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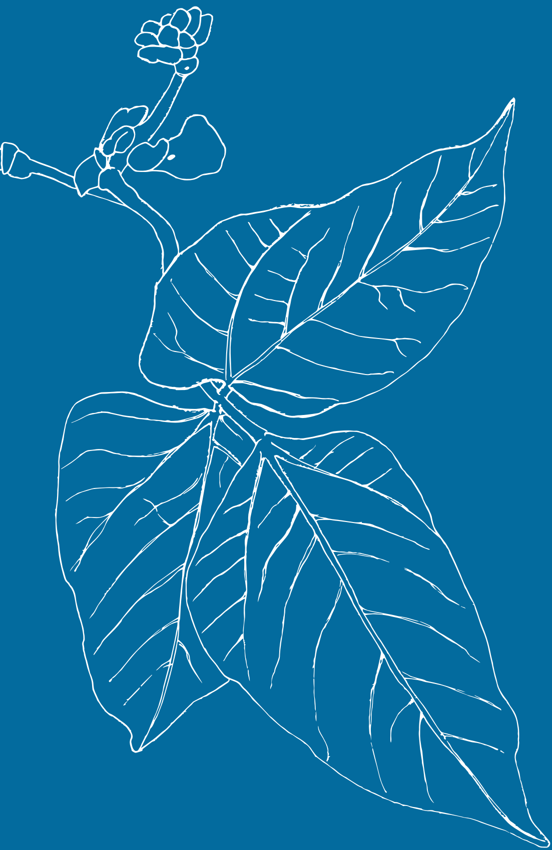
MUNGBEAN PRODUCTION GUIDE

CAMBODIA

ACIAR MONOGRAPH 214



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ACIAR

2020

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Cover: After cassava, maize and soybean, mungbean was the fourth most important non-rice crop in Cambodia in 2016. Mungbean will flower for as long as there is sufficient soil moisture and a single plant can have flowers, green pods and black pods all present at the same time.
Photos: R. Martin and S. Yous

FOREWORD

Mungbean presents smallholder farmers in Cambodia with an opportunity to diversify crop production in traditional rice production systems. The crop has a number of agronomic benefits and meets growing global demand for beans for sprouting, cooking and processing.

Cambodia's National Strategic Development Plan 2019–2023 is the road map for the implementation of the Rectangular Strategy Phase IV. A key element of the Rectangular Strategy is stepping up diversification and productivity in the agriculture sector, which remains a challenge to be addressed in terms of poverty reduction and improvement in livelihoods. According to the Ministry of Agriculture, Forestry and Fisheries, production of mungbean and other rice-diversification crops has been increasing in recent years. This is consistent with priority having been given to diversifying and intensifying sustainable agricultural production, with low inputs, and to developing cost-effective management practices.

The Australian Centre for International Agricultural Research (ACIAR) was mandated, as set out in the *Australian Centre for International Agricultural Research Act 1982*, to work with partners across the Indo-Pacific region to generate the knowledge and technologies that underpin improvements in agricultural productivity, sustainability and food systems resilience. We do this by funding, brokering and managing research partnerships for the benefit of partner countries and Australia.

This guide is based on knowledge and outputs of ACIAR-supported mungbean research carried out in Cambodia over 18 years. Information is drawn from the following projects:

> 'Farming systems research for crop diversification in Cambodia and Australia' (ASEM/2000/109), 2003–07

> 'Enhancing production and marketing of maize and soybean in north-western Cambodia and production of summer crops in north-eastern Australia' (ASEM/2006/130), 2007–12

> 'Market-focused integrated crop and livestock enterprises for north-western Cambodia' (ASEM/2010/049), 2012–16

> 'Sustainable intensification and diversification in the lowland rice system in north-west Cambodia' (CSE/2015/044), 2016–21.

This publication supersedes *Mungbean production guide for Cambodian conditions* (ACIAR Monograph No. 162), published in 2016. Notably, significant progress has been made in satisfying growers' criteria for a mungbean variety with combined attributes of large shiny seeds and resistance to pod shattering. The Cambodian mungbean variety CMB-2 currently best satisfies the grower criteria and will go into commercial production in 2021. The integrated pest management (IPM) schedule for managing mungbean insect pests has been fine-tuned to include biological insecticides and sticky traps that have made it possible to eliminate the use of synthetic insecticides in mungbean.

The projects listed above have made a significant contribution to capacity building for Cambodian provincial staff from the Ministry of Agriculture, Forestry and Fisheries, universities, non-governmental organisations and the private sector, for the implementation of new technologies and improved practices in mungbean production systems. This book is part of a series of publications produced by ACIAR that support of the ongoing roll-out of more productive, economic and environmentally sustainable and diversified cropping systems in Cambodia.

Andrew Campbell
Chief Executive Officer, ACIAR

CONTENTS

ACKNOWLEDGMENTS

This manual is an updated version of ACIAR Monograph No. 162, providing new and additional information.

The information in this manual is based on research by the Cambodian Agricultural Research and Development Institute (CARDI), University of Battambang (UBB), and the Provincial Departments of Agriculture, Forestry and Fisheries (PDAFF) in Battambang, Kampong Cham and Pailin. The research was supported by the New South Wales Department of Primary Industries, the University of New England and the University of Sydney. We also thank the World Vegetable Center (Dr Srinivasan Ramasamy for identification and management of insect pests in mungbean and Dr Abhay Pandey for identification and management of diseases of mungbean). This research was funded by the Australian Centre for International Agricultural Research (ACIAR) in the projects:

- ASEM/2000/109 (2003–07)
- ASEM/2006/130 (2008–11)
- ASEM/2010/049 (2012–16)
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ABBREVIATIONS

2,4-D	2,4-dichlorophenoxyacetic acid
ACIAR	Australian Centre for International Agricultural Research
app	application
AVRDC	Asian Vegetable Research and Development Center
CARDI	Cambodian Agricultural Research and Development Institute
CMB	Cambodian mungbean
Fe	iron
GRDC	Grains Research and Development Corporation
GVB	green vegetable bug
ha	hectare
IPM	integrated pest management
K	potassium
kg	kilogram
m^2	square metre
MAFF	Ministry of Agriculture, Forestry and Fisheries
ML	megalitre
mL	millilitre
mm	millimetre
MYMV	mungbean yellow mosaic virus
N	nitrogen
NCDD	National Committee for Sub-National Democratic Development
P	phosphorus
PDAFF	Provincial Departments of Agriculture, Forestry and Fisheries
PPE	personal protective equipment
S	sulfur
SC	soluble concentrate
SL	soluble liquid
SUT	Suranaree University of Technology, Thailand
t	tonne
UBB	University of Battambang
WVC	World Vegetable Center
Zn	zinc

TABLES

FIGURES

MUNGBEAN IN CAMBODIA

Mungbean production in Cambodia

Mungbean (*Vigna radiata* (L.) R. Wilczek) is a short-duration legume crop. In Cambodia, it begins flowering after approximately 30 days and produces mature pods from 60 to 90 days after sowing.

Mungbean plants are branching, erect and self-pollinating and have a rooting depth of 60–100 centimetres (cm).

Mungbean are grown to supply a human consumption market, so management for high seed quality is essential.

The area of agricultural production in Cambodia was 4.04 million hectares (ha) in 2016 of which rice was 3.12 million ha (77%) (Table 1).

After cassava, maize and soybean, mungbean was the fourth most important non-rice crop in Cambodia with an area of 37,598 ha, or less than 1% of the total cropped area, in 2016. With 5,172 ha, Battambang province accounted for 14% of the mungbean area in Cambodia with an average yield of 900 kilograms per hectare (kg/ha) in 2016 (MAFF 2017).

Table 1. **Cambodia crop production statistics for 2016 (MAFF 2017).**

Crop	Area sown (ha)	Area harvested (ha)	Production (t)	Yield (t/ha)
Rice total	3,118,160	3,099,769	9,952,270	3.21
Rice wet season	2,599,586	2,581,255	7,626,906	2.95
Rice dry season	518,574	518,514	2,315,364	4.47
Cassava	651,862	642,918	14,175,497	22.05
Maize	115,719	112,699	542,288	4.81
Soybean	41,611	41,606	69,406	1.67
Mungbean	37,598	36,587	49,815	1.36
Vegetables	27,310	27,308	238,082	8.72
Sugar cane	17,484	17,484	613,352	35.08
Sesame	14,683	14,603	13,730	0.94
Peanut	12,484	12,484	19,105	1.53
Sweet potato	3,417	3,417	24,472	7.16

Growing season

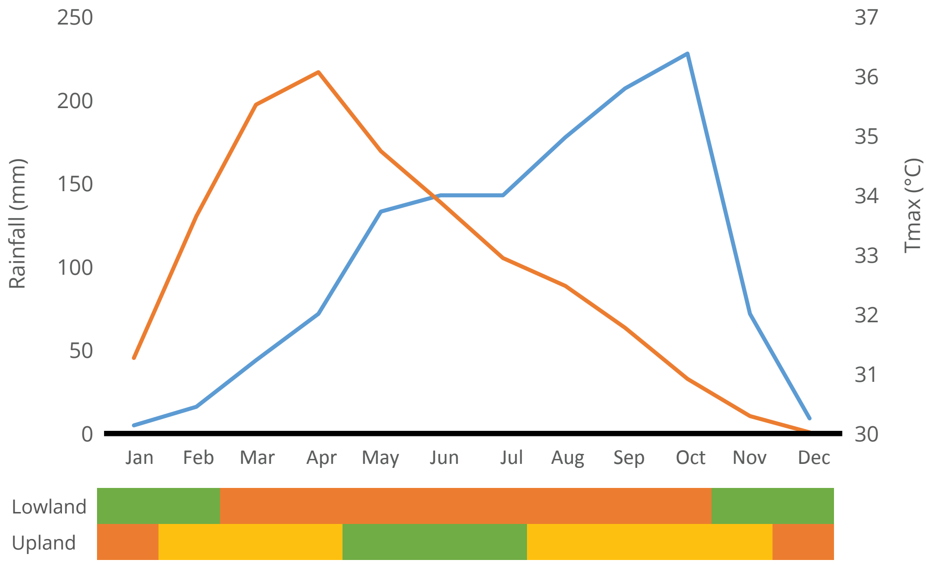

Figure 1. Mungbean growing season windows for lowland and upland. The orange line is average monthly maximum temperature and the blue line is average monthly rainfall. For planting suitability: green = yes; yellow = maybe; orange = no.

