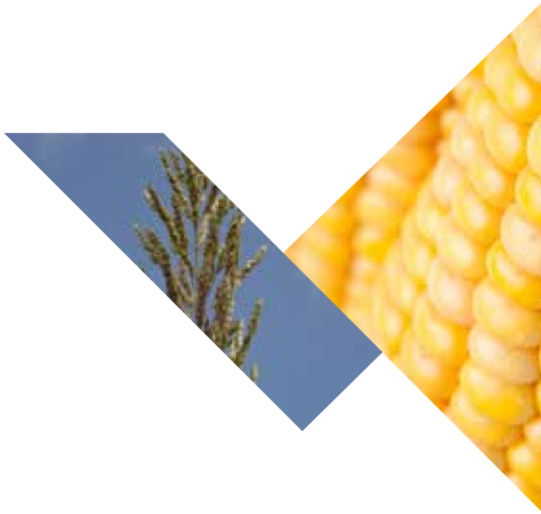
Australian Government

Australian Centre for International Agricultural Research

MAIZE PRODUCTION GUIDE

FOR CAMBODIAN CONDITIONS



MAIZE PRODUCTION GUIDE

FOR CAMBODIAN CONDITIONS

ACIAR
aciar.gov.au

2015

The Australian Centre for International Agricultural Research (ACIAR) was established in June 1982 by an Act of the Australian Parliament. ACIAR operates as part of Australia's international development cooperation program, with a mission to achieve more productive and sustainable agricultural systems, for the benefit of developing countries and Australia. It commissions collaborative research between Australian and developing country researchers in areas where Australia has special research competence. It also administers Australia's contribution to the International Agricultural Research Centres.

Where trade names are used this constitutes neither endorsement of nor discrimination against any product by ACIAR.

ACIAR MONOGRAPH SERIES
This series contains the results of original research supported by ACIAR, or material deemed relevant to ACIAR's research and development objectives. The series is distributed internationally, with an emphasis on developing countries.

Robert Martin, Stephanie Montgomery, Sophanara Phan, Sophoeun Im. Maize Production Guide for Cambodian Conditions

ACIAR Monograph No. 167. Australian Centre for International Agricultural Research: Canberra. 84 pp.

ACIAR Monograph No. 167
ACIAR Monographs
ISSN 1031-8194 (print)
ISSN 1447-090X (online)
ISBN 978 1 925133 87 5 (print)
ISBN 978 1 925133 88 2 (online)

Technical editing by Kate Langford
Design by WhiteFox.com.au

FOREWORD

The National Poverty Reduction Strategy (2003–05) of the Royal Cambodian Government committed research centres and extension systems to focus on small-scale farmers and emphasise the use of improved tools and management practices for cropping systems. Priority was given to diversifying and intensifying sustainable agricultural production, with few external inputs, and to developing cost-effective management practices.

The Australian Centre for International Agricultural Research (ACIAR) took on these challenges in 2003, beginning a project (ASEM/2000/109) to develop sustainable farming systems for a variety of crops. The project initially focused on maize, soybean, sesame, mungbean, peanut and cowpea in upland areas of Kampong Cham and Battambang provinces. The aim of the project series was to help reduce poverty and contribute to food security at the household and national levels in Cambodia through the development of technologies and opportunities for production of the non-rice upland crops. The research process has continuously involved engagement with farmers and local value chain networks for validation of local knowledge, documentation of case studies and identification of priorities for field research and demonstration.

A second ACIAR project (ASEM/2006/130) began in 2008 to increase production and marketing of maize and soybean in north-western Cambodia. The emphasis of this project was for on-farm adaptive trials to evaluate and improve the technologies and practices initially tested in 2007. This project was also expanded to integrate the production and marketing components of the system.

A third and final project, ASEM/2010/049 from 2012 to 2016, extended the focus to market-focused integrated crop and livestock enterprises for north-western Cambodia.

This project, in conjunction with two PhD projects, has made a significant contribution to understanding the impacts of climate change on upland agricultural systems in the region and for validation of adaptation options such as changing planting dates, reduced tillage, preservation of crop residues and introduction of new drought tolerant crops such as sorghum and sunflower.

The overall research program has provided a suite of new technologies and improved practices for upland agricultural production in a changing climatic environment. These crop production packages include improved varieties, fertiliser recommendations, rhizobium inoculation, integrated weed management, reduced tillage, retention of crop residues, crop rotation options as well as enhancing value chain networks and marketing.

The project series has made a significant contribution to capacity building for 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 upland agricultural production systems.

This book is part of a series of publications produced by ACIAR in support of the ongoing roll-out of more productive, economic and environmentally sustainable upland cropping systems in Cambodia.

Nick Austin
Chief Executive Officer

CONTENTS

Crop description	**1**
Seasonal sowing opportunities for maize	**6**
Climate and climate change	6
Rainfall and temperature	7
Field selection	**9**
Land preparation and planting	**11**
Row spacing and plant population	**12**
Crop establishment	**14**
Varieties	**15**
Growth and development	**17**
Germination and establishment	17
Root development	18
Vegetative development	19
Reproductive development	**20**
Nutrition	**23**
Nitrogen	24
The Merck RQeasy® rapid soil nitrate test	26
Economics of nitrogen application to maize in Samlout	28
Phosphorus	31
Potassium	32
Micronutrients	33
Zinc	33
Boron	34
Molybdenum	34
Weed management	**35**

Herbicide application techniques 37
Herbicide injury 37
Integrated weed management 38
Chemical weed control options 39
Making silage from maize 40
Harvest timing 42
Drought-stressed crops 43
Cutting height 43
Chop length 43
Harvesting 44
Harvesting by machine 45
Desiccation 46
Diseases 47
Boil smut or common smut (*Ustilago maydis*) 48
Downy mildew (*Peronosclerospora spp.*) 49
Southern corn leaf blight (*Bipolaris maydis*, *Helminthosporium maydis*) 50
Stalk rot and ear rot (*Fusarium spp.*) 51
Aflatoxin (*Aspergillus flavus*) 52
Tropical corn rust (*Puccinia polysora*) 53
Insect pests 54
Corn aphid (*Rhopalosiphum maidis*) 55
Bean pod borer (*Helicoverpa armigera*) 56
Asian maize borer (*Ostrinia furnacalis*) 58
Armyworm (*Spodoptera litura*) 58
Green vegetable bug (*Nezara viridula*) 59
Termites (*Termitidae*) 60

Beneficial insects **61**
Spined predatory shield bug (*Oechalia schellenbergii*) 62
Lady beetles 63
Parasitoids of green vegetable bug (*Trichopoda spp*.) 64
Storage pests **66**
Grain weevils (*Sitophilus spp*.) 67
Coffee bean weevil (*Araecerus fasciculatus*) 68
Lesser grain borer (*Rhyzopertha dominica*) 69
Correct identification of grain storage pests 70
Contributing authors **71**
References **72**
Appendix 1. Herbicide options for weed control in maize **73**

ACKNOWLEDGMENTS

The information in this manual is based on research by the Cambodian Agricultural Research and Development Institute (CARDI), the Maddox Jolie-Pitt Foundation, CARE Cambodia and provincial offices of the Department of Agriculture in Battambang, Kampong Cham and Pailin. The research was supported by the New South Wales Department of Primary Industries and the University of New England.

This research was funded by the Australian Centre for International Agricultural Research (ACIAR) in the projects:

> ASEM/2000/109 Farming systems for crop diversification in Cambodia and Australia

> ASEM/2006/130 Enhancing production and marketing of maize and soybean in north-western Cambodia and

> ASEM/2010/049 Market-focused integrated crop and livestock enterprises for north-western Cambodia

AUTHORS

Robert Martin, Agricultural Systems Research (Cambodia) Co. Ltd., Battambang, Cambodia.

Stephanie Montgomery, Belfield Agronomy Pty. Ltd., Wagga Wagga NSW, Australia.

Sophanara Phan, Provincial Department of Agriculture, Pailin, Cambodia.

Sophoeun Im, Provincial Department of Agriculture, Pailin, Cambodia.

ACRONYMS AND ABBREVIATIONS

ACIAR	Australian Centre for International Agricultural Research
Bt	Bacillus thuringiensis
CARDI	Cambodian Agricultural Research and Development Institute
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center)
DM	Dry Matter
EWS	Early Wet Season
IPM	Integrated Pest Management
MLS	Milk Line Score
MRR	Marginal Rate of Return
NPV	Nuclear Polyhedrosis Virus
UNFCCC	United Nations Framework Convention on Climate Change

CROP DESCRIPTION

Maize grows well on a range of soils, but does best on deep, well drained, fertile soils that are slightly acid to neutral, pH ($CaOH_2$) 5.5 to 7.0. The most suitable soil types for growing maize in Cambodian upland areas are Labansiek (Ferrosol) and Kampong Siem (Vertosol) (White et al. 1997).

Maize does not grow well on poorly drained soils. No-till and minimum tillage establishment is recommended to conserve soil water and improve soil structure as well as for cost and time savings.

This production guide explains how to grow maize successfully in upland areas of Cambodia in a rainfed system, not under irrigation. However, many principles of agronomy are relevant to both irrigated and rainfed cropping systems.

Crop establishment management tips

- Maize grows well on a range of soils, but does best on deep, well drained, fertile soils that are slightly acid to neutral, pH ($CaOH^2$) 5.5 to 7.0.
- To avoid losses from drought and heat stress at flowering, do not plant maize between November and May in rainfed upland areas.
- Follow the principles of Conservation Agriculture: minimise soil disturbance; preserve crop residues on the soil surface; and rotate with legumes (e.g. mungbean, peanut, soybean).
- Pay attention to plant population: for drier conditions, 40,000-60,000 plants/ha is recommended; and for wetter conditions, 60,000-80,000 plants/ha is recommended.

The main maize cash crop currently grown in Cambodia is red maize (also known as yellow maize) which is grown for the stockfeed market, whereas white maize is grown locally for human consumption. Historically however, white (or waxy) maize which has been grown in Cambodia since around the 17th century was the dominant type of maize grown. Up until 2009, maize was second in importance after rice in terms of cultivated area and production. However, since 2009, maize has been largely replaced by cassava in most upland areas, as the fertility of forest soil and consequently maize yields declined (Figure 1).

This guide is focused primarily on the production of red maize for stockfeed. However, the agronomy applies generally to all types of maize. The main production area of stockfeed maize in Cambodia is in the Provinces of Battambang and Pailin. Maize is also grown in Kampong Cham, Kampot, Kandal, Banteay Meanchey and Takeo Provinces.

The area of maize production in North-West Cambodia expanded rapidly onto newly cleared forest land after the end of the Khmer Rouge civil war in 1998. In North-West Cambodia, the total area of maize peaked at 147,300 ha in 2009, when cassava began to replace maize (Figure 2). The area of maize in the rest of Cambodia has remained relatively stable at around 50,000 ha.

