IMPROVED TECHNOLOGY PACKAGES FOR UPLAND CROPS IN CAMBODIA

Technical Methods Manual for Demonstrations

ROBERT MARTIN & CHAN PHALOEUN (EDITORS)

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

ACIAR-04: CROP DIVERSITY – HEALTHY FOOD – CASH INCOME

Improved Technology Practices for Upland Crops in Cambodia

Technical Methods Demonstration Manual

Edited by Robert Martin and Stephanie Belfield

ACIAR-04: Crop Diversity – Healthy Food – Cash Income

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Introduction

This manual was made possible through funding provided by the Australian Centre for International Agricultural Research (ACIAR). The ACIAR project ASEM/2000/109 'Farming Systems for Crop Diversification in Cambodia and Australia' (ACIAR04) ran for 4 years from 2003 to 2007. The collaborating agencies were NSW Department of Primary Industries (NSW DPI) Australia and the Cambodian Agricultural Research and Development Institute (CARDI). The project leaders were Dr Bob Martin for NSW DPI and Ms Chan Phaloeun for CARDI.

The focus crops for the project in Cambodia were maize, soybean, peanut, mungbean, sesame and cowpea, and the project's experiments and demonstrations were located in Kampong Cham and Battambang Provinces. Socioeconomic surveys, farmer meetings and workshops were conducted to identify problems and farmer's needs. Experiments and demonstrations were carried out in farmers' fields in collaboration with provincial agricultural extension staff plus researchers from CARDI.

A total of 153 on-farm experiments and demonstrations were conducted between 2004 and 2006. The research included:

- variety evaluation
- effect of major insect pests and disease
- agronomy and farming systems
- rhizobium inoculation for legumes
- reduced tillage and crop residues
- socioeconomic analysis.

Potential impacts of the research on upland crops in Cambodia are huge considering that major yield increases can be achieved. In 2006, demonstrations of improved technologies were commenced for mungbean, sesame and peanut in the early wet season and on mungbean, soybean and maize in the main wet season. Farmers at field days at these sites displayed considerable interest in the new technologies, and individual farmers had tried parts of the technology practices on their own farms. Farmer feedback at these field days was recorded to allow the refinement of the improved technology practices (ITPs) in the future.

This manual is part of a package to enable extension workers and other agencies, including Non-Government Organisations (NGOs), to implement on-farm demonstrations of improved technologies for upland crops. In 2007 the on-farm program was successfully piloted with the Maddox Jolie Pitt project (MJP) in the Samlaut district of Battambang and CARE in Pailin municipality. The demonstration program includes:

- pre-season overview and instruction workshop
- technical methods manual
- ready-weighed seed, fertiliser and rhizobium inoculum
- tape measure, string and labels
- instructions on applying the treatments
- rain gauge, measuring sticks
- knapsack sprayer
- data recording sheets
- field day questionnaire
- evaluation form.

Bob Martin and Chan Phaloeun (Project Leaders)

Socioeconomic background and constraints to production

Robert Farquharson, Chea Sareth, Chapho Somrangchittra, Richard Bell, Seng Vang, Wendy Vance, Robert Martin, Ung Sopheap and Fiona Scott.

Summary

Cambodia has achieved food security with respect to rice production and has an opportunity to pay more attention to boosting production of other crops such as soybean, mungbean, maize, sesame, peanut, chilli and cowpea. Although rice remains the main crop in Cambodia, the production of other crops is undergoing rapid expansion and will be especially important for the development of those parts of the Kingdom unsuited to lowland rice.

In 2004, socioeconomic surveys were carried out in the Battambang, Kampong Cham and Takeo provinces to identify available resources, management practices and key constraints for emerging upland cropping systems (Figure 1). These are mainly cash crops, so the important issues to consider are profitability, technological and management changes, and household and social issues.

The surveys were conducted in the districts of Kamrieng, Sampov Lun, Ratanak Mondul and Banan in Battambang province; Chamkar Leu, Ou Reang Ov and Tbaung Khmum in Kampong Cham province; and Tramkak in Takeo province. Sample sizes were 191 in Battambang, 181 in Kampong Cham and 50 in Takeo. Generally, farm families had a male head aged in the mid-40s, with 3 or 4 years of schooling.

Family size averaged 5 or 6 persons, with 2 or 3 being dependents, and levels of off-farm work were very low. Average farm size was 2 to 8 ha, and capital items owned included draft animals, ox carts and mouldboard ploughs, as well as tractors and disc ploughs in some areas.

The main reasons given for not growing crops were poor yield performance, lack of knowledge (especially about insects), concerns about profitability, land/soil constraints, labour/equipment issues, and agronomic and climate risk (including drought).

These results helped us to focus our research on new technologies and management as they affect crop yields and profits, and on increased extension to Cambodian farmers of this information.

Results of the surveys

Factors affecting production

The factors impeding crop production were yield performance, drought, insect problems, small land area and low market demand (Table 1). The major reasons for not growing crops were lack of knowledge; concerns about profitability; land/soil constraints; labour/equipment issues; and agronomic and climate risk.

Table 1. Major factors impeding production of crops and reasons for not growing upland crops.

FACTORS LIMITING CROP PRODUCTION		
Low yield	Drought	Small area
Seed cost	Seed shortage	Insect problems
High labour cost	Soil infertility	Unsuitable time
Management	No irrigation	Low market demand
Not popular crop		
REASONS FOR NOT GROWING A CROP		
Marketing	Profitability	Seed costs
Capital constraint	Labour/equipment	Agronomic risks
Lack of varieties	Climate/drought	Agronomic constraint
Theft	Lack of knowledge	Land/soil constraints

Figure 1: Mr Chea Sareth (right) conducting the socioeconomic survey.

Average farm areas

Average farm areas are shown in Table 2. In general, average farm areas were in the order of 2 to 8 ha. Rice was still grown on many farms in these districts, and there is some evidence of land being rented between farmers. These farm sizes are larger than the rice farms in Cambodia (0.2 to 2 ha per family). The districts of Sampov Lun and Kamrieng were more recently settled and farm size tended to be larger.

Table 2. Average farm areas.

DISTRICT	AREA OPERATED (ha)
Sampov Lun	7.5
Kamrieng	5.9
Ratanak Mondul	3.9
Chamkar Leu	4.0
Tbaung Khmum	4.4

Loans taken out by farmers

The results from the question relating to debt and borrowing are given in Table 3. A higher percentage of the farmers surveyed in Sampov Lun (63%) and Kamrieng (72%) than in the other districts (around 30%) reported crop loans. In the north-west districts the Thai traders may have an influence on loans through financing the cost of hybrid maize seed and crop inputs not normally applied in other areas.

For all loans a similar trend is apparent, with 79% and 97% in Sampov Lun and Kamrieng, respectively, reporting loans and 45%, 51% and 29% in Ratanak Mondol, Chamkar Leu and Tbaung Khmum respectively. Farmers with larger farm areas (Sampov Lun and Kamrieng) appeared to have more and larger loans. Crop loans were generally short term (averaging less than 12 months). Evidence of interest rates paid by farmers was found to be unreliable from this survey. Other information of the interest rates paid by Cambodian upland farmers indicates that they pay a minimum of 3% per month, even for concessional finance from non-government organisations. Information collected for all loans indicates that those borrowing often did so each year, but that the amount generally differed. There seemed to be some choice of lenders, i.e. borrowers did not always use the same lender. Interest rates seemed to vary both within a season and between years.

Table 3. Loans taken out by famers.

	FARMERS (%)	LOAN ('000 R)	TERM (MTHS)
Sampov Lun	63	3403	11
Kamrieng	72	1755	10
Ratanak Mondul	32	670	8
Chamkar Leu	30	390	6
Tbaung Khmum	29	400	6

Capital items owned

Capital items owned are shown in Table 4. Power for farm operations is provided by draft animals (cattle or buffalo) or tractors (smaller hand-steered or larger conventional 4-wheeled). Draft animals and ox carts are the main sources of power and transport, being present in each district. Large tractors were reported in Sampov Lun and Tbaung Khmum, with hand tractors in more traditional areas. Disc and mouldboard ploughs were present in the districts with tractors and draft animals, respectively. Hand-held spray units were owned by a substantial number of farmers, and pumps, tube wells and threshers were owned in only some districts. Unlike in most other parts of Cambodia, farming is more mechanised in the north-west districts of Battambang. There were 737 and 154 private tractors in Battambang and Kampong Cham provinces, respectively, in 2002, and 165,226 ha and 47,204 ha of ploughed area. These statistics have grown substantially in the north-west provinces since 2002.

Table 4. Capital items owned (% farmers).

	SAMPOV LUN	KAMRIENG	RATANAK MONDUL	CHAMKAR LEU	TBAUNG KHMOM
Draft animal	21	17	81	36	50
Tractor	25	6	6		21
Disc plough	21		3		
Mouldboard	4		39	19	21
Spray unit	58	50	35	34	39
Pump			10	6	
Tube well	4	3	16	6	
Ox cart	17	6	55	26	25
Thresher	8			4	17

Crop yields and prices

Maize yields range from 2.6 to 5 t/ha, soybean yields from 1.0 to 1.6 t/ha and mungbean yields from 0.1 to 0.7 t/ha (Table 5). Maize prices varied from 300 to 400 riel/kg in each district. Generally no maize seed was kept for the next year's crop. Yields of the other crops were generally low – 0.3 to 0.4 t/ha for cowpea, 0.7 to 1.7 t/ha for peanut, and 0.3 to 0.7 t/ha for sesame. Prices for these three crops ranged from 1100 to 2000 riel/kg. In comparison with these statistics, the official average yields in 2004 appear to be higher in Battambang and Kampong Cham for maize, but generally equivalent for other crops.

Table 5. Crop production and prices.

CROP	t/ha	r/kg	$/ha
Cowpea	0.350	1163	102
Mung bean	0.380	1157	110
Sesame	0.475	1559	185
Soybean	1.120	1044	292
Maize	4.025	340	342
Peanut	1.133	1925	545

Actual and potential crop yields

As for all farmers, but especially for those with small farms, the achievement of improved income security depends primarily on producing more of a crop in an efficient fashion, so that profits are improved. Potential yields for any particular location depend on a range of management practices being adequate. This includes managing fertile soil to grow a crop free of weeds, pests and diseases in a timely fashion to make most use of available rainfall, along with having the best available crop varieties, and being able to deliver a crop product that is of good quality and for which a fair market price is paid. At this stage it is still unclear what the potential yields are likely to be in the Cambodian upland context.

Two methods were used to derive estimates of the maximum potential crop yields and Cambodian potential farm yields. Our estimates were derived by personal communication with John Holland (New South Wales Department of Primary Industries), and Dr Graeme Wright (Queensland Department of Primary Industries). The maximum potential yields are worldwide, given optimal climatic and unconstrained soil and nutrient conditions (Figure 2).

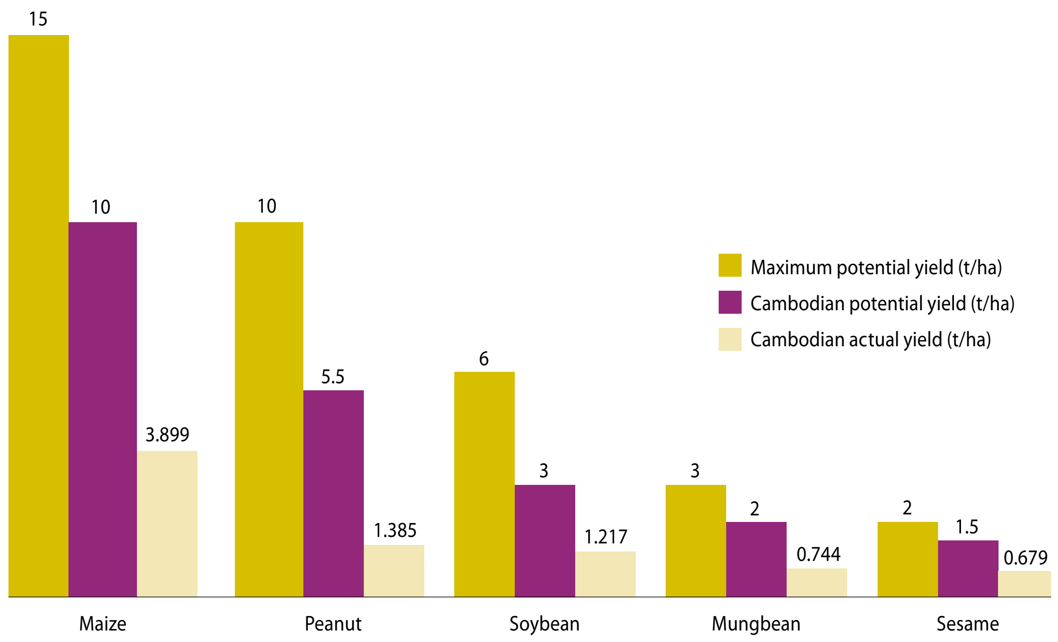


Figure 2. Actual and potential crop yields

The Cambodian potential farm yields are lower, primarily because of solar radiation and temperature factors. In Cambodia the effect of these factors is to reduce crop maturity times and lower the amount of solar radiation available to the crop. Also, some short-duration crop varieties with lower yield potential are often grown to reduce crop losses from drought.

For maize the surveyed yields are less than half the potential yield of 10 t/ha, except in Sampov Lun and Chamkar Leu, where yields are up to 60% of potential. Surveyed soybean and mungbean yields are also less than half the potential yields, substantially so in some cases. Peanut, cowpea and sesame yields are very low compared with the potential farm yields. These comparisons indicate the substantial potential for farming systems research to contribute to improved performance of Cambodian farms and increased farm-family wellbeing.

