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Agrodiversity for **I**n-situ **C**onservation of **L**ocal **R**ice **G**ermplasm **I**n and **N**ear its **C**enter of **D**iversity: **C**ambodia

Contents

Final Report: Cambodia

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Project Title: *Agrodiversity for in-situ conservation of local rice germplasm in and near its center of diversity: Cambodia, Laos and Thailand*

I. Introduction

Being close to the center of origin, Cambodian farmers have been growing thousands of local rice varieties for at least 2000 years. Through natural selection, rice is grown across agro-ecosystems from upland to water depth as much as five meters. Cambodian farmers have grown a diverse rice to cope with this heterogeneity of the growing environment. Therefore, local rice varieties are much more complex in their genetic structure and some of the genetic characters can be use to develop a successful improved rice varieties.

In spite of major changes taken place in its cropping systems in recent years, rice is still the most important crop in Cambodia. The majority of farmers grow rice for home consumption; but sale of the surplus is a very important source of cash income for the countries as well as for their farmers. Since 1980, rice yield per hectare has increased by 4.1% annually. However, reports of high productivity gains are almost always associated with new "improved" rice varieties form national and international breeding programs in favorable environments, especially in irrigated area covering on 13% of total rice area, with 8.9% increase per year; while in rainfed lowland environments covering on 87% of total rice area, with only 3.5% per year.

Increasing labor demand in industry, mainly in garment, results in labor shortage and high cost in agriculture. To cope with this,

Development of new rice high yielding and good grain quality varieties with broad adaptation could not be succeeded without using existing local rice varieties especially for the rainfed lowland environments in Cambodia. Therefore, the project on *Agrodiversity for in-situ conservation of local rice germplasm in and near its center of diversity: Cambodia, Laos and Thailand* played very important role. The general objectives of the project are (i) To develop strategies to improve return from rice farming that is compatible with *in situ* conservation of rice genetic diversity and (ii) To develop the interdisciplinary capacity necessary to accomplish this within and near the centre of diversity of rice in Cambodia, Laos and Thailand. To achieve the two general objectives (GO), four main activities have been taken.

II. Identify agronomic, ecological, economic and social processes relevant to successful rice farming in which genetically diverse local varieties play a key role

To achieve this main objective, three different activities have been taken in 2006 and 2007. First activity was literature review of Cambodian rice, second was baseline survey for rainfed lowland rice and third was baseline survey for deepwater and recession rice.

2.1. Literature Review

Rice is a staple food for Cambodia and grows in four main ecosystems. Rice area under rainfed lowland ecosystem covers about 84% of the total rice growing areas, while dry season (irrigated and recession) covers 12%, upland and deepwater cover similar area (2%). There were more than six thousands of samples of local rice varieties from 20 provinces and cities (there are 24 provinces and cities in Cambodia) have been collected from 1989 to 1996. A total of 2557 distinct accessions have been identified and stored in gene bank at CARDI for short and medium term storage and a duplicated set at IRRI gene bank for long-term storage. Among them, number of local varieties grown in irrigated/recession ecosystem was 0.2%, in deepwater/floating was 1.2%, in upland was 10.6% and the large number (88%) was in rainfed lowland ecosystems (Table 1.1a); 1%, 0.5%, 1.5% and 0.6% having light brown, brown, red and purple, respectively, seed coat color (Table 1.1b); 10% and 0.2% having mild and strong aroma, respectively, and 8.4% are glutinous endosperm (Table 1.1c). Most of local rice accessions are strongly sensitive (63%), while essentially sensitive are 31%, essentially-slightly sensitive are 4.5% and strongly insensitive are 1.7% (Table 1.1d). There was a large variation in qualitative traits of the rice accessions. For example, seedling height ranges from 12 cm to 40 cm, leaf length ranged from 20 cm to 79 cm, Culm length ranged from 46 cm to 194 cm, panicle length ranged from 16 cm to 33 cm, grain length ranged from 4.9 cm to 10.2 cm, and 100-grain weight ranged from 1.3 g to 4.0 g. Base on this review, there is a large diversity of rice in the rainfed lowland ecosystem.

