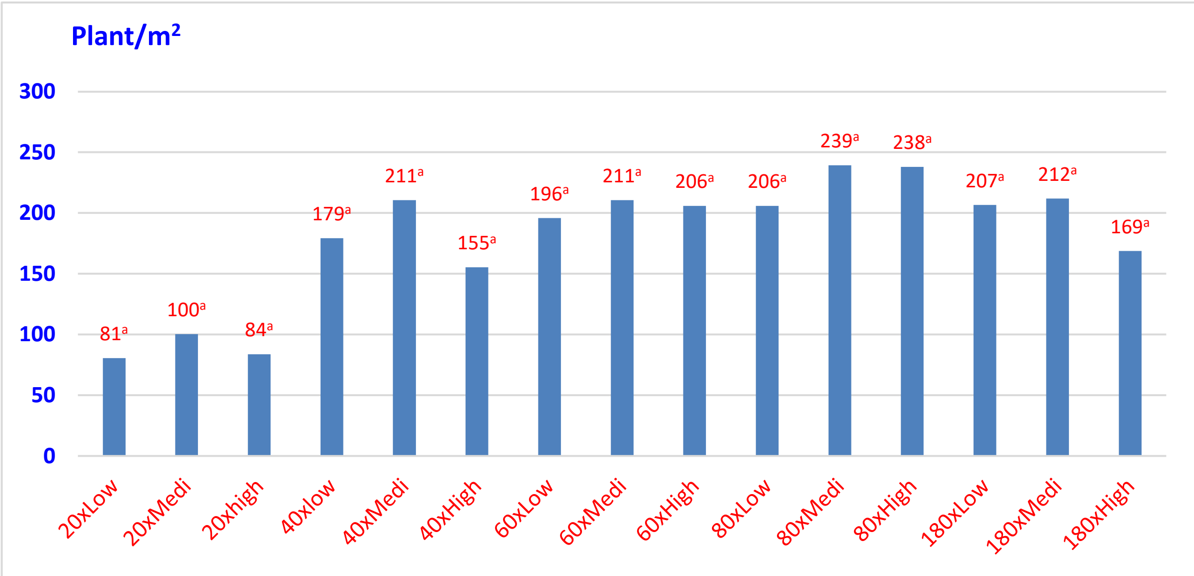
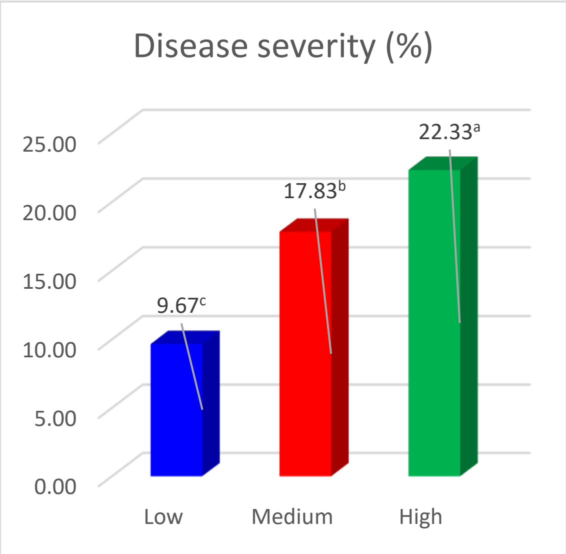


Figure 68. Plant density for the interaction between seeding rate plot and fertilizer plot

The interaction between fertilizer levels and different seeding rates was not significant in plant density sampling after 55 days planting. Although the plant density ranges from 81 plant/m^2 in the treatment 20 kg x low fertilizer application to 239 plant/m^2 in the treatment 80 kg/ha of seeding rate x medium fertilizer application. It is still early to conclude that which seeding rate by fertiliser rate combination will be the optimal treatment.

Disease (rice blast) infection

Rice blast (*Pyricularia oryzae*) was the main disease of rice with Senkraob variety during early wet season at KTL. The presence of rice blast was closely related to the timing and amount of fertilizer applied. For Senkraob variety, if fertilizer application was applied from the early stage, blast will occur very quickly. Through visual observation, blast infection occurred during 20 days after the first fertilizer application on 11st June 2019. Therefore, the first data collection on disease severity was done on 2nd July 2019. Base on IRRI method, each plot was sampled for 15 leaves and graded into 10 categories. There were significant differences in disease severity (rice blast) between different fertilizer application levels at five level. The highest fertilizer application level (N-100, P-80, K-50) had the highest infection at 22.33a%; the lowest fertilizer application (N-75, P-60, K-40) had the lowest infection at 9.67^{c}%. In general, disease infection in Sen Kraob variety increased by with increasing fertilizer application levels; therefore, applying more fertiliser may not always achieve higher rice yields. To achieve high yields. farmers need to understand the whole system integrating other factors including seeding rates, insect pests, weed control, water management, land preparation, varieties selection, planting method. Seeding rates significantly affected disease severity. The highest seeding rates resulted in the heaviest infection from blast. At 20 kg/ha seeding rate, the infection was lowest at 9.72^{d} % and 80 kg/ha seeding rate had highest infection from blast at 26.11^{a}%. Hence, this may explain why farmers get low yields due to high seedings by farmers in the past.



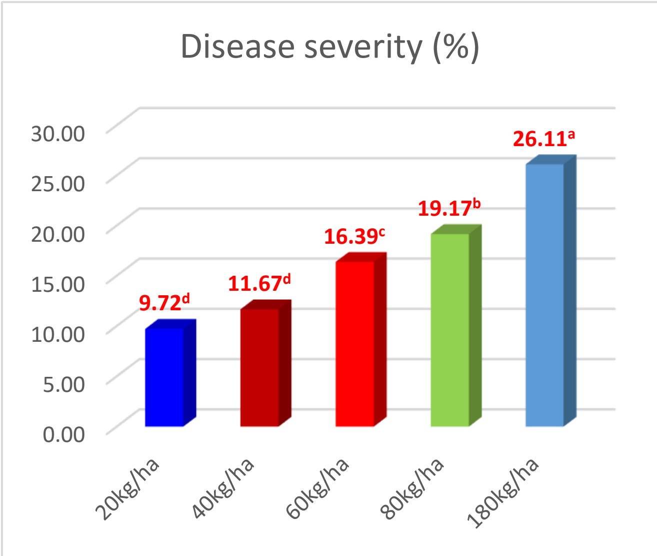


Figure 69. Disease severity by fertilizer level **Figure 70. Disease severity by seeding rates**

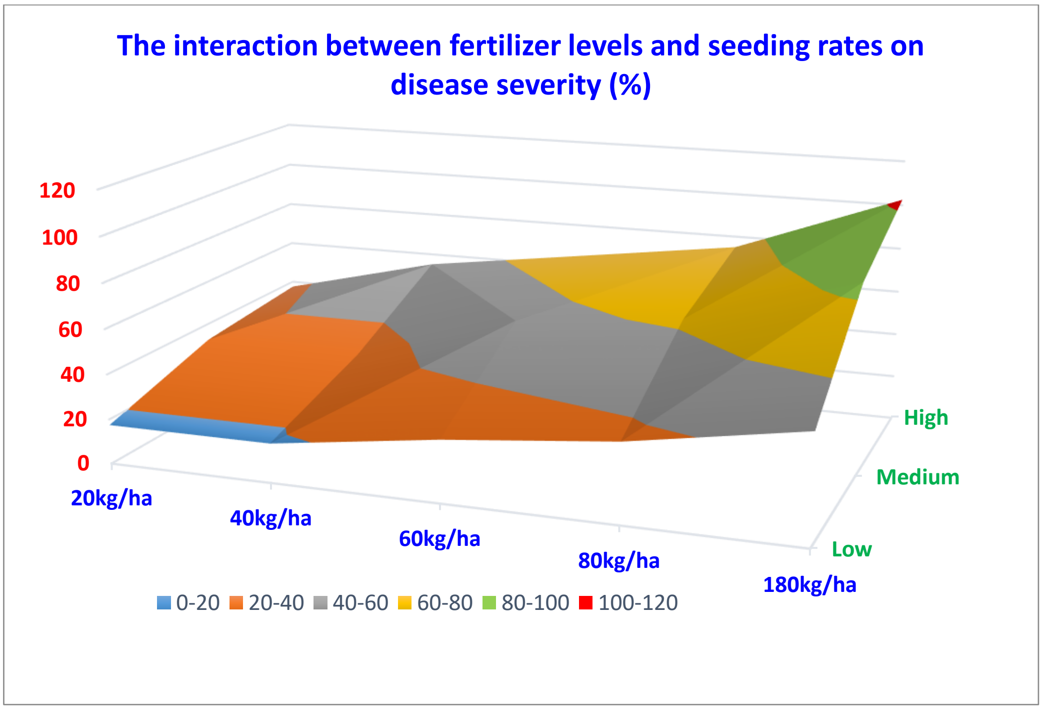


Figure 71. Disease severity by the interaction between seeding rates and fertilizer

The interaction between fertilizer levels and seeding rates were significant differences at 5 levels; blast infection increased from low seeding rates to high seeding rates which is parallel with low fertilizer levels to high fertilizer levels. The interaction of lowest seeding rates and lowest levels of fertilizer application (2 0kg/ha x N 75-P 60-K 40) had the lowest blast infection (5.83%). The interaction of the highest seeding rate (180 kg/ha) and the highest fertilizer application (N 100 –P 80-K 50) had the highest infection from blast (34.17%). Azoxystrobin and Defenoconazole were applied to all plots on 3rd July 2019 with the company recommendation (H.H.I Co Ltd,.) 0.35 L/ha.

Objective 3
Activity 3.1, Output 3.1.1. Scaling - First rice seeding demonstration on 29th May 2019 at Botrong village

a. **General information**

After we had interviewed farmers at Battrong village, Samroung commune, Ouchruv district, BMC, there were 40% of female farmers and 60% of male farmers who joined our demonstration and 38% were members of association and 65% were not members of association. They were between 21 to 30 years old - 6.1%; and 71 to 80 years old - 4.9%. Farmer's land size for rice production: 0.5 to 1.5 ha - 19.5%; 2 to 3.5 ha - 29.3%; 4 to 6 ha - 29.3% and 7 to 15 ha - 18.5% and more than 18 ha - 3.7%.

b. **Sowing method**

The first activity that we wanted to show the farmers was sowing methods by Thai Kid Seeder and Mechanized drum seeder, below were the responses from famers after they saw the operation of the two sowing equipment.

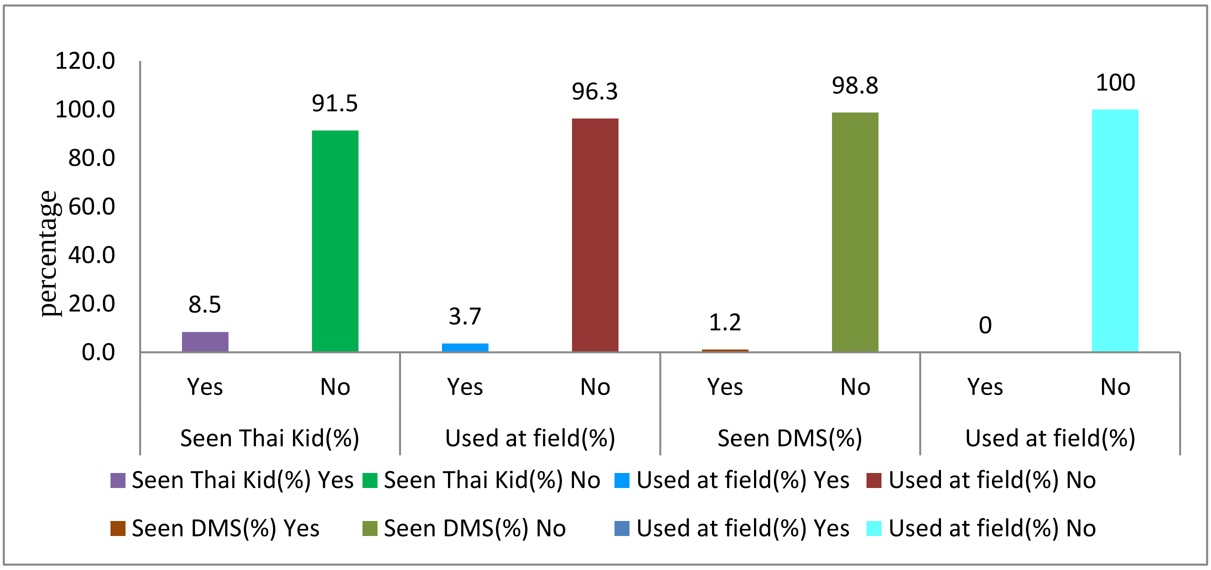


Figure 72. Percentage of farmer who have seen or used Thai Kid Seeder and Mechanize Drum Seeder

There were 8.5% of farmers who have seen Thai Kid seeder for dry seeding and 91.5% of them have never seen this machine for dry seeding; and there were only 3.7% of farmers who used to sow their field by this machine with dry seeding; there were 96.3% of farmers who had never sown their rice field by this machine.

There were 1.2% of farmers who have seen mechanized drum seeder for wet seeding and 98.8% who have never seen this machine. All of them never used this mechanized drum seeder for their dry seeding.

Agronomic techniques

Variety

Farmers in the area above used different kinds of varieties including Senkraob, Phka Roumdoul, Neang Khon, Phka pknhey, Reang chey, Malis, Somali, Neang minh.