Prior to 1998, Cambodia produced around 50,000 tonnes of maize per annum at an average yield of around 1 t/ha (Figure 3, Figure 4). Total production of maize in Cambodia peaked at 522,700 tonnes in 2007, largely due to the expansion in production area and higher yields (4 t/ha) in North-West Cambodia. In the remainder of Cambodia, maize yields have steadily increased to an average of around 2 t/ha. Figure 5 shows how actual yields in Cambodia compare to potential yields, given Cambodian agro-climatic limitations and with adequate inputs.

Maize is one of the world's most important cereal crops after rice and wheat, and because of increasing global demand for stockfeed, especially as China increases its demand for meat, it is predicted that demand for maize will continue to rise.

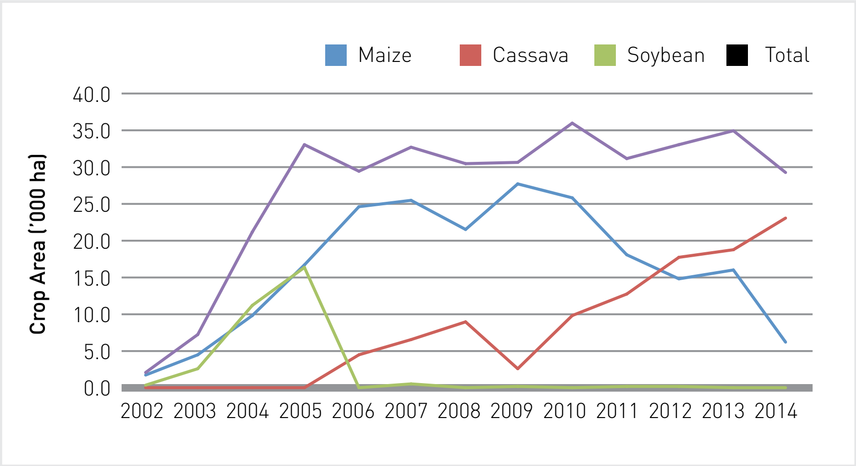


Figure 1. Changing cropping patterns in Pailin Province

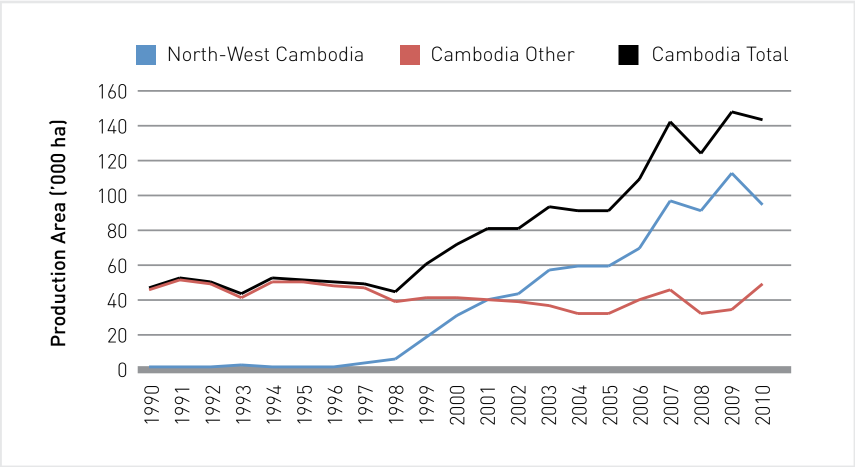


Figure 2. Trends in the production area of maize in Cambodia

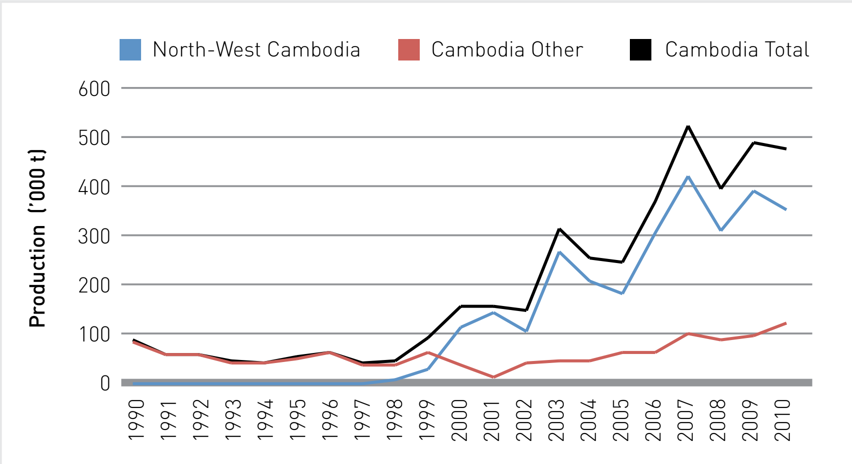


Figure 3. Trends in the production of maize in Cambodia

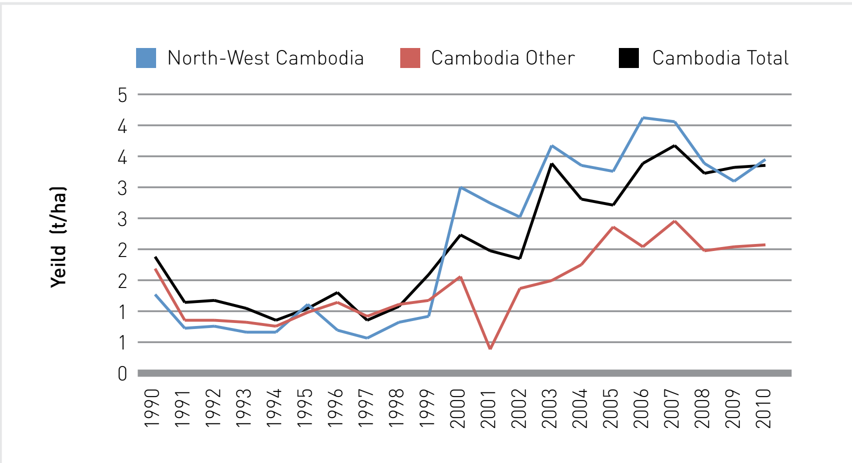


Figure 4. Trends in the yield of maize in Cambodia

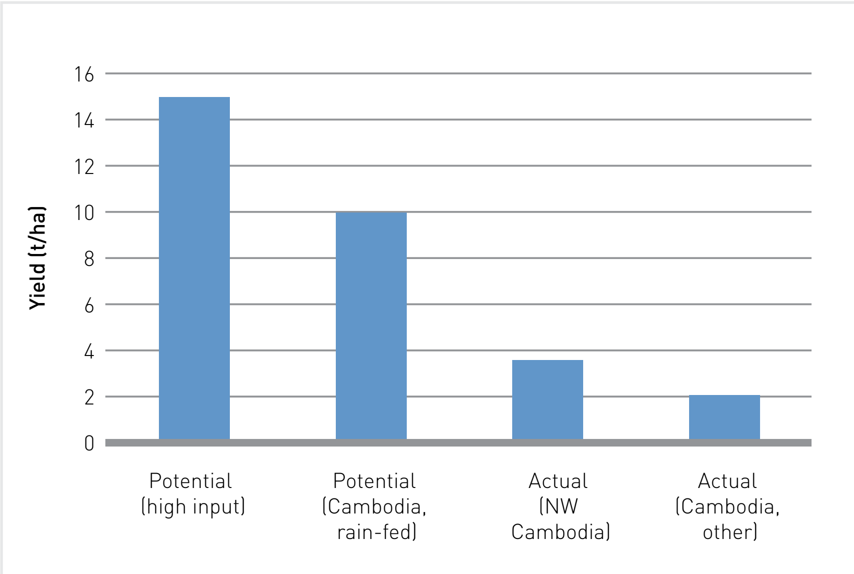


Figure 5. Actual and potential maize yields in Cambodia

In order to achieve better yields and higher profitability, Cambodian farmers will need to adopt improved agronomic methods and technology for maize production. This manual outlines important principles of maize crop agronomy and provides information on the modern methodology and technology that farmers can now access to grow maize in Cambodia.

SEASONAL SOWING OPPORTUNITIES FOR MAIZE

Climate and climate change

Cambodia experiences a monsoonal climate with distinct wet and dry seasons (Nesbitt 1997). The wet (monsoon) season extends from May to late November, and the dry season extends from December to April. The period from February to the beginning of May is often referred to as the early wet season (EWS) in upland cropping systems.

According to the Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC), changes in temperature and rainfall in Cambodia have occurred in the second half of the 20th Century. The projection for the next 80 years is that temperatures will continue to rise, with potential declines in dry season rainfall, and delayed arrival of the wet season (Anon 2013). The rainfall trend has been confirmed for Battambang by Touch Van (pers. comm.); Figure 6.

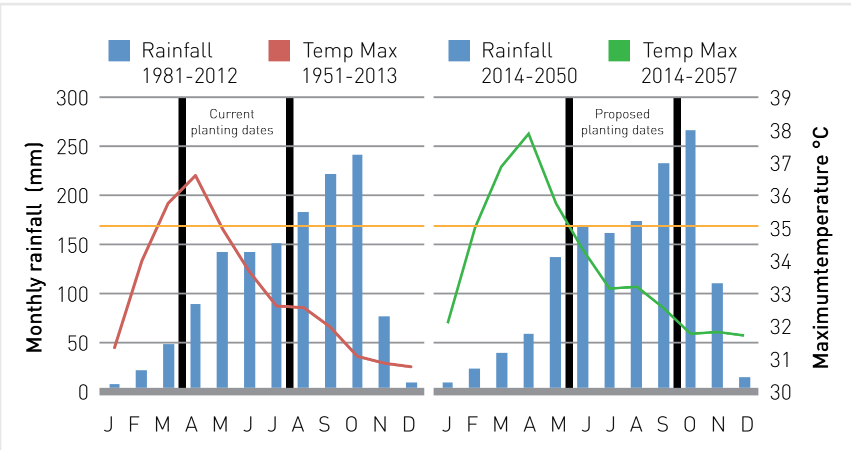


Figure 6. Current average monthly rainfall and maximum temperature (left) and projected future average monthly rainfall and maximum temperatures at Battambang (right). Temperatures above 35°C are inhibitory to maize growth.

The trend to more frequent failures of early wet season maize crops is consistent with predicted hotter and drier conditions between February and May. In recognition of this trend, Montgomery (pers. comm.) has proposed that the seasons be renamed as follows:

- pre-monsoon: hot, dry with increasing humidity, low rainfall
- monsoon: mild, high humidity, high rainfall
- post-monsoon: cool, dry with decreasing humidity, low rainfall.

Rainfall and temperature

Maize is often planted after occasional storms in February to March in the upland areas of North-West Cambodia. This strategy appears to be becoming increasingly risky. Recent research suggests that a safer upland crop planting regime is to delay planting of pre-monsoon crops from February to May or June, followed by a late monsoon season crop planted in September to October, and leaving the pre-monsoon period for soil water recharge (ACIAR project ASEM/2010/049, Stephanie Montgomery and Touch Van (pers. comm.); Figure 6).

The optimum air temperature for maize growth and development is 18-32°C, with temperatures of 35°C and above considered inhibitory. The optimum soil temperatures for germination and early seedling growth are 12°C or greater, and at tasselling 21-30°C is ideal.