Table 1.1. Percentage (%) of number of rice accessions for rice ecosystems, seed coat color, scent, endosperm type and sensitive to photoperiod.

a. Rice ecosystem (2557)			
Irrigated	Rainfed Lowland	Deepwater/Floating	Upland
0.2	88.0	1.2	10.6
b. Seed coat color (2557)			
Light brown	Brown	Red	Purple
1.02	0.51	1.53	0.59
c. Scent and Endosperm type (2557)			
Mild aroma	Strong aroma	Glutinous	
10.0	0.2	8.4	
d. Sensitivity to photoperiod (1614)			
Strongly insensitive	Essentially-slightly sensitive	Essentially sensitive	Strongly sensitive
1.7	4.5	30.7	63.1

Number in parenthesis indicates number of accessions evaluated.

2.2. Baseline Survey for rainfed lowland rice

Baseline survey was conducted in 2006 in 17 villages (randomly sampled) in five selected provinces (two in Bantey Mean Chey, three in Battambang, four in Takeo, two in Kampong Cham and six in Prey Veng) and composed of two parts: (i) individual interview and (ii) group discussion.

Individual interviewing focused on specific information related to family's rice farming and rice security of 118 farmers composed of 35% of female with a large range of age (47 ± 13 years old), experience in rice farming (29 ± 13 years) and different family's size (5.3 ± 2.0 persons) (Table 1.3a). Most of farmers owned more than two rice parcels which are located in different directions of the house and with an average total rice area of 2.2 ± 2.0 ha and had a large difference in harvest of 5.9 ± 8.8 t in 2005. Forty-five percent of farmers reported rice harvested in 2005 providing enough food for whole period till the next harvest, while the remaining (35%) reported food shortage of an average 4.3 ± 2.5 months. There were five different sources of income reported by farmers (rice, other crops, livestock, fisheries and off-farm) (Table 1.2). All farmers reported that income generated from rice was in average of 69%. 69% of farmers reported that income generated from off-farm was about 0.4 times that of the income generated from rice. Only three farmers made sugar from sugar palm tree that contributed to their income of 29%.

Table 1.2. Income allocation from different sources

Variable	Rice	Other crop	Livestock	Fish	Sugar palm	Off-farm
Farmer involvement (%)	100	24	31	18	3	69
Allocation of income (%)	68.9 ± 20.0	12.0 ± 13.8	18.2 ± 15.9	10.5 ± 9.5	29.0 ± 22.0	26.5 ± 18.7

Seventeen group discussion (one in each village) focused on current variety used and abandoned varieties with their reasons. There were 98 rice varieties being grown in the 17 villages in 2006. Among them, eight varieties are early maturity duration, 43 are intermediate maturity duration and 47 are late maturity duration. Number of abandoned varieties reported by the farmers in each village ranged from 5 to 10 varieties with a total of 110. However, some varieties abandoned in one village they are still growing in another village and such varieties are counted to be 38 varieties. Thus, 72 varieties were the complete abandoned varieties from the target villages. There are 12 reasons that influenced abandon of the varieties. The most common reason was low yield potential (13 villages). Second common reason was because the varieties became impurity (10 villages; 4 ± 2 off-types) and the third (7 villages) was the late maturity duration varieties could not cope with the shorter water availability in the growing areas.

2.3. Baseline Survey for deepwater and recession rice

The survey was conducted in 2007 at 6 villages (randomly sampled) in two selected provinces (four in Kampong Thom and two in Siem Reap). Out of 44 individual interviewed farmers, 13 were female. There was a large range of age (51 ± 15 years old), experience in rice farming (33 ± 15 years) and different family's size (6.1 ± 1.7 persons). Forty two farmers owned more than two deepwater rice parcels (2.5 ± 1.7) which are located in different directions of the house and with an average total rice area of 3.7 ± 2.4 ha with 100% direct seeding and had a large difference in harvest of 4.6 ± 4.5 t in 2006. Recession rice was cultivated by only 13 farmers and all had only a parcel of 0.8 ± 0.4 ha in size with 73% practiced direct seeding and 27% practiced transplanting. Production of recession rice was 2.5 ± 1.8 t. Although they are living in most deepwater ecosystem but 20 farmers reported that they had 1.9 ± 1.6 rainfed lowland rice parcels located in upper deepwater areas. The average rainfed lowland rice field size was 1.3 ± 1.2 ha with production of 1.9 ± 1.5 t. Sixty six percent of farmers reported rice harvested from all ecosystems in 2006 providing enough food for whole period till the next harvest, while the remaining (34%) reported rice shortage of an average 4.5 ± 2.5 months.