In Cambodia, mungbean can be grown in the upland and lowland. In lowland rice systems, mungbean is commonly grown as an opportunity crop in the early dry season between November and February depending on residual soil water after the main wet-season rice crop or after receding floodwaters. In upland cropping systems, mungbean is commonly grown in the early wet season between March and July (Figure 1). However, the risk of crop failure of February–April plantings in the upland is very high at 59%, whereas the failure risk is <1% for planting in May (Touch 2016). The prevalence of diseases under humid conditions makes it difficult to grow mungbean in the main wet season in the upland.

Constraints to production

The average yield of mungbean in lowland districts is 819 kg/ha (Table 2; NCDD 2010) but farmers claim they can achieve 1,500 kg/ha. If true, this would give a potential exploitable yield gap of 681 kg/ha for lowland crops (Stuart et al. 2016). Soils are more fertile in the upland and the average yield is 1,119 kg/ha. This compares to an easily achievable yield of 2,000 kg/ha, giving an exploitable yield gap of 881 kg/ha in the upland. However, yields of up to 3,000 kg/ha have been achieved in experimental fields in the upland. In both systems it is estimated that farmers are achieving only 50–60% of obtainable yield.

Table 2. **Actual and achievable mungbean yields in Battambang province (kg/ha).**

System	Actual	Achievable	Gap	Per cent
Upland	1,119	2,000	881	56%
Lowland	819	1,500	681	55%

Effects of straw mulch on mungbean yield in rice fields

Results from a study by Som et al. (2011)

In rice-based lowland areas, the lack of full irrigation water availability for post-rice legume crops and the poor physical and chemical conditions of the soil are major constraints for developing a sound rice–legume double-cropping system. Options to improve legume productivity include using rice straw mulch and various crop establishment methods.

A study by Som et al. (2011) found that mulching of rice straw at 1.5 tonnes per hectare (t/ha) increased mungbean crop establishment from 72% to 83%, reduced weed biomass from 164 to 123 kg/ha and increased yield from 228 to 332 kg/ha. Crop residue mulching was effective in conserving soil moisture, and at crop maturity the mulched area had on average 1% higher soil moisture content. Varying the amount of mulch between 1 and 2 t/ha did not show consistent effects, partly because some mulch treatments resulted in excessive soil moisture content and were not effective for increasing yield.

Rice straw mulch had a significant effect on mungbean yield, and mean yield increase with mulch was 35%. This yield advantage was attributed to better crop establishment, improved vegetative growth and reduced weed pressure, but in some cases only one or two of these factors were effective. On the other hand, planting method, tillage method and planting density had only small effects on mungbean yield in most experiments. Only in one location out of four tested did the no-till treatment produce significantly higher yield than the conventional method (Som et al. 2011).

Machine seed drill produced similar mungbean establishment and grain yield to hand planting, suggesting that the planter can be used to save the labour cost, which is increasing rapidly. Maximum root depth varied little with mulch or plant-density treatments, and was shallow (<20 cm). It is concluded that while rice straw mulch increased yield of mungbean following rice, the inability of mungbean roots to penetrate the hard pan is a major constraint for development of a sound rice–mungbean cropping system in the lowlands with compacted soils (Som et al. 2011).

Opportunities for mungbean in Cambodia

Although the average yield for mungbean in Cambodia is only about 1 t/ha, with reasonable improved practice, farmers should be able to get yields of at least 1.5 t/ha. At a price of 3,000 riel/kg ($750/t), this would return a gross margin of $625/ha.[1] Mungbean is one of the most profitable crops farmers can grow in rotation with rice. Options for increasing mungbean yields have been identified through farmer consultation and benchmarking farmers' fields (Table 3).

Table 3. Options for increasing mungbean yields.

Problem	Current practice	Improved practice
Pod shattering	Limited choice of varieties	Varieties with desired attributes
Lack of soil water	Two passes of a disc plough, hand broadcasting, harrowing after seeding	Crop residue retention, minimum or no tillage, drill planting
Poor crop nutrition	No basal fertiliser, foliar fertiliser application	Basal NPK + trace elements fertiliser + rhizobial inoculation
Poor weed control	Post-emergence herbicide on stressed weeds	Pre-emergence herbicide is more timely and effective
Insect pests	Broad-spectrum insecticides applied in vegetative stage cause flaring of secondary pests (e.g. thrips, aphids, mealybugs)	Seed dressing with systemic insecticide + integrated pest management (IPM) giving priority to managing pests attacking pods
Diseases	Application of fungicide	Resistant varieties, seed treatment
Suspected potassium (K) deficiency	Limited use of foliar fertilisers to promote flowering	Test strips of potassium chloride (KCl) in farmers' fields

1 All dollar amounts are in US$.

CROP PRODUCTION

Key management tips

> Select soil that drains freely.

> Use high-quality seed, and check the germination percentage, disease status and varietal purity of seed.

> Fertilise according to soil test analyses, yield potential and field history.

> Inoculate seed using Nodulaid® Group I peat inoculant or liquid inoculant from Suranaree University of Technology (SUT), Thailand.

> Calculate the required seeding rate to achieve a plant establishment of 20–30 plants.

> Select row spacing to fit the farming system: wide rows offer more flexibility in sowing, and weed and insect management; narrow rows offer higher potential yields and greater weed competition under ideal soil water conditions.

> Assess potential weed problems and carefully plan weed control tactics (options to effectively control broadleaf weeds are limited).

> Begin insect monitoring from the late vegetative (bud initiation) stage (28–35 days after planting) to ensure timely and effective control decisions.

Soil and water management

For machine harvesting, fields selected for mungbean should be fairly uniform in soil type and crop residue cover, and free from harvest impediments such as tree stumps and rocks. These are important considerations because of the low height of mungbean pods and to reduce the tendency for uneven crop maturity.

Field history

Mungbean is best included in the rotation after a cereal crop, such as maize in the upland or rice in the lowland. Because mungbean is sensitive to several residual herbicides, care needs to be taken when selecting fields where residual herbicides have been used on the previous crop or fallow.

Soil management

Mungbean prefers well-drained soils with a medium to heavy texture. It does not grow well where there is soil compaction or waterlogging. In the upland, Ferrosols (Labanseak) and Vertosols (Kampong Siem) are ideal for growing mungbean (White et al. 1997).

Some rice soils, such as Toul Samrong (hard-setting heavy clays), are not suitable for planting mungbean. Rice soils typically have a hard pan at 15–20 cm (Figure 2), and mungbean roots generally do not grow below this layer. Therefore, mungbeans planted after rice will require access to supplementary irrigation on some soil types. The surface of Toul Samrong soil becomes extremely hard and cracks as it dries out. Reference should be made to White et al. (1997) when choosing lowland soil types for mungbean planting.

Mungbean is well suited to no-till situations. Planting into standing maize or rice stubble should result in taller plants with pods higher above the ground, which makes machine harvesting easier. No-till also increases the preservation of residual soil moisture after the main wet-season crop and reduces the risk of crop failure.

Nutrition

Mungbean grow best on fertile, sandy loam soils with good internal drainage and a pH above 6.0. Except for Kampong Siem soil group, most Cambodian cropping soils are below this pH. Root growth can be restricted on heavy clays. Mungbean can show iron chlorotic symptoms and certain micronutrient deficiencies on more alkaline soils such as some soils in the Kampong Siem group.

Fertiliser recommendations are best based on soil test results, yield potential and field history. When properly inoculated and planted into situations with low background soil nitrogen levels, mungbean should fix sufficient nitrogen to support their own growth. Mungbean often leave some residual nitrogen for the following crop.

Basal fertiliser should contain mainly phosphorus (P) and potassium (K) and as little nitrogen (N) as possible. Mungbean should not require fertiliser topdressing. Basal application of di-ammonium phosphate (25 kg/ha) and muriate of potash (25 kg/ha) is recommended, but can be varied depending on soil fertility and yield potential. Because Cambodian soils vary widely in pH and natural fertility, adding trace elements is a precautionary measure.

Mungbean crops in Aek Phnum district, Battambang province, display symptoms of potassium deficiency (Figure 2), but this has yet to be confirmed.

Figure 2. **Suspected potassium deficiency. Photo: R. Martin**

Rhizobial inoculants

Mungbean should be inoculated with a Group I inoculant such as Nodulaid® (Figure 3). Seed should be sown into moist soil as soon as possible after inoculation to increase the survival of the rhizobia. Inoculation may be carried out by two alternative methods: coating the seed with a peat slurry (Nodulaid® product) or coating with a liquid inoculant (Suranaree University of Technology, Thailand). Nodulation should be checked 30 days after sowing for sufficient numbers of active pink nodules (Figure 4). Nodulation failure can lead to a significant yield reduction.

Figure 3. **Nodulaid® Group I root nodule bacteria inoculum for cowpea and mungbean (left), Suranaree University of Technology liquid inoculum for mungbean (right). Photos: R. Martin**

Figure 4. **Rhizobium root nodules (left) and healthy nodules cut open to show pink flesh (right). Photos: R. Martin**

Waterlogging

Mungbean does not tolerate waterlogging, so choice of soil type and irrigation management are very important. Waterlogging reduces the ability of nodules to fix nitrogen and also induces nitrogen deficiency. Irrigated mungbean is estimated to require 3.5–4.5 megalitres per hectare (ML/ha) of water. Where waterlogging is expected, planting mungbean onto hills or raised beds will allow better drainage.