Low temperature is rarely a limiting factor for crop production in Cambodia. However, high temperatures, which can exceed 38°C between March and May, are likely to cause heat stress in maize (Figure 6). If maize is flowering during this period, the silks may wither and burn off before the pollen reaches the ear. Hence, fertilisation does not occur for all kernels and seed set is greatly reduced (Figure 7). This is commonly referred to as pollen blasting. To avoid crop yield losses from heat stress and pollen-blasting, it is recommended that maize not be planted in Cambodia during December, January, February, March or April. As can be seen from Figure 6, this period will become increasingly unfavourable for planting maize as temperature continues to rise in the future.

Figure 7. Maize cobs affected by water stress and pollen blasting. Photo: R. Martin

Field selection

To maximise the retention of soil water, maize should be sown using no-till or minimum-tillage equipment into the residues of the previous crop, and ideally after a legume crop, such as mungbean, peanut or soybean to take advantage of rhizobium-fixed nitrogen (Pin et al. 2009).

No-till has been shown to be a very successful method for growing maize in North-West Cambodia. No-till preserves crop residues on the soil surface which reduces soil temperature and reduces evaporation, therefore minimising the loss of soil water.

Figure 8. Soil erosion in Pailin. Photo: R. Martin

Maize crop residues also provide high levels of ground cover and maximise protection against soil erosion. No-till can also mean the difference between being able to plant a crop or not planting when follow-up rain does not occur after land preparation. There is a high risk of soil erosion in upland areas of Cambodia where annual rainfall can exceed 2,000 mm per annum. Retention of crop residues and no-till can significantly reduce water runoff, soil erosion and soil loss (Figure 8).

Glyphosate can be applied as a desiccant before harvest of maize to ensure timeliness of harvest and to minimise loss of residual soil water.

Fields with large grass weed populations are not suited to maize. Maize is a member of the grass family and therefore in-crop chemical weed control options for grasses are limited. In contrast, broadleaf weed control options are more flexible (see section on weed management).

Land preparation and planting

Residues of the previous crop should be chopped and left in the field to reduce soil surface temperature and soil water evaporation (Montgomery pers. comm.).

Maize stover, after hand picking, should be chopped to form a surface mulch. If a combine harvester has been used, there is no need for further chopping (Figure 9). Residues of legume crops such as mungbean or soybean do not require chopping before planting the next crop. Pre-sowing herbicides are applied immediately after chopping. Planting with a no-till planter (Figure 10) is done approximately seven days after herbicide application. Post-sowing pre-emergence herbicide can be applied, if required.

Figure 9. After combine harvesting, there is no need for further chopping of maize stover before no-till planting. Photo: R. Martin

Row spacing and plant population

Many factors, including soil moisture, climatic conditions, soil fertility, hybrid and end use, determine the best plant population for a maize crop. If the growing season conditions are expected to be dry, then the plant population should be lower than if wet conditions are expected.

Figure 10. No-till planting into 5 t/ha maize residue using a 3-row John Deere Maxemerge planter. Photo: R. Martin

For drier conditions, 40,000-60,000 plants/ha is recommended and for wetter conditions, 60,000-80,000 plants/ha is recommended.

Quick maturing hybrids produce smaller plants, and should therefore be sown at higher population densities. Conversely, slow maturing varieties generally produce larger plants and usually perform best when sown at lower densities. However, within any maturity group, maize hybrids have different tolerances to high plant populations, with the more tolerant having better resistance to lodging, a low percentage of barren plants and good synchronisation of silking with pollen shedding.

If the only available planting window will expose the crop to high temperatures during tasselling, silking and early cob formation, reducing the plant density can reduce moisture stress and mycotoxin risk.

The target plant population depends on the depth of soil moisture at planting and the expected growing conditions. Target populations should range between 40,000 and 80,000 plants/ha depending on expected rainfall and available soil water at sowing.

When calculating the planting rate, allow an extra 5-10% for establishment losses depending on seedbed and moisture conditions. Obtain the number of seeds/kg and the germination percentage from the bag label. The planting rate (kg seed/ha) can be determined as follows:

$$\frac{\text{Required number of plants/m}^2 \times 10{,}000}{\text{Seeds/kg} \times \text{germination \%} \times \text{establishment \%}}$$

Example calculation:

$$\frac{7\ \text{(target plant population/m}^2\text{)} \times 10{,}000}{3{,}000\ \text{(seeds/kg)} \times 0.95\ \text{(germination \%)} \times 0.90\ \text{(establishment \%)}} = 27.3\ \text{kg seed/ha}$$

Maize is typically planted in 60-80 cm rows in Cambodia, however no research on row spacing has been conducted to confirm the optimum spacing. Wider row spacing and lower plant populations will reduce the risk of crop failure for low rainfall conditions.

Crop establishment

Apart from moisture stress and poor crop establishment, poor nutrition and weed competition are usually the major factors that significantly reduce yields. The following recommendations should help to improve crop establishment and yields.

Uniform establishment and accurate depth placement of seed is essential. Precision planters achieve both of these. Planters should have tynes or discs mounted on parallelogram planter units so they independently adjust to uneven soil surfaces. Planter seed plates should be matched to seed size to ensure there are no misses or doubles/ triples on the plates.

Narrow points or discs are better suited to no-till and minimum-till conditions and work very well in free flowing soils, but excessive planting speeds will reduce establishment.

The seed should be placed at a depth of about 3–5 cm. Press wheels are essential not only to improve establishment but also to help control soil insect pests which attack germinating and emerging maize. Crop establishment is improved when the shape of the press wheel matches the shape of the seed trench.

Varieties

The only varieties of stockfeed maize available in Cambodia are hybrids. There are many hybrid maize varieties available for sale but the list of registered varieties in Cambodia is not available to the public. The four main seed companies selling hybrid maize seed are: Advanta-Pacific; Charoen Pokphand (CP); Dupont-Pioneer; and Seed Asia.

Table 1. Maize hybrid characteristics based on experiments in Samlout in 2011 and 2012

Company							Disease tolerance		Maize yields in Samlout (t/ha)		
	Hybrid	Flowering (days)	Plant height (cm)	Ear height (cm)	Maturity (days)	Shelling (%)	Southern corn leaf blight*	Polysora rust	2011	2012	Average
Advanta-Pacific	PAC 224	48	170	68	115-120		P	G	5.3		
	PAC 339	48	165	67	115-121	86%	P	E	6.9	7.5	7.2
	PAC 999S	49	163	70	115-122	85%	A	E	7.2	7.2	7.2
Charoen Pokphand	CP 301					83%				7.3	
	CP 801					84%				8.5	
	CP 888	48	160	80		81%	G	G	5.8	7.3	6.6
	CP AAA	51	158	71		79%	G	G	5.7	7.7	6.7
	CP QQQ	48	173	64		82%	P	G	6.6	7.3	7.0
Dupont-Pioneer	PIO 30B80	53	172	80		84%	G	G	6.7	8.9	7.8
	PIO 30K95	49	156	66		83%	G	G	5.4	8.5	7.0
	PIO 30T60	49	174	71		82%	G	E	6.9	9.2	8.1
	PIO 30Y87	49	165	77		83%	A	E	6.9	7.4	7.2
	PIO 4199	49	165	69		82%	G	G	7.1	8.5	7.8
	PIO 4296	49	191	87		81%	A	E	7.9	8.3	8.1
	PIO 4546	50	175	64		84%	G	E	6.7	8.2	7.5
Seed Asia	SA 282					84%				6.9	
	SA 333	48	151	67	110-115	84%	A	G	5.2	7.6	6.4
	SA 336				105-110	83%				8.7	
	SA 345	48	167	78	100	83%	A	A	4.9	8.5	6.7
	SA 501	48	170	76	110-115	82%	G	G	7.4	8.3	7.9
	TF 222	48	177	74	110-115	84%	G	A	5.9	7.8	6.9
								Average	6.4	8.0	7.2

*Disease tolerance scores: E = excellent; G = good; A = average; P = poor

Although the on-farm average maize yield is around 4 t/ha, with adequate soil moisture, nutrition and weed management, yields of 8 t/ha or more are easily achievable (Table 1). Although there are a large number of maize hybrids available, the range of maturities is narrow; 100-120 days. Hybrids also vary in their tolerance to diseases such as tropical corn rust (*Puccinia polysora*) and southern corn leaf blight (*Bipolaris maydis*) (see section on diseases).

Figure 11. Open husk. Photo: R. Martin

Maize hybrids vary in the degree of the 'open husk' trait (Figure 11). Avoid hybrids with a tendency for open husk when wet conditions are expected at harvest or if the risk of damage by rodents, insects and birds is high.

Growth and development

Germination and establishment

Germination commences once the seed begins to absorb water from the soil. The seedling uses seed starch reserves in the endosperm to germinate, and a root, called the radicle, sprouts from the kernel (Figure 12). Soon after emergence of the radicle, three to four lateral roots sprout from the seed.

Figure 12. A germinating maize seedling. Photo: W. Leedham

Figure 13. Maize seedling with seed (cotyledon) leaf and first true leaf emerging. Photo: S Montgomery

At the same time or soon after, a shoot emerges at the other end of the kernel (Figure 12) and pushes through the soil surface. This breaking through the soil surface is called emergence. When the tip of the shoot breaks through the soil surface, elongation of the middle section of the shoot, called the mesocotyl, ceases and the cotyledon leaf, or plumule, emerges (Figure 13).

Root development

The primary roots develop at the depth at which the seed is sown. The growth of these roots slows down after the shoot emerges above the soil surface and virtually stops at about the three-leaf stage. The first adventitious roots (roots other than those growing from the radicle) start developing from the first node at the mesocotyl, which occurs just below the soil surface. These adventitious roots continue to develop into a thick web of fibrous roots and provide the main anchorage for the maize plant. They also facilitate water and nutrient uptake.

Some adventitious roots emerge at two or three nodes above the soil surface and are called brace or prop roots (Figure 14). The main function of brace roots is to keep the plant upright and prevent it from lodging under normal growing conditions. It is now believed that these roots also help in nutrient and water uptake.

Figure 14. Adventitious roots, including brace roots, growing from the first node. Photo: S. Montgomery

Vegetative development

At three weeks after emergence, the plant is about 40 cm tall and has five fully emerged leaves. At this point, the tassel and cob are initiated and begin development. Rapid leaf growth continues. The growing point, which will become the tassel, remains below the soil surface until about four weeks after emergence. By five weeks after emergence, the crop is 80–90 cm tall, has eight fully emerged leaves and the developing tassel is 15 cm above the soil. Over the next two weeks, the stem continues to elongate, leaves expand to their maximum size and the cob begins rapid development. After about nine weeks, the tassel reaches full size, marking the end of vegetative development (Figure 15).

Figure 15. Maize tassel shedding pollen. Photo: S. Montgomery

Reproductive development

Tasselling and silking

Silks emerge from the top of the uppermost cob and sometimes the second cob a day or two after the tassel completes its development (Figure 16). Air movement through the crop causes clouds of pollen to be dispensed from the tassel, fertilising the silks. This occurs over a three to eight day period. Moisture stress in the weeks prior to flowering can delay the emergence of the silks, causing the pollen to be shed and wasted in their absence, resulting in poor kernel set (Figure 9).