Table 1.3 summaries income generated from different sources of the interviewed farmers. There were six different sources of income reported by farmers (rice, fish, other crops, livestock, sugar palm and off-farm). Rice provided generated income in average of 65% of 100 involved farmers. About 1/3 of interviewed farmers catching fish and they reported that fishing generated in average of 24% of the total income. One fourth of farmers generated their income from growing non-rice crops by 15% in average. About 2/3 of farmers raised livestock with income generation of 16%, while 4.5% of farmers produced sugar from sugar palm with 33% contribution to total income. Off-farm activity was done by 52% of the farmers with 22% contribution to their total income.

Table 1.3. Income allocation from different sources

Variable	Rice	Fish	Other crops	Livestock	Sugar palm	Off-farm
Farmer involvement (%)	100	31.8	25	65.9	4.5	52.3
Allocation of income %	65.1 ± 22.9	23.9 ± 16.5	14.8 ± 14.2	15.7 ± 8.5	32.5 ±24.7	22.0 ± 21.2

Six group discussion focused on current varieties used and abandoned varieties with their reasons for deepwater and recession ecosystems. For deepwater rice, there were 22 deepwater rice varieties being grown in the six villages. Among them, three varieties are reported as early maturity duration, none are intermediate maturity duration and 10 are late maturity duration. Number of abandoned varieties reported by the farmers was 23 with four and 19 are intermediate and late maturity duration, respectively. A total of eight early maturity duration rice varieties were reported to be cultivating while two to be abandoned. Farmer groups reported eight reasons for abandon of deepwater rice and two for recession rice. The most common reason for abandoned deepwater rice was civil war (six villages) followed by low yield potential (3 villages). There were 14 traits (4 ± 1) in five popular rice varieties in two provinces reported by farmers as mixture.

2.4. Implications of the main activity 1

There is a large germplasm material that would be use for improvement and in-situ conservation of rice varieties. Mass selection of best materials in genebank can be introduced back to farmers, while popular rice varieties in specific location could be improved and maintained by minimizing undesired traits to increase its production and market quality.

III. Invasive weedy rice in Cambodia

Gene flow between wild and cultivated rice clearly plays a key role in the emergence of invasive weedy rice as a serious threat to rice production. The weedy rice problem, on the other hand, is now spreading in irrigated and intensive rice farming areas in Thailand. In Cambodia, weedy rice can be found in cultivated rice where the wild rice exists. Therefore, there is a need to study on weedy rice and its invasiveness in rice production of Cambodia. Three activities have been conducted and they are (i) to characterize of wild and cultivated rice, (ii) to study inter-fertility between wild rice and improved rice varieties, and (iii) to map wild and weedy rice.

3.1. Comparison between wild and cultivated rice

Characterization has been done for the parents using in hybridization between cultivated and wild rice. A total of 26 agronomic and morphological characters have been evaluated for wild rice and 18 characters for cultivated rice. Generally, wild rice had higher tillering ability than the cultivated rice (40 *vs.* 12; t-test, $P<0.01$), but significantly shorter plant (74 cm *vs.* 106 cm; t-test, $P<0.05$) and smaller leaf width (0.6 cm *vs.* 0.9 cm; t-test, $P<0.01$) than the cultivated rice. Both had no different in leaf length (34.5 cm *vs.* 35 cm; t-test, $P>0.05$).

