Food and Agriculture Organization of the United Nations

Handbook on

the integrated crop management of rice and paddy 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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Nay Pyi Taw, 2022

Required citation:

FAO. 2022. *Handbook on the integrated crop management of rice and paddy for farmer field schools in central dry zone of Myanmar.* Nay Pyi Taw. https://doi.org/10.4060/cc1163en

ISBN 978-92-5-136689-9

Cover photographs: ©FAO/Kyaw Win Htun, ©FAO/Soe Moe Naing

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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 Center
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 collaboration 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 learning 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 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 hands-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 IRRI (IRRI, 2019). This means the Curriculum for FFS on Rice ICM (integrated crop management) 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 one 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 Plant Protection Department (PPD) (2020), 2 210 839 farmers were trained from the farmer field schools 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 five selected crops, i.e., paddy (*Oryza sativa*), groundnut (*Arachis hypogaea*), sesame (*Sesamum indicum*), green gram (*Vigna radiata*) and chickpea (*Cicer arietinum*) will be briefly outlined rather than giving detailed information on biology and ecology of individual pest species which can be readily available from many reliable sources such as IRRI Rice Knowledge Bank, CABI (Centre for Agriculture and Biosciences International) Plantwise Knowledge Bank, ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), 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

Total sown area, yield and production of five selected crops at 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 yield of national average was about 3.92 metric tonnes per hectare and the total production was about 28 million metric tonnes (MOALI, 2019a). The share of paddy production at 14 townships in three regions of project area was presented in Table 1.2.

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 (Table 1.3).

In Myanmar, 1 074 varieties of rice are listed as local varieties. The most popular varieties planted across the country are Manawthukha, Sinthukha, Ayarmin, Meedone, Shwethwehtun, Sinakari, Hnankar, Ngasein, Pawsanyin and Pawsanhmwe in 2017–2018 monsoon season. Manawthukha, Sinthukha and Ayarmin (Magyandaw) were planted on 900 000, 740 000 and 410 000 ha of land, respectively. Pawsanmhwe area was the lowest, 180 000 ha (DOP, 2018).

Table 1.1 Crop sown area, yield and production of five selected crops at 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: Ministry of Agriculture, Livestock and Irrigation (MOALI) (2019a)

Table 1.2 Sown area, yield and production of paddy in 14 townships of project regions in 2019–2020

Sr.	Region	Monsoon				Summer				Total			
		Planted	Harvest	Yield	Production	Planted	Harvest	Yield	Production	Planted	Harvest	Yield	Production
		(ac)	(ac)	per ac	basket	(ac)	(ac)	per ac	basket	(ac)	(ac)	per ac	basket
	Sagaing	26058	26058	82.54	2150827	4709	4709	88.08	414769	30767	30767	83.39	2565596
	Monywa	4008	4008	83.73	335590					4008	4008	83.73	335590
	Yinmarbin	27967	27967	82.04	2294415	346	346	89.49	30964	28313	28313	82.13	2325379
	Salingyi	4360	4360	81.27	354316	471	471	84.68	39883	4831	4831	81.60	394199
	Shwebo	107624	4008	81.79	7753182	231	231	102.18	23063	107855	95021	81.84	7776785
1	**Sagaing**	**1784420**	**1705777**	**80.05**	**136547748**	**67061**	**65227**	**85.16**	**5554900**	**1851463**	**1771004**	**80.24**	**142102648**
	Pakokku	1247	1247	89.72	111881	1204	1204	93.71	112826	2451	2451	91.68	224707
	Magway	2026	2026	71.72	145297	82	82	73.27	6008	2108	2108	71.78	151305
	Natmauk	24721	24721	62.89	1554786	477	477	71.72	34209	25198	25198	63.06	1588995
	Pwintbyu	71087	71087	82.60	5867520	13769	13763	89.33	1229471	84856	84856	83.69	7096991
	Aunglan	41448	41448	61.86	2563497	4555	4555	82.50	375801	46003	46003	63.90	2939774
2	**Magway**	**630311**	**630139**	**71.10**	**44803460**	**31127**	**31117**	**86.75**	**2699444**	**661458**	**661256**	**71.84**	**47502948**
	Sintgaing	28986	28986	95.25	2760917	681	681	99.30	67623	29667	29667	95.34	2828540
	Mahlaing	4289	4289	52.28	224240	14	14	86.00	1204	4303	4303	52.39	225444
	Natogyi	12173	12173	55.40	674443	136	97	73.67	7146	12309	12270	55.55	681589
	Pyawbwe	29783	29772	66.26	1972693	382	382	122.60	46833	30165	30154	66.97	2019526
3	**Mandalay**	**522413**	**519584**	**80.31**	**41726169**	**85697**	**85498**	**101.75**	**8699812**	**608110**	**605082**	**83.34**	**50425378**

