Food and Agriculture Organization of the United Nations

Handbook on

the integrated crop management of green gram and chickpea for farmer field schools in central dry zone of Myanmar

Climate-Friendly Agribusiness Value Chains Sector (CFAVC) project

Global Agriculture and Food Security Programme (GAFSP)

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Abbreviations and acronyms

AESA	agroecosystem analysis
CABI	Centre for Agriculture and Biosciences International
EIL	economic injury level
EPA	Environmental Protection Agency
ETL	economic threshold level
FAO	Food and Agriculture Organization of the United Nations
FFS	farmer field school
ICM	integrated crop management
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFDC	International Fertilizer Development Centre
IRRI	International Rice Research Institute
GAFSP	Global Agriculture and Food Security Program
GAP	good agricultural practices
PPD	Plant Protection Department
WHO	World Health Organization

Introduction

The Global Agriculture and Food Security Programme (GAFSP) in Myanmar GCP/MYA/027/GAF targeted at least 35 000 households (equivalent to 154 000 persons) living in the project (central dry zone) area including Pakokku, Magway, Aunglan, Natmauk, and Pwintbyu in Magway region; Mahlaing, Pyawbwe, Natogyi, Sintkaing in Mandalay region; and Monywa, Shwebo, Sagaing, Yinmarbin and Salingyi in Sagaing region. Based on 2015 census data, the average household size in the project area is Mandalay (4.4), Sagaing (4.6) and Magway (4.1) (MoIP, 2015).

In the project area, 48 percent of the household are landowners and 52 percent of households are landless (11 percent of total are casual labourers, 16 percent have small livestock as their main activity and 26 percent are engaged in off-farm activities) (Boutry *et al*. 2017). Small-scale family farmers play a major role in producing food for rural and urban populations. Farmers must adapt and fine-tune practices for growing and marketing their produce sustainably, but "ecological intensification" requires adaptive management reflecting the local context: ecological literacy and farmer collabouration are key factors (FAO, 2019a).

In Myanmar, about 70 percent of the population lives in the rural areas and majority of the people depend on rice farming for livelihood. Poverty and food insecurity pervade in the rural areas as farmers have low yields and income. Rice, groundnut, sesame, green gram and chickpea are important crops not only for local consumption but also for export in the project areas. Groundnut is an exception which doesn't meet the local demand of cooking oil. Rice, being the staple food of the people and a major exported product, remains to be the prime agricultural commodity in Myanmar. Sagaing and Mandalay regions are among the largest rice production areas of Myanmar. The rice production in the project regions (5.028 million tonnes) was about 22 percent of the national production (22.575 million tonnes) in 2018 monsoon rice growing season. The production of groundnut (*Arachis hypogaea*), sesame (*Sesamum indicum*), green gram (*Vigna radiata*) and chickpea (*Cicer arietinum*) in the project area, Sagaing, Mandalay and Magway regions was around 80 percent of the national production for each crop. Chickpea was mainly produced in Sagaing region, accounting for 52.58 percent of the national production. The data clearly highlighted that the production of these five crops, i.e., paddy, groundnut, sesame, green gram and chick pea is important not only for the project area but also for the whole country. It is essential to increase the yield of these crops not only to generate more income of the farmers in the project area but also for the domestic consumption and foreign exchange earnings from the export.

The farmer field school (FFS) is a unique approach to educate farmers and improve their skills to produce crops for a market-oriented economy. FFS allows farmers to learn of complex management skills through heuristic approach in a collective manner or farmers to farmers throughout a cropping season of a particular crop. In general, FFS consist of groups of people with a common interest who get together on a regular basis to study the *"how and why*" of a particular topic. The topics covered can vary considerably - from Integrated pest management (IPM), organic agriculture, animal husbandry, and soil

husbandry, to income-generating activities such as handicrafts. The FFS starts with the rice crop but the principles and training modules can be adapted for other crops in the rice-based cropping system.

A hand on training was recently given in Tatkon township, Nay Pyi Taw in 2019 summer season and another training in Yinmarbin township, Sagaing region in 2019 monsoon season by International Rice Research Institute (IRRI) (IRRI, 2019). This means the Curriculum for FFS on Rice ICM was already available and recently utilized in Myanmar. Similarly, Facilitators' guide book for farmers' field schools by Parul (2017), for dry zone area of Myanmar by Morris (1999) and Farmer field school (Upland rice), Facilitator's Handbook both in English and Myanmar language was published by Metta Development Foundation (MDF – 2015). It is not necessary to repeat the same thing for Myanmar farmers. Therefore, integrated pest management will be addressed as a general concept for all crops rather than emphasizing a particular crop or a particular growth stage of each crop.

In this curriculum, integrated pest management (IPM) for these selected crops, paddy, groundnut, sesame, green gram and chickpea, will be briefly outlined. The general concept of IPM will be the same for these crops although the insect pests, diseases and weeds may differ from one crop to another. The name of pests will be listed for information and important messages those are unique for Myanmar situation will be briefed if necessary, rather than giving detailed account of morphology, biology, ecology and management which can be readily available in published literature. It is aimed to improve the knowledge of farmers on the pests including insects, plant diseases, weeds and rodents causing reduction in the yield of field crops and how to manage the crops to boost the crop production without deteriorating environmental resources for sustainable agriculture.

Every year, between 400 000 and 1 million farmers participate in FFS. So far, an estimated 20 million farmers have participated in FFS over 90 countries in Asia, Africa, the Near East, Latin America, and Europe. FFS have adapted to different agroecological zones, from irrigated systems to rainfed and arid zones (FAO, 2019a). According to PPD (2020), 2 210 839 farmers were trained from the farmer field school between 2013-2014 and 1017-2018 in Myanmar.

Bartlett (2005) suggests that the utility of the FFS to farmers is self-evident from the fact that so many have chosen to participate. However, organisational issues such as leadership, policy, human resources, and competition help to explain why the IPM field school has taken off in some places and not in others. To implement the program, it is necessary to consider all fundamental elements of an FFS encompassing the group, the field, the facilitator, the curriculum, the program leader, and financing (Gallagher 2003).

Chapter 1

Crop production in central dry zone (project) areas

1.1 Introduction

In this handbook, integrated pest management (IPM) for legume crops, i.e., green gram (*Vigna radiata*) and chickpea (*Cicer arietinum*), will be briefly outlined rather than giving detailed information on the biology and ecology of individual pest species, which can be readily available from many reliable sources such as IRRI Rice Knowledge Bank, CABI Plantwise Knowledge Bank, ICRISAT, etc. Pests will be categorized as insects, plant diseases, weeds, and rodents.

The central dry zone covers approximately 54 390 square kilometres, or ten percent of the country's total land area. It is considered a vulnerable region with poor natural resources. It stretches across the southern part of Sagaing region, the middle and western part of Mandalay region, and most parts of Magway region (MECF, 2011).

1.2 Crop production in central dry zone

The total sown area, yield, and production of five selected crops at the national level were presented in table 1.1. The total area of paddy was about 7.26 million hectares (comprising 6.2 million hectares under monsoon paddy and more than one million hectares under summer paddy). The national average yield was about 3.92 metric tonnes per hectare, and the total production was about 28 million metric tonnes (Ministry of Agriculture, Livestock and Irrigation (MOALI), 2019a). The share of green gram and chickpea production at 14 townships in three regions of the project area was presented in Table 1.2 and table 1.3, respectively.

Rice, groundnut, sesame, green gram, and chickpea are important crops for local consumption and export in the project areas. Groundnut is an exception which doesn't meet the local demand for cooking oil. Rice, being the staple food of the people and a major exported product, remains to be the prime agricultural commodity in Myanmar. Sagaing and Mandalay regions are among the largest rice production areas of Myanmar. The rice production in the project regions (5.028 million tonnes) was about 22 percent of the national production (22.575 million tonnes) in the 2018 monsoon rice-growing season. The production of groundnut (*Arachis hypogaea*), sesame (*Sesamum indicum*), green gram (*Vigna radiata*) and chickpea (*Cicer arietinum*) in the project area, Sagaing, Mandalay and Magway regions was around 80 percent of the national production for each crop. Chickpea was mainly produced in Sagaing region, accounting for 52.58 percent of the national production (Table 1.4).

Table 1.1 Crop sown area, yield, and production of five selected crops at the national level (2018-2019)

Crop	SOWN ('000 Ha)	YIELD (MT/Ha)	PRODUCTION ('000MT)	GAP area (ha)
Paddy	7 228	3.92	28 016	
Groundnut	1 058	1.50	1 588	220 ha (0.02%)
Sesame	1 547	0.49	727	2 670 ha (0.17%)
Green gram	1 169	1.25	1 458	19 000 ha (1.52%)
Chick pea	383	1.42	543	-

Source: MOALI, 2019a.

Table 1.2 Sown area, yield, and production of green gram in 14 townships of project regions in 2019-2020

Sr	Region	Monsoon			Winter			Total		
		Harvested (ac)	Yield per ac	Production basket	Harvested (ac)	Yield per ac	Production basket	Harvested (ac)	Yield per ac	Production basket
	Sagaing	46 353	16.72	775 022	2 511	1630	40 929	49 182	16.70	821 293
	Monyaw	7 855	16.66	130 864	2 179	16.75	36 498	16 063	16.82	270 156
	Yinmabin	6 654	18.20	121 103	1 977	15.75	31 138	9 609	17.70	170 080
	Salingyi	12 723	15.64	198 937				13 615	15.85	215 840
	Shwebo	1 986	17.75	35 252				13 365	19.45	259 978
1	**Sagaing**	**487 339**	**16.29**	**7 936 728**	**107 951**	**16.51**	**1 782 334**	**595 290**	**16.33**	**971 962**
	Pakokku	12 136	8.51	103 277				12 616	8.51	103 277
	Magway	20 524	9.00	184 667	252	14.23		20 776	9.06	188 252
	Natmauk	35 477	13.25	470 070	6 965	11.18		42 422	12.91	547 939
	Pwintbyu	1 643	14.09	23 155				1 643	14.09	23 155
	Aunglan	66 368	7.61	505 068	14 078	86157		80 446	7.35	591 225
2	**Magway**	**364 399**	**10.55**	**3 843 007**	**72 218**	**9.51**	**686 875**	**436 617**	**10.37**	**4 529 882**
	Sintgaing	7 222	15.10	109 052				7 222	15.10	109 052
	Mahlaing	2 333	5.77	13 473				2 333	5.77	13 473
	Natogyi	12 086	10.16	122 756				10 286	10.16	122 756
	Pyawbwe	44 053	13.24	583 305				44 053	13.24	583 305
3	**Mandalay**	**259 742**	**11.36**	**2 950 746**	**24 454**	**12.22**	**298 863**	**284 196**	**11.43**	**3 249 609**

Source: DoA, 2020.

Table 1.3 Sown area, yield, and production of chickpea in 14 townships of project regions in 2019-2020

Sr	Region	Winter			Total		
		Harvested (ac)	Yield per ac	Production basket	Harvested (ac)	Yield per ac	Production basket
	Sagaing	28 632	11.5	329 240	28 632	11.50	329 240
	Monyaw	20 866	20.85	435 056	20 866	20.85	435 056
	Yinmabin	36 685	11.08	406 342	36 685	11.08	406 342
	Salingyi	39 186	22.5	881 685	39 186	22.50	881 685
	Shwebo	5 757	29.6	170 407	5 757	29.60	170 407
1	**Sagaing**	**460 208**	**19.53**	**8 986 992**	**460 208**	**19.53**	**8 986 992**
	Pakokku	865	19.35	16 738	865	19.35	16 738
	Magway	938	12.65	11 870	938	12.65	11 870
	Natmauk	376	8.95	3 365	376	8.59	3 365
	Pwintbyu	24 310	14.62	355 426	24 310	14.62	355 426
	Aunglan	1 026	12.98	13 317	1 026	12.98	13 317
2	**Magway**	**166 562**	**13.36**	**2 224 943**	**166 562**	**13.36**	**2 224 943**
	Sintgaing	16 304	19.5	317 928	16 304	19.50	317 928
	Mahlaing	2 121	5.62	11 012	2 121	5.62	11 012
	Natogyi	10 104	7.32	73 961	10 104	7.32	73 961
	Pyawbwe	22 409	11.75	263 306	22 409	11.75	263 306
3	**Mandalay**	**231 208**	**14.67**	**2 292 181**	**231 208**	**14.67**	**2 292 181**

Source: DoA, 2020.

Table 1.4 The percentage of crop production in project regions compared with the national production in monsoon season, 2018-2019

Crop	Sagaing region Acres (%)	Magway region Acres (%)	Mandalay region Acres (%)	Union total Acres	percent of Union total
Paddy	3 058 289	1 010 529	948 305	22 525 974	
	(13.58%)	(4.49%)	(4.21%)		(22.28%)
Groundnut	3 058 289	1 010 529	948 305	22 525 974	
	(22.66%)	(34.13%)	(25.68%)		(82.47%)
Sesame	166 566	250 891	188 758	735 098	
	(19.93%)	(34.62%)	(30.82%)		(85.37%)
Green gram	75 218	130 648	116 324	377 428	
	(42.64%)	(27.92%)	(17.22%)		(87.78%)
Chickpea	248 202	162 498	100 236	582 099	
	(52.58%)	(13.02%)	(13.42%)		(79.01%)

Source: DOA, 2020.

The utilization of good quality seeds is vital to increasing rice production. Private companies are encouraged by MOALI for seed industry development. Some private

companies, Dagon International, Golden Sun Land, Sin Shweli, Green Asia, New Ayar, Great Wall, Ayar Hintha and Myint Zayar have been incorporated to improve seed industry development (DOP, 2018). At the early stage of seed industry development, the Ministry initiated to produce 1 311 tonnes on 488 ha of land in 2012-2-13. In 2015-2-16, the farmers participated in producing 980 tonnes of seeds on 460 ha of land. In 2017-2018, the private companies produced 48 000 tonnes of seeds on 541 ha of land (DOP, 2018). So far, the National Seed-related Committee has approved 187 varieties of rice, 18 varieties of groundnut, ten varieties of sesame, 13 varieties of green gram and 12 varieties of chickpea up to 2019 (MOALI, 2019b).

The total sown area, production and GAP area and percentage of five selected crops in Myanmar were presented in table 1. The GAP was not famous among the farmers, and the adoption rate was very low in most regions and states. The largest GAP paddy area was found in Magway Region and Shan State, but the share was only 0.71 and 0.28 percent. Mandalay region has the third-largest with 0.03 percent (Table 1.5). The current situation demands more adoption of GAP in crop production, not only for boosting the yield/production but also for sustainable agriculture without depleting existing natural resources.

To improve the well-being and capacity of smallholder farmers (including women, youth, and children), it is crucial to boost the production of pulses crops such as green gram and chickpea in dry zone areas. Increasing productivity in the production and processing of pulses is one of the three strategic objectives of Myanmar Pulses Sector Development Strategy (DAR, 2017). However, weak extension and education system has been mentioned as one of the challenges. In addition to strengthening technology delivery and extension services, FFS approach should be adopted to enhance the capacity and skills of farmers so that to produce more food crops not only for local consumption but also for export.

1.3 Green gram production

Myanmar produces more than 20 types of pulse crops in diverse and flexible rotation. It is the second-largest producer of pulses in the world, producing 6 million tonnes in 2016. However, there are significant constraints on the availability of improved pulse varieties. Pulse yields are high compared with other pulse-producing Asian countries. Myanmar exports are currently approximately 1 million tonnes (valued at USD 1 billion), 12 percent of total global exports of pulses by volume and 19 percent by value (DAR, 2017). Domestic varieties are not diffused, and international germplasm is underutilised. Farmer-saved seed, as well as much of the commercially-available seed, are traditional varieties or old-released varieties with limited genetic resources.

Black gram, green gram, pigeon peas and chickpeas are the four main pulse crops. Approximately 68 percent of pulses production occurs in the post-monsoon winter season (October to January), and the remaining 32 percent is produced during the monsoon season (June to September). Green gram has the largest diversity in cropping practices, with equal production in the monsoon and winter seasons, mainly in the Central

Dry Zone and northern Delta Zone. Chickpeas are grown almost exclusively in the Central Dry Zone.

1.3.1 Green gram cultivars grown in Myanmar

As of 9 August 2019, National Seed Committee Myanmar has approved seven black gram, 13 green gram, 12 chickpea and six pigeon pea varieties.

The approved varieties of green gram are:

> Petishwewar, Yezin green gram – 2, Yezin green gram – 8, Yezin green gram -9, Yezin green gram – 11, Yezin green gram – 14, Myakyaymon – 1, Myakyaymon – 2, Agri – 1, SAFAL 11 A, SAFAL 21 and Shwetoe 009 (op).

1.3.2 Growth stages of green gram

The growth and development stages of chickpea were described by Pookpakdi *et al*. 1982 as follows:

Table 1.5 growth and development stages of green gram

Growth stage		**Description**
Vegetative growth stage		
VE	Emergence	Cotyledons near the soil surface with the seeding show some plant part from the soil surface.
VC	Cotyledon	Cotyledons separate from each other on the upper surface. Unifoliolate leaves start to unroll so that the edge of the leaves are not touching each other.
V_1	First node	Unifoliolate leaves attached to the first node are fully expanding and flat, while the 1st trifoliolate leaf attached to the upper node starts to unroll.
V_2	Second node	1st trifoliolate leaf attached to the second node is fully expanding and flat, while the 2nd trifoliolate leaf on the upper node starts to unroll.
V3	Third node	2nd trifoliolate leaf attached to the third node is fully expanding and flat, while the 3rd trifoliolate leaf on the upper node starts to unroll.
V_4	Fourth node	3rd trifoliolate leaf attached to the fourth node is fully expanding and flat, while the 4th trifoliolate leaf on the upper node starts to unroll.
V_n	N-node	a node is counted when its trifoliolate leaf is unfolded, and its leaflets are flat
Reproductive growth stage		
R_1	Beginning bloom	one open flower at any node on the main stem.
R_2	Beginning pod	one pod of 1.0 cm. in length is found between node "4" to node "6" of the main stem.

R_3	Beginning seed	one pod of 5.0 cm. in length is found on any of the top three nodes on the main stem
R_4	Full seed	one pod on any of the top three nodes has constriction between seeds.
R_5	Beginning maturity	one pod on the main stem turns to brown, dark brown or black in colour.
R_6	First harvest	fifty percent of pods on the plant mature.
R_7	Second harvest	after harvesting the ripen pods at R_6, when the rest of the pods on the plant mature, then, R_7 is reached

1.4 Chickpea production

1.4.1 Chickpea cultivars grown in Myanmar

Types of chickpea

There are two distinct types of chickpea:

(1) Desi type chickpea has a thick seed coat; the common seed colours include various shades and brown, yellow, green and black combinations. The seeds are generally tiny and angular with a rough surface. The flowers are usually pink.

(2) Kabuli chickpea: are characterized by white or beige-coloured seed with a ram's head shape, thin seed coat, smooth seed surface, white flowers, and lack of anthocyanin pigmentation on the stem.

Figure 1.1 Desi (left) and kabuli (right) type chickpea

The approved varieties of chickpea are:

Karachi, Shwekyayhmone, Yezin – 1, Yezin chickpea – 3, Yezin chickpea – 4, Yezin chickpea – 5, Yezin chickpea – 6, Yezin chickpea – 8, Yezin chickpea – 11, Yezin chickpea – 12, Shwenilonegyi and Yezin chickpea – 13 (op).

1.4.2 Growth stages of chickpea

The growth and development stages of chickpea were described by Muehlbauer *et al*. 1982 as follows:

Vegetative growth stages

Count the number of visible nodes on the main stem up to the node that includes the highest fully developed leaf. Leaves have 3 to 8 pairs of small leaflets that are oval.

VE – seedling emergence
V1 – the first multifoliate leaf has unfolded from the stem
V2 – the second multifoliate leaf has unfolded from the stem
V3 – the third multifoliate leaf has unfolded from the stem
V4 – the fourth multifoliate leaf has unfolded from the stem
Vn – the nth multifoliate leaf has unfolded from the stem.

Figure 1.2 nth multifoliate leaf fully expanded and full bloom, most flowers are open

Reproductive growth stages

The self-pollinated plant produces 1–2 flowers at the tip of axillary branches. Pods may contain up to three seeds and are oval; and at maturity, the plants and pods turn yellow to tan.

R1 – early bloom, one open flower on the plant
R2 – full bloom, and most flowers are open
R3 – early pod visible
R4 – flat pod, the pod has reached its full size and is mainly flat
R5 – early seed, seed in any single pod, fill the pod cavity
R6 – full seed, all seeds fill the rounded pod cavity.

Physiological maturity

R7 – the leaves start yellowing, and 50 percent of the pods have turned yellow

R8 – 90 percent of pods on the plant are golden-brown

Figure 1.3 Full seed, seeds fill rounded pod cavity

1.5 Pest problems in the project areas

The problem of infestation (insects, diseases, weeds, and rodents) in different regions may vary with the season and locality. However, it may be similar in the same area, for example, dry zone. As the conditions are not favourable to go for field visits to the project townships due to the COVID-19 situation in 2020, the existing records will be referred to as background information in this handbook. The records from ADSP (2018) are mainly from the dry zone area; although it is primarily for the irrigated area, it is assumed that the problem will be the same in dry zone areas.

According to Agricultural Development Support Project (ADSP) survey by MOALI (2018), the pest problems in some areas are as follows:

Table 1.5 Major pest problems in Tatkon township as identified by farmers, PPD staff and local DoA staff

Crops	Insect pests	Diseases	Weeds	Rodents
Rice	Stem borer, leaf folder, brown planthopper, gall midge	Bacterial blight, bacterial leaf streak, root rot, false smut	Grasses, sedges, broadleaf weeds	Occur with minimal damage
Pulses	Aphid, armyworm, pod borer	Yellow mosaic, rust	Grasses, sedges, broadleaf weeds	
Sesame	Bollworm, Leaf roller, leaf binder	Black stem rot		
Groundnut	Sucking pests, Leaf roller, leaf binder	*Cercospora* leaf spot		
Chick pea	Pod borer	Fusarium wilt		

Farmers were not familiar with the insect pest in pulses. Plant protection staff reported whiteflies and yellow mosaic virus as the major pest of pulses.

Table 1.6 Major pest problems in part of Mandalay region as identified by farmers, PPD staff and local DoA staff

Crops	Insect pests	Diseases	Weeds	Rodents
Rice	Stem borer, leaf folder, armyworm, aphids	Bacterial blight, bacterial leaf streak	Grasses, sedges, broadleaf weeds	Occur with minimal damage
Pulses	aphid, armyworm, pod borer, leaf folder		Grasses, sedges, broadleaf weeds	
Groundnut	Sucking pests, Leaf roller, leaf binder	Early and late blight	Grasses, sedges and broadleaf weeds	Significant damage in nuts

Farmers spray insecticides 7 to 8 times in the season to control aphids, leaf folders and armyworm in green gram as they believe that they will have 100 percent yield loss if they do not control these insects. The efficiency of insecticide sprays and their impact on the crop's natural enemies and beneficial insects need to be analysed. It is desirable to reduce the use of pesticides to the minimum level to prevent unwanted problems such as pesticide resistance, pest resurgence, and secondary pest outbreak and avoid residue problems in the crop products and the soil.

Rat hunters managed rodents. Farmers also indicated that the labour shortage and wages are soaring due to the labour migration. Consequently, they have no other way but to use herbicide which becomes a wise choice for saving time and cost.

Table 1.7 Major pest problems in Yinmabin townships, Sagaing region as identified by farmers, local extension staff and PPD

Crops	Insect pests	Diseases	Weeds	Rodents
Rice	Stem borer, leaf folder, case worm, brown planthopper	Bacterial blight, rice blast	Grasses, particularly *Leptochloa chinensis* (red sprangle top) sedges, broadleaf weeds	Occur with minimal damage
Pulses	Whitefly, pod borer, aphids	Yellow mosaic		
Sesame	Leaf folder, hoppers	Stem rot, mycoplasma		
Chick pea	Armyworm, leaf folder, pod borer	Fusarium wilt		

Similar situations were observed in Yinmabin township but rodent is observed to a serious pest in groundnut. Pesticide application is a common practice among farmers when they observe insect pests, diseases, and weeds. Some farmers reported that they do not do anything to control rodents as the damage is minimal.

In Yinmabin area, farmers generally plant two or three crops in a year in both irrigated and rainfed areas. The cropping pattern commonly adopted by the farmers include (a) monsoon paddy rice from June to October followed by chick pea as second crop grown from November to December, and (b) the summer paddy rice cultivation is from March to May that precede the growing of chickpea from January to February and sesame from February to March (MOALI, 2018).

Farmers consider pod borer as a highly damaging in chickpea causing a yield loss of up to 80 percent, so they spray Acephate and Cyclone (Chlorpyrifos + Cypermethrin) at least 3 times using calendar spray at two-week intervals.

Farmers observe wilting in plants, but they do not know the casual organism; they perceive this as a disease.

In sesame, leaf folder is the major insect pest, and farmers spray cyclone (Chlorpyrifos 49.5 percent + Cypermethrin 4.95 percent) insecticide. Farmers perceive that this insect can cause 10-15 percent yield loss if it builds up in the field. Stem rot and mycoplasma are the major disease problems. Farmers spray a systemic insecticide called “Danadim” twice in the season. If these diseases are left uncontrolled, farmers perceive 10 to 70 percent yield loss.