3.2. Inter-fertility between wild rice and improved rice varieties

In 2006, hybridization between five cultivated rice varieties (recipient) and four wild rice (WR) samples (donor) have been made and 15 of them were succeeded. Among five cultivated, two varieties [Sen Pidao (SPD) and IR66] are inbred lines developed by hybridization and three [CAR1, CAR3 and Phka Romeat (PRM)] are improved varieties developed by pure line selection of the traditional varieties. The former group are popular varieties in irrigated, dry season, and upper fields of the rainfed lowlands and they have early maturity duration with insensitive to photoperiod. The second group is sensitive to photoperiod with intermediate flowering time (20 Oct to 10 Nov). Wild rice using in crossing were selected from four different areas: CARDI, Pochentong (Phnom Penh), Takeo (TK) and Kampong Thom (KT) provinces. The seed set between varieties developed by hybridization and pure line selection had no difference (t-test, $P>0.05$).

Eight F2 populations derived from hybridization between wild (from Kampong Thom=WRKT and Takeo=WRTK) and cultivated (IR66, SPD, PRM and CAR3) rice from 2006 were grown in pots in August 2007 to observe the segregating traits derived from both parents. Data were recorded and analyzed in early 2008. Eleven morpho-agronomic traits were evaluated for all populations (98 plants for IR66xWRKT, 38 plants for SPDxWRKT, 55 plants for PRMxWRKT, 39 plants for CAR3xWRKT, 107 plants for IR66xWRTK, 81 plants for SPDx WRTK, 16 plants for PRMxWRTK and 62 plants for CAR3xWRTK) and the parents (Table 2.1). In general, F2 plants produced less tillers than the parents and intermediate plant height between both parent types. There was variation within the population for plant type, internode color, panicle type and maturing. Awning was dominant trait for all F2 plants.

Table 2.1. Mean values of 11 plant traits in F2 populations and the parents.

Plant trait	Cultivated rice (CR)				Wild rice (WR)		CR x WR (F2)	
	IR66	SPD	PRM	CAR3	KT	TK	KT	TK
Tillering ability	20	26	11	16	33	26	15	16
Plant height (cm)	94	93	125	132	92	75	106	104
Plant type	1	1	1	1	1	2	1.1	1.9
Internode color	3	3	3	2	3	3	2.8	2.8
Leaf blade color	3	3	3	3	3	3	3.0	3.5
Ligule color	1	1	1	2	1	1	2.0	2.0
Auricle color	1	1	1	1	1	1	1.3	1.3
Panicle type	1	1	1	1	3	3	2.7	2.6
Shattering score	1	1	1	1	2	2	2.0	2.0
Awning	1	1	1	1	2	2	2.0	2.0
Maturing (day)	104	103	124	130	117	117	118	118

In 2008, F2 seeds of all populations were sown on 12 July and transplanted on 22 August in different plot sizes depend upon on seedling availability ranged from 180 plants for PRMxWRKT and PRMxWRTK to 1440 plants for IR66xWRTK with 20 x 20 cm spacing at CARDI. Bulk selection (BS) was applied for eight populations base on shattering, grain types and awning. A total of 24 F3-BS have been selected for F4 plants growing in 2009. Modified bulk selection had been applied to select a total of 43 populations in F5 seeds in 2009. Simultaneously, 10 promising F4 seeds have been backcrossed with three recurrent varieties (SPD, IR66 and PRM).

3.3. Invasiveness of weedy rice

During the baseline survey, the interviewed farmers reported there was no problem of weedy rice in their rice field yet although there were few of them. However, the team spotted three locations in Battambang and one in Kandal province that apparently had higher proportion of weedy rice in 2006. Mapping of these four weedy rice areas has been made by using GPS data and design in Aview 3.1 software. Proportion of weedy rice has been counted for four years (Table 2.2). A sampling frame (0.5 x 0.5 m) was used to count the number of weedy rice population. In each area, six to seven samplings were made.

Table 2.2. Percentage and standard deviation (SD) of weedy rice (WR) from 2006-2009.

