Australian Government

Australian Centre for International Agricultural Research

SUNFLOWER PRODUCTION GUIDE

FOR CAMBODIAN CONDITIONS

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

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FOREWORD

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

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

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

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

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

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

The project series has made a significant contribution to capacity building for provincial staff from the Ministry of Agriculture, Forestry and Fisheries, Universities, non-governmental organisations and the private sector for the implementation of new technologies and improved practices in upland agricultural production systems.

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

Nick Austin
Chief Executive Officer

CONTENTS

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ACRONYMS AND ABBREVIATIONS

ACIAR	Australian Centre for International Agricultural Research
AOF	Australian Oilseeds Federation
APSIM	Agricultural Production Systems sIMulator
GVB	Green Vegetable Bug
IPM	Integrated Pest Management
ML	Megalitre
PSPE	Post-Sowing Pre-Emergence
SLW	Silverleaf Whitefly
UNFCCC	United Nations Framework Convention on Climate Change

CROP DESCRIPTION

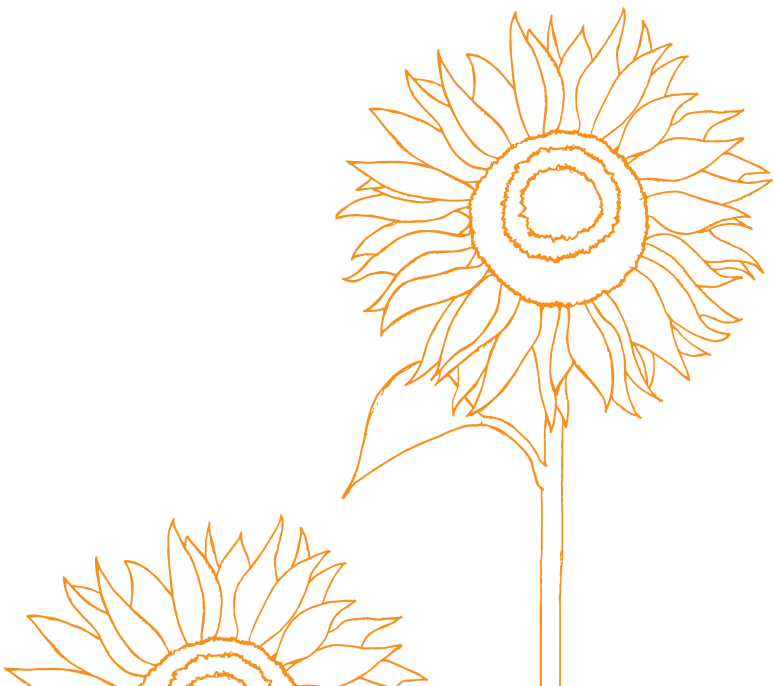
Key management tips

- Select soil that drains freely.
- Use high-quality seed and check the expiry date.
- Determine the amount of stored water in the soil profile prior to dry season sowing.
- If there is less than 80 cm of wet soil, consider not sowing sunflowers.
- Use no-till for non-irrigated crops to prevent loss of soil water and delayed sowing.
- Apply complete NPK fertilizer plus trace elements at sowing under non-irrigated conditions, as there is no opportunity for urea top-dressing in the dry season.
- Assess potential weed problems and carefully plan weed control options (there is no post-emergence broadleaf herbicide option).
- Under dry season conditions, it is essential to apply a pre-emergence herbicide, as weed control during the first four weeks after emergence is critical.
- A uniform crop stand and early canopy closure are essential to maximise crop competition with weeds.
- Monitor and, if necessary, control insects such as bean pod borer from budding through flowering.
- Assess the potential for rat, mice and bird damage.

Sunflower has been successfully grown as a post-monsoon season crop in field experiments in North-West Cambodia between 2012 and 2015. It has also been successfully grown previously in the post-monsoon season by farmers in Samlout and Pailin. Sunflower is well-suited to post-monsoon season cropping as it responds very well to no-till farming systems on the friable upland Ferrosols and Vertosols of Kamrieng, Malai, Pailin, Phnum Proek, Rotonak Mondul, Samlout, and Sampov Lun, districts. For soil type descriptions, see White et al. (1997).

Sunflowers have a strong taproot capable of extracting water from a depth of 2–3 m in ideal situations. They are best suited to well-drained deep clay loams with high water holding capacities. Sunflowers do not tolerate lengthy periods of waterlogging without suffering yield penalties. Sunflowers are highly suited to no-till sowing into residues of the main wet season crop.

Although sunflower is a new crop for Cambodia, recent demand for sunflower from oil crushing companies in Thailand has resulted in offers to Cambodian farmers to grow sunflowers under contract.



Seasonal sowing opportunities for sunflower

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

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

The trend to hotter and drier conditions between February and May have seen more frequent crop failures in upland areas. In recognition of this trend, Montgomery (pers. comm.) has proposed that the seasons be renamed as follows:

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

Sunflower is a drought-tolerant option for planting after the harvest of monsoon season crops; in September to November. Recent research suggests that a safer upland crop planting regime is to delay planting of pre-monsoon crops from February to May, followed by a late monsoon season crop planted in October, and leaving the pre-monsoon period for soil water recharge (ACIAR project ASEM/2010/049, Stephanie Montgomery and Touch Van pers. comm.; Figure 1).