Figure 3. Ms Chan Phaloeun and Mr Seang Lay Heng inspect a mungbean variety trial in Battambang.

Testing of improved varieties

Sakhan Sophany, Seang Lay Heng, Nin Charya, Chou Vichet and Stephanie Belfield.

Objectives

The objectives of the CARDI plant breeding program for upland crops are to select high yielding and good quality varieties of mungbean, soybean, peanut, sesame and maize adapted to the rainfed upland conditions of Cambodia.

Cambodian farmers traditionally grow rice, which is the number 1 crop in Cambodia. Over the last 17 years plant breeding in rice has significantly improved and new varieties have been released for farmers to grow. Farmers have readily adopted the new rice varieties, which provide increased yield, production and quality.

However, little research in Cambodia had been done into plant breeding of upland crops before ACIAR04 began in 2003, so farmers still mostly grow local varieties. ACIAR04 has been evaluating varieties from other countries that may be suitable for release in Cambodia.

What makes a better variety?

Varieties are considered superior to local varieties if they have some or all of the following qualities:

- higher yield
- resistance to the major diseases of that crop
- resistance to the major insects of that crop
- suitable maturity to fit the rotation
- lodging resistance
- drought tolerance
- seed quality to meet market specifications.

Higher yield is important, because if farmers can get more yield on the same amount of land their income will increase and return on equity of the farm will improve. An easy way for the farmer to increase yield is to grow a new variety with a higher yield potential than the local variety. However, it can take 10 to 15 years for a plant breeder to breed a new variety, so ACIAR04 has concentrated on the evaluation of commercial varieties and breeding lines from Thailand, Vietnam and other countries. This evaluation has been done in Kampong Cham and Battambang Provinces. This seed was kindly donated by these countries to help speed up the path to new improved varieties.

New and pre-release varieties

The plant breeding team at CARDI has so far released several improved varieties. Two new maize varieties (Sar Chey and Loeung Mongkul) were released in 2006. Mungbean lines being considered for release include ATF 3944 and ATF 3946 from Australia. Soybean varieties being considered for release include AG-314 (Taiwan), Nakornsawan No. 1 (Thailand) and Sukhothai No. 2 (Thailand). Sesame pre-release varieties include KUM-5016 (Thailand) and Lngor Sar (Cambodia). Peanut pre-releases are Kbal Rolong and Kbal Chruonh (Camodia).

Varieties evaluated since 2004 are shown in Table 6 (promising varieties in bold type) and their key attributes are given in Table 7.

Table 6. Varieties evaluated : 2004–2006.

MUNGBEAN	SOYBEAN	PEANUT	SESAME	MAIZE
ATF 3941	KKU No. 35	KKU No. 1	KUM No. 6026	SUWAN 5
ATF 3942	KKU No. 74	KKU No. 40	KU No. 20	S-99 TLYQ-AB
ATF 3944	**Nakorn sawan No. 1**	KKU No. 72-1	KU No. 19	**COTAXTLA-S0031**
ATF 3945	**Sukhothai No. 2**	Ah Tragnol	**KUM No. 5016**	AGUA-FRIA S0031
ATF 3946	Chiang Mai No. 60	**Kbal Chruonh**	Black grain	POZA-RICA S9627
Chainart No. 36	AGS-2	**Kbal Rolong**	**White grain**	S-0128
Chainart No. 72	AGS-129			S-99 TLWQ-HG-AB
KPS No. 1	**AGS-314**			S-00 TLWQ-B
KPS No. 2	AGS-371			**S-99 TLW-BN SEQ(1)**
CARDI CHEY	AGS-372			AGUA-FRIA S0030
	DT-84			AGOSS S0030
	B-3039			Composite

Table 7. Key attributes of new varieties.

	VARIETY	DAYS TO FLOWER (DAY)	PLANT HEIGHT (cm)	GRAIN YELD (t/ha)
MAIZE	Sar Chey	52	196	6.40
	Loeung Mongkul	46	201	7.40
MUNGBEAN	ATF 3944	55	52	1.07
	ATF 3946	55	44	1.00
SOYBEAN	AG-314	70	32	1.26
	Nakorn Sawan No. 1	71	35	1.27
	Sukhothai No. 2	77	34	1.25
SESAME	KUM-5016	32	39	1.36
	Lngor Sar	36	34	1.27
PEANUT	Kbal Rolong	28	40	2.00
	Kbal Chruonh	29	37	1.70

Figure 4. **Helicoverpa armigera** *(bean pod borer) causes damage to soybean, maize, mungbean and peanut.*

Management of insect pests and diseases

Pol Chanthy, Khiev Bunnarith and Preap Visato

Field experiments were conducted from 2004–2006 to determine the resistance of upland crop cultivars (mungbean, soybean, cowpea, peanut, sesame, and maize) to major insect pests and diseases in Cambodian upland ecosystems.

Insect pests observed (example: Figure 4) are shown in Table 8. Diseases of mungbean include mungbean yellow mozaic virus (MYMV) and powdery mildew. Diseases of soybean include soybean yellow mozaic virus and downy mildew. Diseases of cowpea include yellow mozaic virus and angular leaf spot.

Table 8. Insect pests and diseases of upland crops in Cambodia.

MUNGBEAN	SOYBEAN	COWPEA	PEANUT	SESAME	MAIZE
Pod borer	Lima bean pod borer	Pod borer (*Maruca* spp.)	*Heliothis* spp.	Leaf folder	Asian corn borer
Green semi-looper	Stink bugs	Pod borer (*Helicoverpa* spp.)	Leaf hopper	Green vegetable bug	Unidentified borer
Armyworm	Soybean leaf miner	Green vegetable bug	Thrip	Brown bug	
Hornworm	White fly	Brown bug			
White fly	Aphid	Green leaf hopper			
Aphid	Leaf hopper				
Leaf hopper					

Some of the varieties have shown promise for resistance to major pests and diseases (Table 9), for example, the mungbean line VC 4512 A. However, despite being moderately susceptible to MYMV, the Australian lines ATF 3941 and ATF 3944 have shown greatest promise when yield is taken into account.

Table 9. Reaction of mungbean varieties to insect damage, MYMV and powdery mildew in 2004.

VARIETY	SEVERITY OF LEAF DAMAGE (%) BY INSECT PEST	MYMV–EWS (KCM)	POWDERY MILDEW MWS (BB)
CARDI CHEY	90	MS	HS
VC 4152 A	68	MR	R
VC 2768 A	55	MS	HR
KK2	50	MS	HR
KK3	83	MS	HS
ATF 3941	63	MS	HR
ATF 3942	60	S	S
ATF 3944	65	MS	MR
ATF 3945	60	MS	R
ATF 3946	63	MS	MR

(BB – Battambang, KCM – Kampong Cham)

Similarly, soybean varieties have shown promise for resistance to major diseases (Table 10).

Table 10. Reaction of different soybean varieties to bean mosaic virus (BMV) and downy mildew in wet season 2004.

VARIETY NAME	BMV–BB	BMV–KCM	DOWNY MILDEW–KCM
KKU 5	S	MS	S
KKU 74	HS	S	S
NAKORNSAWAN 1	MS	MS	HS
SUKHOTHAI 2	S	MS	HR
CHIANG MAI 60	MS	MR	R
AGS 2	MS	MR	R
AGS 129	HS	S	HR
AGS 314	MS	MR	R
AGS 371	S	MR	HR
AGS 372	MS	MS	MR
DT 84	MS	HS	HS
B 3039	MS	MS	R

(BB – Battambang, KCM – Kampong Cham)

Results for insect pest damage to soybean are given in Table 11.

Table 11. Damage by insect pests to soybean: wet season 2004.

VARIETY NAME	POD BORER DAMAGE(%)	APHIDS* KCM	APHIDS BB
KKU 35	68	87	53
KKU 74	13	29	19
NANKORNSAWAN 1	12	23	100
SUKOTHAI 2	7	58	67
CHIANG MAI 60	30	74	93
AGS 2	23	100	93
AGS 129	23	39	10
AGS 314	13	93	84
AGS 371	21	47	77
AGS 372	19	40	84
DT 84	9	46	76
B 3039	32	68	79

Summary

- VC 4152-A mungbean showed best resistance to insect damage, MYMV and powdery mildew, whereas CARDI Chey (recommended) was the worst.
- CHIANG MAI 60, AGS-2, AGS-314 and AGS-371 soybeans were resistant to BMV and downy mildew and performed better than DT84 and KKU-5.
- KKU 74 and AGS 129 soybean were most resistant to pod borer damage. They had the least incidence of aphids and performed better than DT84 and B3039
- Maize varieties S 0128, S 99TLWQ HG AB and S 00TLWQ B were resistant to corn borer, whereas the recommended Composite variety was worst.

The local cowpeas were resistant to angular leaf spot, and only one new variety (KKU 7) gave a similar response.

Figure 5. John Holland, Wes Leedham, Kelly Baker and helpers collecting soil samples in Kampong Cham.

Soils and fertiliser responses

Stephanie Belfield, Bob Martin, Seng Vang and Chan Phaloeun

Soil fertility and pH

It is important to know the fertility of the soil and make sure there are enough nutrients to grow the crop. In 2005 a survey of 100 upland crop fields was done in Kampong Cham and Battambang in the early and main wet season (Figure 5). Fifty of the sites were on Labanseak soil and 50 on Kampong Siem. Samples were taken with a hand-held auger from the top 20 cm of soil (Figure 6).

Soil samples for nitrate and pH were collected to determine the usefulness of NO_3 testing for crop choice and fertiliser application decisions. Soil samples were analysed for organic carbon (OC), total nitrogen (TN), plant-available nitrogen (NO_3) and pH (Table 12).

The levels of plant-available nitrogen (NO_3) were determined by using Merck Reflectoquant® test strips together with the Reflectometer RQflex® meter (Figure 7).

Table 12. Soils data (0-20 cm depth) for 50 sites in Battambang and 50 sites in Kampong Cham.

KAMPONG CHAM							
SOIL	STAT.	OC	TN	FEB–MAR 2005		JUL–AUG 2005	
				pH	NO_3	pH	NO_3
LS	Minimum	1.15	0.90	5.0	9	4.5	2
LS	Mean	1.45	0.128	5.5	28	5.0	10
LS	Maximum	1.91	0.151	6.0	46	5.5	24
KS	Minimum	1.38	0.114	5.0	13	5.0	3
KS	Mean	2.13	0.165	5.7	20	5.4	12
KS	Maximum	3.13	0.227	6.0	37	5.5	34
BATTAMBANG							
SOIL	STAT.	OC	TN	FEB–MAR 2005		JUL–AUG 2005	
				pH	NO_3	pH	NO_3
LS	Minimum	1.36	0.115	5.5	8	5.0	1
LS	Mean	2.07	0.176	5.8	20	5.5	38
LS	Maximum	3.81	0.258	6.0	46	6.0	91
KS	Minimum	1.45	0.105	5.5	3	5.0	10
KS	Mean	2.46	0.181	6.7	22	6.5	50
KS	Maximum	4.50	0.342	8.0	90	8.0	116

Figure 6. Soil sampling and analysis for NO_3 (available nitrogen) in Battambang.

Figure 7. Rapid tests are available for determining available soil nitrate (left) and pH (right).

The Labanseak (red) soils are very acidic, with a pH range of 4.5 to 6.0 in Kampong Cham and 5.0 to 6.0 in the Ratanak Mondul district of Battambang. The pH of Kampong Siem soils ranges from 5.0 to 6.0 in Kampong Cham and from 5.0 to 8.0 in Ratanak Mondul. The soil in Kampong Cham is derived from basalt, whereas the soil in Ratanak Mondul is derived from limestone, and this is most likely the reason for the higher pH in Ratanak Mondul.

Levels of plant-available soil nitrogen (NO_3) in the top 20 cm of soil varied from almost zero to over 100 ppm. The average was around 25 ppm, and this did not vary greatly between soil types and seasons. However, the average for Kampong Cham was 18 ppm and Ratanak Mondul, 33 ppm. The lower level of available N in Kampong Cham is consistent with the lower levels of organic carbon and total nitrogen associated with a longer history of cropping.

Soil depth and water storage

Sowing crops in the early wet season is risky because of the low and erratic rainfall. The risk could be reduced by reducing the amount of ploughing and increasing the amount of ground cover, but this is not likely to be enough to prevent crop failure during very dry years.

Waiting for enough rain to store water in the soil could be an option to reduce the risk of crop failure in the early wet season. It is estimated that it would take at least 150 mm of rain to wet the black clay soil to a depth of 25 cm and 300 mm to wet it to 50 cm. This needs to be confirmed for the Kampong Siem and Labanseak soil types by accurate determination of plant-available water content (PAWC).

On average at Battambang, 150 mm would have been received by the end of April and 300 mm by the end of May. Application of a sowing rule of 50 cm depth of wet soil would mean that no crop would be sown in the early wet season in some years, and the farmer would have the option to put the saved inputs into the late wet season crop rather than risking a crop failure in the early wet season.

Farmers take major risks in the early wet season, for example by dry-sowing sesame. There is a strong economic argument for farmers not to attempt an early wet season crop and to concentrate on maximizing the yield of the main wet season crop.

The amount of water the soil can hold depends on the soil structure, amount of clay and the depth. Although the surface soil may appear to have good fertility and water-holding capacity, upland soils in Cambodia can be quite shallow (Figure 8).