Village	Year 2006		Year 2007		Year 2008		Year 2009	
	Weedy rice	SD	WR	SD	WR	SD	WR	SD
Reusey Chhor	58	28	45	23	7	4	NA	
East Kakah	44	22	31	23	18	7	5	2
West Kakah	65	8	45	25	15	8	6	3
Anlong Run	37	5	40	10	21	12	5	3

In general, proportion of weedy rice varied greatly due to seed sources and cultural practice. In the first two years, when farmers broadcasted their own traditional seeds threshed by machine the proportion of weedy rice was relatively high (46 ± 11%), but when farmers used the seeds produced from seed company with transplanting the proportion was remarkably reduced to 6 ± 1% (2008 in Reusey Chhor and 2009 in the three locations). Similar trend was recorded (18 ± 3%) when the fields were replanted in September after drought damaging the earlier crops in East Kakah, West Kakah and Anlong Run in 2008. There was no weedy rice has been observed in the rice fields except a very small number grown on the levees and abundant fields. The proportion of weedy rice in deepwater rice area has not been recorded.

3.4. Long term impact of F_2 generation of weedy rice on productivity of cultivated rice

The F1 seeds selected from crossing in 2006 were subjected to break down dormancy under 55^{o}C for three days. After breaking dormancy, the F1 seeds were grown in pots and subjected to dark room after 45 days of sowing to synchronize and enhance flowering for F2 seeds. The F2 seeds were again broken dormancy and then used for the experiment. Four cultivated rice varieties (Sen Pidao, IR66, CAR3 and Phka Romeat) were grown with different levels of mixed F2 seeds derived from crossing between these varieties and wild rice types.

There were four levels of mixing and they are (i) none mixing as control, (ii) 5% mixed, (iii) 10% mixed and (iv) 15% mixed. A split-split plot design with two replications was conducted with wild rice type as main-plots, cultivated variety as sub-plots and mixed level as sub-sub-plots was used. Number of weedy rice plants in each plot, shattering and type of weedy rice, harvested yield of cultivated rice, number of weedy rice seeds remained in the slot of each plot are being recorded. Seeds harvested from each plot were separately kept and then used for next year experiment in the same plot in all years.

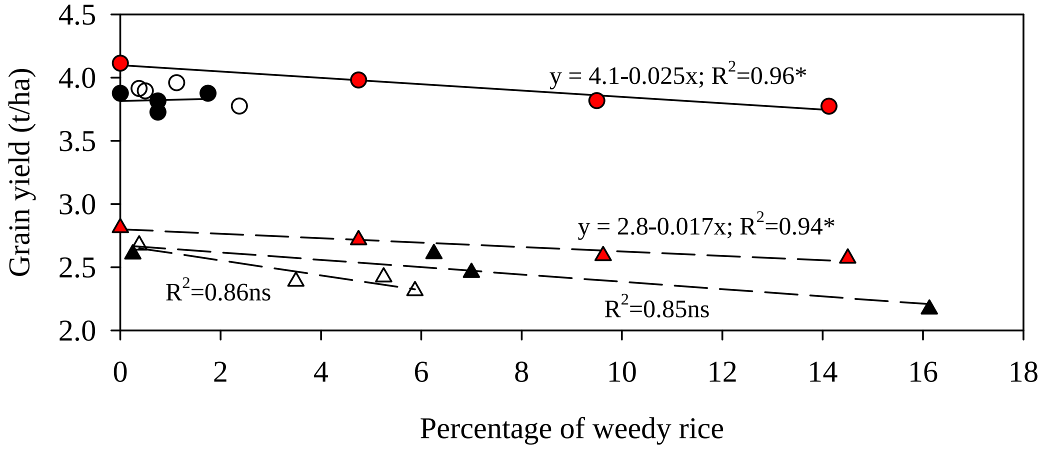

Fig. 1. Effect of percentage of weedy rice on grain yield of medium maturity with sensitive to photoperiod group (circle) and early maturity insensitive to photoperiod group (triangle) in 2007 (red), 2008 (black) and 2009 (opened).

