Training manual for climate resilient maize production in Cambodia

For Project TA 6914-CAM: Climate-Resilient Farming and Supply Chain Development to Support Covid-19 Recovery for Smallholder Poultry and Maize Farmers.

Disclaimer

Foreword

Cambodia is on track to achieve middle-income status by 2030. As GDP rises, the country's protein consumption is expected to increase in line with global trends. Demand for chicken, pork, and beef is projected to grow significantly, and aquaculture production will also expand as natural fish stocks decline due to overfishing and climate change. This will lead to a rising demand for stock feed, and local feed producers will increasingly require maize, cassava, and soy. Local feed millers have an annual demand of around 500,000 metric tonnes, growing at an estimated 10% rate.

Maize production in Cambodia has seen a substantial rise, doubling in area over the past 20 years, making it the third most important annual crop after rice and cassava. Most maize is produced in the uplands of Battambang province, across two distinct seasons, and sold to local feed companies as well as to Thailand. However, climate change poses a serious threat to these growing areas. Feed companies like DeHeus face competition from Thai buyers for local maize supplies and is therefore exploring the potential of developing maize production areas in the Mekong floodplains as an additional sourcing region. Additionally, making maize farmers more competitive means they could potentially fill a part of the maize supply which is currently imported from mainly South America.

Farmers in the Mekong floodplains are also grappling with significant climate change challenges. Currently, maize yield is average around 5 metric tonnes per hectare, which is well below the regional potential of 12 metric tonnes. By adopting improved climate-resilient practices, farmers can enhance productivity, reduce costs, increase supply volume for local feed companies, and boost their incomes.

Key practices that farmers should adopt include:

- Reducing seeding rates with better hybrid seeds, which could save farmers approximately $100 per hectare.

- Apply early weeding, as weeds compete for water, which is becoming a growing constraint due to climate change. Improper weeding practices can reduce yields by up to 1 tonne per hectare.

- Applying the right fertilizer at the right time, along with soil conservation. Healthy, well-nourished plants are more resilient to climate shocks. Farmers should top-dress at the appropriate time, avoiding unnecessary fertilizer application after kernel development, which also saves money. Increasing the use of organic materials will help restore soil health.

- Integrated Pest Management (IPM), as climate change is likely to increase the risk of pests and diseases. Using natural pest control methods and accurately identifying pests can protect crops and save money by reducing unnecessary chemical use.

- Appling appropriate irrigation techniques. In the dry growing season farmers need to invest in additional irrigation provision as drought and hot temperatures will limit crop growth.

To support farmers' climate resilience, SNV and the Farmer Nature Network (FNN) are training 2,000 women and men maize producers on improving production and adapting to a warming climate. The project is funded by the Asian Development Bank, in coordination with DeHeus-TMH Feeds.

This manual provides practical guidance to help farmers adopt climate-resilient practices, improve productivity, and become competitive. By doing so, Cambodia can enhance its local feed supply and meet the growing demand for protein in the country

SNV – Phnom Penh – October 2024

Table of Contents

List of Abbreviations

AC	Agricultural Cooperative
ASR	Agricultural Systems Research (Cambodia) Co. Ltd.
Bt	Bacillus thuringiensis
CA	Conservation Agriculture
DAP	Diammonium Phosphate
DAS	Days after sowing
FAO	Food and Agriculture Organisation of the United Nations
FAW	Fall Armyworm (*Spodoptera frugiperda*)
Ha	Hectares
kg	Kilogram
LCC	Leaf Colour Chart
MAFF	Ministry of Agriculture, Forestry and Fisheries
MoA	Mode of Action
NGO	Non-Governmental Organisation
PDAFF	Provincial Department of Agriculture, Forestry and Fisheries
QR	Quick Response Code
SNV	Netherlands Development Organisation
t	Tonne(s)
t/ha	Tonnes Per Hectare
TE	Trace Elements

Figure 1. Maize in Tbong Khmum province in January 2024

Introduction: Maize production in Cambodia

Red maize (also known as yellow maize) is the main maize cash crop currently grown in Cambodia. It is grown for the stockfeed market; whereas white or waxy maize and sweet corn are grown locally for human consumption. Waxy maize has been grown in Cambodia since the 17th century.

Between 2001 and 2009, the production of maize for livestock feed rapidly increased, making it the second most important crop, both in cultivated area and production, after rice [1]. Between 2016 and 2020, a total of 960,060 tonnes (t) of maize was produced in Cambodia, making it the third most important crop after rice and cassava.

After the end of the Khmer Rouge civil war in 1998, a surge in the clearing of forests allowed for an increase in the land dedicated to maize production, especially in North-west Cambodia. Between 2001 and 2005, the average yield increased from less than 2 t/ha to more than 3 t/ha. More recently, between 2016 and 2020, the average yield of maize increased to 5.17 t/ha. However, it is not clear whether this increase is related to improved practices or expansion into new more fertile land. Land used for maize production more than doubled from 74,109 ha in 2001 to 169,138 ha in 2010. Between 2016 and 2020, the area increased again to 183,710 ha.

According to the Ministry of Agriculture, Forestry and Fisheries [2], in 2019 and 2020, 890,351 tonnes of red maize grain was produced in Cambodia, with an average yield of 4.8 t/ha. More than half (57%) of maize produced came from Battambang Province [2] (Figure 2). Kandal (8%), Banteay Meanchey (7%), Tbong Khmum (6%) and Prey Veng (5%) were the next most productive Provinces.

The last provinces part of the Mekong alluvial flood plain areas are the target areas of the ADB-DeHeus support to smallholder farmers as it offers potentially an alternative sourcing area.

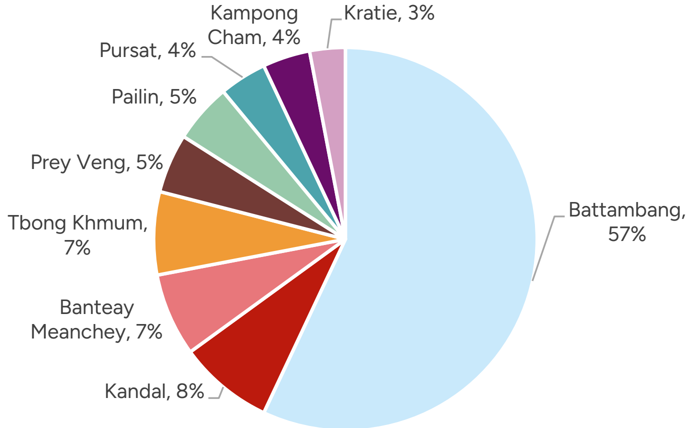


Figure 2. Production of maize by Province in 2019-2020 (%)

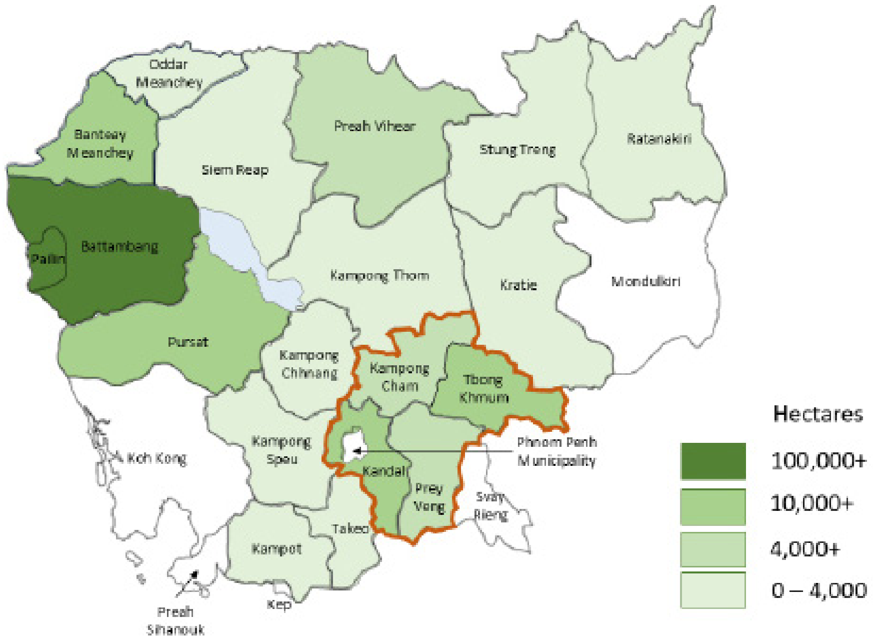


Figure 3. Cambodian maize production (tonnes), by region (ADB – DH SNV target Provinces in the red margin)

Combined, these provinces produce 23% of the national maize crop, with an above-average yield of 5.12 t/ha.

Maize is grown on seasonally flooded terraces along the Mekong River. In Kroach Chhmar District, Tbong Khmum Province, flooding occurs in July and August, whereas in the other maize growing areas, the floods are mainly in September and October (Figure 4).

Worldwide, maize grain yields of 15 t/ha or more can be achieved with good agronomy i.e. with good moisture and soil fertility conditions. Maize hybrid companies claim yield potentials of up to 12 t/ha for hybrids sold in Cambodia. Yields of 10 t/ha or more are achieved on Mekong alluvial soils and are therefore close to potential. The average yield for maize in Cambodia for the 20 years up to 2020 was 3.96 t/ha but in the period 2016-2020 the yield had increased to 5.17 t/ha; therefore, it is possible that further increases in maize yield can be achieved with adoption of improved practices.

Two maize crops can be grown per year in the alluvial areas along the Mekong River in the Provinces of Kampong Cham, Kandal, Prey Veng and Tbong Khmum. From the feed mill point of view, it makes sense to source grain from both regions to even out supply peaks and storage needs.

Training of trainers for maize production

The training modules which follow are focused on teaching maize farmers best practices in climate-smart farming methods, supply chain understanding and market linkages.

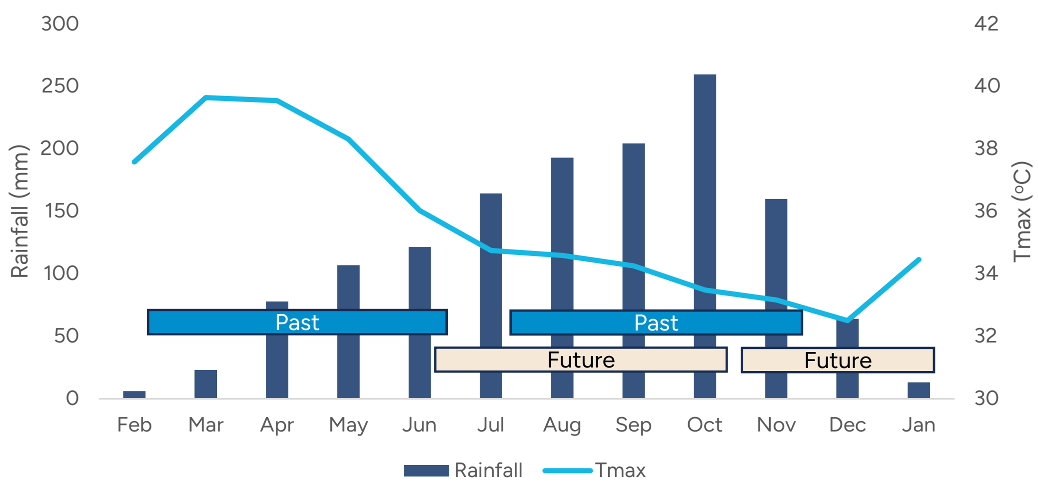


Figure 4. Maize planting windows in the Mekong River alluvial systems

Training of trainers for maize production

The training is focused on teaching maize farmers climate-smart farming methods, supply chain understanding and market linkages including:

1. Best practices in maize farming.

2. Maize and climate change adaptation strategies, including planting and harvest timing adjustments for climate and pest conditions, integrated pest management and monitoring, soil and nutrient management and water and irrigation strategies.

3. Market linkages and understanding of the maize supply chain in Cambodia

4. Financial farm calculations (cost/benefit) of maize production for smallholder famers.

Training Module 1: Climate change adaptation strategies

Purpose

In Cambodia, climate change is characterized by a delay to the commencement and end of the wet season, without a significant change in total rainfall. In addition, the hottest months (March, April, May) are getting hotter compared with the cooler months. Maize farmers need to consider climate change adaptation strategies, including practices to improve water-use efficiency and changes to planting dates. The purpose of this activity is to test farmers' perceptions of changes in climate, impact on their maize production system and to consider their response to adaptation options at their disposal.

Activity 1.1

Method

Participants are asked to rank the amount of rainfall per month with 0 = no rain, 1 = small amount of rain, 2 = medium amount and 3 = large amount of rain [3]. These scores are summed and adjusted according to the average annual rainfall, for example 1,379 mm for Battambang. In Battambang province, farmers are over-estimating rainfall for the months of January, February and March by 98 mm and under-estimating rainfall for October, November and December by 146 mm (Figure 5).

The total annual rainfall has not changed since 1982. However, there has been a delay to the beginning of the wet season and a delay to the end of the wet season during the past 20 years (Figure 6). It is possible that farmer estimates of rainfall distribution are based on memory of a past climate.

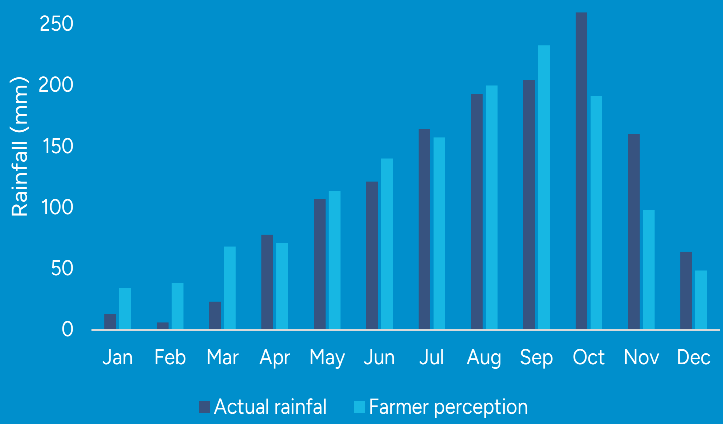


Figure 5. Farmer estimates of monthly rainfall distribution compared to the official average recorded for Battambang.