Figure 16. Silks receiving pollen. Photo: S. Montgomery

Grain fill and denting

The husks, cob and shank of the cob are fully developed approximately 12 days after the silks emerge. This may be referred to as the 'blister' stage, as the kernels are white and resemble a blister in shape. By this stage, potassium uptake is almost complete. The crop continues to rapidly take up nitrogen and phosphorus as the embryos develop within the kernels.

Figure 17. Maize kernels showing the milk line. Photo: S. Montgomery

Embryo development is complete when the kernels display a yellow colour on the outside and are filled with a whitish liquid (referred to as milk). This is usually three to four weeks after the silks first emerge and signifies the commencement of denting. Denting refers to the changing shape of the kernel and signifies that starch is being laid down in the grain. 'Early dent' is when 95% of kernels have a visible dent. At 'full dent' all kernels are dented.

The major process during grain fill is the transfer of nutrients from the stems and leaves (stover) to the kernels for storage as starch. The 'milk line' seen on the surface of the developing kernel is the boundary between the liquid phase and the progressing starch phase. The line moves from the top of the kernel towards the core as the laying down of starch proceeds (Figure 17).

During grain fill, yield gains can still be made from photosynthesis and carbohydrate accumulation that occurs during this time. These are however, often affected by the position of the milk line which is closely related to the dry matter content of the crop and indicates the crop's progress towards harvest.

A scoring system is used to describe the movement of the milk line. The milk line score (MLS) begins at zero when the kernels are fully expanded but there is no visible line at the top of the kernel where starch deposition has commenced. It finishes at five when the milk line reaches the base of the kernel and a black layer forms, indicating physiological maturity (Figure 18). Under most conditions, MLS progresses at the rate of one unit approximately every four days. The process can occur more rapidly in hot, dry conditions, senescence or leaching of nutrients from the lower leaves.

Figure 18. Maize grains showing the black layer indicating physiological maturity. Photo: Mississippi State University Extension Service, http://msucares.com/crops/corn/corn7.html

Physiological maturity

At physiological maturity, the grain is solid and translocation of nutrients to the grain is complete. At this time, a layer of black cells forms at the base of the kernel where it joins the core. Moisture content of grain, when the black layer forms, is 28–34%.

Severe moisture stress and hot temperatures during grain fill can cause premature setting of the black layer. Even if conditions improve, nutrients will no longer be transferred to the grain.

Nutrition

Nutrient management tips

- Without fertiliser application, maize yields have declined from >8 t/ha to <4 t/ha since 2000 in North-West Cambodia.
- On-farm experiments since 2005 have consistently shown that application of diammonium phosphate (DAP) and/or urea can restore maize yields to >8 t/ha.
- Defining a target yield and its expected nutrient removal is the basis of building a nutrition management program for maize.
- Rotations with legume crops, such as mungbean, peanut and soybean, can increase the availability of soil nitrate nitrogen (N) and reduce the N fertiliser requirement for maize.
- Rapid soil nitrate tests can be used as part of an N budgeting strategy for maize.
- Economic analysis has shown that farmers can increase net returns from maize by applying up to 200 kg/ha of urea.
- Check for phosphorous deficiency as it appears to be common in upland soils, and soil testing is recommended.
- Check for potassium deficiency as it is likely to occur where there has been prolonged continuous cropping of maize and/or cassava.
- Be alert to symptoms of micronutrient deficiencies, especially zinc and iron on alkaline soils and boron and molybdenum on acid soils.

The yield of maize grain or silage is related to the level of soil fertility. The amount of nitrogen, phosphorus and potassium required in fertiliser applications depends on previous cropping and fertiliser history, years of cultivation, fallow conditions and yield targets. The overall removal of nutrients is greater in silage compared to grain crops, particularly for potassium. The expected nutrient removal by maize grain and silage crops of varying yields is shown in Table 2. Continuous removal of these nutrients from the soil without replacement leads to declining soil fertility. Defining a target yield and the corresponding expected nutrient removal is the basis of building a nutrition management program for maize.

Table 2. Nitrogen, phosphorous and potassium removal by maize (Serafin and Carrigan 2013)

	Grain yield (t/ha)			Silage yield (t/ha)		
	2.5	5	7.5	22	37	52
	Nutrient removed (kg/ha)					
Nitrogen	40	80	120	68	136	204
Phosphorus	9	17	25	13	26	36
Potassium	11	22	32	65	112	157

Maize takes up only small amounts of nutrients until four weeks after planting when nutrient uptake rapidly increases. More than 90% of potassium uptake occurs between four and seven weeks after planting, when less than half of the final above-ground dry matter has been produced. Nitrogen uptake also increases rapidly with 55% of uptake occurring from seven weeks after planting until the end of silking. Nitrogen uptake is virtually complete two weeks after flowering. Phosphorus uptake is complete four weeks after flowering.

Nitrogen

Nitrogen (N) deficiency is the main nutritional limitation to yield in maize. The challenge is to manage N fertilisers for maximum efficiency of utilisation. N supply must be adequate to meet daily uptake demands whilst minimising losses through runoff, leaching, denitrification and volatilisation.

The quantity of N required to grow a maize crop is about 1.6 times the quantity that will be removed in the grain. About 25 kg N/tonne of dry matter is removed when a maize crop is cut for silage, of which 12–16 kg is in the grain.

N uptake by a crop comes from the available soil nitrate N and from fertiliser N. Soil nitrate N is estimated by testing soil (preferably to 90 cm depth)[1] and by considering the cropping history, especially the grain yield and protein content of the previous crop. Rotations with legume crops such as mungbean, peanut and soybean can increase the availability of soil nitrate N and reduce the N fertiliser requirement for maize.

1 Deep soil sampling is not recommended in Cambodia because of the risk of striking deeply-placed land mines.

Regardless of the form of N applied, the efficiency of N fertiliser use, and thus its cost effectiveness, can be enhanced through the adoption of a split application program. Fertiliser can be applied before sowing, at sowing and during crop development. A typical approach is to apply 100 kg/ha of DAP ($N:P_2O_5:K_2O$ - 18:46:0) at or before sowing. This provides 18 kg N/ha which is adequate as maize needs little N during early vegetative growth up to about the fifth leaf stage. An alternative, especially if potassium deficiency is expected, is to apply an N:P:K fertiliser. There is a range of combinations of these fertilisers available, such as 20:20:15 + trace elements.

Before top-dressing, the crop should be monitored carefully for signs of N deficiency during early vegetative growth. The largest portion of N uptake by maize is between the eighth leaf to tasselling stages. Thus, applying N before the eighth leaf stage is recommended. Urea (46:0:0) is the main N top-dressing option in Cambodia and can be applied in a sequence of split applications of 50 kg/ha under good soil moisture and crop growing conditions.

N budgeting can also be used to determine the N requirements of a crop by using the following calculations.

N removed in grain (kg/ha):
Target yield (t/ha) × grain protein % × 1.6 (conversion factor)

N required for crop (kg/ha):
N removed in grain × 2 (N use efficiency)

Example calculation:
[8 (t/ha target yield) × 10 (% grain protein) × 1.6 (conversion)] × 1.6 (efficiency) = 205 kg N/ha

If, in the example calculation, 95 kg N/ha of nitrate N was available in the soil, then a further 110 kg N/ha would need to be supplied through fertiliser applications. For example, 100 kg/ha 20:20:15 fertiliser provides 20 kg N/ha and therefore urea top-dressings amounting to 200 kg/ha (90 kg N/ha) would be required to satisfy the requirement of an 8 t/ha maize crop for this field.

The Merck RQeasy® rapid soil nitrate test

Rapid field testing kits such as the Merck RQeasy® hand-held instrument and Reflectoquant nitrate test strips now make it possible for soil nitrate tests to be carried out by farmers or extension workers with a minimum of equipment (Figure 19). This opens up the possibility of testing the soil immediately prior to planting the crop and more accurately determining the crop's N fertiliser requirements. This procedure can also be used to identify low- and high-fertility sites for experiments and for characterising experimental sites.

The RQeasy reflectometer is an easy way to measure soil nitrate levels. The instrument can be used with test strips for measurement of different ranges of nitrate levels. Test strips that measure nitrate in the range 3-90 mg/L are suitable for soil nitrate tests. The code for this strip is 777. It is essential that this code is entered on the machine.

Figure 19. Operating elements of the RQeasy soil nitrate meter

If a farmer knows the soil nitrate level before sowing, they can work out how much N they would need to apply to achieve the expected crop yield by reading off the calibration chart (Figure 20) or using the following calculation:

(NO_3 (mg/L)* 3) – 0.00006 = soil N (kg/ha)
(32 * 3) – 0.00006 = 95 kg N/ha

For example, if the farmer expects a maize yield of 8 t/ha then the amount of N required by the crop is 205 kg/ha (see above). If the meter NO_3 reading is 32 mg/L, the farmer will need to apply 95 kg N/ha as urea top-dressing.

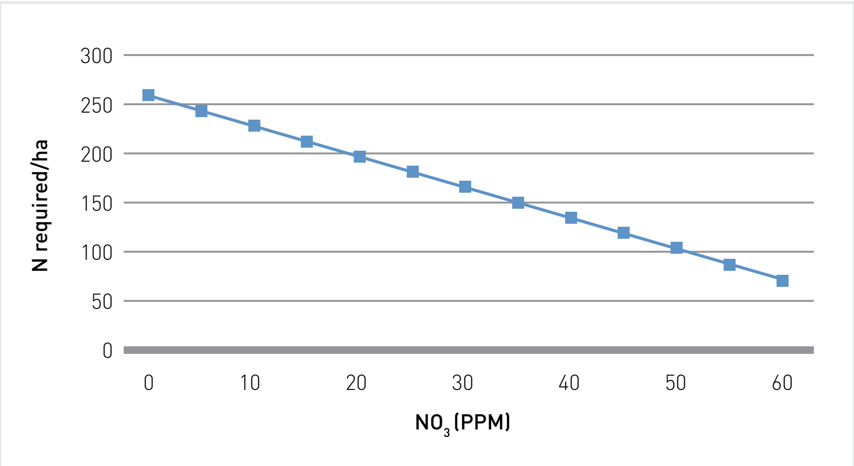


Figure 20. Conversion chart: NO_3 mg/L to N kg/ha

A lookup table, based on soil NO_3 readings, can be used to estimate the amount of urea top-dressing required to achieve maize target yields of 2,4,6 and 8 t/ha (Figure 21).

NO_3 (mg/L)	Urea required (kg/ha)				
	2	4	6	8	10
0	68	179	290	402	513
5		146	258	369	480
10		113	225	336	447
15		81	192	303	414
20		48	159	270	382
25			126	237	349
30			93	205	316
35			60	172	283
40				139	250
45				106	217
50				70	184
55					152
60					119

Figure 21. Urea top-dressing requirements for target yields (2,4,6,8,10 kg/ha) based on soil nitrate test (0-20 cm)

Economics of nitrogen application to maize in Samlout

Methods

An experiment was repeated at four locations on Ferrosol (Labansiek) soil in Samlout district in the main wet season of 2009. The design was a randomised complete block with three replicates at each location. The treatments are shown in Table 3.