Suggested timing of irrigation is:

- irrigation 1—about 7 days before the start of flowering, which is usually around 30 days after planting
- irrigation 2—early pod development.

Irrigating too late into the grain-fill phase may cause another flush of flowers to be produced, causing split maturity in the crop. This will delay harvest and increase the risk of loss in quality.

Land preparation and planting

Mungbean can be planted into rice crop residues from mid-November to mid-January, depending on the rice harvest date and soil moisture content (Figure 5). Earlier sowings could be affected by late rain and waterlogging. Header trails should be removed before planting.

Figure 5. **Machine harvesting of rice can leave a no-till seedbed. Photo: R. Martin**

Burning rice straw should be avoided because it dries out and hardens the soil surface, and can reduce establishment options for mungbean after rice.

Figure 6. **Rice residues can be mulched to keep weed seeds on the soil surface. Photo: R. Martin**

Figure 7. **Planting mungbean. Photo: R. Martin**

Crop establishment

Mungbean is normally hand planted at 40 cm row spacing in Cambodia. The recommended row spacing for machine-planted mungbean in Cambodia is 30 cm under good soil water conditions. A wider row spacing of 60 cm is recommended for dry-season sowing when soil water is limited and no irrigation is available. Narrow rows (30 cm) are recommended on active floodplain alluvial loamy soils with adequate soil water.

Figure 8. Dry-season mungbean machine planted into rice residue at 60 cm row spacing.

Plant population and sowing depth

The aim should be to establish 20–30 plants per square metre (plants/m^2) in non-irrigated dry-season crops and 30–40 plants/m^2 in wet season or irrigated situations. Establishing a uniform plant density is critical to achieving uniform plant maturity across the field. The planting depth across the width of sowing machinery should be even to ensure even crop emergence.

The number of seeds per kilogram of mungbean seed can vary widely—from 10,000 to 20,000 depending on variety and growing conditions. Therefore, it is recommended that the sowing rate is calculated using germination test results, seed count per kilogram, the target plant population and establishment percentage. The sowing depth should be 3–5 cm.

Calculating sowing rates

The following formula can be used to calculate sowing rates, taking into consideration:

- the number of seeds per kilogram (seeds/kg; seed size or seed weight)
- the target plant population
- germination percentage (e.g. 90% germination = 0.9 in the formula)
- establishment rate (usually 80% = 0.8 in the formula, unless sowing in adverse conditions).

$$\text{Sowing rate (kg/ha)} = \frac{\text{Target plant population/m}^2 \times 10{,}000}{\text{Germination} \times \text{establishment rate} \times \text{seeds/kg}}$$

Worked example:

$$\text{Sowing rate (kg/ha)} = \frac{25 \text{ plants/m}^2 \times 10{,}000}{0.9 \times 0.8 \times 12{,}500} = 28$$

Seed size of mungbean grown in Cambodia generally ranges from 11,000 to 14,500 seeds/kg, and the average is between 12,500 and 13,000 seeds/kg. Larger seeds require higher seeding rates (Table 4). The optimum plant population also varies according to the availability of soil water; it can be increased if there is adequate soil water and reduced if soil water is limiting.

Table 4. **Effect of seed size and target plant population on choice of seeding rate (kg/ha).**

Seeds (per kg)	Target plant population (plants/m²)				
	15	20	25	30	35
11,500	18	24	30	36	42
12,000	17	23	29	35	41
12,500	17	22	28	33	39
13,000	16	21	27	32	37
13,500	15	21	26	31	36
14,000	15	20	25	30	35

Seed quality

Seed used for planting should ideally have germination percentages above 90%. Take care with some varieties as hard (dormant) seed levels may vary. A high percentage of hard seed can result in uneven germination and establishment. The level of hard seed (by test) should be kept to a minimum; above 20% hard seed is not advisable in seed for planting.

Seed kept on-farm for re-sowing can lose quality quickly. Seed quality can be reduced by seed-borne diseases, damage by grain storage insect pests, and weed seed contamination. It is recommended that farmers purchase seed with a certification label. Before purchasing seed, check for damage by grain storage insects (see 'Grain storage pests', below).

Varieties

Apart from high yield, mungbean growers are looking for reduced pod shattering (Figure 9) and large-seeded varieties (Figure 10).

Figure 9. **Pod shattering is a problem for DX-208 variety. Photo: S. Chhun**

Figure 10. **Cambodian mungbean (CMB)-2 has large seeds. Photo: R. Martin**

Varietal evaluations 2004–06

Mungbean varieties were evaluated for adaptation to Cambodian conditions over a range of environments in 2004–06 by the Cambodian Agricultural Research and Development Institute (CARDI) (Ouk et al. 2009). Genotypes evaluated were from the Asian Vegetable Research and Development Center (AVRDC—now the World Vegetable Center), Australia and Thailand. These were compared with local farmer varieties.

Two sets of mungbean varietal evaluation experiments were carried out in Cambodia between 2004 and 2006 (Ouk et al. 2009). The best-performing varieties were VC 4152 and VC 3541 (AVRDC), and ATF 3944 from Australia (Figure 11). All varieties outperformed local varieties, and farmers preferred the new varieties. These three varieties have been released by CARDI as CMB-1 (VC 4152), CMB2 (VC 3541) and CMB-3 (ATF 3944). Mungbean seed originating from both Thailand and Vietnam can be purchased at most seed stores. However, quality is inconsistent, and germination tests should be carried out before large amounts of seed are bought.

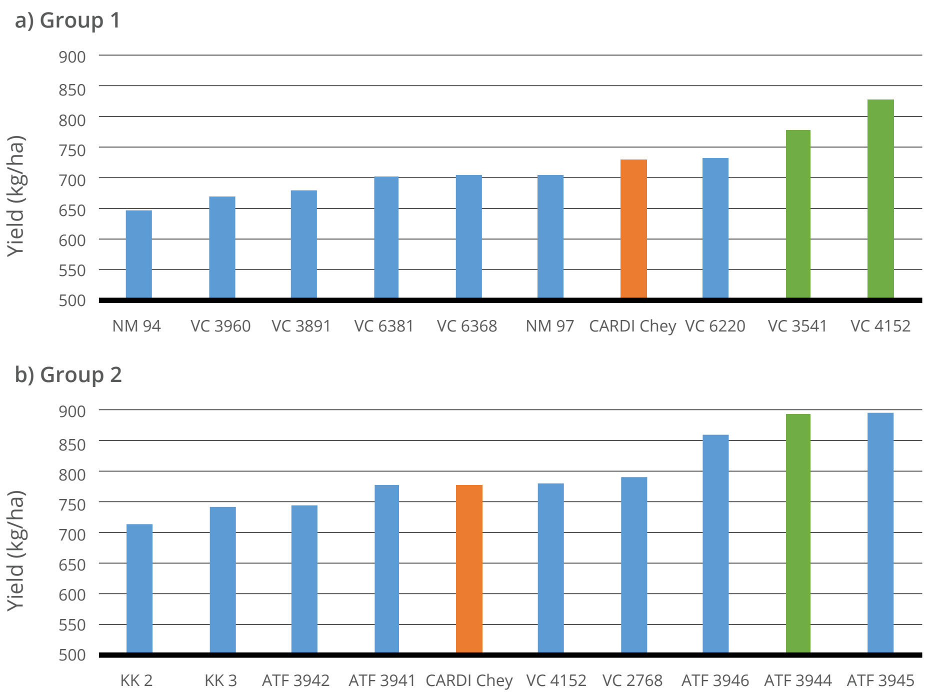

Figure 11. **Evaluation of mungbean varieties for Cambodian conditions. The orange bars are CARDI Chey (locally released variety) and the green bars represent the varieties selected for release.**

Varietal evaluations 2019–20

Mungbean growers in Battambang plant two varieties—DX-208 (Vietnam) and KPS-2 (Thailand)—and pick twice, around 60 and 90 days after sowing. Under this regime, pod shattering is a problem with DX-208 but not with KPS-2. However, DX-208 is preferred for seed size and price.

Although the Cambodian varieties (CMB-1, CMB-2 and CMB-3) were released prior to 2009, they were still not commercially available in 2020. Varietal testing in 2019 and 2020 has revealed that CMB-2 meets farmer specifications with a low level of pod shattering comparable to KPS-2 (Figure 12) and large seeds comparable to DX-208 (Figure 13).

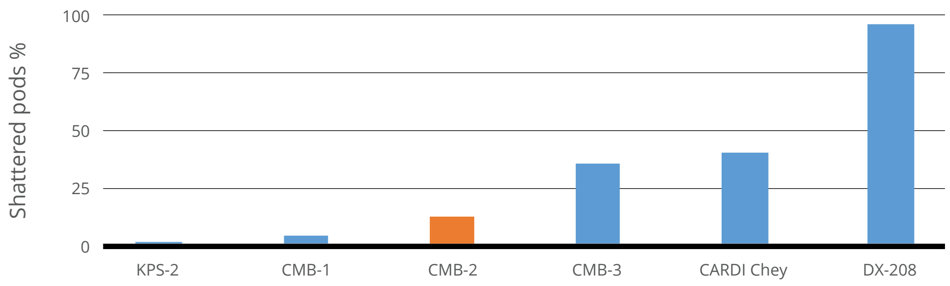

Figure 12. Pod shattering at 62 days after sowing (%).