Mixing treatment significantly ($P<0.05$) affected grain yield of all rice varieties only in year 2007. Combined analysis over years indicated significant effect among rice varieties for grain yield, but not effect of mixing treatment, source of wild rice and all interactions. However, when analysis was done for two groups of rice varieties (early maturity with insensitive to photoperiod (ESP): SPD and IR66, medium maturity with sensitive to photoperiod (MIP): CAR3 and PRM), there was an interaction effect ($P<0.05$) of variety group-by-mixing treatment (Fig. 2.1) with grain yield of the ESP group tended to be affected by mixing treatment while the MIP group was not affected. This is because of the percentage of weedy rice remaining in the ESP group was relatively higher than that in the MIP group in second and third year.

IV. Utilization of rice germplasm for glutinous and drought improvement

This main activity composed of two activities and they are (i) utilizing rice germplasm for improving glutinous rice and (ii) screening existing rice materials for drought tolerance.

4.1. Utilizing rice germplasm for improving glutinous rice

Glutinous rice has been grown in Cambodia at the same time with non-glutinous rice. However, Cambodians use glutinous rice mainly for making cake and only few people using as cooked rice for food. Glutinous rice composes of 8.4% of the 2557 rice accessions that have been conserved in gene bank at CARDI. So far, there was no any varietal improvement program for the glutinous rice in Cambodia. Thus, there is a need to start this program.

In 2008, seeds of 121 accessions of glutinous rice conserved in gene bank were sown on 18 July and transplanted on 25 August 2008 with one seedling per hill. Out of 121 accessions, eight accessions (further refer as line; acc.1719, acc. 1399, acc. 1818, acc. 2643, acc. 1861, acc. 1166, acc. 396-II-1, acc. 396-II-2) have been mass selected by removing undesired types. Simultaneously, about 100 g seeds of all screened accessions were processed as rejuvenated seeds and restored back into genebank. Seeds of eight selected lines were multiplied in wet season 2009. Undesired types in each line have been removed and seeds were bulked for multi-location trial in 2010 using resource from CARDI.

4.2. Screening rice for drought tolerance

A large proportion of the Cambodia's poor farm is in rainfed systems where the water supply is unpredictable and droughts are common. Drought can occur any time during the wet season, and rice production may be reduced greatly. In contrast to the irrigated rice system, yield gains from crop improvement of rainfed rice have been modest, in part because there has been little effort to breed and select for drought tolerance in these target environments. Rainfed lowland rice in Cambodia is diverse and there is a need to identify the varieties that tolerant to drought for direct or indirect use in rice improvement of Cambodia.

Drought screening was conducted at CARDI for three years from 2007 to 2009. A set of 84 rice genotypes composed of traditional (including glutinous rice) and improved released varieties was used in 2007. In 2008 and 2009, out of 84 genotypes, only 71 genotypes (35 glutinous mainly from gene bank, 25 released varieties, 8 sub1 breeding lines from IRRI, and 3 breeding lines) were used. The experiment consisted of two water treatments; flooded, well-watered (WW) and water stressed (WS) (drained fields to develop drought conditions), which were located in adjacent paddies separated by a bund. The WW treatment relied on rainfall and supplementary irrigation. In the WS treatment, small canals (10cm in depth) were dug throughout the fields to collect water into a well 50cm deep, dug in the corner of the fields. The water was pumped from the field during the drained period. The field was drained at 5-6 weeks after transplanting. The experiment was arranged in three randomized complete blocks within the two water treatments. For the analysis of variance, the water-treatments were treated as main-plots, with replicates within main-plots, and genotypes as sub-plots. The sub-plots were 1.2 × 3.0 m in size (six rows). In 2007 and 2008, seeds were sown in July and transplanted about a month later; and in September in 2009.

Mild drought was developed in 2007 with overall mean grain yield reduction of 39%, while in 2008 there was a continuously rains since imposing drought, thus, there was no drought condition developed and the overall mean grain yield of both conditions did not significant difference. Experiment was conducted late in September and all genotypes are at ripening stage so the results are not presented in this final report.