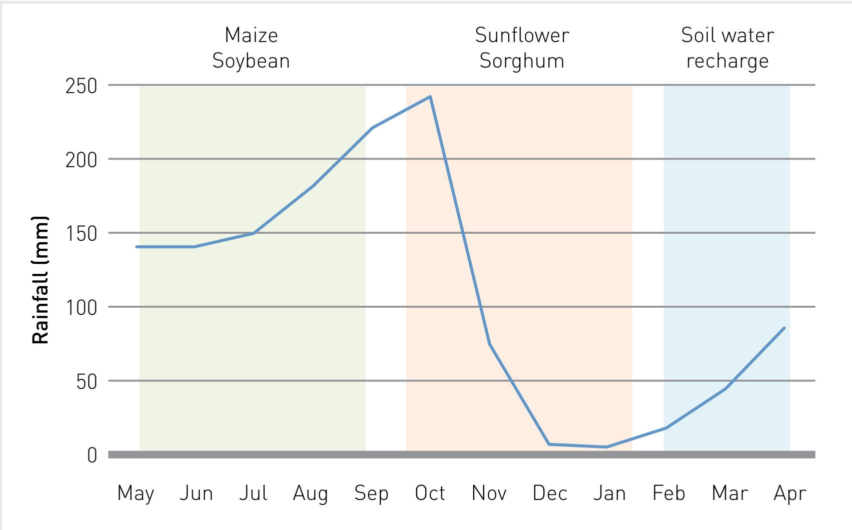


Figure 1. The best fit for sunflower in the cropping calendar for North-West Cambodia is October sowing

Yield potential of sunflower

Post-monsoon sunflower experiments were conducted on upland soils in North-West Cambodia between 2012 and 2015. Without irrigation or rainfall after sowing, sunflower can be expected to yield 1,000-1,400 kg/ha under no-till with good weed control and agronomy. On deeper soils with good ground cover mulch and good nutrition, yields of 2,400 kg/ha have been achieved from post-monsoon sowings.

The crops shown in Figure 2 (27 January 2014) and Figure 3 (4 March 2014) were 500 m apart. The crop in Figure 2 (current farmer practice) was planted after cultivation with a disc plough. This delayed planting and dried out the soil, resulting in poor crop establishment. Pre-emergence herbicide was not applied.

Figure 2. Sunflower can be grown successfully in the post-monsoon season with no-till, pre-emergence weed control and basal fertilizer application. Photo: R. Martin.

Figure 3. Ploughing delays planting, wastes soil moisture and reduces ground cover mulch. It is also likely to result in crop failure for post-monsoon season sunflower. Photo: R. Martin.

Field selection

For machine harvesting, fields selected for sunflower should be fairly uniform in soil type and crop residue cover, and be free of harvest impediments such as tree stumps and rocks. These are important considerations to avoid damage to harvesting equipment.

Field history

Sunflower has been successfully grown, with no-till or minimum-tillage, after sowing in October to November following main wet season maize or soybean crops.

Sunflower is sensitive to several residual herbicides, so caution needs to be exercised when selecting fields where residual herbicides, such as sulfonlyureas and atrazine, have been used.

Soil management

Sunflowers are best suited to deep soils in a no-till system. No-till sunflower planted on residual monsoon season soil moisture requires pre-emergence weed control. Combined with crop residue cover, this improves moisture retention, leading to consistently higher yielding sunflower crops. No-till increases the efficiency of preserving residual soil moisture after the monsoon season crop and reduces the risk of crop failure.

Residues of the previous crop should be chopped and left in the field to reduce soil surface temperature and soil water evaporation (Montgomery pers. comm.) No-till planting sunflower into crop residues at the end of the wet season is essentially a four-step process.

1. Maize stover, after hand picking, should be chopped to form a surface mulch. If a combine harvester has been used, there is no need for further chopping (Figure 4).
2. Pre-sowing herbicides should be applied immediately after chopping.

3. Planting with a no-till planter should be done approximately seven days after herbicide application (Figure 5).
4. Post-sowing pre-emergence herbicide should be applied, if required.

Figure 4. After combine harvesting, there is no need for further chopping of maize stover. Photo: R. Martin.

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

Row spacing and plant population

Sunflowers may be sown at row spacing ranging from 36–100 cm. Row spacing of 75–100 cm allows inter-row cultivation or shielded spraying as additional weed control options.

For dry season planting without access to irrigation, it is recommended that sunflower be planted with a row spacing of 75–100 cm.

Where there is access to supplementary irrigation, narrow rows (40 cm) are recommended because of:

> higher potential yields

> greater competition with weeds

> more even utilisation of moisture across the field.

Establishment of a uniform plant stand of adequate density is a critical first step to a successful sunflower crop. Precision planters place seed more accurately than conventional Thai-style planters. This usually results in better and more even establishment within the row, resulting in more uniform head size, stalk size and soil water use across a field.

The optimum plant population depends on the depth of wet soil at sowing and the availability of supplementary irrigation.

Seed for sowing averages 16,000 seeds/kg but can vary from 10,000-20,000 seeds/kg, depending on variety. The minimum germination percentage is usually greater than 90% but a germination test is recommended.

When calculating seed requirements, allow an extra 30% for establishment losses (see calculation below). Depending on planting conditions, establishment losses for sunflower can range from 20–50%.

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

> number of seeds/kg (seed size or seed weight)
> target plant population
> germination percentage (e.g. 90% germination = 0.9 in the formula)
> establishment: usually 70% or less (70% = 0.7 in the formula).

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

Worked example (good soil water):

$$\text{Sowing rate (kg/ha)} = \frac{5 \text{ plants/m}^2 \times 10{,}000}{0.9 \times 0.7 \times 16{,}000 \text{ seeds/kg}} = 5 \text{ kg/ha}$$

Experiments at Samlout and Pailin in 2012 showed that optimum sunflower plant populations varied according to sowing season and plant-available soil water, and these results were confirmed by APSIM simulations. For May to June sowing, the optimum plant population is 5-6 plants/m^2 and for October to November sowing, the optimum plant population is around 4 plants/m^2 (Figure 6).

It is suggested that the target plant population be adjusted according to the amount of available soil water. If water is limited by low soil moisture or soil depth <1 m, then a seeding rate of 3-4 kg/ha is recommended (adjusted according to the seed size – see above equation).

If there is good soil moisture and soil depth >1 m, then a seeding rate of 4-5 kg/ha is recommended. Under irrigation, seeding rates could be raised to 6-7 kg/ha.