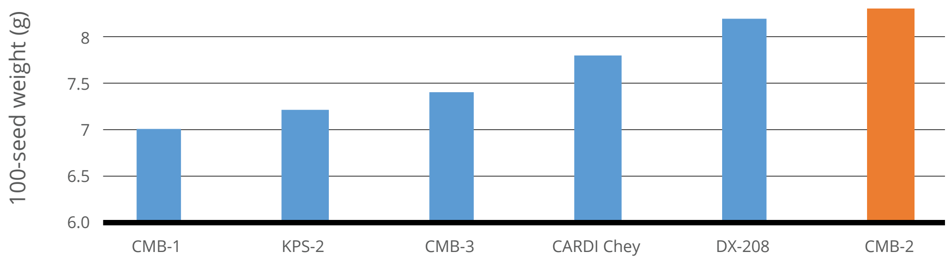

Figure 13. 100-seed weights of mungbean varieties.

Orange bars represent CMB-2, which best satisfies the farmer requirement for resistance to pod shattering combined with large seeds.

Options to improve profitability of mungbean

Improved practices are designed to reduce input costs and at the same time increase yield of mungbean. Although farmers are attempting to grow low-input mungbean at the end of the wet season, excessive tillage reduces valuable soil moisture and, consequently, lowers yield potential (Table 5). Replacing hand broadcasting with machine drill planting enables tillage operations, as well as seeding rates, to be reduced. The comparison in Table 5 assumes that improved practice increases yield from 1.0 to 1.5 t/ha.

Currently, mungbean growers apply up to 10 insecticide treatments throughout the crop cycle regardless of the presence or absence of insect pests. The improved practice alternative is integrated pest management (IPM), whereby insecticides are not applied unless predetermined economic thresholds are exceeded. This can significantly reduce the cost of crop protection without reducing the economic return (Table 5).

Farmers can achieve 1 t/ha. Assuming a price of $1/kg, this would provide an income of $1,000/ha and a gross margin of $564/ha with farmer practice. Experimental yields indicate that improved practices could lift mungbean yields to over 2,500 kg/ha and gross margins up to $2,000/ha. Assuming that improved practice can achieve 1.5 t/ha, an on-farm gross margin of over $1,000 is achievable (Table 5).

Mungbean is a relatively safe crop to grow after rice with a break-even yield of 0.43 t/ha and a break-even price of $288/t. Commercial yields and prices are well above these thresholds (Table 6).

Table 5. **Gross margin comparison for current practice (for a yield of 1 t/ha) vs improved practice (for a yield of 1.5 t/ha) at $1/kg.**

Income		
Yield (kg/ha)	1,000	1,500
Price ($/kg)	1	1
Income ($/ha)	1,000	1,500
Variable costs (US$) Operation	**Current practice**	**Improved practice**
Ploughing (current—twice; improved—once)	60	30
Seeding (current—30 $/ha; improved—24 $/ha)	47	37
Inoculant	0	5
Seed treatment with insecticide	0	5
Seeding method (current—hand broadcast; improved—machine planting)	5	36
Harrowing (current—after broadcasting)	15	0
Herbicide (quizalofop + fomesafen)	18	18
Foliar fertiliser	21	21
Fungicide	13	13
Insect management (current—prescriptive; improved—IPM)	113	52
Hand harvesting	144	217
Total variable costs/ha	436	434
Gross margin per hectare	564	1,068

Table 6. **Effect of varying yield and price for improved practice mungbean gross margin.**

Yield (t/ha)	**Price ($/t)**				
	800	**900**	**1,000**	**1,100**	**1,200**
0.75	168	243	318	393	468
1.13	468	580	693	805	918
1.50	768	918	1,068	1,218	1,368
1.88	1,068	1,255	1,443	1,630	1,818
2.25	1,368	1,593	1,818	2,043	2,268

Mungbean growth stages

Mungbean has epigeal emergence—that is, cotyledons appear above the soil surface. Following cotyledon emergence, a pair of unifoliate leaves begin unfolding. Thereafter, alternate trifoliate leaves arise from all nodes above the unifoliate node. Mungbean are branching, erect or sub-erect and usually stand 0.5–1.0 m high when they have finished vegetative growth.

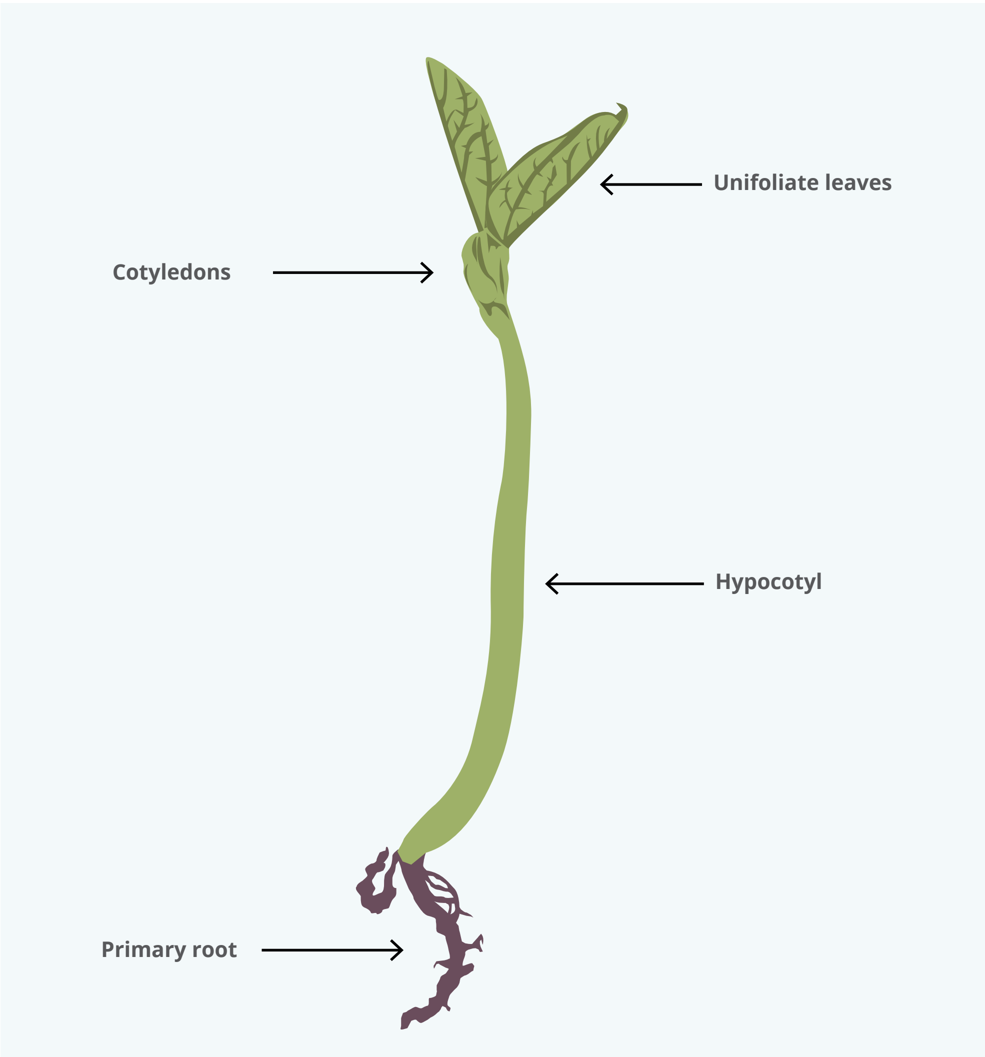

Figure 14. **Mungbean seedling morphology.**

Figure 15. Growth stage VE. Photo: R. Martin

Figure 16. Growth stage VC. Photo: R. Martin

Figure 17. Growth stage V_1. Photo: R. Martin

Figure 18. Growth stage V_2. Photo: R. Martin

Table 7. **Vegetative growth stages for mungbean after Pookpakdi et al. (1992).**

Code	Stage	Description
VE	Emergence	Cotyledons near the soil surface with the seedling showing some part of the plant above the soil surface.
VC	Cotyledon	Cotyledons separate from each other on the upper surface. Unifoliate leaves start to unroll so that the edges of the leaves are not touching each other.
V_1	First node	Unifoliate leaves attached to the first node are fully expanded and flat while the 1st trifoliate leaf attached to the upper node begins to unfold.
V_2	Second node	1st trifoliate leaf attached to the second node is fully expanded and flat while the 2nd trifoliate leaf on upper node starts to unfold.
V_3	Third node	2nd trifoliate leaf attached to the fourth node is fully expanded and flat while the 3rd trifoliate leaf on the upper node starts to unfold.
V_4	Fourth node	3rd trifoliate leaf attached to the fourth node is fully expanded and flat while the 4th trifoliate leaf on the upper node starts to unfold.
$V_{(n)}$	N^{th} node	A node is counted when its trifoliate leaf is unfolded and its leaflets are flat.

Table 8. **Reproductive growth stages for mungbean after Pookpakdi et al. (1992).**

Code	Stage	Description
R_1	Beginning flower	One open flower at any node on the main stem.
R_2	Beginning pod	One pod of 1.0 cm length between nodes 4 and 6 of the main stem.
R_3	Beginning seed	One pod of 5.0 cm length found on any of the top three nodes on the main stem.
R_4	Full seed	One pod on any of the top three nodes has constriction between seed.
R_5	Start maturity	One pod on the main stem turns to brown, dark brown or black.
R_6	First harvest	Fifty per cent of pods on the plant are mature.
R_7	Second harvest	R_7 is reached after the remaining pods on the plant mature.

Mungbean are determinate in their growth habit: vegetative growth stops when flowering commences, meaning that the crop will have reached its final height. However, mungbean have an indeterminate flowering habit: they do not have a defined flowering period and will continue to flower for as long as there is sufficient soil moisture. This means that a single plant can have flowers, green pods and black pods all present at the same time. The reproductive stages of mungbean are described in Pookpakdi et al. (1992) (Table 8).