Farmers have limited knowledge about pests and the proper pest management option, much less about IPM. They have inadequate knowledge of the harmful effects of the use of toxic agrochemicals on the welfare of farmers and the general health condition in their

communities. They indicated that pest management is a priority area for capacity development for all farmers in the two townships.

Chapter 2

Insect pests of pulses and their control

2.1 The common insect pests of in Myanmar

Apart from the classical work – "Insect pests of Burma" by Ghosh (1940), a list of field crop pests by Crowe (1985) and an overview by Waterhouse (1993), Morris and Waterhouse (2001) listed 222 arthropod pests and 170 weeds of agricultural importance in Myanmar. Among them, 44 arthropod pests were mentioned as of major importance in most years. The most important of these, in decreasing order, are *Spodoptera fitum, Helicoverpa armigera, Agrotis ipsilon, Spilarctia obliqua, Thrips palmi, Aphis gossypii, Odontotermes* spp., *Agrotis segetum, Bactrocera cucurbitae, Bactrocera dorsalis* and *Scirtothrips dorsalis.*

The most important weeds, in alphabetical order, are *Amaranthus spinosus, Cyperus iria, Cyperus rotundus, Echinochloa colonum, Fimbristylis miliacea, Impemta cylindrica, Leucas cephalotes, Mimosa pudica, Mitracarpus villosus* and *Trianthema portulacastrum.*

The above-mentioned list was already 20 years old, and the status of the pest might have been changed with the time. So far, there is no other published record with the pest list. Therefore, concerted efforts should be made by all responsible and interested personnel to list the important pests and weeds of Myanmar to reflect in real-time.

Table 2.1 Insect pest of pulses by Morris and Waterhouse (2001)

	Green gram	Chickpea
		Cricket, *Acheta* sp., Orthoptera: Gryllidae
	Black cutworm, *Agrotis ipsilon*, Lepidoptera: Noctuidae	Black cutworm, *Agrotis ipsilon*, Lepidoptera: Noctuidae
	Black bean aphid, *Aphis fabae*, Hemiptera: Aphididae	
		Gram pod borer, *Helicoverpa armigera*, Lepidoptera: Noctuidae
	Striped flea beetle, *Medythia suturalis*, Coleoptera: Chrysomelidae	Termite, Odontotermes sp., Isoptera: termitidae
	Blister beetle, *Mylabris pustulata*, Coleoptera: Meloidae	
	Soybean webworm, *Omiodes indicate, Lepidoptera: Pyralidae*	
	Bean stemfly, *Ophiomyiaphaseoli,* Diptera: Agromyzidae	Bean stemfly, *Ophiomyiaphaseoli,* Diptera: Agromyzidae
	Yellow tea mite, *Polyphagotarsonemuslatus*, Acarina: Tetranichidae	
	Jute hairy caterpillar, *Spilarctia obliqua*, Lepidoptera: Arctiidae	
	Cluster caterpillar, *Spodoptera litura*, Lepidoptera: Noctuidae	Cluster caterpillar, *Spodoptera litura*, Lepidoptera: Noctuidae

		Flax caterpillar, *Thysanoplusia orichalcea*, Lepidoptera: Noctuidae

2.2 Major insect pests of green gram

A total of 64 species of insects were reported to attack mungbean in the field in India (Lal, 1985). However, Swaminathan *et al* (2012) reported that 200 insect pests belong to 48 families in Coleoptera, Diptera, Hemiptera, Hymenoptera, Isoptera, Lepidoptera, Orthoptera, Thysanoptera, and seven mites of the order Acarina are known to infest green gram and black gram. The insect pests: whitefly, *Bemisia tabaci*, leaf hopper, *Empoasca kerri*, black aphid, *Aphis craccivora*, common hairy caterpillar, *Diacrisia obliqua*, stem fly, *Ophiomyia phaseoli* (Tryon), and spotted caterpillar, *Maruca testulalis are lised as important pests.* Under severe cases, stem flies may alone cause more than 90 percent damage with a yield loss of 20 percent (Talekar, 1990). The insect pests that infest green gram can be categorized as (1) stem feeders, (2) foliage feeders, (3) pod feeders, and (4) pests of stored grains. In Myanmar, PPD (2020) has listed 24 species of insects as pests of green gram.

Table 2.2 Insect pests of green gram by PPD (2020)

Sr	Common name	Scientific name	Order	Family
1	Bollworm	*Helicoverpa armigera*	Lepidoptera	Noctuidae
2	Spotted pod borer	*Maruca testulalis*	Lepidoptera	Pyralidae
3	Armyworm	*Spodoptera litura*	Lepidoptera	Noctuidae
4	Pea blue butterfly	*Lampides boeticus*	Lepidoptera	Lycaenidae
5	Common hairy caterpillar	*Amsacta* sp.	Lepidoptera	Arctiidae
6	Common hairy caterpillar	*Spilosoma* sp.	Lepidoptera	Arctiidae
7	Leaf webworm	*Omiodes indicata*	Lepidoptera	Pyralidae
8	Soybean leafroller	*Archips micaceanus*	Lepidoptera	Tortricidae
9	Shoot borer	*Monopis* sp.	Lepidoptera	Tineidae
10	Striped flea beetle	*Phyllotreta striolata*	Coleoptera	Chrysomelidae
11	Flea beetle	*Medythia suturalis*	Coleoptera	Chrysomelidae
12	Leaf beetle	*Monolepta* sp.	Coleoptera	Chrysomelidae
13	Green stink bug	*Nezara viridula*	Hemiptera	Pentatomidae
14	Pod sucking bug	*Riptortus* sp.	Hemiptera	Coreidae
15	Pod sucking bug	*Dolicoris indicus*	Hemiptera	Pentatomidae
16	Jassid	*Empoasca* sp.	Hemiptera	Jassidae
17	Gram pod bug	*Clavigralla gibbosa*	Hemiptera	Coreidae
18	Bud-sucking bug	*Hyalopeplus* sp.	Hemiptera	Miridae
19	Aphids	*Aphis* spp.	Hemiptera	Aphididae
20	Bean stem fly	*Ophiomyia phaseoli*	Diptera	Agromyzidae

21	Migratory locust	*Gastrimargus* sp.	Orthoptera	Acrididae
22	Grasshopper	*Acheta* sp	Orthoptera	Gryllidae
23	Grasshopper	*Atractomorpha* sp	Orthoptera	Pyrgomorphidae
24	Red spider mites	*Tetranychus* sp	Acarina	Tetranychidae

Table 2.3 Major pest infesting selected GAP crops in CFAVC project areas

Sr No	Crop	Major insect pests and diseases	
		Insect pest	**Diseases**
1	**Green gram**	Spotted pod borer, *Maruca testulalis*	Yellow Mosaic Virus
		Spodoptera litura	
		Whitefly, *Bemisia tabaci*	
		Bean aphids, *Aphis craccivora*	
		Leaf hopper, *Empoasca kerri*	
		Gram pod borer, *Helicoverpa armigera*	
2	**Chickpea**	Gram pod borer, *Helicoverpa armigera*	Fusarium wilt, *Fusarium oxysporum f. sp. ciceris* (Foc)
			Dry root rot

Table 2.4 Feedback from the consultation meeting with regional staff

	Insect pests	Diseases
	Green gram	**Green gram**
	Beetles make shot holes at early crop growth	Local varieties of black gram infested with whitefly and yellow mosaic virus - Myaung
	Whitefly - Myaung	Yellow mosaic virus
	Stemfly –Furadan 3G, Cartap Myay Kaung, Regent	Downy mildew
		-zol fungicides
	Chickpea	**Chickpea**
	Helicoverpa armigera – Mandalay Eocanthecona	Phyllody was detected in Pangon Farm, Shwebo
	Stem borer – released Trichogramma	Fusarium wilt in Thazi, 20 packs (1000 MMK/pack) of Trichoderma incorporated into the soil Tri-K
	Hormone spray, Acephate for plant growth and more branching, cut shoots for selling	Use Trichoderma at land preparation or spray at the base of the plant (5 packs/ac)
	After releasing 3000-4000 of *Campoletis* sp in Sagaing 15-20 yrs ago, the incidence decreased	929 is a resistant variety Red seed (erect type) is more tolerant than white seed, but farmers don't like it as the seed is small

The following notes and figures of insect pests are reproduced from TNAU (2015).

2.2.1 Borers

2.2.1.1 Gram pod borer*: Helicoverpa armigera*

Identification of the pest

- eggs - are spherical in shape and creamy white in colour, laid singly;
- larva - shows colour variation from greenish to brown. Green with dark brown-grey lines dorsally on the body with lateral white lines and has dark and pale bands;
- pupa - brown in colour, occurs in soil, leaf, pod, and crop debris; and
- adult - light pale brownish-yellow stout moth. Fore wing grey to pale brown with a V-shaped speck. Hind wings are pale smoky white with a broad blackish outer margin.

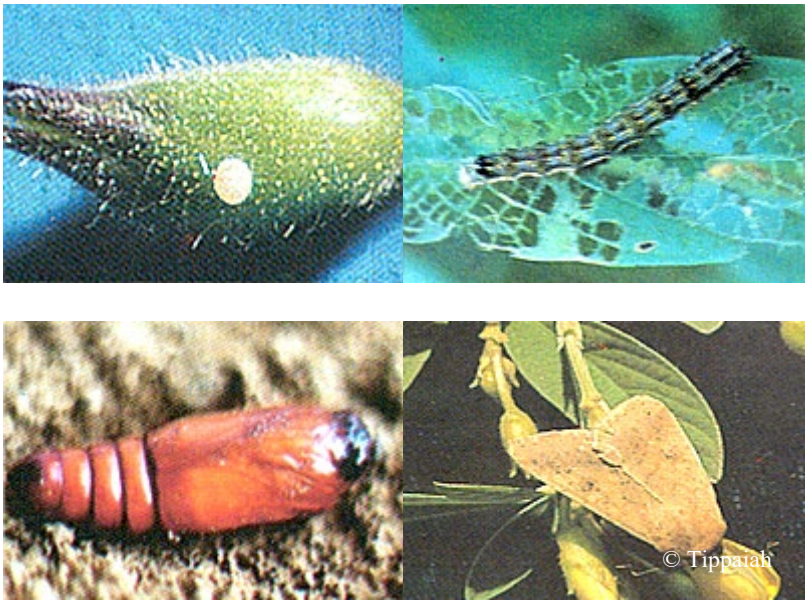
Symptoms of damage

- defoliation in early stages
- larva's head alone thrust inside the pods, and the rest of the body hanging out
- pods with round holes.

Management

- **ETL:** 10 percent of affected pods
- pheromone traps for *Helicoverpa armigera* 12/ha
- bird perches 50/ha
- mechanical collection of grownup larva and blister beetle
- apply any one of the following insecticides:
    - Azadirachtin 0.03 percent WSP 2500–5000 g/ha
    - *Bacillus thuringiensis* serovar kurstaki (3a,3b,3c) 5 percent WP1000-1250 g/ha
    - Dimethoate 30 percent EC 1237 ml/ha
    - Emamectin benzoate 5 percent SG 220 g/ha
    - Indoxacarb 15.8 percent SC 333 ml/ha
    - Chlorantraniliprole 18.5 SC 150ml/ha
    - Spinosad 45 percent SC 125–162 ml/ha.

Figure 2.1 Different stages of Helicoverpa armigera



2.2.1.2 Spotted pod borer, *Maruca testulalis*

Identification of the pest

- **Larva -** Greenish white with a brown head. It has two pairs of dark spots on the back of each segment.
- **Adult - Forewings**- light brown colour with white markings; **Hindwings** – white colour.

Symptoms of damage

- defoliation in early stages
- larva's head alone thrust inside the pods and the rest of the body hanging out
- pods with round holes.

Management

- **ETL:** 3/plant
- Phosalone 0.07 percent (Spray fluid 625 ml/ha)
- note: When the activity of coccinellid predators (both grubs and adults) is seen, insecticide application should be avoided.

Figure 2.2 Larvae of spotted pod borer, larva and adult

Figure 2 3 Damaged pods of black gram

2.2.1.3. Spiny pod borer, *Etiella zinckenella*

Identification of the pest

- **Larval –** greenish initially, turns pink before pupation.
- It has five black spots on the prothorax.

Adult

- brownish grey moth
- **prothorax** – orange in colour
- **fore wing** - has a white stripe along the anterior margin.

Symptoms of damage

- dropping of flowers and young pods; and
- older pods marked with a brown spot where a larva has entered.

Management

- conserve natural enemies like *Bracon hebetor;*

- ETL 10 percent affected parts;
- deep summer ploughing in 2–3 years to eliminate quiescent pupa;
- early sowing, short-duration varieties;
- avoid closer plant spacing;
- grow tall sorghum as a companion crop to serve as biological bird perches;
- collect and destroy larvae and adults to the extent possible;
- install pheromone traps at 50 m @ five traps/ha for each insect pest;
- install Bird perches @ 50/ha;
- setting of light traps (1 light trap/5 acre) to kill moth population;
- control is achieved by releasing *Trichogramma chlionis* at weekly intervals @1.5 lakh/ha/ week for four times;
- conserve green lacewing, predatory stink bugs, spiders, ants;
- spray NSKE 5 percent twice followed by triazophos 0.05 percent; and
- apply any one of the insecticides at 25 kg/ha quinalphos 4D, carbaryl 5D.

Figure 2.4 Different stages of spiny pod borer

2.2.2. Sucking pests

2.2.2.1 Bean Aphids: Aphis craccivora

Identification of the pest

- **Nymphs and Adult –** dark coloured with cornicles in the abdomen.

Symptoms of damage

- leaves, inflorescence stalk and young pods covered with dark-coloured aphids; and
- honey dew secretion with black ant movements.

Management

Spray any one of the following insecticides (Spray fluid 500 l/ha)

- emamectin benzoate 5 percent sg 220 g/ha
- indoxacarb 15.8 percent sc 333 ml/ha
- nske 5 percent twice followed by triazophos 0.05 percent
- neem oil 2 percent.

Figure 2.5 *Spodoptera litura*, aphids and thrips on black gram

2.2.2.2 Leaf hopper - *Empoasca kerri*

Symptoms of damage

- leave mottled and yellowish in colour
- green colour insects found under the surface of leaves.

Identification of the pest

- **Adult – elongate**, active, wedge shape, green insects.

Management:

spray the infested crop with methyl-o- demetonne 750 ml in 700–1000 L water per hectare.

2.2.2.3 Whitefly – Bemisia tabaci

Symptoms of damage

- leave mottled and yellowish in colour
- vector of yellow mosaic virus.

Identification of the pest

- **Adults** are small, yellow bodied insects with white wings which are densely covered with a waxy powder.
- **Nymphs and pupae** -are black and round or oval. Pupae have marginal bristles.

Management of sucking pests

- methyl demetonne 25 ec 500 ml/ha
- dimethoate 30 EC 500 ml/ha.

Figure 2.6 White fly and blister beetle

2.2.3 Flower feeder

2.2.3.1 Blister beetle: Mylabris phalerata

Identification of the pest

- **Eggs** - are light yellowish in colour and cylindrical in shape.
- **Larvae** - Young grubs are white in colour.
- **Adult –** Elytra are black in colour with a round orange spot and two transverse wavy orange bands across the wings.

Symptoms of damage

- The adult feeds voraciously on buds and flowers.

Management

- The only possible solution is manual collection or collection with insect net and killing of adults in keratinized water.

2.3 Major insect pests of chickpea

More than 200 **insect pests** are recorded on pigeon pea in India (Rao and Shanower, 1999).

2.3.1 Gram pod borer (*Helicoverpa armigera*)

It is the most important pest of chickpea in all the chickpea growing areas. It damages almost all the pods in case of severe damage but causes nearly 20–30 percent annual yield losses in India.

The eggs (1 mm diametre) are laid singly on the leaflets, flowers, immature pods, and stem. Larvae can be green, brown, yellow, or pink but are usually striped, irrespective of their colour. Larvae feed on leaves during the vegetative phase and on flowers and pods during the reproductive phase. The third- to fifth-instar larvae feed on the developing seed after making a hole in the pods.

Management of pod borer: Varieties with high resistance levels to pod borer are not available in Myanmar. Though pod borer can be effectively controlled through insecticides, an integrated pest management (IPM) strategy is recommended as it is eco-friendly, does not eliminate the natural enemies of pod borer, reduces pesticide residues, and the risk of development of resistance to insecticides.

In Sagaing region, the incidence of *H. armigera* decreased after releasing 3 000–4 000 parasitic wasp, *Campoletis* sp 15–20 years ago.

Population monitoring: Monitoring of H. armigera population in the field is a prerequisite for successful plant protection. Sex pheromone traps are used to monitor the pest population build-up. Pheromones are specific to individual species. These traps are of different shapes or colours and can be placed at different heights depending upon insect activity and crop architecture. These are placed at 1 m height from the ground level immediately after sowing in chickpeas. The pheromone traps are not useful in controlling the pest directly but provide an estimate of the pest population and are an effective tool for timely use of control measures.

Visual observations should regularly be made on the larval population in the field. The action threshold is 1–2 larvae (2nd to 3rd instars) per metre row. To count the larvae, one should observe ten plants at random at five locations diagonally across the field and calculate mean larval density to decide on the use of control measures.

Control measures

- Early sowing, especially of short-duration varieties, helps avoid pod borer damage.
- Intercropping coriander with chickpea provides nectar sources for adult parasitoids and improves the natural control of *H. armigera*.

- Bird perches (10–15 ha-1) can be installed in the field to attract predatory birds.
- Bio-rational pesticides such as *Bacillus thuringiensis* (Bt), entomopathogenic fungi (*Metarhizium anisopliae*), etc., are generally safe for human beings and for the environment. These products are commercially available in the market, and farmers can even produce them at a minimum cost.
- Application of 5 percent neem fruit powder extract (about 15 kg neem fruit powder ha-1) 15 days after seedling emergence provides effective control of *H. armigera*.
- If the above methods do not control the insect population, then chemical sprays (indoxacarb @ 70 ml a.i. ha-1 or spinosad @ 45 ml a.i. ha-1) can be applied as and when needed.

Figure 2.7 Gram pod borer larva and damaged fruit of chickpea

Figure 2.8 Circular bore hole by gram pod borer and termite damage

2.3.2 Termites: *Odontotermes obesus*

Symptom of damage

- Termite bores into the roots and stem. Due to the bore, the plants soon dries.

- The attack may also continue to the standing crop, especially during the period of drought.

Identification of the pest

- These are social insects living in termitaria, in distinct castes, workers, drones, soldiers, and queens.
- Eggs are laid on plants and in the soil.
- 'Workers' are small (4 mm) and have a soft, white body and a brown head.

Management

- Frequent intercultural operations and irrigation before sowing.
- Field sanitation, timely disposal of crop stables and undecomposed plant parts.
- Undecomposed FYM or composed should not be used
- Two-three deep ploughing could also help control this pest.
- Destroy the termite bunds in and around the field and kill the queen and complimentary form.
- Seed treatment with chemicals before sowing.

2.4 Seed storage

The seed must be properly dried before storage. The ideal seed moisture level is 10–12 percent for short-term storage (up to eight months). After drying, the seed should be either stored in polythene-lined gunny bags or in safe storage structures (metal bins or earthen containers). The bags should be kept in a rodent-free room and placed on wooden planks (not more than five in a stack) and away from walls to avoid dampness to the seeds.

Bruchids (*Callosobruchus* spp.) are the most serious storage pests of chickpea and all other food legumes. Bruchids lay white eggs on the seeds, and the larvae bore into seeds, and adults emerged from the seeds by cutting round holes in the seeds. The infested seeds are unfit for sowing and consumption. Proper control measures should be undertaken to protect chickpea seeds from bruchids.

The traditional methods of protecting the seed from bruchid damage by mixing with ash, dried neem leaves, chickpea, or wheat straw are useful for small quantities of seed. In large-scale storage, the seed store or the seed bins should be fumigated periodically with commercially available fumigants (ethylene dibromide or phosphine) to protect the seed from storage pests. The main advantage of fumigation is that all stages of the insect, including eggs, larvae, and pupae, are controlled and affect other storage pests and rodents.

Chapter 3

Plant diseases of green gram and chickpea

3.1 The common diseases of green gram

Although CPC 2007 listed 12 diseases but Current list indicated 8 diseases of green gram crop and three diseases on green gram seed (Table 3.1)

Table 3.1 Diseases of green gram, black gram in Myanmar

Sr.	Common Name	Pathogen	Order	Family
1	Anthracnose	*Colletotrichum lindemuthianum*	Meloanconiales	Meloanconiaceae
2	Rust	*Uromyces phaseoli*	Uredinales	Pucciniaceae
3	Powdery mildew	*Erysiphe polygoni*	Erysiphales	Erysiphaceae
4	Root Rot	*Thanatephorus cucumeris*	Ceratobasidiales	Ceratobasidiaceae
5	Leaf Spot	*Cercospora canescens*	Moniliales	Dematiaceae
6	Leaf Spot	*Corynespora cassiicola*	Anamorphic fungi	–
7	Collar Rot	*Corticium rolfsii*	Polyporaless	Corticiaceae
8	Root-knot	*Meloidogyne* spp.	Tylenchina	Heteroderidae

Table 3.2 Diseases on seeds of Green gram, Black gram in Myanmar

Sr.	Common Name	Pathogen	Order	Family
1	Fusarium Wilt	*Fusarium udum*	Moniliales	Tubeschlariaceae
2	Phyllody	*Mycoplasma*	–	-
3	Leaf spot	*Cercospora* spp.	Moniliales	Dematiaceae

3.2 Management of green gram diseases

3.2.1 Cercospora leaf spot: *Cercospora canescens*

Symptoms

- Spots produced are small, numerous in number, with a pale brown centre and reddish-brown margin. Similar spots also occur on branches and pods.
- Under favourable environmental conditions, severe leaf spotting and defoliation occur during flowering and pod formation.
- The fungus is seed-borne and survives on plant debris in the soil.
- High humidity favours disease development.

Management

- Spray Mancozeb 1 000g /ha at the initiation of the disease and ten days later.
- Previous crop debris should be removed.

3.2.2 Powdery Mildew: *Erysiphe polygoni*

Symptoms

- White powdery spots emerge on leaves and other green portions, which eventually turn dull. These spots progressively grow in size and become round, encompassing the bottom surface.
- When the infection is severe, the whole surface of the leaves is coated with whitish powdery growth. Parts that are severely impacted fade and become distorted.
- In severe infections, the foliage becomes yellow, causing premature defoliation. The disease also creates forced maturity of the infected plants, resulting in heavy yield losses.
- The pathogen has a diverse host range and persists in the off-season in the conidial form on various hosts.
- Airborne conidia formed during the season cause secondary spread.

Management

- Spray NSKE five percent or Neem oil three percent twice at ten days interval from initial disease appearance.
- Spray Eucalyptus leaf extract ten percent at the initiation of the disease and ten days later.
- Spray wettable sulphur 1 500g/ha or Propiconazole 500 ml/ha at the initiation of the disease and ten days later.

Figure 3.1 Cercospora leaf spot and downy mildew

3.2.3 Root Rot and Leaf Blight: *Rhizoctonneia solani*

Symptom

- Pathogens in green gram cause seed decay, root rot, damping-off, seedling blight, stem canker, and leaf blight.
- The disease occurs commonly at the podding stage.
- In the initial stages, the fungus causes seed rot, seedling blight, and root rot.
- The affected leaves turn yellow, and irregular brown lesions appear on the leaves.
- Big blotches are formed on the coalescence of such lesions, and the affected leaves start drying prematurely.
- The stem's roots and basal portion become black, and the bark peels off easily.
- The affected plants dry up gradually. When the taproot of the affected plant is split open, reddening of internal tissues is visible. The pathogen is soil-borne.

Management

- seed treatment with trichoderma viride 4 g/kg
- basal application of zinc sulphate 25 kg/ha
- basal application of neem cake @ 150 kg/ha; and
- soil application T. viride – 2.5 kg / ha + 50 kg of well decomposed FYM or sand at 30 days after sowing.

Figure 3.1 Root tot symptom and yellow mosaic virus

3.2.4 Yellow mosaic: mungbean yellow mosaic virus

Symptom

- The disease is more common in black gram than in green gram.
- Initially, mild scattered yellow spots appear on young leaves.
- The next trifoliate leaves are emerging from the growing apex show irregular yellow and green patches alternating with each other.
- Spots progressively grow in size, and some leaves eventually become entirely yellow.
- Infected leaves show necrotic signs as well.
- Diseased plants are stunted, mature late, and produce few flowers and pods.
- Pods of infected plants are reduced in size and turn yellow in colour.

Management

- Growing resistant varieties;
- Dimethoate seed treatment (or) Imidacloprid @ 5 ml /kg;
- Setting up yellow sticky traps 12 nos/ha;
- Rogue out diseased plants for up to 45 days;
- Foliar spray of neem formulation 3 ml/lit at 30 DAS; and
- Spray methyl demetonne 25 EC 500 ml/ha or dimethoate 30 EC 500 ml/ha or thiamethoxam 75 WS 1g /3 lit and repeat after 15 days, if necessary.