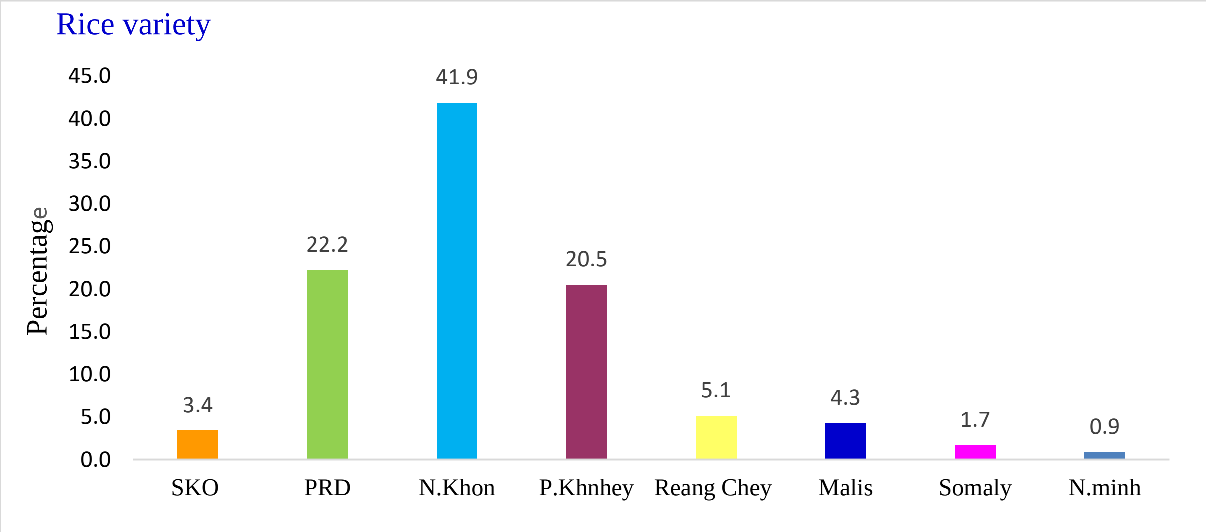


Figure 73. Percentage of farmer have been grown different rice variety in Botrong

There were 3.4% of farmers who used Senkraob Variety; 22.2% used Phka Romdoul Variety; 41.9% used Neang khon Variety; 20.5% used Phka khnhey Variety; 5.1% used Reang chey Variety; 4.3% used Malis Variety; 1.7% applied Somaly Variety and 0.9% applied Neng ming Variety. Neang Khon was the most majority with 41.9%, followed by Phka Roum Doul, and the third most popular variety was Phka Khnhey with 20.5%. Sen Kraob was not grown much in Botrong village.

- Seeding rate applied so far

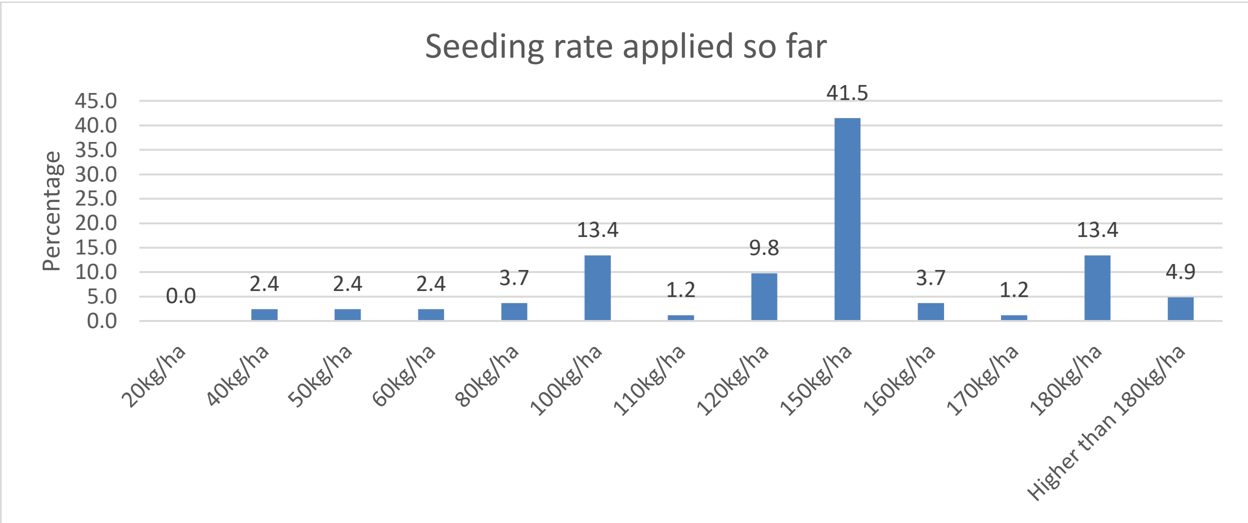


Figure 74. Percentage of farmer have been used different rice seeding rates in Botrong

The most farmers planted rice seed at 150 kg/ha (41.5%); 100 kg/ha and 180 kg/ha (13.4%); 120 kg/ha (9.8%), more than 180 kg/ha (4.9%); 80 kg/ha and 160 kg/ha (3.7%); 40 kg/ha, 50 kg/ha and 60 kg/ha (2.4%) ; 110 kg/ha (1.2%) and no farmers used 20 kg/ha. The farmers were aware that they used very high seeding rates so far; now they reduced the seed rate to lower than 180 kg/ha.

- **Seeding rate farmers prefer**

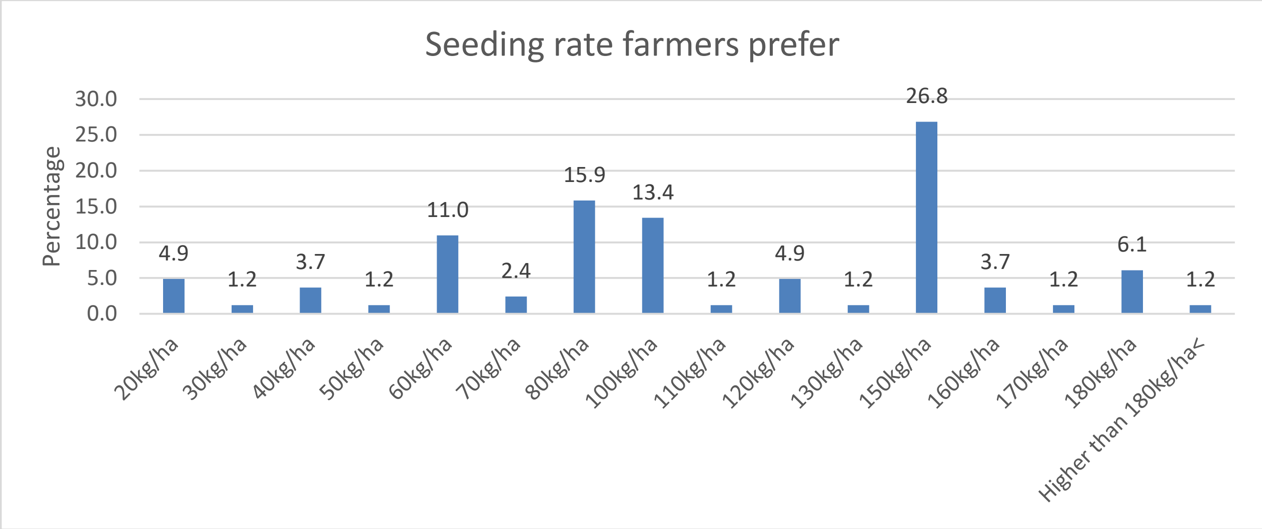


Figure 75. Percentage of farmers who preferred to use different rice seeding rates in Botrong

There are 26.8% of farmers preferred seeding rate of 150 kg/ha; 15.9% preferred seeding rate 80 kg/ha; and 4.9% preferred seeding rate 20 kg/ha.

Seeding rate farmers intend to use in their next dry seeded crop (rice)

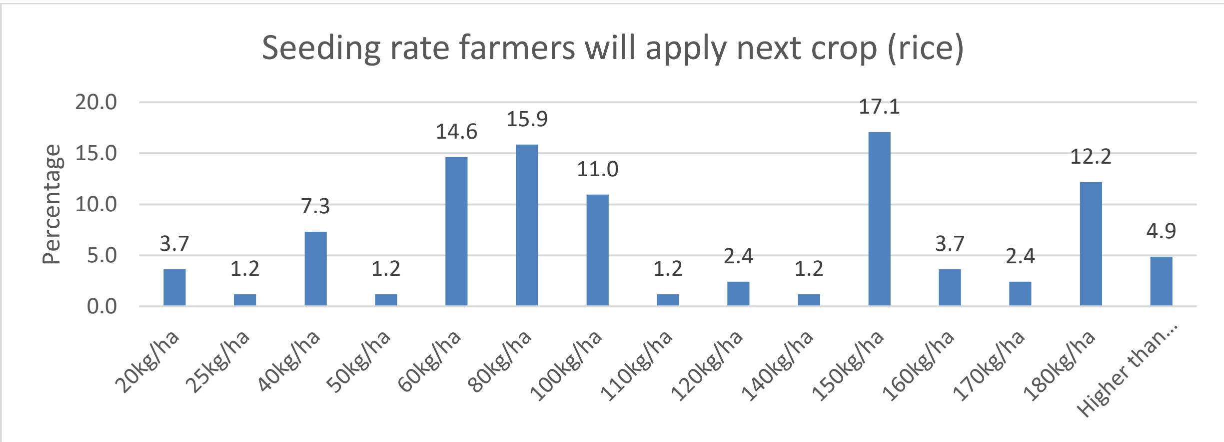


Figure 76. Percentage of farmer preferred will used different rice seeding rates for next crop in Botrong

17.1 % of farmers intend to apply next season 150 kg/ha; 15.9% will apply 80 kg/ha; 14.6% will apply 60 kg/ha;; 3.7% will apply 20 kg/ha; for the next season.

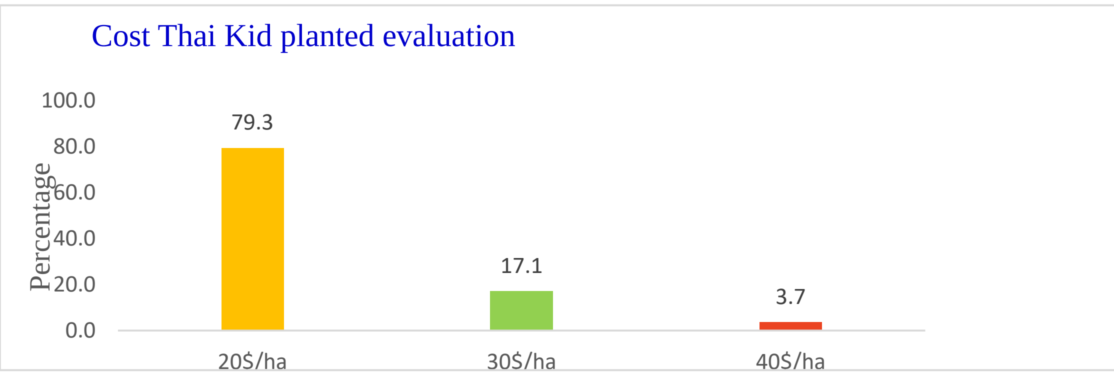


Figure 77. Percentage of farmers who are willing to pay the price for Thai Kid seeder service in Botrong

If Thai Kid Seeder was available to service, the most farmers (79.3%) were happy to rent for 20 US Dollar per hectare, 17.1% happy to rent for 30 US Dollar per hectare and only 3.7% happy to rent for 40 US Dollar per hectare.

Conclusions

The Thai Kid Seeder was introduced to Cambodia over the last three to four years for dry seeding method but it was not used very common in Banteay Meanchey; whereas mechanized drum seeder was not used previously for dry seeding.

In Botrong village, rice variety was very diversified with up to eight varieties used in this area but there were only three dominantly planted in this area; Neang Khon was the most common with 41.9%, followed by Phkar Romdoul with 22.2% and Phkar Khnhey with 20.0%; there was a very small number of Sen Kraob planted in Botrong village.

There was a new trend in reducing seeding rates by small holder farmers in Botrong; most of the farmers were aware of the disadvantages of high seeding rate application. From farmer interviews during the field day, the level of seeding rates applied by farmers ranged from 40 kg/ha to 200 kg/ha of seeding for dry seeding; there were 41.5% of farmers who applied 150 kg/ha; there were 13.4% of farmers who applied 100 kg/ha and 180 kg/ha.

Most of the farmers preferred to use 150 kg/ha whereas the other farmers would like to apply 60 kg/ha and 80 kg/ha. They intend to continue to reduce the seeding rates for the next rice crops. This survey confirmed that most farmers have adopted lower seeding rates compared with two years before CamSID started in Botrong village.

The Thai Kid Seeder could provide sowing service for dry seeding; there were 79.3% of farmers are happy to spend 20 usd/ha; there were 17.1% of farmers agreed to 30 usd/ha; and there were only 3.7% of farmers are willing pay for 40 usd/ha (this number will increase if they see more demo).

Activity 3.1, Output 3.1.2. Second demonstration on 21st June 2019 at Spean Sraeng village, Phnom Srok

General information

After we had interviewed farmers in 4 Villages (Kouk Char, Rouk, Spean and Kadal Village), Spean Sraeng commune, Phnum Srok district, BMC, there were 54.82% of female farmers and 45.18% of male farmers who joined our demonstration and 25.90% of them were members of association and 74.10% were not members of association. They were between 18 to 28 years old - 7.23%; 29 to 38 years old - 18.07%; 39 to 48 years old - 26.51%; 49 to 58 years old - 27.11%; 59 to 68 years old -16.27% and 69 to 78 years old - 4.82%. Farmer’s land size for rice production, 0.5 to 1.5 ha - 40.36%; 2 to 3.5 ha - 47.59%; 4 to 6 ha - 9.04% and 7 to 15 ha - 3.01%.

Sowing method

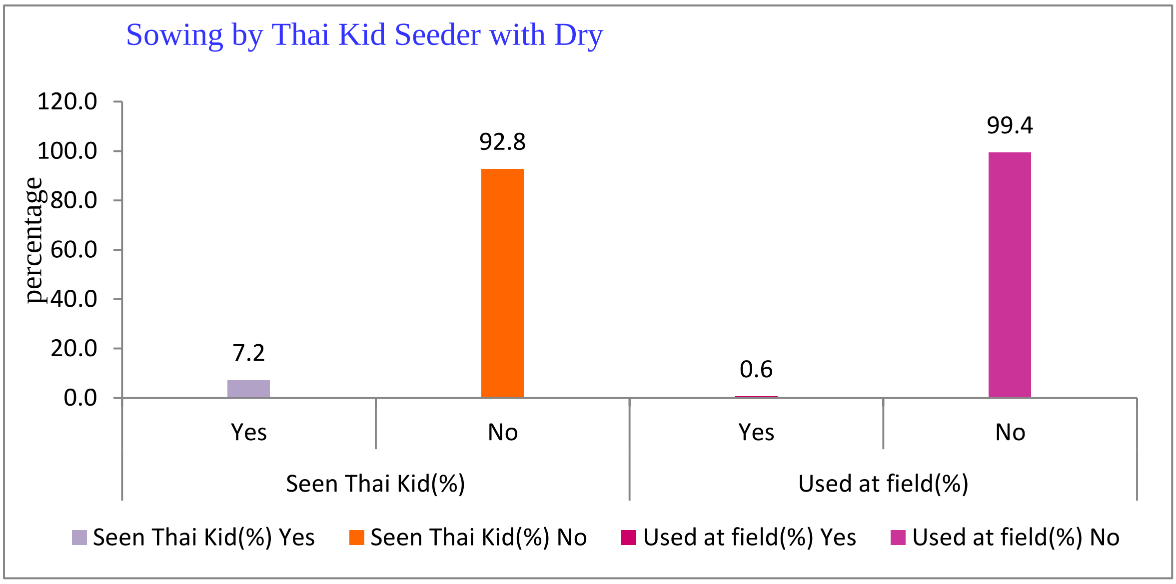


Figure 78. Percentage of farmer who have seen and used Thai Kid Seeder in Spean Sraeng

In this area there were only 7.2% of farmers who have seen Thai Kid seeder and the most of them have never seen this machine (92.8%). Only 0.6% of farmers have sown on their field by Thai Kid Seeder with dry seeding and 99.4% never.