Under Cambodian conditions, mungbean plants progress from emergence to the beginning of flowering in around 30 days. Flowers are yellow or greenish yellow in colour (Figure 19) and are normally grouped in clusters of 5–15. If flowers abort, new flowers will appear if moisture conditions allow. Successive flushes of flowers and pods will occur while the soil stays wet. Most of the pods form on the top third of the plant. Each pod contains 10–15 almost-round, green seeds.

Figure 19. **Mungbean flowers. Photo: S. Yous**

Rats

Figure 20. The rice field rat. Photo: R. Martin

In some districts, including Thmar Kuol and Aek Phnum, some farmers have stopped growing mungbean in the dry season because they have not been able to control rats. Rats are very difficult to control. A combination of methods, such as physical barriers around the perimeter of the field, water moats, traps and rodenticides, are required for control.

Baiting can be done using the anticoagulant flocoumafen. Suitable bait locations include active rat holes, along runs and under rubbish. A barrier of bait locations is established between rat living areas and the crop. Secure three or four bait blocks at each bait location on wire or nails, or inside rat bait boxes. Also place one or two in each rat hole. Inspect the bait locations after 3 days, and select new locations where there has been no rat activity. Inspect again 4 days later and replace any blocks that have been eaten. Repeat the inspection of all bait locations at 7-day intervals, replacing fresh blocks only when blocks have been eaten, until all signs of rat activity have disappeared. Normally only three or four baiting rounds are required.

Harvesting and desiccation

Figure 21. **Combine harvesting mungbeans in Aek Phnum district. Photo: Reaksa Sao**

In Cambodia, mungbean is traditionally harvested by hand. Two or three pickings are required because of the prolonged duration of flowering; however, this can cost more than $200/ha. Some farmers in Battambang are now picking once only and finishing off with a combine harvesting machine (Figure 21). Machine harvesting requires even maturity across the field, and desiccation may be required to maximise yield and quality. Glyphosate can be applied as a desiccant when 90% of pods are yellow or black. Harvesting can commence 8–16 days after herbicide application when the leaves are dry. Harvest losses can result when mungbean are too dry when harvested, due to both the increased risk of shattering and moisture weight losses. Mungbean are susceptible to wet weather at maturity, which causes seed swelling, discolouration, moulds and cracking. They should therefore be harvested as early as practical.

WEED MANAGEMENT

Descriptions of weeds commonly found in upland mungbean crops in Cambodia can be found in *Weeds of upland crops in Cambodia* (Martin and Pol 2010).

Weed management tips

> Include cereal crops (rice, maize) in the rotation.

> Make sure seed for planting is free from weed seeds.

> Control weeds, especially those that reproduce vegetatively, before sowing.

> Use a post-sowing, pre-emergence herbicide as a priority.

> Apply post-emergence herbicides if necessary.

> Prevent weeds from setting seed during the crop cycle and post harvest.

It is important to control weeds before sowing. This applies especially to weeds that reproduce from rhizomes, stolons, tubers (such as *Cyperus rotundus*) or pieces of stem (such as *Cyanotis axillaris*). If such species are present, the final cultivation should be replaced by application of glyphosate + 2,4-D.

Mungbean are generally regarded as being poor competitors with weeds. However, mungbean planted after rice or flood into the dry season is able to capture soil water ahead of the weeds. Weed competition reduces water use efficiency, interferes with harvesting and contaminates the seed sample. Weeds such as *Ageratum conyzoides* can also be alternative hosts of diseases such as mungbean yellow mosaic virus (MYMV). The virus can be transmitted from the weed to mungbean by whitefly (*Bemisia tabaci*).

Herbicide options for control of broadleaved weeds in mungbean are limited (Table 9). Emphasis must therefore be on selecting fields that do not have a problem with broadleaved weeds.

Table 9. **Herbicides that can be used in mungbean in Cambodia.**

Active ingredient	Mode of action group	Pre-plant	Post-sowing pre-emergence	Post-emergence
2,4-D	4	✓		
Glyphosate	9	✓		
S-metolachlor	15		✓	
Pendimethalin	3		✓	
Imazethapyr	2		✓	
Fomesafen	14			✓
Clethodim	1			✓
Quizalofop	1			✓

Because herbicides are now widely used in Cambodia, herbicide resistance should be kept in mind when selecting herbicides for use in mungbean. Rotating grass crops (maize, rice) with mungbean enables rotation of herbicides with different modes of action (WSSA 2020), which will delay the development of herbicide resistance. However, herbicides are only part of an integrated weed management strategy to better manage weeds and reduce the likelihood of the development of herbicide resistance.

Mungbean can be damaged by residues of sulfonylurea herbicides such as metsulfuron methyl + chlorimuron ethyl or bensulfuron methyl, which are used in rice, or atrazine, which is used in maize. Under normal conditions, residues should not be a problem, but mungbean should not be planted as a replacement for failed maize or rice crops when herbicide residues could still be active in the soil. Residues tend to stay in the soil for longer under alkaline or dry conditions, but these conditions are unusual for Cambodia, where most soils are acidic.

DISEASES

Disease management tips

- Include cereal crops (rice, maize) in the rotation.
- Make sure seed for planting is coated with fungicide.
- Prevent damage from insects, birds and rodents, because such damage can allow pathogens to enter the plant through wounds.
- Avoid stresses to the crop, including water stress and too much fertiliser.
- Control weeds, because weeds are alternative hosts for many diseases.
- Apply fungicide if appropriate.

Mungbean yellow mosaic virus

Figure 22. **Mungbean yellow mosaic virus (MYMV) symptoms on mungbean leaf. Photo: R. Martin**

Control of the vector *Bemisia tabaci* is the main option for control of mungbean yellow mosic virus (MYMV) (Figure 22), but it is important to be sure that the pest is present in the crop before applying insecticide.

Integrated pest management is the best approach to maintain populations of beneficial insects. IPM is also important to delay or avoid the development of insecticide resistance in important insect pests such as *B. tabaci.*

Weeds that host MYMV, such as *Ageratum conyzoides*, should be controlled in and around the mungbean field. MYMV is widely touted as a major disease of mungbean in South-East Asia. It occurs in mungbean-growing areas in eastern Cambodia, such as Chamkar Leu district in Kampong Cham province, but it does not appear to be a common disease of mungbean in north-west Cambodia.

Cercospora leaf spot

(*Cercospora canescens*)

Figure 23. **Cercospora leaf spot on mungbean. Photo: cropgenebank.sgrp.cgiar.org**

Cercospora leaf spot (Figure 23), caused by the fungus *Cercospora canescens,* is an important fungal disease of mungbean in Cambodia. It is most destructive under humid, tropical conditions. A range of registered fungicides effectively control this disease, including carbendazim, difenconazole, hexaconazole, mancozeb, propiconazole and thiophanate methyl.

Halo blight

(*Pseudomonas savastanoi* pv. *phaseolicola*)

Figure 24. Halo blight. Photo: R. Martin

Symptoms appear 7–10 days after infection. Extensive yellow halos surrounding small (1–2 millimetres (mm)) dark, water-soaked (shiny) spots appear on younger leaves (Figure 24). On older leaves the halo is not apparent. A shiny circular lesion develops on infected pods and a cream-coloured exudate containing bacterial cells may ooze from the lesion.

Alternative hosts of *P. s.* pv. *phaseolicola* occurring in Cambodia belong to the family Fabaceae and include: *Phaseolus vulgaris, Cajanus cajan, Centrosema* spp., *Desmodium* spp., *Glycine max, Lablab purpureus, Macroptilium* spp., *Pueraria* spp. and *Vigna unguiculata.*

P. s. pv. *phaseolicola* can survive between crops on alternative hosts, and in infected seeds, and to a limited extent on infected plant residues. Infected seed is considered to be the major mode of survival and spread of the pathogen, and one infected seed in 10,000 can start an outbreak under suitable weather conditions.

P. s. pv. *phaseolicola* is spread during wet, windy weather, with entry through stomates or wounds under moist conditions (dew, rain or irrigation). Temperatures in the range 18–25 ^{o}C are most conducive for infection and disease.

Powdery mildew

(*Erysiphe polygoni*)

Figure 25. Powdery mildew. Photo: R. Martin

Powdery mildew can be a serious disease of mungbean (Figure 25). It is favoured by warm, humid conditions. Mungbeans are usually planted in the early wet season (February–March) in the upland and after flood or the main wet-season rice crop in the lowland (November–December). Mungbeans are not normally grown in the main wet season when powdery mildew could be an economic problem.

In the dry season, powdery mildew is found on lower leaves as the crop matures, but does not cause economic damage.

Sulfur-based fungicides provide good control of powdery mildew. Carbendazim can also be used to control powdery mildew in mungbean.

INSECT PESTS

Insect management tips

- Keep weeds under control between crop plantings.
- Make sure seed for planting is coated with insecticide.
- Carefully check for pests and beneficial insects before applying insecticide.
- Avoid application of broad-spectrum insecticides in the vegetative stage, to preserve beneficial arthropods.
- Control weeds in and around the field, because weeds are alternative hosts for many insects.
- Apply insecticide if crop damage thresholds are exceeded.

Pest and beneficial insects commonly found in upland crops in Cambodia are described in *Insects of upland crops in Cambodia* (Pol et al. 2010).

Bean fly

(*Ophiomyia phaseoli*)

Figure 26. **Bean fly pupae (left) and adult (right). Photos: W. Leedham**

Adult bean flies (Figure 26) are tiny black flies, 3 mm long (about one-quarter the size of a common housefly), with one pair of transparent wings. Larvae are small, white maggots with brown heads. Pupae are pale yellow, straw-coloured or light brown, and can be seen sticking under the membranous epidermis, usually at the root–shoot junction.

Mungbean, cowpea, soybean and other legumes are attacked at seedling and vegetative growth stages. Attacked seedlings may be wilted or dead, and leaves of older plants may be yellow and stunted. Damaged stems are thicker than normal and cracked lengthwise just above the soil.