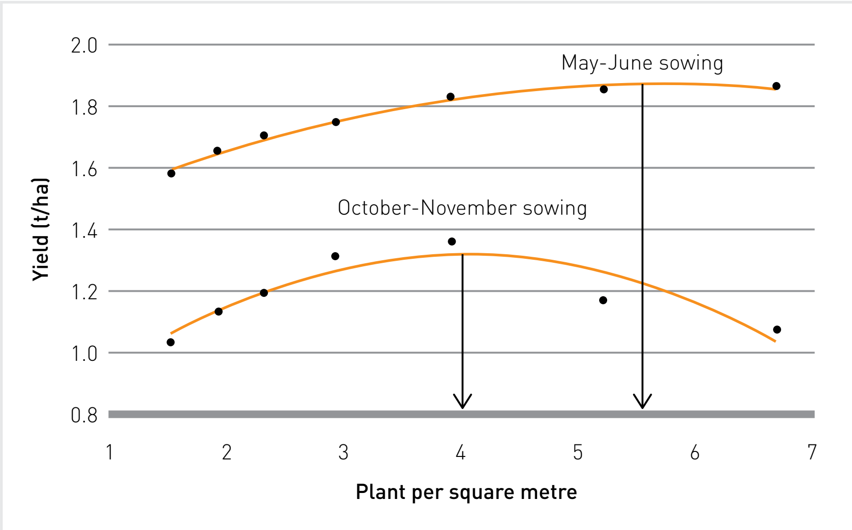


Figure 6. Relationship between plant population and yield of sunflower (Agricultural Production Systems sIMulator - APSIM simulations)

Sowing depth and crop establishment

Sowing depth is dictated largely by available moisture and the soil type. Sowing depth is most commonly 3–5 cm. Press wheels are essential for obtaining good seed-soil contact under no-till conditions.

Seed is usually pre-treated with insecticide to provide protection against soil-dwelling insects.

Varieties

Two sunflower hybrids were available for sowing in North-West Cambodia in the 2014-15 dry season.

SY 3950 HO (Syngenta, Thailand)

SY 3950 HO is a high-oleic sunflower hybrid which was tested at Pailin in the 2013-14 dry season and yielded 1,325 (976-1,644) kg/ha. Flower buds appeared at about 40 days and physiological maturity was 110 days after sowing. The oil content was 40.3% with 88.2% oleic acid and 3.2% linoleic acid.

Olisun 3 (Pacific seeds, Thailand)

Olisun 3 is also a high-oleic sunflower hybrid that has been tested in North-West Cambodia since 2012. It is grown widely in Thailand and has similar maturity to SY 3950 HO, i.e. 110 days to physiological maturity. The oil content in 2014 was 44.2% with 81.7% oleic acid and 10.7% linoleic acid. The low oleic oil content of Olisun 3 is of concern as it is usually expected that this should be >85%.

Growth and development

Germination and emergence

The rate of emergence for sunflower can vary, but usually it takes between five and 10 days, however it may be up to 30 days in certain situations. The speed of germination is critical for dry season sunflower because the seedbed moisture declines quickly if there is no rain after sowing.

Seedling vigour as well as high germination percentage is critical. Old seed can have >90% germination but low vigour. It is recommended to check the expiry date for the seed on the packet and if in doubt, conduct a germination test and record the speed of germination.

Vegetative growth to bud initiation

Sunflower can tolerate temperatures ranging from 8°- 34°C during growth but grows best between 25°- 28°C.

Between November and March, the average minimum and maximum temperatures at Battambang town are 21°C and 32°C respectively (Figure 7).

Leaf formation and development is initially controlled by sunlight, but is most influenced by hybrid, day length and nutrition. Leaves initially develop in pairs and then emerge as singular alternate leaves up the stem.

Sunflower has a taproot which, as a general rule, is equivalent to or greater than the plant height in rooting depth. For example, when the plant has 8–10 leaves (~25-30 cm tall) the taproot is about 40-50 cm deep. The taproot reaches its maximum depth at flowering. Sunflower taproots allow the crop to extract more water than sorghum or maize.

Wilting in the middle of the day in hot dry conditions is common in sunflower, as the plant does not have the ability to close leaf stomates to reduce transpiration losses.

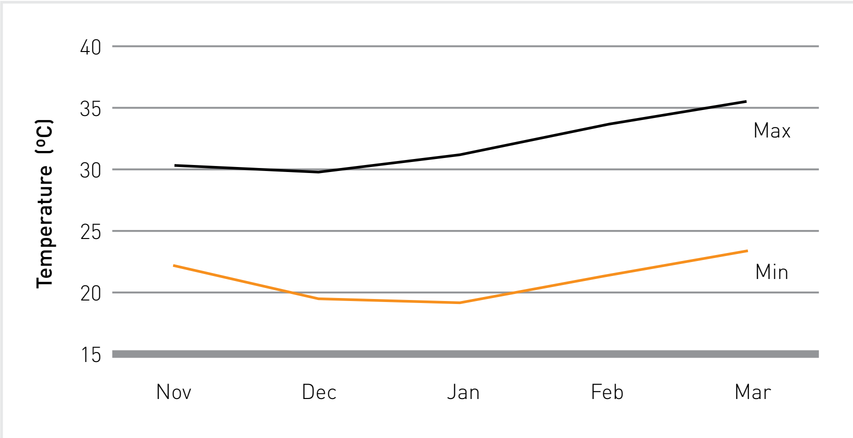


Figure 7. Average monthly maximum and minimum temperatures at Battambang

Growth stages of sunflower

Bud initiation to start of flowering

Once bud initiation starts, no more leaves will develop, but the leaves will continue to unfold. During leaf development, the plant is responsive to day length, with photoperiod affecting the speed of development. Day length at Battambang ranges from 11½ hours in November to 12 hours in March, and it is expected that day length will not have a significant effect on sunflower growth and development. The beginning of flowering occurs when the terminal bud forms a miniature floral head rather than a cluster of leaves. When viewed from directly above, the immature bracts form a many-pointed star-like appearance (Table 1).

Figure 8. R1 stage beginning of flowering

Table 1. Sunflower growth stages (after Schneiter et al. 1981).