Table 3. Fertiliser (urea) treatments applied to maize at Samlout in 2009

Basal (kg/ha)	Top-dressing (kg/ha)	Total applied (kg/ha)
Nil	Nil	Nil
Nil	50	50
Nil	100	100
Nil	200	200
Nil	400	400
50	Nil	50
50	50	100
50	100	150
50	200	250
50	400	450

Biological yield results

The basal fertiliser treatment (+/- 50 kg/ha urea) did not significantly affect maize yield and there was no basal * top-dressing interaction. Therefore, results are presented for the top-dressing main effect only.

Urea top-dressing increased the average maize yield over the four locations from 6.770 t/ha with nil urea to 8.815 t/ha when 400 kg/ha of urea was applied (Figure 22).

Economic analysis

An economic analysis was carried out using the method of CIMMYT (1988). It is assumed that the minimum rate of return acceptable to farmers is 100%. This gives confidence to make a urea (nitrogen) recommendation to farmers who are currently not using nitrogen fertiliser on their crop. The recommendation can be based on the partial budget analysis of returns versus costs. This will largely be determined by the cost of urea and the price of maize. An example is given in Table 4.

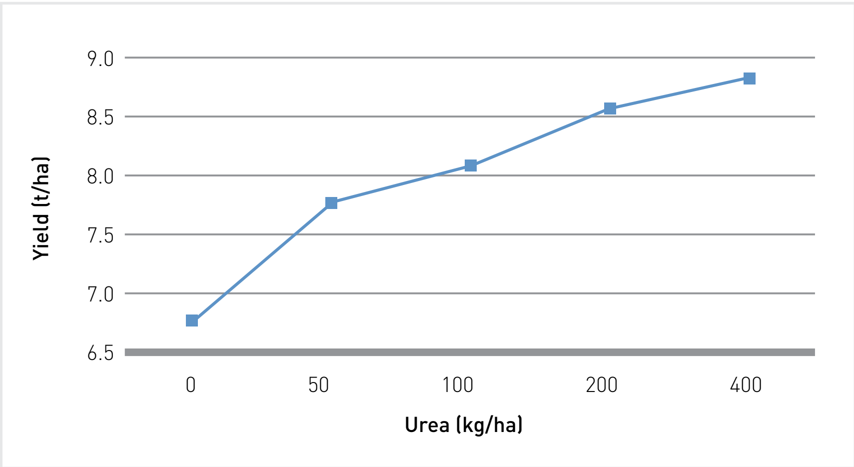


Figure 22. Effect of urea top-dressing on maize at four locations in Samlout in 2009

Table 4. Partial budget for urea top-dressing on maize

	Urea (kg/ha)				
	0	50	100	200	400
Yield (t/ha)	6.770	7.773	8.082	8.559	8.815
Return ($/ha)	$1,523	$1,749	$1,818	$1,926	$1,983
Cost of urea ($/ha)	$-	$22	$44	$88	$176
Benefit ($/ha)	$1,523	$1,727	$1,774	$1,838	$1,807

The following assumptions have been made:

> price of urea = $0.44/kg

> farm-gate value of maize grain = $225/tonne

> cost of fertiliser application if applied by seeding machine = $0

> minimum rate of return = 100%.

The net return from urea application increased up to 200 kg urea/ha (Table 4; Figure 23).

Table 5. Marginal analysis for urea application on maize

Treatment (urea kg/ha)	Total costs that vary ($/ha)	Net benefits ($/ha)	Marginal rate of return
0	0	1,523	
50	22	1,727	927%
100	44	1,774	107%
200	88	1,838	73%
400	176	1,807	-18%

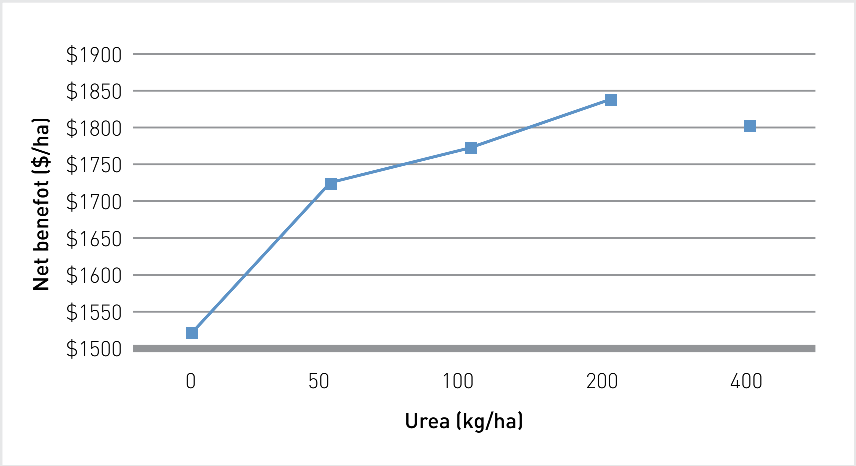


Figure 23. Net benefit curve for urea application on maize

The marginal rate of return (MRR) of the change from 0 kg urea/ha to 50 kg urea/ha is 927%, well above the 100% minimum (Table 5). The MRR from 50 kg N/ha to 100 kg urea/ha is 107%; also above 100%. But the MRR between 100 kg urea/ha and 200 kg urea/ha is only 73%. Therefore, of the treatments in the experiment, urea at 100 kg/ha would be the best recommendation for farmers if a MRR of 100% is expected. However, some farmers might choose 200 kg/ha if they are confident they can improve yields by addressing other constraints such as weeds.

Phosphorus

Phosphorus (P) deficiency appears to be common in the soils of North-West Cambodia. Laboratory testing of soil for P will identify soils with insufficient reserves to meet crop demands. P deficiency is indicated by dark green leaves with reddish-purple tips and leaf margins (Figure 24). It is more likely to appear on young plants.

Figure 24. Phosphorus deficiency symptoms in maize. Photo: R. Martin

Potassium

Commonly, 10 kg of potassium (K) per tonne of dry matter is contained in the above-ground biomass of a maize crop, of which only 3–4 kg is contained in the grain. When the crop is harvested for silage (or when the grain is harvested and the stubble burnt) more than 150 kg K/ha might be removed (Table 2). This K will eventually need to be replaced to maintain high yield potential. K remaining in the roots and retained stubble is rapidly returned to the soil as K is readily leached from plant material.

The amount of fertiliser K required depends on the level of available K in the soil. Plants absorb K directly from soil solution which is a far smaller pool than the exchangeable and fixed pools of K in the soil. Particularly in clay soils with shrink-swell properties, K added as fertiliser may be fixed in the soil yet not immediately available for plant uptake.

Soil testing gives an indication of the likely response to K on some soil types, but is not totally reliable. Such a test measures the size of the exchangeable pool rather than the K immediately available to plants in the soil solution. Test strips are worthwhile to validate results where field history suggests large volumes of K have been removed. Prolonged K removal can reduce supplies of K in the fixed pool, and thus lead to the need for large applications of K to overcome deficiencies if they occur.

Micronutrients

Many nutrients are required by maize in small amounts. These are referred to as trace elements or micronutrients. Zinc (Zn), boron (B) and molybdenum (Mo) deficiencies are common in maize.

Zinc

Figure 25. Zinc deficiency symptoms on maize. Photo: R. Martin

Zinc (Zn) fertilisers are needed for maize grown on heavy alkaline soils, and deficiencies have been found to occur on *Kampong Siem* soils derived from limestone parent material in North-West Cambodia (Figure 25). Zn can be broadcast at 10–20 kg Zn/ha and incorporated at least three months prior to planting. This application rate should last for five to six years as Zn is relatively immobile in the soil. Lower rates are sufficient on lighter textured soils.

Applying Zn with the seed at planting, as either a blended fertiliser product or as a water-injected solution, is an effective alternative way to apply zinc. In-crop foliar applications can also be used. When the maize is 20–30 cm high, apply two foliar sprays, seven to 10 days apart, of zinc sulphate heptahydrate solution (1 kg per 100 L of water) at 300–400 L/ha.

Boron

Boron (B) deficiency has been found in sunflower on *Labansiek* (Ferrosol) in Pailin and Prateah Lang soil in Kampong Thom (Martin pers. comm.). Symptoms include stunting with short, thickened stems and lateral roots. The cob leaves remain closed, inhibiting emergence of the silks, and tassels fail to emerge. If a deficiency is suspected, a foliar fertiliser can be applied when symptoms appear. Care must be taken to apply the correct amount otherwise toxicities can be a problem.

Molybdenum

A risk of molybdenum (Mo) deficiency exists on the acid soil groups: *Prey Khmer*, *Prateah Lang*, *Labansiek* and *Toul Samroung*. Deficiency may be apparent in seedlings, with the tips of the lower leaves turning yellow and dying, and plants being stunted or even dying. Adding Mo to a starter fertiliser at sowing, can minimise Mo deficiency, or Mo can be applied as a foliar spray. Applying lime to raise the soil pH can also increase Mo availability over the longer term.

Weed management

Weed management tips

- Pre-emergence weed control is essential as post-emergence herbicides alone have been shown to provide inferior weed control in maize.
- Avoid fields that are infested with grass weeds, especially *Boart Salay* (*Sorghum* hybrid) or Treng (*S. propinquum*).
- Use a post-sowing, pre-emergence herbicide as a priority.
- If Sorghum weeds have become dominant, replace atrazine with pendimethalin or s-metolachlor post-sowing pre-emergence, or nicosulfuron post-emergence.
- Control weeds before sowing, especially those that reproduce vegetatively.
- Prevent weeds from setting seed during the crop cycle and post-harvest.

Without good weed control, crops can be completely overrun by weeds in Cambodian upland conditions (Figure 26). Maize is most susceptible to weed competition in the early stages of growth until the crop reaches 0.8 m in height, around eight weeks after planting. Effective weed control through this period is essential for high yields, particularly in rainfed crops. Maintaining weed control beyond this stage is important for harvestability and preventing contamination of the grain sample.

An integrated approach to weed management is recommended as herbicide-tolerant and herbicide-resistant weeds are an emerging problem, especially in North-West Cambodia. Repeated use of atrazine for weed control in maize in North-West Cambodia has resulted in an increase in atrazine–tolerant weed species, such as *Boart Salay (Sorghum* hybrid*)* and *Treng (S. propinquum)* which cannot be controlled by atrazine (Figure 27).

Figure 26. Maize crops can be completely overrun by weeds in Cambodian upland conditions. Photo: R. Martin

Figure 27. (a) *Sorghum* hybrid in maize, (b) panicle of *S.* hybrid, (c) panicle of *S. propinquum.* Photo: R. Martin

Farmers should target their weed control operations carefully so that the correct rate and time of application of herbicide is achieved.

Herbicide application techniques

For all herbicide use patterns in maize (pre-planting, post-sowing pre-emergence and post-emergence) applications can be made using a conventional hydraulic boom sprayer. Water rates in the 50-100 L/ha range will ensure adequate soil and/or weed coverage.