Figure 8. Left: gravelly phase of dark brown soil (proposed O Rieng Ov soil group), intermediate between Kampong Siem and Labanseak soils in Kampong Cham. Right: Kampong Siem (proposed Kampingpouy soil group) in Battambang.

Figure 9. Some examples of fertilisers available in village markets in Kampong Cham and Battambang.

Major nutrients

The nutrients most commonly available as fertiliser in Cambodia are nitrogen (N), phosphorus (P) and potassium (K) (Figure 9).

Nitrogen is an important nutrient that determines the number of leaves the plant produces, the number of seeds per pod or cob, and therefore the yield potential. Plants with nitrogen deficiency are pale green or yellow and stunted (Figure 10). Plants with adequate N are dark green.

Figure 10. Nutrition of maize. Left: Maize showing N deficiency (plot on right of photo, without N; plot on left, with N). Right: Maize showing P deficiency.

Matching fertiliser application to expected yield and price

The actual yields of upland crops in Cambodia range between 20% and 50% of the potential (Table 13).

Table 13. Estimates of yield gaps of upland crops in Cambodia.

CROP	MAXIMUM POTENTIAL YIELD (t/ha)	CAMBODIAN POTENTIAL YIELD (t/ha)	ACTUAL FARM YIELD (t/ha)	ACTUAL AS % OF POTENTIAL YIELD
Maize	15	10	2–5	20–50
Soybean	6	3	1–1.5	30–50
Mungbean	3	2	0.2–0.8	10–40
Peanut	9–10	5–6	0.7–1.7	10–20
Sesame	2	1.5	0.3–0.7	20–50
Cowpea	3	2	0.3–0.7	20–40

A range of factors could be responsible for low yields, including lack of adapted varieties, drought, patchy plant stands, damage from pests and diseases and poor plant nutrition. A survey of contemporary practices, constraints and opportunities for non-rice crops in Cambodia has shown that very few Cambodian farmers apply fertilisers to upland crops, although there is a wide range of fertiliser types available in village markets (Figure 9).

A typical fertiliser recommendation for upland crops is a basal dressing of 15:15:15 (NPK) at 100 kg/ha applied immediately before planting, followed by a topdressing of urea at 50 kg/ha at 18–20 days after planting. A second application of urea at 50 kg/ha may be applied 35–45 days after planting.

Responses to fertiliser vary widely depending on the soil fertility. The availability of nutrients, especially nitrogen, can also vary during the year, depending on the rate of mineralisation of organic matter. In Table 14, we have provided the CARDI-recommended fertiliser rates for the major upland crops in Cambodia. These are the rates we will include in the demonstrations in 2007. In the table we have tried to match up the nitrogen (N) required by the crop with the amount provided by the soil, rhizobium and fertiliser. We feel that the recommended application rates of urea are likely to be more than are required for all crops except maize. We have therefore included only one treatment with urea for mungbean, peanut, soybean and sesame in our ITPs.

Table 14. How much fertiliser should I apply?

CROP	DAP AT SOWING (kg/ha)	UREA AT SOWING (kg/ha)	UREA AT FLOWER.(kg/ha)	YIELD TARGET (t/ha)	N REQUIRED (kg/ha)	N AVAILABLE (kg/ha)	N BALANCE (kg/ha)
Mung bean	100	45[1]	45[1]	0.8	51	151	100
Sesame	100	45[2]	45[2]	0.6	34	126	92
Soybean	100	45[1]	45[1]	1.2	120	176	56
Maize	100	45	45	4.5	144	126	-18
Peanut	100	45[1]	45[1]	1.7	109	176	67

[1]*Urea is applied to one treatment only in the demonstrations for mungbean, peanut and soybean to allow comparison with* Rhizobium *inoculation.*

[2]*Because of its low nitrogen requirement, sesame is unlikely to respond to urea topdressing. Therefore urea topdressing is applied to one treatment only in the demonstration.*

Calculating the crop's nitrogen fertiliser needs

If we know how much nitrogen there is in the soil, we can calculate the crop's needs. To do this either measure the amount of nitrate-N in the soil profile or estimate this figure by using the total-N in the soil. The following example is based on average nitrate levels of approximately 25 ppm NO_3 in the top 20 cm of soil across the 100 sites sampled (18 ppm in Kampong Cham and 33 ppm in Ratanak Mondul).

Before you can proceed to determine the amount of fertiliser needed, you need to convert the NO_3 ppm reading from our nitrate meter to mg/kg N. The atomic weight of nitrogen is 14 and that of oxygen is 16. Therefore, each unit of NO_3 contains 0.226 units of N $(14 \div (14 + 16 \times 3) = 0.226)$.

In our soil tests, we add 50 g of wet soil to 100 mL of water, shake, and then extract the sample for analysis. We assume the soil moisture content is 0.25 g/g, but you can use the actual soil water content if you have it. The next calculation is:

$$\text{N (mg/kg)} = (\text{ppm } NO_3 \times 0.226 \times 100) \div [50/(1+.25)]$$

$$= (25 \times 0.226 \times 100) \div [50/(1+.25)]$$

$$= 565 \div 40$$

$$= 14.125$$

$$\text{N (kg/ha)} = (\text{mg/kg N} \times \text{bulk density} \times \text{sample depth}) \div 10$$

$$= (14.125 \times 1.0 \times 20) \div 10$$

$$= 28.25$$

We have assumed that the crop will also access N from farther down the soil profile. If there is 28.25 ppm in the top 20 cm, we assume there is also 14.13 (20–40 cm), 7.06 (40–60 cm) and 3.53 (60–80 cm). giving a total for the profile of 53 kg N/ha.

We also allow for in-crop mineralisation in the top 20 cm of soil equivalent to 80% of the amount in the topsoil at sowing. For our example this would be 22.6 kg N/ha. Therefore, we estimate that the soil in this example could provide approximately 53 + 22.6 = **75.6** kg nitrate-N/ha in the soil profile to a depth of 80 cm. This estimate should be reduced accordingly on shallower soils.

The amount of nitrate N required to produce 1 tonne of maize grain is 16 kg/ha. Therefore a 2 t/ha crop will require 32 kg/ha, a 3 t/ha crop will require 48 kg/ha and a 4 t/ha crop will require **64** kg/ha. However, the maize can take up only about 50% of the available soil nitrate-N, and therefore the crop would need twice as much N applied so it is able to uptake the amount required through the roots (Table 15).

Table 15. Maize requirements for soil nitrate-N.

GRAIN YIELD (t/ha)	1	2	3	4
SOIL NITRATE-N NEEDED (kg/ha)	32	64	96	128

So a 4 t/ha maize crop would need **64** x 2 = **128** kg/ha of nitrate-N available in the soil. Now, if the farmer applies DAP (18% N) at 100 kg/ha at sowing, this would supply 100 x 0.18 x 0.8 = **14.4** kg N/ha. Therefore, with **75.6** kg/ha being supplied from the soil and **14.4** kg/ha from the DAP, the amount that needs to be applied as urea is: **128** – **75.6** – **14.4** = **38** kg/ha of N.

Importantly, when fertiliser is applied there are losses from volatilisation and tie-up in the soil, so an **80**% conversion from fertiliser N to plant-available N should be assumed. We have taken this into account in estimating the fertiliser N required for a 4 t/ha maize crop, and the amount of N required becomes **38** x **1.25** = **47.5** kg N/ha.

It is recommended that farmers use urea in-crop to supply this requirement. Urea is 46% N, so the amount of urea required would be **47.5** x (1/0.46) = **103** kg in-crop to achieve the target grain yield of 4 t/ha for maize.

You can use a look-up table (Table 16) to read off the urea rates required to achieve yield targets of 1, 2, 3 and 4 t/ha for a range of soil NO_3 readings from 0–60 ppm. For maize yields of 4 t/ha and less, no urea would be required for readings above 60 ppm. These calculations are based on a soil water content of 25% and a soil bulk density of 1.0. The Merck meter reading for NO_3 (ppm) is used to read off the amount of fertiliser urea required to achieve target maize yields (1, 2, 3, 4 t/ha).

Using the look-up table, if you refer to the example we worked through above, we started with 25 ppm nitrate N in the soil. Reading off the table, we can see that a 1 or 2 t/ha crop of maize would not require urea ,but that a 3 t/ha crop would require 16 kg urea/ha and a 4 t/ha crop would require 103 kg urea/ha. If you are in the light yellow area, you don't need to apply urea. If you are in the dark yellow area, read off the amount or urea required to reach the target yield.

Table 16. Nitrogen Calculator: if you know how much nitrate N is in the soil at sowing, you can estimate the amount of urea you need to achieve your yield target.

NO_3 (ppm)	EXPECTED GRAIN YIELD OF MAIZE			
	1	2	3	4
	UREA (kg/ha)			
0	48	135	222	309
5	7	94	181	268
10	0	53	140	227
15	0	12	99	185
20	0	0	57	144
25	0	0	16	103
30	0	0	0	62
35	0	0	0	21
40	0	0	0	0
45	0	0	0	0
50	0	0	0	0
55	0	0	0	0
60	0	0	0	0

Rhizobium inoculation

Pin Tara, Chan Phaloeun, Natalie Elias, Fiona Scott and Bob Martin

Introduction

Nitrogenous fertilisers such as urea, DAP and MAP are costly, and many Cambodian farmers cannot afford to use them. A more cost-effective approach to soil fertility management is to incorporate legume crops such as soybean, mungbean, cowpea and peanut into the rotation. These crops, when effectively nodulated by rhizobium root-nodule bacteria (*Bradyrhizobium* species), utilise nitrogen from the air. *Bradyrhizobium* is a species of bacteria that is found naturally in soils where tropical legumes grow.

As the legume root grows through the soil, it meets with the rhizobium bacteria and the rhizobium enters the root and starts to grow inside it. As the rhizobium grows it forms a lump on the root called a 'nodule'.

Legume nodules contain millions of rhizobium bacteria that convert gaseous nitrogen (N_2) from the air into ammonia (NH_3), a form that can be taken up by the plant. This process is known as nitrogen fixation.

Rhizobium bacteria are not always present in the soil and may need to be introduced in the form of inoculum, especially in new cropping areas where legume crops have not been grown before. There are numerous species and hundreds of strains of rhizobium; they can differ in the types of legume they nodulate and in the efficiency they fix atmospheric nitrogen. Soybeans belong to inoculant group H and require rhizobium strain CB1809. Mungbean and cowpea belong to group I and require rhizobium strain CB 1015. Peanuts belong to group P and require strain NC92.

Effective nodules contain strains of rhizobium that, with their specific host plants, are highly efficient converters of atmospheric nitrogen. They are characterized usually by being few in number, large, situated near the crown of the plant, and pink inside when young. Ineffective nodules are usually small and numerous, located over the entire root system, and completely white or green.

Few soils contain sufficient effective root-nodule bacteria strains to promote maximum growth of legumes. To ensure that effective nodulation will occur when growing legumes it is recommended that you add (inoculate) large numbers of an effective strain of rhizobium to the seed or to the sowing furrow when planting (Figure 11). This ensures that the correct strain of rhizobium is in close proximity to the roots of the germinating seedling and thus in a position to cause effective nodulation. Rhizobium inoculum is not commercially available in Cambodia but can be imported from other countries such as Australia. The cost of inoculation is about $7/ha.

Wild strains of rhizobium effective on mungbean and cowpea are likely to be widespread in Cambodia, but it is less likely that there will be naturally occurring rhizobia that are effective for soybean or peanut. Inspection of soybean crops in Kampong Cham in 2002 showed some well nodulated soybean crops, but the majority of crops were poorly nodulated. Local strains of cowpea rhizobium are effective on mungbean. However, results can vary from field to field, depending on the cropping history and soil conditions.

Figure 11. Mr Pin Tara, Ms Natalie Elias and Mr Katam Sonovan preparing to inoculate soybean seed with Rhizobium.

Results of experiments on rhizobium inoculation in Cambodia

A total of 30 rhizobium inoculation experiments were conducted in Kampong Cham and Battambang between 2004 and 2006. The response of rhizobium inoculation of mungbean, peanut and soybean was compared with the response to application of nitrogenous fertiliser.

The experimental design was a split-plot factorial with 2 rhizobium (+/–) treatments, 3 nitrogen treatments and 4 replications. Rhizobium inoculum imported from Australia was applied to the seed, and the nitrogen treatments were 0, 40 and 80 kg N/ha applied as urea. The plot size was 5 m by 2.5 m. Planting was by hand, with 40 cm between rows, 30 cm between plants and a total of 96 hills/plot.

Results obtained for soybean (Figure 12a) were consistent with results in Thailand and Vietnam.