Agronomic techniques

Variety used so far

Farmer in the area above use different rice varieties like Senkraob, Phka Roumdoul, Malis, Malis Krohorm, and local varieties like Leak Sleok, Leak Sleok Leang Teok, Neang Rose, Sai Bour, Somaly and Reang Chey.

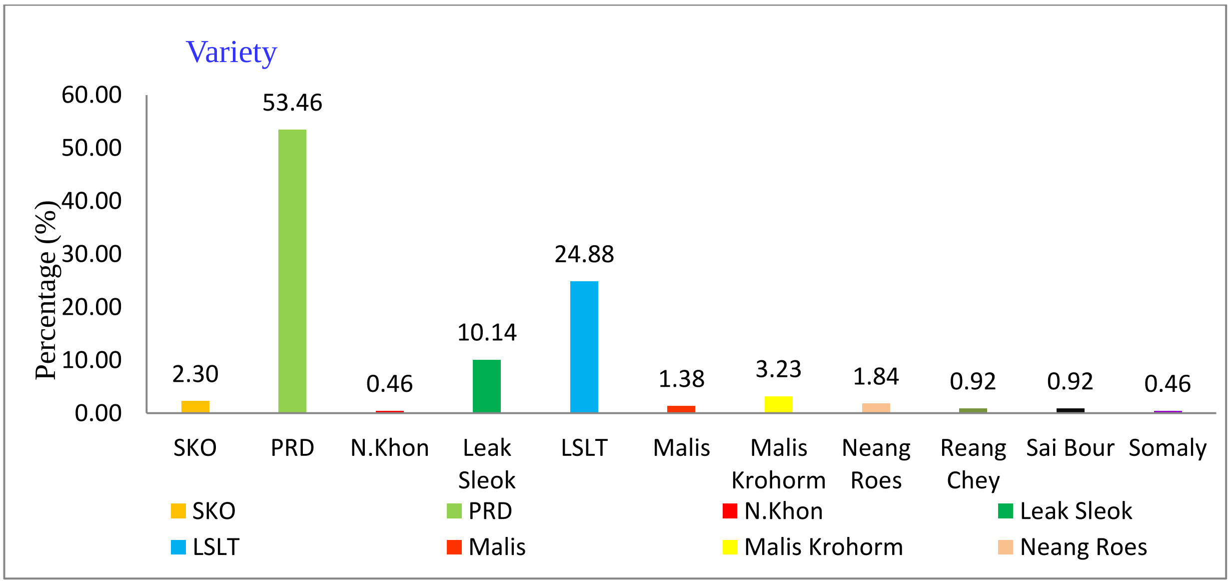


Figure 79. Percentage of farmer have been used different rice variety in Spean Sraeng

Variety Phka Romdoul is the most common in this area (53.46%); then local variety, Leak Soeok Leang Toek - 24.88%; local variety, Leak Sleok 10.14%, Malis Krohorm or Red Jasmine variety -

3.23%, Sen Kraob - 2.30%; local variety - Neang Roes 1.84%; Malis or Jasmine 1.38%; Reang Chey and Sai Bour are local variety - 0.92%; Neang Khon and Somaly - 0.46%.

- Seeding rates applied so far

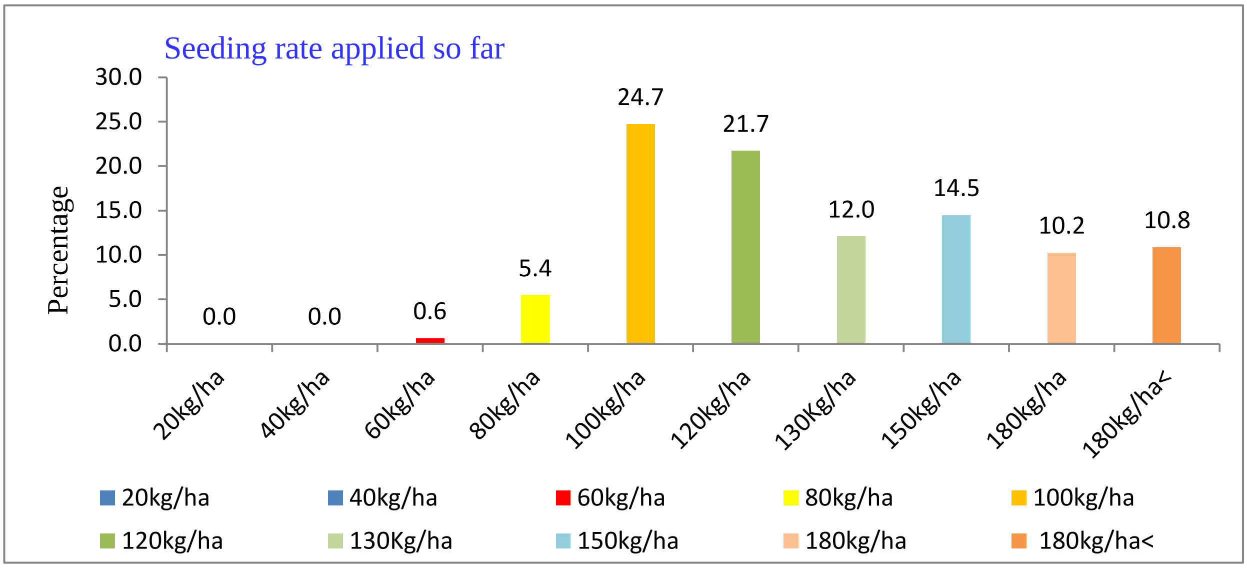


Figure 80. Percentage of farmer have been used different rates of seed in Spean Sraeng

Seeding rates that farmer applied so far on their field, are 100 kg/ha - 24.7%; 120 kg/ha - 21.7%; 150 kg/ha - 14.5%; 130 kg/ha - 12%; more than 108 kg/ha- 10.8%; 180 kg/ha - 10.2%, 80 kg/ha - 5.4% and 60 kg/ha - 0.6%.

- Seeding rate farmers preferred

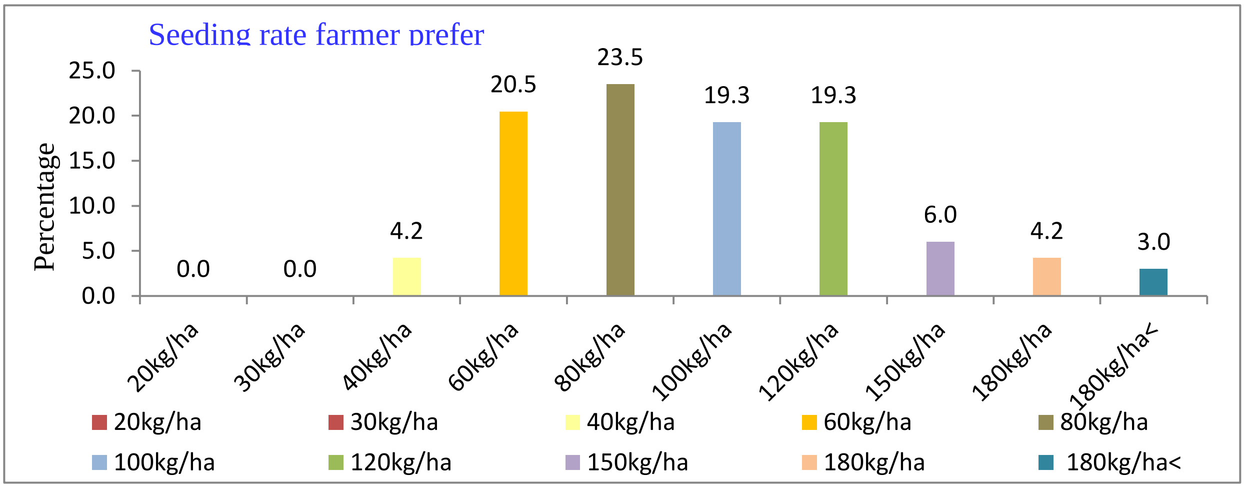


Figure 81. Percentage of farmer preferred to use - different rates of seed in Spean Sraeng

For seeding rate that farmers prefer, they are 80 kg/ha - 23.5%; 60 kg/ha - 20.5%; 100 kg/ha and 120 kg/ha - 19.3%; 150 kg/ha - 6%; 40 kg/ha and 180 kg/ha - 4.2%; and more than 180 kg/ha - 3%

- Seeding rate farmers intend to use for the next dry seeded crop (rice)

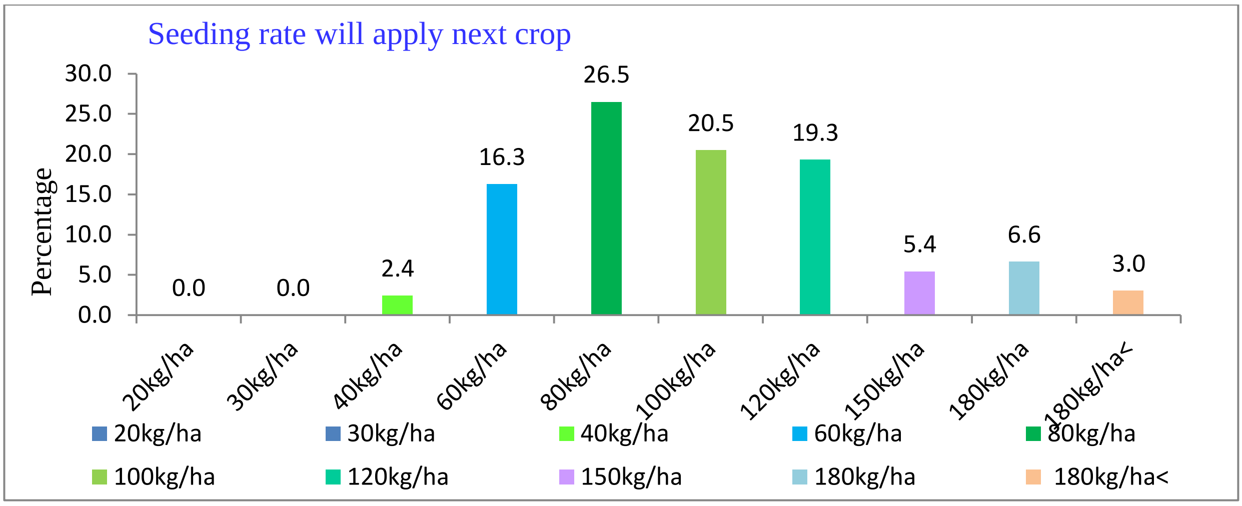


Figure 82. Percentage of farmer who intend to use the following seed rates for next crop in Spean Sraeng

In the next season (dry seeded rice) farmer will apply seeding rate on their field with 80 kg/ha - 26.5%; 100 kg/ha - 20.5%; 120 kg/ha - 19.3%; 60 kg/ha - 16.3%, 180 kg/ha - 6.6%; 150 kg/ha - 5.4%; more than 180 kg/ha - 3% and 40 kg/ha - 2.4%.

- Cost of Thai Kid Seeder

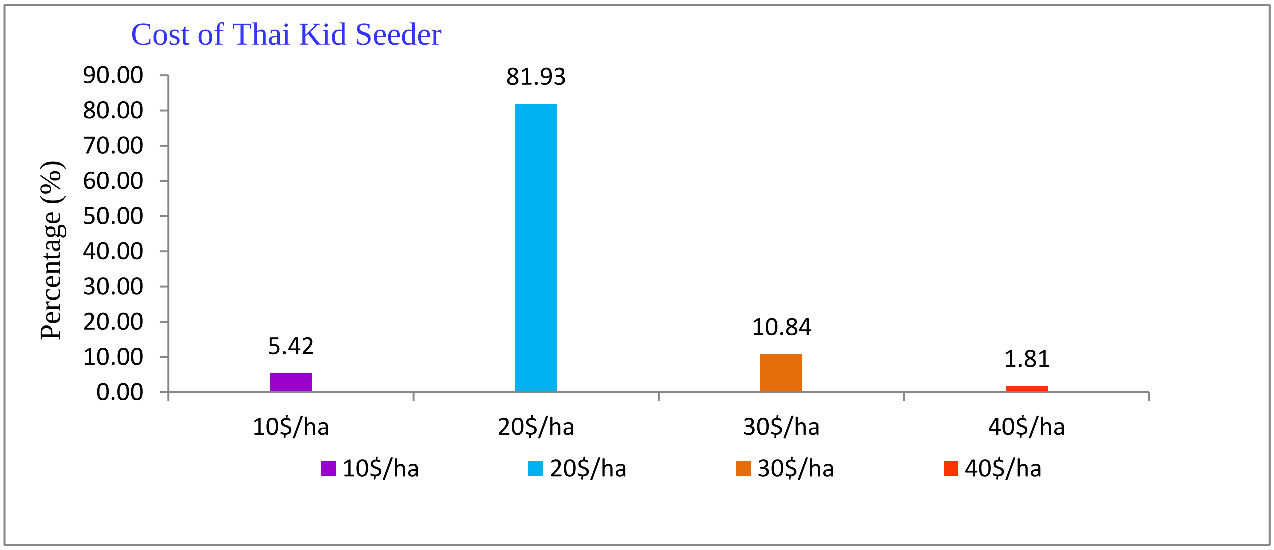


Figure 83. Percentage of farmer will provide the price for Thai Kid seeder service in Spean Sraeng

There are a lot of farmers were interested in Thai Kid Seeder and if this machine available to service, most farmers (81.93%%) were happy to rent for 20 USD per hectare followed by 10.84% happy to rent for 30 USD per hectare, 5.42% happy to rent for 10 USD per hectare and the last 3.7% happy to rent for 40 USD per hectare.