For herbicides used post crop emergence, nozzle configuration is also important to prevent crop injury. Drop nozzles are recommended for application of 2,4–D from when the crop has four fully emerged leaves through until tasselling. Drop nozzles avoid the accumulation of herbicide in the whorl of the plant, which may damage the developing tassel and cob. Drop nozzles also have the advantage of improving herbicide coverage on the weeds. Shielded sprayers can be used in place of drop nozzles to apply post-emergence herbicides.

Herbicide injury

2,4-D

2,4-D is commonly used as a post-emergence herbicide in maize in Cambodia. It can be applied between the three and four leaf stage of maize. After the four leaf stage, drop nozzles must be used to avoid 2,4-D injury to maize (Figure 28). The injury symptoms of 2,4-D include malformation of brace roots and twisted appearance of leaves. Misapplication of 2,4-D can also increase the brittleness of the stem which results in lodging under windy conditions.

Figure 28. 2,4-D injury in maize. Photo: R. Martin

Paraquat

Paraquat is a restricted-use herbicide in Cambodia and is not registered for use in maize. Despite this, it is commonly used in maize as a directed post-emergence spray application. Paraquat injury is common in maize crops where it has been applied carelessly or in windy conditions (Figure 29).

Figure 29. Paraquat injury in maize from an application 10 m away. Photo: R. Martin

Integrated weed management

Significant yield losses occur if weeds are not controlled in maize before and immediately after planting. Pre-sowing or post-sowing pre-emergence weed control is essential. Post-emergence herbicide applications have been shown to be less effective for weed control compared to pre-emergence herbicides.

Farmers are encouraged to use an integrated weed management approach that combines all available options. The aim should be to keep weed numbers low and prevent weeds from producing seeds throughout the cropping cycle.

Weeds commonly occurring in upland crops in Cambodia are described by Martin and Pol (2009). Special attention should be given to controlling weeds before the crop is sown. This means preventing weeds from setting seeds in the previous crop and controlling weeds around the edge of the field, along waterways and in adjacent non-cropped areas. Special attention also needs to be given to weeds that regrow from stolons, rhizomes, underground tubers or bulbs (Appendix 1). These weeds are difficult to control by cultivation and regrow from cut plant parts after the crop is sown.

Chemical weed control options

For effective control of most weeds, apply atrazine or other pre-emergence herbicides either before planting, at planting or immediately after planting (Appendix 1). Where *Sorghum* weed species are present, pendimethalin and s-metolachlor can be applied as a post-sowing pre-emergence alternative to atrazine.

Herbicides can be used for weed control in maize pre-sowing, post-sowing pre-emergence and post-sowing (Appendix 1; Table 6). Replacing the final cultivation with herbicide application reduces the number of weeds emerging with the crop, and 33% of farmers in Pailin Province have adopted this practice for establishment of maize (Touch et al. 2013). This is also the time to control perennial or vegetatively reproducing weeds.

Table 6. Herbicides registered in Cambodia that can be used in maize

Active ingredient	Group	Pre-plant	Post plant pre-em	Post-em	Harvest desiccation
2,4-D	I	✓		✓	
Atrazine	C	✓	✓	✓	
Glyphosate	M	✓			✓
Pendimethalin	D		✓		
S-metolachlor	K		✓		
Fluroxypyr	I			✓	
Nicosulfuron	B			✓	

Making silage from maize

Small-scale cattle farmers in Cambodia face a shortage of feed in terms of quality and quantity, especially during the dry season. This is one of the most serious problems faced by these farmers, who are in the process of transitioning from keeping cattle as draught animals to keeping cattle for fattening and sale. There are a range of options to overcome feed shortages during the dry season, and by-products from agriculture and other industries can be fed to cattle as roughage or concentrate feed (Figure 30).

Figure 30. Most drought-affected maize crops are poorly utilised in Cambodia. Photo: R. Martin

Maize can be grown with the aim of making silage, or maize crops that have failed because of drought can be ensiled. Methods of silage making include: concrete bunkers; concrete trenches; plastic stacks; and plastic bags. The plastic bag technique has been successfully trialled in North-West Cambodia. The bag capacity is 40-50 kg (Figure 31).

There are very few forage harvesters in Cambodia and maize must be cut by hand and chopped with a small chopping machine that can be driven by a small engine or connected to a two-wheel tractor engine (Figure 32).

Figure 31. Silage making from maize at Samlout. Photo: R. Martin

Figure 32. Silage chopping machine. Photo: R. Martin

Harvest timing

The timing of harvest is a compromise between maximum dry matter yield, moisture content and potential feed quality. These factors need to be balanced to ensure the silage will ferment and ensile effectively without spoiling. Ideally, harvest should occur 10–14 days prior to physiological maturity, when the maturing grain reaches the milk line score (MLS) of 2.5. When the milk line score is in the range 2–3, dry matter production is near to the maximum and moisture content is 63–67% which is ideal for fermentation, as shown in Table 7.

Table 7. The relationship between MLS and forage yield and quality for rainfed maize (Kaiser et al. 2003)

	Milk Line Score (MLS) at harvest				
	>0-1	>1-2	>2-3	>3-4	>4
Yield (t/ha)	57.5	56.7	50.3	46.0	36.4
DM (%)	27.3	29.8	33.2	39.1	44.0
DM (t/ha)	15.7	16.9	16.7	18.0	16.0
Grain content (%DM)	33.4	39.7	42.8	45.8	48.0
Crude protein (% DM)	7.2	7.1	6.9	6.7	6.6
ME (MJ/kg DM)	10.3	10.2	10.1	10.0	9.8

Feed quality declines rapidly if crops are held over for more than 10–14 days past the optimum harvest time. After that time, dry matter yield is lost and the chopped material becomes difficult to compact, resulting in poor fermentation and ineffective silage. If harvest at the optimum time is delayed due to rain, it may be preferable to hold the crop for grain.

At MLS 2.5 the milk line is halfway down the grain. This often coincides with the cob husk turning from green to white and the dying-off of lower leaves.

Drought-stressed crops

The effect drought has on yield and forage quality will depend on the timing and severity of the moisture stress. Drought-stressed maize can be harvested at a dry matter (DM) content of 30–40%.

When a crop grown with high nitrogen inputs becomes drought-stressed, there may be a risk of nitrate poisoning if the crop is grazed or fed as green chop. Ensiling will reduce this risk as nitrate concentrations fall by 40–60% during the first three to four weeks of storage. Harvest should be delayed while plants have green leaf if there is a chance of rain.

Cutting height

Choosing an optimum cutting height is difficult because of differences between hybrids and growing conditions. The lower the cutting height, the higher the dry-matter yield. However, higher cutting heights increase silage quality by increasing the proportion of grain in the chop. Raising the cutting height from 15 cm to 45 cm would reduce yield by 15% and raise digestibility by 2%. The value of keeping the remaining stubble as ground-cover mulch to assist the establishment of the next crop in the field should also be considered when choosing a cutting height.

Chop length

Aim for a chop length of 10–15 mm. Very fine chopping will crack more grain but increase power requirements. If harvesting is delayed (DM>38%) the chop length should be set as fine as possible to aid effective compaction. If forced to harvest early (DM <28%) a longer chop length of 15–20 mm will aid compaction. However harvesting at low DM is not advised as poor fermentation and unacceptable effluent losses can result.

Harvesting

Traditionally, when red maize cobs have dried down and it is time for harvest, the practice is to handpick, husk and sell on-the-cob without drying (Figure 33). The increasing shortage of rural labour is making hand harvesting and husking less feasible and more expensive for most small-scale farmers.

Figure 33. Hand husking maize. Photo: R. Martin

Most shelling is done by machine at the roadside or at the silo (Figure 34). Moisture levels for grain on the cob are 18-24%. After shelling, grain is sun-dried or dried at the silo where cob shanks are used as fuel for the dryers. Maize is then stored and/or sold at 14% moisture.

Figure 34. Shelling maize at a large silo. Photo: R. Martin

Harvesting by machine

Maize can be harvested by machines that pick the cobs only or by combine harvesters which husk and thresh as well (Figure 35).

Figure 35. Combine harvesting maize. Photo: R. Martin

Figure 36. Grain handling after machine harvesting is at a primitive stage in Cambodia

Grain handling after machine harvesting is at a primitive stage in Cambodia (Figure 36) although it is expected that bulk handling will be rapidly adopted.

Desiccation

Desiccation of maize can be done to reduce the time to harvest, control late season weeds and start the fallow to store more soil moisture. It effectively reduces late season transpiration losses such that soil moisture may be conserved for use by the subsequent crop or for earlier commencement of the fallow period.

Pre-harvest glyphosate can be applied immediately after physiological maturity has been reached. This will hasten dry-down of the grain and should kill or desiccate the crop. Desiccation allows crops to be harvested earlier and more efficiently than if crops are not sprayed.

DISEASES

Disease management tips

- Include legume crops in the rotation (e.g. mungbean, peanut, soybean).
- Make sure seed for planting is coated with fungicide.
- Prevent damage from insects, birds and rodents that can provide entry of pathogens into the plant.
- Avoid stresses to the crop, such as water stress or too much fertiliser.
- Control weeds as weeds are alternative hosts for many diseases.
- Apply fungicide if appropriate.

Many diseases in maize can be overcome by selecting resistant hybrids. Additionally, good farm hygiene, including washing down equipment and controlling weeds and volunteer maize plants, can minimise disease spread from crop to crop and season to season.

While diseases are important to maize production because of their potential to reduce yield, the marketing of grain can be severely restricted by the presence of disease, adding further to the need to choose hybrids carefully. Refer to Table 1 for details of disease reactions in current hybrids.

Figure 37. Fruiting body of boil smut or common smut (*Ustilago maydis*). Photo: R. Martin

Boil smut or common smut (*Ustilago maydis*)

Symptoms

Young seedlings become swollen and distorted. Infections during the vegetative stage of growth are expressed as galls (boils) on the stems, leaf axils and leaves, which are initially pale green and become white and full of black powdery spores at maturity. In more mature plants, boils form in kernels causing them to enlarge and deform, distorting the cob (Figure 37).

Conditions favouring development

The fungus develops in temperatures over 25°C and dry conditions, however it spreads in rainy or high humidity conditions. High soil nitrogen also favours the fungus, and physical damage to plants can also increase infection.

Spores are dispersed by wind and through contact sources. Inoculum may remain viable in the soil for many years. While losses are not usually significant, occasionally yield loss is severe.

Management

Varietal selection may assist in reducing risk of infection, however an integrated management program is necessary for greater effectiveness. This involves: cleaning machinery and boots to reduce contamination; regularly inspecting crops; removing infected plants; minimising plant injuries; careful rotations; and applying seed treatments.

Figure 38. Downy mildew-infected maize: Leaf streaks and malformed tassel (left); Yellow chlorotic and necrotic leaf (centre); Stem elongation with multiple cobbing (right). Source: Queensland Department of Primary Industries and Fisheries.

Downy mildew (*Peronosclerospora* spp.)

Downy mildew (Figure 38) is considered the most damaging disease of maize in South Asia (Kim et al. 2006). There are numerous types of the disease, several of which may be present in Cambodia.