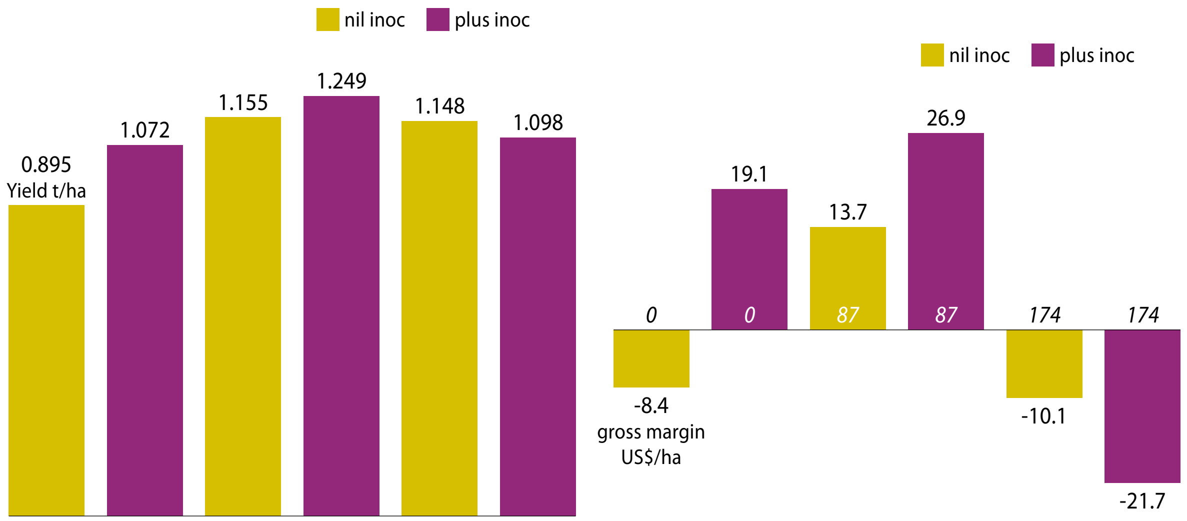


Figure 12. Effect of rhizobium inoculation and nitrogen fertilisation on (left) soybean yield and (right) gross margin ($US).

Without nitrogen fertiliser, inoculation increased soybean yield by an average of 20% (Figure 12a). Soybeans also responded to fertiliser at 40 kg N/ha with a 30% yield increase. Inoculation increased the gross margin by $28US (Figure 12b). With improved agronomy and higher yields it is expected that responses to rhizobium could be even greater.

Demonstration trials in the early wet season 2006 gave even better results for mungbean and peanut (Figure 13). The average yield increase for the rhizobium-inoculated treatment compared to farmer practice for mungbean was 296 kg/ha (41%) and 379 kg/ha (27%) for peanut. This gave an increase in profit (gross margin) of $104 for mungbean and $115 for peanut.

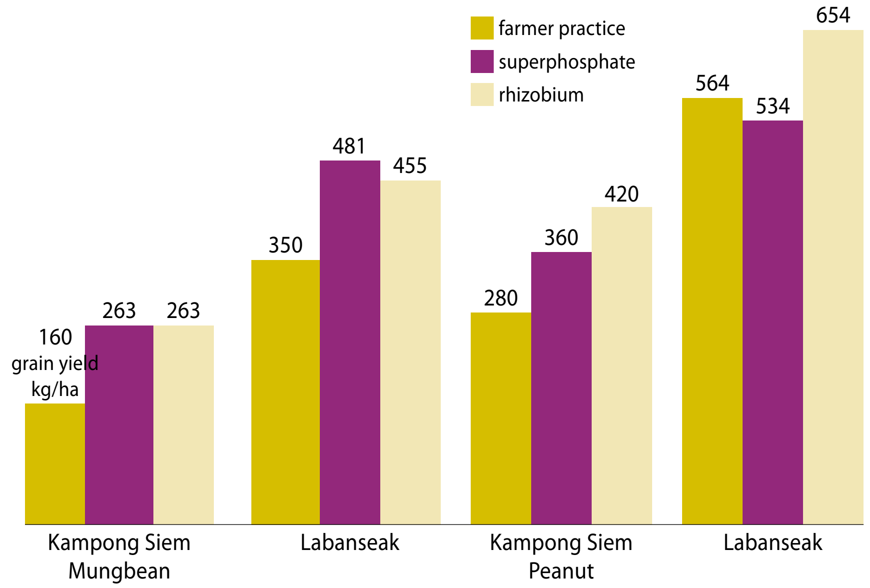


Figure 13. Effect of fertiliser application and rhizobium inoculation on the yield of mungbean and peanut in 2006.

Figure 14. Planting soybeans under the direct-seeding mulch-cropping system (DMC) being tested by Mr Stephan Boulakia (CIRAD) in Kampong Cham.

Figure 15. Traditional tillage with cattle or buffalo is being replaced by tractor and 7-disc plough in Cambodia

Reduced tillage

Pao Sinath and Som Bunna

Introduction

Traditional tillage in Cambodia is with a wooden mouldboard plough drawn by cattle or buffalo, although direct-seeding, mulch-cropping systems are now being tested (Figures 14 and 15). Tractor-drawn ploughs are now becoming common, particularly in the north-west of Cambodia. These heavy disc ploughs used to prepare fields for planting upland crops and incorporate crop residues expose the soil to erosion. Therefore, there is a need to reduce the amount of tillage and maintain ground cover to reduce soil erosion.

Farmers in upland areas of Cambodia usually chop, burn or remove crop and weed residues from their fields before ploughing. The seedbed is ploughed twice or three times, first by a 3 disc-plough, followed by a 7 disc-plough set at a depth of 20–25 cm (Figure 15). Crop residues are incorporated into the soil. The cost of seedbed preparation is between US$27 and $38/ha.

Reduced tillage has been evaluated and introduced under rainfed farming conditions in many parts of the world. The wide adoption of this tillage practice has been in response to maintained or increased crop yields, lower costs, less weeds, reduced runoff and reduced soil losses. The average annual rainfall in Cambodia exceeds 1400 mm and this, combined with sloping and friable forest soils, results in a high risk of soil erosion.

The first progression towards reduced tillage is to change to a chisel plough. The chisel plough can loosen up the soil surface and improve infiltration. Chisel ploughs developed for ACIAR-04 have 7 tynes on 2 tool bars (Figure 16).

This implement is designed to cultivate soil to a depth of 8–10 cm. It controls weeds and prepares the field for seeding without the need to turn the topsoil upside down. When fitted with sweeps, the chisel plough cuts off the weeds and leaves them mostly on the soil surface.

No-tillage is a management practice in which there are no cultivations during the fallow period between subsequent crops. All weed control is achieved by the use of herbicides applied at appropriate stages depending on weed type and growth (Figure 16). The next crop is then sown directly into the soil through the crop and weed residue remaining. Research was commenced in Cambodia in 2004 to:

1. identify the optimum tillage practice for the establishment of upland crops
2. evaluate the effects of stubble retention and reduced tillage on crop yield
3. determine the potential for reduced erosion through the adoption of sustainable farming techniques.

The studies were conducted under upland conditions on Kampong Siem and Labansiek soils in Battambang and Kampong Cham provinces. The trials were established in two or three locations in each province. Experiments were carried out in the early and main wet seasons to test tillage treatments under chemical and manual weed control. Three tillage practices were evaluated:

1. conventional tillage practices (disc plough)
2. residue retention tillage (chisel plough with sweeps)
3. no-tillage.

Figure 16. Reduced tillage (chisel plough) and no-tillage have been tested for upland crops in Cambodia between 2004 and 2006.

There was good crop establishment in all crops for all tillage treatments (Figure 17). However, there was generally more weed growth in the no-tillage treatments, except with cowpea and sesame. Grain yields were similar for all treatments in all crops. No-tillage was the most profitable treatment, except in the case of sesame, where the chisel plough treatment was the most profitable. The financial advantage of no-tillage was mainly due to the reduced costs compared with those of ploughing.

Results of tillage research

The take-home messages of this research were that:

- practising no tillage can establish a good even germination of crops in upland soils;
- the farmer does not need to spend a lot of money ploughing to establish a good crop; and

in general, the farmer can produce similar grain yield from no tillage as he produces from ploughing.

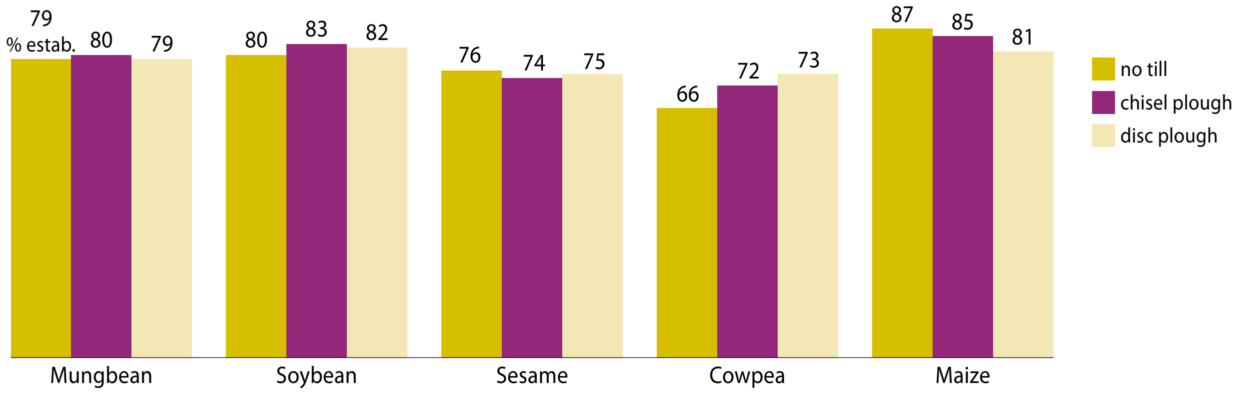


Figure 17. Effect of tillage practice on crop establishment, weed biomass, grain yield and gross margin for upland crops (continued overleaf).

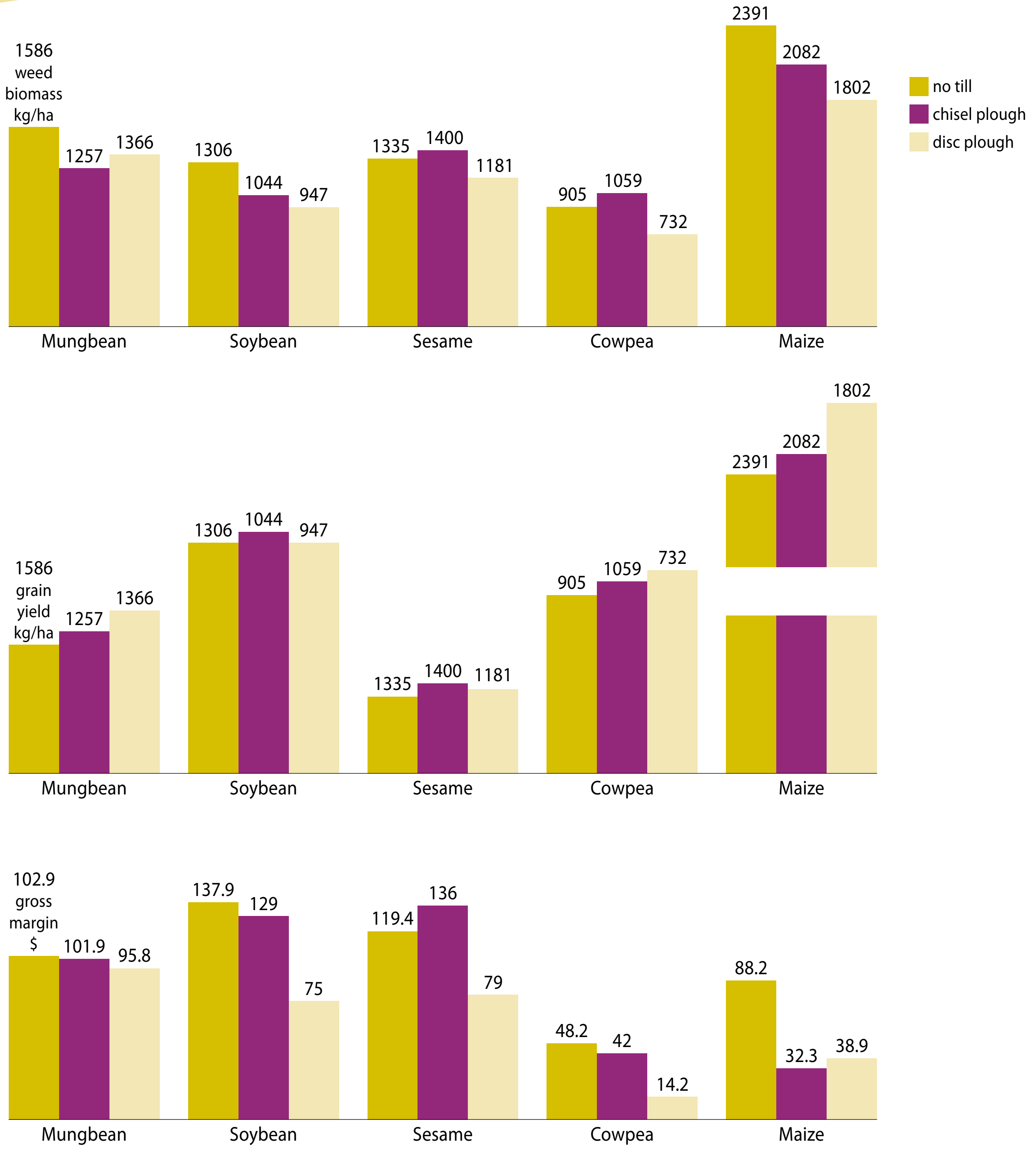


Figure 17 continued. Effect of tillage practice on crop establishment, weed biomass, grain yield and gross margin for upland crops.

Figure 18. After threshing is complete, the residues of upland crops are burned rather than being returned to the field.

Mulching

Pin Tara, Chan Phaloeun and Bob Martin

Farmers in upland areas of Cambodia usually remove or burn crop and weed residues from their fields before ploughing (Figure 18). In other areas of South-East Asia, farmers spread crop residues on the fields to conserve soil moisture, prevent weed growth and reduce soil erosion. The crop residues gradually decompose, adding humus and nutrients to the soil for the benefit of subsequent crops. This practice of using crop residues as mulch contributes towards maintenance of soil fertility over a long period of time.