Source: DOA. 2020. Bimonthly Reports of Crop Production, Internal Report

Table 1.3 The percentage of crop production in project regions compared with the national production in 2018–2019 monsoon season

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. Bimonthly Reports of Crop Production, Internal Report

In summer season, the most popular varieties in term of sowing acreage in descending order were Theehtutyin (380 000 ha), Shwethweyin, Sinthukha, Manawthukha, Yadanartoe, Yetkoesae (90-days), Palethwe, IR-474, Pakhanshwewar and Hmawbi-3 (10 000 ha) (DOP, 2018).

Other popular varieties widely sown (more than 100 000 acres each) for export as well as for local consumption include Kayinma hteiksaung, Shwewartun, Sinthwelatt, Thaigauk, TunPu, and Yarkyaw. Although Pawsanhmwe and Pawsanbaykyar are popular varieties with good eating quality, the volume of its export is small compared to other varieties (Mr Khin Soe, pers.comm. 2020).

The most popular rice varieties in Shwebo area are IR-747, Palethwe, Manawthukha, Shwewartun and Pawsan (Su Mon *et al.,* 2016). However, Rice Division (2018) reported that Ayarmin, Hmawbi-2, Shwebopawsan, Shwethweyin and Sinakari-3 were the most widely grown varieties in Sagaing region (Table 1.4). The popularity may change with the time.

Utilization of good quality seeds is vital to increase 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 incorporating 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 to produce 980 tonnes of seeds on 460 ha of land. In 2017-2018, the private companied 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, 10 varieties of sesame, 13 varieties of green gram and 12 varieties of chick pea up to 2019 (MOALI, 2019b).

The total sown area, production and good agricultural practices (GAP) area and percentage of five selected crops in Myanmar was presented in table 1. The GAP was not popular among the farmers and the adoption rate was very low in most of the 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, respectively. Mandalay region has the third largest with 0.03 percent (table 1.5). The current situation is demanding for more adoption of GAP in crop production not only for boosting the yield/production but also for the sustainable agriculture without depleting existing natural resources.

Table 1.4 The most widely grown varieties of paddy in project regions and union level in 2017–2018

Sr	Variety	Union Total	Sagaing Region	Magway Region	Mandalay Region
1	Ayarmin	/	/	/	/
2	Hmawbi -2		/	/	
3	Local				/
4	Manawthukha	/		/	/
5	Meedon	/			
6	Ninety days				/
7	Shwebopawsan		/		
8	Shwemanaw				/
9	Shwethweyin		/		
10	Shwewarhtun	/			
11	Sinakayi-3		/		
12	Sinthukha	/		/	
13	Yadanartoe			/	

Source: Rice Division (2018)