3.3 Plant diseases of chickpea

Although CPC 2007 listed eight diseases but Current list indicated only two diseases in chickpea crops and four diseases in chickpea seeds (Table 3.3 & 3.4)

Table 3.3 Diseases of chickpea (seed) in Myanmar

Sr .	Common Name	Pathogen	Order	Family
1	–	*Aspergillus flavus*	Moniliales	Dematiaceae
2	–	*Aspergillus niger*	Moniliales	Dematiaceae

Table 3.4 Diseases of chickpea in Myanmar

Sr.	Common Name	Scientific Name	Order	Family
1	Aspergillus ear rot	*Aspergillus flavus*	Moniliales	Monilialiaceae
2	Fusarium wilt of chickpea	*Fusarium oxysporum*	Moniliales	Tuberculariaceae
3	Collar rot	*Aspergillus niger*	Moniliales	Monilialiaceae
4	Basal stem rot	*Rhizoctonneia solani*	Moniliales	Dematiaceae

Source: CPC, 2007.

3.4 Management of chickpea diseases

3.4.1 Fusarium wilt (*Fusarium oxysporum f. sp ciceri*):

It is a vascular disease that produces xylem browning and blackening. Affected seedlings first show drooping of the leaves, then collapse. The roots look healthy, but the vascular tissues show brown to black discolouration when split vertically. The fungus is seed and soil-borne and can survive in the soil without a host.

Symptom

- The disease can harm the crop at any stage of development.
- The field symptoms of wilt are dead seedlings or adult plants, usually in patches.
- At the seedling stage, whole seedlings collapse 3–5 weeks after sowing and lie flat on the ground with dull green leaves and shrunken stems.
- Dark brown or dark discolouration of the internal stem tissues is visible.
- At the adult stage, drooping of petioles, rachis, leaflets, and the entire plant occurs.

Figure 3.2 Chickpea plot infected with Fusarium wilt and mealy bugs on the stem

Management

- Deep ploughing during summer and removal of host debris from the field can reduce the level of inoculum.
- Follow crop rotation measures continuously. Exclude chickpea from the crop rotations in infested fields for at least three years.
- Follow 6-year crop rotations with sorghum.
- Always use disease-free seeds.
- Avoid sowing when temperatures are high.
- Use resistant varieties (e.g., Yezin-5, Yezin-6, Yezin-8 and Shweni-lonegyi and 929). Red seed (erect type) is more tolerant than white seed, but farmers don't like as the seed is small.

- Apply FYM 10-15 cart load/ha. DAR has recommended incorporating 20 packets (500 g each) of *T. viride* per acre into the soil. Some farmers use spray *T. viride* spray at the base of the plants.

3.4.2 Dry root rot: Rhizoctonneia bataticola/Macrophomina phaseolina

Symptom

- The disease appears from flowering to the podding stage as scattered dried plants.
- The leaves and stems have become straw-coloured.
- Affected plants wither and spread over the field.
- The roots of infected plants become brittle and dry.

Figure 3.3 Fusarium wilt and dry root rot of chickpea

Management

- deep ploughing in summer;
- grow cultivars resistant to dry root rot;
- drought should be avoided;
- sowing should always be done at the recommended time;
- germinating and young seedlings should be saved from high temperatures;
- seed treatment with *t. viride* @4g/kg of seed; and
- spot drenching with *T. viride* 2.5 kg/ha with 50 kg FYM.

Table 3.5 Green gram and chickpea varieties resistant to insect pests and diseases

Variety	Cercospora leaf spot	Leaf blight	Sheath blight		
Green gram	**Yellow mosaic virus**	**Leaf spot**	**Wilt**		
Yezin-8	R				
Yezin-9	R	R			
Yezin-11	R		R		
Yezin-14	R	MR			
Kanti					
Shwekyaymon					
Chickpea	**Fusarium wilt**	**Bruchid**			
Yezin-5	R				
Yezin-6	R			Heat tolerant	
Yezin-8	R				
Yezin-11	MR				
PCHL	R				
ICCV	R				
Shweni lonegyi	R	R			

Source: DAR, 2019.

Chapter 4

The role of pesticides in crop protection

4.1 Introduction

Insecticides are the most powerful pest management technique available. They are highly effective, rapid in curative action, adaptable to most situations, and flexible in meeting changing agronomic and ecological conditions. Pesticide use is indispensable in agricultural production as approximately 9 000 species of insects and mites, 50 000 species of plant pathogens and 8 000 species of weeds damage crops globally, causing an estimated loss of 14 percent, 13 percent and 13 percent by insect pests, plant pathogens and weeds, respectively (Pimentel, 2009). However, excessive and non-judicious use of insecticides has led to the degradation of environmental quality, pest resistance, pest resurgence and the contamination of agricultural products and natural resources. Some advantages and limitations of insecticides were discussed by Metcalf (1975).

4.2 Advantages of insecticides for pest management

a. Insecticide affords the only practical control measure for insect pest populations approaching or at the economic threshold.
b. Insecticides have rapid curative action in preventing economic damage.
c. Insecticides offer a wide range of properties, uses, and application methods to pest situations.
d. The use of insecticide is low in cost and results in substantial financial returns.

4.3 Limitations in the use of insecticides for pest management

a. insect resistance to insecticides;
b. outbreaks of secondary pests;
c. adverse effects on nontarget species;
   -natural enemies
   - honeybees and other pollinators
   - effects on wildlife.
d. hazards of pesticide residues, and
e. direct hazards from insecticide use.

4.4 The use of pesticides on selected crops in Myanmar

Before introducing the modern varieties, the rice crop survived for centuries with traditional varieties with robust plant types but low yields. Farmers began using heavier fertilizer dosages in general and nitrogen in particular. They resulted in an altered micro-climate, which led to the accentuation of the insect pest and disease problems. Many diseases have grown serious in various sections of the nation, including sheath blight, sheath rot, false smut, and leaf scald. Yield decreases ranging from 21 to 51 percent have been estimated due to moderate to severe incidence of stem borer, gall midge, plant-

hoppers and other sporadic pests in the rice-growing areas of the country. To overcome these constraints, mainly pests and diseases, to realize the yield potential of rice, the development of suitable Integrated Pest Management (IPM) strategy is essential. But as the farmers have been most confident in chemical control for managing the pests, it has become imperative to develop a holistic system of tackling environment-friendly, economically viable, and socially acceptable problems. Any IPM program requires time, money, patience, short- and long-term planning, flexibility, and dedication to be successful (Sehgal *et al*., 2018).

In Myanmar, the net sown area of different crops was about 13.369 million ha and the net irrigated was 2.303 million ha (about 25.1 percent). The use of pesticides on five selected crops was as shown in the table.

Table 4.1 The amount of pesticides used on selected crops

Crop	Pound	Gallon
Paddy	1 934 178	796 999
Groundnut	1 912 841	713 939
Sesame	1 903 412	321 020
Pulses	1 950 573	1 014 605

Source: MOALI, 2019a.

The trend of pesticide use is changing these days. In the past, the volume of insecticides was the largest, but herbicide use has become more and more popular to solve the farm-labour shortage due to migration to neighbouring countries. The most widely used pesticides are listed in table 4.2.

Table 4.2 The most widely used pesticides and volume in Myanmar in 2018

Pesticides	Volume used in 2018 (tonnes)
Herbicides	
Glyphosate	6 945.80
Paraquat	1 420.49
Atrazine	517.47
2,4 - D	382.63
Pretilachlor	160.88
Insecticides	
Cypermethrin	1 456.12
Chlorpyrifos	722.63
Carbofuran	696.76
Imidacloprid	380.90
Abamectin	371.73
Fungicides	
Mancozeb	409.77
Carbendazim	386.76
Azoxystrobin	192.04
Metalaxyl	109.34

Chlorothalonil	108.88

Source: Thant Sin, 2019.

4.5 Problems with pesticides

Although pesticides are used to combat the pests in the crop, they may not be necessary all the time. Based on their survey of 10 Asian countries (Myanmar is not included), Heong and Escalada (1997) pointed out that farmers usually overreacted to leaf-feeding pests, collectively referred to as 'worms", and tended to apply their first insecticide sprays during the first four weeks after crop establishment. They suggested that to improve farmers' pest management perceptions and decision making; research needs to address issues such as the influence of communication media on perception and attitude. This is suggested more than two decades ago. There were some initiations in Myanmar to get awareness and change farmers' perceptions through a variety of media such as Farmer Channel, the PPD app from the government sector, and Greenway Htwettoe apps from the private sector.

According to Indonesian experience, fields sprayed repeatedly with pesticides in the run-up to harvest are showing the lowest yields because of the brown plant hopper (BPH) as broad-spectrum insecticides, such as endosulfan control golden snail, shatter the ecological balance of the fields. The insect predators that feed on rice pests - dragonflies, wasps, spiders, pond skaters and many others - are wiped out by heavy pesticide applications. BPH came along and multiplied rapidly in a low natural enemy environment. Excessive use of pesticides was causing a resurgence of BPH, which was spreading like wildfire and causing widespread crop losses. Indonesia farmers are practising PM and rarely use pesticides. Consequently, BPH predators flourish, and healthy rice plants continue to grow in their fields.

Between 1968 and 1970, aerial treatments of phosphamidon (Dimecron 50; Ciba Geigy Ltd., Switzerland) were used to treat 800 X 103 hectares of rice in Indonesia for yellow stem borers (Mochida 1978). Government subsidy on pesticides for about 20 percent of the actual cost (van der Fliert 1993). Insecticide subsidies grew every year, and by the mid-1980s, the annual subsidy averaged U.S.$120 X 106. Before 1970, when phosphamidon was widely used, the brown rice planthopper was not considered a pest in Indonesia. By 1974, a new pest, Nilaparvata lugens (Stal), had emerged in several regions and was being treated as a pest substantially worse than stemborers (Rubia *et al*. 1989).

Similar situations were observed in Myanmar, especially in Shwebo area, where Shwebo Pawsan, commonly known as Pawsanbaykyar, has been widely grown. The growing of Shwebo Pawsan is a lucrative business for farmers as it can fetch double or more income compared with growing other rice cultivars. Naturally, farmers looking for windfall profits have stepped up their use of fertilizers and pesticides in the paddy fields. Many paddy farmers prefer to start spraying pesticides ahead of time, even in the nursery plot or when the plant is only 45 days old, without any evidence of pests, as prevention. There was an outbreak in yellow stem borers in Shwebo in 2013. By the time the farmers identified the symptoms, it was too late. Farmers responded to this stem borer outbreak in the following seasons by overusing pesticides, which killed beneficial insects, thereby

inviting more problematic ones. The next year, there was an outbreak of brown plant hopper, a species typically controlled through a natural balance with friendly insects (Su Mon *et al*., 2016).

They used a number of insecticides to control stem borers although the infestation level. As a result, BPH outbreaks followed up within a few years, and farmers had to double their use of pesticides to tackle the problem but further aggravated rather than solved the problem. Local authorities believed that bph resurgence was mainly due to the use of (a) Acephate and (b) the combination of Chlorpyrifos and Cypermethrin. However, research indicates that a variety of factors contribute to BPH resurgence. The degree of resurgence is dependent on the method, timing, the number of insecticide applications and the level of varietal resistance to BPH (Chelliah and Heinrichs, 1980).

In Myanmar, the most prevalent way of administering pesticides is foliar spraying. *Nilaparvata lugens* feeds mainly on the base of the host plant near the water level, where the levels of insecticide are sublethal because of the dense canopy above. Because of its high reproductive rate, *N. lugens* rapidly develop resistance to insecticides in areas that have been used excessively.

Buprofrezin is an insect growth regulator active against the BPH nymphal stages but not against the egg and adult stages. It should be used only when most field populations are second or third instar. Overuse of insecticide applications, including sublethal doses, killed natural enemies, resulting in the resurgence of *N. lugens.* Preventive' and calendar-based pesticide controls should be avoided in rice due to the possibility of BPH resurgence.

The situation calls for integrated pest management rather than solely relying on chemical pesticides alone. Actions need to be taken immediately otherwise, it may be too late to do anything.

PPD is trying its best to encourage the use of biopesticides for crop protection. It also allows certain biopesticides to get provisional registration and import so that to combat invasive pests like the fall armyworm threatening the maize industry in Myanmar. At the same time, PPD banned some highly hazardous pesticides and announced the restricted to use list after getting approval from the Pesticide Registration Board. So far, 54 pesticides have been banned in Myanmar as of July 2020.

4.6 Banned and restricted pesticides in Myanmar

The Deputy Minister chaired the pesticide registration board has regular meetings and allows or rejects the registration of a pesticide. The board also issues the banned and restricted pesticides from time to time. There are 54 pesticides already banned in Myanmar as of January 2020, and seven are restricted (table 4.3 & 4.4). According to a survey in irrigated project areas, the farmers have no idea whether a pesticide has been banned or not, although they are applying it (MOALI, 2018).

Table 4.3 Notification of the Banned Pesticides List in Myanmar

PESTICIDE REGISTRATION BOARD
Notification Number (1/2020) dated by 7.1.2020

No	Active Ingredients	Reason	Usage	Remark
1.	Aldrin	Carcinogenicity, Bioaccumulation, Hazard to wild life, Chronic effects	Insecticide	POP List
2.	Aldicarb	Highly Acute toxicity	Insecticide	PIC List
3.	Alachlor	Carcinogenicity	Herbicide	PIC List
4.	Alpha Hexachlorocyclohexane	Adverse liver, Fetotoxic and Reproductive effects, Tumors in Animals	Insecticide	POP List
5.	Arsenic Compound	Carcinogenicity, Neurotoxicity, Highly Acute toxicity	Rodenticide	
6.	Beta-Hexachlorocyclohexane (BHC)	Oncogenecity, Carcinogenicity,	Insecticide	POP List
7.	Binapacryl	Carcinogenicity Fetotoxicity	Fungicide, Acaricide	PIC List
8.	Captafol	Oncogenecity, Carcinogenicity	Fungicide	PIC list
9.	Chlordimeform	Oncogenecity, Carcinogenicity	Insecticide	PIC List
10.	Chlordane	Carcinogenicity, Long Residual Effect, Hazard to Living Organism	Insecticide	POP List
11.	Chlordecone	Carcinogenicity	Insecticide	POP List
12.	Chlorobenzilate	Carcinogenicity, Adverse testicular Effects	Insecticide, Acaricide	PIC List
13.	Cyhexatin	Teratogenecity, High risk to the Environment	Acaricide	PIC List
14.	Dieldrin	Carcinogenicity, Bioaccumulation, Hazard to wildlife, Other Chronic effects, Long Residual effects, Bioaccumulation	Insecticide	POP List
15.	Dinoseb	Teratogenicity, Reproductive effects, Acute effects, Carcinogenicity, Possible Teratogen	Herbicide	PIC List
16.	DNOC	Highly acute toxicity	Insecticide, Acaricide	PIC List

No	Active Ingredients	Reason	Usage	Remarks
17.	Ethylene Dibromide (EDB)	Oncogenecity, Mutagenecity, Reproductive effects, Carcinogenicity, Fetotoxicity	Insecticide, Nematicide	PIC List
18.	Ethylene Dichloride	Neurotoxicity, Persistent in environment, Chronic toxicity	Insecticide (Fumigant)	PIC List
19	Endosulfan	Volatile and Persistent, Bioaccumulation in fatty tissues	Insecticide, Acaricide	POP List
20	Endrin	Oncogenecity, Teratogenecity, Reduction in endangered and non-target species, Long residual effects	Insecticide	POP List
21	EPN	Neurotoxicity, Hazard to aquatic Organisms, Cholinesterase inhibitor, Dermal toxicity	Insecticide, Acaricide	
22	Ethylene Oxide	Carcinogenicity, Mutagenecity	Co-Formulant	PIC List
23.	Fluoroacetamide	Highly acute Toxicity	Rodenticide	PIC List
24.	Hexachlorobenzene (HCB)	Carcinogenicity, Persistent in the environment	Fungicide	POP List
25.	Heptachlor	Long residual effect, Bioaccumulation	Insecticide	POP List
26.	Lindane (Gama Hexachlorocyclohexane)	Persistent in Environment, Bioaccumulation, Carcinogenic Potential	Insecticide	POP List
27.	Methomyl	Acute toxicity-humans, Cholinesterase inhibitor, Highly toxic-crustaceans, Moderate toxic to fish	Insecticide, Acaricide	
28.	Mercury Compounds	Highly acute toxicity, Persistent in environment, Toxic to aquatic Organisms	Fungicide	PIC List
29.	Methamidophos	Highly acute toxicity	Insecticide, Acaricide	PIC List
30.	Methyl Parathion	Highly acute toxicity, Dermal toxicity	Insecticide	PIC List
31.	Monocrotophos	High acute toxicity, Cholinesterase inhibitor,	Insecticide, Acaricide	PIC List
32.	Mirex	Carcinogenicity, Persistent in environment, Biomagnifications in the food chain	Insecticide	POP List
33.	Parathion Ethyl	Toxic to aquatic Organisms, High acute toxicity	Insecticide, Acaricide	PIC List

No	Active Ingredients	Reason	Usage	Remarks
34.	Pentachlorophenol (PCP)	Highly acute toxicity, Persistent in the environment	Insecticide, Fungicide	PIC List
35.	Phosphamidon	Highly acute toxicity,	Insecticide, Acaricide	PIC List
36.	Strobane (Polychloroterpenes)	Oncogenecity, Persistant in Environment, Bioaccumulation, Carcinogenicity	Insecticide, Acaricide	
37.	2,4,5 - T and 2,4,5-TP	Oncogenecity, Carcinogenicity, Fetotoxicity, Long residual effect	Herbicide	PIC List
38.	Toxaphene	Oncogenecity, Acute toxicity to aquatic Organism, Chronic effects to wildlife, Carcinogenicity, Long residual effect	Insecticide, Acaricide	POP List
39.	Tributyltin	Highly toxic to aquatic organisms, Highly Acute toxicity, Fetotoxicity, Bioaccumulation	Fungicide	PIC List
40.	Trichlorfon	Cholinesterase inhibitor, Reproductive effects, Carcinogenicity, Highly acute toxicity,	Insecticide	PIC List
41.	D. D. T (Dichloro-diphenyl-trichloroethane)	Bioaccumulation, Persistent in Environment, Carcinogenicity	Insecticide	
42	Tridemorph	Reproductive Effects, Highly Acute Toxicity,	Fungicide	
43	Triflumizole	Reproductive Effects, Highly Acute Toxicity,	Fungicide	
44	Diafenthiuron	Persistent in Environment, Bioaccumulation,	Insecticide	
45	Terbufos	Highly Acute Toxicity, Inhibition of Brain Cholinesterase, Reproductive Effects	Insecticide	
46	Borax Decahydrate	Reproductive Effects, Fetotoxicity, Possible Liver Carcinogen	Insecticide	
47	Hydramethylnon	Reproductive Effects, Highly Acute Toxicity, Possible Human Carcinogen	Insecticide	

No	Active Ingredients	Reason	Usage	Remarks
48	Metaflumizone	PBT, Neurotoxicity (Block the sodium channel of the Nervous System causing Paralysis)	Insecticide	
49	Mineral oil	Carcinogenicity, Skin Burning, Dermal Toxicity	Insecticide	
50	Boric acid	Reproductive Effects, Chronic Effect, Kidney Damage,	Insecticide	
51	Carbofuran	Highest Acute Toxicitiess to humans, Cholinesterase inhibitor, Neurotoxin, Highly toxic to vertebrates and birds	Insecticide	PIC List
52	Carbendazim	Mutagenecity, Reproductive Effects, Teratogenicity, Hepaatocellular dysfunction, Endocrine-disrupting, Disruption of Haematological functions, Disrupted the various ecosystems	Fungicide	-
53	Benomyl	Mutagenecity, Reproductive Effects, Skin Irritation, damaged Liver occurred Cirrhosis, Possible Carcinogen in liver tumours	Fungicide	-
54	Glufosinate-ammonium	Reproductive Effects, Neurotoxicity Cardiovascular and CNS Adverse Effects, Inhibit Glutamine synthetaase, Persistent through the soil	Herbicide	-

Source: MOALI, 2018.

Table 4.4 Notification of the Restricted Pesticides List in Myanmar

PESTICIDE REGISTRATION BOARD
Notification Number (5/2018) dated by 9.8.2018

No	Active ingredients	Restrict for specific usage
1	Methyl Bromide	Fumigant
2	Phosphine	Fumigant
3	Magnesium Phosphide	Fumigant
4	Bromadiolone	Rodenticide
5	Zinc Phosphide	Rodenticide
6	Brodifacoum	Rodenticide
7	Fenthion	Malaria control

After conducting a survey in some areas of Myanmar in 2019, Dr KL Heong (2020) suggested that

- High use of **secondary pest inducing insecticides** such as cypermethrin, emamectin, chlorpyrifos and imidacloprid would make Myanmar rice production vulnerable to **brown planthopper outbreaks** and a threat to future rice production.
- Myanmar farmers will be **much better off not using any insecticide** at all in rice production, and they will gain an extra profit of about USD 35 per ha per season.

He has further advised that **farmers' ecological illitreacy** has deepened their dependency on insecticides. Important interventions to help **wean rice farmers from insecticide use in rice production** will need to include **innovative training** courses focusing on ecological principles.

Rothschild (2020) has listed a number of pesticides used in Myanmar, and most of them have been already banned in European Union (Table 4.5 and 4.6). He has pointed out that more than 50 percent of pesticides registered for use in Myanmar have been banned in European Union and it will be problems with GAP export markets. On the other hand, cheap unregistered products were very widely used (including illegal imports (regional cooperation), counterfeits). Therefore, law enforcement is needed and full participation of pesticide suppliers as responsible stewardship. There may need to create some incentives to do so and need local community stakeholder platforms rather than centralised national systems.

Table 4.5 The comparison of insecticides used in European Union and Myanmar

INSECTICIDES

Pesticide	EU status	Myanmar status	No. users in WP3 survey 474 total	No. users in IFDC-LIFT 337 total	WP3 +IFDC-LIFT users 811 total
Acetamiprid	Banned	Approved (62)	7	12	**19**
Acephate	Banned	Approved (75)	19	70	**89**
Bacillus thuring - Bt	OK	OK	14	-**	**14**
Carbaryl	Banned	Approved (19)	18	-**	**18**
Carbofuran	Banned	Approved (48)	1	4	**5**
Carbosulfan	Banned	Approved (23)	1	-**	**1**
Cartap hydrochloride	OK	OK	15	1	**16**
Chlorantraniliprole	OK	OK	- **	7	**7**
Chlorpyrifos	Banned	Approved (152)	18	68	**86**
Cypermethrin	OK	OK	143	133	**276**
Deltamethrin	OK	OK	6	-**	**6**
Dimethoate	Banned	Approved (28)	- **	2	**2**
Emamectin	OK	OK	68	42	**110**
Endosulfan	Banned	Banned ***	10	-**	**10**
Imidacloprid	Banned	Approved (138)	24	18	**42**
Indoxacarb	OK	OK	1	-**	**1**
Lambda-cyhalothrin	OK	OK	20	19	**39**
Neem	OK	OK	8	-**	**8**
Profenofos	Banned	Approved (55)	4	28	**32**
Propapargite	Banned	Approved (3)	2	-**	**2**
Temephos	Banned	Approved (12)	2	-**	**2**
Thiamethoxam	Banned	Approved (37)	3	-**	**3**

Highlighted in yellow = four highest total households

***** NOTE: PRODUCTS OFTEN REGISTERED AS MIXTURES OF INSECTICIDES, OR WITH FUNGICIDES**

**** = No products listed, but may have been included in the "unknown" category**

Table 4.6 The comparison of fungicides and herbicides used in European Union and Myanmar

FUNGICIDES

Pesticide	EU status	Myanmar status	No. users in WP3 survey 474 total	No. users in IFDC-LIFT 337 total	WP3 +IFDC-LIFT users 811 total
Azoxystrobin	OK	OK	1	28	29
Benomyl	Banned	Approved (20)	4	1	5
Carbendazim	Banned	Approved (77)	12	2	14
Chlorfenapyr	Banned	Approved (12)	1	-**	1
Chlorothalonil	Banned	Approved (40)	2	11	12
Copper oxychloride	OK	OK	4	4	8
Cymoxanil	OK	OK	18	19	37
Difenoconazole	OK	OK	8	7	25
Dimethomorph	OK	OK	5	1	6
Hexaconazole	Banned	Approved (54)	2	9	11
Kasugamycin	Banned	Approved (47)	-**	2	2
Mancozeb	Banned	Approved (118)	25	46	71
Metalaxyl	OK	OK	4	6	10
Propiconazole	Banned	Approved (30)	2	-**	2
Thiophanate-methyl	Banned	Approved (27)	-**	4	4
± 60% fungicides banned in EU, and often registered as Mixtures					
HERBICIDES					
Bispyribac-sodium	OK	OK	15	-**	15
Fenoxaprop-ethyl	OK	OK	14	-**	14
Glyphosate	OK but pending	OK	-**	85	85
Imazethapyr	Banned	Approved (17)	-**	1	1
Pendimethalin	OK	OK	-**	1	1
Quizalofop-p-ethyl	OK	OK	-**	1	1

± 17% herbicides banned in EU

** = no products listed, but may have been included in the "unknown" category

Chapter 5

Precaution measures for safe handling of pesticides and container disposal

5.1 Introduction

Pesticides can poison both bugs and people. It is necessary to take precautions not to harm people, livestock and non-target organisms. Careless handling and application of pesticides will pose a hazard to the user and contaminate the environment. Most pesticides will cause adverse effects if intentionally or accidentally ingested or if they are in contact with the skin for a long time. Pesticide particles may be inhaled in the air while they are being sprayed. An additional risk is the contamination of drinking water, food or soil. Special precautions must be taken during transport, storage and handling. Spray equipment should be regularly cleaned and maintained to prevent leaks. People who work with pesticides should receive proper training in their safe use.