Twenty-eight spotted ladybird

(***Henosepilachna vigintisexpunctata***)

Figure 27. Twenty-eight spotted ladybird adult (left) and larva (right). Photos: R. Martin

Adults are 5–8 mm long and are dull orange with black spots. The upper wing surface is covered in short downy hairs (Figure 27). This distinguishes plant-feeding ladybird beetles from their beneficial bug-feeding relatives. The eggs are yellow, elongate and oval, and are usually laid on the undersurface of leaves in batches of 5–40.

Larvae are elongate and elliptical with moderately long legs and a well-developed head and mandibles. The body of the larva is covered with long, branched processes (scoli) bearing spines (Figure 27). Adults and larvae scrape away leaf surface cells between the veins to leave irregularly shaped holes or strips. They commonly feed on solanaceous crops and weeds such as eggplant, tomato, potato and *Physalis angulata* but also feed on other crops.

Cluster caterpillar

(*Spodoptera litura*)

Figure 28. Cluster caterpillar adult (left) and larva (right). Photos: R. Martin, W. Leedham

Moths of cluster caterpillar (Figure 28) are up to 25 mm long. The eggs are laid in clusters of up to 300 and are covered with a mat of grey–brown hairs. Mature larvae grow to up to 30 mm in length. They have black triangles in a line on both sides of the back, and the body narrows towards the head. Larvae can almost completely destroy leaves, and heavy infestations also destroy buds and flowers.

Legume web spinners

(*Omiodes indicata, O. diemenalis*)

Figure 29. **Legume web spinner: adult *O. diemenalis* (left) and *Omiodes indicata* (centre); and *Omiodes* larva (right). Photos: W. Leedham, R. Martin**

Adult moths have a wingspan of 20–28 mm. *O. indicata* adult colour ranges from reddish yellow or orange–brown to dark grey with some lighter grey markings. *O. diemenalis* adults are yellow with brown, broad wavy bands and spots. Larvae are 15 mm long, light to dark green on top and yellowish green underneath; a single, thin, greenish stripe runs lengthwise down the middle of the back. The head is light brown. Larvae live between two leaves spun together. In later stages they may spin several leaves together, forming a mass of partially eaten leaves. They are most active during the vegetative stage and are usually in insufficient numbers to do economic damage.

Maruca podborer

(*Maruca vitrata*)

Figure 30. Maruca podborer adult (left) and larva (right). Photos: W. Leedham, R. Rien

Young larvae may be found together among the flowers. Flowers may be damaged and discoloured; flower-bud shedding may occur and pod production may be reduced. Pods have small, darkened entry holes on the surface. Leaves and pods are stuck together by webbing and show signs of surface feeding.

Pea blue and gram blue butterflies

(*Lampides boeticus* and *Euchrysops cnejus*)

Figure 31. **Pea blue (left) and gram blue (right) butterfly adults (above) and larvae (below). Photos: R. Martin, R Rien**

The wingspan is 24–34 mm. Males have a mainly blue-violet upper face of the wings with brown edges, while the females have only a small amount of blue colour in the centre of the wings. Both sexes have a long, thin tail in the hindwings and two black spots in the anal angle. Eggs are white with a greenish tinge and have a disc-shaped form. They can reach a diameter of 0.5 mm and are laid singly on the flower buds of the host plants. Old caterpillars are green or reddish brown, with a dark dorsal stripe.

Caterpillars reach a length of 14–15 mm. Pupae reach a length of 9–10 mm. They are light grayish brown with medium-sized dark spots and a dark dorsal stripe. Larvae of pea blue and gram blue butterflies feed on flowers, seeds and pods of many legume species. Crops attacked in Cambodia include cowpea, crotalaria, long bean, mungbean, soybean and other legume crop species.

Thrips

(Thripidae)

Figure 32. Bean flower thrip adults. Photos: R. Martin

Bean flower thrips (*Megalurothrips usitatus*; Figure 32) are very small—about 1 mm long—and barely visible to the naked eye. Larvae are either yellow or white. Older individuals are yellowish brown and move quickly. Bean flower thrips can infest crops from the seedling stage, but are more common at the bud initiation stage through to flowering.

Thrips damage the seedling growing point and embryonic leaves. However, damage is not evident until the first trifoliate leaves open. Damaged leaves can be severely distorted and discoloured. Damage to flowering plants can result in flower abortion and pod distortion.

Deformed pods may be difficult to thresh, resulting in further yield losses. There are no thresholds for thrips at the seedling stage. It is unlikely that this pest will reduce mungbean yields except under extreme circumstances.

The spraying threshold for flowering plants is 4–6 thrips per flower at flowering and pod setting. Thrips are easily controlled with systemic insecticides, such as imidacloprid or thiamethoxam.

Whitefly

(*Bemisia tabaci*)

Figure 33. Whitefly. Photo: R. Gunning

Adult *Bemisia* (Figure 33) are soft and whitish yellow when they first emerge from the nymph stage. Within a few hours, the wings become iridescent white as a result of a powdery wax. The body remains light yellow with a light dusting of wax. The female is 0.96 mm long, and the male is slightly smaller (0.82 mm). Tobacco whitefly transmits MYMV, which is a serious disease in mungbean (see 'Mungbean yellow mosaic virus', above). Seed treatment with imidacloprid is effective against *B. tabaci.*

Cowpea aphid

(*Aphis craccivora*)

Figure 34. Cowpea aphids clustered on flowers (left) and in close up on a stalk (right). Photos: J. Holland, R. Martin

Adult cowpea aphids (Figure 34) are 2 mm long, soft bodied, pear shaped and shiny black. Both winged and wingless forms occur. Two sharp points protrude from the sides at the rear of the body. Aphids form masses on growing points, where they suck sap from flowers, pods and stems.

Plants can be stunted and deformed. Leaves become very sticky from aphid excretion. Control plants should be checked for aphids from flowering to maturity. Look for beneficial insects eating aphids. Also look for virus symptoms, as aphids may transmit viruses to other plants in the crop.

Mealybugs

(Pseudococcidae)

Figure 35. **Mealybugs in a cluster (left) and a single mealybug (right). Photos: W. Leedham**

Male and female mealybugs have distinct morphological differences. Female adults are about 3 mm long. Female adults and nymphs are oval and covered by a white, waxy coating. Males are small, aphid-like, winged insects. Female mealybugs colonise shoots, stems and leaves, forming a white mass. They are piercing and sucking insects that can stunt plant growth. Male mealybugs are short-lived and do not feed as adults.

Helicoverpa podborer

(*Helicoverpa armigera*)

Figure 36. Helicoverpa podborer adult (left) and larva (right). Photos: Pol C.

Moths of helicoverpa podborer (Figure 36) are 35 mm long. Newly hatched larvae are white with dark heads. Larvae go though up to six stages (instars). As they grow, larvae become darker, with dark spots on their segments, but vary widely in colour. Medium larvae (10 mm long) have lines along the side of their body and a saddle of darker colour on the fourth segment back from the head. Large larvae are 35–40 mm long, and have white hairs around the head and on the body.

Helicoverpa can cause severe damage at all crop stages and all plant parts of mungbean. High populations in seedlings or drought-stressed crops can cause considerable damage if vegetative terminals and stems are eaten. This type of damage results in pods being set closer to the ground. Such pods are more difficult to harvest.

Once the mungbeans reach flowering, larvae focus on buds, flowers and pods. Young larvae are likely to feed on shoot tips, young leaves and flowers before attacking pods. In drought-stressed crops, the last soft green tissue is usually the shoot tips, which are thus more likely to be totally destroyed.

Small pods may be totally eaten by *Helicoverpa*, but larvae usually eat only the seeds in large pods. Mungbeans are better able to recover from early damage than from late pod damage. However, in rainfed crops, where water is limiting, significant early damage may delay or increase the duration of podding, with consequent yield and quality losses. Damage to well-developed pods also results in staining of uneaten seeds from water entering the pods.

Green vegetable bug

(*Nezara viridula*)

Figure 37. Green vegetable bug adult (left) and 3rd instar nymphs (right). Photos: R. Martin

In the upland, green vegetable bug (GVB; Figure 37) is the most damaging pod-sucking bug in mungbean as a result of its abundance, widespread distribution, rate of damage and rate of reproduction. However, GVB appears to be a minor pest in lowland crops sown in the dry season after rice.

GVB is primarily a pod feeder, with a preference for pods with well-developed seeds. GVB also damages buds and flowers, but mungbean can compensate for such early damage. Mungbean remain at risk until pods are too hard to damage (i.e. very close to harvest). Damage to young pods causes deformed and shrivelled seeds, and reduced yield. Seeds damaged in older pods are discoloured, and this reduces quality and price.

It is best to take an IPM approach to managing GVB since this pest causes little or no damage to mungbean in the vegetative stage. Spraying broad-spectrum insecticides early in the crop can seriously reduce the populations of beneficial insects. Natural enemies of GVB include feather-legged flies (*Trichopoda* spp.) and the wasp *Trissolcus basalis* (see 'Beneficial insects', below).

Red-banded shield bug

(*Piezodorus hybneri*)

Figure 38. **Red-banded shield bug adult (left) and nymph (right). Photos: R. Martin**

Adults are 9 mm long and light green or yellow in colour, with a red or yellow band across the 'shoulders' and around the edge of the body. Nymphs are initially orange-brown. Older nymphs are mainly green with red-brown marks in the centre of the back.

The eggs are laid in two rows on the underside of leaves in groups of 15–40. Adults and nymphs pierce and suck developing seeds and pods, which are then lost, deformed or develop dark marks. Crops attacked include mungbean, soybean, cowpea, sesame and peanut. Crops should be inspected from budding to late pod fill. Check early morning.