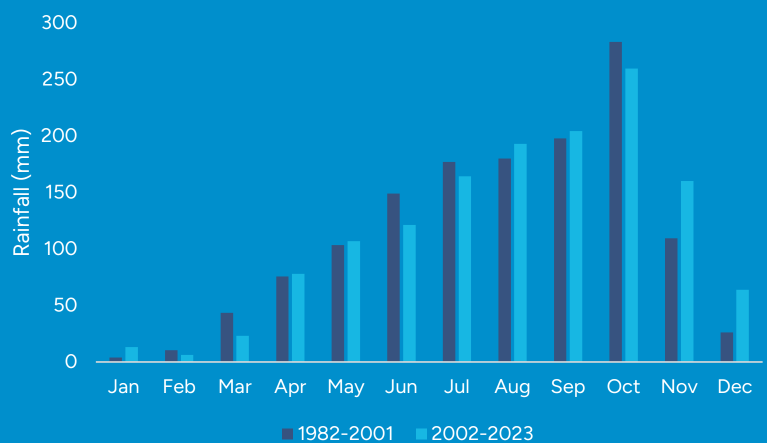


Figure 6. Change in the distribution in monthly rainfall at Battambang over time

Farmers are asked to indicate which months they perceive to be getting hotter and, according to farmers in Battambang Province, the most affected months are likely to be March, April and May (Figure 7). When these perceived rising temperatures are plotted together with the change in rainfall distribution, it is clear that the period from January to April is becoming increasingly hostile to crop production (Figure 7).

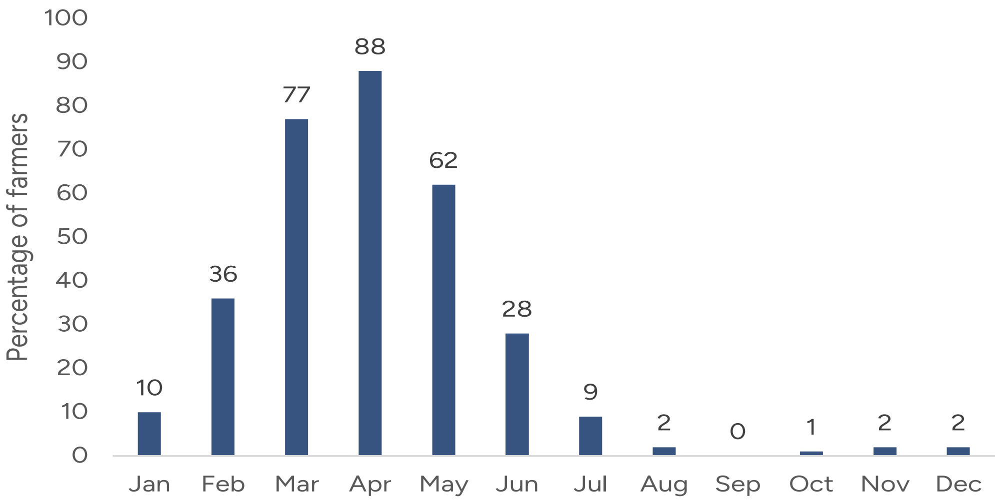


Figure 7. Farmer estimates of which months are getting hottest due to climate change

Activity 1.2

Maize farmers can be asked how would they rank the following opportunities for increased crop production: Do they agree or disagree with the following statements?

Statement	Ranking				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
My maize production system is becoming risky because of climate change.	❐	❐	❐	❐	❐
My planting date for the wet season crop is delayed because of high temperature and lack of rain.	❐	❐	❐	❐	❐
Planting date for the dry season crop is affected by increasing unpredictability of flooding.	❐	❐	❐	❐	❐
Crop yield can be increased by reduced tillage, increased retention of crop residues and crop rotation.	❐	❐	❐	❐	❐
I would like to change the crops I grow but there is no market for alternative crops in my area.	❐	❐	❐	❐	❐

Training Module 2: Plant population density

Purpose

Maize farmers in Cambodia tend to plant too much seed, which often results in plant populations being too high to obtain maximum yield potential. The purpose of this training activity is to make farmers more aware of the importance of aiming for an optimum plant population. An important first step is to empower farmers with the capability to test the viability of their own seed kept or purchased for sowing.

Optimum plant population per hectare for maize

Under ideal conditions, maize plant populations should be 50,000 to 60,000 plants per hectare, depending on the environmental conditions and hybrid yield potential. As with all crop species, excessive plant populations can result in a higher risk of serious reduction in yield and even crop failure under drought conditions. Consequently, lower plant populations of 37,000 to 40,000 plants per hectare should be used if periods of drought are expected (Figure 8). For maize in Cambodia, farmer practice is to plant too much seed.

The farmer should consider two pieces of information to calculate the optimum seeding rate: (1) germination percentage (%) of the seed; and (2) the number of seeds per kg.

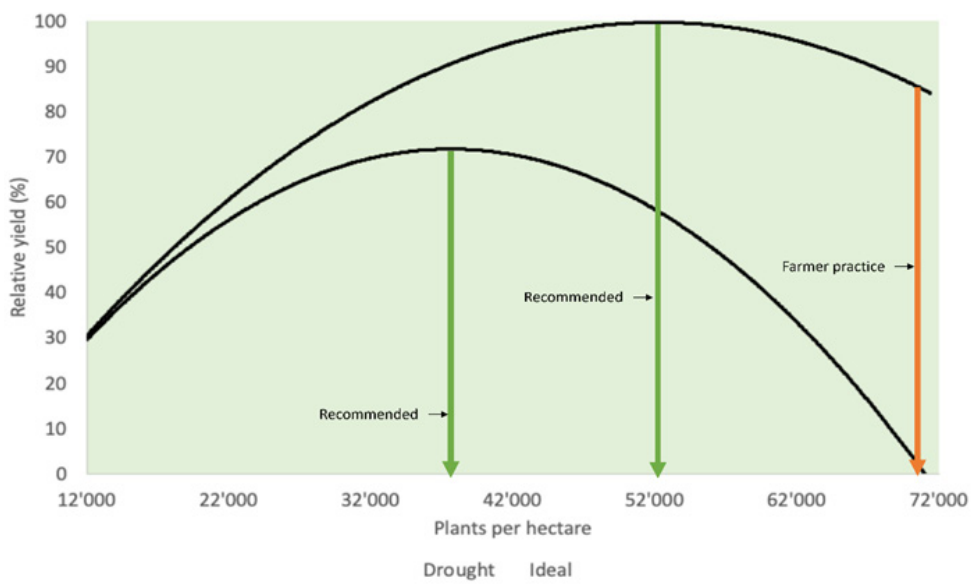


Figure 8. Effect of plant population on the yield potential of maize under drought and ideal growing conditions

Activity 2.1: Testing seed for percent germination

The materials you need to do a simple seed germination test at home are polystyrene food trays, paper towels, seed for testing, clean water, permanent marker and rubber bands (Figure 9).

Figure 9. Materials required for the germination test

Method:

1. Fold two paper towels to fit the food tray.

2. Add clean water until the paper is completely wet and pour out excess water.

3. Count out 100 seeds and spread them evenly in the tray.

4. Repeat steps 1 to 3 with two more trays to make up three tests per bag of seed.

5. Use the permanent marker to write your test number, date and time the test commenced, the hybrid name and the seed lot number from the bag on each tray lid.

6. Use an elastic band to keep the tray closed and store the germination trays in a cool dry place.

7. After 24 hours (1 day), check the water content of the paper and add more water if required.

8. After 48 hours (2 days), count and remove the germinated seeds (with radicles > 3 mm) and write the number of germinated seeds on the tray with the permanent marker. Add more water if needed.

9. After 72 hours (3 days), count and remove the germinated seeds and write the number of germinated seeds on the tray lid with the permanent marker.

10. Add the number of seeds germinated at 48 hours and 72 hours and divide by 100 to get the final germination percentage.

11. Keep the hybrid seed bag with seed batch details in case a complaint should be made to the dealer or seed company in the event of a poor germination result.

Figure 10. Germination test at 48 hours

The first count of germinated seed is at 48 hours (Figure 10). The chart (Figure 11) shows the germination test result for different seed samples.

A rate of germination > 90% after 72 hours is acceptable. Germination rate between 70% and 90% is considered marginally acceptable. Germination rate below 70% should be considered as unacceptable. Seed in this category should be returned to the dealer for a refund.

Seed germination testing is something farmers can, and should do, before buying seed to reduce the risk of poor crop establishment and loss of income.

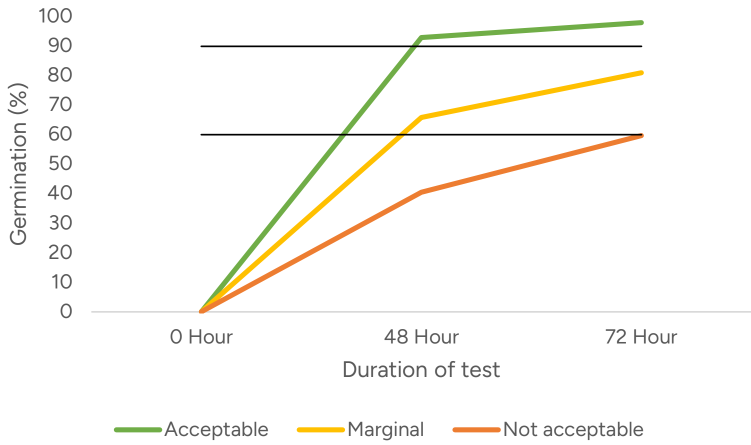


Figure 11. Germination test result for three different seed samples

In May 2024, germination tests were carried out on 11 samples of seed being sown by farmers in Koas Krala and Samlout districts, Battambang Province. Five samples averaged 80% germination, and five samples averaged 60% germination after 72 hours of incubation and only one sample had a germination of more than 90% (Figure 11).

The expected seed germination (%) should be marked on the hybrid seed bag and is usually between 90% and 100% (Figure 12).

The cost of low germination (%) of seed

The cost of maize hybrid seed is around US$5/kg. At 90% to 95% germination, 18 kg/ha would be required to deliver a plant population of around 60,000 plants/ha at a cost of US$90/ha (Table 1). If the farmer wishes to maintain plant population as seed germination % declines, the cost of seed increases by US$5 for every extra kg of seed sown. For seed of 60% to 65% germination, the cost of seed rises to US$140 kg/ha, or US$50/ha more, than for seed at 95% germination. In addition, the rate of germination becomes slower as germination % declines (Figure 11). This results in established seedlings being less vigorous and less able to survive stresses such as drought, disease or insect attack.

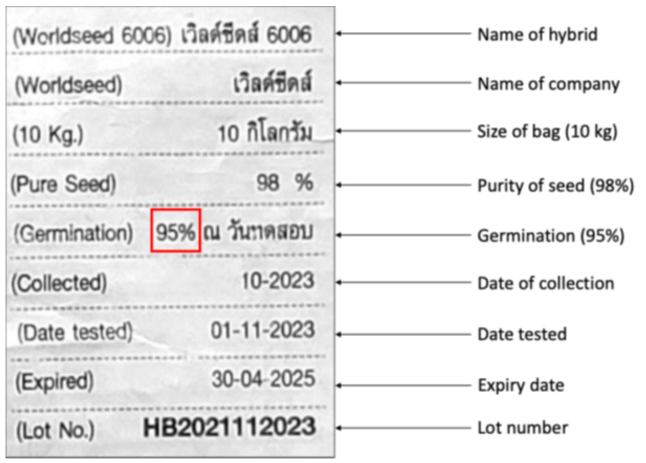


Figure 12. Description of the seed lot which can be found on the back of the bag

Table 1. The effect of germination (%) on target plant population and required seeding rate, assuming 4,000 seeds/kg.

Germination (%)	Planting rate (kg/ha)					
	18	20	22	24	26	28
60	38,880	43,200	47,520	51,840	56,160	60,480
65	42,120	46,800	51,480	56,160	60,840	65,520
70	45,360	50,400	55,440	60,480	65,520	70,560
75	48,600	54,000	59,400	64,800	70,200	75,600
80	51,840	57,600	63,360	69,120	74,880	80,640
85	55,080	61,200	67,320	73,440	79,560	85,680
90	58,320	64,800	71,280	77,760	84,240	90,720
95	61,560	68,400	75,240	82,080	88,920	95,760

Activity 2.2: Calculating the number of seeds per kg

Maize hybrids vary widely for the number of seeds per kg and seeds per kg must be taken into account for the calculation of the optimum seeding rate (kg/ha). Using the three 100 seed samples for the germination test:

1. Weigh the samples of 100 seeds.
2. Calculate the weight of an individual seed. For example, if the average weight is 25g per 100 seeds, the weight of individual seeds = 25 / 100 = 0.25 g.
3. Calculate the number of seeds per kg. For example, 1,000 / 0.25 = 4,000 seeds.
4. Use the look-up table (Table 2) to calculate the planting seed rate In this example, the planting seed rate is 18 kg/ha.

Table 2. Look-up table for choosing seeding rate according to number of seeds/kg. The green boxes represent the recommended seeding rate according to the number of seeds per kg.

Seeds/kg	Planting rate (kg/ha)				
	16	18	20	22	24
2,500	34,200	38,475	42,750	47,025	51,300
3,000	41,400	46,170	51,300	56,430	61,560
3,500	47,880	53,865	59,850	65,835	71,820
4,000	54,720	61,560	68,400	75,240	82,080
4,500	61,560	69,255	76,950	84,645	92,340

Activity 2.3: Estimating the actual plant population in the field

The farmers are asked to nominate one of their maize fields for collection of samples and taking measurements. In the case of established plant population, measurements should be at five locations in the field. Crop measure-ments are taken from 5m of row at each of the five locations in the field.

Measurement	Location in field					Avg.
	1	2	3	4	5	
Spacing between rows (m)						
Number of crop plants per 5m of row						

1. Calculate the average row spacing (m) from the five field locations (e.g. 0.70 m).
2. Calculate the average plant spacing within rows (m) = metres of row/number of plants (e.g. 5 m / 20 plants = 0.25 m between plants).
3. Plant population per hectare = 1 / (row spacing * plant spacing) * 10,000. For example, 1 / (0.70 * 0.25) * 10,000 = 57,143 plants/ha).