Stage	Title	Description
Vegetative stages		
VE	Emergence	Seedling has emerged and the first leaf beyond the cotyledons is less than 4 cm long.
V1-VN	First to Nth leaf	These are determined by counting the number of true leaves at least 4 cm in length beginning as V-1, V-2, V-3, V-4, etc. If senescence of the lower leaves has occurred. count leaf scars (excluding those where the cotyledons were attached) to determine the proper stage.
Reproductive stages		
R1	Star	The terminal bud forms a miniature floral head rather than a cluster of leaves. When viewed from directly above, the immature bracts form a many-pointed star-like appearance.
R2	Immature bud	The immature bud elongates 0.5-2.0 cm above the nearest leaf attached to the stem. Disregard leaves attached directly to the back of the bud.
R3	Bud elongation	The immature bud elongates more than 2.0 cm above the nearest leaf.
R4	Opening flower	The inflorescence begins to open. When viewed from directly above, immature ray flowers are visible.
R5	Flowering stages	Decimal: (i.e. R-5.1, R-5.2, R-5.3, R-5.4, R-5.5 through R-5.9, etc.). This stage is the beginning of flowering. The stage can be divided into substages dependent upon the percent of the head area (disk flowers) that has completed or is in flowering. E.g. R-5.3 (30%), R-5.8 (80%) etc.
R6	Flowering complete	Flowering is complete and the ray flowers are wilting.
R7		The back of the head has started to turn a pale yellow color.
R8		The back of the head is yellow but the bracts remain green.
R9	Physiological maturity	The bracts become yellow and brown. This stage is regarded as physiological maturity.

Start of flowering to physiological maturity

Once the ray petals are fully open, flowering will commence. Sunflower heads turn to follow the sun during the day, referred to as heliotropism, which increases photosynthesis by 9%. This will cease at flowering, at which point most of the heads remain facing north-east.

The sunflower head consists of the yellow ray petals, which have a minimal role but are highly attractive to bees and other insects, and the disc flowers which form the face of the head, and are the start of developing seeds.

Disc flowers progressively open in concentric rings, beginning from the outside and working towards the centre. Individual disc flowers complete flowering in three days, however between one and four rings of flowers open each day, usually over a period of five to 10 days (Figure 9).

There are between 800 and 3,000 disc flowers per head, each of which is capable of producing a seed.

Figure 9. Sunflower at R5.5 reproductive stage – 50% of florets completed flowering. Photo: R. Martin.

Sunflower hybrids are generally self-pollinating, however a large number of bees, especially Asian honeybee (*Apis cerana*) normally invade the crop during flowering (Figure 10). Langridge et al. (1974) found that bee pollination can increase sunflower yield by 60%. Trials in Pailin in 2013-14 showed there is potential to introduce hives of Asian honeybee to sunflower fields to increase pollination and yield.

Figure 10. Honey bees can increase seed yield of sunflower. Photo: R. Martin.

Figure 11. A sunflower at reproductive stage R6 (70 days). The ray florets have wilted and flowering is complete. Photo: R. Martin.

Physiological maturity

Moisture stress is important at two critical stages: head formation to the start of flowering (which affects seed yield), and grain fill when oil content will be reduced. The combination of high temperatures and moisture stress can drastically reduce yield and oil content. If supplementary irrigation is available, it could be applied at this time.

At the end of flowering, the ray petals will wilt (Figure 11) and fall off, and this is referred to as petal drop. The disc flowers will also fall off just prior to physiological maturity.

Sunflowers reach physiological maturity when the bracts around the back of the sunflower head turn brown (Figure 12). This is usually occurs five to six weeks after the start of flowering. At this point, the sunflower seeds have completed filling and their moisture content is approximately 30%.

From physiological maturity to harvest the sunflower plant and seeds lose moisture (dry down). Physiological maturity is the correct time to apply a desiccant if needed.

Figure 12. Sunflower at physiological maturity (110 days). Photo: R. Martin.

Nutrition

Sunflowers require adequate nutrition yet they have a significantly lower requirement for several of the major nutrients when compared to other crops. Table 2 shows the amount of each nutrient contained in the seed, stover (all other parts of the plant) and as a total.

Table 2. Sunflower nutrient removal (kg/ha).

Yield	1.0 t/ha			2.5 t/ha		
Nutrient	Seed	Stover	Total	Seed	Stover	Total
N	26	14	40	60	35	95
P	4	1	5	9	3	12
K	8	22	30	18	55	73

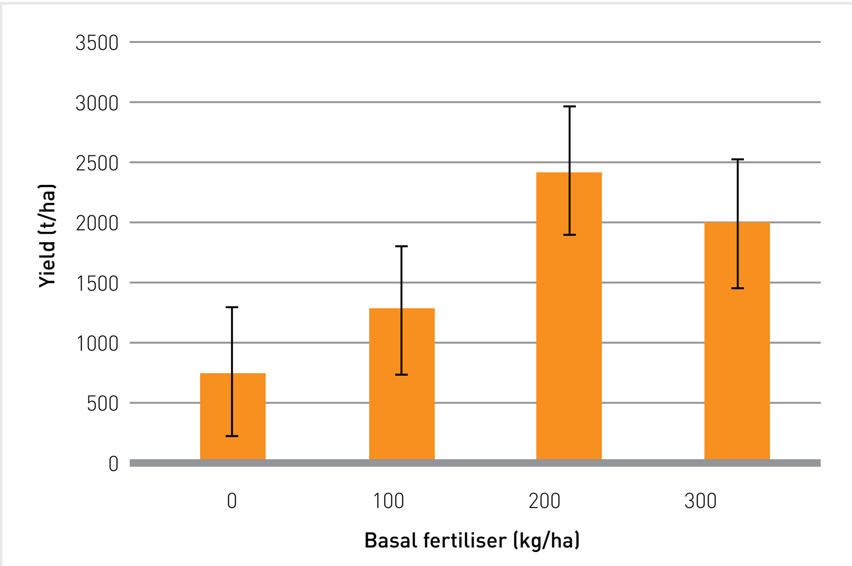


Figure 13. Effect of basal fertiliser, 20:20:15 ($N:P_{205}:K_{20}$) + trace elements, on achene yield of sunflower (kg/ha)

In 2013-14, a sunflower fertilizer experiment was conducted at Pailin (Martin et al. 2015).

The results suggest that at least 100 kg/ha of NPK fertilizer applied at sowing is required to achieve an economic yield (Figure 13). It seems that yields of up to 2,400 kg/ha can be obtained with 200 kg/ha NPK fertilizer.

The experiment also included urea topdressing treatments of up to 150kg/ha urea, however there was no response since there was no rain or irrigation to take the fertilizer into the sunflower root zone.