A potential beneficial effect of straw mulch is the reduction of soil temperature, and hence, crusting of the soil surface and evaporation of moisture. In Indonesia, the use of rice straw spread over plots to a depth of 4–10 cm increased soybean yields by an average of 41%. Results can vary widely, because the beneficial effect of rice straw mulch depends on the degree of moisture stress and the physical properties of the soil. The mulch does not have to be rice straw. In fact, the ideal situation is to retain residues in the field from the previous crop or return those crop residues to the field before sowing. Any upland crop residues, including threshings may be used, or alternative sources of mulch may be required, such as banana leaves and grass cuttings.

ACIAR04 commenced experiments in Cambodia in 2005 to determine the effect on upland crops (corn, soybean, mungbean, peanut, sesame and cowpea) of retaining crop residues on the soil surface to improve rainfall infiltration, preserve soil moisture and reduce the emergence of weeds. We are also evaluating a range of mulches (maize, mungbean, peanut, soybean and leucaena) for their ability to attract or repel pests such as subterranean termites (Figure 19).

Results of mulching experiments and demonstrations

In 2005, an experiment in Kampong Cham was carried out in the early wet season with very encouraging results. Rice straw mulch at 3 t/ha provided good ground cover and increased the yield of upland crops, especially maize (61%) and soybean (136%). The maize yield was increased by 1.79 t/ha and the soybean yield by 0.8 t/ha. Mulching increased the gross margin (cash income) for maize by $148/ha and for soybean by $108/ha (Table 17).

Figure 19. In ACIAR04 we are looking at a range of different crop residue types with regard to their value as mulches as well as their ability to attract or repel crop pests.

Table 17. Effect of mulch on the yield and profitability of upland crops.

TREATMENT	YIELD (t/ha)	PRICE ($/t)	INCOME ($/ha)	COSTS ($/ha)	GM ($/ha)
Maize – mulch	2.93	120	352	323	29
Maize + mulch	4.72	120	566	390	176
Soybean – mulch	0.587	210	123	221	-98
Soybean + mulch	1.387	210	291	280	11
Mungbean – mulch	0.403	350	141	208	-67
Mung + mulch	0.571	350	200	276	-76

In 2006, demonstrations of mulching continued to show good results (Figure 20). The best results have been obtained in the early wet season with all crops except sesame. It is less likely that a good response will be obtained in the main wet season because the risk of drought is less and the mulch could inhibit crop emergence.

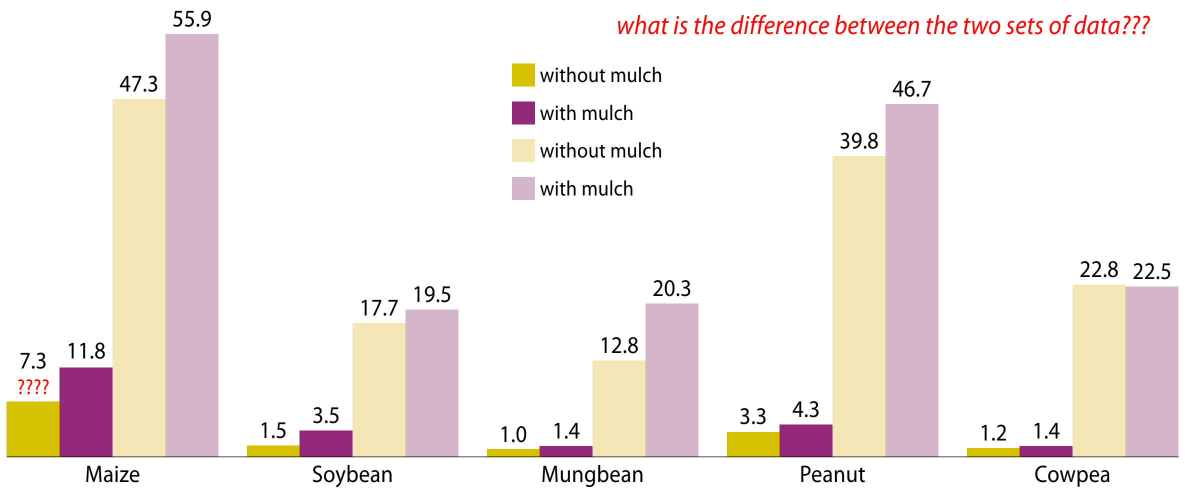


Figure 20. Effect of straw mulching on biomass and yield of upland crops in 2006.

Design and layout of the demonstration

Bob Martin and Stephanie Belfield

Select the site

Selecting the site (Figure 21) can be difficult and frustrating. You need to consider the needs of the demonstration, but also be aware of the needs of the farmers and how the demonstration might affect their livelihood. Your demonstration may take up a significant part of the farmer's field, and they may be concerned that the crop will fail and they will lose income. On the other hand, you should try to avoid agreeing to a site that is unsuitable (Figure 22). The following points should be considered.

Timeliness. You need to select the site well before the farmers begin to prepare their fields for planting. This is especially important if your treatments involve reduced or no tillage. It is also important that you are ready to plant at the same time as the farmer. If you plant late, your demonstration could suffer more damage from insect pest and disease.

Crop residues. If your demonstration is to have a no-tillage treatment, you need to choose a site that has not been ploughed. There should be 2–3 t/ha of crop residues if possible, and no weeds.

Soil type. The most important step in selecting a site for an experiment or demonstration is to make sure that it is representative of the soil type and farming system you are interested in. For example, if you want to test improved practices for upland crops on Kampong Siem or Labanseak soil types, you need to put the demonstration in the right place and not at the site most convenient for you.

Uniformity. The demonstration site must be as uniform as possible. Avoid areas with variable soil types, rocky outcrops and uneven slopes. The site must not be too close to roads, trees or buildings, as these will affect the plots unevenly. Avoid sites that are prone to soil erosion or flooding.

Availability. Make sure the site is available for as long as you need it. For example, if your demonstration is in the early wet season, make sure you have time to harvest before the farmer begins to prepare for the main wet season crop.

Farm animals. Protect the site from farm animals. Young green plants are very tempting to chickens, cattle and goats, so check that the fences around the field can keep out animals.

Outside effects. You need to minimise outside effects on your demonstration. The site should not be unevenly affected by other activities. For example, if your experiment is too close to fruit trees where farmers are using herbicides to spray weeds, chemicals may drift onto your site, killing some plants.

Field history. Ask the farmer about the history of crop or farming activities in the field, and keep a record. Also make sure the site does not have different crop or fertiliser histories, old building sites, or areas where tree stumps have been burned.

Weeds. Avoid sites with weeds such as Kravanh Kruck (*Cyperus rotundus*), Sbauv Klang (*Imperata cylindrica*) or Paklab (*Mimosa pudica*). These weeds regrow after cultivation and require high rates of glyphosate (Figure 23).

Figure 21. An experimental site with beds made up ready for sowing.

Figure 23. Weeds to avoid when choosing a site: **Cyperus rotundus** (left), **Mimosa pudica** (centre) and **Imperata cylindrica** (right).

*Figure 22. The site at left is not a good site: it is uneven, has trees and stumps, and has **Imperata,** a weed that is difficult to control. The site on the right is a good site: it has an even slope and soil type and there are no weeds or tree stumps.*

See the section on 'Further Reading' for a comprehensive presentation on practical tips for setting up field experiments and demonstrations.

Describe the site

You need a good description of the site to help you and other people better understand the results of the demonstration. The site description should include:

- GPS coordinates
- long-term climate information (where available)
- soil characteristics (surface characteristics, depth, drainage, pH)
- site factors (slope, previous land uses, accessibility, weeds, non-uniform conditions, erosion potential).

Prepare a map of the site

The site map should show where the treatments are located. Mark north on the site map on page 43 and include all obvious features such as roads, streams, houses and fences (Figure 24). Check that everyone involved understands the map.

Fill out the details about the farmer, location, crop and date of sowing. Record GPS coordinates.

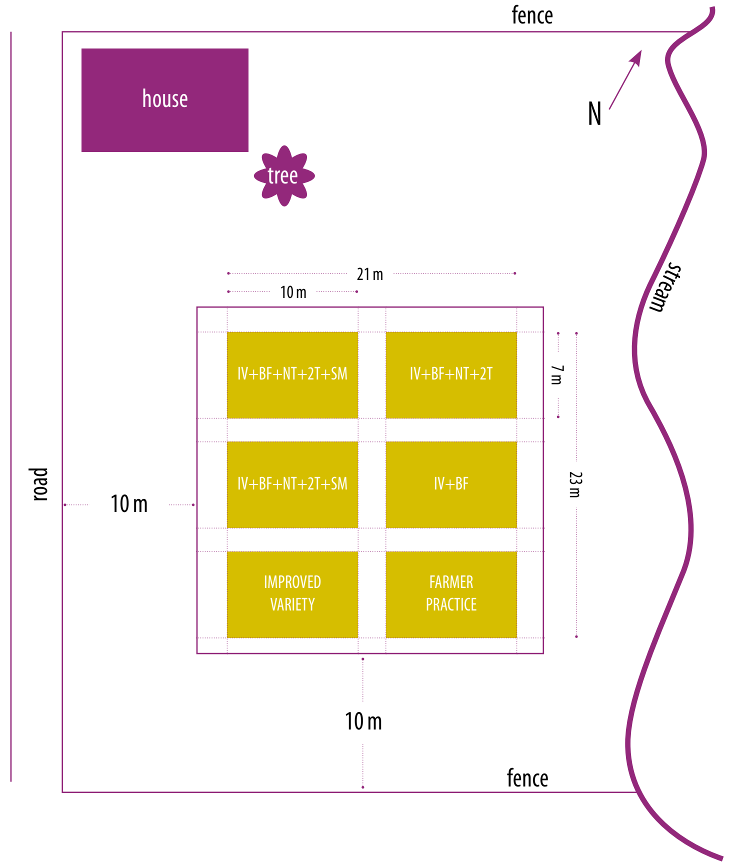


Figure 24. Prepare a map of the site.

Figure 25. Traditional ploughing and harrowing with cattle.

Site preparation and application of treatments

Bob Martin and Stephanie Belfield

Application of tillage treatments

For the early wet season demonstration, the field should be ploughed once or twice in February by disc or chisel plough, respectively, and the last ploughing will be carried out a day before the crop is planted. Remember to leave an unploughed area for the no-tillage treatments.

The no-tillage treatment is established by application of glyphosate at the rate 2.0 L ha (Table 18), applied 10 days before the crop is planted on the no-tillage treatment areas. Sites should be avoided if they have hard-to-control weeds such as Kravanh Kruck (*Cyperus rotundus*), Paklab (*Mimosa pudica*) or Sbauv Klang (*Imperata cylindrica*).

Table 18. Glyphosate rates recommended for weed control under Cambodian conditions.

WEED SPECIES	RATE (L/ha)	AMOUNT OF WATER USED (L/ha)
Mixed and annual weeds	1.5–2	300–400
Kravanh Kruck	3	200–300 (spray 2× every 60 days)
Paklab, Sbauv Klang	6	600–800

You need to assess the weather conditions before you begin to spray, and you need to monitor any changes in the conditions during the spraying operation. Herbicide applications above 30 ºC, below 45% relative humidity and at wind speeds greater than 15 km/h are high risk. Therefore, in Cambodia the best conditions for chemical application are likely to be in the early morning.

Remember that glyphosate is a poisonous substance. To avoid hazards please be careful while spraying. Follow the instructions and recommendations as below:

- Use protective clothing: mask, gloves, boots, face barrier etc.
- The spray operator must stand upwind.
- Do not spray herbicide in strong wind or rain.
- Wash your hands and face clearly with soap before eating, drinking or smoking.
- After spraying, take a shower and wash your clothes, then dry them for safe use later.
- Destroy or bury empty bottles or cans of herbicide after use.
- Do not burn herbicide containers.
- Do not use herbicide cans or bottles for other purposes
- Do not pour herbicide wastes into ponds, lakes or other water reservoirs.
- Wash the knapsack sprayer properly after use and before use with other agricultural chemical or substances.

Preparing the land

With the exception of the no-tillage treatment areas, the experimental field will be ploughed and properly levelled to control water flow and make soil fertility uniform. The first ploughing is 15–20 cm deep and is followed by land levelling. The land is allowed to dry in the sun to kill the weeds. Plough again to a depth of 8–10 cm just before planting (Figure 25). Rake and make small ditches 15 cm deep.

After raking, raise the beds into plots 10 m long and 7 m wide, with the distance from one plot to another being 1 m. The total experimental area will be:

1. maize, sesame: 21 m × 23 m (483 m^2)
2. mungbean, peanut, soybean: 21 × 31 m (651 m^2).

Marking out the site

Make sure to allow for the laneways between plots. Double-check measurements. Use the 3-4-5 rule to square the site (Figure 26).

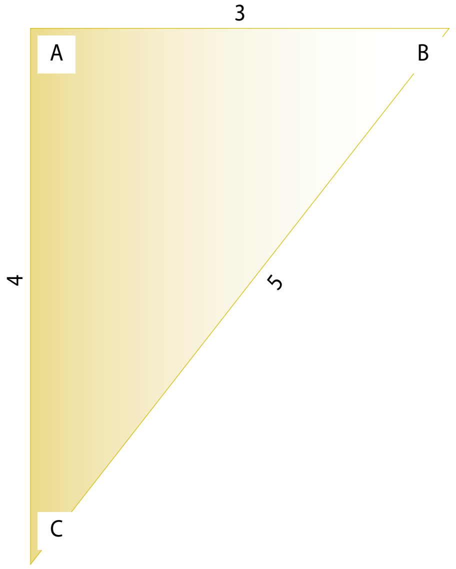


Figure 26. Use the 3-4-5 rule to square the site.