Symptoms

Maize is susceptible to downy mildew from seedling to anthesis stages. Symptoms include white and yellow striping of leaves and leaf sheaths, and stunting of the whole plant, which produces no yield. The other major symptom is downy growth on or under the leaf due to conidia formation.

Management

It is advisable to choose resistant varieties. Avoid planting maize after maize in the same field.

Figure 39. Leaf symptoms of southern corn leaf blight (*Bipolaris maydis, Helminthosporium maydis*). Photo: R. Martin

Southern corn leaf blight (*Bipolaris maydis, Helminthosporium maydis*)

Symptoms

Leaves are affected by lesions which when they first form are small and diamond-shaped, elongating as they mature (Figure 39). The final lesion is rectangular and 2-3 cm long. Each lesion is light brown with a reddish-brown border and a light yellow ring around it. Lesions may merge, producing a complete burning of large areas of leaf. This may lead on to stalk and cob rot which can cause significant yield loss.

Management

It is advisable to choose resistant varieties (Table 1). If varieties are not resistant, farmers must at least plant disease-free seed, as the disease can be seed borne. Do not plant maize after maize in the same field.

Figure 40. Left: Fusarium ear rot-infected maize. Source: Iowa State University Department of Entomology www.ent.iastate.edu. Right: Fusarium stalk rot. Source. S. Montgomery

Stalk rot and ear rot (*Fusarium* spp.)

Symptoms

These different species of fungi produce stalk rots, ear rots and seedling blights (Figure 40). Whitish-pink cottony fungal growth develops on and between the kernels and sometimes on the silks. Infected plants are weakened and can break easily during strong winds and rains. Mycotoxins, which are harmful to humans and livestock, are also produced.

Management

These diseases can be controlled by the use of resistant varieties together with the use of optimum plant populations and nitrogen applications.

Figure 41. Aflatoxin spores on maize kernels. Source: Iowa State University Department of Entomology www.ent.iastate.edu

Aflatoxin (*Aspergillus flavus*)

Symptoms

Masses of yellow to dark green spores develop on kernels, which may be slightly enlarged (Figure 41). Crop symptoms include terminal drought stress, such as permanent wilting of the foliage, receding canopy cover between rows and leaf drop.

Management

Aflatoxin is a fungus that is toxic to humans and affects maize kernels. It affects not only the quality of the crop but also the safety of anyone who consumes affected kernels. Its onset is encouraged by drought. Growing maize during the main monsoon season, when there is reduced likelihood of drought, should decrease the chances of aflatoxin becoming a problem. If growing maize in the dry season, do not delay harvest.

Figure 42. Tropical corn rust leaf symptoms. Photo: R. Martin

Tropical corn rust (*Puccinia polysora*)

Symptoms

Small round to oval, brown or orange pustules are distributed uniformly over the upper leaf surface (Figure 42). Brown to black circles may appear around the pustules. Severely affected leaves turn yellow and die early. Ears on severely affected plants are much lighter than normal and the seeds are pinched and loose on the cob.

Management

Control volunteer maize plants and other grass weeds that may act as a host to the fungus. Avoid planting two maize crops in a row. Plant resistant varieties if they are available.

INSECT PESTS

Insect management tips

- Keep weeds under control between crop plantings.
- Make sure seed for planting is coated with insecticide.
- Carefully check for insect pests as well as the presence of beneficial insects before applying insecticide.
- Apply insecticide if thresholds are reached.
- Avoid application of broad spectrum insecticides in the vegetative stage to preserve beneficial insects. If necessary, use biological (Bt, NPV) or selective insecticides.
- Control weeds as weeds are alternative hosts for many insects.

The first step in managing insect pests is to identify the insect and determine the numbers of pest and beneficial insects present. Crops should be checked regularly to determine the extent of an insect infestation and to assess the damage it is causing. This information can then be used to determine whether control is required and what is the most suitable management method.

Following are some of the major maize insect pests in Cambodia and a brief description of the damage they cause. For more detail, the common insect pests and beneficial organisms for upland crops in Cambodia are described in Pol et al. (2010).

Figure 43. The corn aphid (*Rhopalosiphon maidis*). Photo: R. Martin

Corn aphid (*Rhopalosiphum maidis*)

Maize is the primary host to *Rhopalosiphum maidis* but can also be found on grasses, sugarcane and sorghum.

Description

Adults are up to 2 mm long and light to dark olive-green in colour, with a purple area at the base of small, tube-like projections at the rear end (Figure 43). They are usually wingless. Antennae extend to about one-third of the body length. Nymphs are similar but smaller in size.

Damage

Adults and nymphs suck sap and produce honeydew. Very high numbers may turn plants yellow. High populations on the fruit heads produce sticky grain. A combination of aphid attack and water stress can cause reduced crop yield. All stages of the crop are attacked, but the most serious damage is when high numbers infest cobs.

Management

Chemical control of corn aphid is usually not necessary. Before applying insecticide, inspect the crop for beneficial insects such as lady beetles (see beneficial insects).

Figure 44. Bean pod borer (*Helicoverpa armigera*) larva. Photo: C. Pol

Bean pod borer (*Helicoverpa armigera*)

Description

Larvae range in colour from yellow-green to red-brown (Figure 44). They are hairy and develop a 'saddle' of darker pigment on the fourth segment back from the head. Fully grown larvae are 40–50 mm long. Infestations usually occur during silking/tasselling, when crops are most attractive to moths laying eggs.

Damage

Larvae feed on the leaves, tassels, silks and the tops of cobs. Economic damage to silks can prevent pollination and kernel set. As a result, cobs tend to develop with poorly filled-out tops and are susceptible to cob rots. Larvae may also eat through the husks and enter the middle and lower parts of the developing cobs. In some seasons, crops may be infested well before tasselling. The larvae will eat holes in the funnel and leaves, arranged in transverse parallel rows, allowing entry of other pests and diseases. Damaged plants may look weakened but yield will be unaffected unless infestation is very severe.

Threshold

Damage prior to tasselling does not warrant control measures, and spraying is unlikely to be economic.

Management

Regular monitoring is required, as early detection will allow control during egg laying or small larvae stages when the larvae are most susceptible to insecticides, and before damage occurs. Natural enemies of bean pod borer, such as lady beetles, may regulate the population below damaging levels. There are a range of insecticides registered for bean pod borer control in maize.

The biological insecticides, Bacillus thuringiensis (Bt) and nuclear polyhedrosis virus (NPV), are safe to use with beneficial insects. Insecticides targeting larvae should be applied using a high clearance sprayer. Alternatively, target eggs laid prior to canopy closure. Large larvae and larvae entrenched in the funnel of younger plants, or the cobs of older plants, will not be controlled.

Figure 45. Asian maize borer. Photo: C. Pol

Figure 46. Armyworm. Photo: W. Leedham

Asian maize borer (*Ostrinia furnacalis*)

Description

Adult moths are 20 mm long and brown or yellow in colour. They lay oval, light yellow eggs on top of leaves or on the husk. Young larvae are pink or yellow-grey with black heads. Older larvae are whitish and spotted (Figure 45). Eggs are laid in clusters on the top side of the leaf or husk and turn black just before hatching.

Damage

Young larvae hatch from an egg mass and eat maize leaves still rolled up in a whorl. Older larvae bore into the stalk behind the leaf sheath, which causes significant damage when the plant has elongated and is at risk of lodging.

Armyworm (*Spodoptera litura*)

Description

As larvae grow they develop obvious black triangles along each side of their body. Larvae grow up to 3 cm long and are narrowest at the head (Figure 46). Eggs are laid in clusters of up to 300.

Damage

Mass hatchings of armyworms begin feeding on leaves, scraping the surface off and creating a 'window pane' effect. The damage becomes progressively worse, starting at the margins and moving inward, with the armyworms eating entire leaves or defoliating plants.

Figure 47. Green vegetable bug. From left to right: adult; 5th instar nymph; 3rd instar nymphs; egg raft. Photo: R. Martin

Green vegetable bug (*Nezara viridula*)

Description

Adults are 15 mm long and bright green all over. Nymphs go through five different instar stages where they change colour and pattern. The first instar is orange and subsequent instars progress through black, then black, red and yellow patterns, and eventually green becomes dominant (Figure 47).

Damage

Adults and nymphs pierce and suck developing seeds and cobs, which may be lost, deformed or have dark marks on them.

Figure 48. Termite damage (left), termite soldier (right). Photos: W. Leedham

Termites (Termitidae)

Description

Three separate genera of termites have currently been identified as a problem in Cambodian maize crops, including *Microtermes* sp., *Hypotermes* sp., *Globitermes* sp. and *Macrotermes gilvus*.

Hypotermes sp. and *Globitermes* sp. Build short, broad based, dome shaped mounds in the field whilst the other two species build their nests entirely below ground. Termites are small, white and honey coloured insects with a soft body and live in colonies in the soil. You will always find them in groups and the termites may be different sizes. The workers are the smallest and soldiers are significantly larger.

Damage

Traditionally termites are fungus producers and they harvest plant material to feed the fungus which they then feed on themselves.
In Cambodia, the termites chew maize roots and dry the plant out, usually resulting in patches of crop death. They may also tunnel up the inside of the stem, resulting in crop lodging and significant yield loss.

BENEFICIAL INSECTS

There are some beneficial insects, including predators and parasitic wasps, which commonly occur in maize crops. Farmers should be able to distinguish these insects from maize pests and use them as a tool in integrated pest management.

When present in high numbers, these beneficial insects may be effective in controlling pests and preventing yield loss.

Figure 49. Spined predatory shield bug. Photo: W. Leedham

Spined predatory shield bug (*Oechalia schellenbergii*)

Description

Adults are 15 mm long, shield-shaped with obvious spines at either side of the shoulders and a light mark in the middle of the back (Figure 49). Nymphs are almost black with a red ring on their backs.

Benefit

The adult and nymphal stages of this predator use their beaks to pierce insects, especially caterpillars, and suck out the body contents.

Figure 50. Transverse ladybird (*Coccinella transversalis*). Adult (left), pupae (centre) and larva (right). Photo: R. Martin

Lady beetles

The most common species of lady beetles found in upland crops in Cambodia are the six-spotted lady beetle (*Cheilomenes sexmaculata*) and the transverse lady beetle (*Coccinella transversalis*).

Description

Lady beetles have four distinct growth stages: egg, larvae/pupae and adult (Figure 50). Adults are 5-8 mm long with two pairs of wings. They are oval in shape with obvious spots or lines on their backs in black, red, orange or yellow.

Benefit

The adults and larvae of lady beetles are important predatory insects in field crops. Adults mainly feed on Lepidoptera eggs and aphids, whilst nymphs will also eat Lepidoptera hatchlings. Two or more per plant may make a useful contribution to integrated pest management.

Figure 51. *Tricopoda* spp. parasitoid of *Nezara viridula*. Photo: R. Gunning

Parasitoids of green vegetable bug (*Trichopoda* spp.)