]If the plant population in the field is outside the range of 40,000 to 60,000 plants/ha, the following questions can be asked of the farmers:

1. What was the seeding rate for this crop? (kg/ha)	
2. Was size of seed taken into account when choosing seeding rate?	Yes ❒ No ❒
3. Did the farmer do a germination test on the seed?	Yes ❒ No ❒
4. Did the farmer choose a target plant population?	Yes ❒ No ❒
5. If yes, what was the target plant population (plants/ha)?	
6. If the farmer's plant population in the field is excessive (>60,000 plants/ha). Why did this farmer plant too much seed?	

What is the cost of planting too much seed?

The current cost of registered maize hybrid seed is around $5/kg, so at 20 kg/ha, the cost of seed for planting is US$100/ha. Farmers are planting maize hybrids at an average of 20 kg/ha and the seed they are using is 4,500 seeds/kg and this will deliver a plant population of 76,950 plants per hectare. The recommended seeding rate for seed of 4,500 seeds/ kg is 16 kg/ha. Therefore, the farmers are spending US$20/ha too much for seed. In addition, excessive plant population might result in a reduction in yield or crop failure under drought conditions with further losses in income. Please note that drought conditions, defined as periods of 4 to 6 weeks with no rain, do occur during the wet season.

Training Module 3: Nutrient management

Purpose

Maize farmers along the Mekong are not following recommendations for fertiliser application provided by the hybrid seed companies. Farmer practices include application of nutrients at the wrong time. For example, phosphorus (P) and potassium (K) should be applied at sowing and not as side-dressings later during crop growth. Side-dressings of urea (a form of nitrogen, N) are recommended at 20 to 25 days after sowing (DAS) and again at 40 to 45 DAS. However, there is a tendency for farmers to not apply side-dressing at 40 to 45 DAS. The purpose of this training module is to help farmers understand the benefits of following recommended fertiliser application practices.

Activity 3.1

Select a field for data collection

Ask the farmer group if there is a maize crop in the village that is between the growth stages of V5 to V12, or 20 to 40 days after sowing (DAS). If so, the trainers and trainees should visit the field to collect samples for soil texture assessment and to take soil pH and leaf colour chart (LCC) readings. Samples should be taken from five locations in the field. The sampling pattern should take account of differences in slope, soil type, crop growth, etc. across the field.

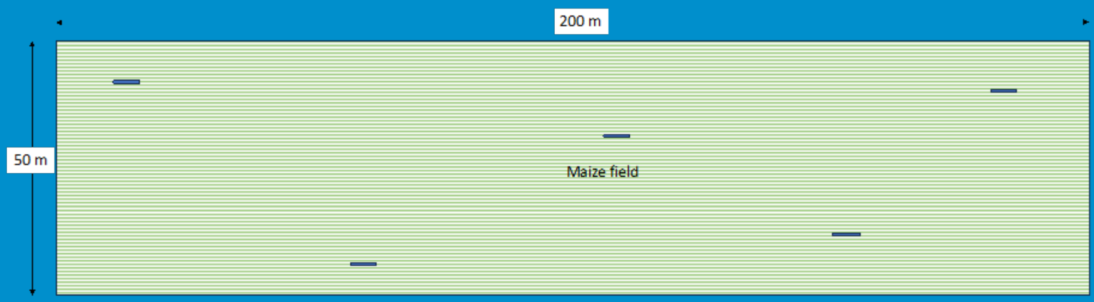


Figure 13. Sampling pattern in the field

Soil pH

The optimum soil pH for maize is between 6.0 and 6.5 [4]. In acidic soils with a pH less than 6.0, the availability of N, P, K, sulphur (S), calcium (Ca), and other nutrients is reduced (Figure 14). On the other hand, in soils of high pH, a reduced availability of P, zinc (Zn), iron (Fe), copper (Cu), boron (B), and manganese (Mn), can occur which results in stunted plant growth. In general, as pH rises, most micronutrients decrease in availability. Alkaline soils typically have higher levels of Ca, magnesium (Mg), and sodium (Na). The majority of high-pH soils contain calcareous materials such as limestone and are often found in black soil in areas.

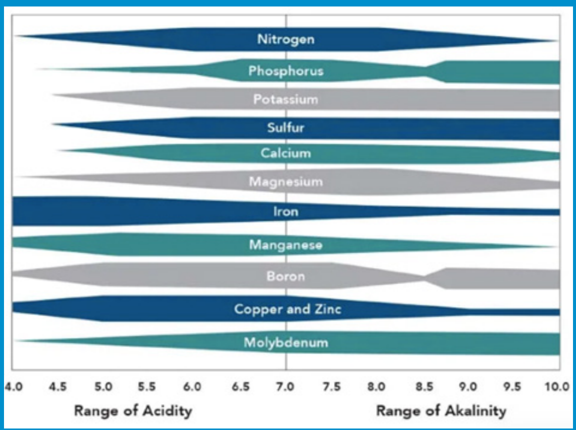


Figure 14. The effect of soil pH on nutrient availability

Take pH probe samples to a depth of 10 cm along 5 m of row at each location in the field.

	Location in field					Avg.
	1	2	3	4	5	
Sample 1						
Sample 2						
Sample 3						
Sample 4						
Sample 5						
Average of soil pH						

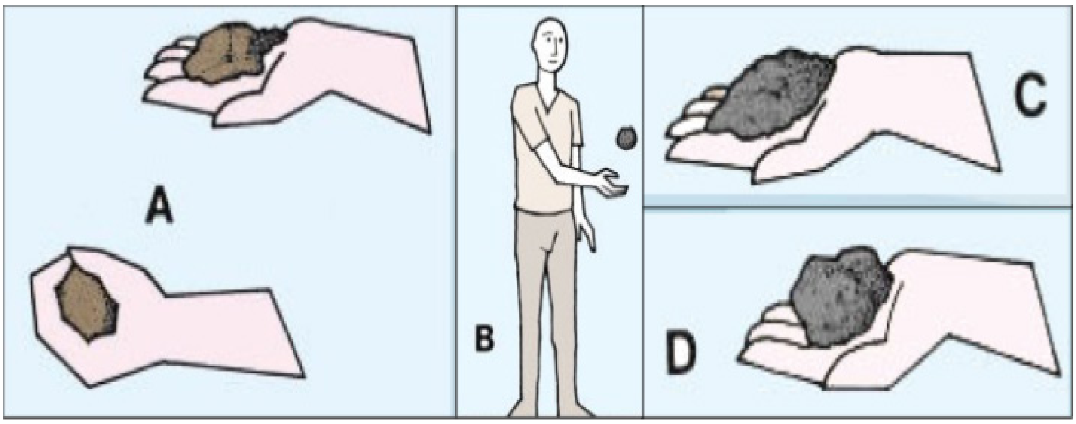
The group should calculate the average pH for the field and discuss the implications:
1. If the soil pH is below 5.0, there is a risk of aluminium (Al) toxicity to maize. Low pH can be corrected by the addition of lime.
2. If soil pH is above 8.0, fertilisers containing trace elements (TE) such as 15:15:15+TE or 20:20:15+TE, should be applied at planting.

Activity 3.2: Soil texture assessment [5]

Texture indicates the relative content of soil particles of various sizes, such as sand, silt and clay. Texture influences the ease with which soil can be worked, the amount of water and air it holds, and the rate at which water can enter and move through soil. The following procedure is used to assess soil texture:

Take handful size samples of topsoil at each of the five locations in the field and place them in labelled plastic bags

A. Take a handful of moist soil and squeeze it into a ball.
B. Throw the ball into the air about 50 cm and then catch it
C. If the ball falls apart, it is poor soil with too much sand.
D. If the ball sticks together, it is probably good soil with enough clay in it.



Write the result as 'C' if mainly clay and 'S' if mainly sand.

	Location in field					Avg.
	1	2	3	4	5	
Sample 1						
Sample 2						
Sample 3						
Sample 4						
Sample 5						

Determining fertiliser needs [6]

High yields of maize require high levels of soil nutrients. The amount of N, P and K required in fertiliser applications depends on previous cropping and fertiliser history and years of cultivation. Removal of nutrients without replacement leads to declining soil fertility. Defining a target yield and its expected nutrient removal is the basis for building a nutrition program for maize.

Timing of fertiliser application is extremely important. Crop accumulation of N, P and K is rapid in the early growth stages. Banding fertiliser at planting improves the access of the crop to nutrients from the very early stages of root development. Referred to as the 'pop-up effect', seedlings are observed to develop faster when sown with banded fertiliser. An added advantage of band-applied fertiliser over broadcast fertiliser is that the nutrients remain in available forms for longer.

At planting, apply mixed fertilisers (N, P and K) in a band 5 cm to the side of the seed and 5 cm below it. This placement prevents the fertiliser burning the seedling, which is a risk if the seed and fertiliser are in direct contact with each other. Maize planters with fertiliser hoppers place the seed in this way.

As the growth of maize begins to accelerate at around 20 DAS, the demand for N increases accordingly and side-dressings of N (e.g. urea) might be needed to enable the crop to achieve its potential under the prevailing environmental conditions. The maize crop takes up N most rapidly between 20 and 65 DAS (Figure 15). Therefore, side-dressings of N are recommended at 20 to 25 DAS and again at 40 to 45 DAS.

Table 3. Amounts of nitrogen, phosphorus and potassium removed by maize (t/ha)

Nutrient	Yield (t/ha)					
	2.5	5.0	7.5	10.0	12.5	15.0
Nitrogen	40	80	120	160	200	240
Phosphorus	9	17	25	32	39	46
Potassium	11	22	32	41	51	60

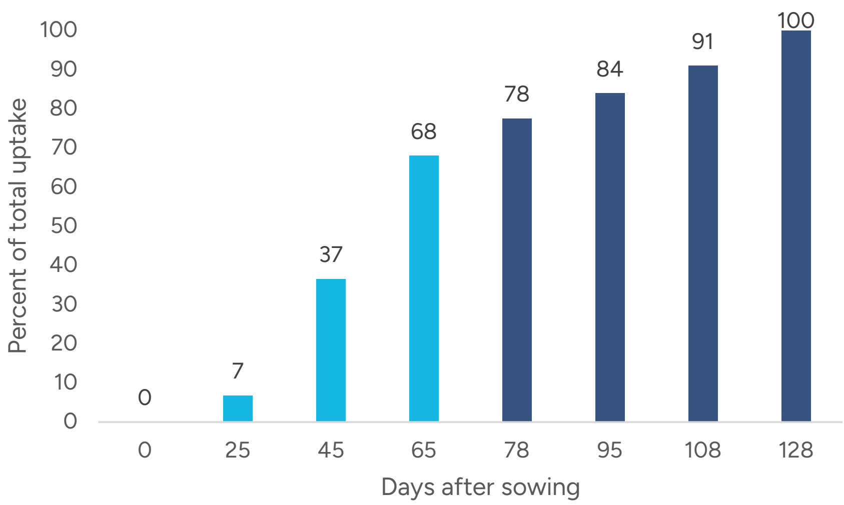


Figure 15. The period of most rapid nitrogen uptake by the crop and N side-dressings should be made between 20 and 45 DAS

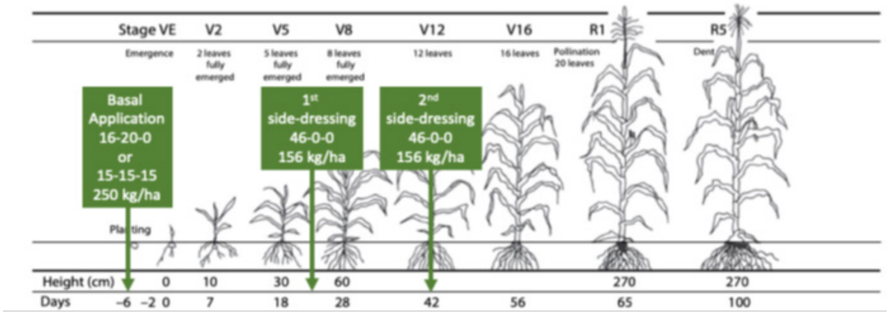


Figure 16. Fertiliser application schedule for maize according to recommendations on hybrid seed bags

Fertiliser recommendations for maize

Fertiliser recommendations for maize are usually found on the bags of hybrid seed (Figure 16). For example:

1. First application at planting: 16:20:0 or 15:15:15 is 30-40 kg/rai (200-250 kg/ha)

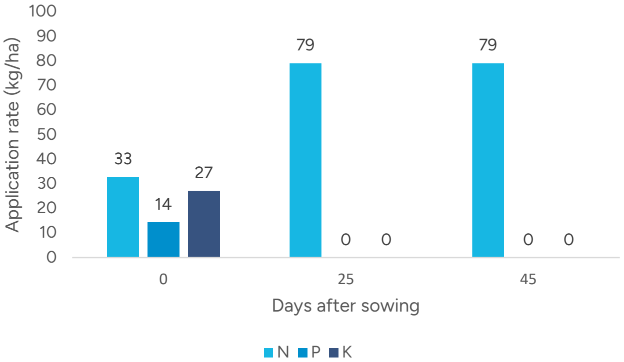
2. Side-dressing with 46:0:0 at 20 to 25 DAS at 25-30 kg/rai (150-200 kg/ha)

3. Side-dressing with 46:0:0 at 40 to 45 DAS at 25-30 kg/rai (150-200 kg/ha).

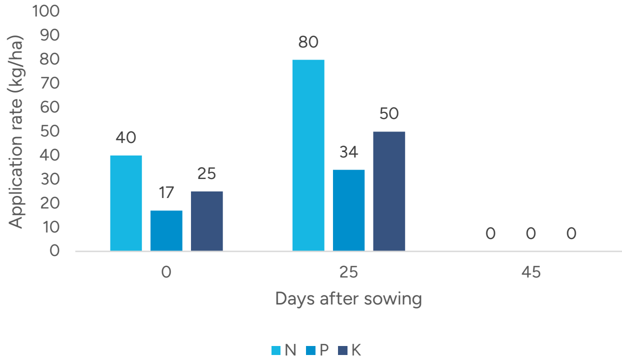
It should be noted that fertiliser bags marked with amounts of N:P:K are actually N:P_2O_5:K_2O. So, to calculate actual N:P:K, multiply P_2O_5 by 0.426 to get P and K_2O by 0.83 to get K. For example: 15:15:15 becomes 15:7:12 of elemental N:P:K.