Use the following steps to square the site and line up the pegs (Figure 27):

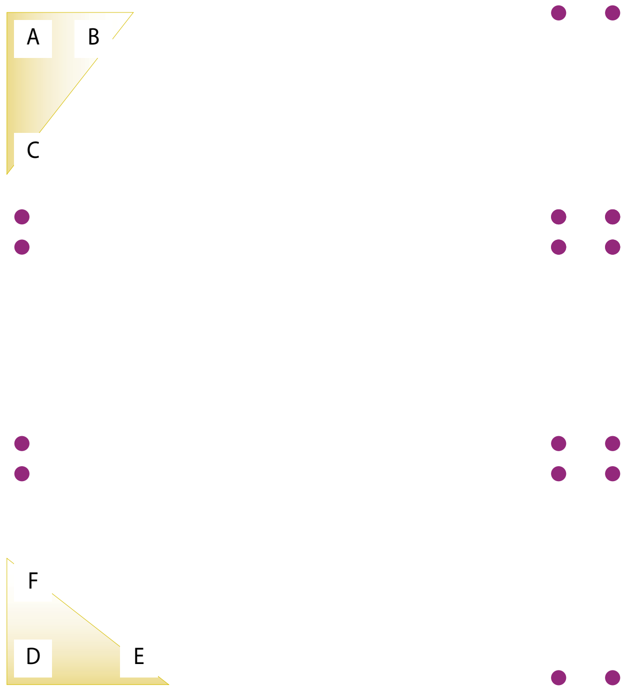
1. Put a peg at A and fix the tape to it.
2. Measure 3 m to B and put in another peg.
3. Run the tape around peg B and walk to C (8 m on the tape.)
4. First person stays at C holding the peg at 8 m.
5. Second person runs the tape back to A and holds the tape at 12 m on the peg.
6. First person pulls tape tight with the peg on the 8-m mark and puts peg in the ground.

Attach the string to Peg A and, using the tape measure and by sighting, put in the plot pegs (Figure 28).

Make up the raised 10 × 7 m beds to be 15–20 cm high. Use string to mark the rows. Put the seed and fertiliser packets on the correct plots.

Once the plots are marked out, you can place the treatment bags of fertiliser on the plots. Check that all the treatments are on the right plots.

Figure 27. Squaring the site and lining up the pegs.



Attach the tape measure to peg A and measure 23 m to point D. Pull tight and make sure that the tape is in line with peg C and insert peg D.

Repeat the 3-4-5 method at D-E-F.

Now measure 21 m from A–G. Pull tight and make sure the tape is in line with peg B and insert peg G.

Repeat for D–H.

Now you can position the remaining pegs using the tape measure.

Figure 28. Marking out the site.

For maize, field testing includes the following treatments (Figure 29):

1. Farmer Practice (FP)
2. Improved Variety (IV)
3. IV + Basal Fertiliser (BF)
4. IV + BF + Nitrogen Topdressing (NT)
5. IV + BF + NT + Zero Tillage (ZT)
6. IV + BF + NT + ZT + Straw Mulching (SM).

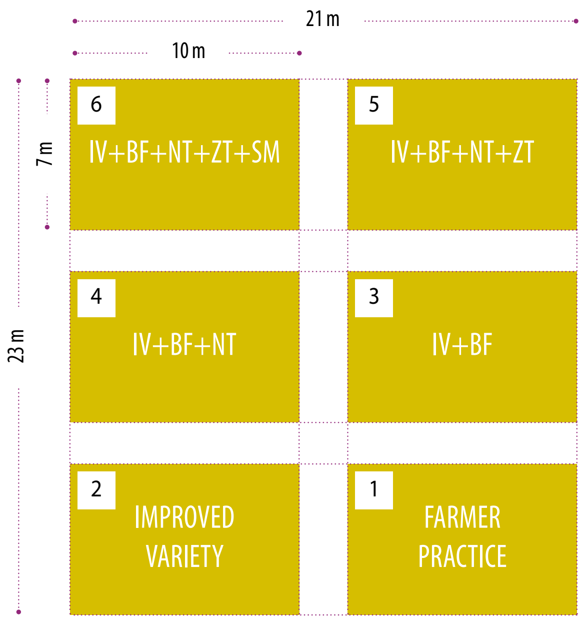


Figure 29. Field layout for the maize demonstration.

For sesame, field testing includes the following treatments (Figure 30):

1. Farmer Practice (FP)
2. Advisor Choice (AC)
3. Improved Variety (IV)
4. IV + Basal Fertiliser (BF)
5. IV + BF + Zero Tillage (ZT)
6. IV + BF + ZT + Straw Mulching (SM).

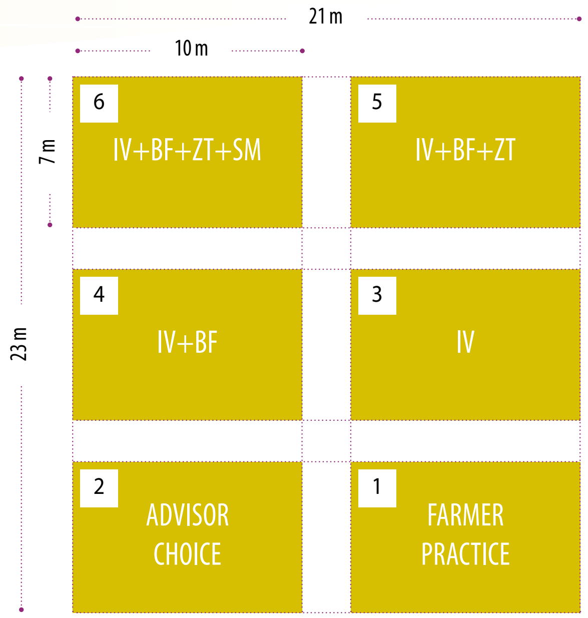


Figure 30. Field layout for the sesame demonstration (note that urea topdressing is not applied to sesame).

For legume crops (mungbean, soybean, peanut) field testing includes the following treatments (Figure 31):

1. Farmer Practice (FP)
2. Adviser Choice (AC)
3. Improved Variety (IV)
4. IV + Basal Fertiliser (BF)
5. IV + BF + Nitrogen Topdressing (NT)
6. IV + BF + Rhizobium Inoculation (RI)
7. IV + BF + RI + Zero Tillage (ZT)
8. IV + BF + RI + ZT + Straw Mulching (SM).

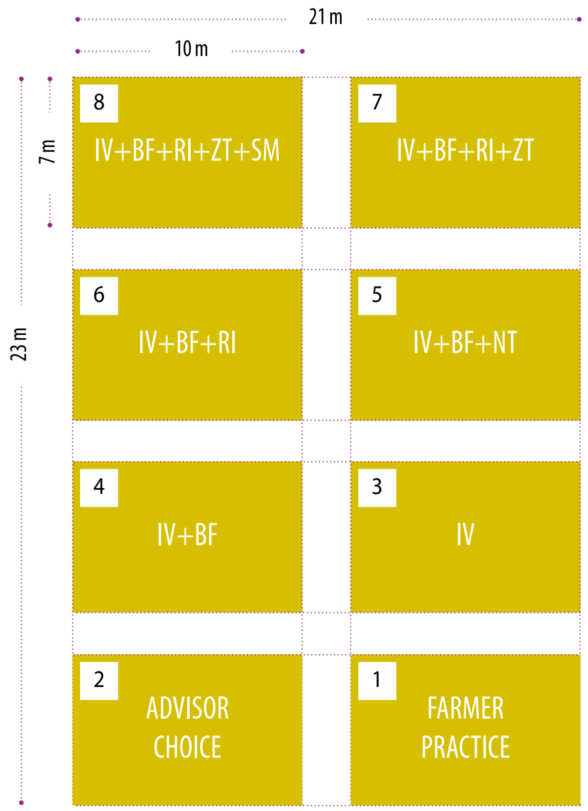


Figure 31. Field layout for the mungbean, peanut and soybean demonstration.

Figure 32. Using the string to mark out the seeding rows and spaces between hills.

Figure 33. Planting sesame (left) and (right) the sesame shaker with two holes in the base

Sowing and fertiliser application

With the tape measure and string, mark out the seeding rows and the spacing between the hills (Figure 32). If you are planting the crop by hand, you need to know the row spacing, the space between the hills within rows, and the number of seeds sown per hill (Table 19). These vary among crop species. The amount of seed required varies according to the weight of seed.

Table 19. Row and hill spacing and seeding rates for hand-sown upland crops.

TREATMENT	SESAME	MUNGBEAN	PEANUT	SOYBEAN	MAIZE
SPACING BETWEEN PLANTS (cm)	10	30	30	30	50
SPACING BETWEEN ROWS (cm)	40	40	40	40	70
SEEDS SOWN PER HILL	5	5	5	5	3
PLANTS/HILL AFTER THINNING	2	3	2	3	2
PLANTS/m ROW AFTER THINNING	20	16	6	16	3.5
SEED NEEDED PER PLOT (g)	70	280	770	560	190

If you are planting by machine, you should refer to Table 20.

Table 20. Target plant populations and seeding rates for machine-sown upland crops.

TREATMENT	SESAME	MUNGBEAN	PEANUT	SOYBEAN	MAIZE
TARGET PLANT POPULATION (plants/m^2)	50	40	15	40	5
TARGET PLANT POPULATION (plants/ha)	500 000	400 000	150 000	400 000	50 000
TARGET YIELD (t/ha)	1.5	1.5	4.0	2.5	6.0
PLANTING DEPTH (cm)	2–3	3–4	3–4	3–4	3–4
SEEDING RATE (kg/ha)	10	40	110	80	27
100 SEED WEIGHT (g)	0.3	7.0	53.5	15.0	30.0

The 100-seed weight varies among crop species and can also vary among varieties. To check the seed weight, you should count and weigh several 100-seed samples and take an average value.

Seed is usually planted manually, and seed and seed holes are made with a stick or hoe in the case of mungbean, peanut, soybean and maize. The depth of placement is 3–4 cm, with low pressure. Peanut calculations are based on the numbers of kernels after threshing; this is usually the best method of planting.

For sesame, the seed is planted in a drill (also known as furrow) row at a depth of 2–3 cm. It is usual to expect 40%–50% field establishment losses for sesame, so it is better to plant too many seeds rather than not enough. There is no need to count out sesame seeds per hill; the best method is to use a shaker stick for planting (Figure 33).

If necessary, missed hills are replanted about 7 days after planting. Table 19 indicates the amount of seed required per plot, as calculated on an average seed weight. However, extra seed is provided in the kits in case replanting is required, so don't worry too much if there is leftover seed.

Thinning is done approximately 10 days after planting. The establishment conditions will determine how much thinning is needed. The protocols currently are designed for hand-planting of the demonstrations. However, separate protocols can be designed for machine-sowing of plots if that is the method of planting preferred by collaborators and farmers.

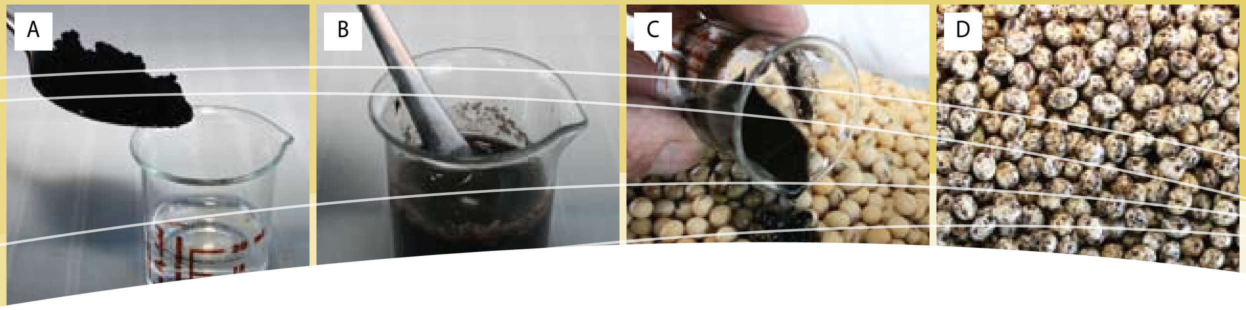
Fertiliser application

A basal fertiliser application of DAP (18:20 N:P) will be applied at 100 kg/ha. Fertiliser will be applied in the seed furrow or seed hole at planting. It should be placed below the seed, so it needs to be placed in the hole first. Fertiliser application rates for the demonstrations are given in Table 21.

Table 21. Fertiliser application rates.

TREATMENT	SESAME	MUNGBEAN	PEANUT	SOYBEAN	MAIZE
DAP AT SOWING (kg/ha)	100	100	100	100	100
(g/plot)	700	700	700	700	700
UREA AT SOWING (kg/ha)	0	0	45	45	45
(g/plot)	0	0	315	315	315
UREA AT FLOWERING (kg/ha)	0	0	45	45	45
(g/plot)	0	0	315	315	315

Figure 34. Applying the rhizobium inoculum to the seed.



The recommended basal fertiliser is di-ammonium phosphate (DAP), which contains 18% N and 46% P2O5. Urea (46% N) at 45 kg/ha will be applied as a basal dressing, and another 45 kg/ha will be applied during the flowering stage. All basal fertiliser should be applied at planting. Urea is applied to soybean, maize and peanut only.

Applying rhizobium inoculum to the seed

The demonstration kit contains ready-weighed amounts of rhizobium inoculum in plastic bags for each treatment. So you don't need to go through all the steps below and can start at Step 4.