Brown bean bug

(***Riptortus linearis***)

Figure 39. **Brown bean bug adult (left) and nymph (right). Photos: R. Martin**

Adult brown bean bugs (Figure 39) are 16–18 mm long and have yellow stripes along each side. The nymphs look like ants but can be distinguished from ants by the presence of the sucking mouthparts of bugs. The eggs are laid singly and are shiny brown.

Adults and nymphs of the brown bean bug pierce and suck contents from developing seeds and pods. This results in deformed or discoloured seeds. Mungbean, soybean, cowpea and sesame are attacked. Mungbean crops should be inspected for brown bean bug from flowering to late pod fill. Check in the early morning before bugs become too active.

BENEFICIAL INSECTS

A broad range of insects, and spiders, consume other insects or parasitise them, and reduce the number of pest insects. These predators and parasites are called beneficial insects or ‘good bugs’ because they do more good than harm to the crop.

Beneficial insects seek out and destroy other insects in a wide range of crops, and are an important component of natural pest control.

Parasitic insects need other insects to complete their life cycle. They interfere with the pest by slowing the build-up of pest numbers, and can prevent major outbreaks. A healthy predator population may be effective in controlling pest insects. It could save the farmer time and money by reducing the need to apply insecticides.

The number of beneficial insects in a crop depends on the food resources available, shelter, climatic conditions and use of insecticides. Farmers should check to see whether the crop has a healthy and viable population of predators and parasites by examining the life cycle stages and numbers of these species.

Many insecticides will kill both pest and beneficial insects, although there are a few that only kill target pests. For sustainable pest management, pest control should not rely solely on chemical insecticides; try to retain beneficial insects.

Knowing which bugs are beneficial can help farmers decide on pest control options. Some common beneficial insects found in mungbean are described below. For a more complete range, see Pol et al. (2010).

Six-spotted ladybird

(*Cheilomenes sexmaculata*)

Figure 40. Six-spotted ladybird adult (left), larva (centre) and pupa (right). Photos: R. Martin

Adult six-spotted ladybirds are 3–6 mm long and 3–5 mm wide. The body is oval in outline and shiny, and the background colour is orange, light red, yellow or pinkish (Figure 40). There are six black spots on the wing covers, including two zigzag lines and a rear black spot. Larvae are dark grey to brown, with yellowish patches. Pupae are yellow with black spots.

Ladybirds are important predators of insect eggs and larvae of aphids, mealybugs, thrips and whitefly. Ladybirds are good predators and eat a lot of small pest insects. They can reach large numbers and can successfully control pests in combination with other predators.

Transverse ladybird

(*Coccinella transversalis*)

Figure 41. Transverse ladybird adult (left), larva (centre) and pupae (right). Photos: R. Martin

Adult transverse ladybirds are 5 mm long and bright orange-red in colour, with black markings on the back (Figure 41).

There is a dark strip down the centre of the back where the wings meet, and prominent V-shaped markings on each side. These ladybirds are active during the day. Adults and larvae can be found living on the same food plants. Transverse ladybirds eat the same pest insects as six-spotted ladybird.

Feather-legged flies

(*Trichopoda* spp.)

Figure 42. Adult *Trichopoda* (left) and a small white egg on a *Nezara viridula* adult (right). Photos: R. Gunning, Pol C.

Trichopoda is a genus of small, brightly coloured flies that range in size from 5 to 13 mm (Figure 42). The flies have a distinctive fringe on the hind legs. The eggs are laid on adult or late nymphal stages of green vegetable bug (*Nezara viridula*). On hatching, the maggot bores into the body of the host and feeds on the host's fluids for about 2 weeks. When fully grown, the maggot emerges, killing the host, and pupates in soil. The adult fly emerges after about 2 weeks.

Trichopoda species have been released as a biological control for green vegetable bug in various parts of the world. Impact parasitism rates can be as high as 50%, but there is conflicting evidence of the effectiveness of biological control by this parasitoid.

Pentatomid egg parasitoid

(*Trissolcus basalis*)

Figure 43. *Trissolcus basalis* adult ovipositing into green vegetable bug eggs. Photo: T. Smith

Trissolcus basalis is a very small black wasp (about 2 mm long), with downward bent antennae and a flattened abdomen (Figure 43). Wing veins are not obvious. In parts of the world where it has been released, *T. basalis* usually occurs in all crops attacked by green vegetable bug (GVB), including cotton, maize, soybean and other legumes. It lays eggs inside pentatomid eggs, where they develop to adulthood. The primary host is GVB, but *T. basalis* also parasitises eggs of other bugs, including beneficial ones.

T. basalis can reduce GVB numbers by more than 50%. Planting trap crops of early-maturing soybeans could be an IPM strategy to reduce GVB numbers in the main crop.

INTEGRATED PEST MANAGEMENT FOR MUNGBEAN

Integrated pest management (IPM) is a strategy or plan that uses various tactics or control methods—cultural, plant resistance, biological and chemical—in a harmonious way. Control actions are based on frequent monitoring of pests.

Pesticides are now widely used in mungbean in Cambodia. However, through lack of knowledge, farmers often misuse pesticides by:

> choosing the wrong pesticide
> applying on a calendar-based schedule without regard to pest numbers
> using incorrect rates
> not using enough water to thoroughly cover the plants.

Pesticide misuse may result in failure to kill the target pest, which might increase either its number (resurgence) or that of a formerly minor pest (secondary pest outbreak). Pesticide misuse can also result in the development of pesticide-resistant populations.

The main insect problem in mungbean in Aek Phnum district, Battambang, is the bean flower thrip (Figure 32). This is a secondary pest outbreak as a result of application of broad-spectrum insecticides in the vegetative stage. Beneficial organisms such as ladybird beetles are killed, leaving bean flower thrips populations to increase unchecked.

Pesticide misuse also seriously harms the farmer. In a recent survey in Battambang, Chhun et al. (2019) found that most farmers (94%) said they were aware of pesticide exposure risks.

However, the use of personal protective equipment (PPE) was at a low level of sophistication: face mask (76%), hat (73%), long shirt (67%), and gloves (54%). Only 10% of farmers wore boots and none used gas masks or aprons. Farmers also use spray wands sweeping side to side in front of them and thereby are continuously exposed to the pesticide during spraying.

All too often the immediate solution to a pest problem has meant repeated applications of pesticides, and mungbean are no exception. In Battambang, mungbean growers apply non-selective broad-spectrum insecticides up to 10 times per crop cycle. These insecticides are inexpensive and easy to apply and give immediate results. Farmers are focused on 'eradication' rather than 'management' where the goal is to reduce pest populations to levels that are economical to control. Low pest populations should be tolerated. Important definitions for IPM include:

> The 'economic injury level' is reached when the pest population is large enough to cause crop losses costing more than the control.
> The 'economic threshold' is the pest population at which control measures should be taken to prevent pest numbers from reaching the economic injury level.

Integrated pest management

Integrated pest management (IPM) is a strategy or plan that uses various tactics or control methods—cultural, plant resistance, biological, and chemical—in a harmonious way. Control actions are based on frequent monitoring of pests.

Integrated pest management depends on multidisciplinary ecological strategies to weigh the effect of each tactic, as part of the agroecosystem, in producing the least disturbance and yield loss in the long run.

No pest control strategy increases potential yield. Such strategies can only ensure that the maximum yield physiologically obtainable in a particular field and season will not be significantly reduced by pests (Reissig et al. 1986).

Insects can significantly affect the overall profitability of a mungbean crop by reducing both yield and seed quality. Accordingly, insect damage is one of the main reasons for price downgrades for mungbean. Crops should be inspected weekly from the vegetative stage to the beginning of flowering, and then twice weekly to the completion of pod fill. Crops that are producing buds, but not flowers, may contain damaging numbers of sucking insects that cause the buds to abort before the flowers open.

The preferred method for insect checking is to use a beat sheet between crop rows to identify, monitor and count insects (Figure 44). However, a sweep net is more suitable for broadcast crops (Figure 44). Mungbean also usually support quite high populations of beneficial insects, which should be considered when selecting insect control measures.

Figure 44. Using beat sheet (left) and sweep net (right) to check on insect populations in soybean. Photos: Pol C.

The reproductive threshold for late-flowering/early-podding to late-pod-fill stages is based on the rate of damage at late pod fill, with a range of 1–5 larvae/m^2, depending on the cost of control and the price of mungbean. This threshold allows for possible yield loss in drought-stressed crops damaged by caterpillars at flowering. Mungbean should be monitored weekly during the vegetative stage, and twice weekly from early budding until late podding. A variety of control options are available. Consideration needs to be given to the number and size of caterpillars, and the number of unhatched eggs in the crop. Knowledge of the level of insecticide resistance in insect pest populations and the beneficial population will help in selecting the most suitable chemical for spraying.

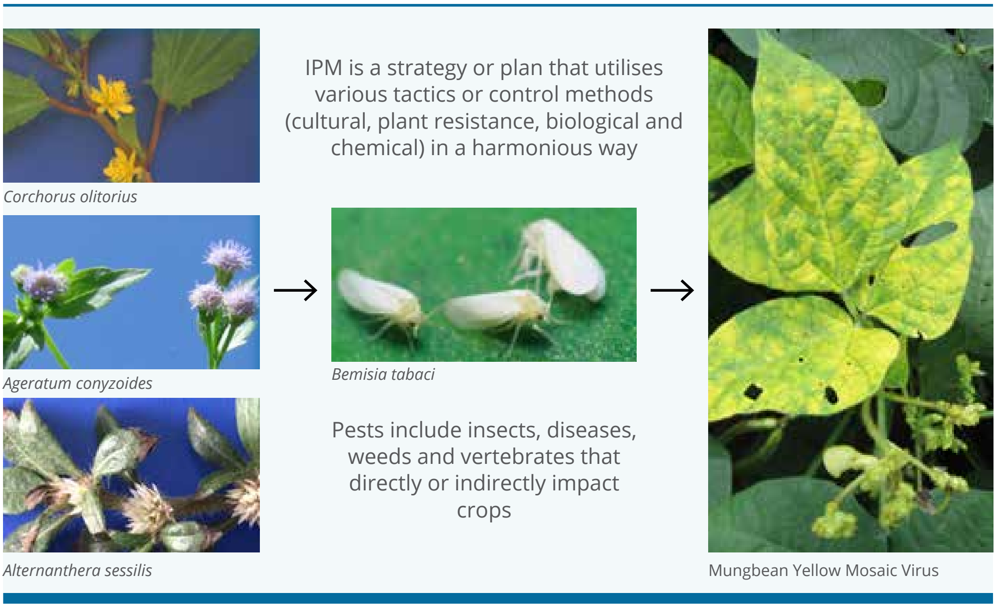

Figure 45. Example of IPM in mungbean.