Table 1.5 Total sown area and GAP area of paddy during 2019–2020

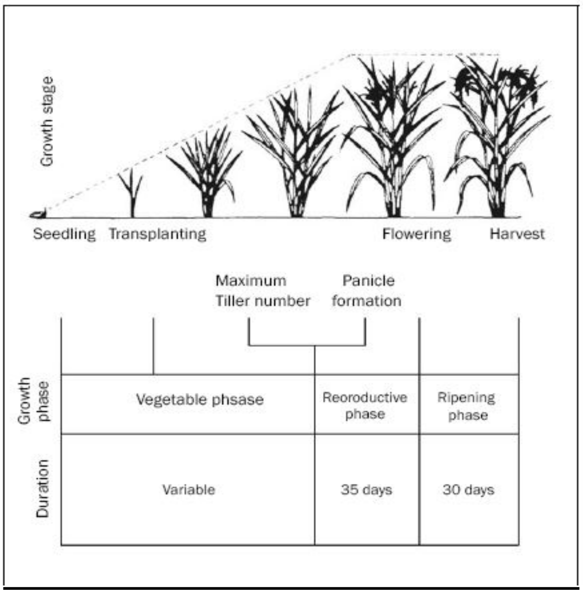
Sr.	State/Region	Total Sown Area (acre)	GAP Area (acre)	GAP %	Remark
1	Magway region	675 065	4 799.50	0.71%	
2	Shan state	1 297 857	3 639.73	0.28%	
3	Mandalay region	661 175	183.34	0.03%	
4	Kayin state	526 796	3.00		-
5	Yangon region	1 355 489	20.00		-
6	Sagaing region	1 962 577	30.00		-
7	Ayeyarwady region	5 099 081	50.00		-
Total			**8 725.57**		

To improve the well-being and capacity of smallholder farmers (including women, youth, and children) is one of five the Strategic objectives of the Myanmar Rice Sector Development Strategy - MRSDS (MOAI, 2015). However, weak extension and education system has been mentioned as one of the challenges. In addition to the strengthening technology delivery and extension services, farmer field school 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 Growth stages and growth phases of rice plant

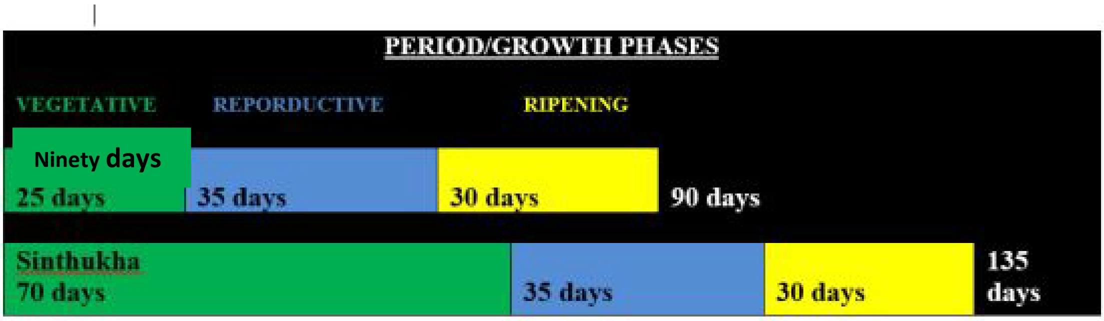
The growth stages of a rice plant are seedling, tillering, panicle initiation, booting, heading, flowering, milky and ripening. They can be divided as three phases as - (1) vegetative phase - from germination to panicle initiation, (2) reproductive phase – from panicle initiation to flowering, and (3) ripening phase – from flowering to maturity. Rice may have different life span but is has the same (fixed) period for reproductive phase - 35 days and ripening phase – 30 days for all varieties in the tropics as shown in fig.1.1. The difference is only for vegetative phase; the vegetative phase is longer in late maturing varieties, and it was shorter in early maturing varieties. For example, 90 days variety which matures in 90 days has a 25-day vegetative phase, whereas Sinthukha which matures in 135 days has a 70-day vegetative phase (fig. 1.2).

Figure 1.1 Growth stages of a rice plant



Source: Vergara, B.S. 1992. A farmer's primer on growing rice. International Rice Research Institute, Philippines.