Sunflower is very susceptible to boron deficiency and this has been recorded on sunflower at Pailin and Kampong Thom (Figure 14).

Figure 14. Boron deficiency in sunflower. Photo: R. Martin.

Symptoms of boron deficiency include curling, chlorosis and necrosis of leaves. Symptoms first appear on older leaves and move up the stem. In acute deficiency, flower stalks may break and flower heads fall off.

Irrigation

Where irrigation is available there is a potential to achieve higher sunflower yields. Care should be taken with irrigation systems not to create an environment favourable to diseases such as powdery mildew.

Sunflower yields will be reduced by waterlogging, so quick, even and efficient irrigation is important. The maximum depth of water extraction is thought to be reached at 50% flowering. Root growth occurs at a rate of 3.2-3.5 cm per day, with the extraction front proceeding at around 3.8 cm per day.

Water uptake peaks at about 40 days after sowing or at budding (R1). Sunflower water use in NSW, Australia is 4.5–7.5 ML/ha. This demand can be met by a combination of stored soil moisture, rainfall and irrigation.

Water stress between flowering and maturity has the biggest impact on grain yield. Sunflowers have a relatively low demand for water until about 10 days after buds are visible. The demand for water then increases dramatically until approximately 26 days after 50% flowering. The recommended times for surface irrigation are:

1. prior to sowing – pre-water fields
2. budding – first irrigation
3. start of flowering – second irrigation
4. early seed fill– third irrigation.

Caution should be exercised if using overhead irrigation, to try and avoid irrigation during the period of flowering, to ensure seed set is not affected. Furthermore, irrigating too late into seed fill will increase the risk of fields remaining wet at harvest, reducing machinery access and potentially causing compaction.

Weed management

Weed management tips

- Include cereal crops (rice, maize) in the rotation.
- Avoid fields with a broadleaf weed problem.
- Control weeds, especially those that reproduce vegetatively, before sowing.
- Use a post-sowing, pre-emergence herbicide as a priority.
- Apply post-emergence herbicide for control of grass weeds if necessary.
- Prevent weeds from setting seed during the crop cycle and post-harvest.

Integrated weed management

In the upland situation in Cambodia, water is often the most critical factor for reducing potential crop yield. Crops can fail because of heat and drought, especially in the pre-monsoon season when rainfall is variable and unreliable. Good weed control is essential under these conditions, especially before sowing, to avoid the depletion of sub-soil water by competing weeds.

Significant yield losses occur if weeds are not controlled in sunflower immediately after planting. For post-monsoon crops, pre-sowing or post-sowing pre-emergence weed control is essential. Post-emergence herbicide applications have been shown to be ineffective because weeds are water-stressed in the dry conditions (Martin et al. 2015).

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

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

Chemical weed control options

Table 3. Herbicides registered in Cambodia that can be used in sunflower (see also Appendix 1.

Active ingredient	Group	Pre-plant	Post plant pre-em	Post-em	Harvest desiccation
2,4-D	I	✓			
Glyphosate	M	✓			✓
Alachlor	K		✓		
Pendimethalin	D		✓		
S-metolachlor*	K		✓		
Fluroxypyr	I			✓	
Fluazifop-p	A			✓	

Good weed control is essential for high yielding sunflowers. The first four weeks after emergence is the most critical period for weed competition in dry season sunflower.

Early sunflower growth can be reduced by as much as 40% without effective weed control. Additionally, weeds can also harbour pests and diseases of the crop.

Fields with high broadleaf weed populations should be avoided as there are no in-crop control options for broadleaved weeds available for sunflower in Cambodia. Post-sowing pre-emergence application of pendimethalin or s-metolachlor are options for controlling several grass and broadleaf weeds in sunflower.

In an experiment at Pailin in the 2013-14 dry season, post-sowing pre-emergence (PSPE) application of alachlor and s-metolachlor gave 88% and 93% reduction of weed biomass in sunflower respectively.

Herbicides are available for post-emergence control of grass weeds in sunflower. These include fluazifop and quizalofop. However, in the above experiment, quizalofop, paraquat and hand-weeding had no significant effect on sunflower grain yield.

S-metolachlor gave significantly higher grain yields compared to alachlor and increased grain yield by 49% compared to nil PSPE herbicide application. The sunflower plant population for s-metolachlor was 34% greater than nil PSPE herbicide application. This suggests that weed competition for soil water immediately after sowing has the greatest impact on sunflower yield. PSPE herbicide application is therefore essential for dry season sunflower sowing.

DISEASES

Disease management tips

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

The main diseases of sunflower are usually related to weather conditions. In order to minimise field losses from diseases, rotate crops to include non-susceptible hosts.

Sunflower is a new crop for Cambodia and no diseases have been recorded to date. Elsewhere, common diseases of sunflower include powdery mildew, *Alternaria*, *Sclerotinia*, *Phoma* black stem and *Phomopsis* stem canker.

Figure 15. Severe *Alternaria* blight in sunflower. Photo: G. Kong.

Alternaria blight (*Alternaria helianthi*)

Symptoms

This disease appears as roughly circular/angular dark brown to black spots on the lowest leaves. Stems, petioles, flower bracts and petals can show symptoms under favourable conditions. Disease spots may be surrounded by yellow halos. If the disease infects a leaf vein, a long black area may develop following the vein and leading to quicker rapid blackening of the leaf. Severe infection may cause premature death and shrivelling of leaves with a dark brown colour (Figure 15).

Note: This disease can be confused with Septoria leaf spot (*Septoria helianthi*). The most obvious difference is that Septoria causes a large lighter brown spot often without a halo, whereas *Alternaria* causes a black lesion, usually with a halo. Septoria is generally a less damaging disease of the lowest leaves.

Conditions favouring development

Spores are airborne and survive on crop residues, self-sown and wild sunflowers. *Alternaria* is favoured by wet, warm weather (26–30° C) over three to four days, especially at flowering. Successive wet cycles can accelerate epidemic development, causing leaves to fall off. Plants are more susceptible as seedlings and at flowering.

Management

Avoid planting near standing sunflower crop residue which may be harbouring the pathogen.