Actual types, rates and timing of fertiliser application for maize

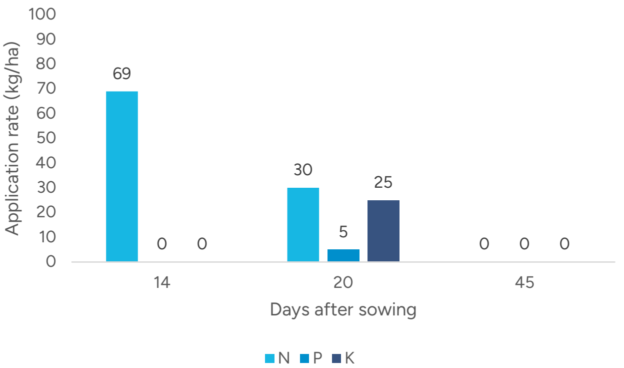
During the scoping mission in December 2023, it was found that the actual types, rates and timing of fertiliser applied to maize varied between provinces and, in all cases, fertiliser practice was not consistent with hybrid seed company recommendations (Figure 17). Actual amounts of fertiliser applied to maize at districts across the target provinces are shown in Figure 17.



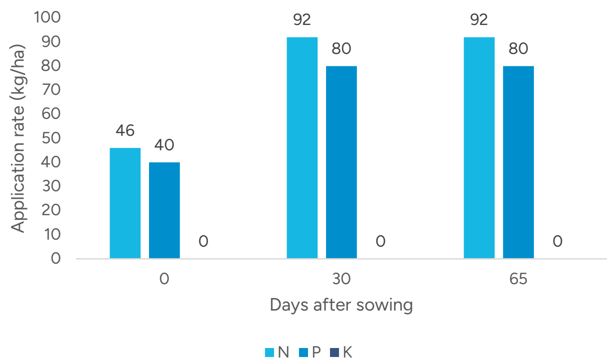
Recommended by hybrid company



Phum Pir village (Tbong Khmum)



Lvea Tey village (Kampong Cham)



Ko Chek village (Prey Veng)

Figure 17. Recommended and actual amounts of fertiliser applied to maize

Farmer practice for fertiliser application in Phum Pir village, Kroach Chhmar district at planting was close to the recommendation. However:
1. P and K were applied unnecessarily at 20-25 DAS.
2. No N was applied at 40-45 DAS.

In Lvea Tey village:
1. At planting, too much N was applied, and no P or K were applied.
2. P and K were applied too late at 20-25 DAS.
3. No N was applied at 40-45 DAS.

In Koh Chek village:
1. At planting, N was adequate but too much P and no K was applied.
2. At 30 DAS, P was applied unnecessarily.
3. 65 DAS is too late to apply N and P was applied unnecessarily.

Therefore, we can conclude that farmers would benefit from training on the type of fertiliser, rate and timing of application for maize production along the Mekong.

Activity 3.3 Why are maize farmers not following fertiliser recommendations?

Ask the group how they decide on their fertiliser schedule for maize? Ask them to raise their hands for each question (they can say yes to more than one question). Write down the number of responses to each question.

Source of advice on fertiliser decisions	Number of respondents
1. Follow the instructions on the bag of hybrid seed	
2. Follow advice from other farmers	
3. Follow the advice from the dealer/input seller	
4. Follow the advice from NGOs or Donors	
5. Follow the advice from the Provincial Department of Agriculture, Forestry and Fisheries (PDAFF) or Commune office	
6. Other ______________________________________	

Acitivity 3.4 Using the leaf colour chart (LCC) to estimate N side-dressing needs

The LCC can be used to determine the N fertiliser needs of maize crops (Figure 18). The LCC has versions with four or six green panels, with colours ranging from yellow green to dark green. The LCC puts a value on the greenness of the leaf, which is an estimate of its N content. The LCC can be used to measure the greenness of leaves between 20 and 40 DAS. Compare the topmost, fully expanded and healthy leaf of each of the 10 plants with the LCC colour panels.

Figure 18. The LCC is used to determine the N fertiliser needs of crops

At each of the five locations in the field:
1. Place the middle of the leaf on top of the LCC colour panels for comparison. Do not detach the leaf.

2. Take readings at the same time of the day (between 8 and 10 am).

3. Do not expose the LCC to direct sunlight during readings, use your body as shade.

Take LCC readings from leaves of 10 plants (1 = colour 2 to 4, 0 = colour 5)	**Location in field**				
	1	2	3	4	5
Plant 1					
Plant 2					
Plant 3					
Plant 4					
Plant 5					
Plant 6					
Plant 7					
Plant 8					
Plant 9					
Plant 10					
Sum of plants with LCC colour 2, 3 or 5					

Estimating the amount of urea to apply as a side-dressing using the LCC:

1. If six or more out of 10 leaves match colour panels 2,3 or 4, apply 50 kg of urea per hectare.

2. If the colour of five or more leaves is equal to or darker than panel 5, no urea should be applied.

3. Repeat the readings every 10 days between 20 and 40 DAS.

4. The use of the LCC should be discontinued after silking in maize and no urea should be applied afterwards.

Since maize farmers tend to apply no side-dressing at 40-45 DAS, the best use of the LCC would be to do the test at about 40 DAS to see if there is a benefit of a second side-dressing of urea.

Training Module 4: Weed management

Purpose

In general, farmers underestimate the potential for weeds to reduce crop yields but weeds often have a greater economic impact compared with insect pests, fungi and other crop pests. The purpose of this activity is to make farmers more aware of the economic losses caused by weeds, the importance of timely control and the available options for control.

Yield loss caused by weeds

Typically, weeds can reduce maize yield by 25% and in severe infestations, up to 65%. Assuming a weed-free yield potential of 8 t/ha, these losses range from 2 to 5 t/ha. At a maize grain price of US$250/t, the cost of failure to control weeds could range from US$500 to more than US$1,000/ha.

Timing of removal of weeds

In maize, it is important to control weeds between the V3 and V10 growth stages, or between 14 and 35 DAS to provide acceptable grain yield (Figure 21). Note that tassel and ear initiation occur at the V5 growth stage of maize. The maize canopy closes over at about 42 DAS and weeds emerging after 35 DAS have little effect on yield.

Figure 19. Weeds compete with maize for water and nutrients. This crop is at least at the V6 growth and these weeds have already had an economic impact on the crop

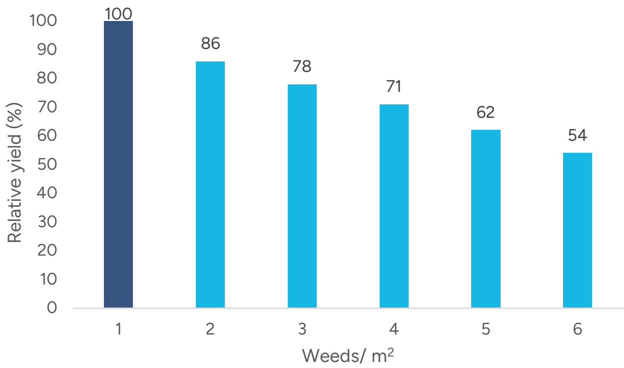


Figure 20. Effect of weed density on relative yield of maize

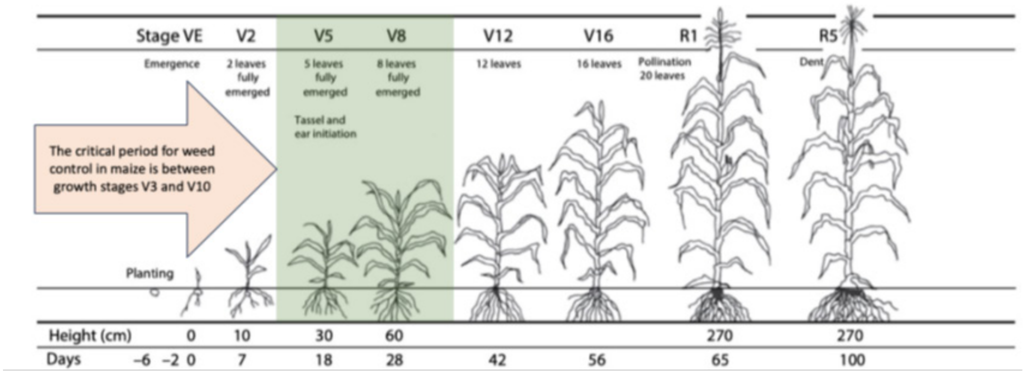


Figure 21. The critical period for weed control in maize

Another point to consider is that the critical time for weed control corresponds with the most rapid rate of uptake of nutrients such as nitrogen by the maize crop (Figure 22).

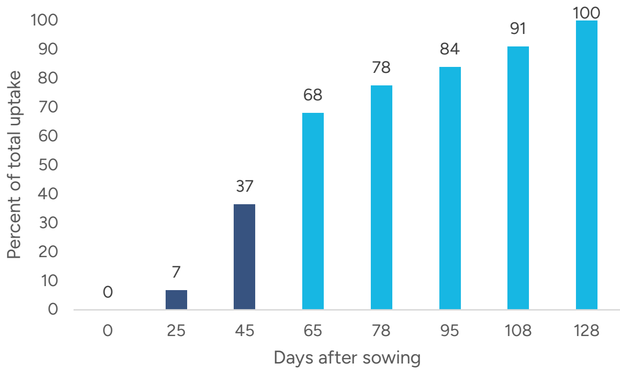


Figure 22. Rate of uptake of nitrogen (N) by a maize crop

Estimating weed cover

Canopy cover is a useful way of monitoring crop productivity, and it can also be used to measure weed canopy cover. The Canopeo app [7] is a more accurate method of estimating weed canopy cover compared to visual estimation (Figure 23).

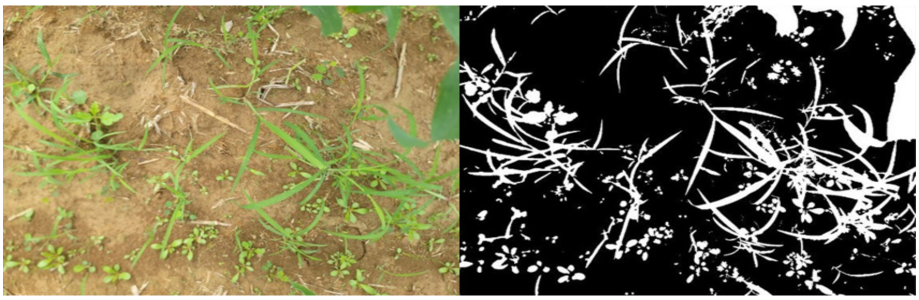


Figure 23. Using Canopeo to estimate weed canopy cover: 8.85% in this example

Canopeo directions for use

Directions for use:
1. Download the Canopeo application to your phone and sign up for an account.
2. Open Canopeo and hold the phone at the mid-point between maize rows at a height of around 60 cm. Make sure there are no maize leaves in the view.
3. Capture a perpendicular image of the ground using Canopeo.
4. Record the % ground cover readings for five images at each of the five locations in the field.

Take Canopeo images from five locations in the 5 m sampling area	Location in field					Avg.
	1	2	3	4	5	
Image 1						
Image 2						
Image 3						
Image 4						
Image 5						

By the time the crop reaches the V5 stage, weeds are at their most competitive for removing water and nutrients from the soil. Even a weed canopy cover of only 10% can reduce maize yield potential by around 10%. It is up to the farmer to decide how much weed canopy cover can be tolerated, bearing in mind that weeds should be controlled before the V5 growth stage if yield losses are to be avoided.

Types of weeds present in the crop

Seedlings of grasses and broadleaves can be distinguished at emergence (Figure 24).

Figure 24. Grass (left) and broadleaf (right) weed seedlings at 14 DAS

The number of grass and broadleaved weed seedlings can be counted from the images stored by Canopeo on the phone. The images should capture around 60 x 80 cm of the soil surface, so you can multiply this by two to get numbers/m2.

Number of weed seedlings per m2	Location in field					Avg.
	1	2	3	4	5	
Grasses						
Broadleaves						

Farmers can be asked if the weed densities in this field are acceptable or not:

Not acceptable	Undecided	Acceptable
❐	❐	❐

If farmers are prepared to delay control of weeds beyond maize V5 growth stage or 30 DAS what is their reasoning behind such a decision?

Herbicide options for maize

Plants can be classified as monocots and dicots. Grasses are monocots and most broadleaved weeds are dicots. Monocots have one cotyledon, or embryonic leaf in the seed, whereas dicots have two embryonic leaves in the seed. This makes it easy to recognise monocots and dicots at the seedling stage (Figure 25). Maize is a monocot and is therefore more closely related to grass weeds than to dicots and this means that grass weeds compete more strongly with maize for water and nutrients.

Four selective herbicides are most commonly used in maize in Cambodia: 2,4-D, Atrazine, Mesotrione and Nicosulfuron. Selective herbicides, such as these, control specific weed species whilst leaving the crop relatively unharmed. Non-selective herbicides, such as glyphosate, kill plants indiscriminately. However, maize hybrids with genetically engineered tolerance to glyphosate are approved for use in Vietnam [8] and, although not registered in Cambodia, are used, especially in provinces adjacent to Vietnam.

Herbicide products are available with one or more active ingredient. For example, products are available that contain Atrazine + Mesotrione, Atrazine + Nicosulfuron or Atrazine + Mesotrione + Nicosulfuron. The choice of herbicide should be based on whether grasses, broadleaves, or both are the main problem. For example, if both grasses and broadleaves are present, then atrazine, or Mesotrione + Nicosulfuron should be used (Table 4).

Table 4. Herbicide options for maize in Cambodia

Active ingredient	MoA group	Pre-planting	Post planting pre-emergence	Post-emergence
2,4-D	4	√		√
Atrazine	5	√	√	√
Mesotrione	27		√	√
Nicosulfuron	2			√

The mode of action (MoA) describes how the herbicide kills the weed, or which physiological process is disrupted within the plant. MoA provides another way of classifying herbicides. Repeated use of herbicides belonging to the same MoA group can lead to weeds becoming resistant to that MoA group and as such, are no longer able to be controlled by herbicides in the relevant MoA group.