Figure 1.2 Growth phases of two rice varieties (Ninety- day variety and Sinthukha variety)



1.4 Pest problems in the project areas

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

Table 1.6 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 plant hopper, gall midge	Bacterial blight, bacterial leaf streak, root rot, false smut	Grasses, sedges, broadleaf weeds	Occur with minimal damage
Pulses	Aphid, army worm, 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		

Source: MOALI. 2018. Agricultural Development Support Project, Ministry of Agriculture, Livestock and Irrigation, Myanmar

Table 1.7 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, army worm, aphids	Bacterial blight, bacterial leaf streak	Grasses, sedges, broadleaf weeds	Occur with minimal damage
Pulses	aphid, army worm, 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

Source: MOALI. 2018. Agricultural Development Support Project, Ministry of Agriculture, Livestock and Irrigation, Myanmar

In rice, farmers reported that stem borer, leaf folder, case worm and army worm are the major insect pests. The common diseases include bacterial leaf blight and rice blast. Weeds are a common problem in both monsoon and summer seasons, especially in the direct seeded rice areas and in irrigation tail end areas. Rodents are a minimal problem especially at panicle initiation to grain filling stage.

Table 1.8 Major pest problems in Pale and 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 plant hopper	Bacterial blight, rice blast	Grasses, particularly *Leptochloa chinensis* (red sprangle top) sedges, broadleaf weeds	Occur with minimal damage
Pulses	White fly, pod borer, aphids	Yellow mosaic		
Sesame	Leaf folder, hoppers	Stem rot, mycoplasma		
Chick pea	Army worm, leaf folder, pod borer	Fusarium wilt		

Source: MOALI. 2018. Agricultural Development Support Project, Ministry of Agriculture, Livestock and Irrigation, Myanmar

The problem of infestation (insects, diseases, weeds and rodents) in different regions is more or less similar. The records from ADSP 2018 are mainly from the irrigated area, it is assumed that the problem will be the same for dry zone areas. The insect pest and diseases are serious problems. Weed also becomes a threat in the regions where the famers faced with farm labour shortage due to migration to work in neighbouring countries. Rodent is not serious in most crops except groundnut in some region.

Chapter 2

Insect pests of paddy and their control

2.1 The common insect pests of paddy in Myanmar

Rice is the most important staple food crop, accounting for 20 percent in grain yield worldwide. Insect pests are the most consistent constraining factors in rice production. A total of 342 arthropod species in paddy was documented comprising 282 species of insects in 90 families and 17 orders and 60 species of arachnids in 14 families. Majority of the arthropods recorded were predators (149 species), dominated by spiders. Diversity of terrestrial arthropods in the field proper positively correlated with crop age and height of the rice plant, and in field bunds with the weed-cover. The composition of the arthropod communities is known to change with the growth of the rice crop (Bambaradeniya and Edirisinghe 2008; Heong *et al.,* 1991).

In Myanmar, apart from the classical work – "Insect pests of Burma" by Ghosh (1940), a list of field crop pests was reported by Crowe (1985) and an overview by Waterhouse (1993) was available. After that, 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 litura, Helicoverpa armigera, Agrotis ipsilon, Spilarctia obliqua, Thrips palmi, Aphis gossypii, Odontotermes* spp., *Agrotis segetum, Boctrocera cucurbitae, Bactrocera dorsalis* and *Scirtothrips dorsalis.*

The above-mentioned list was already 20 years old and the status of 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 with the real time.

PPD (2014) has listed 13 species of insects as major pests of paddy in Myanmar. However, only eight species of them were reported as pest of paddy in the project area (Table 2.1). Stem borer is one of the most omnipresent species across the country. After the introduction of summer rice as a double crop together with high yielding varieties, rice leaf folder, *Cnaphalocrocis medicnalis* becomes a major pest in some area. With the use of chemical insecticides more and more, the brown planthopper, *Nilaparvata lugens* and white back planthopper, *Sogatella furcifera* appeared as serious problem threatening rice industry especially in Shwebo area where high valued Pawsanbaykyar variety was widely planted. The use of chemical insecticide becomes a common practice among the farmers with the encouragement of agrochemical dealers. The heavy use of highly toxic chemical pesticides has led to insecticide resistance in certain pests and caused frequent outbreaks of secondary pests due to the extermination of their natural enemies. The use of highly potent chemical pesticides one after another is creating more problems rather than solving it as the chemicals killed the natural enemies in the paddy field. The problem of the brown planthopper is, in fact, the evidence of the secondary pest outbreak. On the other hand, there may be problems with pesticide residues in the product, in turn, that will threaten consumer safety.