Figure 16. Charcoal stem rot of sunflower. Photo: S. Thompson.

Charcoal stem rot (*Macrophomina phaseolina*)

Symptoms

Diseased stalks can be discoloured at the base, with the pith having a peppery grey appearance (Figure 16). Severely infected stems can appear whitened with an ashy or silvery grey appearance as the stems dry out. In conditions of high soil temperatures and low soil moisture, plants can rapidly die off; leading to smaller head diameters and/or lower seed weights. Severe infection can also impact on oil composition.

Conditions favouring development

Charcoal rot usually occurs in moisture-stressed crops when soil temperatures are above 35°C. It is a disease of many crop and weed species, and often does not show until the crop becomes stressed. Microsclerotes (which cause the peppery appearance in the pith) are survival structures which can survive in the soil for many years, infecting both grasses and broadleaved species.

Management

Avoid any management practices which will stress the crop, such as water stress, excessive nitrogen, low potassium or herbicide injury etc.

Stress of irrigated crops can be reduced by irrigating to avoid moisture stress during the stage of seed fill. Crop rotations with sorghum or corn following sunflower help limit build-up of this disease. Rotating with more susceptible crops, such as mungbean and soybean can lead to a build-up of disease spores.

Fungicides can act as effective seed treatments.

Figure 17. Rhizopus head rot in sunflower. Photo: S. Thompson.

Rhizopus head rot (*Rhizopus spp.*)

Rhizopus head rot is a common disease in sunflowers.

Symptoms

The infected area in the back of the head develops a brown colour and can become sunken with a very soft and mushy, water-soaked appearance (Figure 17). If infection is advanced, the inside of the head will appear brown, sometimes with a dark grey/black peppery appearance caused by fruiting bodies (sporangia).

The sporangia can be confused with the small black sclerotes of charcoal rot. Generally, the mushy, water-soaked appearance of the head is characteristic of *Rhizopus*, often with dark greyish fungal threads giving a cotton-wool type effect on the front of the head. Heads can dry prematurely, shrivel and sometimes shred.

Conditions favouring development

Rhizopus head rot is promoted by insect, bird, mouse or hail damage to the back of the head, combined with warm, humid conditions.

Management

Limiting insect, rat or bird damage will reduce the risk of infection.

Figure 18. Sunflower rust. Photo: S. Thompson.

Rust (*Puccinia helianthi*)

Symptoms

Look for small reddish-brown pustules of dark brown dust-like spores that will rub off onto the end of your finger. This is a good check to limit confusion with early *Alternaria* infection. Infection starts on the underside of the lowest leaves, moves to both upper and lower leaf surfaces and can progress up the plant to infect the flower bracts if conditions are ideal (Figure 18).

Conditions favouring development

Rust spores are spread by wind. The pathogen can also survive in crop residues as telia, large blackish fruiting bodies which develop amongst the reddish brown pustules in cool conditions. Wild sunflowers and self-sown sunflowers also contribute to spore build- up.

Rust epidemics are favoured by successive cycles of moist, warm weather (around 18–23°C). Moisture from light rainfall or dew is enough to cause infection. Leaf wetness for at least 10–12 hours is ideal.

Figure 19. *S. sclerotiorum* sclerotia in stem and base of sunflower. Photo: S. Thompson.

Sclerotinia stem and head rot (*Sclerotinia minor, Sclerotinia sclerotiorum*)

Sclerotinia species have a wide host range of broadleaved crops and weeds, including soybeans, vegetable crops, legumes and sunflowers. A build-up of *Sclerotinia* is often the result of inappropriate rotational choices, although floods can carry sclerotes to previously clean fields. Generally, planting cereal crops (e.g. rice, maize) after sunflower is the best option to limit disease build-up if *Sclerotinia* is present.

Symptoms

Basal and mid-stem lesions usually don't appear before budding. A light brown lesion will develop either at the base or along the stem (*S. minor*) (Figure 19) eventually encircling the stem and causing the plant to either lodge or die early. Dark orange bands may stripe the basal lesion and a darker edge may develop as the lesions age. *S. sclerotiorum* can also cause head infection.

The pith inside the stem and head becomes filled with a white cottony fungal growth, sometimes extending outside the stem. Both species produce sclerotes, small, black irregularly-shaped survival structures which develop in the infected tissue and can survive many years in the soil.

The sclerotes of *S. minor* are smaller than those of *S. sclerotiorum* and are a useful diagnostic feature. As the disease develops, stems and heads often shred which releases the sclerotes into the soil as the plants lodge or the heads fall apart.

Conditions favouring development

Sclerotinia minor will infect during warmer conditions whereas *S. sclerotiorum* is favoured by cool, wet weather (less than 18°C; 15–17°C is ideal) which allows germination of the sclerotes in the soil.

Management

As the sclerotes can survive in plant debris and the soil for many years, rotation with non-susceptible crops is an important management tool. Crop residues protect the sclerotes and delay breakdown, and many weeds are significant hosts. Weed control is essential.

Sclerotes are also easily transported on machinery, boots, plant debris and water. Good farm hygiene will help limit spread.

Figure 20. Powdery mildew on sunflower. Photo: S. Thompson.

Powdery mildew (*Golovinomyces cichoracearum*)

Powdery mildew is favoured by mild, humid conditions.

Symptoms

Powdery mildew appears as greyish-white spots of fungal threads (Figure 20), firstly on the lower leaves and then spreading up through the plant canopy if favourable conditions persist. The fungal threads grow across the leaf surface and a large number of spores are produced, giving the leaves a powdery appearance. Severe infections can cause leaf death and pinched seed.

Conditions favouring development

Powdery mildew prefers cool conditions with high humidity. Spores germinate at 20–25°C under high humidity, in as little as two to four hours. Under ideal conditions, the life cycle can be complete in five to seven days; hence the build-up of powdery mildew within a crop can be very rapid. Regular crop inspections are essential if conditions favour powdery mildew build-up.

Management

Propiconazole (250 g/L) at one to two applications, at a rate of 250–500 mL/ha can be applied before 5% ray floret emergence. One application of 500 mL/ha around the time of bud initiation will give good control of powdery mildew under moderate disease pressure until physiological maturity.