In Cambodia, farmers recognise herbicides by distinguishing features on the label and are generally not aware of the active ingredient(s). Furthermore, the MoA classification is not marked on the label. Another problem is that labels often display incorrect or misleading information such as photos of weeds not controlled by the product. For example, a product containing Mesotrione might feature photos of grasses on the label whereas Mesotrione only controls broadleaves.

Difficulty of weed management in maize crops

Ask the farmers, as a group, how they would rank weeds as a problem compared with other problems with maize production. For example, compared with insect pests, diseases etc.

Least difficult	Slightly difficult	Average	Difficult	Most difficult
❒	❒	❒	❒	❒

Identification of weeds by farmers

The farmers are shown photos of weeds likely to be found in their maize crop (Table 5). Then they are asked the following questions:
1. Do they recognise the weed (Yes/No).
2. Is it a common weed in their maize crops (Yes/No).
3. Is it difficult to control (Yes/No).

Table 5. Identification of weeds found in maize crops

No.	Scientific name	Know it (Y/N)	Common (Y/N)	Difficult (Y/N)	No.	Scientific name	Know it (Y/N)	Common (Y/N)	Difficult (Y/N)
1	*Trianthema portulacastrum*				33	*Crotalaria pallida*			
2	*Amaranthus spinosus*				34	*Dunbaria rotundifolia*			
3	*Amaranthus viridis*				35	*Mimosa diplotricha*			
4	*Celosia argentea*				36	*Mimosa pigra*			
5	*Gomphrena celosioides*				37	*Mimosa pudica*			
6	*Centella asiatica*				38	*Mucuna pruriens*			
7	*Acmella paniculata*				39	*Abutilon indicum*			
8	*Ageratum conyzoides*				40	*Corchorus olitorius*			
9	*Crassocephalum crepidioides*				41	*Urena lobata*			
10	*Eclipta prostrata*				42	*Boerhavia erecta*			
11	*Synedrella nodiflora*				43	*Passiflora foetida*			
12	*Tridax procumbens*				44	*Phyllanthus niruri*			
13	*Vernonia cinerea*				45	*Brachiaria reptans*			
14	*Heliotropium indicum*				46	*Cynodon dactylon*			
15	*Cleome rutidosperma*				47	*Dactyloctenium aegyptium*			
16	*Cleome viscosa*				48	*Digitaria bicornis*			
17	*Commelina benghalensis*				49	*Echinochloa crus galli*			
18	*Ipomoea obscura*				50	*Echinochloa colona*			
19	*Ipomoea triloba*				51	*Eleusine indica*			
20	*Jacquemontia paniculata*				52	*Imperata cylindrica*			
21	*Coccinia grandis*				53	*Pennisetum polystachion*			
22	*Gymnopetalum integrifolium*				54	*Sorghum bicolor*			
23	*Cyperus rotundus*				55	*Sorghum propinquum*			
24	*Dioscorea glabra*				56	*Portulaca oleracea*			
25	*Acalypha indica*				57	*Borreria alata*			
26	*Euphorbia heterophylla*				58	*Richardia brasiliensis*			
27	*Euphorbia hirta*				59	*Cardiospermum halicacabum*			
28	*Aeschynomene americana*				60	*Physalis angulata*			
29	*Alysicarpus monilifer*				61	*Solanum nigrum*			
30	*Calopogonium mucunoides*				62	*Cayratia trifolia*			
31	*Centrosema molle*				63	*Tribulus terrestris*			
32	*Coccinia grandis*								

Herbicides used by farmers

1. Ask the farmers if they use herbicides for selective weed control in maize and record the number of farmers in the group who do not use herbicides.

2. The farmers are shown photos of labels of herbicides commonly used in maize and to comment on efficacy of the ones they have used (Table 6).

3. If farmers are using different products to the ones shown, ask them if they have containers that they can bring to the training venue so the products can be identified and included in Table 6.

Table 6. Examples of selective herbicides used in maize

No.	Product name	Active ingredient(s)	Know it (Y/N)	Have used it (Y/N)	Efficacy
1.	Maizin	Atrazine + Mesotrione			
2.	Sega Atra	Atrazine			
3.	Zip-Smaopot	Atrazine + Mesotrione			
4.	Corn Saviour	Atrazine + Mesotrione			
5.	Yensozine	Atrazine + Mesotrione + Nicosulfuron			
6.	Smao Boart	Mesotrione			
7.	Ni-pir, buon D	2,4-D			
8.	Zen-Co	2,4-D			
9.	Other				
10.	Other				

Training Module 5: Insect pest management

Purpose

Cambodian farmers rely heavily on chemical insecticides to control insect pests in crops, including for maize crops. Management of insect pests in maize was generally not difficult until the arrival of the fall armyworm (FAW) in Cambodia in 2019. Since then, FAW has become a major pest of maize in Cambodia and farmers are relying on a narrow range of insecticides, such as Emamectin benzoate, to control it.

Activity 5.1

Identifying insects for management practices

The purpose of this activity is to help farmers identify the FAW and to diversify management practices to avoid the development if insecticide resistance in FAW.

Figure 25. *Spodoptera frugiperda*, fall armyworm: larva (a); male adult (b); female adult (c); egg mass (d)

Materials required

Alcohol (500 mL)

Specimen jar

Insect ID sheets

Insecticide ID sheets

Pheromone trap

Beneficials ID sheets

Figure 26. Materials required to identify pests

Sampling the field

The farmer group is asked if there is a maize field available for sampling in the village. The crop should be at 20 to 40 DAS, if possible. Also, if possible, a pheromone light trap should be placed in the field on the day before the activity. Samples are taken from five locations in the field. The sampling pattern should take account of differences in slope, soil type, crop growth, etc., across the field.

Collection of insect and spider specimens in the field

1. Carefully inspect the crop plants for the presence of insects and spiders. Alternatively place an empty fertiliser bag on the ground next to the row, shake the crop plants over the bag and collect specimens.

2. At each of the five locations in the field, place all insects and spiders collected into a specimen jar containing alcohol.

3. Take the samples back to the training venue for closer inspection and identification, if possible.

4. Recover the pheromone trap (if used) and take it to the training venue.

Recognition of insects in maize crops

The group is shown a set of laminated sheets with photos of 21 insect species or groups of related insects and asked the following questions (Table 7):

1. Have they seen this insect in their maize crops?

2. Is the insect commonly seen in maize crops?

3. If they have tried to control it, is it easy or difficult to control?

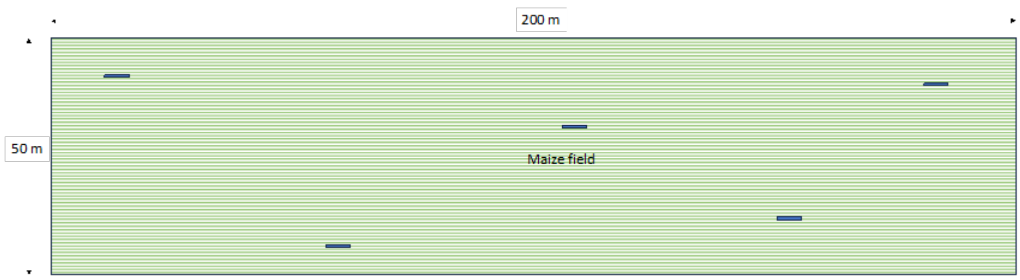


Figure 27. Sampling pattern in the field

Table 7. Identification of insects found in maize crops

No.	Insect group	Know it (Y/N)	Common (Y/N)	Difficulty (Y/N)
1	Leaf beetles			
2	Ladybird adults			
3	Ladybird larvae			
4	Hoverflies			
5	Tachinid flies			
6	Corn aphid			
7	Sucking bugs			
8	Predatory shield bug			
9	Assassin bug			
10	Parasitic wasps			
11	Predatory wasps			
12	Yellow peach moth			
13	Asiatic corn borer			
14	Black cutworm			
15	Corn ear worm			
16	Beet armyworm			
17	Fall armyworm			
18	Cluster caterpillar			
19	Praying mantises			
20	Grasshoppers			
21	Thrips			

Having completed Table 7, ask the group to comment on the results for "know it", "common" and "difficulty to control" in Table 8.

Table 8.The top five insects for "know it", "common" and "difficulty" caught in maize crops

Know it (Y/N)	Common (Y/N)	Difficulty (Y/N)

Inspecting the catch in the pheromone trap

"The pheromone trap attracts only male moths of the Fall Armyworm (*Spodoptera frugiperda*). If they are present in the trap, refer to the section on Fall Armyworm.

Beneficial insects and integrated pest management (IPM)

There is a resident community of beneficial arthropods (insects and spiders) that are living in maize fields which can reduce the impact of pest insects. If farmers apply chemical insecticides indiscriminately, they will also kill beneficials leading to pests, such as the FAW, increasing to out of control levels. The group are likely to have misidentified some beneficials as pests. Show the group the laminated sheets showing some predators and parasitoids of the FAW.

Table 9. Statements about practices to manage insect pests

Statement	Ranking				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I agree that beneficial insects and spiders help control FAW	❒	❒	❒	❒	❒
I always check for the presence of pests in the field before I spray	❒	❒	❒	❒	❒
I follow a calendar-based schedule for application of insecticide	❒	❒	❒	❒	❒
I see no reason to change my insect management practices	❒	❒	❒	❒	❒
I am confident to follow the advice of the input seller	❒	❒	❒	❒	❒

Insecticides used

1. Ask the farmers what insecticides they have used for maize crops and record the number of farmers in the group who do not use insecticides.

2. Show the farmers photos of labels of insecticides commonly used in crops and ask them to comment on the efficacy of the ones they have used. Record their answers in Table 10.

3. If the farmers are using different products to the ones shown, ask them if they have containers that they can bring to the training venue so the products can be identified and included in Table 10.

Table 10. Common insecticides used

No.	Name	Seen	Used	Efficacy	No.	Name	Seen	Used	Efficacy
1	Aba				20	Emamectin			
2	Azaba				21	Emamectin benzoate			
3	Atylo				22	Winner			
4	Boxer				23	Do Do			
5	Zentari				24	Fordonkov			
6	Bitadin				25	Anmantox			
7	King dragon				26	Mekomectin			
8	MetaBe				27	Mekomectin			
9	Prevathon				28	Thai label			
10	Virtako				29	Eska			
11	Kaito A				30	Emat			
12	Nato				31	Klang			
13	ToTo				32	Winner			
14	Wellof				33	Rambo			
15	Neak Chambang				34	Lufen			
16	Samurai				35	PCX			
17	Arson				36	Donkouv Boun Muk			
18	Os Steah				37	Radiant			
19	AK 47				38	Premier			

Fall Armyworm (FAW) - a new insect pest in Cambodia

The FAW is native to eastern and central North America and South America. It was first reported outside its native range in 2016 when it was found in Africa and causing significant damage to maize. In 2018, FAW began to spread in India. FAW was first found in Cambodia in 2019 in maize fields in Malai District, Banteay Meanchey Province. FAW has subsequently become an key problem in maize across Cambodia.

FAW was nominated as the most important insect pest of maize, especially in the dry season, in all villages interviewed during a scoping mission of maize growing areas along the Mekong River in December 2023.

Farmers in one village indicated that ladybird beetles were pests of maize. This is not the case and emphasizes the need for training on insect pest management as part of an IPM training program for maize.

Beet armyworm (*Spodoptera exigua*)

Fall armyworm (*Spodoptera frugiperda*)

African leafworm (*Spodoptera litoralis*)

Cluster caterpillar (*Spodoptera litura*)

Figure 28. Larvae of four species of *Spodoptera* found in Cambodia

Identification of the FAW

FAW have four life cycle stages: eggs, larvae, pupa and adult (moth). However, identifying FAW from the eggs, pupa and moths is very difficult. The cater-pillars have an inverted "Y" marking on the head and four large black spots in a square on the second last body segment. Please note, the beet armyworm (*Spodoptera exigua*) and cluster caterpillar (*S. litura*) also have the "Y" mark on the head but not the four black spots (Figure 28).

The female FAW moth can be confused with the moth of the corn earworm (*Helicoverpa armigera*). The two moths can be distinguished by looking at the hindwings (Figure 29). The hindwing of the FAW is silvery-white with a narrow, dark margin. Whereas the hindwing of the corn earworm is pale with a broad, dark outer margin.

Fall armyworm

Corn earworm

Figure 29. Differences between FAW (female) and corn earworm moths

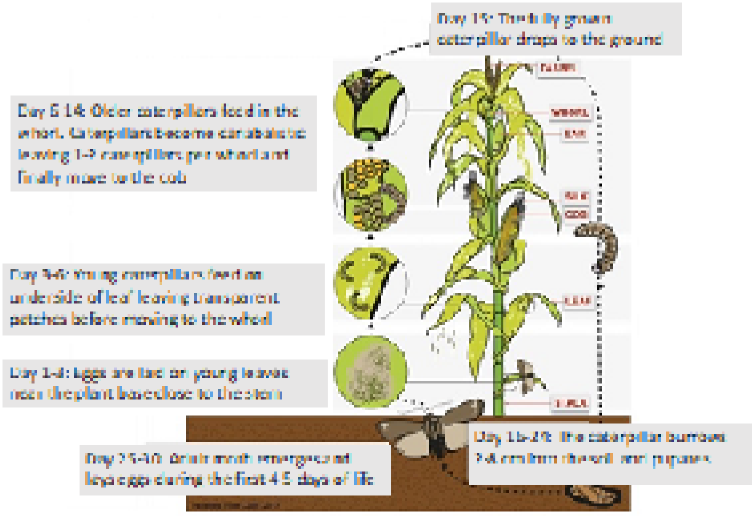


Figure 30. Life cycle of the FAW

Lifecycle of the FAW [9]

The female moth lays 100 to 200 eggs on the underside of the leaves, near the base of the plant. Eggs are covered in protective scales rubbed off from the moth's abdomen after laying. When populations are high, the eggs may be laid higher up the plants or on nearby vegetation.