IPM strategy for managing mungbean insect pests

Vegetative stage

> Avoid using chemical insecticides during the vegetative stage unless leaf loss is greater than 30% or there are 8–9 folded leaves/plant.

> Use biological insecticides such as *Beauveria bassiana* at 15 and again at 25 days after sowing (DAS) to control caterpillars as well as flower thrips.

> Deploy 24 blue sticky traps per hectare at 15 DAS and again at 25 DAS to control bean flower thrips.

Reproductive stage

> At 35 DAS, inspect buds and flowers for podborer larvae and pod-sucking insects.

> If economic thresholds are exceeded, apply selective insecticides that do not harm beneficial arthropods such as ladybird beetles.

Figure 46. Blue sticky traps for control of flower thrips. Photo: R. Martin

Insect identification mobile phone application for mungbean

A basic prerequisite for insect IPM is that farmers must be able to tell the difference between good and bad insects. Farmer workshops have revealed that farmers have difficulty recognising beneficial insects and particularly beneficial ladybird beetles. The 28-spotted ladybird (*Henosepilachna vigintisexpunctata*) is a pest of vegetable crops in the region, and it is possible that farmers are suspecting the beneficial ladybirds of also being pests. The upper wing surface of the 28-spotted ladybird is covered in short downy hairs and this distinguishes plant-feeding ladybird beetles from their beneficial bug-feeding relatives (Figure 47).

a) 28-spotted ladybird (*Henosepilachna vigintisexpunctata*)

b) Rice ladybird (*Micraspis discolor*)

c) Transverse ladybird (*Coccinella transversalis*)

d) Six-spotted ladybird (*Cheilomenes sexmaculata*)

Figure 47. Good vs bad ladybirds: the 28-spotted ladybird (a) is a pest while the other ladybirds (b-d) feed on bugs. Photos: R. Martin

Mungbean is facing significant yield loss due to direct impacts of insect and disease pests. Improper pest management has worsened the issue, causing economic losses to farmers and environmental disruption through ill-informed chemical use. Use of broad-spectrum insecticides as a solution to all observed insect pests is commonplace in mungbean fields of lowland Cambodia and can be linked to lack of agricultural information (Hinchcliffe et al. 2019).

This project aimed to discover the pest and beneficial species most common in mungbean fields of lowland Cambodia, and to use this information to develop an informative image-rich mobile phone application to aid Cambodian farmers with insect and disease identification, and so provide specific management recommendations applicable to the Cambodian context.

The feasibility of the app was evaluated through a survey with potential users. Responses were incorporated into developing the Pest ID app prototype, which was trialled with farmers and subsequently refined by adding audio content in Khmer. The majority of farmers were unable to distinguish between beneficial organisms and pest insect species. The Pest ID app has been well received by farmers, with users seeing its potential to support crop management decisions. This app holds potential as an important agricultural education tool and may be applied to a broader range of mungbean farmers in the future.

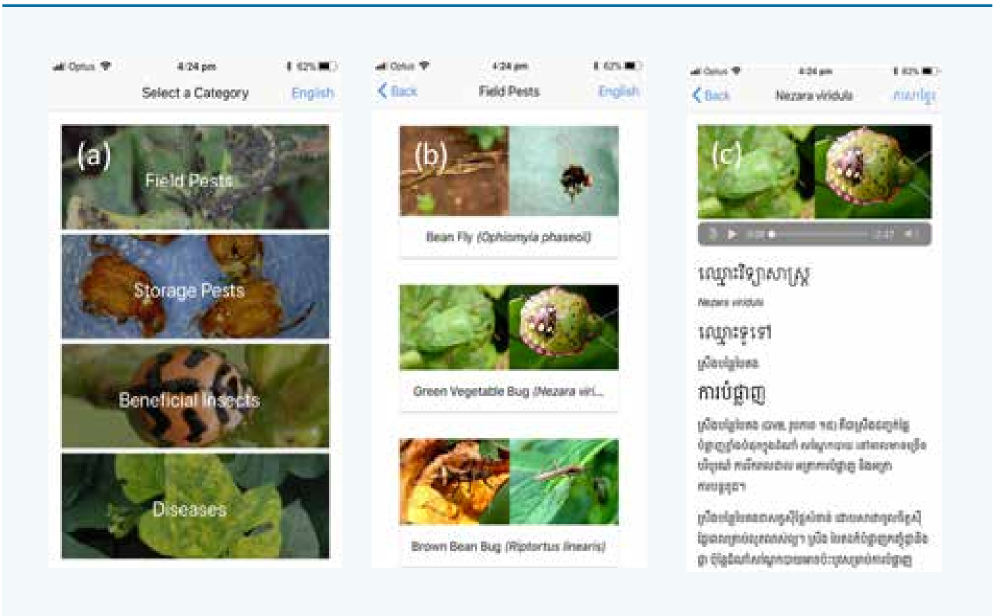

Figure 48. **Screenshots of the Pest ID app (a) Division into four distinct categories of 'Field Pests, 'Storage Pests', 'Beneficial Insects' and 'Diseases' (b) Scroll-through function relying on images for identification of insect species (c) Species-specific information including control recommendations, as well as a voice over feature of all written information.**

GRAIN STORAGE PESTS

Cowpea bruchid

(*Callosobruchus maculatus*)

Figure 49. Cowpea bruchid adult (left) and bruchid eggs on mungbean seed (right). Photos: R. Martin

The cowpea bruchid (C*allosobruchus maculatus*; Figure 49) infests seeds of legumes, especially mungbean and cowpea. It is the most important post-harvest storage pest of *Vigna* spp. throughout the tropics. Adult beetles are 3 mm in length. The wing covers are orange with brown spots. Bruchids do not have a long snout like the true weevils, which infest cereals such as maize. Bruchid eggs are glued to the pod or seed (Figure 49).

Crops may be first infested in the field before harvest, leading to transfer of insects with the harvested grain. This may also lead to re-infestation of seeds contained in the same storage facility. When larvae hatch, they bore directly into the seed, where their development continues as they eat out the seed. Adults emerge through windows in the grain, leaving round holes that are the main evidence of damage. Insect damage can cause heating and extensive mould growth, reducing the quality of the grain.

Rice weevil

(***Sitophilus oryzae***)

Figure 50. Rice weevils. Photo: R. Martin

Adult rice weevils (Figure 50) are dark brownish black and 2–4 mm long, and have a long weevil 'snout' (GRDC 2020). They have four small light-coloured patches on their rear wing covers. They rarely fly, but climb vertical surfaces (e.g. in a glass jar). Similar species include *S. zeamais* (maize weevil) and *S. granarius* (granary weevil). Adults live 2–3 months. Larvae are generally not seen—they feed and develop inside single grains. The life cycle is completed in 4 weeks at 30 °C and 15 weeks at 18 °C. Breeding stops below 15 °C.

Under warm conditions, or when grain is moved, rice weevils are often observed climbing out of grain up vertical surfaces. Sieving and probe traps are recommended to detect low numbers.

Lesser grain borer

(***Rhyzopertha dominica***)

Figure 51. Lesser grain borers. Photo: R. Martin

Lesser grain borer (Figure 51) is a serious pest of most stored grains and has developed resistance to a number of grain insecticides (GRDC 2020). It is a dark brown, cylindrically shaped beetle, up to 3 mm long, with club-like antennae. Viewed from the side, the beetle's mouth parts and eyes are tucked underneath the thorax. Adult beetles are strong flyers. The life cycle is completed in 4 weeks at 35 °C and 7 weeks at 22 °C. Breeding stops below 18 °C. Females lay 200–400 eggs on the grain surface. Young larvae (white with brown heads) initially feed outside the grain, then bore into the grain. Adults live for 2–3 months. The borer's habit is to remain hidden in grain. Regular sampling and sieving is required for detection.

Seed storage options

Grain storage pests are generally controlled by fumigants such as phosphine.

However, under Cambodian conditions, this process is difficult and dangerous. Addition of various vegetable oils to stored seed has been shown to give good control of bruchids without affecting seed viability. Sesame and sunflower oils, at a rate of 7–10 millilitres per kilogram (mL/kg) of seed, have been found to be effective in preventing oviposition by bruchids. Local farmers do not use these methods and experience serious losses from bruchids in seed stored for sowing.

Bags that can be hermetically sealed exclude the passage of air, oxygen, or other gases, thus eliminating the flow of both oxygen and water between the stored seed and the outside atmosphere. When properly sealed, respiration of grain and insects inside the bag reduces oxygen levels from 21% to 5%.

This reduction reduces insects to less than 1 insect/kg of grain without using insecticides. Hermetic storage products such as GrainPro™ bags are made of lightweight, multi-layered plastic with a proprietary barrier that prevents moisture and air exchange.[2] GrainPro™ bags come in sizes of 15 and 30 kg, which are suitable for Cambodian smallholder mungbean farmers.

Figure 52. GrainPro™ seed storage bags.

2 https://grainpro.com/en

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