Conclusions

There was up to 92.8% of farmers who have never seen the Thai Kid Seeder used for dry seeding method in Spean Sraeng. 99.4% of farmers never used this machine for sowing their field.

In Spean Sraeng, the rice variety is more diversed than in Botrong village; there were up to eleven varieties used this area. Phkar Romdoul was planted dominantly in this area with 53.46%; followed by Leak Sleok Lerng Teok (LSLT) with 24.88%; Leak Sleok was number three with 10.14%. The other 8 varieties were not very common planting in this area with less than 4%.

There were no farmers in Spean Sraeng who used seeding rates lower than 60 kg/ha for dry seeding; the majority of farmers applied between 100 kg/ha and 120 kg/ha. Around 12% of farmers applied between 130 kg/ha and 180 kg/ha; there was 10% of farmer still used more than 180 kg/ha. For the next dry seeded rice crop, most of the farmers preferred to use between 60 kg/ha 120 kg/ha, and there will be lower than 7% of farmers who still intend to continue to use higher than 150 kg/ha.

The Thai Kid Seeder could provide sowing service for dry seeding; there were 81.93% of farmers who were happy to spend 20 usd/ha 10.84% of farmers agreed to pay 30usd/ha; and there were only 1.81% of farmers are willing pay for 40 usd/ha (this number will increase if they see more demo).

Activity 3.1, Output 3.1.2. Banteay Meanchey – Scaling of mechanized sowing across the province

Our project team has assisted a farmer at Thmorkol (Mr Sovien) to grow 60 ha of wet seeding.

Khim and the team has helped Mr Sovien use mechanized drum seeder, land preparation, pre-emergence herbicide application, based fertilizer application, and provide advice on blast and insect control method. They will communicate with each other after sowing rice.

Figure 84. Farmer Sovien is driving mechanized drum seeder and sowing rice for his friend

Activity 3.1, Output 3.1.2 Banteay Meanchey - Scaling - enhance partnership and support Ockenden Cambodia for rice seed production with drum seeder. Key implementation team: Dr Cuong, SFSA

Context

- Conventional method to produce rice seeds by seed producers like Ockenden at Banteay Meanchey relies on manual transplanting. It is a highly labour intensive & hard work consuming up to 30 man-day per ha for both transplant and root uptake. It triggers high production costs, hence low margin, which is a major concern for rice seed producers.

- Hand seed broadcast, another traditional method in rice cultivation could also be practiced in paddy rice production. But it is not developed in seed production due to practical constraints to manage the crop. There are no clear rows allowing farmers to walk inside the field to do rogueing and other agronomy works. On top of that, the seeding rate is very high, ranging from 150 – 250 kg/ha.


Solutions

- Recently, Syngenta Foundation for Sustainable Agriculture (SFSA) has supported Ockenden to produce quality rice seed with direct-seeded method to enhance partnership with professional & entrepreneurial seed producers
- SFSA initiated the use of drum seeder combined with new agronomic techniques including good land preparation, seed treatment with insect control and lower seed rate: 20 kg/ha sown in lines
- It required a modification on “hole-distances” for optimum spacing at 40 cm & 20 cm alternative rows to row with regular distance of 7 cm hill to hill. An integrated weed management is critical, using pre-emergence herbicide, keeping water standing in the field combined with hand weeding during each time of rogueing.
- The new technique of direct seeded by drum seeder replacing manual transplant in rice seed production saves as much as 27 man-day per ha in planting while yield increases by 5%.
- Ockenden was officially registered at PDAFF of Banteay Meanchey as a seed producer in July 2018 with excellent seed standards: 99% purity; 85% germination; 12 – 13 % moisture; wrapped in 50 kg bag.
- This new convenient method helped Ockenden expand its geographical production from Banteay Chmar district in the past to Monkei district with 2,600 kg of quality seed harvested and 3 ha under cultivation. From October 2018, Ockenden started to sell its quality seed to farmers with 1,800 kg in quantity and gained 85% in margin.


- In first week of October 2018, SFSA financed a visit to the seed production fields at Monkei district. After checking the production status in the field, a short training course to Ockenden field staff was conducted by SFSA at Ockenden office.
- In order to scale up the production, during August – September 2018, SFSA tested in Vietnam field and worked closely with Vietnamese manufacturer to modify & improve the mechanised drum seeder – version 1.0. SFSA will provide to Ockenden one mechanized drum seeder made in Vietnam – version 2.0 with a capacity of 8-10 ha per day for both sowing & spraying pre-herbicide at the same time. This will help Ockenden to increase sowing capacity up to 10 times compared to the manual drum seeder.
- The success of switching from transplanting to direct seeding via mechanization, encourages Ockenden to set up a new projection plan for quality seed production.

Item	2018		2019		2020		2021	
	Season Jan - May	Season Jun - Oct	Season Jan - May	Season Jun - Oct	Season Jan - May	Season Jun - Oct	Season Jan - May	Season Jun - Oct
Area (ha)	2	2	4	4	5	5	10	10
Yield (kg/ha)	1.500	3,000	4,000	4,000	4,000	4,000	4,500	4,500
Quantity (kg)	3,000	6,000	16,000	16,000	20,000	20,000	45,000	45,000

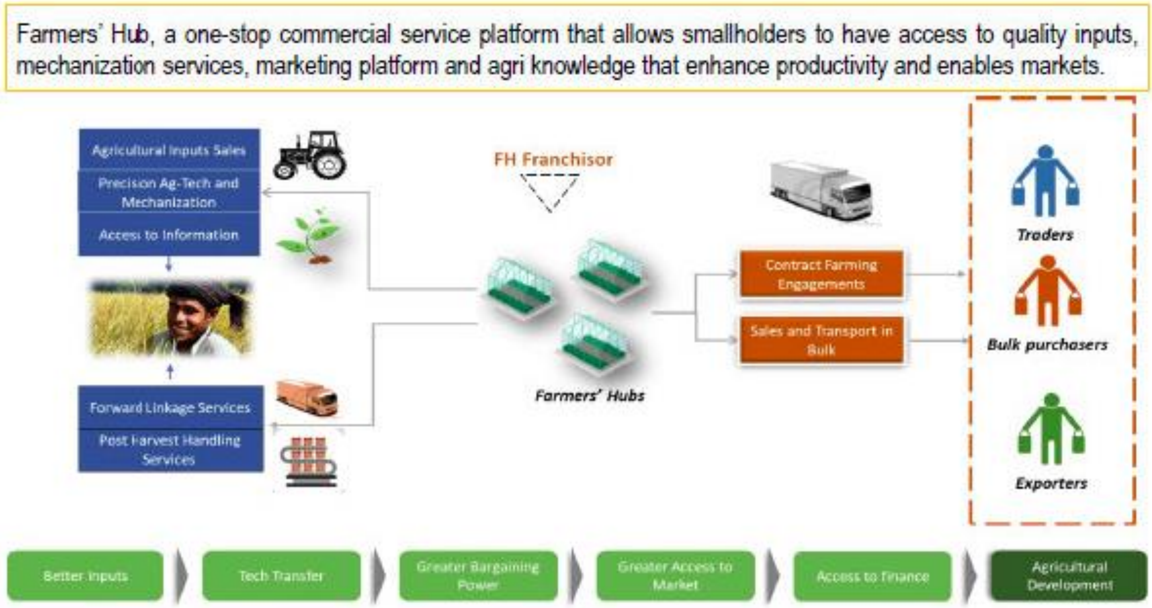
Ockenden has established a wide network of rice farmers in 34 agricultural cooperatives in Banteay Meanchey. This network could potentially become Farmer Hubs for seed production. In order to gain more knowledge on how to establish and manage Farmer Hubs, SFSA sponsored Director of Ockenden, Mr. Nhov Nharn to visit SFSA Farmer Hubs Bangladesh. It was a fruitful visit. It helped to gain more knowledge on Farmer Hub model. It gave an opportunity to Ockenden to enhance partnership with different stakeholders including SFSA, MCU, CamSID staff and private farmers.

Ockenden expects to harvest at least 10 to 15 tons of quality rice seed from the 4 ha (on schedule – see above table) in this coming September 2019 if rain continues to fall. In this cycle 1 (May-Sep 2019), Ockenden used the CARDI tool for dry seeding due to dry weather. The VN mechanized drum seeder is not suitable for dry seeding. The VN mechanized drum seeder will be used in cycle 2 starting from October 2019. Ockenden will be sourcing drying equipment and a separate seed storing warehouse to protect from insect pests. Ockenden have learnt that packaging with 25 kg bag is better than with 40 kg bags and it is better to use Syngenta and Ockenden logos on bags for marketing purposes. Ockenden is also exploring other varieties of rice, including Phka Romdul, Red Jasmine Rice and Black rice for quality seed production.

Figure 85. Ockenden rice seed production at Kok Balaing village, Mongkul Borei district dry seeded by CARDI drill seeder at 90 kg/ha on 6 May 2019 (Photo taken on 29 May 2019 by Ockenden).

Activity 3.1, Output 3.1.1. Banteay Meanchey – Farmer Hub Establishment in North West Cambodia (SFSA). Key implementation team: Herve Thieblemont & Cuong, SFSA

SFSA initiated and launched a specific program to establish Farmer Hubs in North West Cambodia. Farmer Hubs are essentially commercial services innovation platforms in communities, providing a one-stop shop for farmers. Farmer Hubs develop solutions within existing value chain networks that better link farmers to markets and enable smallholders to access and use technologies productively. Hence, local farmer communities improve their productivity and resilience, creating more opportunities in the agricultural sector for future generations. In their most developed form, Hubs provide most of the services the farmers need – inputs, mechanical (sowing and harvesting), marketing, knowledge and training. They can be grafted on to existing formal Agricultural Cooperatives (AC), where appropriate, but they can also be run by individuals – new entrepreneurs or established service providers – the essential characteristic is that they are self-sustaining small businesses.



Source: SFSA

To move this program forward, SFSA actively engaged with CamSID members and drafted a high level road map for the Farmer Hub establishment in North West Cambodia:

- In June 2018, SFSA organised a workshop in Meanchey University (20 participants) to co-design Farmer Hubs structure while reflecting on SFSA experience in South Asia and leveraging existing dynamic in the pre-selected villages in Cambodia
- In September 2018, SFSA and MCU recruited a Farmer Hub program manager to drive this program under CamSID and SFSA leadership
- In December 2018, SFSA invited a few CamSID members to Bangladesh to visit operational Farmers Hubs and transfer the learning to Cambodian context

The visit of the Farmers Hubs in Bangladesh in December has been rewarding for the participants. They came back home inspired, energized and motivated. The feed-back they provided is very instructive and paves the way for the Farmer Hub establishment in Cambodia:

- Related to Farmer Hub concept
  - Difference between Co-op and Hub is clear now
  - Need FARMERS data before and after Farmer Hub establishment in order to demonstrate the benefits: +34% - $450 net income per year
- Related to Farmer Hub services
  - 4 key pillars: buying and selling services, mechanization, post-harvest handling services, agriculture and market information services
  - Seedling nursery is a very important component of the offer
  - Seed treatment could be part of the offer
- Related to Farmer Hub establishment
  - Good understanding and good clarity on how to set-up a Farmer Hub

    - Include Phase-out strategy at the beginning of the Farmer Hub set-up
    - Role of government to set-up Farmer Hub is limited and similar to Cambodia (provide license only)
- Related to Farmer Hub governance
    - SFSA office and staff very active and well connected with farmers
    - Farmer Hub has a very clear administration system even though not always clear how to use the e-tool
    - Development of Farmer Hub for potatoes well organized and efficient

The feed-back from Yann Sakhon and Chiv Sarit: two farmers interested in establishing a farmer hub in the current CamSID villages is also very instructive:

- Learn about hub management
- Understand the different steps to set-up Farmer Hub and aware of the link between market and farmers
- Will bring great ideas back to Cambodia
    - Connect farmers with markets: selling farmer outputs: rice, mung bean
    - Produce rice seeds and sell to farmers
    - Selling farm inputs
    - Propose mechanization
    - Post-harvest transportation (all crops)
    - Learn how to make compost
- Still some challenges to overcome: capital, market linkage and agricultural knowledge

The Farmers Hubs owners in Bangladesh provided amazing advice to our Cambodian team in order to succeed in their enterprise: Planning is essential, Technical knowledge and Agronomy advisory is a must, Set-up the hub at the right location, Already have a business experience, Be smart and well accepted by farmers (meaning customers), Love his/her business (heart), Maintain accounting up to date, Promote the business, Provide integrated services and reach excellence in service delivery, Balance cash uptake and investment.

They also insisted on the necessary soft and hard skills to be successful: Honesty, Trust and reliability, Dedicated, hard worker, Agriculture knowledge, Communication and relationship skills, Financial solvency, Right location, Young (mindset), be well connected and with business acumen.

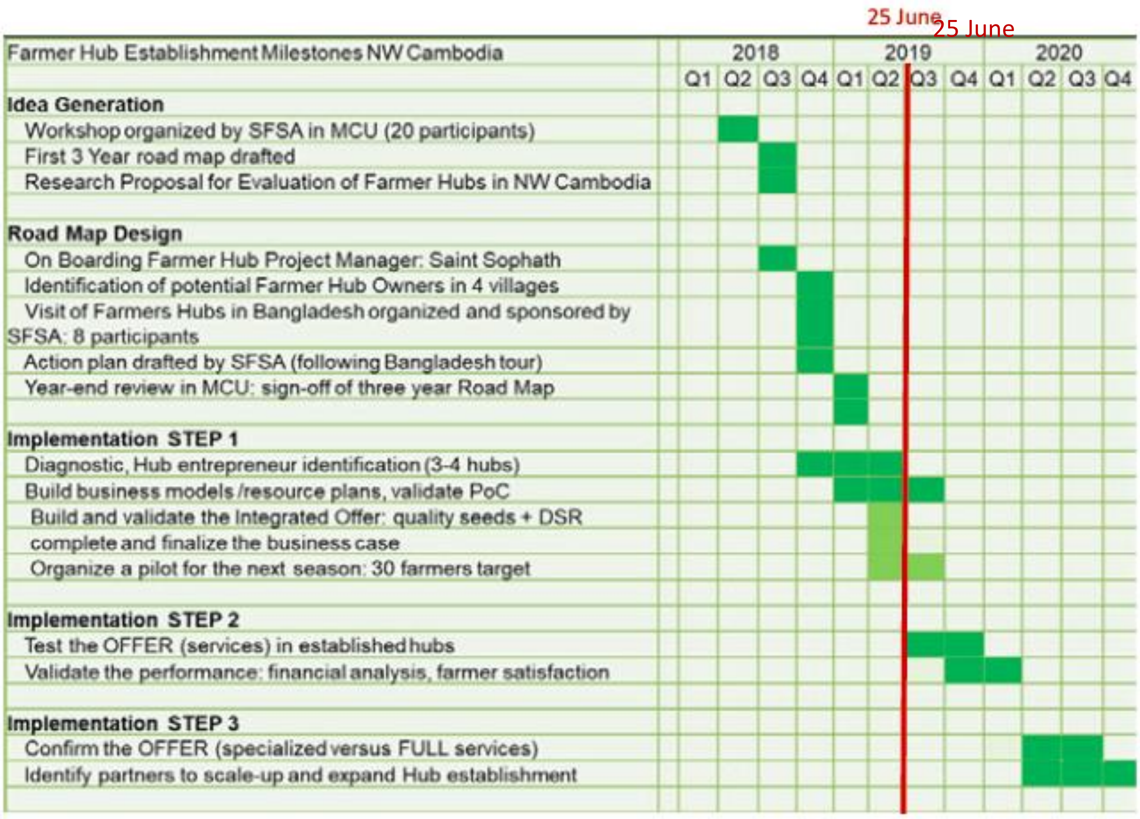
A good omen before moving to the implementation phase in 2019.