Always add rhizobium to the seed immediately before planting (Figure 34). Inoculum in sealed packets can be reliably used for 6–12 months after manufacture (always check the expiry date).

1. Make sure you have the correct rhizobium strain: Group I (cowpea, mungbean), Group P (Peanut) or Group H (soybean).
2. Calculate how much inoculum you need. For every 1 kg of seed you need 5 g of inoculum and 15 mL of drinking-quality water.
3. Weigh the correct amount of inoculum and add to a mixing bowl (Figure 34a). Seal the bag of inoculum and put it in a cool place.
4. Add water to the inoculum and stir thoroughly. This mixture is called the 'slurry' (Figure 34b).
5. Add slurry to the seed and mix thoroughly (Figure 34c). It is important that all seeds are well covered (Figure 34d).

VERY IMPORTANT! When you are applying the treatments to an experiment or demonstration, seed that is inoculated with rhizobium must be sown LAST to avoid contamination of uninoculated seed.

Remember that rhizobium is a living thing. You also need to take precautions as per the manufacturer's directions for use (Figure 35).

Most importantly, you need to keep the inoculum in a cool place.

Pesticides: Most pesticides are toxic to inoculants. Do not use a container that has been used for poisonous sprays or dusts.

Fertilisers: Do not mix the inoculated seed with fertilizer, because the fertiliser will KILL the rhizobium.

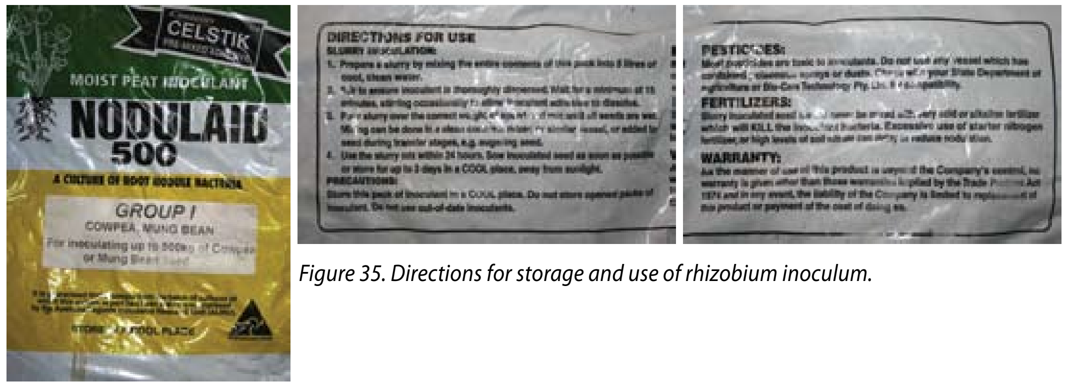


Figure 35. Directions for storage and use of rhizobium inoculum.

Data collection and recording

Stephanie Belfield and Bob Martin

Date of planting

Details about the farmer, location, crop and date of sowing can be entered on the Field Plan (see Appendix). You can also record the GPS coordinates and other notes on this Plan.

Seedling emergence and plant density

The date of emergence is usually recorded 14 days after sowing, but this may depend on the weather conditions. If it is dry, then germination may be delayed. Emergence records are done by observing the plot and estimating when 80% of the plot has emerged and recording this data.

Plant density should also be recorded at this time. Take five samples (1 m^2) for maize, mungbean, peanut and soybean and five samples (1 metre of row) for sesame (Figure 36). Record the results on the data sheet provided.

Nodulation (mungbean, peanut, soybean)

For mungbean, peanut and soybean, sampling is carried out to determine the number and effectiveness of the rhizobium nodules. At 40 days after sowing, dig five random plants per plot, being careful not to damage the roots. Wash the roots and score for the presence of nodules (Table 22). Cut five nodules per plant and record the colour (Figure 37).

Table 22. Nodulation scoring system for legumes

SCORE NODULE NUMBER	SCORE NODULE COLOUR
none – 1	green – 1
some – 2	white – 2
many – 3	pink – 3

Monitoring major pests and diseases

There are many insects that attack upland crops (example, Figure 38) and some are more important than others. It is important to monitor these pests for their numbers and the damage they cause. The greatest constraint to upland crop production is generally reduced yield and quality from pests and diseases.

Figure 37. A nodulated root system (left) and sections of nodules (right) showing the pink effective nodules.

Figure 38. Juvenile green vegetable bug, **Nezara viridula***.*

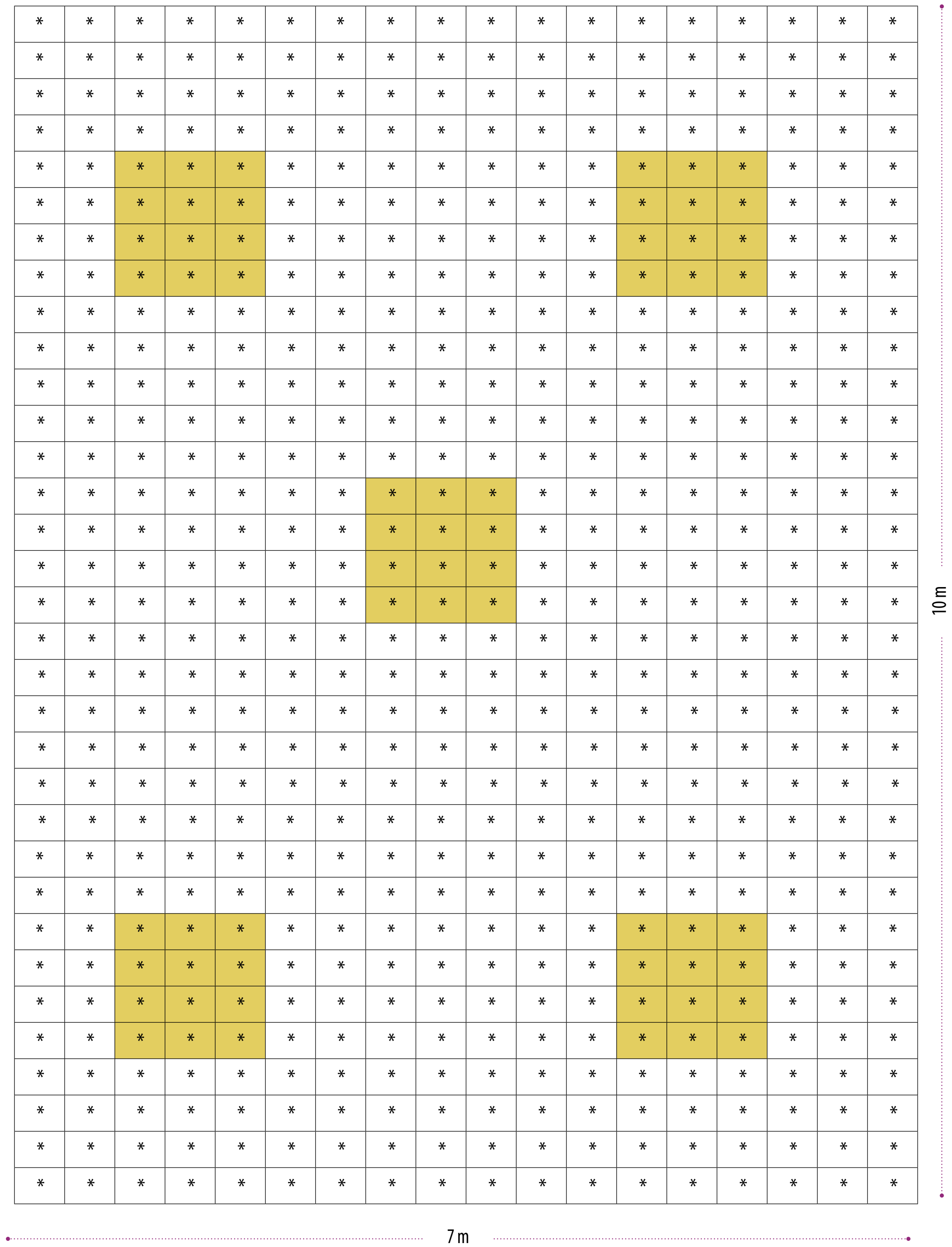


Figure 36. Sampling for seedling emergence and plant density.

You should monitor the incidence of pests and disease in demonstrations whenever you visit the site, from seedling emergence to crop maturity. However, the most important stage for insect damage is from flowering through to crop maturity.

You need to look for major insects pests and disease for each crop and in each treatment, as the damage may vary between treatments. See the chapter on 'Management of insect pests and diseases' for descriptions of the major insects and diseases that you are likely to find.

Method

On each visit to the site, keep a record of pests and diseases present. Walk up a row in the middle of the plot, taking care not to damage the plants. Monitor for insects and disease in five locations along the row. Disease damage can be rated as the percentage of plants affected.

Early vegetative stage:

1. Visual inspection of plants in 2 metres of row (to either side of a 1-m ruler). Record the number of insects of each type and the presence of any disease.
2. For diseases, record the percentage of the plant/ leaf affected.

Flowering to pod maturity:

3. Take the beat sheet provided (a 50 × 75 cm fertiliser bag) and place in between two rows. Shake the plants on either side of the sheet to drop insects feeding in the plants onto the sheet. Count how many of types of insect and record on the insect monitoring sheet (see Appendix).
4. Take the sweep net provided and walk up one row of each plot, sweeping the net back and forth across your path. At the end of the row, hold the neck of the net closed with your hand and count the number and types of insects captured. Record on the monitoring sheet (see Appendix).

Most damage by Helicoverpa is from the larvae feeding on tips, buds, flowers and pods. Larvae will also feed on leaves, but this does not usually cause significant damage (Figure 39).

Figure 39. Example of a major pest, **Helicoverpa armigera** *(Dangkov kbal kmao).*

Figure 40. Example of a major disease, mungbean yellow mosaic virus (MYMV), and its vector the whitefly.

This pest should be monitored at all stages of crop growth. Most field crops need to be checked from the budding and flowering stages through to maturity. Crops attacked include maize, soybean, mungbean, cowpea and peanut.

MYMV (Figure 40) is a widespread disease of mungbean worldwide and is spread by the whitefly insect. Symptoms first appear on young leaves as yellow specks and spread throughout the leaf. Infected plants bear few flowers and mature late. Pods become yellow and curved and remain underdeveloped.

The disease can cause significant damage to mungbean. Seed filling is incomplete, and upon maturity the seeds show yellow patches and a high percentage of hardness. Grain yield losses of up to 100% occur when the crop gets infected at an early stage.

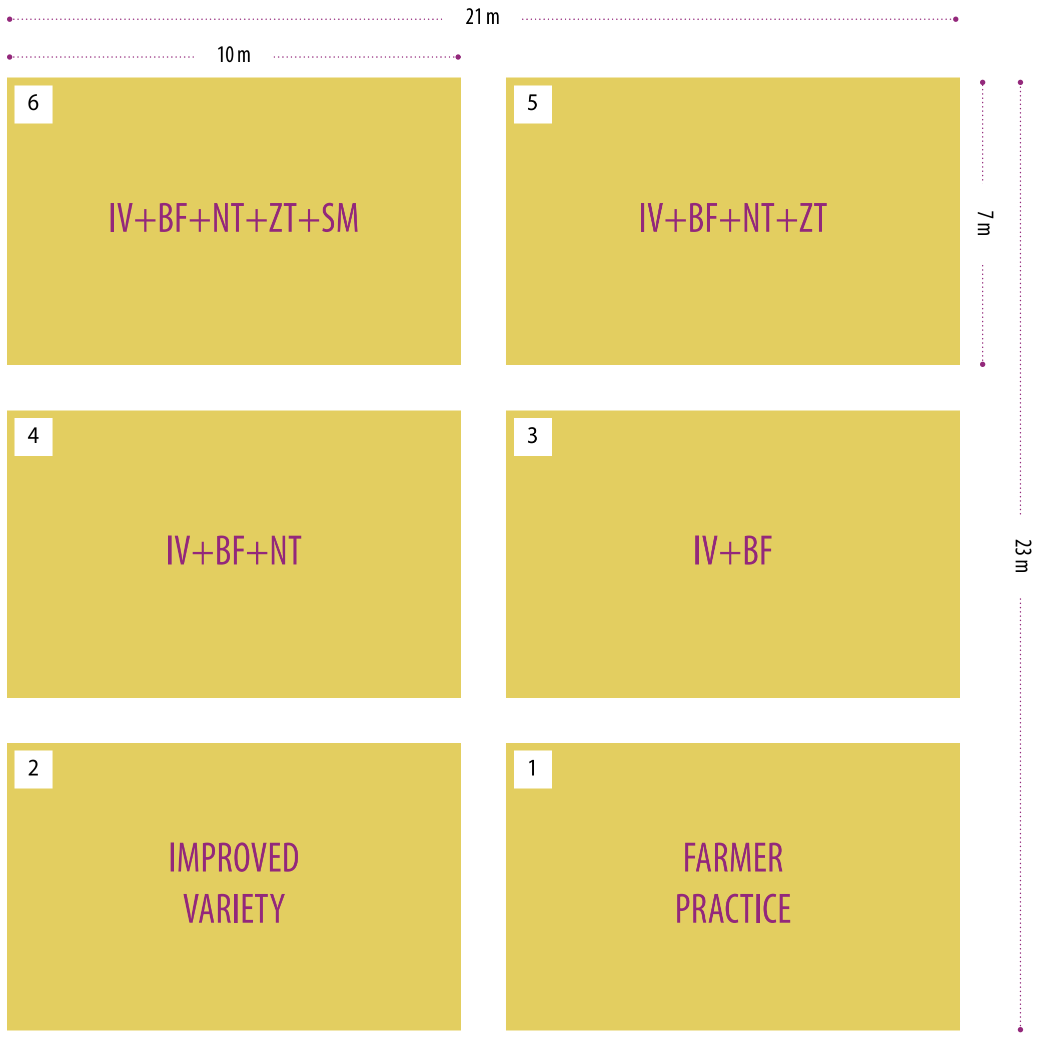
Further reading

Cheng Y and Horne P (1998). Field experiments with forages and crops: Practical tips for getting it right the first time. ACIAR Monograph No. 53, 48 pp.