Farmers lose an estimated average of 37 percent (ranging from 24 to 41 percent) of their rice crop to pests and diseases every year (Savary *et al.,* 2000). In addition to good crop management, timely and accurate diagnosis can significantly reduce losses. Evidences suggest that the use of chemical pesticide alone won't be a solution in the long run. In this case, the concept of integrated pest management (IPM) should be widely introduced to get awareness of the farmers for sustainable agriculture. In Myanmar, information on the pest record, level of infestation, damage to the crop and yield losses is available as appeared in the newspaper or internal report rather than officially published documents. Sometimes, it is not easy to get clear picture of current situation.

Table 2.1 Insect pests of paddy in Myanmar

Sr. no.	Important insect pests in Myanmar	Important insect pests in project area
1	Yellow stem borer*, Scirpophaga incertulas* (Lepidoptera: Crambidae) White stem borer*, Scirpophaga innotata* (Lepidoptera: Crambidae) Striped stem borer, *Chilo suppressalis* (Lepidoptera: Crambidae) Dark headed stem borer, *Chilo polychrysus* (Lepidoptera: Crambidae) Pink stem borer, *Sesamia inferens* (Lepidoptera: Noctuidae)	Yellow stem borer*, Scirpophaga incertulas* (Lepidoptera: Pyralidae)
2	Brown planthopper, *Nilaparvata lugens* (Homoptera: Delphacidae)	Brown planthopper, *Nilaparvata lugens* (Homoptera: Delphacidae)
3	White backed plan hopper, *Sogatella furcifera* (Homoptera: Delphacidae)	White backed planthopper, *Sogatella furcifera* (Homoptera: Delphacidae)
4	Green leaf hopper, *Nephotettix apicalyx* (Homoptera: Cicadellidae)	Green leaf hopper, *Nephotettix apicalyx* (Homoptera: Cicadellidae)
5	Rice leaf folder, *Cnaphlocrocis medinalis* (Lepidoptera: Crambidae)	Rice leaf folder, *Cnaphlocrocis medinalis* (Lepidoptera: Pyralidae)
6	Rice swarming caterpillar, *Spodoptera litura* (Lepidoptera: Noctuidae)	Rice swarming caterpillar, *Spodoptera litura* (Lepidoptera: Noctuidae)
7	Rice head-earbug, *Leptocorisa* sp. (Hemiptera: Alydidae)	Rice head-earbug, *Leptocorisa* sp., (Hemiptera: Alydidae)
8	Rice ear cutting caterpillar, *Mythimna separata* (Lepidoptera: Noctuidae)	Rice ear cutting caterpillar, *Mythimna separata* (Lepidoptera: Noctuidae)
9	Rice thrips, *Stenchaetothrip biformis* (*Baliothrips biformis*) (Thysanoptera: Thripidae)	
10	Rice case worm, *Parapoynx stagnalis*, syn. *Nymphula depunctalis* (Lepidoptera: Pyralidae)	
11	Rice hispa, *Dicladispa armigera* (Coleoptera: Chrysomelidae)	

12	Rice gall midge, *Orseolia oryzae* (Diptera: Cecidomyidae)	
13	Rice whorl maggot, *Hydrellia* sp (Diptera: Ephydridae)	

Source: PPD. 2014. Bacterial leaf blight of rice, Pest Management Decision Guide: Green and Yellow list, CAB International, UK

2.2 Insect pest at different growth stages of crop

The insect pests infesting the crop will vary with the plant growth stages and the season. The compensation of the plant to insect attack will also depend on the crop growth stage and environmental factors.

Different pests are found at different crop growth stages as follows:

Vegetative phase

1. rice stem borers
2. sucking pests: thrips and green leafhopper
3. leaf eating insects: rice hispa, rice case worm, rice leaf folder, rice hairy caterpillar and rice swarming caterpillar
4. rice ear cutting caterpillar
5. rice stem gall midge.