Description

Trichopoda is a genus of small, brightly-coloured flies that range in size from 5-13 mm. The flies have a distinctive fringe on the hind legs. The eggs are laid on adult or late nymphal stages of the green vegetable bug (Figure 51). On hatching, the maggot bores into the body of the host and feeds on the host's fluids for about two weeks. When fully grown, the maggot emerges, killing the host, and pupates in soil. The adult fly emerges after about two weeks.

Benefit

Trichopoda species have been released as a biological control for *N. viridula* in various parts of the world. Parasitism rates can be as high as 50% but there is conflicting evidence of the effectiveness of biological control by this parasite.

Figure 52. *Trissolcus basalis* wasp parasitising *Nezara viridula* eggs (left), Nezara viridula egg raft (right). Photo: T. Smith

Description

Trissolcus basalis is a very small black wasp (about 2 mm long) with downward elbowed antennae and a flattened abdomen. Wing veins are not obvious. In parts of the world where it has been released as a biological control agent, *T. basalis* usually occurs in all crops attacked by *Nezara viridula*, including cotton, maize, soybean and other legumes. *T. basalis* lays eggs inside pentatomid eggs, where they develop to adulthood (Figure 52). The primary host is *N. viridula*, but *Trissolcus* parasitises eggs of other pentatomids, including beneficial ones.

Benefit

T. basalis can reduce *N. viridula* numbers by more than 50%. Planting trap crops of early maturing soybeans could be an integrated pest management strategy to reduce *N. viridula* numbers in the main crop.

STORAGE PESTS

attack by diseases. It can also be damaged by rodents and birds. It is important to fumigate or periodically expose grain to the sun to kill storage insect pests, such as the lesser grain weevil. Cleaning of the grain store to remove all traces of the previous crop, preferably by disinfecting the structure before use, is important. It is also necessary to monitor the condition of the stored grain throughout the storage period to ensure it is free from insect pests and diseases, and that appropriate temperature and moisture are maintained. Insects that commonly occur in stored maize in Cambodia are described below.

Figure 53. Maize weevil (*Sitophilus zeamais*). Photo: R. Martin

Grain weevils (*Sitophilus* spp.)

Description

Maize can be attacked by grain weevils, including *Sitophilus zeamais* (maize weevil), *S. oryzae* (rice weevil) and *S. granaries* (granary weevil). Adults are 2-3 mm long with a long snout and four reddish spots on the wing covers (Figure 53). The maize weevil is a strong flier.

Damage

Grain weevils infest stored grain or maize ears before harvest and the larvae develop into pupae inside the kernel. They begin as a pest in the field but continue on to become a major pest of stored grain.

Signs

Removal of husks in the field will reveal weevils and the irregular punctures they make in kernels during feeding or egg laying. They create web-like galleries as they feed inside the kernels.

Figure 54. The coffee bean weevil (*Araecerus fasciculatus*). Photo: R. Martin

Coffee bean weevil (*Araecerus fasciculatus*)

Description

The coffee bean weevil (*Araecerus fasciculatus*) is a small, dome-shaped beetle, 3-5 mm in length that is a pest of stored food products. The beetle is mottled dark brown with lighter brown patches. It has long legs and antennae and its body is covered in short hairs (Figure 54).

Damage

The coffee bean weevil attacks stored products such as coffee, cocoa, yams, maize, peanuts, Brazil nuts, nutmeg and ginger.

Life cycle

The larvae tunnel into and hollow-out stored food products. They pupate inside and adults bore circular holes when they emerge.

Figure 55. Lesser grain borer (*Rhyzopertha dominica*). Photo: R. Martin

Lesser grain borer (*Rhyzopertha dominica*)

Description

The lesser grain borer is a serious pest of most stored grains and has developed resistance to some grain insecticides. It is a dark brown cylindrical-shaped beetle (up to 3 mm long) with club-like antennae (Figure 55). Viewed from the side, the beetle's mouth parts and eyes are tucked underneath the thorax. Adult beetles are strong flyers.

Life cycle

The life cycle is completed in four weeks at 35°C and seven weeks at 22°C and breeding stops below 18°C. Females lay 200 to 400 eggs on the grain surface. Young larvae (white with brown heads) initially feed outside then bore into the grain. Adults live for two to three months.

Detection

Their habit is to remain hidden in grain. Regular sampling and sieving is required for detection.

Correct identification of grain storage pests

Weevil damage on the cob can easily be confused with Asian maize borer damage. The damage is similar, however usually later instar maize borers will create more frass which is a fine, powdery material excreted after chewing the maize. On closer inspection, a weevil or borer can generally be found.

Control measures

The best method of control is through plant breeding to develop harder kernels and tighter husks to prevent the entry of weevils.

It is important that growers clean out their grain storage containers before newly-harvested grain is placed there. Sealed containers help to keep grain pests out but if pests are already in the grain from the field, they are difficult to control.

Grading samples will help to remove chipped, small or damaged grain but will not totally remove weevils.

Harvest fields as soon as grain is ready. Delays to harvest can increase infestation by weevils.

References

Anon. 2013. Cambodia Climate Change Strategic Plan: 2014 – 2023. National Climate Change Committee, Royal Government of Cambodia.

CIMMYT. 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. International Maize and Wheat Improvement Centre: Mexico.

Kaiser A.G. Piltz J.W. Burns H.M. and Griffiths N.W. 2003. Top Fodder Successful Silage Manual. Dairy Australia and New South Wales Department of Primary Industries.

Kim S.K. Yoon N.M. Kim H.J. Kim Y.B. Chhay N. Kim S.M. Oeun K.S. Bora P. Glaudino N. Fontes L. Tam T.T. and Cho M.C. 2006. Severe Epidemics of Downy Mildew (Peronosclerospora sorghi) on Maize in Cambodia, East Timor and Vietnam. Kyungpook National University and the International Corn Foundation: Daegu, South Korea.

Martin R. and Pol C. 2009. Weeds of upland crops in Cambodia. ACIAR Monograph No. 141. Australian Centre for International Agricultural Research: Canberra.

Nesbitt H.J. 1997. Rice production in Cambodia. International Rice Research Institute: The Philippines.

Pin T. Martin B. Ung S. Elias N. and McKorkell B. 2009. Rhizobial inoculation versus nitrogen fertilizer for mungbean, peanut and soybean in rainfed upland areas of Cambodia. Cambodian Journal of Agriculture 9: 54-61.

Pol C. Belfield S. and Martin R. 2010. Insects of upland crops in Cambodia. ACIAR Monograph No. 143. Australian Centre for International Agricultural Research: Canberra.

Touch V. Martin R.J. and Scott J.F. 2013. Economics of Weed Management in Maize in Pailin Province Cambodia. International Journal of Environmental and Rural Development 4: 215-219.

White P.F Oberthür T. and Sovuthy P. 1997. The soils used for rice production in Cambodia: A manual for their identification and management. International Rice Research Institute: The Philippines.

Appendix 1. Herbicide options for weed control in maize

			Pre-sowing			Post-Sowing Pre-emergence			Post emergence			
Khmer name	Scientific name	Type	Atra-zine	Glypho-sate	2,4-D	Atra-zine	Pendim-ethalin	S-meto-lachlor	Atra-zine	2,4-D	Flur-oxypyr	Nicos-ulfuron
Kravanh Chruk	*Cyperus rotundus**	Sedge		✓	✓					✓		✓
Smao Ko	*Brachiaria reptans*	Grass		✓				✓				
Smao Chenh Chean	*Cynodon dactylon**	Grass		✓								✓
Smao Cheung Kras	*Dactyloctenium aegyptium*	Grass		✓								✓
Smao Sambok Mon	*Digitaria spp.*	Grass	✓	✓		✓	✓	✓	✓			✓
Smao Bek Kbal	*Echinochloa colona*	Grass	✓	✓		✓	✓	✓	✓			✓
Smao Samsorng	*Eleusine indica*	Grass	✓	✓		✓		✓	✓			
Sbauv Klang	*Imperata cylindrica**	Grass		✓								
	Leptochloa chinensis	Grass		✓								✓
	*Melinis repens**	Grass		✓								✓
Boart Salay	*Sorghum hybrid*	Grass	✓	✓		✓			✓			✓
Treng	*Sorghum propinquum**	Grass	✓	✓		✓			✓			✓
Kantraing Kath	*Ageratum conzoides*	Broadleaf	✓	✓	✓			✓	✓	✓	✓	
Phti Banla	*Amaranthus spinosus*	Broadleaf	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Phti Daung	*Amaranthus viridus*	Broadleaf	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Bidens pilosa	Broadleaf		✓	✓					✓	✓	
Phti Thmar	*Boerhavia erecta**	Broadleaf			✓					✓		
Maam Phnom	*Borreria alata*	Broadleaf	✓					✓	✓			
Kos Ambeng	*Cardiospermum halicacabum*	Broadleaf										

Khmer name	Scientific name	Type	Pre-sowing			Post-Sowing Pre-emergence			Post emergence			
			Atra-zine	Glypho-sate	2,4-D	Atra-zine	Pendim-ethalin	S-meto-lachlor	Atra-zine	2,4-D	Flur-oxypyr	Nicos-ulfuron
Slab Tea	*Comellina benghalensis**	Broadleaf		?	✓			✓		✓	✓	✓
	Crassocephalum crepidioides	Broadleaf	✓	✓	✓				✓	✓		
Changkrang Svar	*Crotalaria pallida*	Broadleaf	✓	✓					✓			
Mok Chhneang	*Eclipta prostrata*	Broadleaf										
Tuk Das Khla Thom	*Euphorbia heterophylla*	Broadleaf										
Sandar Chhou	*Ipomoea triloba*	Broadleaf	✓		✓	✓			✓	✓	✓	
Voir Mouy Lib	*Ipomoea obscura*	Broadleaf	✓		✓	✓			✓	✓	✓	
Phreah Khlob Damrei	*Mimosa invisa**	Broadleaf	✓						✓		✓	
Phreah Khlob	*Mimosa pudica**	Broadleaf									✓	
Sav Mao Prey	*Passiflora foeteda**	Broadleaf	✓	✓					✓		✓	
Pang Pos Srom	*Physalis angulata*	Broadleaf	✓	✓					✓		✓	
Kambet Chun	*Portulaca oleracea*	Broadleaf	✓	✓	✓		✓	(S)**	✓	✓	✓	✓
	Richardia brasiliensis	Broadleaf										
Kantraing Bay Sar Nhi	*Sida acuta*	Broadleaf	✓	✓					✓		✓	✓
Kantraing Bay Sar	*Sida rhombifolia*	Broadleaf	✓	✓					✓		✓	✓
	Solanum nigrum	Broadleaf	✓		✓	✓			✓	✓	✓	
Smao Krab SaHeth	*Stachytarpheta indica*	Broadleaf			✓					✓	✓	
Chung Kong Proes	*Trianthema portulacastrum*	Broadleaf	✓	✓	✓			✓	✓	✓	✓	
	Tribulus terrestris	Broadleaf		✓	✓		✓	✓		✓	✓	✓
	*Tridax procumbens**	Broadleaf			✓					✓		

* Perennial or reproduces vegetatively. ** S = suppression.

ACIAR

Research that works for developing countries and Australia

aciar.gov.au

Australian Aid

ACIAR MONOGRAPH NO: 167