The safe use of pesticides is contingent on a number of factors. Selecting a suitable product and utilizing it according to the label guidelines are two of the most important elements. The instructions on the label are intended to reduce the possibility of difficulties and identify the product's lawful usage.

In Myanmar, farmers commonly use pesticides to solve pest problems, but they have never realized that they are dealing with toxic materials. They have only one thing in mind, just want to kill the pest. A survey conducted in Shan State revealed that farmers did not care much about the pesticide risks (Myint Thaung, 2018).

With the storage of pesticides, some farmers keep pesticides safely in a box, on the shelf, in a store room or hung above where the children cannot reach. Some farmers kept them in the corner of the house. Some kept them in the field.

Some Basic Pesticide Safety Principles

Before purchasing or applying a pesticide, always read and follow the label guidelines.

Safe use of pesticides does not have a simple, one-size-fits-all solution, but here are some basic pesticide safety principles – a starting point for safety from purchase to disposal.

1. Read the *entire* pesticide label before purchase and use. You are legally required to read and follow everything on the label except the information about crops or sites that you will not treat.
2. Follow all applicable federal, state, tribal and local laws and regulations concerning the use of pesticides and personal protective equipment.
3. Seek *competent* advice if there is something you don’t understand on the label or in other applicable laws and regulations.

4. Keep pesticides apart from passengers, groceries, and animal feed in the trunk or truck bed, and lock the containers to prevent spillage.
5. Keep pesticides stored away from food, feed, and personal protective equipment in a secured cabinet or safe room.
6. Measure and mix pesticides away from children, pets, toys, and food in a well-ventilated location.
7. Ensure that application equipment is calibrated and maintained so that the amount of pesticide sprayed is exact, consistent, and lawful.
8. If required, keep pesticides on target, employ untreated buffers or postpone spraying if wind or water is likely to cause off-target movement.
9. Identify any sensitive places or organisms that the application may touch, and take all required safeguards.
10. Do everything you can to avoid spills and leaks, and have an absorbent material on hand, such as cat litter or sawdust.
11. Separately wash slightly contaminated work garments before reusing them and follow all personal protective equipment care and disposal instructions.
12. Dispose of the pesticide properly and any excess spray mixture, empty containers, and contaminated cleanup material and clothing.

5.2 Reducing pesticide risk

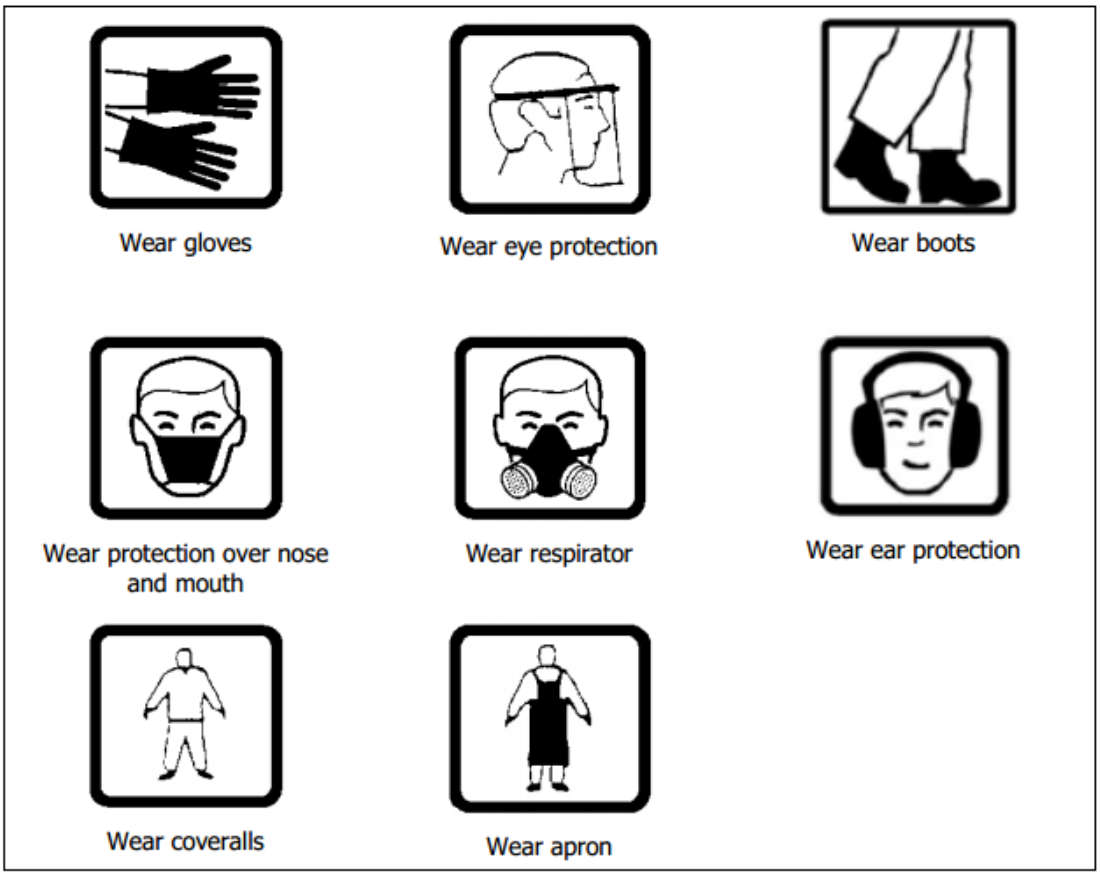
Risk is the product of hazard (i.e. chemical property) and exposure (i.e. intensity and duration). Risk reduction can be achieved by decreasing hazards and/or reducing exposure (Walter-Echols, 2007). Hazard can be reduced by selecting less toxic products (when pesticide use is justified), while exposure is reduced by using fewer pesticides (reducing reliance on pesticides in favour or alternative pest management options), better application methods and ensuring proper use of protective equipment (FAO, 2013).

When the problems of risk were enquired, 59 percent said that there was no problem, but 16 percent said that they have problems like dizziness, itchy and get rashes where the pesticide spilt over the body part, blurred eyes, and one said that he was collapsed while spraying. One farmer said that he had a problem with poisoning and had to be operated on at the neck. Another farmer said that he was seriously ill after spraying pesticides for many years, and he was lucky enough to be alive. Now he has become an advocate for using PPE. In Myanmar, most farmers don't use personal protective equipment when they are spraying. Sometimes, they didn't wear shoes.

Figure 5.1 Farmers spraying pesticides in the field

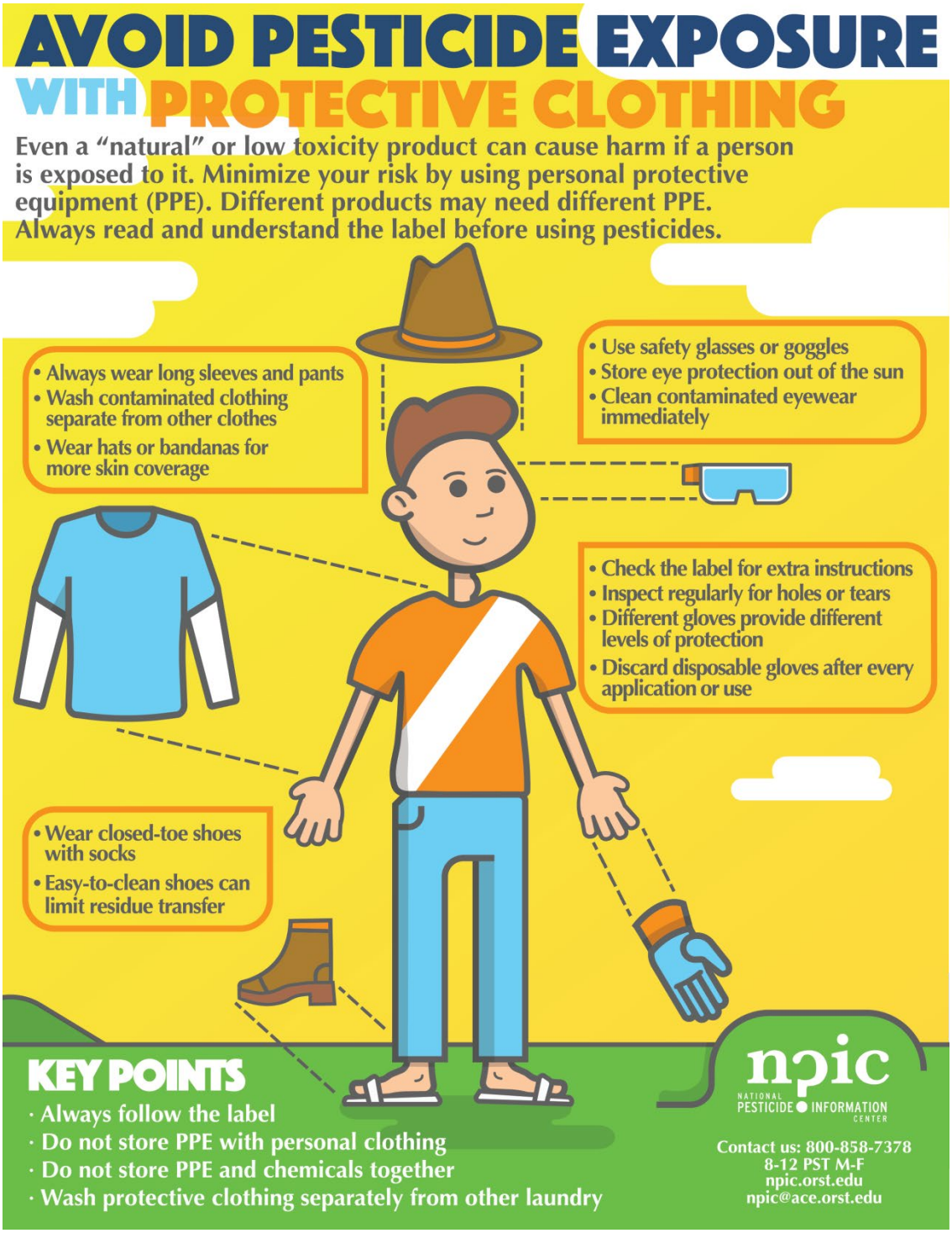
Figure 5.2 Farmer spraying pesticides in the field and getting wet after spraying

Figure 5.3 Examples of common PPE pictograms for pesticide use



Source: FAO / WHO, 2020.

Figure 5.4 Poster how to avoid pesticide exposure with PPE



Source: http://npic.orst.edu/health/safeuse.html

NPIC (2020) has outlined some tips to be considered when using pesticides:

- Before mixing and applying pesticides, kids, pets, and anyone non-essential to the application is out of the area.

- Wear protective clothing when using pesticides. Consider wearing a long-sleeved shirt, long pants, closed-toe shoes and any other protective clothing or equipment required by the label.
- Mix pesticides in a well-ventilated place or outside.
- Mix only what you need to use in the short term to avoid storing or disposing of excess pesticides.
- Be ready for a pesticide spill. Have paper towels, sawdust or kitty litter, garbage bags, and non-absorbent gloves on hand to contain the spill. Avoid using excessive amounts of water, as this may only spread the pesticide and could be harmful to the environment.
- Read the first aid instructions on the label before using the product.
- When applying pesticides as a spray or dust outside, avoid windy conditions and close the doors and windows to your home.
- Wash your hands after applying insecticides before smoking or eating.

5.3 Disposal of pesticides

To avoid accidents and safeguard the environment, pesticides must be removed and disposed. If you have unwanted pesticide products, store them safely and dispose of them as soon as possible.

- Dispose of pesticides as instructed on the product label. Look for the "Storage and Disposal" statement on your pesticide label.
- After emptying a pesticide container, rinse it properly for disposal or recycling. Never reuse a pesticide container for any purpose!
- Be sure to wear protective clothing when rinsing pesticide containers, such as chemical resistant gloves and eye protection.
- Apply rinse water according to label directions; only where the pesticide was intended to be used.
- Do not pour rinse water into any drain or on any site not listed on the product label; it could contaminate the environment.
- If you mixed or diluted a pesticide and you have a little too much left over, try to use it up while following the label. Consider asking a neighbour if they can use any leftover mixtures.

The empty containers were burned or disposed in a pit. However, some farmers said that they threw away the empty containers. In Ayeyarwady region, DoA staff demonstrate and encourage farmers to dispose of empty pesticide containers properly.

Figure 5.5 Mass activity for pesticide container disposal in Ayeyarwady region

The best advice for the farmer is:

- Practice IPM to reduce the need for pesticides.
- Identify the pest and make sure the product will be effective against that pest before buying the product.
- Buy only what you need this season; mix only what you need today.

Tips for transporting pesticides for disposal

- Keep the pesticides in their original containers with the labels attached.
- Place containers so they won't shift and/or spill.
- Line the transport area in your vehicle or place pesticides in a plastic bin to contain any spills in case of an accident.
- If pesticides are carried in the back of an open vehicle, secure and cover the load.
- Don't put pesticides in the passenger compartment of a vehicle.
- Keep pesticides away from groceries, including food for animals.
- Go straight to the collection site once you have loaded your vehicle. Drive carefully!

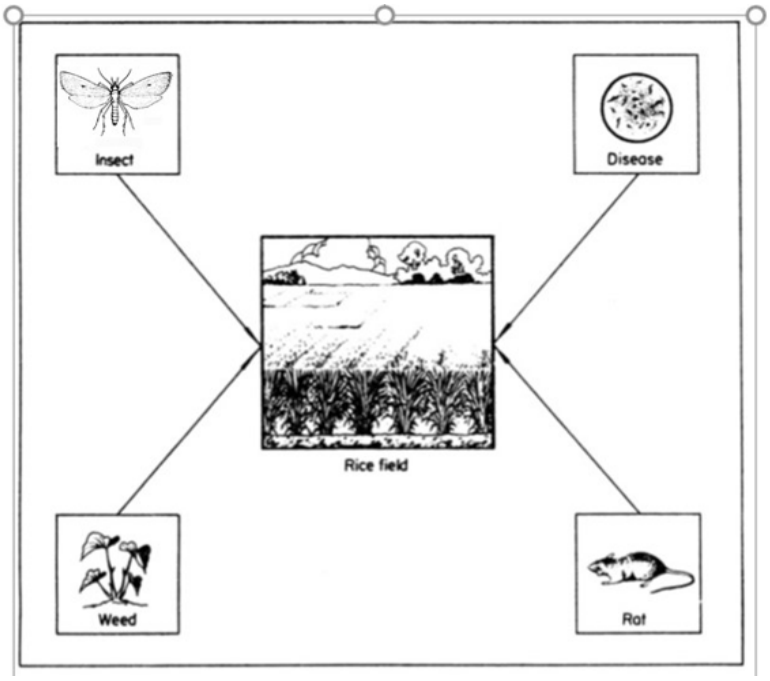
Chapter 6

Integrated pest management

6.1 Introduction

Pests are defined as any species, strain, or biotype of plant, animal, or pathogenic agent that is harmful to plants and plant products, materials, or environments, as well as vectors of parasites or pathogens of human and animal disease and animals that cause public health nuisance (FAO/WHO, 2014).

Figure 6.1 Rice IPM and Pests



Source: Reissig.

In phrases such as "integrated pest management" and "pest control", the term pest is used in a broader sense to mean all harmful organisms such as fungi, bacteria, viruses and virus-like organisms, and weeds.

Table 6.1 The types of pests

Insects	Aphids, beetles, caterpillars, mosquitoes, cockroaches etc.
Insect-like organisms	Mites, spiders, ticks, etc
Weeds	Any plant growing where it is not wanted
Parasitic weeds	Orobanche, Striga (witchweed), etc.
Molluscs	Slugs, snails, etc.
Vertebrates	Rats, mice, etc.
Nematodes	Root knot nematode, etc.
Micro-organisms	Bacteria, fungi, viruses

6.2 Definition of IPM

Integrated Pest Management has several definitions (see Bajwa and Kogan, 2002). Initially, it was referred to as Integrated Control and defined by FAO in 1967 as:

> "Integrated control is a pest management approach that, in the context of the related environment and the pest species' population dynamics, employs all appropriate techniques and procedures in the most compatible way feasible to keep pest populations at levels below those causing economic harm." (FAO. 1967).

In the International Code of Conduct on the Distribution and Pesticides usage, which the FAO Council adopted in November 2002, the following definition of IPM is used:

Integrated Pest Management (IPM) means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that dispirit the development of pest populations and keep pesticides and other interventions to economically justified levels and decrease or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.

Pest management is the intelligent selection and use of pest control actions that will be favourable economic, ecological, and sociological consequences. Geier has described the practice of pest management (1966) as: (1) determining how the life system of a pest needs to be modified to reduce its number to a tolerable level, that is, below the economic threshold, and (2) applying biological knowledge and current technology to achieve the desired modification, that is, applied ecology, and (3) devising procedures for pest control suited to current technology and compatible with economic and environmental quality aspects, that is economical and social acceptance. An integrated pest management approach should be ecologically sound, economically profitable, and socially acceptable.

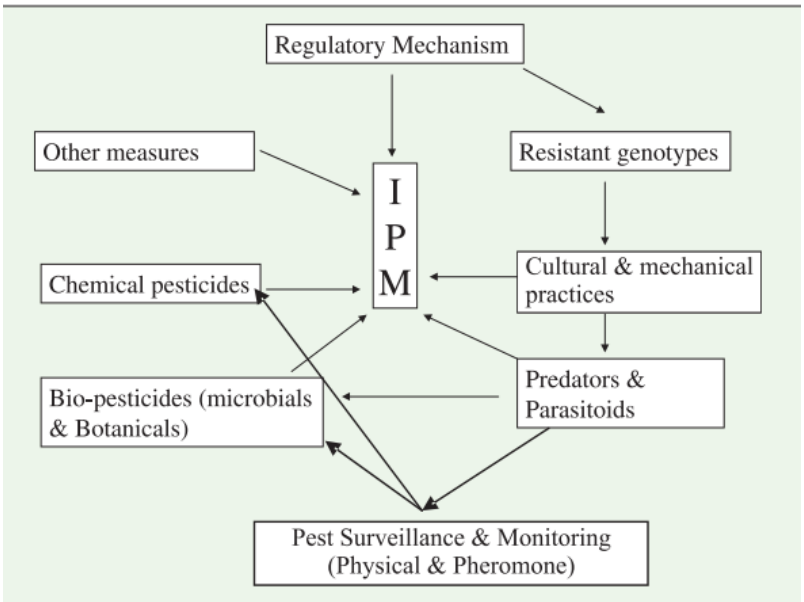
The IPM concept is based on the principle that it is not necessary to eliminate all pests but to reduce pest populations to levels where pests cannot cause significant loss. An integrated pest management strategy includes using pest-resistant crop varieties, modifying agronomic practices to reduce pest incidence, biological control, and other innovative approaches to pest suppression and need-based judicious use of chemical pesticides.

IPM programs are created by combining these IPM ideas and techniques. While each situation is different, five major components (Stein, 2006) are common to all IPM programs:

1. identify the pest
2. monitor pest activities
3. determine action thresholds
4. explore treatment options and make treatments
5. evaluate results.

IPM is a knowledge-intensive sustainable approach for managing pests by combining compatible cultural, biological, chemical, and physical tools to minimise economic, health, and environmental risks with the help of pest scouts. Prakesh *et al*., (2014) explained the components of IPM with the following figure.

Figure 6.2 Diagrammatic representation of IPM components



IPM is not just a simplified insecticide application program based on the economic threshold concept. It will consider the ecology of the pest, the mechanism of pest population regulation, including biotic (the crop, competitors of the pest and natural enemies) and abiotic factors such as soil fertility and weather conditions that will influence the survival and growth of the host plant, pests, and natural enemies. The coevolution of insects and plants and the compensation ability of the crop also need to be considered.

IPM is neither organic nor it relies solely on biological control to achieve the desired sustainable outcome. It often tries to assist and augment the efficacy of natural enemies by limiting the impact of pesticides on their populations and providing a clean and safe niche. It seeks to conserve balance between the crop and the natural environment.

Although it is not feasible to do everything, some of the procedure for pest monitoring suggested for India by Prakesh *et al*., (2014) is worth mentioning here.

6.3 Pest monitoring:

a. Survey/field scouting

The objective of roving surveys is to monitor the initial development of pests in endemic areas. So, routes based upon the endemic areas must be identified at the beginning of crop season to undertake roving surveys. Based on the results of the roving surveys, the state extension functionaries must concentrate on more significant efforts at block and village levels and through farmers to initiate field scouting. Therefore, field scouting farmers should be mobilised to observe the insect pest and disease occurrence at the stipulated. The plant protection measures must be taken only when insect pests and diseases cross Economic Threshold Level (ETL) as per the results of field scouting.

1. **Roving survey:** - Undertake a roving survey at every 10 km distance at 7–10 days intervals (depending upon pest population). Every day at least 20 spots should be observed.
2. **Field scouting:** - Field scouting for pests and bio-control fauna by extension agencies and farmers once in 3–5 days should be undertaken to workout ETL.

b. Pest monitoring through pheromones/light traps etc.

The majority of the insect population can be monitored by fixing and positioning pheromones or light traps at the appropriate stage of the crop. PPD can initiate this action at strategic locations at the village level as per the following details:

1. **Pheromone trap-monitoring** - 5 traps per ha may be used to monitor yellow stem borer and moth population.
2. **Light trap** - A light trap can be operated for two hours in the evening to observe photo-tropic insect pests.
3. **Sweep-nets - water pans** - Besides visual observations, sweep-nets and water pans may also be used to assess the population of insect pests and biocontrol agents to determine the type of pesticides to be recommended or used.

6.4 Cultural control

Increasing nitrogen levels, closer plant spacing, and higher relative humidity are known to increase *N. lugens* populations, but not to a level that is economically significant when natural enemies are present.

Draining rice fields can be effective in reducing BPH at initial infestation levels.

Growing no more than two crops per year and using early-maturing varieties were recommended. Judicious use of fertilizer by splitting nitrogen applications can also reduce planthopper outbreaks. The field should be drained for 3 or 4 days when heavy infestations occur.

Synchronous planting, including planting neighbouring fields within three weeks of each other and maintaining a rice-free period, may be effective, but this approach is

controversial. Asychronous rice cultivation within areas provides better continuity of natural enemy populations.

Wider spacing (22.5 x 20 cm and 30 x 20 cm) and low usage of nitrogenous fertilizer decrease the percentage of leaf folder, *Cnaphalocrocis medinalis* infestation. Early planting may enable plants to escape a high degree of defoliation.

6.5 Biological control - Existing species and levels of natural enemies in Asian rice areas are currently regarded as the key to BPH management. *N. lugens* is normally controlled at low levels by the numerous predators, egg and nymphal parasites, pathogens and nematodes found in rice field environments.

Anagrus spp. and *Oligosita* spp. are the most important egg parasitoids, while the mirid *Cyrtorhinus lividipennis* is often the principal egg predator.

The beetles *Micraspis* and *Coccinella*, the bug *Microvelia*, and the spider *Lycosa pseudoannulata*, are important predators of mobile *N. lugens* nymphs and adults.

6.6 Host plant resistance

High yielding varieties were found to be susceptible compared to local varieties. See the rice varieties resistant to some pests and diseases reported by DAR in sections 2 and 3.

6.7 Chemical control as a component of IPM

Currently, rice protection from insect pests solely depends on chemical pesticides, which have a tremendous impact on biodiversity, the environment, animals, and human health. According to the Bangladesh experience, there exists a technology that can reduce 75 percent of insecticide usage in the rice field (Ali *et al*., 2017). They found that predatory insects were higher in numbers in IPM plots than insecticide treated fields. They conclude farmers should refrain from insecticide applications up to 30–40 days after transplanting to enhance higher predatory arthropod population numbers, which might check pest populations in the rice field. Insecticide applications should be made based on ETL. Myanmar farmers were advised to use some ETL developed by other countries. For example, a control threshold of 20 to 25 planthoppers per hill was recommended, but the critical economic injury level may be much lower - 2 to 5 planthoppers per hill, as suggested by Sogawa and Cheng (1979). So far, there is no specific ETL for many crops, including rice pests in Myanmar, although some other countries have their own.

Surprisingly, many paddy farmers prefer to start spraying pesticides ahead of time, even in the nursery plot or when the plant is only 45 days old, without any evidence of pests, as prevention. There was an outbreak in yellow stem borers in Shwebo in 2013. By the time the farmers identified the symptoms, it was too late. Farmers responded to this stem borer outbreak in the following seasons by overusing pesticides, which killed beneficial insects, thereby inviting more problematic ones. In the next year, there was an outbreak of brown plant hopper, a species typically controlled through a natural balance with friendly insects (Su Mon *et al*., 2016)

Heong and Escalada (1997), based on their survey data in ten Asian countries (unfortunately, Myanmar was not on the list), pointed out that most of the sprays were applied during the seedling, tillering, and booting stages of the rice crop. Farmers usually overreacted to leaf-feeding pests, collectively referred to as "worms," and tended to apply their first insecticide sprays during the first four weeks after crop establishment. They strongly believed that leaf-feeding insect pests were damaging and reduced yield. Based on this perception, farmers chose Insecticides (or medicine) to kill pests to protect their yields. They suggested that it is necessary to carry out further research to change farmers' perception influenced by the media.