After hatching, the young caterpillars feed superficially, usually on the undersides of leaves. Feeding results in semi-transparent patches, or "windows", on the leaves. Young caterpillars can spin silken threads which catch the wind and transport the caterpillars to a new plant. The leaf whorl is preferred in young plants, whereas the leaves around the cob silks are attractive in older plants. If the plant has al-ready developed cobs, then the caterpillar will eat its way through the protective leaf bracts into the side of the cob where it begins to feed on the developing kernels. Feeding is more active during the night.

By 6 to 14 days, the larvae will have reached the whorl, where they do the most damage, resulting in ragged holes in the leaves. Feeding on young plants can kill the growing point, resulting in no new leaves or cobs. Often only one or two caterpillars are found in each whorl, as they become cannibalistic when larger and will eat each other to reduce competition for food. Large quantities of frass (caterpillar poo), which resembles sawdust, will be present.

After approximately 14 days the fully grown caterpillar will drop to the ground. The caterpillar will then burrow 2 to 8 cm into the soil before pupating. The pupa cocoon is 20-30 mm in length. If the soil is too hard then the caterpillar will cover itself in leaf debris before pupating. After approximately 8 or 9 days the adult moth emerges to restart the cycle (Figure 30).

Problems with managment of FAW

1. FAW begin to attack maize at a very early stage and farmers should check their crops when plants are at the V2 to V3 growth stage.

2. When the plants are young and the leaf tissues are soft, first-instar FAW larvae produce clusters of pinhole-type damage or small, round holes.

3. Later larval instars chew larger holes, causing ragged whorl leaves, and produce sawdust-like larval droppings. Damage to cobs may lead to fungal infection and aflatoxins, and loss of grain quality.

4. In badly infested fields, larvae feed inside whorls and can destroy silks and developing tassels, thereby limiting fertilization of the ear.

5. Larvae move to the ear zone and start feeding after tassel emergence.

Activity 5.2: FAW Management

Ask the group about their problems with controlling FAW. Table 11 sets out five statements. The group is asked, by a show of hands, whether they agree or disagree with each statement.

Table 11. Statements about management of FAW

Statement	Ranking				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I do not have any problems controlling FAW in maize	❐	❐	❐	❐	❐
Problems controlling insects have increased in the last 5 years	❐	❐	❐	❐	❐
I am confident I can manage the FAW	❐	❐	❐	❐	❐
I need help to control the FAW	❐	❐	❐	❐	❐
If I cannot control FAW, I will stop growing maize	❐	❐	❐	❐	❐

Strategies for the management of FAW

Farmers are relying heavily on emamectin benzoate for the control of FAW, and this poses a significant risk of the development of resistance to this group of insecticides which includes abamectin. FAW poses a significant threat to maize production and farmers will need to re-think their strategies if the pest is to be brought under control [10].

Monitoring

Installation of pheromone traps is an option for monitoring but might not be feasible under Cambodian conditions.

Scouting

1. Farmers should start scouting as soon as maize seedlings emerge.

2. At seedling to early whorl stage (3 to 4 weeks after emergence), action can be taken if 5% plants are damaged.

3. At mid to late whorl stage (5 to 7 weeks after emergence), action can be taken if 10% whorls are freshly damaged in mid whorl stage and 20% whorl damage in late whorl stage.

4. At tasselling and post tasselling (silking stage), do not spray chemical insecticides. Suitable bio-pesticide may be used in the event of ear/cob damage (Figure 31).

Bitadin:
Bacillus thuringiensis + NPV

MetaBe:
Beauveria + Metarhizium

Red dragon:
Beauveria

Figure 31. Bio-insecticides registered for use in Cambodia

Cultural measures

1. Deep ploughing is recommended before sowing. This will expose FAW pupae to predators.
2. Timely and uniform sowing over a large area is advised. Avoid staggered sowings.
3. Intercropping of maize with a suitable pulse crop such as mungbean.
4. Erection of bird perches during early stage of the crop (up to 30 days).
5. Sowing of 3 to 4 rows of trap crops (e.g. Napier grass) around maize fields and spray with Neem extract as soon as the trap crop shows symptom of FAW damage.
6. Use of maize hybrids with tight husk cover will reduce ear damage by FAW.

Mechanical controls

1. Hand removal and destruction of egg masses and neonate larvae in mass by crushing.
2. Mass trapping of male moths using FAW specific pheromone traps.

Bio control

1. Protection of natural enemies by habitat management: Increase the plant diversity by intercropping with pulses, oil seeds and ornamental flowering plants which help in build-up of natural enemies.
2. Bio-pesticides: If infestation level is at 5% damage in seedling to early whorl stage and 10% ear damage, then Bitadin and MetaBe can be used as per instructions.

Chemical controls

1. Seed treatment is recommended but hybrid seed is usually already treated with insecticide and fungicide.
2. First window (seedling to early whorl stage): Control FAW larvae at 5% damage to reduce hatchability of freshly laid eggs, spray Neem extract if available.
3. Second window (mid to late whorl stage): If 2nd and 3rd instars larvae having more than 10% foliar damage the following chemicals may be used up to early tasselling: Spinetoram or Chlorantraniliprole or Thiamethoxam + Lambda cyhalothrin.

Spinetoram

Chlorantraniliprole

Thiamethoxam + Lambda cyhalothrin

Figure 32. Examples of alternative insecticides to emamectin

Training Module 6: Economic analysis of maize production

Purpose

Most farmers do not keep sufficient records of the costs associated with growing a crop to enable an economic analysis to be performed. This makes it difficult to compare the relative profitability of different farm enterprises. Furthermore, it is difficult for farmers to identify inputs where costs could be reduced. The purpose of this activity is to make farmers more aware of the economics of crop production where costs can be reduced or where income can be increased.

Gross margin analysis

A 'gross margin' is the gross income from a farming operation, such as growing a crop, less the variable costs incurred in growing it. It does not include fixed or overhead costs such as depreciation, interest payments or land rental. Gross margin budgets are intended to provide a guide to the relative profitability of similar enterprises and an indication of management operations involved in different enterprises [11, 12] .

Budgets are calculated using:

- maize yields that are in the range of those achieved by smallholder farmer.
- the range of recent farmgate prices for maize.
- current input costs obtained from input sellers.
- technical information provided by hybrid seed companies and input sellers.

The aim of gross margin budgets is to provide farmers with an additional planning tool to help evaluate options to increase the return on investment. The budgets are intended to provide a projection of price expectations in the near future, rather than a statement of the recent past.

Information required

Prior to the training session, participants should be asked to itemise the inputs required for a typical maize crop on their farm together with their costs. Including an input seller in the group would be useful since farmers often forget names and costs of products. Participants should take photos of bags, packets and bottles of products if possible, because this enables accurate identification of products, quantities used and prices. Contract rates should be used for labour inputs regardless of whether the labour is family or hired. If this is not done, comparisons cannot be made between farms or districts. Similarly, contract rates should be used for machinery operations to enable between farm comparisons.

Examples of gross margin analysis

A scoping mission in December 2023 found that 80% of maize in Tbong Khmum province is harvested by contracted combine harvesters at a cost of around US$125/ha. Yields are generally higher in the dry season. Yields were quoted as freshly harvested grain (>25% moisture content) and ranged from 7 to 8 t/ha in the wet season and 9 to 11 t/ha in the dry season. Prices ranged from US$200 to US$275/t and are similar to the average world price in 2023 of US$240-270/t . A gross margin for a typical smallholder maize crop is given in (Table 12). The example gives a gross margin of US$1,073/ha for an 8t maize crop at a grain price of US$250/t.

Table 12. Gross margin for machine-harvested maize for smallholder farmers

Income (A)	Description	Unit	Units/ha	Unit value (USD)	Total (USD)
Grain (t/ha)	14% moisture content	t	8	250	2,000
Variable costs	**Description**	**Unit**	**Units/ha**	**Unit value (USD)**	**Total (USD)**
Land preparation	Disc plough	ha	3	32.50	97.50
Fertiliser applied at planting	N:P:K - 15:15:15 (50 kg bag)	bag	4	40.00	160.00
Labour	Contract rate	p/p/d*	1	25.00	25.00
Seed	Hybrid seed (AS 2838)	kg	20	7.20	144.00
Planting	Planting machine	ha	1	25.00	25.00
Fertiliser 20-25 DAS	Urea (50 kg bag)	bag	3	37.50	112.50
Fertiliser 40-45 DAS	Urea (50 kg bag)	bag	3	37.50	112.50
Labour to apply fertiliser	Contract rate	p/ha/d	2	25.00	50.00
Insecticide	Prevathon	packet	3	6.00	18.00
Labour	Contract rate	p/ha/d	3	10.00	30.00
Herbicide 15-20 DAS	Atrazine	kg	1	10.00	10.00
Herbicide 15-20 DAS	Mesotrione	mL	1	8.00	8.00
Labour	Contract rate	p/p/d*	1	10.00	10.00
Harvesting	Combine harvester	p/ha/d	1	125.00	125.00
Total variable costs USD/ha (B)					**927.50**
Gross Margin USD/ha (A-B)					**1,072.50**

*person per day

A sensitivity analysis can be done to see what happens to the gross margin when the yield and price vary (Table 13).

Table 13. Gross margin sensitivity analysis for machine-harvested maize

Yield (t/ha)	Price (USD/t)				
	200	225	250	275	300
2	-128	-28	73	173	273
4	113	243	373	503	633
6	353	513	673	833	993
8	673	873	1,073	1,273	1,473
10	833	1,053	1,273	1,493	1,713
12	993	1,233	1,473	1,713	1,953
14	1,153	1,413	1,673	1,933	2,193

The worst-case price scenario was set at US$200/t and the best-case price scenario was set at US$300/t. These scenarios can be varied if required. The worst-case yield scenario was set at 2 t/ha for grain and the best-case yield scenario was set at 14 t/ha. These scenarios can be varied if required.

For this example, the break-even yield (variable costs/price of grain) is 3.7 t/ha and the break-even price (variable costs/yield) is US$116/t. Gross margins for the worst-case yield scenario (2 t/ha) ranged from -US$128/ha at US$200/t to US$273/ha at US$300/t. Gross margins for the best-case yield scenario (14 t/ha) ranged from US$1,153/ha at US$200/t to US$2,193/ha at US$300/t.

Fertiliser, based on seed company recommendations (Figure 17a), accounted for 51% of variable costs in the gross margin analysis for the recommended crop input scenario (Figure 33). Side-dressings of urea are recommended at 20 to 25 and at 40 to 45 DAS. The LCC can be used before the second side-dressing to adjust the application rate according to crop needs. Depending on the greenness of the leaves, the amount of urea can be reduced or in-creased at the second side-dressing to maintain the target yield. Not a lot can be done about reducing planting and harvesting costs. However, land preparation costs can be reduced by reducing the amount of tillage and adoption of no-tillage. Yields can also be increased by no-tillage with improved water-use efficiency.

The input costs were grouped for the operations of land preparation; seed and planting; fertiliser application; crop protection (control of weeds and insect pests); and harvesting.

Data collected in Prey Veng province during the scoping mission in December 2023 indicated that these smallholder farmers were allocating resources to inputs in line with recommendations (Figure 33).

In contrast, maize growers in Leuk Daek district, Kandal province [13] spent 23% of inputs on crop protection compared with an expected 6%. Data collected in Tbong Khmum were similar to those collected in Kandal province [13]. In these provinces, the features were:

1. Higher cost of planting in Tbong Khmum which appears to be related to slow adoption of mechanised planting.
2. Lower investment in fertiliser which could be a factor limiting grain yield.
3. The high level of spending on crop protection in Kandal and Tbong Khmum Provinces suggests excessive use of pesticides.

The use of fertiliser was high in Prey Veng province and close to recommended but could be too high. In contrast, Kandal and Tbong Khmum maize growers used less fertiliser than recommended. Farmers could be encouraged to use the LCC to decide if a second side-dressing of urea is required at 40 to 45 DAS.

The cost of crop protection is largely associated with application of herbicides and insecticides. Adoption of IPM is an option to reduce these costs.

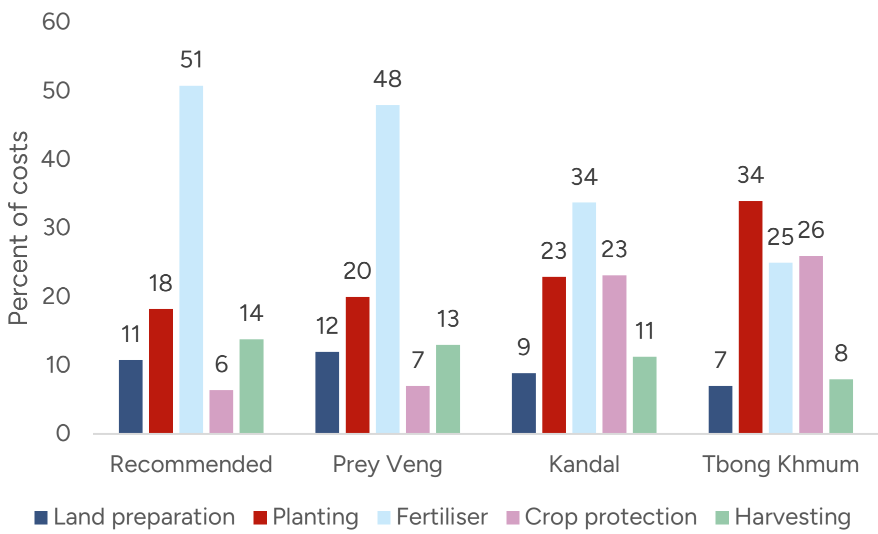


Figure 33. Variations between provinces for input costs for smallholder maize crops

Training Module 7: Financial Literacy for Maize Production

Purpose

Maize farming holds great potential to improve the livelihoods of small-scale farmers, offering both food security and income opportunities. To succeed, farmers need a strong foundation in both effective farming practices and financial decision-making. This manual bridges the gap by providing practical guidance on maize cultivation while introducing essential financial skills to support better planning and profitability.

This module is designed to deliver an engaging and practical program that connects maize production techniques with simple financial tools. By empowering farmers to make informed choices and manage resources effectively, it paves the way for improved yields, stronger incomes, and long-term success in maize farming.

Key Financial Literacy Concepts for Maize Farming

Budgeting: Plan for key costs such as seeds, fertilizers, labor, and harvesting. Creating and following a budget ensures that spending is controlled and farming remains profitable.