Figure 21. *Phomopsis* stem canker of sunflower. Photo: T. Gulya.

Phomopsis stem canker (*Phomopsis helianthi*)

Phomopsis helianthi can cause losses of up to 50%.

Symptoms

Characteristic brown lesions dot the stems at the nodes (Figure 21), similar to those of *Phoma* black stem (*Phoma* spp.) which displays black lesions dotted at the nodes and is less damaging. Yield losses are caused by pith breakdown, behind the lesions and throughout the stem, as the disease progresses. Lesions extend above and below the node as the plant ages and often develop a darker edge. Mid-stem lodging may occur. Dark coloured fruiting bodies (pycnidia) may be seen as a speckle of dots at the site of the lesion as the stems dry out.

Conditions favouring development

Warm wet conditions favour the disease, with optimal temperatures for infection of 23–25°C. Infection occurs via the leaf margin and progresses down the leaf stem to the node where the characteristic brown lesion becomes evident on the stems from flowering onwards.

Management

Phomopsis spp. can survive on crop residue, and crop residue management is essential to limit disease build-up. Burial to 15 cm is recommended. Strategic burial or processing of crop residue should be considered to control spread and survival of this pathogen.

Rotation away from sunflower for a minimum of three to five years is recommended. Good farm hygiene will limit the spread of the pathogens on plant debris.

Care should be taken when allowing farm equipment, such as contract headers, onto the farm if they come from fields where crops have been infected.

Phomopsis species may be seed-borne, however no information is available for the significance of seed borne infection.

Residues will tend to persist for longer periods in alkaline soils and dry conditions, which are unusual for Cambodia.

INSECT PESTS

Insect management tips

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

Very little is known about potential insect pests of sunflower in Cambodia. In other countries, pests of seedling sunflower include cutworms, wireworms, adults and larvae of false wireworms, and field crickets. Potential pests from budding to maturity are green vegetable bug and *Heliothis* caterpillars. Check the seedbed before planting and check the crop regularly and thoroughly for insect pests. Spray only when the insect population exceeds the economic threshold and only use registered insecticides.

Figure 22. The green vegetable bug (Nezara viridula).

Green vegetable bug (*Nezara viridula*)

Damage

The green vegetable bug (GVB) is a sap sucking insect that could damage sunflower during the reproductive stage (Figure 22). It needs to be monitored because of its abundance, widespread distribution, rate of damage and rate of reproduction. GVB can appear suddenly in sunflower crops, especially when adjacent infested crops such as soybean are harvested when sunflowers are at the reproductive stage.

Natural enemies

It is best to take an integrated pest management (IPM) approach to manage GVB since the insects cause little or no damage to sunflowers in the vegetative stage. Spraying broad-spectrum insecticides early in the crop can seriously reduce the populations of beneficial insects. Natural enemies of GVB include the tachinid fly, *Trichopoda spp* and the wasp, *Trissolcus basalis* (Figure 23).

Trichopoda is a genus of small, brightly-coloured flies that range in size from 5-13 mm (Figure 23a). The flies have a distinctive fringe on the hind legs. The eggs are laid on adult or late nymphal stages of GVB. On hatching, the maggot bores into the body of the host. *Trichopoda* species have been released as a biological control for GVB in various parts of the world. Parasitism rates can be as high as 50%.

Figure 23. *Trichopoda* spp. Photo: Robin Gunning (left) and *Trissolcus basalis*. Photo: Tanya Smith (right).

Trissolcus basalis is a very small black wasp about 2 mm long (Figure 23b). *T. basalis* usually occurs in all crops attacked by GVB. It lays its eggs inside the GVB eggs thus killing them. *Trissolcus basalis* can reduce GVB numbers by more than 50%.

IPM for green vegetable bug

The GVB spray threshold is one adult per m^2. Crops should be inspected for GVB regularly, from budding until close to harvest. Monitor populations using the beat sheet method and spray once numbers reach thresholds, taking into account the likely returns from the crop.

Figure 24. Bean pod borer. Photo: Im Sophoeun.

Bean pod borer (*Helicoverpa armigera*)

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

Damage

Heliothis feed on leaves, buds and the face and back of heads (Figure 24). Developing buds may be damaged. Caterpillars bore holes into the backs of heads and predispose the plant to *Rhizopus* head rot, which is a major problem. Sunflower can tolerate large numbers of *Heliothis* caterpillars, especially from flowering onwards. There is no significant yield reduction documented in the absence of secondary head rots. Larvae are difficult to control when feeding on the sunflower face and under bracts, especially once the head turns over.

Threshold

At budding, more than four 5 mm long larvae per head is the threshold for spraying. Natural mortality rates of 30% for larvae less than 5 mm are common and should be taken into account. Therefore, by including expected mortality, the threshold for larvae in the 1–5 mm size range is six larvae per head.

Management

Choose control options that are compatible with a Heliothis insecticide resistance management strategy. Normally, insecticide applications are only effective until the heads turn to face the ground.

Figure 25. Whitefly. Photo: R. Gunning.

Whitefly (*Bemisia tabaci*)

Description

Adult *Bemisia* are soft and whitish-yellow when they first emerge from the nymph (Figure 25). Within a few hours, the wings become iridescent white due to a powdery wax. The body remains light yellow with a light dusting of wax. The female is 0.96 mm long and the male is slightly smaller (0.82 mm).

Damage

First discovered in Australia in 1994, silverleaf whitefly (SLW) pose a greater threat than greenhouse whitefly to field crops. SLW can cause significant damage to a wide range of broadleaf crops, including sunflower, mungbean, soybean, peanut and cotton.

SLW has a very wide host range (over 500 plant species globally), a high reproductive capacity and an ability to develop resistance to insecticides within two to three generations.

Management

Immature SLW are susceptible to attack by several wasp species, big-eyed bugs, lacewing larvae and ladybeetles. Maintaining beneficial insects in sunflowers can therefore play an important role in reducing the number of SLW. Maintenance of clean fallows and consideration of nearby host crops also play a role in managing SLW.

Harvesting and desiccation

Sunflower harvesting is best carried out as close to 9% seed moisture content as possible. There is a tendency to overestimate moisture content of a sunflower crop, meaning harvest is often delayed until moisture contents are on average 7%. This results in a loss in yield and more difficulty in obtaining a clean sample.