6.8 Concept of economic thresholds in IPM

(a) Economic injury level

Insect colonization and feeding often cause injury to plants. The injury does not necessarily result in damage. The latter refers to a measurable loss of host ability, most often including yield quantity, quality, or aesthetics. The lowest level of injury where damage can be measured is called the damage boundary (DB), while the lowest number of insects that will cause economic damage is referred to as the economic injury level (EIL), which can be worked out as follows:

EIL = C/VID
EIL = No. of injury equivalents per production unit (insects/ha)
C = Cost of management activity per unit of production (per ha)
V = Market value per unit of product (per tonne)
I = Crop injury per pest density
D = Damage per unit injury (tonne reduction/ha).

(b) Economic threshold level

Economic threshold level (ETL) is the best known and most widely used index in making pest management decisions. It is defined as the population density at which control measures should be initiated against an increasing pest population to prevent economic damage. Although represented in insect numbers, ETL is a temporal parametre, with pest numbers used as an index to determine when management methods should be implemented. As with the EIL, the ETL can also be expressed as an insect equivalent. In economic terms, ETL is defined as the level to which a pest population should be reduced to reach the point where marginal revenue just exceeds marginal costs. ETL is fixed arbitrarily at around 75 or 90 percent of EIL, so necessary control measures are initiated at this level to contain the pest population from reaching EIL.

The economic threshold varies with the ability of different varieties depending on their resistance, tolerance, or susceptibility to the insect attack. For example, the five to ten BPH nymphs/hill attacked at seedling, fifteen to twenty at tillering and 20 to 25 at booting stage can cause yellowing in lower leaves, then wilting and death in the susceptible varieties like TN-1 and Karma mahsuri. At the same time, the other varieties like Ptb-33

are not affected because of their high level of resistance to BPH under the glasshouse in India (Kushwaha *et al*., 2016).

(c) Limitations of economic threshold level

Both EIL and ETL are deceptive since they are defined in terms of population densities, with the former representing an injury level and the latter the appropriate time to begin control measures. This constraint can be circumvented by describing these levels in terms of damage equivalents.

- There is no rigorous definition of economic damage (the amount of injury that will justify the cost of control). Because economic damage was not described mathematically in terms of its components, it could not be assessed solely based on the definition by Stern *et al.,* (1959).
- EILs cannot be used to calculate decision levels for the control of specific pests. Aside from medical and veterinary pests, it contains the majority of vectors. It is very difficult to monetize the reduction in aesthetic value caused by a given injury. A similar problem is also encountered when assessing damage caused by forest pests. Almost all EIL components are difficult to estimate for pests; determining accurate market values is a problem; management costs may vary greatly and frequently include only environmental and social costs, and the injury/crop-response relationship may be difficult to determine.
- The concept is unsuitable in the case of a multiple pest attack on a single crop at the same stage. However, the EIL and ETL concept offers a practical approach to pest-related decision-making despite these limitations.

6.9 Pest management in chickpea

Chandrashekar *et al*., (2014) have mentioned the economic threshold level of some important insect pests and diseases in Table 6.2.

Table 6.2 Economic Threshold Levels (ETLs)

S. No	Pest insects	Stage of the crops	Economic threshold Levels (ETLS)
Insects			
1	Cut worm (*Agrotis ipsilon* HufInagel and *Spodoptera exigua* Hubner)	Seedling stage	One larvae/ square metre under the soil near cut plant.
2	Termite (*Odontotermes obesus* or *Microtermes obesi*)	Seedling stage	damaged plants/sq. metre
3	White grub (*Phyllophaga implicita)*	Seedling stage	grubs/sq. metre
4	Gram pod borer (*Helicoverpa armigera*)	Vegetative/ reproductive	5 to 8 eggs or 2 early instar /10 plants or one mature larvae (more than 1cm in length)/10 plants or I metre row
5	Semilooper (*Autographa nigrisigna*)	Vegetative phase	2 larvae/10 plants

Disease			
6	Wilt & root rot (*Fusarium oxysporum*)	Seedling/vegetative	5-10 percent plants infested
Rodent			
7	Working index(ETL)	Before podding	25 live burrows/ha
Nematode			
8	Nematodes	Vegetative phase	1-2 larvae/g of soil

Chandrashekar *et al*., (2014) have also mentioned some IPM practices to follow based on the crop growth stage of chickpea

Table 6.3 Crop stage-wise IPM practices on chickpea.

S. No.	Crop stage	Pest	IPM component	IPM Practices
1	Pre-sowing	Pod borer/ Cut worm/ Termite	Cultural practices	1. Deep summer ploughing after harvest. 2. Apply well-decomposed FYM or neem cake 3. Synchronised sowing single recommended varieties in village/area. 4. Marigold plantation should be adopted as trap/indicator crop/ antagonistic crop for the nematode. 5. Inter cropping with Linseed/ Coriander/ Mustard/ Wheat/Sorghum (*rabi*) 6. Early planting i.e., mid-October to escape the peak activity of *H. armigera.* 7. Use tolerant/ resistance varieties
		Wilt/root rots		1. Destruction of disease crop debris/ un-decomposed organic matter by deep tillage/ burn. 2. Timely sowing to avoid drought.
		Dry root rot Collar root rot	Cultural practices	1. Timely sowing to avoid drought 2. Mild irrigation during disease outbreaks under stress conditions to reduce soil temperature. 3. Cultivation of resistant variety
		Nematode (Rootknot, Reniform, Root lesion)	Cultural practices	Use of organic amendments including neem and castor cake @ 1 tonne/ha 10 days before sowing in the infested field and their combination with seed treatment with carbosulfan (25 DS) @ 3 percent a.i. (w/w).
			Biological control	Seed treatment with *Trichoderma viride* each @ 10g/kg seed
2	Seed and Seedling	Cut worm/ Termite/ Collar rot/ Dry root rot	Mechanical cultural practices	1. Use *Rhizobium* culture @ 1pkt (200g) per ha for effective nodulation. 2. Thinning should be done a month after in case of dense plant population
		Nematode	Biological control	Seed treatment with *Trichoderma viride* (effective strain) @ 10g/kg of seed.

		Weed	Cultural practices	Follow recommended agronomic practices for land preparation, proper seed rate and balanced fertilizer for a good crop stand.
3	Vegetative stage	Weed	Cultural practices	1. Inter-culture and hand weeding for keeping the crop weed-free for 6 to 8 weeks. 2. Detopping or nibbling wherever possible at 30 days after sowing to reduce pest occurrence and induce branch initiations.
		Pod borer	Cultural practices	Regular monitoring of gram pod borer during entire crop season.
			Biological control	Conservation of predatory wasp, spider, insect parasitoides by growing coriander as intercrop.
			Chemical control	If the pest crosses ETL level use pesticide having label claim only
4	Flowering and podding stage	Gram Pod borer	Biological control	*Bt*. var kurstaki 1kg/ha or NSKE 5 percent or neem oil 0.03 percent (3000 ppm). *Beauveria bassiana* @ 3 kg/ha.
			Chemical control	Spray Chlorantraniliprole 18.5 percent SC @ 0.15ml/l or Emamectin benzoate 5 SG @ 0.2g/l, or Deltamethrin @ 0.5 ml/litre of water 500 to 600 litre of water/ha or dust Quinalphos 1.5 D 25kg /ha.
		Semipooper	Biological control	1. Conservation of predators like spiders, *Chrysopa* and other natural enemies by avoiding indiscriminate use of pesticides. 2. Installation of bird perchers for predatory birds.
		Rodents	Chemical control	Apply Bromadiolone (0.005 percent) baits inside rodent's burrows.
5	After harvest		Mechanical	1. Destroy crop residue infested with disease and nematodes. 2. Remove and burn Nematode infested crop to destroy the inoculums and to check further multiplication and spread.

Note: - First spray preferably be started first with bio-pesticides and 2nd spray, if required, by conventional insecticides having label claim.

6.10 Do's and don'ts in chickpea IPM

Chandrashekar *et al*., (2014) have also recommended some do's and dont's for the crop management of chickpea as follows:

Table 6.4 Some do's and dont's for the crop management of chickpea

Sr No	DO's	DON'T's
1	Deep ploughing is to be done on bright sunny days during May and June. The field should be exposed to sunlight for at least 2-3 weeks.	Do not plant or irrigate the field after ploughing, at least for 2-3 weeks, to allow desiccation of weed bulbs and/or rhizomes of perennial weeds.
2	Adopt crop rotation	Avoid monocropping
3	Grow only recommended varieties.	Do not grow varieties not suitable for the season or the region.
4	Sow early in the season	Avoid late sowing as this may lead to reduced yields and incidence of white grubs and diseases
5	Always treat the seeds with approved chemicals/biopesticides to control seed-borne diseases/pests.	Do not use seeds without seed treatment with biopesticides/chemicals.
6	Sow in rows at optimum depths under proper moisture conditions for better establishment.	Do not sow seeds beyond 5-7 cm depth.
7	Apply only recommended herbicides at the recommended dose, proper time, as appropriate spray solution with standard equipment, and f at fan or f at jet nozzles.	Pre-emergent and soil incorporated herbicides should not be applied in dry soils. Do not apply herbicides along with irrigation water or mix with soil, sand or urea.
8	Maintain optimum and healthy crop stand which would be capable of competing with weeds at a critical stage of crop weed competition.	Crops should not be exposed to moisture deficit stress at their critical growth stages.
9	Use NPK fertilizers as per the soil test recommendation	Avoid imbalanced use of fertilizers.
10	Use micronutrient mixture after sowing based on test recommendations.	Do not apply any micronutrient mixture after sowing without test recommendations.
11	Conduct weekly AESA in the morning, preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only.	Do not take any management decision without considering AESA and P: D ratio
12	Install pheromone traps at the right time.	Do not store the pheromone lures at normal room temperature (keep them in the refrigerator).

13	13 Release parasitoids only after noticing adult moth caught in the pheromone trap or as pheromone trap or as per field observation	Do not apply chemical pesticides within seven days of the release of parasitoids.
14	In the case of pests active during the night, spray recommended biopesticides/chemicals at the time of their appearance during the evening.	Do not spray pesticides at midday since most insects are not active during this period.
15	Apply short persistent pesticides to avoid pesticide residue in the soil and produce.	Do not apply pesticides during the preceding seven days before harvest.
16	Follow the recommended procedure of trap crop technology.	Do not apply long persistent pesticides on trap crops; otherwise, they may not attract pests and natural enemies.

Source: Chandrashekar *et al.*, 2014.

Chapter 7

Concept of Agroecosystem Analysis (AESA)

7.1 Introduction

Globally, IPM underwent several changes over the years in its focus and approaches, namely damage threshold, EIL, ETL and currently standardized as AESA-based IPM, which has gained universal acceptance. In 2002, FAO defined IPM as the careful consideration of all available pest control techniques and the subsequent integration of measures that discourage the development of pest populations and keep pesticides and other interventions to levels acceptable from an economic, environmental, and public health perspective. IPM emphasizes healthy crop growth with the least possible disruption to agroecosystems and encourages natural pest control mechanisms. FAO is promoting AESA-based IPM.

Extension functionaries and farmers can use the AESA approach to analyse field situations regarding pests, defenders, soil conditions, plant health and climatic factors, and their interrelationship for a healthy crop. A critical field analysis will help take appropriate decisions on pest management practices.

7.2 AESA by extension functionaries/farmers

During their regular village visits, extension functionaries mobilize farmers, conduct an AESA and critically analyse factors such as the pest population vis-á-vis the defender population and their role in natural pest suppression, the influence of weather and conditions on the likely build-up of the defender/pest population. They may also decide based on the AESA, which uses IPM components like the release of defenders, application of neem formulations and other safe pesticides for specific pest situations. Extension functionaries can repeat this exercise during every village visit to motivate farmers to adopt AESA.

Following a brief exposure to AESA during IPM demonstrations/field training, farmers can implement it in their fields. Trained farmers can train fellow farmers, thereby making a large group of farmers proficient in conducting a weekly AESA and deciding on action suited to specific pest situations. A farmer-to-farmer training approach will go a long way in promoting IPM across a large area on a sustainable basis.

Ecologically-based approaches to pest management have been developed and deployed in several countries of Southeast Asia. The concept of “ecological engineering” was introduced to Myanmar through a training workshop in 2011.

7.3 Economic threshold level vs Agroecosystem analysis-based IPM

The ETL approach considers only the pest population, but farmers must base decisions on a larger range of observations when using the Agroecosystem Analysis. Unfortunately, the ETL approach is still being recommended as an IPM method. But

there are many reasons for not using an ETL approach: it is based on parametres that change all the time and are often not known. An ETL is calculated from:

1. the management cost per hectare;
2. the price of the farm produce per kilogram; and
3. expected damage or yield loss (kilogram/pest).

While management cost can be estimated, it is usually not possible to know the product price per kilogram when the crop is still growing. Damage caused by a certain density of insects cannot be predicted at all as it depends on many other factors, such as crop variety, weather conditions, water and nutrient availability and the stage of the plant. It also depends on the presence and performance of natural enemies. There is a big difference between "a bean plant with 20 aphids" and "a bean plant with 20 aphids and one hover fly larva".
Therefore, the ETL that is 'recommended' in manuals for farmers can never be applied in a farmer's field. Farmers cannot base decisions on only a simple pest count but have to consider many other aspects such as crop ecology, growth stage, natural enemies and weather condition, and their economic and social situation.

Another important consideration is that good crop management depends not only on pest control, but also on the prevention of pests. IPM specialists have realized the limitations of the ETL and gradually developed the AESA as a more flexible tool for crop management decisions.

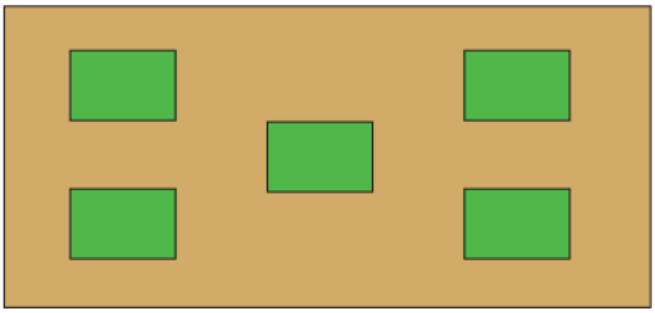
AESA considers:

- the crop growth stage
- weather conditions
- crop development factors (including plant compensation ability)
- type and number of insect pests
- type and extent of disease
- type and number of natural enemies
- type and amount of natural disease control agents (if applicable)
- type and amount of weeds
- water availability (irrigation, drainage)
- soil fertility status
- fertilizer application
- field activities since the preceding week
- other observations and farmers' experiences.

7.4 AESA methodology

Prakesh *et al*., (2014) suggested that field observations on insect pests and diseases are to be initiated after 20 days of transplanting. In each field, select five spots randomly,

as shown in the figure (four in the corner, at least five feet inside the border and one in the centre). At each spot, select four hills randomly for recording observations (A total of 20 hills/field).



Data recording

Farmers should record data in a notebook and draw on a chart

- Keep records of what has happened
- Help us make an analysis and draw conclusions

Data to be recorded

Plant growth (weekly)

- height of hill
- number of tillers per hill
- number of leaves.

Crop situation (e.g., for AESA)

- plant health: observe the crop stage and deficiency symptoms etc.;
- pests, diseases, weeds: count insect pests at different places on the plant and identify any visible disease symptoms and severity. Observe weeds in the field and their intensity. for rats, count the number of plants affected by rats;
- natural enemies: count parasitoids and predators;
- soil condition;
- irrigation; and
- weather conditions.

Input costs

- seeds
- fertilizers
- pesticides
- labour.

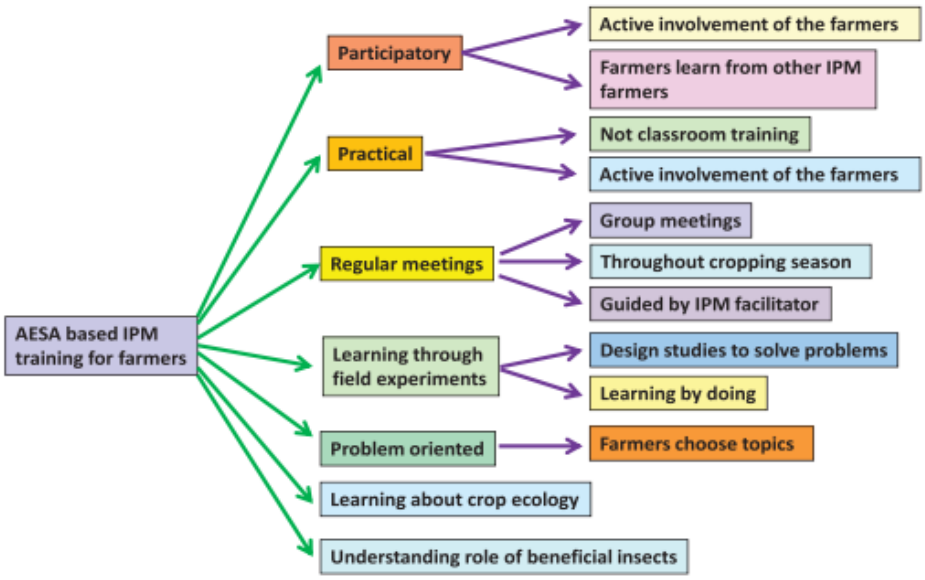
Harvest

- yield (kg/ha)
- price of produce (MMK/kg).

Farmers can learn from AESA:

- identification of pests and their nature of damage;
- identification of natural enemies;
- management of pests;
- water and nutrient management;
- influence of weather factors on pest buildup; and
- role of natural enemies in pest management.

FFS to teach AESA based IPM skills:



Source: Satyagopal *et al*., 2014.

7.5 Important instructions while taking observations

- Collect insects in plastic bags while walking through the field. To gather more insects, use a sweep net. Gather plant components that have disease signs.
- Find a shaded spot to sit in a small circle as a group for drawing and conversation.
- If necessary, kill the insects on a piece of cottonne with chloroform (if available).
- Each group will fist identify the pests, defenders and diseases collected.
- Each group will then analyse the field situation in detail and present their observations and analysis in a drawing (the AESA drawing) shown in MODEL AESA CHART.

- Each drawing will show a plant/hill representing the field situation. The weather condition, water level, disease symptoms, etc., will be shown in the drawing. Pest insects will be drawn on one side.
- Defenders (beneficial insects) will be drawn to another side.
- Put a number beside each bug. Indicate the plant section that contained the pests and defenders. Try to depict the interplay between pests and defenders.
- Each group will discuss the condition and make a crop management recommendation.
- The tiny groups then merge, and one person from each group will now deliver their analysis to all attendees.
- The facilitator will guide the conversation by asking leading questions and ensuring that all participants (even timid or illitreate individuals) are actively engaged in this process.
- Create a unified conclusion. The entire group should agree on what field management is necessary for the AESA plot.
- Ensure that the required activities (based on the decision) are completed.
- Keep the drawing for comparison purposes in the following weeks.

7.6 Population assessment

Fixed plot survey: The plot is fixed in an area, and the counts are made periodically at weekly intervals from seedling to maturity phase.

Roving Survey: Data on insect population and damage will be gathered from randomly selected plots in an area.

When the number of insect present on an area is relatively less, counting is done by visual observation. The other methods used in insect population assessment are:

- net sweeping for hoppers, dragonfly, damselfly, grasshoppers etc;
- wet palm sweeping for rice thrips in nursery;
- light trapping for phototrophic insects;
- pheromone trapping for species specific insects;
- sticky traps for whitefly, aphids, and hoppers;
- bait traps like fish meal trap for sorghum shoot fly and methyl eugenol for tephritid fruit flies;
- assessment after knocking down of insects using chemicals;
- use of berlese funnel for soil and storage mites; and
- extraction of subterranean pests like grubs, earwigs etc from soil.

7.7 Pest: Defender ratio (P: D ratio)

The identification of pests and beneficial insects assists farmers in making suitable pest control decisions. Sweep net, visual counts etc., can be adopted to arrive at the numbers of pests and defenders. The P: D ratio might vary based on the natural enemy's feeding capacity and the type of pest. The natural enemies of chickpea pests can be divided into 3 categories 1. parasitoids; 2. predators; and 3. Pathogens (Chandrashaker *et al*., 2014).

As there was no reference for oilseed crops, the P: D ratios for yellow stem borer are given below.

Table 7.1 The P: D ratios for yellow stem borer

Sr. No.	Predator	Predator :YSB Ratio
1	Carabid beetle	5 : 1
2	Mirid bug	3 : 1
3	Reduviid bug	6 : 1
4	Wolf spider	15 : 1
5	Lynx spider	2 : 1
6	Jumping spider	8 : 1
7	Dwarf spider	4: 1
8	Long jawed spider	2: 1
9	Long horned grasshopper	3: 1
10	Ear wig	20:1
11	Wasp	30:1
12	Praying mantids	4:1

Source: ICPM, 2014.

Model AESA chart

Date: ..... Village: .....Farmer.....

Source: Chandrashekar *et al*., 2014.

7.8 Ecologically sustainable strategies for pest management

IPM strategies differ for each crop, country, region, or even location, depending on local varieties used, agronomic practices, and available crop protection options. IPM can never be delivered in a "package"; it needs to be developed, adapted and tailor-made to fit local requirements. Designing and implementing efficient IPM systems entails constantly learning and finding answers to changing field settings and difficulties.

Prevention is the most effective method of controlling pests and diseases. To limit pest and disease damage:

1. practice good cleaning of equipment and field between seasons;
2. use clean seeds and resistant varieties;
3. plant at the same time as your neighbours;
4. do not over apply fertilizers;
5. encourage natural pest enemies;
6. do not apply pesticides within 40 days of planting; and
7. properly store grain.

Understand and conserve defenders

Biological control agents (parasites, predators, antagonists) are the defenders of the crop because they are natural enemies of the pests. IPM farmers know defenders and understand their role through regular observations of the agro-ecosystem. They will try to conserve them by avoiding pesticides and creating field conditions that favour their development.

Visit fields regularly

Regular field visits by the farmer will keep him/her up-to-date on the condition of the crop. By knowing what is going on in the field, the farmer can take the correct decisions and take swift action when needed.

As FAO (2016) stated, Good Agricultural Practice (GAP) should:

- Use resistant cultivars and varieties, crop sequences, linkages, and cultural approaches to reduce pressure and maximize biological pest and disease avoidance.
- Maintain a regular and quantitative evaluation of the balance state of pest and disease organisms as well as beneficial organisms in all crops.
- When available, use pest and disease forecasting methodologies.
- Recognize and employ non-chemical pest and disease management strategies.
- Make intervention decisions after considering all feasible approaches and their short- and long-term consequences on farm production and environmental

implications to reduce the use of agrochemicals and promote integrated pest management (IPM).

- Store and use agrochemicals in accordance with regulatory regulations, such as crop registration, rates, timing, and pre-harvest intervals.
- Assure that specially trained, knowledgeable persons only apply agrochemicals.
- Assure that equipment used to handle and apply agrochemicals complies with established safety and maintenance standards.
- Keep accurate records of agrochemical usage.
- Avoid any agrochemical point source contamination caused by the use, storage, cleaning, and disposal of goods or application equipment.
- Minimise the effects of any pest and disease management effort on non-target regions.

7.9 Biopesticides for IPM

Biopesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals. For example, canola oil and baking soda have pesticidal applications and are considered biopesticides. As of April 2016, there are 299 registered biopesticide active ingredients and 1401 active biopesticide product registrations (EPA -2016).

They can be categorized (Lindberg and Arthurs, 2017) as follows:

(a) Biochemicals - derived from naturally occurring substances such as plant extracts. This includes insect repellants, insect attractants and repellants, pheromones, and non-pest management class—plant growth regulators, for example, Azadirachtin (broad-spectrum insecticide).

(b) Microbials - products containing micro-organisms or their fermentation by-products such as:
   - The bacterium *Bacillus thuringiensis* for used against caterpillars.
   - The fungus *Beauveria bassiana* for used against whiteflies, aphids, and thrips.

Major advantages of bio pesticides

Bio-pesticides are preferred over chemical pesticides for the following reasons:

- no harmful residues;
- target specific and safe to beneficial organisms like pollinators, predators, parasites etc.;
- growth of natural enemies of pests is not affected, thus reducing the pesticide application;
- environmentally friendly;
- cost-effective; and
- important component of IPM as 1st line and 2nd line of defence, chemicals being the last resort.

Some bacteria and fungi are also used for plant protection, such as *Bacillius thuringiensis* as an insecticide and *Trichoderma harzianum* against root pathogens. In Myanmar, Trichoderma is used to prevent and control soil-borne fungal diseases. It is also used to accelerate the compost making process. The research was initiated in 1986–1987, and production was started in 1994–1995 at DAR.

Trichoderma was tested for the control of black sesame stem, chilli wilt, root rot and rice sheath blight. It can reduce the death rate of the plant by 25 percent for chilli wilt, 30 percent for black sesame stem. It also reduced the disease severity of rice sheath blight by 43.5 percent (DAR, 2019). The use of biopesticides is very limited in Myanmar. Kumar *et al*., (2014) mentioned that the popularization of biopesticides is very slow compared to chemicals, and only two percent of biopesticides are available in India**.** *Trichoderma,* mainly *Trichoderma viride* and *Trichoderma harzianum* are most exploited and have many success stories.

Advantages of Trichoderma application

- ecofriendly
- can be used along with organic manure
- trichoderma spp. is also known to suppress plant-parasitic nematodes (roo-knot nematodes)
- lower cost and longer efficacy than fungicides
- does not lead to the development of resistance in plant pathogens
- no physotoxic effects
- minimises losses and cost of production and increases yield & profit
- promoter plant growth.