Record-Keeping: Keep track of all expenses, yields, and sales. Accurate records help identify where money is being spent and highlight opportunities to save costs or increase income.

Input Management: Evaluate the costs and benefits of using hybrid seeds, fertilizers, and pest control methods. Use this understanding to choose the most cost-effective inputs for better yields.

Risk Management: Anticipate potential risks such as pest infestations, drought, or price fluctuations. Create plans to manage these risks, such as timely pest control and storing maize for better market prices.

Profitability Analysis: Compare the money spent on inputs with the income from selling maize. Understanding profits helps farmers refine their practices to focus on the most rewarding activities.

Market Awareness: earn about local grain prices and buyer preferences, including demand for quality and moisture content. Selling maize at the right time and quality maximizes returns.

Cost-Reduction Strategies: Identify areas to save costs, such as using the LCC to optimize fertilizer usage or adopting integrated pest management to reduce pesticide expenses.

Investment in Practices: Understand the long-term benefits of practices like reduced tillage or crop rotation. These practices improve soil health and yield over time, enhancing overall farm sustainability.

Learning Financial Literacy Through Case Studies

This manual introduces financial literacy concepts through relatable maize farming scenarios, demonstrating how everyday decisions directly impact farming success. By examining real-world examples, farmers will learn how thoughtful planning, tracking costs, managing inputs, and addressing risks can lead to better harvests and higher incomes. These examples highlight how simple financial practices can result in smarter resource use, increased profits, and more resilient farming operations.

To support farmers in achieving these goals, the manual focuses on three key areas:

- Seed Selection and Planting Practices
- Fertilizer, Pest, and Crop Care Management, and
- Harvesting and Post-Harvest Management.

Each section provides practical guidance and actionable strategies, empowering farmers to improve yields, reduce costs, and make decisions that promote sustainable and profitable maize farming.

7.1 Seed Selection and Planting Practices

Case Study 1: Planting too many seeds vs. planting the right amount

Scenario 1: Planting Too Many Seeds

Sokha, a farmer in Prey Veng province, believed that planting more seeds would result in a larger harvest. She decided to use 30 kgs of hybrid seed per hectare, exceeding the recommended rate of 20 kgs. However, her field became overcrowded, causing her maize plants to compete for sunlight, water, and nutrients. As a result, the plants grew weak, and the yield was much lower than expected.

Sokha's results with too many seeds:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Hybrid Seeds (30 kg)	7.20	30 kg	216.00
Fertilizer (400 kg total)	0.80	400 kg	320.00
Labor (planting, weeding, harvesting)	100.00	-	100.00
Total Costs	**-**	**-**	**636.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (6 tonnes)	250.00	6 tonnes	1,500.00
Profit Calculation	**Revenue - Costs**		**864.00**

Scenario 2: The Better Way - Planting the Right Amount of Seeds

After attending a training, Sokha learned about the benefits of following the recommended planting density. The next season, she used 20 kgs of seed per hectare, giving her plants enough space to grow strong and healthy. She also applied fertilizers based on the crop's needs and controlled weeds early. This time, her field produced a higher yield with fewer inputs.

Sokha's results with recommended practices:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Hybrid Seeds (20 kg)	7.20	20 kg	144.00
Fertilizer (400 kg total)	0.80	400 kg	320.00
Labor (planting, weeding, harvesting)	100.00	-	100.00
Total Costs			**564.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (8 tonnes)	250.00	8 tonnes	2,000.00
Profit Calculation	**Revenue - Costs**		**1,436.00**

Revenue Analysis

In Scenario 1, planting too many seeds (30 kg/ha) led to overcrowding, weaker plants, and a lower yield of 6 tonnes, earning USD 1,500 and leaving a profit of USD 864.

In Scenario 2, planting the recommended amount (20 kg/ha) allowed plants to grow healthier, yielding 8 tonnes and earning USD 2,000, with a much higher profit of USD 1,436.

Key Insights

Wasted Inputs: Planting too many seeds increases costs without improving yields. Instead, it leads to overcrowding and competition among plants.

Higher Profits with Good Practices: Following the recommended planting rate (20 kg/ha) not only saves money but also improves yields and profits.

Efficient Resource Use: Proper seed spacing ensures plants grow healthier, requiring less fertilizer and producing better-quality maize.

Call to Action

Farmers are encouraged to follow the recommended planting rate of 20 kgs per hectare for better yields and higher profits. Overcrowding fields may seem like a way to grow more, but it only leads to wasted resources and reduced income. By adopting good practices, farmers can make their work more rewarding and sustainable.

Key Takeaway

Following the recommended seed rate ensures better yields, reduces costs, and maximizes profits.

Case Study 2: Choosing the right seeds for better yields

Scenario 1: Using low-quality seeds

Vanna, a farmer in Tbong Khmum, decided to save money by buying cheaper, low-quality seeds from a local trader. Although these seeds cost less, they had a poor germination rate, and the plants that did grow were weak and less resistant to pests and diseases. At harvest, Vanna managed to produce only 5 tonnes of maize per hectare, far below the expected yield.

Vanna's results with low-quality seeds:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Low-Quality Seeds (20 kg)	4.00	20 kg	80.00
Fertilizer (400 kg total)	0.80	400 kg	320.00
Labor (planting, weeding, harvesting)	100.00	-	100.00
Total Costs	-	-	**500.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (5 tonnes)	250.00	5 tonnes	1,250.00
Profit Calculation	**Revenue - Costs**		**750.00**

Scenario 2: The Better Way - Using high-quality hybrid seeds

The next season, Vanna decided to invest in high-quality hybrid seeds recommended by her local agricultural extension officer. Although these seeds were more expensive, they had a higher germination rate and produced stronger, more disease-resistant plants. She followed the recommended planting rate and applied fertilizer as needed, resulting in a harvest of 8 tonnes per hectare.

Vanna's results with high-quality hybrid seeds:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Hybrid Seeds (20 kg)	7.20	20 kg	144.00
Fertilizer (400 kg total)	0.80	400 kg	320.00
Labor (planting, weeding, harvesting)	100.00	-	100.00
Total Costs			**564.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (8 tonnes)	250.00	8 tonnes	2,000.00
Profit Calculation	**Revenue - Costs**		**1,436.00**

Revenue Analysis

In Scenario 1, using low-quality seeds saved money upfront but resulted in a low yield of 5 tonnes, earning USD 1,250 with a profit of only USD 750.

In Scenario 2, investing in high-quality hybrid seeds produced a much better yield of 8 tonnes, earning USD 2,000 with a profit of USD 1,436.

Key Insights

False Savings: While low-quality seeds are cheaper upfront, they lead to lower yields and reduced profits.

Investing in Quality: High-quality hybrid seeds are more expensive but produce healthier plants with better resistance to pests and diseases, resulting in higher yields and profits.

Smart Decisions Pay Off: Spending more on seeds can lead to significantly better results, making the investment worthwhile.

Call to Action

Farmers should choose high-quality seeds from reliable sources, even if they cost more. Better seeds lead to better yields, stronger profits, and a more secure farming operation. Investing in the right inputs at the start is the foundation for success in maize farming.

Key Takeaway

Investing in high-quality seeds pays off through higher yields and significantly better profits.

7.2 Fertilizer, Pest, and Crop Care Management

Case Study 1: Fertilizer, Pest, and Crop Care Management

Scenario 1: Using too much fertilizer and ignoring the LCC

Srey, a farmer in Kandal province, wanted to ensure her maize grew quickly, so she applied double the recommended amount of fertilizer without using the LCC to guide her application. While her maize initially grew well, heavy rains washed away much of the excess fertilizer, wasting her investment. Additionally, the overcrowded plants made it harder to manage pests, leading to leaf damage from pests she didn't notice in time. Srey's yield was only 6 tonnes per hectare, and her profits were lower than expected.

Srey's results with excess fertilizer and poor pest control:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Fertilizer (800 kg)	0.80	800 kg	640.00
Pest Control (minimal use)	10.00	2 sprays	20.00
Labor	100.00	-	100.00
Total Costs	**-**	**-**	**760.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (6 tonnes)	250.00	6 tonnes	1,500.00
Profit Calculation	**Revenue - Costs**		**740.00**

Scenario 2: Following recommended fertilizer application and pest management (good practices)

The following season, Srey attended a training session where she learned about using the LCC to guide her fertilizer application and applying pest control at the right time. She used the recommended amounts of fertilizer and sprayed pesticides at the first signs of pest infestation. As a result, her maize grew healthier and produced 8 tonnes per hectare, maximizing her profit.

Srey's results with LCC and good pest control:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Fertilizer (400 kg)	0.80	400 kg	320.00
Pest Control (timely use)	10.00	3 sprays	30.00
Labor	100.00	-	100.00
Total Costs	**-**	**-**	**450.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (8 tonnes)	250.00	8 tonnes	2,000.00
Profit Calculation	**Revenue - Costs**		**1,550.00**

Revenue Analysis

In Scenario 1, Srey's overuse of fertilizer and poor pest control led to wasted inputs and only 6 tonnes of maize, earning USD 1,500 with a profit of USD 740.

In Scenario 2, efficient fertilizer use with the LCC and timely pest control resulted in a healthier crop and 8 tonnes of maize, earning USD 2,000 with a profit of USD 1,550.

Key Insights

Fertilizer Efficiency: Using the LCC ensures the right amount of fertilizer is applied at the right time, reducing waste and costs.

Pest Management: Timely pest control prevents crop damage and ensures higher yields, while excessive use of pesticides adds unnecessary costs.

Healthy Practices Lead to Profits: By following recommended practices, Srey saved money, improved her yields, and significantly increased her profits.

Call to Action

Farmers should use tools like the LCC to manage fertilizer use and adopt IPM techniques to handle pests effectively. These practices reduce costs, protect the environment, and result in healthier crops and higher profits.

Key Takeaway

Smart input management boosts yields, reduces costs, and significantly increases profits.

Case Study 2: Neglecting Pest Control Vs. Timely Pest Management

Scenario 1: Neglecting pest control

Chan, a farmer in Tbong Khmum, decided to skip pest control to save money. While his maize initially grew well, pest infestations damaged the leaves and cobs. This reduced his yield to 6 tonnes per hectare and lowered the quality of the grain, forcing him to sell at a lower price of USD 230 per tonne.

Chan's results with no pest control:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Fertilizer (400 kg)	0.80	400 kg	320.00
Labor	100.00	-	100.00
Pest Control (none)	0.00	0 sprays	0.00
Total Costs	**-**	**-**	**420.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (6 tonnes)	230.00	6 tonnes	1,380.00
Profit Calculation	**Revenue - Costs**		**960.00**

Scenario 2: Timely pest management

The following season, Chan followed the advice of his local extension officer and implemented IPM. He monitored his crops regularly and applied pest control only when necessary. This prevented pest damage, improved grain quality, and allowed him to sell at the higher price of USD 250 per tonne, yielding 8 tonnes per hectare.

Chan's results with timely pest management:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Fertilizer (400 kg)	0.80	400 kg	320.00
Labor	100.00	-	100.00
Pest Control (3 sprays)	10.00	3 sprays	30.00
Total Costs	**-**	**-**	**450.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (8 tonnes)	250.00	8 tonnes	2,000.00
Profit Calculation	**Revenue - Costs**		**1,550.00**

Revenue Analysis

In Scenario 1, Chan's neglect of pest control resulted in a lower yield of 6 tonnes and poorer grain quality, forcing him to sell at a lower price. His profit was only USD 960.

In Scenario 2, timely pest management through IPM increased his yield to 8 tonnes and improved grain quality, enabling him to earn a higher price and achieve a profit of USD 1,550.

Key Takeaway

Regular pest monitoring and timely control prevent crop damage, improve grain quality, and maximize profits.
Skipping pest management to save costs results in lower yields and income.

7.3 Harvesting and Post-Harvest Management

Case Study 1: Harvesting and post-harvest management

Scenario 1: Poor post-harvest practices

Sokun, a farmer in Prey Veng, harvested her maize when the grain moisture content was still high (above 25%) to save time. She did not properly dry the maize before storing it. As a result, a significant portion of her maize developed mold during storage, reducing its quality and market value. She could only sell her maize for USD 200 per tonne instead of the average USD 250 per tonne.

Sokun's results with poor practices:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Harvesting (manual labor)	100.00	-	100.00
Drying (minimal effort)	0.00	-	0.00
Labor and Transport	50.00	-	50.00
Total Costs	**-**	**-**	**150.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (8 tonnes, poor quality)	200.00	8 tonnes	1,600.00
Profit Calculation	**Revenue - Costs**		**1,450.00**

Scenario 2: Proper harvesting and drying practices

After attending a training session, Sokun learned the importance of harvesting maize at the right time and properly drying it to reduce moisture content to 14% before storage. She used a combine harvester for efficient harvesting and invested time in proper drying techniques. This improved the quality of her maize, allowing her to sell it for the full price of $250 per tonne.

Sokun's Results with proper practices:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Harvesting (combine)	125.00	-	125.00
Drying (improved)	20.00	-	20.00
Labor and Transport	50.00	-	50.00
Total Costs	**-**	**-**	**195.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (8 tonnes, good quality)	250.00	8 tonnes	2,000.00
Profit Calculation	**Revenue - Costs**		**1,805.00**

Revenue Analysis

In Scenario 1, Sokun's poor drying practices caused a drop in grain quality, reducing her revenue to USD 1,600 and leaving her with a profit of only USD 1,450.

In Scenario 2, proper harvesting and drying ensured high-quality maize, allowing her to earn USD 2,000 in revenue with a profit of USD 1,805.

Key Takeaway

Harvesting maize at the right time and reducing grain moisture through proper drying protects quality and market value.
Investing in better post-harvest practices results in higher revenues and greater profits.

Case Study 2: Manual harvesting vs. mechanized harvesting

Scenario 1: Manual harvesting

Sitha, a farmer in Tbong Khmum, chose to harvest her maize manually to save money on machinery. However, the manual process was slow, taking 10 days to complete, during which time some maize was exposed to rain, increasing moisture content and risking spoilage. Additionally, the slower pace led to losses from rodents and pests in the field. In the end, she harvested 7 tonnes of maize with slightly lower quality, selling it for USD 240 per tonne.