Figure 86. Visiting vegetable seedling production hub in Bangladesh

Figure 87. Discussion on farmer hubs in Bangladesh

Key Achievements to date

The project is currently on track with the initial road map (*table hereunder*). The first semester of the year 2019 has been dedicated to the implementation of the STEP 1. This phase is now completed knowing the pilot phase has been replaced by large scale demonstrations at farm gate. The main objective being to share the outcome of the experimentation conducted within CamSID program; focusing on direct seeding rice systems and high quality seeds.



The team made the decision to concentrate all efforts in establishing SPECIALIZED Farmer Hubs:

- in rice seed production with Mr Yann Sophon in Battrong
- in mechanization services with Mr Chiv Sarith in Banteay Neang
- in fertilizer retail with Ms Un Sophai in Samraong
- in Vegetables: seedlings, field production, marketing: not identified yet

In February 2019, the CamSID team signed-off the road map during the mid-year review.
In April 2019, SFSA with Meanchey University (MCU) support, conducted a Business Plan training to pressure test the robustness of the value proposition, to assess the capacity and the capabilities of the Farmer Hub owners to translate a business idea into a coherent actionable business plan while checking the readiness of the Farmer Hub owners to move the project forward.

In May 2019, SFSA and MCU visited the three potential farmer hubs owners in their farms with their family in order to reflect on the Business Plan training, check how the project "matures" and to engage on the investment plan. After discussion, the team made the following recommendations:

- Go ahead with the Rice seed production hub led by Mr Yann Sophon; assuming we clarify the business model, get the customer data base and can improve seed processing and seed quality
- Go ahead with the Mechanization services hub led by Mr Chiv Sarith; assuming we can re-focus the services delivery on a 10km radius, agree on which services to deliver: land levelling and/or direct seeding and align on the fact that investing in a 4WT is premature in 2019
- Put on hold the Fertilizer retail hub led by Ms Un Sophai; knowing the business opportunity to sell fertilizers in the targeted area is too limited and the competition has not been assessed.

2019 Business Plan assessment	Un Sophai On Hold	Chiv Sarith GO	Yann Sophon GO
Product Offer	Sell fertilizers	Sell Rice seeds	Sell Rice seeds
Service Offer	Deliver technical support	Land preparation Direct seeding	Provide agronomy advices
Targeted farmers	15	15	30 + NGOs
Targeted RICE acreage	2500 ha	20.000 ha	14.000 ha
Market landscape	250 Tons	20.000 ha	600 Tons
Competitors	2	Not really	Not really
Volume sold at peak	>250 Tons???	500 ha	45 Tons
Net Income at peak	$25000	$20000	$17000
Investment	storage	4WT 30k$	2+k$
Business Model Assessment	Very weak (no service/Credit)	Rather weak (no customer base)	Unclear (small customer base)
Risk assessment	HIGH (storage, price<)	MID (4WT invt, scatter)	MID (volatile customers)
Sustainability Assessment	LOW	MID	MID

Mr Chiv Sarith Farm and Farmer Hub operations

Mr Yann Sophon Farm and Farmer Hub operations

100km*100km => 70km large * 40km high blue rectangle
Total acreage: 28.000ha if 50% rice = 14000 Ha rice - 840 Tons if 60kg per ha

In June 2019, we decided to conduct large scale demonstrations to show-case the "*Rice crop establishment Integrated Offer = high quality seeds from Mr Yann Sophon and land preparation + direct seeding services from Mr Chiv Sarith* ". Three demonstrations have been conducted with the support of each farmer hub owner and MCU/SFSA. (*Refer to the demonstration at Battrong village hereunder as an illustration*)

Farmer's demonstration for rice seed production at Battrong village, BMC, Cambodia
SFSA contributed to a large farmer demonstration in BMC jointly organized with MCU (Meanchey University). The demonstration conducted on 29th May 2019 at Battrong village - a farmer hub on rice seed production; gathered more than 130 persons: 85 farmers and 45 students from MCU
Dr DX Cuong did share the work SFSA has undertaken over the last two years with direct seeders including Quality seed and Mechanized drum seeder
Mr Chiv Sarith, engaged in a farmer hub establishment dedicated to land preparation and direct seeding services did show-case his offer; applying low seeding rate used to save production cost and gain a better yield.
The local farmers invited at the demo field from very early morning were very pleased and engaged with the new seeding systems. They also appreciated the importance of having high quality seeds and protecting these seeds with adequate seed care solutions.

Learning from the IMPLEMENTATION step 1

- **What went well?**

- Willingness to become an entrepreneur and endorse the role of Farmer Hub (FH) owner
- Can do attitude, ready to pilot proof of concept case
- Expressed need for collaboration and best practices sharing, team work
- Complementarity in Services delivery by the three hubs: space for NEW rice agro-systems, higher quality seeds, DSR mechanization, agronomy services
- Better understanding of what a business plan means and ability to think globally and differently

- **What was difficult?**

- No real change vs current activities: FH owners intend simply to do better / expand what they currently do but no real breakthrough ideas
- Overall weak business model mainly due to the lack of visibility on their current and future customer base, the lack of consideration of the competitive space, the absence of data and some grey areas in the whole transactional flow (including credit)
- Engagement and commitment driven mainly by the support SFSA is expected to provide to finance FH' s investments
- Rather difficult for the FH owners to understand the financial logic and jargon: net income, gross margin, ROI, payback …
- Current FH program manager not actively engaged in delivering ad-hoc coaching and mentoring to the FH owners: still in a learning phase

- **What could we do differently?**

- Re-assess the market opportunity and the competitive landscape: need more granular data
- Fine-tune the value proposition: clarify the differentiating points with competitors

Seize the huge opportunity of creating and delivering an <u>Integrated Offer</u> matching rice's small-holder farmers demand: land leveling and DSR mechanized services plus high quality seeds

Figure 88. Training on seed treatments *by Dr Cuong*

Figure 89. Sowing by mechanized drum seeder by Tekhong

Monitoring, evaluation and learning

Rebecca Cross, Linh Nguyen and Van Touch will lead the monitoring, evaluation and learning activities in September 2019.

2 Achievements against project activities and outputs/milestones

Objective 1: Identify the local socio-economic and agronomic trends, constraints and opportunities for SID adoption for small and medium farm households.

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	Conduct foresight study and establish a multi-skilled team and strong governance to oversee the design and implementation of the project	1.1.1: Foresight study and stakeholder engagement completed	31/3/17	Foresight study and stakeholder engagement completed during the inception workshops on 6-8th November 2016. Collaborative agreements have been signed with NGOs, VSO for Battambang Province and Ockenden for Banteay Meanchey Province.
		1.1.2: Workshop report on foresight study and project initiation meeting submitted	31/3/17	Inception workshop report on foresight study and project initiation meeting was submitted on 8 December 2016.
		1.1.3: Monitoring and evaluation framework developed and human research ethics approved	31/6/17	Monitoring and evaluation framework developed and submitted on 20 June 2017 (see Annex 1). Bill Rathmell and Peter Ampt visited project sites during October/November 2017 for monitoring, evaluation and learning. Human Research Ethics Committee (HREC) approval obtained on 24 November 2017 (Project No. 2016/882)
1.2	Conduct participatory rural appraisals (PRAs) to assess the socio-cultural context formally, identify local needs and opportunities and build cohesion and a shared vision for project staff and stakeholders	1.2.1 PRA report submitted	30/9/17	The PRA was completed over a 13-day period in Nov-Dec 2016. 144 interviews were conducted in 8 villages across the Battambang (BTB) and Banteay Meanchey (BMC) Provinces. Preliminary PRA report submitted on 20 February 2017.
		1.2.2 Socio-economic and farming system survey completed using PRA	31/10/17	Socio-economic and farming system analysis in progress. This analysis will include the PRA data as well as baseline survey data. Final report for PRA and baseline survey submitted to ACIAR on 16 June and accepted by ACIAR on 17 June 2019.
		1.2.3 Traditional/indigenous technologies identified and documented	31/10/17	Identification of indigenous technologies in progress.
		1.2.4 Prototype business models within VCN to meet local needs developed	31/10/17	Work in progress by value chain task force led by Drs Bob Martin, Yorn Try, Van Touch, Ratha and Sophea. Dr Bob Martin will develop a business model for quality declared rice seed production in collaboration with CAVAC.

1.3	Conduct a socioeconomic household livelihood and farming system survey based on PRA findings. The diagnostic survey will quantify system components and likely impacts of interventions, make an assessment of market opportunities in the future including network value chain analyses and will include household consumption and production strategies and decision-making.	1.3.1 Protocol developed for baseline diagnostic survey and MCU students trained on survey methodology	30/6/17	The protocol was developed for the baseline diagnostic survey in early May 2017. Over 60 MCU and UBB students were trained in using CommCare software (mobile acquired data technology).
		1.3.2 Survey on land tenure, farm types, livelihood consumption and production strategies (including remittances from migrants), and current technologies completed for 90 households	31/12/17	Approximately 524 households were interviewed in 10 villages across BTB and BMC in May 2017. The data is being checked for inconsistencies by Dr Rebecca Cross and will be available for analysis by 17 July 2017. Drs Peter Ampt, Rebecca Cross and Van Touch will be leading this analysis for the same 524 households with support from Prof Thilak (UQ). Final report for PRA and baseline survey submitted to ACIAR on 16 June and accepted by ACIAR on 17 June 2019.
		1.3.3 Future farm household strategies and scenarios (stepping out, stepping up) and future technology needs determined for 90 households	31/12/17	Dr Clemens Grunbuhel will lead in this analysis for the same 524 households.
		1.3.4 Network value chain analysis data collected and analysed using Social Network Analysis	31/12/17	Social network analysis of Angsangsak village completed. Led by USYD honours students, Aaron Zhang and Kirstan Xing – supervised by Dr Petr Matous
		1.3.5 Using Social Network Analysis, map and measure relationships, information-knowledge flows that affect farmers' decision making	31/12/17	Social network analysis of Angsangsak village completed. Led by USYD honours students, Aaron Zhang and Kirstan Xing – supervised by Dr Petr Matous
		1.3.6 Develop a communication strategy based on the Social Network Analysis	31/12/17	Social network analysis of Angsangsak village completed. Led by USYD honours students, Aaron Zhang and Kirstan Xing – supervised by Dr Petr Matous
1.4	Refine agronomic and institutional research priorities and interactions and interventions based on the survey	1.4.1 Agronomic and institutional research priorities refined in workshop	31/12/17	This was completed during the Annual Progress Meeting at BTB in February 2018.
		1.4.2 Survey results published in scientific journals and ACIAR workshop proceedings	31/3/18	Survey results being prepared for publication – led by Dr Van Touch, Dr Rebecca Cross and Dr Clemens Grunbuhel.

		1.4.3 Women's livelihood consultative groups (four groups) established in target villages with regular meetings for the life of the project to provide ongoing formative advice on whether strategies are on track to improve household incomes and improve quality of life	31/3/18	Dr Rebecca Cross is leading this activity, including longitudinal case studies. Dr Cross has just completed a preliminary visit during June/July 2018 to work with Flavia Ciribello (VSO) to finalise the consultation. Analysis of gender roles in vegetable production: Rebecca Fong (USYD honours student).
1.5	Conduct a mid-project survey to evaluate which innovations and approaches are more effective for farmer adoption and improved livelihoods (USYD, CARDI, AIT)	1.5.1 Effectiveness of innovations and approaches for 90 households and 36 agribusinesses evaluated through focus group discussions with farmers, input and output suppliers	31/12/19	This mid-project survey and MEL is being led by Drs Rebecca Cross, Linh Nguyen and Van Touch in September 2019.
		1.5.2 Interim survey results published in scientific journals and ACIAR workshop proceedings	31/3/20	
1.6	Initiate another survey near the end of project to monitor impact in relation to objectives, assess effectiveness of scaling methods adopted and generate recommendations for future research from participants	1.6.1 Mid-project survey report for noting any changes in baseline areas and effective scaling methods for 90 households and 36 agribusinesses	30/9/21	
		1.6.2 Final survey results published in scientific journals and ACIAR workshop proceedings	31/12/21	

PC = partner country, A = Australia

Objective 2: Establish participatory on-farm pilot trials to test SID innovations and approaches at field scale and evaluate which approaches are most effective for farmer adoption

No.	Activity	Outputs/ milestones	Completion date	Comments

2.1	Identify and establish leading farmers, smallholder, input and output supply and local value chain networks (VCNs) to test SID innovations and evaluate effectiveness for adoption. Upskill these networks in farm and business planning and management tools (USYD, SFSA, MCU)	Output 2.1.1 Four pilot leading farmers or farmer groups selected and identified (two in each of Banteay Meanchey and Battambang)	31/1/18	Leading farmers and farmer associations have been identified during the PRA survey. SFSA together with the BMC team is in the process of developing a road map for the farmer hub initiative. BTB team will continue to work with existing farmer groups led by VSO.
		2.1.2 Key credit, market access to inputs, soil, water, nutrient and biotic constraints identified for the four focus villages	28/1/18	BTB team is leading the collection of biophysical data while VSO is assisting with the collection of Sustainable Rice Platform (SRP) data from smallholder farmers.
		2.1.3 Key farmer group leaders, university staff and PDAs trained in farm and business planning and management skills and tools	30/6/18	Preliminary training (train-the-trainer) provided to key staff and NGOs through the Crawford Fund training activity from 16 October to 1 November 2016.
2.2	On-farm field experiments and demonstrations on rice and other rotation crops [e.g. mung bean, waxy maize, and vegetable crops] conducted to refine and adapt successful SID innovations	2.2.1: Pilot demonstrations of alternative rice sequences and crop rotation options to compare traditional practice of one rice crop per year with two wet season rice crops and options for rotation crops after rice	28/2/18	Pilot demonstrations have started with planting equipment (including Eli air seeder, mechanised drum seeder, manual drum seeder, hand broadcasting) on 28 June 2017 at Svay Cheat Village (comparison with transplanting for seed production) and on 7 July 2017 at Don Bosco, BTB and 10 July 2017 at Kuok Tonlaop Village during the early wet season. A seeder trial was planted on 14 Sept 2017 at Svay Cheat Village to compare mechanised seeders with broadcasting and on 30 Oct 2017 at Omal Village and on 30 Sept 2017 at Kuok Tonlaop Village during the main-wet season (second rice crop) In 2018, Dry seeding experiments with KID seeder for planting density/weed management established at Kuok Tonlaop Village (planted 25 April 2018 and harvested on 17th Aug 2018) and Svay Cheat Village (planted June 2018). Rice husk ash (DB) and nutrient omission experiments have also been established at BTB. Wet seeding experiments also completed with mechanised drum seeder at Kuok Tonlaop Village (24th Sep 2018) in main wet season and at Oambel Serisophon City in the dry season (28th Mar 2019) at BTB.