Reproductive phase

1. rice stem borers
2. sucking pests: brown planthoppers, white backed planthopper, green leafhopper
3. leaf eating insects: rice leaf folder
4. rice ear cutting caterpillar
5. rice ear bug.

The information on the biology, ecology and management of insect pests in rice can be available from a variety of sources among which IRRI Rice Knowledge Bank is the most informative in different aspects. A brief account of some insect pests on paddy in the project area is highlighted below.

2.2.1 Rice leaf folder, *Cnaphalocrocis medinalis*

In the past this pest was not a problem like rice case worm, *Nymphula depunctalis* which is quite serious in lower Myanmar. Leaf folder becomes serious after the introduction of high yield varieties in 1980s.

2.2.2 Stem borers

Yellow stem borer: *Scirpophaga incertulas* – the most common species, moth has slender body, lay eggs underside of the leaves and covered with yellowish-brown hairs from the anal turfs of mother moths.

Striped stem borer: *Chilo suppressalis* and Dark head stem borer: *C. polychrysus* – lay eggs in flat, naked cluster of overlapping rows at the basal half of the leaf or sometimes on leaf sheaths.

Pink stem borer: *Sesamia inferens* – moth has stout in body, *lay bare eggs between the leaf sheath and the stem*

Figure 2.1 Egg mass of pink stem borer (left) and yellow stem borer (right)

When stem borers infest paddy during the vegetative phase, the central leaf does not unfold, turns brownish, and dries off. This symptom is known as "dead heart" and affected tillers dry off without bearing panicles. After panicle initiation, they may not come out at all, and those that have already come out do not produce grains, and dry off. Being empty the panicles remain erect and are whitish, hence to symptoms "white heads" (Fig. 2.2).

Figure 2.2 Damage symptoms of rice stem borers

Dead heart

White head

2.2.2.1 Control measures

Rice yellow stem borer, *Scirpophaga incertulas* is the most serious pest in monsoon rice but the dark-head stem borer, *Chilo polychrysus* is abundant in summer rice according to PPD (2014). Management strategies involve:

- picking egg masses;

- weeding in the field and on the bund (this practice is not encouraged by Dr K.L. Heong of IRRI. He pointed out the practice of cleaning the bund is counter-productive. He suggested that growing flowering plants on the bund may serve as food source and sheltering site for the natural enemies. However, there may be some other cases like rice thrips where rapid infestation from weed to rice seedlings);
- burning stubble and straw;
- deep ploughing to kill pupae and larvae in the soil;
- drain one or two days when dead heart symptom is observed in the field (this practice may not work for rice thrips which is a serious pest in summer rice under water scarcity or drought conditions. For thrips, the opposite action, i.e., irrigation is needed);
- use light traps to catch stem borer moths (community action may be needed for this activity, otherwise undesirable results may come out);
- use potash fertilizers; and
- encourage the natural enemies.

Introduction of high yielding, BPH-susceptible rice varieties, use of high levels of nitrogen fertilizers, continuous cropping, staggered planting, and use of some insecticides are the reported causes for increased BPH populations.

2.2.2.2 Biological control

Trichogramma japonica was used to control rice stem borers in Myanmar. The rearing facility of Trichogramma was already in place at the Yangon PPD Head Office, Paleik, Mandalay Region, Shwebo, Sagaing Region and Yezin Agricultural University, Nay Pyi Taw Council Area. Regional authority from CABI stated that they will 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. Public as well as private sector should encourage the farming communities to produce biocontrol agent in their locality by giving technical and financial support as much as possible

2.2.2.3 Cultural control

Planting or seeding times may be delayed to avoid the peak emergence of moths from the diapausing population, but fields planted later than neighbouring fields may suffer high late season damage.

The population of insect pest and natural enemy varied with the plant density of paddy and it was found that the plat population should be kept between 110 000 and 130 000 per acre. When the plant population exceeds 140 000 per acre, care must be taken to prevent pest outbreak which can occur anytime.