Sitha's results with manual harvesting:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Labor (10 days)	12.00	10 days	120.00
Drying	20.00	-	20.00
Transport	50.00	-	50.00
Total Costs	**-**	**-**	**190.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (7 tonnes, medium quality)	240.00	7 tonnes	1,680.00
Profit Calculation	**Revenue - Costs**		**1,490.00**

Scenario 2: Mechanized harvesting

The next season, Sitha decided to hire a combine harvester to complete her harvest efficiently and protect her crop from weather and pest damage. The harvesting was completed in one day, and the maize was properly stored and dried, maintaining its quality. She harvested 8 tonnes of maize and sold it for the full price of USD 250 per tonne.

Sitha's results with mechanized harvesting:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Combine Harvester	125.00	-	125.00
Drying	20.00	-	20.00
Transport	50.00	-	50.00
Total Costs	**-**	**-**	**195.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (8 tonnes, good quality)	250.00	8 tonnes	2,000.00
Profit Calculation	**Revenue - Costs**		**1,805.00**

Revenue Analysis

In Scenario 1, Sitha's manual harvesting saved machinery costs but resulted in slower harvesting, crop losses, and reduced grain quality, leaving her with a profit of USD 1,490.

In Scenario 2, mechanized harvesting protected her crop quality and increased her yield to 8 tonnes, earning her a profit of USD 1,805.

Key Takeaway

While manual harvesting might save costs upfront, it often leads to lower yields and quality losses. Mechanized harvesting ensures faster, more efficient operations, better grain quality, and higher profits.
Investing in the right tools for harvesting pays off in the long run.

Case Study 3: Timing harvesting for maximum quality

Scenario 1: Harvesting too early

Pisey, a farmer in Prey Veng, wanted to sell her maize quickly and decided to harvest when the grain still had a moisture content of 20%. While this saved time, it meant her maize required extra drying, increasing costs. Additionally, buyers offered her a lower price because of the high moisture content, reducing her overall income. Pisey harvested 8 tonnes of maize but could only sell it for USD 230 per tonne.

Pisey's results with early harvesting:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Harvesting (manual labor)	100.00	-	100.00
Drying (extra cost)	40.00	-	40.00
Transport	50.00	-	50.00
Total Costs	**-**	**-**	**190.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (8 tonnes, medium quality)	230.00	8 tonnes	1,840.00
Profit Calculation	**Revenue - Costs**		**1,650.00**

Scenario 2: Mechanized harvesting

The following season, Pisey learned to wait until the grain moisture content dropped to 14%, ensuring the maize was properly dried before harvesting. This improved the grain quality, enabling her to sell it at the full market price of USD 250 per tonne. Pisey harvested 8 tonnes again but earned significantly more due to the better quality.

Pisey's results with timely harvesting:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Harvesting (manual labor)	100.00	-	100.00
Drying	20.00	-	20.00
Transport	50.00	-	50.00
Total Costs	**-**	**-**	**170.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (8 tonnes, good quality)	250.00	8 tonnes	2,000.00
Profit Calculation	**Revenue - Costs**		**1,830.00**

Revenue Analysis

In Scenario 1, Pisey's early harvest required extra drying costs and reduced her selling price, leaving her with a profit of USD 1,650.

In Scenario 2, harvesting at the right time improved grain quality, allowing her to earn the full market price and achieve a profit of USD 1,830.

Key Takeaway

Harvesting maize at the correct moisture content ensures high grain quality and reduces drying costs. Rushing the harvest may seem convenient but leads to lower prices and reduced profits.
Patience and proper timing lead to better outcomes.

7.4 Record-Keeping: A Tool for Better Farming Decisions

Case Study 1: Harvesting and post-harvest management

Scenario 1: Poor post-harvest practices

Sokun, a farmer in Prey Veng, harvested her maize when the grain moisture content was still high (above 25%) to save time. She did not properly dry the maize before storing it. As a result, a significant portion of her maize developed mold during storage, reducing its quality and market value. She could only sell her maize for USD 200 per tonne instead of the average USD 250 per tonne.

Sokun's results with poor practices:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Harvesting (manual labor)	100.00	-	100.00
Drying (minimal effort)	0.00	-	0.00
Labor and Transport	50.00	-	50.00
Total Costs	**-**	**-**	**150.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (8 tonnes, poor quality)	200.00	8 tonnes	1,600.00
Profit Calculation	**Revenue - Costs**		**1,450.00**

Scenario 2: Proper harvesting and drying practices

After attending a training session, Sokun learned the importance of harvesting maize at the right time and properly drying it to reduce moisture content to 14% before storage. She used a combine harvester for efficient harvesting and invested time in proper drying techniques. This improved the quality of her maize, allowing her to sell it for the full price of USD 250 per tonne.

Sokun's Results with proper practices:

Costs	Price per Unit (USD)	Quantity	Total (USD)
Harvesting (combine)	125.00	-	125.00
Drying (improved)	20.00	-	20.00
Labor and Transport	50.00	-	50.00
Total Costs	**-**	**-**	**195.00**

Revenue	Price per Unit (USD)	Quantity	Total (USD)
Maize (8 tonnes, good quality)	250.00	8 tonnes	2,000.00
Profit Calculation	**Revenue - Costs**		**1,805.00**

7.4 Record-Keeping: A Tool for Better Farming Decisions

Record-keeping is one of the most effective yet simple tools farmers can use to improve their farming practices and profits. By tracking every expense, activity, and sale, farmers gain a clear picture of their costs and income. This helps them identify areas for improvement, avoid unnecessary spending, and plan better for the future.

1. Why Record-Keeping Matters
2. Understand Your Profits: It shows exactly how much money you're earning and spending.
3. Find Cost-Saving Opportunities: Spot areas where you're overspending, like buying too much fertilizer or seeds.
4. Plan for the Next Season: Knowing your costs helps you budget for critical inputs like seeds, fertilizer, and labor.
5. Make Smarter Decisions: Records help you see which practices worked well and what can be improved for better results.

What to Record

Farmers should keep track of:

Expenses: Costs for seeds, fertilizer, pest control, labor, transportation, and equipment.
Yields: How much maize was harvested and its quality (e.g., moisture content).
Income: The quantity of maize sold and the price received.
Key Dates: Important activities such as planting, fertilizer application, pest control, harvesting, and selling.

Simple Example Record

Date	Expense/Income	Description	Amount (USD)	Notes
01/05/2025	Expense	Bought hybrid seeds	144.00	20 kg, high-quality seeds
15/05/2025	Expense	Fertilizer purchase	320.00	Urea, 400 kg
20/08/2025	Income	Sold maize (8 tonnes)	2,000.00	Good quality, $250/ tonne

Case Study 1: How record-keeping transformed Chan's farm

Chan's Challenge

Chan, a farmer in Tbong Khmum, had been growing maize for years but always struggled to save money for the next season. He never kept records of his expenses or sales, relying only on memory. At a training session, Chan learned about record-keeping. Initially skeptical, he decided to give it a try after realizing he didn't actually know where his money was going.

What Chan Discovered

After his first season of record-keeping, Chan reviewed his records and made some surprising discoveries:

Overusing Fertilizer: He was applying too much fertilizer, wasting USD 80 per hectare.

Buying Too Many Seeds: He planted 25 kilograms of seed per hectare instead of the recommended 20 kilograms, costing him USD 36 more per hectare.

Selling Too Soon: He rushed to sell his maize immediately after harvest when prices were low, missing the opportunity to earn USD 20 more per ton by waiting.

The Change

The next season, Chan used his records to guide his decisions:

1. He applied fertilizer more efficiently, saving USD 80 per hectare.
2. He followed the correct planting rate, saving USD 36 per hectare on seeds.
3. He waited until prices rose to sell his maize, earning USD 20 more per tonne.

These small changes increased his profit by USD 250 per hectare, translating to an extra USD 1,000 profit for his 4-hectare farm.

The Impact

With the additional income, Chan:

1. Paid off his debts.
2. Invested in better-quality seeds for the next season.
3. Saved money for his children's school fees.
4. Inspired other farmers in his village to adopt record-keeping.

Behaviour Change Insights

Social Proof: Chan was inspired by seeing how record-keeping worked for others.

Loss Aversion: Realizing he was wasting money motivated him to act.

Incremental Gains: Small changes in fertilizer use, seed purchase, and sales timing led to big improvements in his income.

How to Start Record-Keeping

1. Use a Notebook: Keep it simple. Write down every expense and income in one place.
2. Organize by Date: Track key activities like planting, fertilizer application, and harvesting.
3. Review Regularly: Check your records at the end of the season to understand your profit and identify areas for improvement.

Key Takeaway

Record-keeping is a simple but powerful tool that can help farmers like Chan improve their profits and decision-making. It's not about complicated systems - just tracking your expenses and income can make a big difference. Start today, and see how small changes can lead to big results!

7.5 Reflection questions for farmers

After each section, use these questions to encourage farmers to think critically about their practices and how they can improve:

1. Seed Selection and Planting Practices

- What kind of seeds are you currently using? Are they high-quality or low-cost seeds?
- How many kilograms of seeds do you plant per hectare? Is this the recommended amount?
- Have you noticed differences in your yield based on seed quality or planting density?

2. Fertilizer, Pest, and Crop Care Management

- How do you decide how much fertilizer to use and when to apply it? Do you use tools like the LCC?
- Do you check your fields regularly for pests or weeds? How do you decide when to act?
- Are there ways you could save money on fertilizers or pest control without reducing your yield?

3. Harvesting and Post-Harvest Management

- When do you usually harvest your maize? Do you check the moisture content before harvesting?
- How do you dry and store your maize? Have you experienced any issues like mold or spoilage?
- Have you tried selling your maize at different times to get better prices?

4. Record-Keeping

- Do you currently keep records of your expenses and income? If not, why not?
- What information would be most useful for you to track in your farming records?
- How could keeping records help you make better decisions for your farm?

Encouraging Behavior Change

- Group Discussions: Use the questions as prompts for group conversations so farmers can share their experiences and learn from each other.
- Practical Exercises: Have farmers create sample records for one planting season or estimate their expenses and profits for past harvests.
- Success Stories: Share examples of farmers who improved their profits by applying these practices and keeping records.

By reflecting on their current practices and considering new approaches, farmers can take small, manageable steps toward improving their yields, reducing costs, and increasing their income.

7.5 Reflection questions for farmers

After each section, use these questions to encourage farmers to think critically about their practices and how they can improve:

1. Seed Selection and Planting Practices

- What kind of seeds are you currently using? Are they high-quality or low-cost seeds?
- How many kilograms of seeds do you plant per hectare? Is this the recommended amount?
- Have you noticed differences in your yield based on seed quality or planting density?

2. Fertilizer, Pest, and Crop Care Management

- How do you decide how much fertilizer to use and when to apply it? Do you use tools like the LCC?
- Do you check your fields regularly for pests or weeds? How do you decide when to act?
- Are there ways you could save money on fertilizers or pest control without reducing your yield?

3. Harvesting and Post-Harvest Management

- When do you usually harvest your maize? Do you check the moisture content before harvesting?
- How do you dry and store your maize? Have you experienced any issues like mold or spoilage?
- Have you tried selling your maize at different times to get better prices?

4. Record-Keeping

- Do you currently keep records of your expenses and income? If not, why not?
- What information would be most useful for you to track in your farming records?
- How could keeping records help you make better decisions for your farm?

Encouraging Behavior Change

- Group Discussions: Use the questions as prompts for group conversations so farmers can share their experiences and learn from each other.
- Practical Exercises: Have farmers create sample records for one planting season or estimate their expenses and profits for past harvests.
- Success Stories: Share examples of farmers who improved their profits by applying these practices and keeping records.

By reflecting on their current practices and considering new approaches, farmers can take small, manageable steps toward improving their yields, reducing costs, and increasing their income.

Maize trade in Cambodia

A desktop review of maize trade in Cambodia yielded little useful information. Most reports seem to relate to official trade statistics whereas, it is clear that there is significant informal trade with Vietnam and Thailand. Pheakdey [13] described the maize production and marketing chain in Leuk Daek District, Kandal Province, Cambodia. These farmers sell maize to collectors, where 80% was exported to Vietnam with no regulation or rules.

Anecdotal evidence from interviews with traders in Battambang and Tbong Khmum Provinces suggests that maize is mainly sold to domestic feed mills or exported to Thailand. In 2014 maize was sold in wet and low-quality condition, for a low price. It appears that smallholder maize farmers in Kandal and Prey Veng Provinces could benefit from improvements in post-harvest drying of maize, which could improve access to the domestic market and possibly the Thai market (Figure 34).

Figure 34. Informal export pathways for maize in Cambodia. Improvement of post-harvest quality could be of benefit to smallholder maize farmers in Kandal and Prey Veng

References

1. https://www.fao.org/faostat/en/#data/QCL

2. Annual Report of Agriculture, Forestry and Fisheries 2016-2017 and Directions 2019-2020. Ministry of Agri-culture Forestry and Fisheries, Kingdom of Cambodia, 2020.

3. https://beamexchange.org/practice/programme-index/310/Annual Report of Agriculture, Forestry and Fisheries 2016-2017 and Directions 2019-2020. Ministry of Agriculture Forestry and Fisheries, Kingdom of Cambodia, 2020.

4. https://www.beckshybrids.com/resources/croptalk-newsletter/croptalk-soil-ph-and-nutrient-availability

5. https://www.fao.org/fishery/docs/CDrom/FAO_Training/FAO_Training/General/x6706e/x6706e06.htm

6. https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/summer-crop-management-guide

7. Canopeo application https://canopeoapp.com/#/login

8. https://www.syngenta.com/en/company/media/syngenta-news/year/2015/further-corn-trait-expansion-approval-vietnam

9. https://blog.plantwise.org/2017/07/17/the-life-cycle-of-fall-armyworm/

10. https://ppqs.gov.in/sites/default/files/faw_do.pdf

11. https://www.dpi.nsw.gov.au/agriculture/budgets/about

12. https://www.statista.com/statistics/675820/average-prices-maize-worldwide/

13. Pheakdey, D. Maize Production and Marketing in Leuk Daek District, Kandal Province, Cambodia. Mekong Institute. Research working paper series 2014 No 4., 2014.

Contact us:
cambodia@snv.org | snv.org