Botanical pesticides

Botanical pesticides or natural **insecticides** are organic and natural **pesticides** derived from plants and minerals with naturally occurring defensive properties. Also, they have proven to be more valuable than conventional **insecticides** as insects become more resistant to synthetic **pesticides**.

Neem pesticides play a vital role in pest management and have been widely used in agriculture. There has been an evident shift worldwide from synthetic pesticides to non-synthetic ones. This is mainly because of the widespread awareness of the side effects of these synthetic pesticides on plants and other living organisms. However, the commercialization of new botanical insecticides can be hindered by several issues, as Isman (1997) pointed out. The principal barriers to the commercialization of new botanicals are (i) scarcity of natural resource, (ii) standardization and quality control, and (iii) registration.

In Myanmar, neem trees, *Azadirachta indica* are naturally grown primarily on upper Myanmar. The insecticide neem oil is commercially produced from the Paleik factory in Mandalay region. The seeds are commonly available in the summertime. There is an excellent chance to make neem seed kernel extract to control insect pests. Neem

insecticide is effective in controlling beetle larvae, butterfly and moth caterpillars, stalk borers, true bugs, plant and leaf-hoppers, adult beetles, thrips, and fruit flies, scale insects, mealy bugs etc.

Process of neem seed kernel extract from neem seeds

Dried neem seeds are used to make neem seed kernel extract. Neem trees bear fruits once a year, and it is better to harvest the fruits rather than collect fallen ones – fallen fruit in contact with the soil can be infested with fungus. Before harvesting, ensure the neem fruits are yellow (not greenish-yellow or yellowish-green). Put a plastic sheet beneath the neem tree and beat the branches with a stick. Collect the falling fruit off the plastic sheet. Throw away bad or mouldy ones. Remove the fruit's pulp by twisting the Neem fruit between the thumb and index finger. The seeds must be milky white. For 2 or 3 days, hang them upside down on a mat or sheet in the shade. They must not be exposed to direct sunshine or rain. Keep the seeds dry by storing them in well-aerated baskets or gunnysacks (not in plastic bags). The kernel extract should be made from 3 to 7 months old seeds.

Making neem insecticide (TNAU, 2014)

For the preparation of 100 litres of five percent NSKE solution, the following material is required

1. neem seed kernels (well dried) – 5 kg
2. water (reasonably good quality) – 100 litres
3. detergent - 200 g
4. muslin cloth for filtering.

Methodology

1. take the required quantity of neem seed kernel (5 kg);
2. grind the kernels gently to powder them;
3. soak it overnight in ten litres of water;
4. stir with a wooden plank in the morning till the solution becomes milky white;
5. filter through a double layer of muslin cloth and make the volume 100 litres;
6. add one percent detergent (make a paste of the detergent and then mix it in the spray solution); and
7. mix the spray solution well and use it.

Things to be taken care

- Collect the Neem fruits during the bearing season and air-dry them under shade.
- Do not use the seeds over eight months of age. The seeds stored over and above this age lose their activity and are not fit for NSKE preparation.
- Always use freshly prepared neem seed kernel extract (NSKE).
- Spray the extract after 3.30 pm to get effective results.

Preparing spray solution (TNAU Agritech Portal)

- Neem Kernel extracts (500 to 2 000 ml) is required per tank (10 litres capacity). 3–5 kg of neem kernel is required for an acre. Remove the outer seed coat and use only the kernel. If the seeds are fresh, 3 kg of the kernel is sufficient. If the seeds are old, 5 kg is required.
- Pound the kernel gently and tie it loosely with a cottonne cloth. Soak this overnight in a vessel containing 10 litres of water. After this, it is filtered.
- On filtering, 6–7 litres of extract can be obtained. 500–1 000 ml of this extract should be diluted with 9 ½ or 9 litres of water. Before spraying, khadi soap solution @ 10 ml/litre should be added to help the extract stick well to the leaf surface. This concentration of the extract can be increased or decreased depending on the intensity of pest attack.

Precautions in using neem extracts/formulations

1.) Neem is almost non-toxic to mammals and is biodegradable and it is used in India as an ingredient in toothpaste, soap, cosmetics, pharmaceuticals, and cattle feed. The plant leaves are used for tea. Neem trees are very confused with the Persian lilac or chinaberry tree a relative of neem, which thrives in high altitudes, whereas neem thrives at low altitudes (up to 1 200 m).

2.) Neem chemical structure is so complex (the tree has many different compounds, many functioning quite differently and on different parts of an insect's life cycle and physiology), scientists believe it will take a long time for insects to develop resistance to it. To minimize the chance of affecting beneficial (natural enemies) and to discourage the development of pest resistance, use neem sprays when necessary, and only on plants you know are affected by pests.

3.) Neem seed extracts do not kill insect pests immediately. They change the feeding behaviour and life cycle of the pests until they are no longer able to live or reproduce. Effects are not visible before ten days after application. Thus, severe pest attacks will not be controlled within time. For reliable and satisfying control, neem extracts should be applied at an early stage of the pest attack.

4.) Neem products break down quickly, generally within 5 to 7 days in sunlight and the soil, so you could need to repeat the application during the growing season to deal with new pests that arrive from outside during this time.

5.) Neem works fastest during hot weather, and heavy rains within a few days of application may wash off the protective cover of neem on plants. Reapply if pests are a problem.

6.) If crops have to be watered, water must be targeted to the soil because water running over the leaves of sprayed plants may wash off the neem water extract.

When controlling pests with the plant extracts, Pesticide Action Network (PAN) Germany (2007) has recommended the standard procedures for their preparation and application as follows:

1. Select plants/plant parts that are pests-free.
2. When storing the plants/plant parts for future usage, ensure that they are properly dried and stored in an airy container (never use a plastic container), away from direct sunlight and moisture. Make sure that they are with homemade and free from moulds before using them.
3. Do not use cooking and drinking utensils for extract preparation. Clean properly all the utensils every time after using them.
4. Do not have direct contact with the crude extract while in the process of the preparation and during the application.
5. Make sure that you place the plant extract out of reach of children and house pets while leaving it overnight.
6. Always test the plant extract formulation on a few infested plants first before going into large scale spraying.
7. Wear protective clothing while applying the extract.
8. Wash your hands after handling the plant extract.

Chapter 8

Biocontrol agents: predators and parasitoids

8.1 Introduction

Biological control is the use of non-chemical and environmentally friendly methods of controlling insect pests and diseases by the action of natural control agents. Biological control has become more and more popular due to its safety, species-specific and long-term action on the target pests. Unlike the chemical method, which kills non-target species, causes detrimental health effects to human beings, and pollutes the environment. Natural enemies used in biocontrol measures include parasitoids, predators, microbes, and beneficial nematodes. Among them, the use of predators and parasitoids is the most common.

The difference between predators, parasites and parasitoids is outlined here by Stehr (1975) as follows:

A predator is a free-living organism throughout its life: it kills its prey, is usually larger than its prey, and requires more than one prey to complete its development. Mantids, spiders, and many species of ladybird beetles are good examples of predators.

A parasite is an organism that is usually smaller than its host, and a single individual usually does not kill the host. Numerous individuals may irritate, weaken, or otherwise debilitate the host and occasionally cause its death.

A parasitoid is a special kind of predator which is often about the same size as its host, kills its host, and requires only one host (prey) for development into a free-living adult. Braconid wasps are good examples of parasitoids.

8.2 Predators

Predators often are the most important group of biological control agents in the rice field. However, most of them are generalist feeders preying on any insects they found in the crop. So, it is difficult to rely on them to regulate any particular pest species. Each predator will consume many preys during its lifetime. Predators occur in almost every part of the rice environment. The most common species are spiders, lady beetles, guitar beetle, carabid beetles and dragonflies. They search the plants for prey, such as leafhoppers, planthoppers, moths, and larvae of stem borers and defoliating caterpillars. Many beetles, some predatory grasshoppers, and crickets prefer insect eggs. It is not uncommon to find 80–90 percent of the eggs of certain insect pests consumed by predators. An adult wolf spider may attack and consume 5–15 brown planthoppers each day. The immature and adult stages of most predators attack insect pests, and many preys are required to develop each predator.

8.2.1 Syrphidfly

The adults lay eggs in the aphid colony, and the emerging maggots feed on aphids.

Figure 8.1 Syrphid fly adult and maggot

8.2.2 Green lacewing: *Chrysoperla carnea* (Neuroptera, Chrysopidae)

Larvae are important predators of insect pests, viz., aphids, mealy bugs, eggs, and smaller larvae of various insects of agricultural importance and mites. Each larva has the potential to feed 12 aphids per day on average, or about 120 aphids during the entire developmental period.

Figure 8.2 Green lacewing: *Chrysoperla carnea*

8.2.3 Ladybird beetles

***Cryptolaemus montouzieri:* (Coccinellidae: Coleoptera)**

The adults and larvae of these insects eat scale insects, especially mealybugs. Females lay their eggs among the egg sack of mealybugs. Larvae feed on mealybug eggs, young crawlers, and their honeydew. They become adults in 24 days, after three larval stages and a pupal stage. The life span lasts two months.

Figure 8.3 Ladybird beetle: *Cryptolaemus montouzieri* adult and larva

***Cheilomenes sexmaculata* (Coccinellidae: Coleoptera)**

Cheilomenes sexmaculata is a very important, polyphagous predator of aphids and other soft-bodied insects. It has been recorded in most crop ecosystems, particularly where aphids are serious pests. It has been produced in the laboratory and used to suppress *A. craccivora* on groundnut.

Figure 8.4 Ladybird beetle: *Cheilomenes sexmaculata* (egg, larva, pupa and adult)

8.2.4 Ground beetle

Ground beetle adults and larvae are commonly found moving around and feeding on insect pests of groundnut.

Figure 8.5 Ground beetle adult and grub

Figure 8.6 Black ant, *Camponotus compressus* and aphids on groundnut

8.3 Some predators found in the pulse fields of Myanmar

As in the paddy field, most of the predators, such as spiders, ladybird beetle, syrphid fly, ground beetle, dragonfly, assassin bug, etc., were observed in oilseed crops. Some of them are mentioned below.

Figure 8.7 Stethorus beetles feeding on spider mites

Figure 8.8 A larva of ladybird beetle larva feeding on aphids, and a ladybird beetle

Figure 8.9 Assassin bug

8.4 Parasitoids

A parasitoid is an organism with young that develops on or within another organism (the host), eventually killing it. Parasitoids have characteristics of predators and parasites. Most insect parasitoids target a specific life stage of one or more related species. The immature parasitoid develops on or within a pest, feeding on bodily fluids and organs

before pupating or emerging as an adult. The life cycle of the pest and parasitoid can coincide, or the parasitoid may alter that of the pest to accommodate its development.

Beneficial parasitoids' life cycles and reproductive behaviours can be complicated. Only one parasitoid will develop in or on each pest in certain species, but hundreds of immature larvae may grow within the pest host in others. Overwintering behaviours might also differ. Female parasitoids may also kill many pests by directly feeding the pest eggs and immatures **(**Hoffmann and Frodsham, 1993**).**

Major characteristics of insect parasitoids

- they are specialized in their choice of the host;
- they are smaller than the host;
- only the female searches for the host;
- different parasitoid species can attack different life stages of the host;
- eggs or larvae are usually laid in, on, or near the host;
- immatures remain on or in the host; adults are free-living, mobile, and maybe predaceous; and
- immatures almost always kill the host.

Egg parasitoid: *Trichogramma* sp. (Hymenoptera, Trichogrammatidae)

Trichogramma species are of common occurrence and distributed throughout the world. They parasitise eggs of Lepidopteran mainly but are also reported from Coleoptera, Neuroptera and Diptera. In India, it is commercially available for the pest suppression of sugarcane, cottonne, sorghum, maize and paddy borers.

***Trichogramma* spp. for the control of yellow stem borer in rice**

Two species of *Trichogramma* are common in the rice crop (*T. japonicum* and *T. chilonis*). In Myanmar, there are four rearing facilities: in Shwebo, Sagaing Region, Myitnge, Mandalay Region, Yezin Agricultural University, Nay Pyi Taw Council Area and PPD, Yangon.

How Trichogramma works

Trichogramma is an egg parasitoid that is, female wasps lay their own very, very small eggs into the eggs of their hosts, such as stem borer, caseworm and leaf roller. The *Trichogramma* larva hatches inside of the host egg to feed on the host tissue from inside. Within about ten days (at 25°C), the *Trichogramma* larva completes its development and emerges from the host eggs. Due to the killing of the pest before the larvae start feeding, the application of *Trichogramma* has the potential to prevent damage in a very early stage.

How Trichogramma is to be applied

Despite *Trichogramma* can reproduce and multiply on hosts present in the rice field, in most situations, several introductions need to be conducted within a cropping cycle, also due to the short longevity of the tiny wasps. The *Trichogramma* biological control agent is released into rice fields by small cards on which about 1 000 parasitized eggs have been glued that harbour the wasps at a stage close to emergence. Good timing for the placement of these egg cards is crucial: if you place egg cards too late, the wasps might have emerged already before reaching the rice fields; if you place egg cards much earlier than the expected emergence date, damage to egg cards might occur due to weather conditions or predators feeding on the eggs exposed. Again, due to the small size and relatively poor flying abilities, the *Trichogramma* wasps need to be released from several points to achieve good pest control. The recommended procedure is to place 100 cards at regular intervals (about 10 x 10 m) per ha of rice, resulting in 100 000 wasps per ha.

Advantages of using *Trichogramma*

Using *Trichogramma* to control lepidopteran rice pests:

- controls major lepidopteran pests with biological means;
- reduces the use of insecticides;
- avoids insecticide resistance development in insect pests;
- reduces exposure of farmers to insecticides;
- poses no health risk for farmers and does not leave any residues in food;
- helps protecting other natural enemies in the fields, ecosystem balance and the environment;
- does not pose any threat to other organisms in the rice crop, and neither to the soil, water or atmosphere;
- does not cause any resistance problems; and
- is a sustainable and cost-efficient approach.

Figure 8.10 An adult of *Trichogramma* sp. (egg parasitoid)

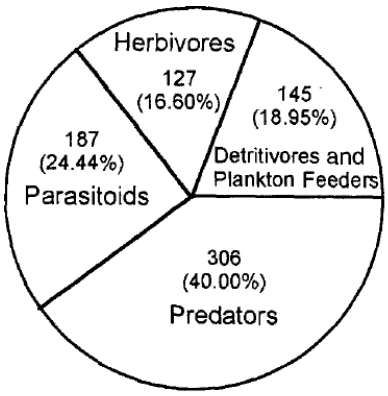
Figure 8.11 An ant attending aphids and aphid mummies on cowpea

Figure 8.12 An official from DAR educates farmers on how to use *Trichogramma* parasitoids in paddy field

8.5 The role of predators and parasitoids in the rice ecosystem

Settle *et al*., (1996) reported that abundant and well-distributed populations of generalist predators can be found in most early-season tropical rice fields. They found that parasitoids were the most abundant, 187 species (24.44 percent) of the whole fauna, and herbivore consist of 127 species (16.60 percent). High populations of generalist predators are likely to be supported, in the early season, by feeding on abundant populations of detritus-feeding and planktonne-feeding insects, whose populations consistently peak and decline in the first third of the season.

Figure 8.13 Number of species and (percentage) recorded in lowland irrigated rice in Indonesia



Source: Settle *et al*., 1996.

8.6 Feeding/egg-laying potential of different parasitoids/predators

The potential predation and parasitism of some predators and parasitoids found in the green gram and chickpea were presented in the following table.

Table 8.1 Feeding/egg-laying potential of different parasitoids/predators

Predators/Parasitoids	Feeding potential/ Egg-laying capacity
Ladybird beetle	One adult ladybird beetle eats 50 aphids per day 1st & 2nd nymphal instars can consume one small larva/day 3rd & 4th nymphal instars can consume 2 to 3 medium larvae/day 5th nymphal instar & adult can consume 3 to 4 big larvae/day
Hoverfly	1st instar larva can consume 15–19 aphids/day 2nd instar larva can consume 45–52 aphids/day 3rd instar larva can consume 80–90 aphids/day In total life cycle, they can consume approx. 400 aphids.
Reduviid bug	In total life cycle, they can consume approx. 250 to 300 larvae
Green Lace wing	Each larva can consume 100 aphids, 329 pupa of whitefly and 288 nymphs of jassids during the entire larval period
Spider	5 big larvae/adults/day
Bracon hebetor	Egg-laying capacity is 100–200 eggs/female. 1–8 eggs/larva
***Trichogramma* sp**	Egg-laying capacity is 20–200 eggs/female
Predatory mite	The predatory rate of an adult is 20–35 phytophagous mites/female/day

8.7 Biological Control Practices

The details of biological control practices are given below

Augmentation and Conservation

- *Trichogramma japonicum* and *T chilonis* may be released @ one lakh/ha on appearance of egg masses / moth of yellow stem borer and leaf folder in the fild.
- Natural biocontrol agents such as spiders, drynids, water bugs, mirid bugs, damsel fles, dragonfles, meadow grasshoppers, staphylinid beetles, carabids, coccinellids, *Apanteles, Tetrastichus, Telenomus, Trichogramma, Bracon, Platygaster* etc. should be conserved.
- Collecting egg masses of borers and putting them in a bamboo cage-cum-percher till flowering will permit the escape of egg parasites and trap and kill the hatching larvae. Besides, these would allow the perching of predatory birds.
- Habitat management: Protection of natural habitats within the farm boundary may help in conserving natural enemies of pests. Management of farmland and rice bunds with planting flowering weeds like marigold and sun hemp increases beneficial natural enemy populations and reduces the incidence of root-knot

nematodes. Provide refuge like straw bundles having charged with spiders to help build up spider population and provide perch for birds.

Chapter 9

WEED CONTROL

9.1 Definition of weeds

The common definitions are a plant out of place, or an undesirable plant, or a plant with a negative value, or plants which compete with man for the soil (Muzik, 1970). Therefore, corn in a groundnut field is a weed. Weeds encompass all types of undesirable plants – trees, broadleaf plants, grasses, sedges, aquatic plants, and parasitic flowering plants (dodders, mistletoe, witchweed) (Klingman *et al*., 1982).

Weeds cause damage to crop by (a) Competing with crops for light, water, nutrients, and other growth requirements, (b) acting as alternate hosts for pests and diseases, (c) reducing crop yield and quality.

9.2 Weed classification

Weeds can be classified as annual weeds (for example, barnyard grass, Echinochloa), biennial weeds (e.g., wild carrot), and perennial weeds (e.g. nutsedge) according to their life span.

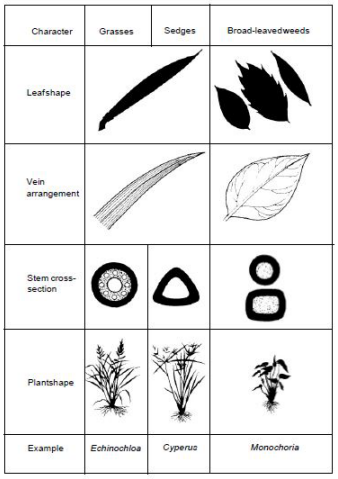
According to their morphological features, weeds are classified as follows:

(a). Grasses: Their leaves are narrow with parallel venation. They possess a fibrous root system. Stems or culms are round. The leaf comprises two parts: leaf blade and leaf sheath with ligule at the junction of those two parts (e.g., barnyard grass, *Echinochloa crusgalli*)

(b) Sedges: They look like grasses but can be identified by their triangular stem, the absence of the ligule and the fusion of the leaf-sheath to form a tube around the stem (e.g., red sprangletop, *Leptochloa chinensis*).

(c) Broadleaf weeds: Their leaves are broad and usually net-veined (e.g., pickerelweed, Monochloria).

Figure 9.1 Weed classification



Grass

Sedge

Source: Vergara.

9.3 The dirty dozen in the rice fields of Asia

Some weeds are referred to as the dirty dozen of weeds in Asia rice fields by IRRI Rice Knowledge Bank. Purple nutsedge is a notorious weed in upland crops, but it is also reported to be occurring in summer rice. This weed is a carry-over from the upland crop and has been shown to adapt to lowland conditions. This is difficult to control weed as no herbicide can control it. Mechanical and hand weeding are the most effective approaches to reducing purple nutsedge's population.

Sedges are troublesome, and farmers apply post-emergence herbicides such as “Nominee Gold”, “Complete”, and Shwe Tonnee. Farmers perceive that yield loss caused by this weed is at 50 percent (MOALI, 2018).

Figure 9.2 *Cyperus iria* and *Cyperus difformis*

Figure 9.3 ***Echinochloa colona*** **and** ***Echnichloa crus-galli***

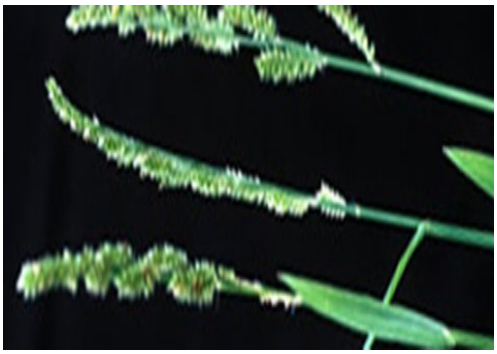
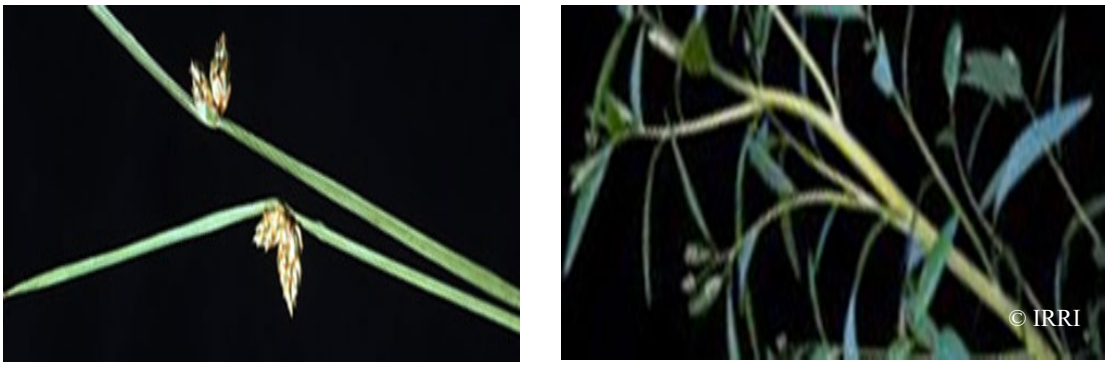


Figure 9.4 ***Eclipta prostrata*** **and** ***Fimbristilis miliacea***

Figure 9.5 Ischaemum rugosum and Leptoochloa chinensis

Figure 9.6 ***Ludwigia hyssopifolia*** **and** ***Scirpus grossus***

Figure 9.7 ***Schoeoplectus juncoides*** **and** ***Spheoclea zeylanica***



9.4 Some upland weeds found in the project areas

In their experiment with green gram-based cropping patters in Magway upland, Maung *et al*., (2019) reported that dominant weeds were two sedges, viz., *Cyperus iria* (umbrella sedge) and *Cyperus rotundus* (purple nut sedge), and two grasses, viz., *Digitaia ciliaris* (finger grass), *Dactyloctenium aegyptium* (crowfoot grass). Broadleaved weeds were *Commelina benghalensis* (tropical spiderwort), *Cleome viscose* (wild cassia), *Lecuas lavandulifolia* (leucas), *Richardia brasiliensis* (Mexican clopver), and *Phyllanthus niruri* (niruri) *and Achyranthes aspera* (devil's horsewhip).

Figure 9.8 Devil's horse whip, *Achyranthes aspera* and Velvet leaf, *Abutilon indicum*

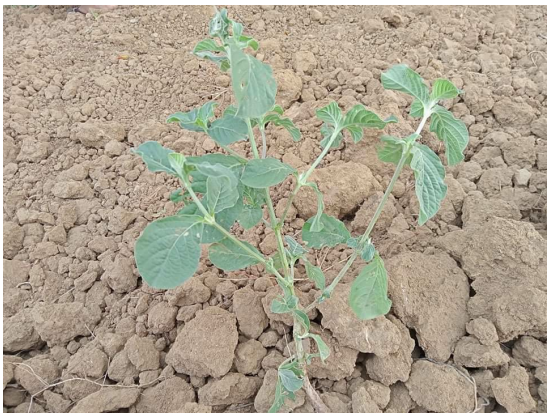


Figure 9.9 Indian pennywart, *Centella asiatica* and Leucas, *Leucas lavandulifolia*

Figure 9.10 *Isachne globosa* and Awnless barnyard grass, *Echinochloa colona*

Figure 9.11 Spiny amaranth, *Amaranthus spinosus* and Basil, *Ocimum gratissimum*

Figure 9.12 Niruri, *Phyllanthus niruri* and *Wild jute, Corchorus trilocularis*

Figure 9.13 Puncture vine, *Tribulus terrestris* and Wild cassia, *Cleome viscose*

Figure 9.14 Purple nutsedge, *Cyperus rotundus* and *Scirpus juncoides*

Figure 9.15 Red spiderling, *Boerhavia diffusa* and Snake weed, *Euphorbia hirta*

Figure 9.16 ***Cocculus hirsutus*** **and** ***Celosia argentia***

Figure 9.17 ***Celosia argentea*** **weed in black gram and wild-cape gooseberry,** ***Physalis angulata*** **in chickpea**

9.5 Reproduction and dispersal

9.5.1 Reproduction: The reproduction mechanism of weeds is very effective in nature. They reproduce by sexual and asexual (vegetative) means.