		2.2.2: Alternative rice and non-rice crop varieties evaluated for local conditions	31/12/20	Mungbean lines have been obtained from CARDI, Thailand and Vietnam with the focus on short-duration lines for mechanical harvesting and for use of residual soil water after the flood or main wet season rice crop. Farmers are also looking for lines that resist pod shattering (led by Dr Bob Martin). **Cambodian varieties identified for seed increase include CARDI Chey and CMB-3.** A follow-up experiment was carried out during January-April 2019 to evaluate a selection of 11 Australian mungbean varieties. **Promising varieties were Shantung, White Gold, CARDI Chey and CMB-3.** Dr Cuong led the watermelon variety and best practice trials. The best performing watermelon varieties during the dry season experiment were: **Variety 020 F1, Hoang Chau, Superman and EW 06 averaging 28 t/ha. Thai variety C 29 was best on taste and good texture** as Cambodians were used to the taste of the local variety. A subsequent experiment in 2019 showed that **flat or raised seedbeds with either plastic mulch or rice straw gave the best watermelon yields and economic returns**. Seyma is led fish demonstrations at Battrang together with lead farmer, Mrs Champey and also with Mr Yann Sukkhon at Batrong during 2018-19.
		2.2.3: Guidelines for rice intensification and rotation crop options produced	31/12/20	Dr Yorn Try is compiling a textbook for rice production for MCU and UBB students. Bob Martin is leading the updating of the mungbean technical manual.
2.3	Evaluate new 12-month calendar for rice variety and crop rotations in appropriate areas	2.3.1: New cropping calendars established and evaluated. Climate risks evaluated using APSIM modelling	31/12/19	Dr Van Touch will lead in this activity.
		2.3.2: Economics of new cropping calendars developed based on Yr 2 trials and validated in Yr 3 trials	31/12/20	
		2.3.3: Market analysis for new rotation crops	31/12/19	Work has commenced on documenting the mungbean and vegetable market chains led by Dr Bob Martin, Ratha, Sophea, and by Khim, Seyma and Hong in BMC.

		2.3.4: Cropping options developed for farmers subject to soil type, water availability and market access	31/12/20	Plans for rice-mungbean rotational experiments in progress for Svay Cheat and Kuok Tonloap.
2.4	Optimise direct seeding methods by evaluating no-till direct drill, conventional drill, drum seeding and alternative wet seeding methods for rice compared with traditional broadcast	2.4.1: Farmers consulted and technologies for on-farm research identified	31/1/18	Farmers were extensively consulted during the PRA and baseline surveys. Follow-up surveys on diversification crops after rice are being conducted by Dr Bob Martin, Ratha and Sophea.
		2.4.2: Optimal seeding methods and seeding rates evaluated and developed in relation to soil type, crop residue management and water availability	31/12/18	Pilot demonstrations have started with planting equipment (including Eli air seeder, mechanised drum seeder, manual drum seeder and hand broadcasting) on 28 June 2017 at Svay Cheat Village and on 7 July 2017 at Don Bosco, BTB and 10 July 2017 at Kuok Tonlaop Village during the early wet season. Similar demonstrations on 14 Sept 2017 at Svay Cheat Village and on 30 Oct 2017 at Omal Village and on 30 Sept 2017 at Kuok Tonlaop Village during the main-wet season (second rice crop) Dry seeding experiments with KID seeder for planting density/weed management established at Kuok Tonlaop Village (planted 25 April 2018 and harvested on 17th April 2018) and Svay Cheat Village (planted June 2018). Rice husk ash (DB) and nutrient omission experiments have also been established at BTB. Wet seeding experiments also completed with mechanised drum seeder at Kuok Tonlaop Village (24th Sep 2018) in main wet season and at Oambel Serisophon City in the dry season (28th Mar 2019) at BTB. The aim is to replace hand broadcasting (for paddy rice production) and transplanting (for quality seed production) with mechanised seeding at optimal seeding rates.
		2.4.3: Most effective land preparation, crop residue and seeding methods/rates	31/12/19	Minimum tillage for mungbean after rice being planned for Svay Cheat and Kuok Tonloap
2.5	Evaluate high quality seed of registered varieties of high value [e.g. certified seed of approved rice varieties, mung bean, waxy maize and vegetable crops] compared	2.5.1: High quality seed and varieties of high value evaluated in comparison with farmer practice	31/12/18	A survey of weed seed contamination in rice seed kept for sowing has been published in Weed Research. Although farmers can reduce weed contamination by 60%, the project can help them reduce the level further. A significant proportion of 'Certified' seed lots tested were found to be heavily contaminated by weed seeds and weedy rice.

	with traditional farmer saved seed	2.5.2: Explore options for contract cooperative marketing of quality assured produce with potential buyers	31/12/18	BTB team is partnering with VSO to explore use of the SRP standard to underpin contracts between Chamroeunphal FA and AMRU rice mill. BMC team is working with SFSA and Ockenden to establish functional farmer hubs in BMC.
		2.5.3 Supply chain network (seed producers, input suppliers, farmers and markets) for high quality seed and varieties of high value linked up with local VCN	31/12/19	Bob Martin is exploring a program for quality declared seed (QDS) production with CAVAC and VSO with Svay Cheat (Chamroeunphal - rice) and Angsangsak (mungbean) as a pilot. This will be scaled to other BMC hubs in 2019 led by Herve and Dr Try.
2.6	Evaluate best practice management (e.g. land levelling, crop nutrition, water management, crop establishment, crop protection) options for rice and other rotation crops [e.g. mung bean, waxy maize, mushroom and vegetable crops]	2.6.1: On-farm demonstrations of best management packages established with four farmer groups	31/12/18	Demonstration of machine seeders for wet seeded rice commenced in 2017. Experiments on optimising N topdressing and calibration of NDVI reflectance meter and free smartphone App, Canopeo – led and monitored by PhD student, Chinaza. One experiment completed, second commenced.
		2.6.2: Most effective crop agronomy methods to farmers and private sector showcased in field days and practical training workshops	31/12/19	Eight field days completed for demonstration of wet seeding machines. In 2018 and 2019, the Thai KID seeder has been trialled for dry seeding in both BTB (Svay Cheat, Tahen) and BMC (Kouk Tonloap, Batrong) for EWS rice.
		2.6.3: Best practice guidelines for crop agronomy established	31/12/19	Mungbean production manual produced by ASEM/2010/049 will be used as a guide. Working draft manual for best practice in DS in progress.
2.7	Evaluate available chemical and non-chemical protocols and options for integrated weed, insect and disease management in the crop sequence	2.7.1: Most effective integrated pest management methods showcased to farmers and private sector in field days and practical training workshops	31/12/18	USYD PhD student, Lucinda Dunn (Indi) has enrolled in a PhD on integrated pest management for rice in January 2018. She is supervised by Drs Latty, Tan, Martin and Try. Lucinda is monitoring low, medium and high rice intensification systems for predator-prey relationships. A fungicide and rice husk ash (to provide silicon/silica) experiment has been completed to manage rice blast at Don Bosco farm (planted in June 2018). The experiment was led by USYD honours student, Dan Howell and supervised by A/Prof Rosanne Quinnell. There was little evidence of efficacy of rice husk ash for control of rice blast due to low incidence of rice blast in EWS.

		2.7.2: On-farm demonstrations of integrated weed, disease and insect management practices established with four farmer groups	31/12/18	A manual on Integrated Crop Management is being compiled by Dr Yorn Try
		2.7.3: Databases and identification kits published for the major weeds, diseases and insect pests in the rice system	31/12/19	Weed identification App has been developed by Masters student, Yehezkiel Henson and now available to smallholder farmers in Khmer (on IOS devices). Mungbean pest identification App developed by Honours student, Isabel Hinchcliffe and now available to smallholder farmers in Khmer (on IOS and Android devices). This App has 1,260 active installs (iOS: 1.15K, Android: 112) (as of June 2019).
2.8	Evaluate the use of low cost Unmanned Aerial Vehicles (UAVs) for measuring yield limiting factors: land levelling, crop establishment and crop/weed biomass. Ground-based EM38 used to detect subsoil constraints and soil water holding capacity (USYD, CARDI)	2.8.1: On-farm maps of Normalised Difference Vegetation Index (NDVI) developed using UAVs to predict rice yields and to monitor changes at field scale in farmers' fields before and after SID adoption. EM38 used to evaluate subsoil constraints and soil water holding capacity	31/12/18	UAV trials piloted. However, UAV from Waypoint company is not always reliable as the company is not able to fly the UAV at the required crop developmental stages. The focus has now turned to developing a real-time NDVI-based N-topdressing calculator to avoid over- and under-fertilisation in rice. PhD student, Chinaza is trialling Canopeo App which is a free App that can provide an estimate of the NDVI real-time in the field.
		2.8.2: on-farm research designed with fertiliser rates based on management zones to develop optimal fertiliser rates based on soil type for maximum nutrient use efficiency	31/12/20	Experiments commenced to optimise N topdressing rate and timing with regards to rice crop needs and target yield. Comparison of NDVI reflectance and IRRI LCC and Canopeo smartphone App for estimating N topdressing needs.
		2.8.3: Evaluate the use of UAV NDVI imagery to provide early warning of emerging weed, disease or insect pest outbreaks in farmers' fields	31/12/20	UAV trials piloted. However, UAV from Waypoint company is not always reliable as the company is not able to fly the UAV at the required crop developmental stages.

PC = partner country, A = Australia

Objective 3: Comparative evaluation of scale-up and scale-out models for SID adoption at village and community level

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Evaluate most successful farmer-led prototype groups and community-led VCN communication models to scale up SID through local VCNs	3.1.1: Most effective farmer group approach evaluated with four farmer groups for scaling from pilot results and through farmer focus group discussions (including using IAT modelling)	31/3/19	SFSA and BMC team now working on pilot farmer hubs at BMC. BTB team working with existing farmer hubs led by VSO.
		3.1.2: Scale-up farmer groups to at least 9 villages in 3 provinces completed (Battambang, Banteay Meanchey, northern Pursat) (MCU, SFSA). Evaluated using IAT modelling.	31/12/20	BTB team has commenced scale-up to Tahen. Scaling partner, CAVAC has reported that over 16 KID drill seeders have been purchased by Battambang province agricultural cooperatives and farmers and over 200 ha planted using these drill seeders (as of July 2019). Field demonstrations of the Cambodian-invented Eli seeder have led to over 100 Eli seeders being sold. The BMC team has facilitated over 100 ha being planted by mechanised drum seeders.
		3.1.3: Use participatory network mapping to identify and overcome barriers to the flow of information to communities beyond the project target groups	31/12/20	
3.2	Support private sector input and machinery service suppliers, NGOs and traders to promote SID methods to their farmer clients through local VCNs including analysis of components of input prices and credit provision	Output 3.2.1: Negotiate with PDA to include relevant project outputs into the existing 5-day Input Seller Certificate Course	31/12/19	Dr Try and Bob have successfully negotiated MOU with PDAFF (in both BTB and BMC) regarding engagement with private sector. On 13th July 2019, the input seller survey questionnaire will be finalised in a workshop with PDAFF.
		3.2.2: Effectiveness of PDA staff evaluated and farmers surveyed on whether suppliers and NGOs are servicing them more effectively	31/12/20	

		3.2.3: Communicate with input sellers, machinery contractors and collector-traders and overcome barriers to adoption of SID technologies	31/12/20	
3.3	Support local VCNs and the development of self-sustaining agribusiness (e.g. input and machinery services) where appropriate to continue to support farmers through local VCNs	3.3.1: Niches in the local VCN for opportunities for development of agribusiness identified	31/12/19	
		3.3.2: Technical and business and financial skills training support provided to new start-up agribusinesses	31/12/20	

PC = partner country, A = Australia

Objective 4: Build the capacity of local farming communities and tertiary agricultural educational institutions to implement SID technologies and approaches beyond the life of the project

No.	Activity	Outputs/ milestones	Completion date	Comments
4.1	Upgrade curriculum and multilingual teaching materials to use for "train-the-trainer" dissemination of practical knowledge of SID	4.1.1: Market needs for graduate staff analysed and criteria for training syllabus developed to suit	31/12/18	Curriculum of agronomy is being developed to meet job market needs. Workshop on soils analysis and soils curriculum held by GAU in February 2018 training over 13 scientists from UBB and MCU
		4.1.2:Training syllabus developed for best practice management	31/12/19	Four young agronomy lecturers are being trained in rice disease, entomology, and integrated pest management at MCU Three UBB students doing their research projects on rice pests (e.g., rice leaf folder) with Dr Try.
		4.1.3: Training workshops provided for regional universities and PDAs in Cambodia to share SID technologies	31/12/20	Four PDAFF staff in BMC are being trained in disease, entomology, and integrated pest management
4.2	Develop and disseminate information tools and messages using extension support materials	4.2.1: Most effective information tools for dissemination of SID techniques evaluated	31/12/20	A pilot radio system at the village level is being proposed for Mungkul Borei district initially.