Results obtained from 2007 experiment indicate that there was an effect of water treatment and genotype on grain yield (GY), days-to-maturity (DTM, for genotype only), plant height (PH) and spikelet sterility (SS) and their interaction for the first three variables (Table 3.1). Water-stress treatment reduced GY by 39%, PH by 12 cm and SS by 14%. Grain yield reduction due to water-stress treatment was positively associated with reduction in spikelet fertility ($y = 2.94x – 0.9$; $R^2 = 0.81$**) and DTM ($y = 1.59x – 178.5$; $R^2 = 0.56$**), indicating that late maturing genotypes were stronger affected by drought. However within the maturing group (except early maturing), genotypes respond differently under water-stress treatment. For example, G64 and G70 had similar GY under both water treatments, but in other three maturing groups there was a difference among the genotypes G81, G83 and G25 in maturing group 130-149 days, G37, G76 and G42 in maturing group 140-149 days and between G27 and G15 in maturing group later than 149 days (Table 3.2).

Table 3.1. Mean and ANOVA for grain yield (GY), days-to-maturity (DTM), plant height (PH) and spikelet sterility (SS) at CARDI, 2007-2008.

Growing condition	GY (t/ha)	DTM (day)	PH (cm)	SS (%)
Water-stress treatment	1.520	139	96	34
Well-watered treatment	2.487	137	108	20
Difference	0.967	3	12	14
Source of variance				
Water treatment (WT)	*	ns	**	*
Genotype (G)	**	**	**	**
G x WT	**	**	**	ns

** = significant at $P<0.01$, * = significant at $P<0.05$, ns = not significant.

Table 3.2. Different responses to water-stress treatment among different maturing groups

Genotype	DTM (day)	Grain yield (t/ha)		GYR (%)	SFR (%)
		WSC	WWC		
Maturing group: <130 days (27 genotypes)					
G64	123	2.485	3.086	19	3
G70	123	2.315	3.002	23	7
Maturing group: 130-139 days (12 genotypes)					
G81	130	2.096	3.473	40	7
G83	138	1.690	3.148	46	11
G25	133	0.631	3.150	80	27
Maturing group: 140-149 days (27 genotypes)					
G37	141	2.268	3.279	31	11
G76	143	1.793	3.390	47	25
G42	146	1.205	3.115	61	12
Maturing group: ≥150 days (18 genotypes)					
G27	151	2.686	3.268	18	15
G15	150	0.566	2.986	81	23

Thus, genotypes G64, G81, G37 and G27 performed better in moderate drought stress. However, this result will be confirmed with 2009 experiment result when data collection has been completed.

V. Collaborative experimentation and demonstration strategies for improving return from rice farming based on genetically diverse rice varieties

Rainfed lowland rice in Cambodia is very diverse in which thousands of rice varieties are being grown every year. This diversity indicates that rainfed lowland rice is grown under erratic and unpredictable rainfall, diverse biotic and abiotic stresses, and different farmers and consumers preferences. The breeding program of Cambodia with respect to this situation has released about 30 rice varieties to cope with this diversity. However, the breeding program uses broad adaptation strategy for release of these varieties. In fact, a specific adaptation plays very important role in rice diversity. In contrast, seed impurity was reported by the farmers interviewed in 2006 as the second main reason for farmers to abandon the varieties. Thus, there is a need to train farmers on how to maintain phenotypic purity of local rice varieties for increase productivity and market value with minimizing loss of genetic diversity. To achieve this main objective, three sub-activities have been carried out and they are (i) introduction of improved traditional popular variety by mass selection method, (ii) increase rice productivity by eliminating undesired types from existing varieties, and (iii) introducing improved rice varieties.

5.1. Introducing improved traditional popular variety by mass selection method

In 2005, more than 100 panicles of Phka Khnei, a popular traditional rice variety, have been selected from different fields in Takeo province. All panicles were grown separately in 2006 and three lines have been selected by mass selection method. In 2007, the selected lines were grown at CARDI and after evaluation one has been selected. The selected line then has been introduced to farmers through demonstration plot comparing with farmer's Phka Khnei variety at 10 locations in Takeo (one was failed by flood) in year 2008 and 40 locations (25 in Takeo, 15 in Battambang) using the project resource. Three locations at Battambang were damaged by early drought at seedling stage.