Sexual reproduction requires the pollination of flowers and, subsequently formation of seeds. Most annual weeds flowering starts as early as five weeks after sowing. This coincides with the maximum tillering period. Then the duration of the reproductive period is quite long, and flowers are successively produced. Some weeds are abundant seed producers.

Vegetative reproduction is carried out by stems, roots, leaves, or rhizomes (underground horizontal stem), stolons (above ground horizontal stem), tubers, corms, bulbs or bulblets.

9.5.2 Dispersal: While reproductive capacity determines the abundance of a weed species, dispersal determines the spread of a weed. The agents of weed dispersal are wind, water, and animals, including man and machinery.

Weed dispersal within small areas may be accomplished by the following means.

(a) the use of weed-infested crop seed or stock feed
(b) animals or birds carry weed seeds in the digestive tract
(c) wind
(d) irrigation water
(e) manure from weed-infested area
(f) transport the use of farm implements.

9.6 Crop-weed competition

Weeds compete with crops in many cases, such as competition for light, water, and nutrient. The most serious damage caused by weeds is the reduction in yield. This is due to interference in acquiring light, moisture, and nutrients by the crops and by harmful allelopathic interactions. In the case of crop-weed interference, allelochemicals may be released by the leaves, stems or root of weeds or crops either during their life or during their decay on or in the soil. The resulting inhibition of germination or root growth of the susceptible plants may be short-lived or last for a year or more.

Critical competitive period

The critical period for weed control (CPWC) is a period in the crop growth cycle during which weeds must be controlled to prevent yield losses (Knezevic *et al.* 2002). It is very important to control weeds at the early stage of crop growth, generally speaking, one-third of the crop's life span. This period is called the Critical Competitive Period (CCP). Ahlawat *et al*. (1981) in India estimated a CPWC from 28 to 56 DAE in legumes. Saxena *et al*. (1976) in India estimated that hand weedings at 30 and 60 DAE would prevent unacceptable yield losses from weeds in chickpea. The critical period of weed control for some crops is listed below.

Table 9.1 Critical period for weed control in different crops

Crop	Period from planting (days)	Days to maturity
Upland rice (HYV)	40	120
Lowland rice (HYV,TPR)	30–40	120
Peanut (CES-101)	42	105
Sesame (RAMA)	19–42	80–99
Mung bean (CES-14)	21–35	60–65
Chickpea (Sierra)	16–26	95–105

Source: Madrid *et al*., 1972; Duary and Hazra 2013.

9.7 Methods of weed control

Weed multiplication can be prevented by reducing the number of weed seeds, and vegetative propagules returned to the soil by farm hygiene and spray topping. On the other hand, several environmental management measures can be taken to suppress the weeds. They include managing the soil environment by putting the organic matter, nutrients, and moisture.

We control methods are listed below.

(a) Hand pulling:

- Pulling weeds by hand is a manual method of control.
- Hand pulling takes a lot of time.

(a) Control by mechanical means:

- A rotary weeder is more efficient than hand weeding.
- Straight row planting is necessary when using a rotary weeder.
- Drain standing water from the field when using a rotary weeder.

(c) Control by water management:

- Most grasses and sedges will not grow when covered with 5–10 of water.
- Flooding will not control some broad-leaved weeds.
- Many weed seeds do not germinate underwater.

(d) Control by land preparation:

- Weeds can grow better than rice when land is poorly and unevenly prepared, and some areas are not covered by water. However, the timely operation is beyond a farmer's capacity, only possible when weather conditions are favourable.

(e) Control by crop competition:

- The closer the plant spacing, the fewer the weeds because there is less light for the weeds to germinate and grow in.
- The shorter the weeds, the less weed damage.

(f) Biological weed control

The biological control of weeds is the control of unwanted plants by living organisms. In lowland rice fields, the ability of a thick Azolla mat to suppress weed development has long been observed. In rice, a 79 percent reduction in total weed weight at 50 DAT has been measured in IRRI.

(g) Control by herbicides

Nowadays, a variety of herbicides are widely used to control weeds in field crops. Herbicides are categorized in different ways.

(i) Based on formulation

Herbicides are formulated according to their solubility and the way they are applied. The formulation can influence herbicide volatility, biological effect, safety, and ease of application.

- Commercial herbicides are available in granular, liquid, or powder form.
- Granular forms are broadcast; no special equipment is needed for the application.

(ii) Based on the time of application

- Preplant - Any herbicides applied before the crop is seeded or transplanted.
  - *Preplant foliar* is sprayed on the existing vegetation to kill weeds before planting (e.g. glyphosate).
  - *Preplant into the soil* - incorporated into the soil to prevent volatilization losses or place the chemical in the zone where needed.
- Preemergence - application to the soil surface before the emergence of the crop or the weeds. (e.g., butachlor).
- Post emergence - Any treatment made after the emergence of a particular crop or weeds. (e.g., 2, 4-D). Time of application is significant in post-emergence sprays. Application, when weeds are tall, is too late.

(iii) Based on selectivity

- *Selective herbicides* - Any herbicide that kills or stunts some plants with a little or no injury to others is said to be selective. 2, 4-D (at low concentration) applied to rice 30 days after seeding to contact broadleaved weeds and sedges is an example of a selective herbicide. Carefully check the application rate-even for selective herbicides.
- *Non- selective herbicides* - Glyphosate and Paraquat are toxic to all plants. In this case, the soil must be the moist condition. For upland crops, spraying in the dust is a waste of time and money.

(iv) Based on mode of action

- *Contact herbicides* - applied to foliage and kill the parts of the plant sprayed at or very close to the application site.
- *Translocated (systemic) herbicides* - are capable of movement inside the plant and kill the whole plant. (e.g., Glyphosate and 2, 4-D)

9.8 Integrated weed control

Integrated weed management (IWM) involves a combination of cultural, mechanical, biological, genetic, and chemical methods for effective and economical weed control (Swantonne and Weise, 1991). IWM uses the best mix of principles, practices, technologies, and strategies to control weeds and takes into consideration the environmental, social, and economic impact of the combined control strategies (Casimero *et al*., 1995).

Weed control is essential to prevent losses in yield and production costs and preserve good grain quality.

Specifically, weeds:

- decrease yields by direct competition for sunlight, nutrients, and water;
- increase production costs, e.g., higher labour or input costs; and
- reduce grain quality and price.

For example, weed seeds in grain can cause the buyer price to be reduced.
Control of weeds during land preparation is crucial to reduce the amount of weed pressure in the field. Land preparation should start 3−4 weeks before planting. Plowing destroys weeds and remaining stubble from the previous crop. Weeds should be allowed to grow before the subsequent cultivation. In addition, a level field helps retain a constant water level that controls weeds.

Hand weeding - The first six weeks after transplanting is critical for weed competition. Hand weeding in drill seeded and hand pulling in broadcast seeded rice should be done early, although it may be difficult to distinguish grassy weed seedlings from rice seedlings early. Two or three timely weedings will provide adequate weed control. Hand weeding requires about 120 labour-hours ha^{-1}.

Weed control in legumes

There are different cropping systems for legumes. In some areas, they are inter-cropped mainly with maize. The critical period of weed competition is between 10 and 30–40 days after crop emergence. This period is shorter if the crop row spacing is closer. Inter-row cultivation is useful for weed control during the first month after crop emergence and can be combined with the application of a selective herbicide sprayed along the crop rows.

Based on a 5 percent yield loss threshold, the CPWC for the 'Sierra' chickpea was 16 to 26 DAE. Alternatively, the CPWC could be expressed as 162 to 256 GDD or the 9 to 13 node stage in terms of crop development. (Smitchger, 2010)

Several herbicides can be used selectively in beans (Table 9.3 & 9.4). The feasibility of their use will depend on the economy of the farm. Application as pre-or post-emergence treatments along the crop row i.e., 20 cm width, combined with inter-row cultivation, is often economically viable for small farmers.

Table 9.2 Herbicides for general use

1	Glyphosate	Annual grass, Sedge and Broadleaf weed	Pre-plant application for existing weed on all crops and inter-row application.
2	Paraquat	Annual grasses, Sedge and Broadleaf weed, Some shallow-rooted perennial weeds	Pre-plant application for existing weed on all crops and inter-row application. (Remark- Do not contact green parts of plants.)

Table 9.3 Herbicides recommended controlling weeds in legumes by PPD, Myanmar

Sr	Herbicide	Weed	Crop
1	Clethodim	Annual grass, Perennial grass	Leguminous
2	Imazethapyr	Grass, Sedge and Broadleaf weed	Pulses
3	Fomesafen	Broadleaf weed	Pulses

Table 9.4 Selective herbicides to control weeds in beans

Sr	Herbicides	Treatment	Remarks
1	Trifluralin	PPI	Annual weed control
2	Pendimethalin	Pre	Annual grass weed control
3	Metolachlor	Pre	Annual grass weed control
4	Metobromuron	Pre	As mentioned above Annual weed and sedge control
5	Fomesafen	Post	Annual grasses
6	Quizalofop-ethyl	Post	Grass weed control
7	Haloxyfop-methyl	Post	Grass weed control

Pre = pre plant-incorporated herbicide, Pre = preemergence herbicide, Post = post-emergence herbicide

9.9 Problems with herbicide application

As smallholder farmers have little knowledge about herbicides, they encounter several problems when applying herbicides. Most farmers don't use the proper nozzle, for example, flat-fan nozzle for high volume herbicide spray. Instead, they use the conventional hollow cone nozzle which is meant for the insecticide spray. On the other hand, they may use a lower or higher dosage rather than the recommended dosage. As a result, the weed is not killed as desired, or sometimes the crop is burned to some extent. The herbicides are being applied too late to positively affect the weeds. In some extreme cases, poisoning may occur through ingestion of pesticides, skin absorption, or inhalation, and lack of appropriate protective equipment and training make it almost inevitable.

In the early 1970s in Asia, formulations of 2,4-D and MCPA were recommended for controlling annual weeds in transplanted rice, while granular formulations of the selective herbicides butachlor and thiobencarb were reported effective in direct-seeded rice as alternatives to hand weeding.

Formulations allowing the application of herbicides directly to irrigation water without spraying equipment have advantages for the small farmer and have become established practice in many areas.

One thing to bear in mind is that frequent use may create resistant problems as experienced in the United States of America. For example, 30 years of propanil use resulted in resistant Echinochloa sp. After four years of continuous use, bensulfuron resistance emerged in four aquatic weed species. The evolution of herbicide-resistant weeds is a real threat to effective weed control, where herbicides are frequently used. Smallholder systems may be particularly vulnerable as herbicides are often not used at appropriate times or dosages, which may hasten the development of resistance (Johnson, 1996).

Herbicide resistance implies reducing the use of a certain herbicide, which should be replaced by another herbicide or another non-chemical control strategy to maintain adequate control of the weed in the field.

Because farmers often employ the most effective and least priced pesticide, resistance results in cost rises (Orson, 1999; Prestonne *et al*., 2006). Thus, prevention is an obligatory measure if one wishes to have the best control strategy for a more extended period.

Because no single control method can successfully and sustainably remove resistant weeds, resistance avoidance necessitates an integrated weed management approach (Storrie, 2006).

Chapter 10

Rodent management

10.1 Introduction

Rodents are mammals belonging to the order Rodentia, consisting of 2 277 (about 42 percent) of the 5 419 mammalian species. Two continuously-growing incisors characterise them in the upper and lower jaws, which must be kept short by gnawing hard objects. With their sharp incisors, they used to gnaw wood, break into food, and bite predators.

Rodents are the most serious and important vertebrate crop pests, inflicting damage from sowing onwards until harvesting, storage, distribution, and actual consumption of the produce, besides acting as a reservoir of major diseases such as plague, murine typhus, leptospirosis, and salmonellosis.

Common rodents include mice, rats, squirrels, chipmunks, gophers, porcupines, beavers, hamsters, gerbils, and guinea pigs. Two-thirds of living rodent species belong to just one family, the Muridae, and most of the rodents found in Asia, both pests and non-pests, also belong to this family. There are 17 species of rodents have been collected in Myanmar (Nyo Me Htwe, 2013).

10.2 Kinds of rodents

There are four kinds of rodents mostly found in Myanmar Agriculture (Nyo Me Htwe *et al*., 2017).

1. rats and mice
2. bamboo rats
3. squirrels
4. porcupines (only in the agroforestry area).

In June 2017, thousands of rats swarmed villages in Ayeyarwady region, mainly Napudaw Township, devastating local crops. Rodent experts from PPD found that rat populations can double when they have access to bamboo fruit, which causes reproduction rates to spike. Similarly, many villages in the state's Pekon Township, Shan state, have been plagued by infestations of rats, which have gnawed their way through many hectares of paddy fields for the past three years. The Shan State government has provided villages with hundreds of snakes to control rat infestations that have destroyed rice crops.

10.2.1 Lesser bandicoot, *Bandicota bengalensis*: The lesser bandicoot rat, *B. bengalensis* is the predominant rodent pest species found in crop fields and urban areas. It is a robust rodent with a body weight of 200–300 g, a rounded head, and a broad muzzle. The tail is shorter than the combined head and body length, and the dorsum is coloured brown and has coarse hair. These are found in various ecological conditions. Bandicoots are nocturnal and fossorial, living in self-constructed burrows and causing extensive damage to agricultural crops (Uniyal, 2015).

Figure 10.1 A Lesser bandicoot rat (left) and burrows of lesser bandicoot rat (right)

The burrow system is extensive and elaborate, consisting of numerous chambers (sleeping, storing, etc.), galleries and exits or 'bolt-holes', which are covered with loose earth, facilitating an easy escape during emergencies. The storage chambers are stocked with large amounts of grain, especially during harvest time. Usually, one bandicoot is found in one burrow, except when a mother is with young. They are common in both village and towns and associated cropping areas. It is usually most abundant in higher rainfall areas. They damage all kinds of field crops and also attack stored grain. There are about 8-9 offspring per delivery. They peak breeding season is from the booting stage to the ripening stage in the rice crop (Nyo Me Htwe, 2018).

10.2.2 Larger bandicoot, *Bandicota indica*: It is the largest commensal rodent with a body weight of 500-1, 500 g. The body is robust with rounded ears and a short, broad muzzle. It is covered with piles of long hairs which stand erect on being excited. The tail is shorter than the body and is naked with short hairs throughout its length. It is omnivorous and nocturnal, living in villages, burrowing in the mud walls of huts, and in backyards and gardens. It also consumes soil invertebrates like earthworms and insects.

Figure 10.2 Larger bandicoot

10.2.3 Roof rats (*Rattus rattus*) are small-sized with a bodyweight of 80–120 g. Their bicoloured and ringed tail is longer than the combined length of the head and body.

Living on the upper floor of sheds but sometimes seen in sewers, the roof rat is also called black rat, house rat or ship rat. It is nocturnal and has a travelling range. Other rodent species such as *Bandicoota savilei*, *Mus musculatus* and *Mus cerivcolour* also are listed in the pest list of Myanmar by Nyo Me Htwe (2013).

10.2.4 House mouse (*Mus musculus*)

They do considerable damage by destroying crops and consuming and/or contaminating food supplies intended for human consumption. They are prolific breeders, sometimes erupting and reaching plague proportions. As commensal animals, house mice live closely associated with man — in houses, outbuildings, stores, and other structures.

They can reproduce 15–150+ young per female adult per year, depending on conditions. Females as young as five weeks can breed. The gestation period is 19–21 days, although this may be extended by several days if the female is lactating. There are usually 5–10 litters per year depending on conditions, but up to 14 may be produced. Litters range from 3–12, but typically 5–6 young. In the wild, mice rarely live longer than 18 months. Captive mice live two years on average, although there are records of some individuals living up to six years.

Figure 10.3 *Rattus* sp and *Mus musculus*

10.3 Rodent damage and crop compensation

In Asia, the pre-harvest loss of rice, *Oryza sativa,* due to rodents is estimated to be five percent of production, or approximately 30 million tonnes (i.e., enough rice to feed 180 million people for a year). The post-harvest losses are likely to be similar (Uniyal, 2015).

Rodent damage to rice in Myanmar was estimated as 5–40 percent (Singletonne, 2013). The dominant species in the field of Delta region were *Bandicota bengalensis* and *B. indica*, whereas in grain stores, the dominant species were *Rattus rattus* and *R. exulans* (Nyo Me Htwe *et al*., 2017).

According to a survey of 350 farmers from ten villages in Mandalay, Bago and Yangon Divisions between 2003 and 2005, farmers believed that rodents were one of the main pests causing the most damage to their crops monsoon rice, summer rice and mung bean (Brown *et al*., 2008). A recent survey in 2018 also showed that they cause significant damage to groundnut pods in the field. Apart from that, they are a minor problem with rice production. Farmers in Yinmabin township said that rodents are a minimal problem,

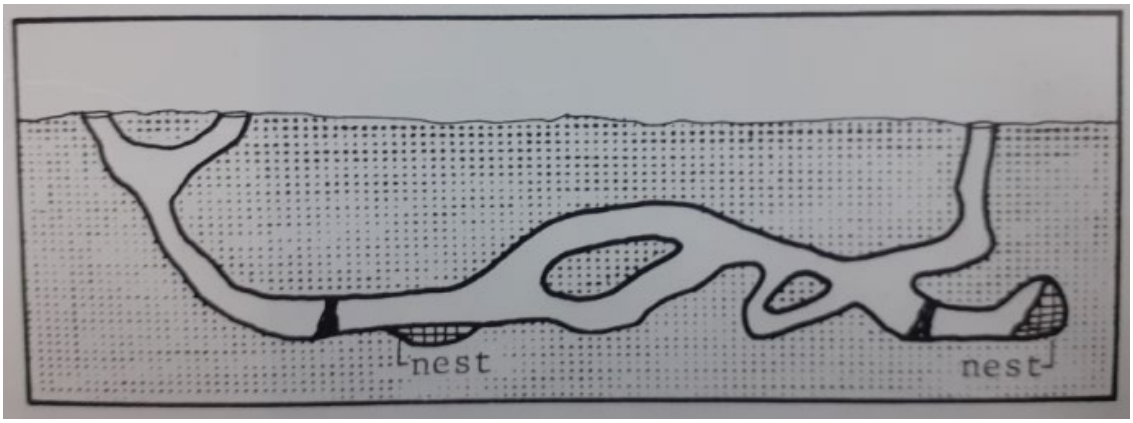
especially at the stage of panicle initiation to grain filling. However, some outbreaks occur in some parts of Myanmar.

Growth compensation has two components in cereal crops- tiller growth and panicle filling. Any tiller that is cut through by a rodent is likely to regrow. If this occurs before the maximum tillering stage, the tiller may go through normal panicle initiation. Although the damaged tiller is shorter than the normal one, the panicle size will not be affected. When the attack comes after the maximum tillering stage, the number of panicles will be less than that of the non-affected hill, but the panicle size will be larger with higher grain weight (Aplin *et al*., 2003). So, there is no need to worry much about the rodent damage before the maximum tillering stage.

In Malaysia, the rats (only for *Rattus argentiventris*) move into the paddy field about one month after transplanting. During this period, the first burrows are made. A nesting site (fig. 10.4) consists of initially a main burrow for the removal of earth and an access tunnel which leads to the litter. The latter is used as an emergency exit but is often closed during the breeding period. Depending on the size of the available location, the number of tunnels per nesting site increases during the season. At the peak of this period, two nests with different ages of litter can be found. This height of breeding activities is closely associated with the reproductive phase of the crop. There is only one breeding cycle in single-cropped areas, but if double-cropping is practised, two breeding cycles are common. The number of offspring ranges from 3–17 but often averages around nine individuals (van Vreden and Ahmad, 1986).

Singletonne (2003) also reported that the breeding of the rice field rat is linked to the development of the rice crop, and they give birth to 10–14 young. They start breeding before panicle initiation and end when the crop is ready. If crops are planted more than two weeks apart, the rats will move to the late-planted crops and continue breeding. The rice field rat has an equivalent number of breeding seasons with the number of rice planting seasons per year. That means one crop, one breeding season and two crops, two breeding seasons, etc.

Figure 10.4 Cross-section of nesting site of Rattus argentiventer



Source: Lam, 1978.

Figure 10.5 Rat burrows on the bund of a filed planted with black gram

Female rats are pregnant for 21 days, and they can mate the day after they give birth. One female can give birth to three litters (12 young per litter) in one planting season resulting in a total of 36 rats. These young will not breed until the next crop unless neighbouring farmers plant their crops more than two weeks apart. Then this will extend the breeding season of the rats throughout the year. Six females from the first litter will breed at seven weeks of age. One adult female rat could potentially give rise to 120 rats in a single rice-growing season (Singletonne, 2003).

10.4 Rodent feeding on stored produce

Rats eat an amount of food equivalent to seven percent of their body weight daily, i.e. a rat with a body weight of 250 g will eat around 25 g daily, amounting to 6.5 kg of grain a year. Mice eat a daily amount equivalent to about 15 percent of their body weight, i.e. a mouse weighing 25 g will consume between 3 and 4 g a day, amounting to 1.4 kg of grain a year. Besides feeding on stored produce, actual losses are much higher, as rodents contaminate the stored produce with urine, faeces, hair, and pathogenic agents. As it is challenging if not impossible to remove filth produced by rodents from the stored produce, infested batches often have to be declared unfit for human consumption.

There are many clear signs of rodent infestation:

- live animals
- droppings
- runs and tracks
- footprints and tail marks.
- tell-tale damage
  rats leave relatively large fragments of grain they have nibbled at (gnaw marks), they generally only eat the embryo of maize, sharp and small leftovers are typical for mice.
- burrows and nests
- urine.

10.5 Storage hygiene and technical measures

• Keep the store clean! Remove any spilt grain immediately as it attracts rodents!
• Store bags in tidy stacks set up on pallets, ensuring that there is a space of I m all around the stack!
• Store any empty or old bags and fumigation sheets on pallets, and if possible, in a separate store!
• Keep the store free of rubbish in order not to provide the animals with any places to hide or nest! Bum or bury it!
• Keep the area surrounding the store free of tall weeds so as not to give the animals any cover! They have an aversion to crossing open spaces.
• Keep the area in the vicinity of the store free of any stagnant water and ensure that rainwater is drained away, as it can be used as a source of drinking water.

10.6 Integrated rodent management strategies

Rodents may successfully be controlled with a combination of methods preferable applied over a relatively large area. A single farmer is usually unable to solve his rat problem if his neighbours do not join in the control efforts. If the population in a territory drops off if it is exterminated, for example, due to control measures, rats from surrounding territories will flock into these areas. Therefore, in some cases, control measures on a small scale may worsen rather than reduce the problem (van Vreden and Ahmadzabidi, 1986).

Rodent control in crop fields is difficult to achieve as it is aimed at removing pests during outbreaks. It should be done as an ecological operation involving the regulation of populations rather than the destruction of individuals. Rat control can be best achieved by being aware of the rat's basic needs, such as food and shelter and then limiting the factors that favour rats. A variety of management strategies can be carried out to limit rat population growth.

1. Harbourage reduction/habitat management
    - Deep ploughing and removal of weeds, both within the crop and along the bunds, have an important limiting effect on the rat population.
    - Reduce the size and number of bunds to limit burrowing sites and places for weeds to grow.
    - Synchronized planting of rice with varieties having the same duration over wider areas acts as a natural check on rat population growth as rat breeding is linked with the growth phases of the rice crop.
    - Protect seedlings in the nursery by surrounding the seedbed with plastic or zinc sheets of about 60 cm in height.
    - Destroy nests and burrows by digging them up and killing rats and their offspring. The most effective period is the flowering stage of the crop.

2. Rodent-proofing
   Rodent-proofing of storage structures is the first line of defence.

3. Mechanical control
   Trapping
   Trap barrier system (TBS) is successfully used in some Southeast Asia countries, but it is not working in Myanmar (Singletonne, 2003).
   Burrow smoking

4. Chemical control

   The control of rodents with rodenticides is the most common practice. It is better to undertake rodent control using poison baiting during the lean periods when the rodent
   population is at its minimum. The two most used groups of rodenticides are:
   1. Acute rodenticides like aluminium phosphide and zinc phosphide
   2. Chronic rodenticides like Warfarin and Bromadiolone - a single dose of anticoagulants (bromadiolone, broadifacoum and flocoumafen) among anticoagulants are more effective than multi-dose anticoagulants and are widely used.

   3. Bait preparation**:** To prepare 500 g of solid bait, take 450 g (four teacups) of locally preferred crushed cereal bait, 15 g (three teaspoons) of sugar and 10 g (two teaspoons) of oil. Mix these thoroughly and add 25 g (five teaspoons) of anticoagulant. Mix thoroughly.
   Placement of bait – burrow baiting: Identify live burrows and place 10 g of bromadiolone (0.005 percent) bait (96 parts of rice broken + 2 parts of edible oil + 2 parts of bromadiolone concentrate) inside the burrow. Station baiting: A quantity of 50-100 g prepared cereal/ready to use bait is placed in bait stations and kept at selected points.