	(e.g. radio/TV programs) and information and communications technology for local communities (PDA, MCU, USYD)	4.2.2: Pocket guides on integrated nutrient and pest management strategies developed	30/6/21	Weed identification App has been developed by a Masters student, Yehezkiel Henson and now available to smallholder farmers in Khmer (on IOS and Android devices). A new mungbean IPM App has been developed by honours student, Isabel Hinchcliffe. This App has 1,260 active installs (iOS: 1.15K, Android: 112) (as of June 2019).
		4.2.3: Simple phone based apps or chart based tools developed to enable farmers to plan cropped based on residual soil water, water storage or seasonal climate forecasting	30/6/21	
4.3	Increase the supply of practically trained university, PDA, private sector suppliers/trader staff to provide support and sustainability for SID adoption by farmers	4.3.1: Local university, PDA and private sector staff trained and supporting farmers	30/6/21	
		4.3.2: Evaluate the establishment of an on-the-job training program for final year MCU students during vacations	30/6/21	
4.4	Identify key constraints and higher level interventions that cannot be implemented at the local level and make policy recommendations	4.4.1: Policy and extension briefs (at least 2) provided to key decision makers in government and private sector	30/6/21	
		4.4.2: Policy recommendations briefs (at least 2) made to industry leader through the Cambodian Rice	30/9/21	

PC = partner country, A = Australia

3 Impacts

3.1 Scientific impacts

Scientific papers published and in preparation include:

Scientific papers

Chhun S, Kumar V, Martin RJ, Srean P. 2019. Weed management in smallholder rice systems in North West Cambodia. Crop Protection (In Press).

Martin RJ, Janiya JD, Som B, Oum E, Chuong S. 2019. Effect of seeding method and seeding rate on weed growth and rice yield in Cambodia. Crop Protection (In Press).

Martin RJ, Van Ogtrop F, Henson Y, Broeum R, Rien, R, Srean, P, Tan DKY (2017). A survey of weed seed contamination of rice paddy in Cambodia. *Weed Research* **57,** 333–341: DOI: 10.1111/wre.12265.

Martin RJ. 2017. Weed Research Issues, Challenges, and Opportunities in Cambodia. *Crop Protection*, https://doi.org/10.1016/j.cropro.2017.06.019.

Srean P, Eang B, Rien R, Martin RJ (2018). Paddy rice farming practices and profitability in northwest Cambodia. Asian Journal of Agricultural and Environmental Safety 1, 1–5 ISSN: 2575423, https://www.ajaes.org/

Conference papers

Campbell-Ross, H., Yous, S., Martin, R., Tan, DKY (2019). Mungbean (*Vigna radiata* (L.) R. Wilczek) varietal evaluation for northwest Cambodian lowland rice systems. *19th Australian Agronomy Conference 2019*, Wagga Wagga, Australia: Australian Society of Agronomy.

Fong, R., Cross, R., Martin, R., Tan DKY (2019). Analysis of the vegetable value chain and gender roles in vegetable production in northwest Cambodia. *19th Australian Agronomy Conference 2019*, Wagga Wagga, Australia: Australian Society of Agronomy.

Hinchcliffe, I., Quinnell, R., Martin, R., Touch, V., Tan DKY (2019). Development of a pest identification mobile phone application for mungbean in Cambodia. *19th Australian Agronomy Conference 2019*, Wagga Wagga, Australia: Australian Society of Agronomy.

Henson H., Robert J. Martin, Rosanne Quinnell, Floris Van Ogtrop, Yorn Try, Daniel K.Y. Tan. Development of Weed Identifier Mobile Application for Cambodian Rice Farmers. Proceedings of the 2017 Agronomy Australia Conference, 24 – 28 September 2017, Ballarat, Australia. www.agronomyconference.com https://www.cabdirect.org/cabdirect/abstract/20183145637

Loveday J, Ormiston J, Cutcher L. Community-based entrepreneurship and hybrid organising: Engaging communities in social innovation in rural contexts. Proceedings of the International Social Innovation Research Conference, 11-14 December 2017, Melbourne, Australia. <http://www.isirconference.com>

Martin R, Montgomery S, Touch V, Scott F, Cowley, F. 2017. A blueprint for sustainable upland cropping practices in North-western Cambodia. Keynote Address at the 4th National Conference on Agriculture and Rural Development. “Promoting sustainable

agriculture and rural development for the future", 18-19th November 2017, University of Battambang, Battambang, Cambodia.

Rien R, Srean P, Martin RJ. 2017. Weed seed and weedy rice contamination of harvested paddy in Cambodia. Proceedings of the 7th International Graduate Research Conference, Ubon Ratchathani University, Thailand, October 2017. http://www.nigrc2017.ubu.ac.th/document/igrc_prceedings.zip

Tan D.K.Y., Robert Martin, Yorn Try, Chea Sareth, Van Touch, Clive Murray, Clemens Grünbühel, Lingling Li, Peter Ampt, Rebecca Cross, Jarrod Ormiston, Tyson Nash, William Rathmell 2016**.** The potential for conservation agriculture based sustainable intensification in Cambodia. 4th International Agronomy Conference. 22-26 November 2016. The Indian Society of Agronomy: New Delhi http://www.isa-india.in/IAC2016/

Tan D.K.Y., Robert Martin, Yorn Try, Chea Sareth, Van Touch, Clive Murray, Clemens Grünbühel, Lingling Li, Peter Ampt, Rebecca Cross, Jarrod Ormiston, Tyson Nash, William Rathmell 2017. Partnerships for the sustainable intensification of farming systems in lowland Cambodia. RDI Conference 2017, Partnering for Impact on Sustainable Development. 13-14 June 2017, p. 104-105. The University of Sydney, Sydney http://www.rdiconference2017.org.au/ https://rdinetwork.org.au/resources/development-bulletin/

Hinchcliffe, I. (2018). Development of a Pest ID mobile phone app for Cambodian mungbean farmers. 2018 Sydney Institute of Agriculture Research Showcase - Growing sustainable communities globally, Sydney, 6th July 2018. https://sydney.edu.au/content/dam/corporate/documents/sydney-institute-of-agriculture/outreach-engagement/SIA-research-showcase-program.pdf

Martin RJ. 2018. Climate change adaptation options for rainfed rice systems in Cambodia. UNICAM Conference. Siem Reap, Cambodia, 27-29 August 2018.

Workshop presentations

Martin RJ. 2018. Advancing Cambodian agriculture for the 21st Century (Bob Martin) ASIAN Agri Tech Innovation Lab Cambodia leg program. University of Battambang, 16 July 2018

Martin RJ. 2018. Transitioning from hand broadcast to machine row seeded rice in NW Cambodia. AGRITECHNICA ASIA. 22-24 August 2018, BITEC, Bangkok

Martin RJ. 2018. Site specific nutrient management options for rice in NW Cambodia. AGRITECHNICA ASIA. 22-24 August 2018, BITEC, Bangkok

Martin RJ. 2018. Best management practices for rice in NW Cambodia. AGRITECHNICA ASIA. 22-24 August 2018, BITEC, Bangkok

Theses

Campbell-Ross HEG. 2018. Mungbean (*Vigna radiata* (L.) R. Wilczek) Varietal Evaluation for North-West Cambodian Lowland Rice Systems. Bachelor of Science in Agriculture. AFNR4101 Research Project B/Research Paper

Fong RWL. 2018. Analysis of the Vegetable Value Chain and Gender Roles in Vegetable Production in North-West Cambodia: Assessing its Potential for Economic Growth and its Role in Minimising Regional Poverty. Bachelor of Science in Agriculture, the University of Sydney. AFNR4102 Research Project B.

Hinchcliffe I. 2018. Development of a pest identification mobile phone application for mungbean in Northwest Cambodia. Bachelor of Science in Agriculture / BScAgr (Hons). AFNR4102 Research Project B / Research Paper. The University of Sydney.

Howell D. 2018. Viability of rich husk ash and fused magnesium phosphate for managing *Magnaporthe oryzae*, a pathogenic rice fungus. Thesis.

Zhang AJ. 2018. The Role of Social Networks for the Adoption of Agricultural Innovations in Rural Cambodia. A Thesis submitted in partial fulfilment of the requirements for the Degree of Bachelor of Engineering in *Civil Engineering*. University of Sydney.

Patent (record of invention)

A patent (record of invention) was lodged/submitted for the Cambodian WeedID app (available both on iOS) (#CT19091) CDIP Ref. 2017-026

https://sydney.edu.au/news-opinion/news/2017/07/18/what_s-that-weed-in-my-rice-field-.html

A patent (record of invention) was lodged/submitted for the Mungbean Pest ID app (available both on iOS and Android) CDIP Ref. 2018-080

https://wordvine.sydney.edu.au/files/892/21751/#1gzht4n-research-whats-the-bug-in-my-mung-bean-field

3.2 Capacity impacts

3.2.1 Joint Crawford Fund Training Activity

See Section 4.1 for details

3.2.2 Project inception and project staff induction

Project partners participated in the foresight and external stakeholders' workshop at project inception which resulted in bonding and team building with a common vision and mission for this project. Local project staff were inducted and trained in rice production technology by Dr Cuong at the start of their employment.

3.2.3 CommCare (Mobile Acquired Data) training and use in baseline survey

Over 30 from MCU and 30 from UBB were trained for 3 days at the MCU campus in May 2017 to familiarise students with the purpose of the interview as well as test the questionnaire delivered in CommCare (Mobile Acquired Data) in nearby villages outside the sample. A total of 10 villages across both provinces and 50 interviews in each village (total: 524 interviews) were conducted in the baseline survey.

3.2.4 UBB student projects

These projects are included as individual skill development for Cambodian University students.

Survey of weed and weedy rice contamination of farmer rice seed kept for sowing

Mr Keouk Broeum is preparing a Bachelor thesis on a survey of freshly harvested paddy and farmer-kept seed for sowing in Battambang and Takeo provinces.

Evaluation of Normalised Difference Vegetation Index (NDVI) as an aid to optimising timing and application rates for nitrogen topdressing in rice

Mr Song Pherom is preparing a Bachelor thesis on the hand-held GreenSeeker® NDVI reflectance meter as an aid to optimising timing and application rates for nitrogen topdressing as part of the development of best-practice guidelines for rice production in Cambodia.

Study on Economic Injury Level Caused by Rice Leaf Folder Cnaphalocrocis medinalis (Guenee)

Mr Seng Bundoeun is preparing a Master thesis on the economic injury level caused by rice leaf folder and to determine the economic injury thresholds for Cambodia as part of the development of best practice IPM guidelines for rice production. He is supervised by Dr Try

Composition of egg wasp parasite on rice leaf folder

Ms Khem Sokheng is preparing a Master thesis on composition of egg wasp parasite on rice leaf folder as part of the development of best practice IPM guidelines for rice production in Cambodia. She is supervised by Dr Try

3.2.5 USYD student projects.

USYD student projects were reported here as USYD students worked alongside Cambodian University students in northwest Cambodia on collaborative projects. They played an important role in information exchange and building the research capacity of Cambodian students. For example, the development of the Weed ID App (including Khmer version) was developed collaboratively with Cambodian counterparts.

IPM for stemborers and pests in rice in NW Cambodia

Lucinda Dunn is a PhD candidate working on IPM for stemborers, pest and beneficials in rice in NW Cambodia. She is supervised by A/Prof Daniel Tan, Dr Tanya Latty and Dr Bob Martin.

Optimising farming systems in rice-based systems in NW Cambodia

Chinaza Onwuchekwa-Henry is a PhD candidate working to optimize agronomy for rice-mungbean systems in northwest Cambodia. She is supervised by A/Prof Daniel Tan and Dr Bob Martin.

Is the use of rice husk ash, a silica rich by-product of rice production, a viable management application for rice blast (Magnaporthe oryzae), in the Cambodian context?

Daniel Howell tested rice husk ash for the control of rice blast. He was supervised by A/Prof Rosanne Quinnell and Dr Bob Martin (completed)

Social network analysis of Angsangsak Village

Aaron Zhang mapped the social network of Angsangsak Village. He was supervised by Dr Petr Matous (completed)

Vegetable production and value chain in Cambodia

Rebecca Fong studied the feasibility of vegetable production and value chain in NW Cambodia through smallholder and value chain surveys. She was supervised by Dr Bob Martin and A/Prof Daniel Tan (completed)

Evaluation of mungbean varieties for northwest Cambodia

Harry Campbell-Ross has evaluated mungbean varieties for northwest Cambodia. He was supervised by Dr Bob Martin and A/Prof Daniel Tan (completed)

Development of a mungbean pest identification App for mungbean farmers in Cambodia

Isabell Hinchcliffe has developed a mungbean pest identification App for mungbean farmers in Cambodia. The app contains information on field and storage pests, diseases and beneficial insects. The app is now available on IOS and Android devices (completed)

Development of a weed identification App for rice farmers in Cambodia

Yezekiel Henson has developed a weed identification App for rice farmers in Cambodia. A prototype App in both English and Khmer has been developed with 10 common rice weeds and tested out with farmers during the participatory rural appraisal (PRA) survey. A more comprehensive App with over 45 weeds is now being developed for technical staff in CARDI, PDAFF and input suppliers (completed with over 200 downloads in IOS alone with over 100 downloads from the Apple Store site in the USA).

Rice value chain (RVC) network analysis

Yi Ling Ng has analysed: Current practice and situation within the actors of the RVC including farmers, brokers, millers, market; Identifying weakness, challenges and area for improvement within the RVC for improvement in global rice export competitiveness; and Quantify value distribution along the RVC (completed).

Options for sustainable intensification for small-holder rice farming households

Sarah Condran's project aim is to identify areas of potential intervention for intensification and diversification of the rice systems in NW Cambodia using a grounded theory approach. The project expects to achieve identification of barriers, threats, constraints and opportunities for NW Cambodian rice production and was based on the data from the participatory rural appraisal survey (PRA). This will lead to poverty reduction and improved food production in line with Sustainable Development Goals SDG (completed).

Production and marketing of mungbean

Ashley Rootsey analysed the Project's proposed mungbean diversification option using the value chain framework analysis to highlight opportunities that require intervention. The benefits of utilising entrepreneurship strategies was also being explored regarding mungbean diversification options (completed).