As sunflowers become drier and more brittle, the bracts and parts of the head break into small pieces which are difficult to separate from the seeds. As a result, admixture levels are usually higher when moisture contents are lower at harvest. Sunflower trays can be fitted to the cutter bar to reduce head shattering and harvest losses (Figure 26).

Figure 26. Sunflower trays fitted to the harvesting machine will reduce harvest losses. Photo: R. Martin.

Harvesting sunflowers when they are too moist leads to problems with threshing the heads as these retain a significant amount of moisture, particularly in the pith. Slow drum speeds aid in harvest. Speeds of around 450 rpm for conventional headers are suggested. Fan speeds should be fairly fast, but will often depend on the size of the seed (figure 27).

Receival standards

On receipt at the warehouse, the seed delivered by the grower will be inspected with regard to the buyer standard specifications: moisture content <10%; foreign matter <3%; small or immature seed <5%.

Deductions will apply to consignments that do not comply with these specifications; see Tables 4, 5 and 6.

Figure 27. Quality testing for sunflower. Photo: R. Martin.

Table 4. Moisture content deductions

(%)	Deduction (kg/100 kg)
0.0 – 10.0	Nil
10.1 – 10.5	0.6
10.6 – 11.0	1.2
11.0 – 11.5	1.8
11.6 – 12.0	2.4
12.1 – 12.5	3.0
12.6 – 13.0	3.6
Over 13.1 (Fail)*	25

Table 5. Foreign matter deductions

(%)	Deduction (kg/100 kg)
0.0 – 3.0	Nil
3.1 – 3.5	1.0
3.6 – 4.5	2.0
4.6 – 5.5	3.0
5.6 – 6.0	4.0
Over 6.1 (Fail)*	25

Table 6. Deductions for small and immature seed

%	Deduction (kg/100 kg)
0.0 – 5.0	Nil
5.1 – 6.0	1.0
6.1 – 7.0	2.0
7.1 – 8.0	3.0
8.1 – 9.0	4.0
Over 9.1 (fail)*	25

* The grower has the option to re-process consignments that fail to meet specification with regard to the quality standards, and return the consignment for re-testing.

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Appendix 1. Herbicide options for weed control in sunflower

			Pre-sowing		Post-sowing pre-emergence				Post emergence	
Khmer name	Scientific name	Type	Glyph-osate	2,4-D	Alachlor	Imaze-thapyr	Pendim-ethalin	S-met-olachlor	Flura-zifop	Quizal-ofop
Kravanh Chruk	*Cyperus rotundus**	Sedge	✓							
Smao Ko	*Brachiaria reptans*	Grass	✓		✓			✓		
Smao Chenh Chean	*Cynodon dactylon**	Grass	✓						✓	✓
Smao Cheung Kras	*Dactyloctenium aegyptium*	Grass	✓							✓
Smao Sambok Mon	*Digitaria spp.*	Grass	✓		✓	✓	✓	✓	✓	✓
Smao Bek Kbal	*Echinochloa colona*	Grass	✓		✓	✓	✓	✓	✓	✓
Smao Samsorng	*Eleusine indica*	Grass	✓		✓	✓		✓	✓	
Sbauv Klang	*Imperata cylindrica**	Grass	✓							
	Leptochloa chinensis	Grass	✓							✓
	*Melinis repens**	Grass	✓							
Boart Salay	*Sorghum bicolor*	Grass	✓			✓			✓	✓
Treng	*Sorghum halepense**	Grass	✓			✓			✓	✓
Kantraing Kath	*Ageratum conzoides*	Broadleaf	✓	✓				✓		
Phti Banla	*Amaranthus spinosus*	Broadleaf	✓	✓	✓	✓	✓	✓		
Phti Daung	*Amaranthus viridus*	Broadleaf	✓	✓	✓	✓	✓	✓		
	Bidens pilosa	Broadleaf	✓	✓				✓		
Phti Thmar	*Boerhavia diffusa**	Broadleaf		✓						
Maam Phnom	*Borreria alata*	Broadleaf						✓		
Kos Ambeng	*Cardiospermum halicacabum*	Broadleaf								
Slab Tea	*Comellina benghalensis**	Broadleaf	?	✓				✓		
	Crassocephalum crepidioides	Broadleaf	✓	✓						
Changkrang Svar	*Crotalaria pallida*	Broadleaf	✓							

Khmer name	Scientific name	Type	Pre-sowing		Post-sowing pre-emergence				Post emergence	
			Glyphosate	2,4-D	Alachlor	Imazethapyr	Pendimethalin	S-metolachlor	Fluazifop	Quizalofop
Mok Chhneang	*Eclipta prostrata*	Broadleaf								
Tuk Das Khla Thom	*Euphorbia heterophylla*	Broadleaf								
Sandar Chhou	*Ipomoea triloba*	Broadleaf		✓		✓				
Voir Mouy Lib	*Ipomoea obscura*	Broadleaf		✓		✓				
Phreah Khlob Damrei	*Mimosa invisa**	Broadleaf								
Phreah Khlob	*Mimosa pudica**	Broadleaf								
Sav Mao Prey	*Passiflora foeteda**	Broadleaf	✓					✓		
Pang Pos Srom	*Physalis angulata*	Broadleaf	✓							
Kambet Chun	*Portulaca oleracea*	Broadleaf	✓	✓	✓		✓	Đ(S)**		
	Richardia brasiliensis	Broadleaf					✓			
Kantraing Bay Sar Nhi	*Sida acuta*	Broadleaf	✓							
Kantraing Bay Sar	*Sida rhombifolia*	Broadleaf	✓							
	Solanum nigrum	Broadleaf		✓	✓	✓		✓		
Smao Krab Sa-eth	*Stachytarpheta indica*	Broadleaf		✓						
Chung Kong Proes	*Trianthema portulacastrum*	Broadleaf	✓	✓				✓		
	Tribulus terrestris	Broadleaf	✓	✓	✓		✓	✓		
	*Tridax procumbens**	Broadleaf		✓						

* Perennial or reproduces vegetatively. ** S = suppression

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