10.7 Rodenticides in Myanmar

Five different active ingredients, zinc phosphide, brodifacoum, bromadiolone, flocoumafen and warfarin, were registered with 20 different names by different agochemical companies (PPD, 2020). Among them, zinc phosphide is an inorganic compound used as rodenticide baits. When an animal eats the bait, the acid in the animal's stomach turns the *zinc phosphide* into phosphine which is a very toxic gas.

Warfarin is a multiple-dose anticoagulant. A rat needs to eat multiple doses of the bait over several days. Brodifacoum and bromadiolone are single-dose anticoagulants, and they are more toxic, and one day's feeding can deliver a toxic dose (NPIC, 2016).

Second-generation rodenticide such as Brodifacoum and bromadiolone was allowed to register by changing formulation type. However, the use of Mandalar 2 (bromadiolone) was not encouraged by PPD, Myanmar (Dr Nyo Me Htwe, pers.comm. 2020). Mandala 2 is meant to be used only in a closed environment, not allowed in an open environment.

The Shan State government has provided villages with hundreds of non-venomous snakes to control rat infestations that have destroyed rice crops in many villages of Pekon Township (Zaw Zaw Htwe, 2020).

In Ayeyarwady region, volunteer exterminators from the infested villages laboured from dawn to dusk dispatching the rodents for a bounty of 50 Myanmar kyat (about 4 cents) per animal, using "sticks, slingshots and rocks," it was learnt.

Table 10.1 Action plan for rodent control measures in field

Day 1	**Identify live burrows and place 20 g of pre-bait material inside the burrow and leave the bait for 2–3 days.**
Day 3	Place 10 g zinc phosphide/15 g bromadiolone poison bait inside the burrow.
Day 4	Collect and bury dead rats, if any, and close all burrows.
Day 5	Eliminate the residual population by trapping or burrow fumigation with burrow fumigator in the case of zinc phosphide poisoning. Treat opened burrows with aluminium phosphide –2 pellets per burrow.
Day 14	Eliminate residual population by trapping or burrow fumigation in the case of bromadioline poisoning.

Chapter 11

The use of fertilizers in Myanmar

11.1 Introduction

Fertilizers commonly used in Myanmar are chemical fertilizers, organic or natural fertilizers, and biofertilizers. The Fertilizer Law 2002 of Myanmar defines a chemical fertilizer that is prepared with chemicals using any means and not being naturally made or composed. It also includes mineral fertilizer or organic and inorganic chemical fertilizer produced by a factory. Natural fertilizer means the remains, waste, or byproducts of fauna and flora obtained and prepared through decomposition.

Table 11.1 Types of Organic Fertilizers

Type	Source
Naturally occurring materials Peat	Naturally occurring materials Peat
Farm wastes	Crop residues
	Animal manures
	Compost
	Green manures
Residues from processing plant products	Fibers, pressed cakes (from oilseeds), grinds
	Wood materials
	Bagasse (sugar industry)
	Byproducts from the starch industry
	Seaweed extracts
Residues from processing animal products	Blood, horn, and bone meal
	Byproducts from the fish processing industry
	Leather dust, feathers
Urban wastes	Composted household refuse
	Sewage sludge

Source: IFDC, 2018.

11.2 Biofertilizers in Myanmar

During the past decade, the fertilizer market in Myanmar grew at a compound growth rate of 10–15 percent per year to about 1.6 million metric tonnes (t) in 2016. Despite the recent growth in demand, the intensity of fertilizer use in Myanmar is only about 25 percent of the fertilizer use level globally (fertilizer use per hectare of agricultural land). In Myanmar, fertilizer consumption was about 17.87 kg/ha/yr annually, using 138,791 tonnes of N -, 31 411 tonnes of P_2O_5 and 758 tonnes of K_2O fertilizers. The current fertilizer use practices also result in unbalanced nutrient applications, with an N:P:K use ratio of 6.5:1.6:1 (IFDC, 2018).

Nutrients are removed after growing crops, and the nutrient removal depends on the crop, as shown in the table. Therefore, the soil should be enriched with fertilizer for crop growing.

Table 11.2 Area sown, yield, production, and nutrient removal by harvested component and all Parts for Key Crops in Myanmar for 2015/2016

	Sown Area	Yield	Produc -tion	Nutrient Removed by Harvest (t)			Total Nutrient Removed by Harvest plus Straw (t)		
Crops	**('000 ha)**	**(t ha-^{1})**	**('000 t)**	**N**	**P**	**K**	**N**	**P**	**K**
Rice	7,212	3.6	26 210	382 666	68 670	68 146	581 862	81 251	686 702
Pulses	4,382	1.0	4 225	257 656	22 001	160 973	325 325	26 026	176 183
Groundnut	955	1.6	1 518	58 636	5 291	8 943	87 080	8 082	38 088
Sesame	1,530	0.5	827	33 131	6 898	33 907	42 177	7 443	35 561

Sources: reproduced from IFDC, 2018

"Biofertilizer" generally refers to products containing one or more living microorganisms able to stimulate plant growth and development in different ways. According to Vessey (2003), a biofertilizer is a substance which contains living microorganisms that, when applied to seed, plant surfaces (leaves), roots or soil, colonize the rhizosphre or the interior of the plant and promote growth by several mechanisms that increase the supply or availability of primary nutrients to the host plant.

The key role of biofertilizers is to improve the accessibility of plant nutrients through (1) increased biological N fixation, (2) solubilization of bound nutrients, (3) increased root distribution system, (4) biological control of plant pathogens, and (5) enhanced crop resistance to diseases and pests.

In Myanmar, legumes are mainly grown by smallholder farmers with minimal application of fertilizers resulting in poor yields from low soil nutrients. Groundnut was planted on 1 033 942 ha of land producing 1 582 693 tonnes in Myanmar in 2017 (FAOSTAT, 2019). Previous studies have also reported poor nodulation of several legume species, highlighting the low population of native rhizobia in this region (Herridge *et al*., 2008).

11.3 Rhizobium fertilizer

The inoculation of soils or legume seeds with *Rhizobium* bacteria is a well-established practice in Myanmar supported by DAR. In 2007, the production of inoculants in the unit was about 100 000 packets/year, but it was estimated that this volume of biofertilizers would be sufficient to inoculate only <5 percent of total legumes grown in CDZ (Atieno *et al.,* 2019). Since the end of the project in 2018, the unit has produced more than 250 000 packets annually of peat-based rhizobial inoculants for seven main legumes crops grown in the country. Rhizobium inoculation with the application of 56–112 lb/ ac P_2O_5 and 28–56 lb/ac K_2O should be applied for good nodulation and maximum yield in soybean and mungbean cultivation (Atieno *et al.,* 2019).

For different pulses such as green gram, black gram, groundnut, pigeon pea, chickpea, soybean and cowpea, different strains of Rhizobium harzianum are produced. In

producing Rhizobium bacteria, peat soil rich in organic matter was used as carrier material. Peat soil can be available from Heho, Shan State and Pyinoolwin, Mandalay region. In one gram of carrier material, there were about 100 million bacteria. One pack of Rhizobium (weighing 150 g) is sold at 700 MMK. In the past, four packages of rhizobium were recommended to use in one acre of green gram field. Nowadays, one pack is recommended to mix with 18 lb (8.18 kg) of seed and 4 to 6 packages may be needed for one acre where the seed rate is about 108 lb (49.1 kg) per acre. So far, 8 133 847 packages of rhizobium fertilizer have been distributed to the farmers. In some years, the demand was as high as 250 000 packages.

The benefit of rhizobium fertilizer

1. Nitrogen needed for legume crops can be supplied at a low cost.
2. Nitrogen removed from the soil by the crop can be replaced.
3. Following crop after legume can get a high yield indirectly.
4. Nitrogen fertilizer can be used for other crops and
5. The yield can be increased by 27–48 percent, depending on the type of legume.

How to use rhizobium fertilizer efficiently

1. The appropriate strain of rhizobium fertilizer should be broadcasted over the legume seed and mixed with the seeds by using some water to make it moist under the shade.
2. Seeds should be sown in the furrows immediately after mixing with rhizobium under the shade.
3. By using 56–112 lb of triple superphosphate and 28–56 lb of muriatic of potash as basal per acre, nodulation can be enhanced to increase the yield of the crop.

In the past, the efficacy of rhizobium fertilizer deteriorated during transportation due to the high temperature. The rhizobium fertilizer packages were transported in refrigerated containers, and the efficacy was no longer lost.

***Trichoderma viride* production**

DAR has been producing a small volume of biofertilizers containing *Trichoderma harzianum* for use in integrated disease management in the soil and on decaying plant residues, as well as AMF-containing inoculants (Maw *et al*., 2003; Than & San, 2006).

It is a local strain and produced 10 000 bags per month with the financial assistance of Proximity Design. It was distributed in Sagaing and Magway regions. One bag of *T. viride* is sold at 1 000MMK. It is recommended to use 60 bags per acre. However, ten bags can be mixed with two baskets of organic manure plus five pyis of bran and apply for one acre to reduce the cost. DAR produces 2 000 bags with DoA budget (Daw Si Si Myint, pers. comm, 2021).

Trichoderma is used to prevent or control all soil-borne diseases like fusarium wilt, black stem rot and dry root rot caused by rhizoctonneia dry root rot. It can also control sclerotium wilt if used at the early stage of disease progress.

Although the production started in 1995, it became popular among the farmers in 2015-16 after the year of heavy rain. (T. *harzianum* was a problem to use in the chickpea field, and it is not produced for upper Myanmar.)

11.4 Compost preparation and use

Organic materials as fertilizer: A mixture of all kinds of organic wastes such as agril-crop by products (straw, leaves, manure etc), agricultural-industry by-products, ash, manure and kitchen waste, green manure, etc.

- Crop residues, green manures, animal wastes, food processed by-products, agricultural industry by-products, household waste, dead-animal-body etc., can be used as alternative or supplementary sources of plant nutrients.
- Organic fertilizers can improve soil qualities and prevent soil degradation.

Benefit of compost use

- improve soil structure and texture;
- improve the chemical properties of soil;
- improve micro-organism activities in soil;
- improve water holding capacity of soil;
- balance soil temperature, aeration, and toxicity due to chemical application;
- supply plant nutrients for a long time;
- cost-effective; and
- environment friendly.

Composting

- Composting allows a mixture of organic materials to decompose under controlled conditions to produce a stable end-product which is used as fertilizer.
- The materials commonly used are crop residues (rice straw, corn stubbles, grass trimmings, or leaves), animal manures (cattle, duck, or chicken) and other farm or urban wastes.

Procedures for making compost

- Choose a shady level area (The best place to pile the compost is a compost room with a roof).
- Collect all waste materials (Straw, Grass, Any crop residue, Kitchen waste, Cow/goat/sheep manure, Leaves/branches/dead roots/other parts of plants, Wood dust, Ash, etc.).
- Pile by layering different composting materials:
  a. after every 10–15 cm layer – put 200g urea and 200g TSP evenly on the layer;
  b. continue until 1.2 m height of the heap;
  c. 7days after heap preparation, insert a stick to check the moisture inside (watery condition);
  d. if there is more moisture – make some holes to dry out; and
  e. if drier – put water mixed with cow-manure through the holes.
- water the pile evenly but avoid overwatering;
- cover the pile with the plastic sheet; and

- turn the pile upside down when it has cooled down (1st turning – after one month; 2nd turning: 1 month after 1st turning:
  a. The objectives of turning over are improving the compost aeration, radiating the fermentation heat, and turning the unfermented portion over to the inside of the compost to make full fermentation.
  b. After 1–2 weeks of a high-temperature stage, the temperature will go down gradually.
  c. One should practice turning it over, that is, turning the outer portion over to the inside and the inner portion to the outside to let the compost temperature go down and stay between 113ºF (45°C) to 140ºF (60°C).
  d. If the temperature is beyond this range, one should continue turning the compost over.
- **Determine full-fermented compost**
  a. below 102ºF (40°C);
  b. the appearance of compost becomes dark brown;
  c. no unpleasant smell but with soil aroma;
  d. the materials become soft and fragile; and
  e. height of the heap will be 1/3 of the initial.

Composting under soil

a. dig a hole of 3 m long x1.25 m breadth x 1 m deep;
b. make a bund of 15–20 cm height from the soil surface;
c. base of the hole should be pressed to hard;
d. spread a straw mat (7–10 cm thick); and
e. follow the composting as stated above.

Chapter 12

Cropping pattern and ecological engineering

12.1 Introduction

The process of growing several crops on the same piece of land during a given period is termed as Intensive Cropping (Chandrasakaran, *et al*., 2010). The methods involved in intensive cropping are as follows.

Multiple cropping is growing two or more crops on the same field in one year. Multiple cropping can be divided into (a) *sequential cropping,* (b) *relay cropping*, (c) *ratoon cropping or ratooning* and (d) *overlapping system of cropping*.

Intercropping is growing two or more crops simultaneously on the same field. Intercropping is termed m*ixed intercropping* (*mixed cropping*) when two or more crops are grown simultaneously with no distinct row arrangement. It is called *row intercropping* (*intercropping*) when two or more crops are grown simultaneously where one or more crops are planted in rows.
The crop intensification is in both temporal and spatial dimensions. Types of intercropping are (a) *parallel cropping*, (b) *companion cropping* and (c) *synergistic cropping*.

Principles of Intercropping

- The associating crop should be complementary to the main crop.
- The subsidiary crop should be of shorter duration and of faster-growing habits to utilize early slow growing period of the main crop.
- The component crops should require similar agronomic practices.
- Erect growing crops should be intercropped with cover crop.
- Erosion permitting crop should be intercropped with erosion resisting crop.
- The component crops should have different rooting pattern and depth of rooting.

Advantages of Intercropping

- It offers similar benefits to that from rotational cropping.
- The total biomass production/unit area/unit time is increased because of the fullest use of land as the inter-row spaces are utilized which otherwise would have been used for weed growth.
- The fodder value in terms of quantity and quality becomes higher when a non-legume is intercropped with legume. *e.g.,* Napier + desmanthus, sorghum + cowpea.
- It provides crop yields in different times, which reduces the marketing risks.
- It offers more employment and better utilization of labourers, machines, and power throughout the year.

- It is insurance against drought.

6. Crop rotation

Crop rotation may also be defined as a process of growing different crops in succession on a piece of land in a specific period with the object of getting maximum profit from minimum investment without impairing soil fertility.

Principles and advantages

If the same crop is repeatedly grown on the same land, it is referred to as *monoculture* or *monocropping* (*e.g.,* rice-rice-rice), whereas *crop rotation* is the repetitive cultivation of an orderly succession of different crops and crops and fallow on the same land. One cycle may take several years (one year or more than one year) to complete, *e.g.,* rice-rice-pulse (one year), sugarcane–ratoon sugarcane–Rice (2 or 3 years), banana–ratoon banana–rice (3 years).

Advantages of crop rotation

• Crop rotation helps maintain soil fertility, organic matter content and recycling of plant nutrients. All crops do not require the plant nutrients in the same proportion. If different crops are grown in rotation, land fertility is utilized more evenly and effectively.
• Restorative crops like heavy foliage crops and green manure crops included in rotation increase the soil's nitrogen and organic matter content.
• Helps control specific weeds like bermudagrass, cyprus (sedges) and *Trianthema portulacastrum.*
• Toxin buildup is avoided, and the physical qualities of the soil are preserved.
• Controls certain soil-borne pests and diseases.
• Reduces work pressure due to different farm operations in a stipulated period.

12.2 Cropping pattern in some project areas

According to GRET (2019), the main cropping systems are:

(a) In lowland areas:
- CS1- Rotation between summer paddy/monsoon paddy/winter cash crops (chickpea, green gram or wheat); and
- CS2 - Rotation between summer cash crops (green gram, black gram)/monsoon paddy/winter cash crops (wheat, chickpea, or groundnut).

(b) In the mid-land area:
- broadcasted paddy systems in the monsoon season
- direct seeded paddy
- intercrop between pigeon pea and groundnut
- perennial crops- mango, thanakha (*Limonia crenulata*) or betel vine.

(c) In upland area where the soil is light textured sand with low water holding capacity:
- pigeon pea with groundnut

- pigeon pea with green gram
- winter wheat, chickpea, sesame and groundnut.

Tatkon township

According to MOALI (2018) survey, in Tatkon township under the Sinthe Irrigation Scheme), farmers practised the rice-based cropping system was practised as follows:

(a) monsoon rice - summer rice - sesame/green gram; and
(b) monsoon rice - black gram – sesame/green gram.

Mandalay region

Most farmers grow single crop of paddy, but some farmers practised double-cropping patterns such as monsoon paddy-summer paddy, monsoon paddy-winter seed corn, monsoon paddy – winter groundnut and monsoon paddy-winter mungbean.

Pale and Yinmabin townships, Sagaing region

In Pale township, farmers adopt two common cropping patterns; (1) monsoon paddy rice (medium maturing variety) from June to October, followed by chickpea as the second crop grown from December to March and (2) monsoon paddy rice (traditional variety) from August to December followed by summer paddy rice cultivation (short maturing variety) from March to June. Some farmers also plant sesame from May to August followed by monsoon rice, then followed by the green gram. Farmers plant green gram or sesame from April to July in the rainfed areas, then monsoon rice (medium or late-maturing variety) from August to December.

In Yinmarpin Township, the cropping patterns were; (1) monsoon paddy rice from June to October, followed by chickpea as the second crop grown from November to December and (2) the summer paddy rice cultivation is from March to May which precede the growing of chickpea from January to February and sesame from February to March.

12.3 Ecological engineering for integrated pest management

Ecological engineering for pest management has recently emerged as a paradigm for considering pest management approaches that rely on cultural techniques to effect habitat manipulation and enhance biological control. The cultural practices are informed by ecological knowledge rather than by high technology approaches such as synthetic pesticides and genetically engineered crops.

According to Gurr (2009), “Ecological engineering” for pest management has emerged from conservation biological control and habitat manipulation. It is characterized by being based more comprehensively on ecological theory and developed via rigorous experimentation. The development process typically aims to identify and provide the most functional components of biodiversity rather than simply increasing diversity in an untargeted fashion.

Ecological engineering, defined as the design of sustainable ecosystems that integrate human civilization with its natural environment for the benefit of both, has grown quickly in the last 30 years. Its goals include the restoration of ecosystems that have been substantially disturbed by human activities and the development of new sustainable ecosystems that have both human and ecological values. It is especially needed as conventional energy sources diminish, and more amplification of nature's ecosystem services is required (Mitsch, 2012).

In 2008, the technique was established in rice cultivation in China, and it was then adopted in Vietnam and Thailand. Recently, the Philippines initiated a project as well. In Vietnam, to kick-start the process, rice farmers are initially given seedlings, which they plant on the bund and irrigate together with the rice plants. Although many nectar flowers die during the dry season, enough survive and go to seed for the next rice-growing cycle.

When the flowers are in bloom, a planthopper predator – like the tiny parasitoid wasp– lives off the pollen and honey from the flowering plant. After living in the nectar flower on the bund, they fly to find the insect nest and then lay their eggs inside the eggs of the insect nest. Soon after that, the insect numbers generally die off.

Natural enemies may require;

- Food in the form of pollen and nectar for adult natural enemies
- Shelters such as overwintering sites, moderate microclimate etc.
- Use other hosts when the primary hosts are unavailable.

Ecological engineering for pest management – Above ground

- Raise the flowering plants / compatible cash crops along the orchard border by arranging shorter plants towards the main crop and taller plants towards the border to attract natural enemies as well as to avoid immigrating pest population
- Grow flowering plants on the internal bunds inside the orchard
- Not to uproot weed plants that are growing naturally like Tridax procumbens, Ageratum sp, Alternanthera sp etc., which act as nectar source for natural enemies,
- When the P: D ratio is favourable, not apply broad-spectrum chemical pesticides. The plant compensation ability should also be considered before using chemical pesticides.

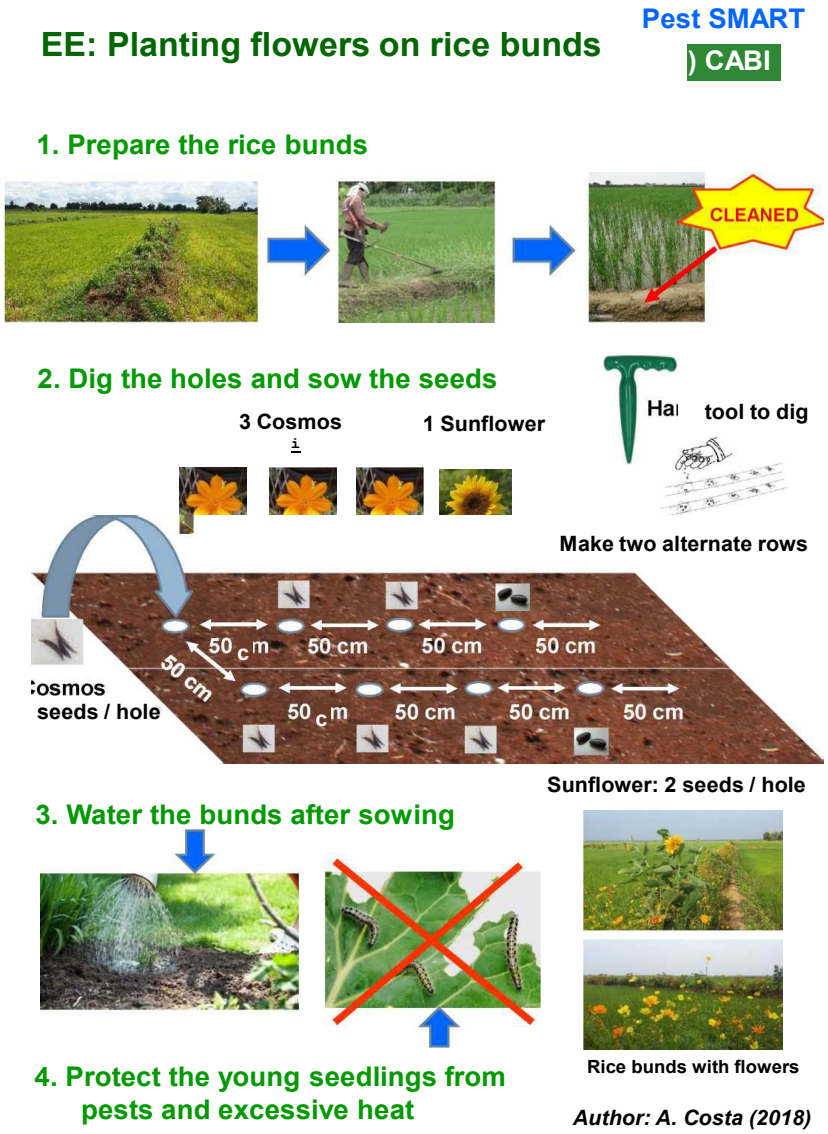
Ecological engineering for pest management – Below ground

- keep soils covered year-round with living vegetation and/or crop residue;
- add organic matter in the form of farmyard manure (FYM), Vermicompost, and crop residue, which enhances below ground biodiversity;
- lower tillage intensity to safeguard hibernating natural enemies;
- apply a balanced dose of nutrients using biofertilizers;
- apply mycorrhiza and plant growth-promoting rhizobacteria (pgpr); and

- apply Trichoderma spp. and Pseudomonas fluorescens as seed/seedling/planting material, nursery treatment and soil application (if commercial products are used, check for label claim. However, biopesticides produced by farmers for own consumption in their fields, registration is not required).

Due to the enhancement of biodiversity by the flowering plants, parasitoids, and predators (natural enemies), the number will increase due to the availability of nectar, pollen, fruits, insects, etc. The major predators are many spiders, ladybird beetles, long-horned grasshoppers, Chrysoperla, earwigs, etc.

Flowering plants such as cosmos and sunflower are planted on the bund of rice fields to attract the natural enemies of insect pests in Vietnam, as shown in the following figure (Costa, 2018).



Source: A. Costa, 2018.

Figure 12.1 Marigold, *Tagetes* sp, Asteraceae on the bund and Tichocard in paddy in Seinsarbin village, Nay Pyi Taw (Myanmar)

Ecologically-based approaches to pest management have been developed and deployed in several countries of Southeast Asia. The concept of "ecological engineering" was introduced to Myanmar through a training workshop in 2011.

The biggest challenge in its adoption is to motivate the farmers to adopt these concepts rather than looking for quick knockdown by chemical sprays, raising awareness among them to stop the routine sprays and ask them to enrich the bunds with nectar-rich flower crops.

Dr K.L. Heong, one of the pioneers of integrated pest management (IPM) and ecological engineering, believes that Myanmar farmers are much better off not using any insecticides at all. He suggested that there needs to be licensing and advertising restrictions, coupled with training and awareness programs, in order to avoid overuse.

On the other hand, it is necessary build the capacity of agro-advisory services using equitable information and decision-making tools so they can share knowledge about agricultural practices with their farmers. At the same time, to help smallholder farmers produce higher quality and safer food, it is needed to work with women and young people so they can run small agri-businesses that facilitate access to and use of low-risk products and practices.

It is desirable to work towards improved availability of safer plant protection products so farmers can put them to use. It will call for working with agro-input dealers to make these products accessible and affordable at the local level. In this case, it will need to test how small-scale businesses could produce biocontrol and biopesticide products and use them in their communities, assessing how the mode and demand for these products would allow for a sustainable financial return.

Finally, to implement these tasks successfully to achieve the goal of sustainable agriculture and a safer environment, it will be almost impossible without the cooperation, collaboration, and concerted efforts of all stakeholders such as the government officials form DOA, the General Administration Department, NGOs, agrochemical dealers, local community, and farmers.

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