Figure 41. Data recording at Rong Chak Pailin.

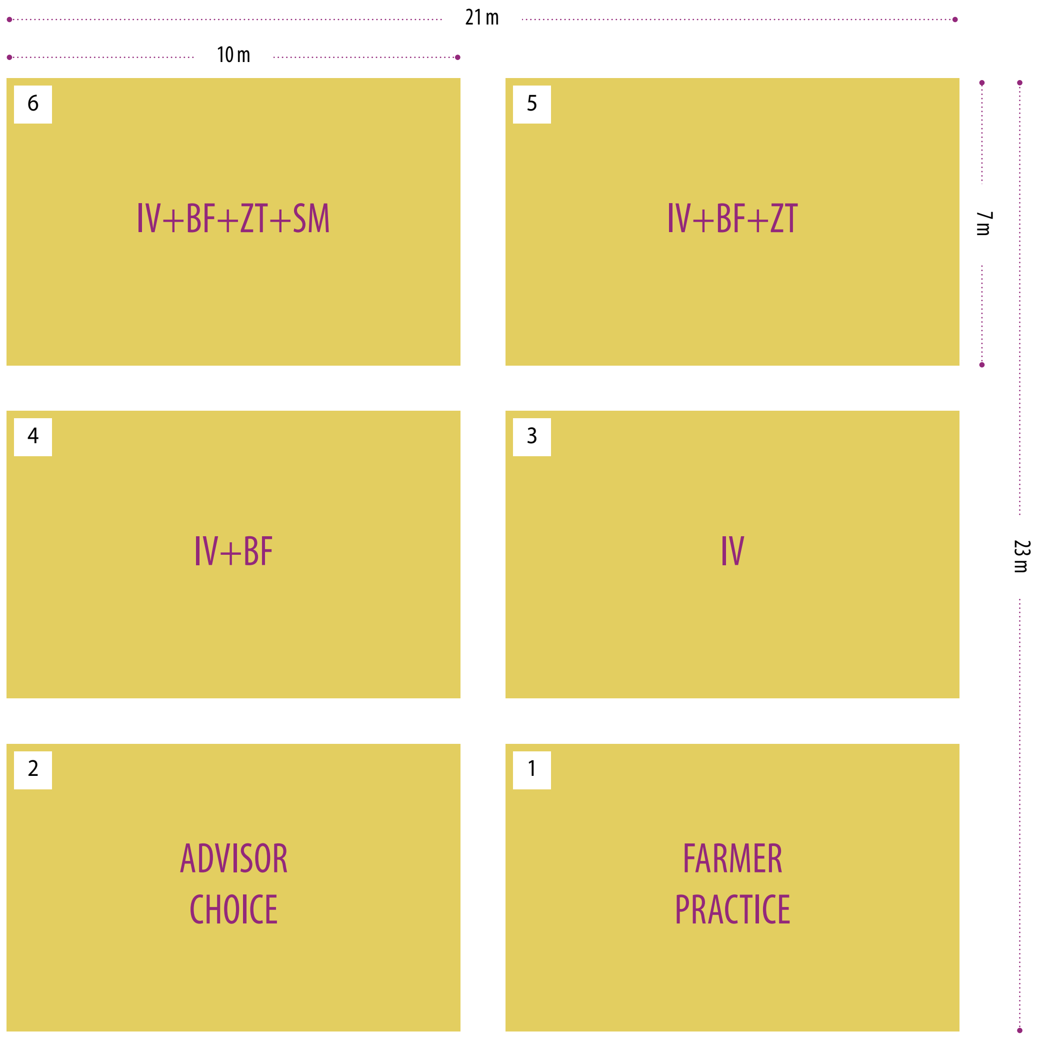
Appendix: Field plans and data sheets

MAIZE TRIAL DATA SHEET	
Trial number	Sowing date
Farmer name	Village
District	Province
GPS coordinates	



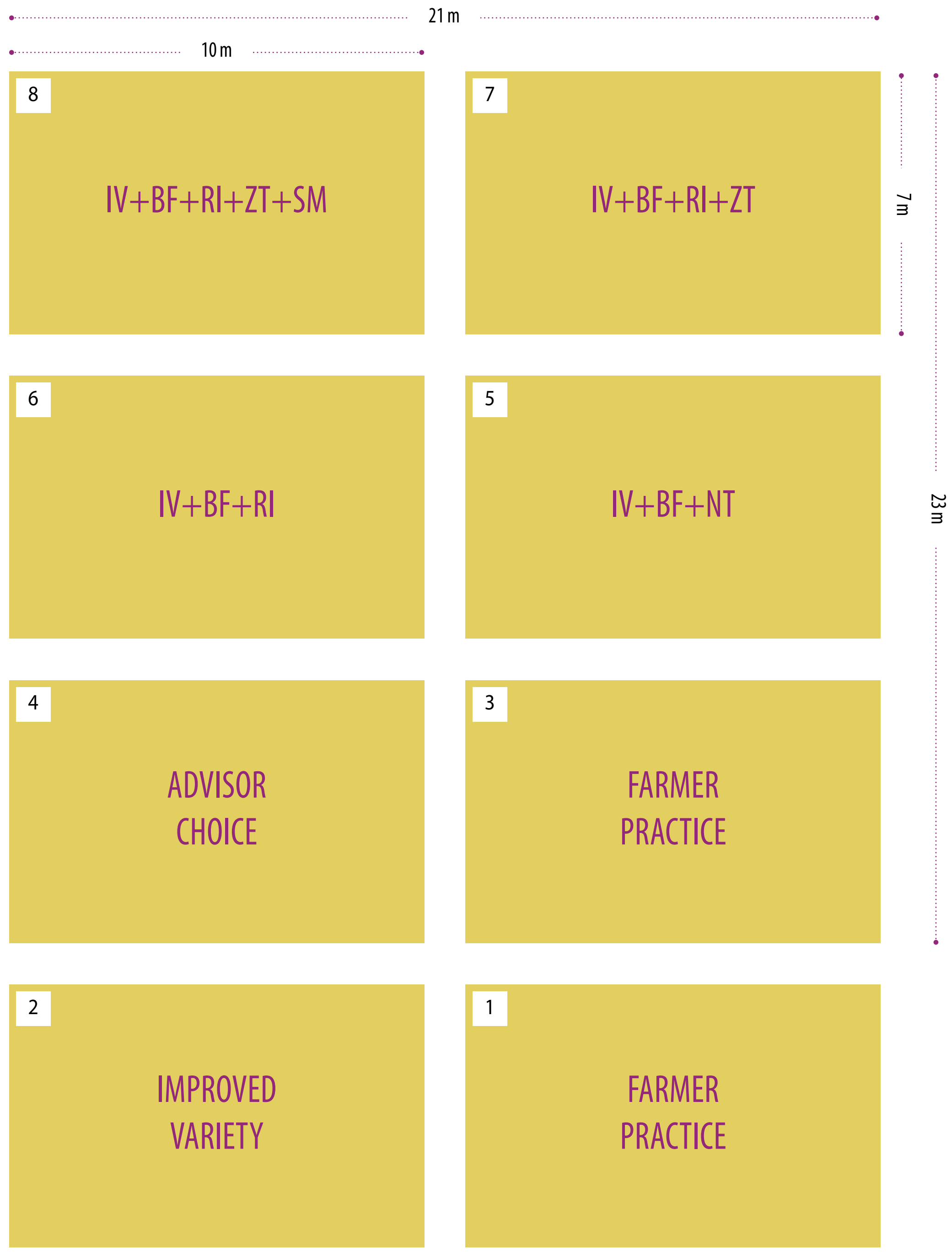
Notes

SESAME TRIAL DATA SHEET	
Trial number	Sowing date
Farmer name	Village
District	Province
GPS coordinates	



Notes

MUNGBEAN, PEANUT, SOYBEAN TRIAL DATA SHEET	
Trial number	Sowing date
Farmer name	Village
District	Province
GPS coordinates	



Notes

RAINFALL CHART		
Year	Location	Cooperator

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
Rain days												
Total												
Cum. total												

CAMBODIAN AGRICULTURAL RESEARCH & DEVELOPMENT INSTITUTE MAP OF THE SITE	
Name of the trial	
Farmer name	Cooperator
Location	GPS coordinates
Soil type	Village
Commune	District
Province	

The site map should show where the treatments are located. Mark North on the map and include all obvious features such as a road, a stream, a house. Check that everyone involved understands the map.

CAMBODIAN AGRICULTURAL RESEARCH & DEVELOPMENT INSTITUTE AGRONOMY DATA SHEET	
Name of the trial	
Farmer name	Cooperator
Location	Soil type
Village	Commune
District	Province
Date of planting	Date of harvest

PLOT	% GERM.	DATE OF FLOWERING	
		50%	100%
1			
2			
3			
4			
5			
6			
7			
8			

PLANT HEIGHT AT FLOWERING (cm)				
1	2	3	4	5

PLOT	PLANT HEIGHT AT HARVESTING (cm)				
	1	2	3	4	5
1					
2					
3					
4					
5					
6					
7					
8					

PODS PER PLANT				
1	2	3	4	5

PLOT	DATE OF MATURITY

YIELD	
kg/plot	kg/ha

BIOMASS	
kg/plot	kg/ha

CAMBODIAN AGRICULTURAL RESEARCH & DEVELOPMENT INSTITUTE INSECT PEST DATA SHEET	
Name of the trial	
Farmer name	Cooperator
Location	Soil type
Village	Commune
District	Province
Date of planting	Date of harvest

PLOT	INSECT NAME (NUMBER)				
	1	2	3	4	5
1					
2					
3					
4					
5					
6					
7					
8					

INSECT NAME				
1	2	3	4	5

PLOT	INSECT NAME				
	1	2	3	4	5
1					
2					
3					
4					
5					
6					
7					
8					

INSECT NAME				
1	2	3	4	5

CAMBODIAN AGRICULTURAL RESEARCH & DEVELOPMENT INSTITUTE
DISEASE DATA SHEET

Name of the trial	
Farmer name	Cooperator
Location	Soil type
Village	Commune
District	Province
Date of sampling	

PLOT	DISEASE NAME (% AFFECTED)					DISEASE NAME				
	1	2	3	4	5	1	2	3	4	5
1										
2										
3										
4										
5										
6										
7										
8										

PLOT	DISEASE NAME					DISEASE NAME				
	1	2	3	4	5	1	2	3	4	5
1										
2										
3										
4										
5										
6										
7										
8										

CAMBODIAN AGRICULTURAL RESEARCH & DEVELOPMENT INSTITUTE
RHIZOBIUM INOCULATION DATA SHEET

Name of the trial	
Farmer name	Cooperator
Location	Soil type
Village	Commune
District	Province
Date of sampling	

PLOT	NODULES PER PLANT					NODULE COLOUR				
	1	2	3	4	5	1	2	3	4	5
1										
2										
3										
4										
5										
6										
7										
8										

Score nodule number: none (1), some (2), many (3).
Score nodule colour: green (1), white (2), pink (3).

FIELD DAY QUESTIONNAIRE		
Name of the trial		Date
Village	Commune	
District	Province	

WHAT ARE THE OCCUPATIONS OF THE PARTICIPANTS? (WRITE IN NUMBERS)	
Farmer	
Government extension worker	
NGO representative	
Researcher	
Aid agency representative	
Student	
Other	

FOR THE FARMERS ONLY, HOW WOULD THEY DESCRIBE THEIR SITUATION? (WRITE IN NUMBERS)	
Male head of household	
Female head of household	
Wife of farmer	
Husband of farmer	
Son of farmer	
Daughter of farmer	
Other	

WHAT IS YOUR ROLE IN DECISION-MAKING IN THE FARM HOUSEHOLD?	
Make the farm decisions yourself	
Involved in making farm decisions	
Not involved	

WORK ON THE FARM. WHAT WORK/JOBS DO YOU DO ON THE FARM?	
Ploughing the field	
Sowing the crop	
Weeding the crop	
Harvesting the crop	
Transport to market	
Other	
None	

WHAT PRACTICES WOULD THE FARMERS LIKE TO KNOW MORE ABOUT AT FUTURE FIELD DAYS?	

HOW WELL DO THE PRACTICES BEING DEMONSTRATED APPLY TO YOUR FARM?	
PLOT	COMMENT
1	
2	
3	
4	
5	
6	
7	
8	

WHY WOULD YOU CONSIDER ADOPTING THIS PRACTICE ON YOUR FARM?	
PLOT	COMMENT
1	
2	
3	
4	
5	
6	
7	
8	

IF YOU HAVE TRIED THE PRACTICE ON YOUR FARM, WHAT WAS THE RESULT?	
PLOT	**COMMENT**
1	
2	
3	
4	
5	
6	
7	
8	

WHY WOULD YOU NOT ADOPT THIS PRACTICE?	
PLOT	**COMMENT**
1	
2	
3	
4	
5	
6	
7	
8	

NSW DEPARTMENT OF
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