Table 4.1. Grain yield (t/ha) and farmer's preference for Phka Khnei line selected by pure line selection method.

Year	Phka Knei line	Farmer's Phka Khnei	% Yield advantage	Farmer's first preference	
				Phka Khnei line	Farmer's Phka Khnei
2008 (9)	3.359	2.860	17	7	2
2009 (37)	3.986	3.523	13	37	0
Overall mean	3.915	3.423	14	44	2

At all succeeded locations, the Phka Khnei line performed better than the farmer's Phka Khnei variety in grain yield by 14% in average (Table 4.1). Out of 46 farmers, 44 preferred Phka Khnei line. To release this Phka Khnei line, the team conducted field day on 6th December 2009 involving 132 participants (105 are farmers, the rest are chief and staff of district administrative and director and staff of provincial department of agriculture) and chaired by Minister of the Ministry of Agriculture, Forestry and Fisheries. After seeing the overall performance of rice in the field; grain, milled and cooked rice; and preliminary results obtained from 2008 and harvested fields in 2009, farmers and Minister approval for release and name it as Phka Chan Sen Sar. The team also distributed to all participated farmers of 5 kg seed each.

HE Dr Chan Sarun, Minister of MAFF chaired the field day and named Phka Khnei line as Phka Chan Sen Sar in Sunday 6th December 2009 at Kandoul village, Bati, Takeo.

5.2. Increase rice productivity by eliminating undesired types from existing varieties introducing and improved rice varieties

In 2006, 10 farmers in five provinces were collaborated in purifying their local varieties to improve productivity and market value. In wet season 2007, purified seeds were grown in the 10 farmer's fields. Unfortunately, early flood in Northwest provinces completely damaged four farmer's fields and only one field in Battambang was not affected. Two fields in Kampong Cham were seriously damaged by Brown plant hopper. Thus, only four fields are good and now at harvesting time. In 2007, the team also extended this activity and methodology into 16 farmers more in Prey Veng. They are growing 10 different rice varieties including three glutinous rice varieties. The farmer's purified seeds of 16 farmers in 2007 were grown in 2008 with two improved rice varieties (Phka Rumduol and Phka Romeat) and farmer's unpurified seeds. Also in 2008, three improved varieties (Phka Rumduol, Phka Romeat and Phka Rumdeng) were introduced to 20 farmers (one failed) in Svay Rieng and Battambang to compare with their local varieties.

Results obtained from 2007 (four fields) and 2008 (16 fields) indicate that purified seeds produced higher grain yield around 20% than the unpurified seeds (Table 4.1). Mean grain yield of purified seeds in 2007 was 2.53 t/ha and in 2008 was 3.00 t/ha. Meanwhile, two improved varieties also produced higher grain yield than the purified seeds of about 3% and unpurified seeds of 27%. Phka Rumduol yielded 2.87 t/ha which was 49% higher than the. all improved varieties yielded of 27% to 49% higher than the farmer's local variety, Phka Romeat was 24% and Phka Rumdeng was 27% (Table 4.2).

Table 4.1. Results obtained from purified seeds in farmer's fields, 2007-2008.

Farmer's variety	2007 (4 fields)		Variety	2008 (16 fields)	
	Yield (t/ha)	%YA		Yield (t/ha)	%YA
Purified	2.53	18	Phka Rumduol	3.09	27
Unpurified	2.15		Phka Romeat	3.07	27
			Purified	3.00	24
			Unpurified	2.42	

Table 4.2. Results obtained from on-farm trial, 2008

Variety	Yield (t/ha)	%YA
Phka Rumduol	2.87	49
Phka Romeat	2.39	24
Phka Rumdeng	2.46	27
Farmer's variety	1.93	

Post-graduate study: Mr Leng Lay Hout, a MSc. student in Chiang Mai University, was successful completed in late 2009 and back to work for CARDI in the Plant Breeding Division.