Opportunities for vegetable and fish production

Louise Capistrano has reviewed the current situation of aquaculture and vegetable production in Cambodia and will evaluate the constraints and opportunities farmers are facing and implications towards socioeconomic status, location and access to water. It is expected that these findings will assist CamSID in defining community research priorities for vegetable and aquaculture diversification (completed).

Evaluation of Normalised Difference Vegetation Index (NDVI) as an aid to optimising timing and application rates for nitrogen topdressing in rice

Bintu Moseray has evaluated the hand-held GreenSeeker® NDVI reflectance meter as an aid to optimising timing and application rates for nitrogen topdressing as part of the development of best-practice guidelines for rice production in Cambodia in a Masters project. The work also involved using GreenSeeker® to calibrate Unmanned Aerial Vehicle (UAV) remotely sensed NDVI. The work is being carried out in collaboration with Bob Martin, Don Bosco Foundation Cambodia and SM-Waypoint Co. Ltd. Further work is now being done to explore practical applications for Cambodian farmers (completed).

Assessment of forest change dynamics with remote sensing

Bhakti Uday Haldankar has completed a multi-scale assessment of land clearing the northern floodplains of the Tonle Sap Lake (TSL) which is a significant wetland area. This is of importance to the project because it coincides with the Active Flood Plain (AFP) targeted area. A ground-truthing survey in May 2017 provided insights into land clearing and land tenure arrangements that will influence project developments in this area (completed).

Entrepreneuring towards sustainable development

Jamie Loveday has completed an honours thesis with the Sydney School of Business. He aims to make a contribution by being the first empirical application of the concept of ‘entrepreneuring’ as a practice-approach to entrepreneurship in a Cambodian context. He has interviewed leading farmers identified in the Banteay Meanchey and Battambang Provinces in May 2017 (completed).

3.3 Community impacts

Community impacts relate to changes in social, economic, or environmental conditions due to uptake of project outputs by collaborators outside the project. To this end, collaborative agreements have been signed with Ockenden in Banteay Meanchey and with Voluntary Service Overseas (VSO) in Battambang. Currently the project is engaged with five communities in Battambang. Collaboration with VSO is enabling project innovations to be directly extended to a total of 13 Farmer Associations in Battambang. An example of progress toward impact is that Ockenden helped organise for 120 farmers in BMC to participate in the seed planting demonstration at Kuok Tonloap Village on 10 July 2017.

3.3.1 Economic impacts

Through on-farm demonstrations, the project is engaging with smallholder farming communities to grow two short duration rice crops (where irrigation water is available) and a non-rice rice crop on residual soil water to increase and diversify their income sources.

3.3.2 Social impacts

The project has become engaged with 10 communities in the target region through Participatory Rural Appraisal (PRA) and the Baseline Survey (BS) in Objective 1. These communities have expressed strong interest for engagement in Objective 2 activities such as assisting farmers to adopt more sustainable and profitable production practices by benchmarking against the Sustainable Rice Platform (SRP) Standard.

3.3.3 Environmental impacts

Training smallholder farmers in optimised use of fertilisers will increase fertiliser use efficiency and reduce the risks of nutrient pollution and eutrophication. As part of best practice farm training, training materials are currently being developed to identify beneficial and destructive insects/diseases and weeds and to implement integrated pest management practices. Another initiative is a new trial with rice husk ash as a soil ameliorant and to provide silicon to protect rice crops from blast.

3.4 Communication and dissemination activities

A survey of farmers' communication needs and a pilot radio show were conducted with CamSID target villages in Battambang in early 2017. The talk-back radio show attracted very little feedback from listeners and it was subsequently found that only 44% of survey respondents listened to radio compared to 78% who watched television. In addition, only 12% of respondents used radio to source technical information for agriculture. Although more respondents watched television only 2% used it as a source of technical information.

Farmers' information needs were aligned with input and marketing information and less towards management information. All respondents favoured NGOs for the provision of agricultural information and this is likely to be affected by their proximity to the Battambang provincial centre. Although only 2% of respondents currently source technical information from television, 93% said they would like to source agricultural information from television compared to 49% for radio.

There was little interest in print media for the communication of agricultural information with the possible exception of Factsheets. The level of literacy might be a factor here and simpler Factsheets with more pictures and less words might be worth following up.

There was no interest in obtaining agricultural information via mobile/SMS or computer Apps and a possible reason for this was the absence of the 15-24 age group in the survey. This might be a problem where village officials are left to decide on who should join the surveys. Stratified sampling to ensure equal representation * age group would remedy this problem.

A newsletter currently edited by Dr Van Touch (3 produced so far), Khmer Rumduol Meas has been distributed to partners and stakeholders to disseminate progress and news on the project. Khmer TV8 crew filmed the rice direct seeding demonstration at Kuok Tonloap Village on 10 July 2017 and was broadcasted on Saturday 15th July and re-broadcast on Monday 17th and Tuesday 18th July 2017.

https://www.youtube.com/watch?v=iAiZK6zZJcs

The Crawford Fund training group has set up an Crawford Ag Leaders (New) Facebook site:
https://www.facebook.com/groups/1728309297492681/permalink/1741938839463060/

A Facebook page for CSE-2015-044 has also been set up and moderated by postdoctoral fellows, Dr Van Touch and Dr Rebecca Cross:

https://www.facebook.com/CambodiaSID/

4 Training activities

4.1 Crawford Fund training activity

A Crawford Fund (CF) training activity organised jointly between our project team and the Crawford Fund, was held in Banteay Meanchey and Battambang provinces from 16th October to 1st November 2016. The course was designed by SFSA's Clive Murray, working closely with Dr Yorn Try, MCU's Vice-Rector. Trainers came from Cambodian and Vietnamese research and education institutions, CropLife Asia (part of a global federation of agribusinesses) as well as USYD and SFSA. The trainees were mostly young graduate employees of government research institutes and extension services, NGOs and private-sector input suppliers; a few of the latter attended at their own expense. Training was conducted in English and Khmer, and copies of the presentations were distributed on USB drives. The feedback from the trainees about all the trainers was uniformly positive; almost all trainees said the course would help them in their job of transferring technology to farmers and that they would attend again if offered the chance. Many wished the course had been longer and more detailed; a few had had problems of language comprehension, including the sole trainee from Laos.

In future, we should also list the number of farmers that have been trained. This should be over 300 by now across all the demo days. In future, we should also include sessions organised by Ockenden as well those that Try and Cuong have supported.

4.2 Training of students through the Participatory Rural Appraisal and Baseline Study

A key ongoing legacy of this project is likely to flow from the training and participation of MCU and UBB students in the PRA and BS. These students received invaluable experience in participatory methods, developed skills in interviewing, translating and data entry, and interacted face-to-face with many farmers and community members. This will make them highly employable in ongoing projects. These MCU and UBB students, and young field staff already employed, could be brought together in a network to share experiences, develop skills and improve coordination of projects.

4.3 Soils workshop

About 3 years ago, Yunnan Agricultural University and Agricultural Department of Yunnan Province, China donated a series of soil analyzing equipment with a total investment of half million US$, set up the soil analyzing lab in MCU, all the equipment were made in China, with manual all in Chinese. Prof. Renzhi Zhang and Prof. Lingling Li of Gansu Agricultural University visited MCU December 2017, together with Dr. Try, raised an idea to organize a workshop on soil chemical analyzing to enable MCU to develop a soil analyzing lab, and made a start on revising curriculum for Agronomy in MCU. The workshop was then carried out by Profs Renzhi Zhang, Lingling Li and Liqun Cai in February 2018. Over thirteen staff from MCU and UBB were trained in soil sampling and handling, analysis techniques for soil total N, P, K, available N, P, K and soil organic carbon. A soil analysis manual and curriculum for soil science is also being developed.

4.4 Gender capacity building workshop

A specialised workshop was held over two days in 6-7 July 2018. The workshop had 15 participants which included Flavia, Rebecca, Van (who translated all material into Khmer), Seyma Ngann (CamSID), Sophea Yous (CamSID), Yaro Nheb (VSO), Pheakdei (VSO), Nita (VSO), June (VSO), Kea Thavy (Provincial Department of Women's Affairs), Nuon (Provincial Department of Women's Affairs), Vanna (JICA), Rath (UBB), Rosanne Quinnell (USYD) and Bob Martin (CamSID). Flavia Ciribello, VSO gender and social inclusion specialist presented the first half of the workshop on day 1. She focused on gender as a cultural product, gender roles and expectations, and gendered understandings of work in farming households. Participants were asked to reflect on gendered bias in their own lives and completed group tasks to discuss the expected roles of men and women in Cambodian society. Rebecca Cross, CamSID human geographer/social researcher then presented the second half of day 1 by introducing quantitative and qualitative research methodologies, interview and focus group design, and ways to produce qualitative research with a specific focus on gender. Participants were asked to reflect on the benefits of different research methods, design research questions and participate in a photovoice activity. On the second day, participants shared their photovoice images with each other to discuss personal/everyday understandings of gender in their lives.

5 Intellectual property

Enter text

6 Variations to future activities

Variation 1 was approved on 8 June 2017. The main changes were SFSA as a sub-grantee rather than as a partner and several project staff appointed at MCU. There was a sub-contract change as Dr Clemens Grunbuhel has moved from AIT to Stockholm Environmental Institute (SEI), Bangkok.

7 Variations to personnel

In Variation 1, there was change in time allocations for CARDI staff: Dr Chea Sareth's time commitment has been changed to 10% and Mr Som Bunna's time commitment has been changed to 20%.

Dr Petr Matous from USYD Engineering has joined the team to support social network analysis.

A/Prof Rosanne Quinnell from the Faculty of Science has joined the team to support the supervision of Faculty of Science honours students and for her expertise in biology and mobile applications.

8 Problems and opportunities

The project had several opportunities during the past 9 months including partnerships with VSO and Ockenden, and collaborations with CAVAC.

Dr Try was invited to Yunnan to explore collaborations with perennial rice material from China.

Another opportunity was the use of CommCare (mobile acquired data, MAD) for the baseline survey which was piloted by Dr Rebecca Cross (after undergoing initial RAID training) with support from Dr Clemens Grunbuhel and Dr Van Touch.

Challenges and opportunities

- There should be better alignment of the trial protocols between BMC and BTB.
- There should be critical common measurements in all future trials e.g. we need to measure actual seed rates in seed rate trials. This is to allow meta-analysis.
- Review of the ways trials and villages are managed.
- Critical outputs from the MEL (monitoring, evaluation, learning)

Future plans in the main wet season are:

- Pilot for Quality Declared Seed (QDS) for rice (Svay Cheat) and mungbean (Angsangsak) (led by Dr Bob Martin)
- Field benchmarking for mungbean in BMC (led by Dr Try in collaboration with Dr Bob Martin)
- Rice field benchmarking (led by Dr Bob Martin)
- Compilation and analysis of vegetable production and value chain (led by Dr Bob Martin)
- Analysis and survey of minimum till and previous plastic mulch vegetable grower in BTB.
- Rice wet seeding experiments (led by Dr Try).
- Establishment of hubs in BMC (from existing farmer associations & value chain) (led by Herve and Dr Try)
- Mid-term survey (led by Dr Rebecca Cross)
- Ramp up of scaling plans with engagement with PDAFF BTB and BMC.

9 Budget

Enter text

Annex 1: Monitoring and Evaluation Framework

ACIAR CSE-2016-044

Sustainable intensification and diversification in the lowland rice system in Northwest Cambodia

Monitoring, Evaluation, Reporting and Improvement Plan (MEPlan) DRAFT

Key ME activities (Objective 1)

1. Participatory Rural Appraisal PRA

A qualitative interview and workshop-based survey conducted November 2016 – 8 villages visited, 144 interviews conducted, report produced, used to help design BS and establish contact with villages, identify innovators and potential collaborators, orientate project team to local context, team building, training of project staff and student interviewers.

Outputs: PRA summary report, interview recording and transcriptions, interview analysis, student research paper (Sarah Condran)

2. Baseline Survey BS

A quantitative questionnaire survey conducted May 2017 – re-visited the same 8 villages + 2 more, conducted 526 surveys each of 43 questions, designed and recorded on COMMCARE, to be analysed June/July 2017. Used to design implementation plan to cover Objectives 2 and 3.

Outputs: BS Report, analysis, recommendations for preparation of mid-project survey (MPS) and end of project survey (EPS), recommendations for implementation Plan.

3. Activity Evaluations AEs

Create one or a number of short questionnaires on COMMCARE so that each time there is a project activity, participants can be surveyed. This will require project staff developing activities (demonstrations, consultations, field days, training days, workshops) to make sure people are available with COMMCARE enabled tablets/phones to administer surveys.

Outputs: Activity evaluations collated after each activity and included in MPS and EPS

4. Incidental Evaluations IEs

Create interview pro formas for a range of stakeholders and add them to COMMCARE so that project staff can interview key stakeholders at strategic times, and that data become part of the overall project data.

Outputs: summarised and sent to relevant project members, included in MPS and EPS

5. Focus Groups

Conduct a number of focus groups at strategic points in the project with specific stakeholder groups, villages, researchers, input suppliers, credit suppliers, rice buyers, members of value chain, women empowerment groups etc.

Outputs: Outputs: summarized and sent to relevant project members, included in MPS and EPS

6. Mid Project Survey MPS (formative)

A quantitative questionnaire survey conducted mid to late 2018, designed and recorded on COMMCARE, consisting of some of the same questions from the BS with additional questions to help assess mid project progress towards achieving project objectives and to guide changes to the implementation plan based on the results of the survey. Collate, summarize and analyze AEs, IEs and Focus Groups to include in the report.

Outputs: MPS Report, recommendations for changes to implementation plan

7. End of Project Survey EPS (summative)

A quantitative questionnaire survey conducted mid to late 2021, designed and recorded on COMMCARE, consisting of some of the same questions from the BS and MPS with additional questions to help assess achievement of project objectives at the end of the project and provide legacy information to empower project participants with information to continue the work of the project beyond its formal completion.

Outputs: Final Project reports, papers, legacy data sites, legacy recommendations, post project plan.

8. End of project personnel evaluations (summative)

A mixed methods survey conducted late 2021 with key project managers, staff and participants to crystalize understandings, key learning, reflections on and lessons from the project as well as next steps for a follow-up project.

Outputs: Final project reports, final evaluation, legacy recommendations, post project plan.