If rice is planted in July, gall midge infestation can be serious (up to 28.66 percent) in September. So seed treatment should be given before rice is planted in July.

2.2.2.4 Host plant resistance

The phenomenon of host plant resistance may not be permanent. Some rice cultivars, for example, Pawsan baykyar and Manawthukha, moderately resistance to yellow stem borer in 1994–1995, were no longer resistant to YSB after 2010. The overuse and misuse of chemical insecticides may be partly responsible for this phenomenon (DAR, 2019).

Some rice cultivars were reported to be resistant to certain insect pests in Myanmar (Table 2.2). Twenty cultivars were found to be highly resistant to BPH, seventeen cultivars resistant to whitebacked planthopper and nine cultivars resistant to gall midge (DAR, 2019).

Table 2.2 Paddy varieties resistant to insect pests

Variety	Brown planthopper	Whit backed planthopper	Gall midge
China-203	/		
Hnankar		/	
IR-747	/		
Kaukhnyin Khuni		/	
Kyawzeya	/		
Natpyihmwe		/	
Ngakywehmwe	/		/
Palethwe	/	/	/
Patheinhmwe		/	
Shweman 1		/	
Pawsanhmwe	/		
Seinkalay			/
Shwethweyin	/	/	
Sinakari-2	/	/	
Sinakari-4	/	/	
Sinshwethwe	/		
Sinkalyar			/
Sinthiri	/		
Theehtut-3	/	/	
Theehtut-4	/		
Theehtut-5	/		
Theehtutyin	/	/	
Yadanaraung	/	/	
Yar -1			/
Yar-2	/	/	
Yar-3			/
Yar-4		/	/
Yar-6			/
Yaynetsabar			/
Yezin-1	/	/	
Yezin-2	/	/	
Yezin-3	/	/	

Source: DAR. 2019. Research outcomes after 65 years of DAR's effort (in Myanmar), Department of Agricultural Research, Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw

2.2.2.5 Chemical control

Foliar sprays act on the adult, egg and larvae but also adversely affect natural enemies, particularly parasitoids and predators searching for the prey on the rice canopy. The use of systemic granules at the tillering stage in irrigated conditions is effective in preventing dead heart symptoms but this is expensive in practice. It may also adversely affect predators and other microorganisms which live in the soil and paddy water. Insecticides should, therefore, only be used when necessary and the need should be determined by actual counts.

The economic threshold for *S. incertulas* is two egg masses per 20 hills up to panicle initiation stage, and 1 egg mass thereafter. Egg masses may be counted on 20 random hills along the diagonal of the field. In Myanmar, 5–10 percent of white head is referred as the economic threshold but it is too late to give any treatment as the plant has no time for compensation.

Carbofuran was recommended to control stem borers but it will be banned in June 2021. So, alternative chemical is needed to replace carbofuran.

In Myanmar, farmers become more organised in times of emergency, for example, in Shwebo, farmers organised to set village-level light traps to catch the yellow stem borers (Su Mon *et al.,* 2016).

2.2.3 Rice Thrips *Stenchaetothrips biformis* (Thysanoptera: Thripidae)

Thrips are very small insects with thin bodies and short legs, it looks like a cigar shape. The adults are dark brown in colour while the young ones are paler. The adult thrips are active in the day moving to look for young rice plant and other hosts. The life cycle of thrips is 10–20 days and most of them live on rice or corn or weeds. It can exist in two forms; winged or wingless

The rice thrips becomes abundant in dry periods from July to September and January to March. (IRRI, RNB). Both nymphs and adults lacerate the tender leaves and suck the plant sap, causing yellow or silvery streaks on the leaves of young seedlings. Terminal rolling and drying of leaves from tip to base is the typical symptom of attack. It causes damage both in nursery and main field. In severe infestation, the leaf tips wither off. Infestation at the panicle stage causes unfilled grains.

The life cycle consists of an egg, two larval instars, a prepupa and pupa, and the adult. Egg period 3–5 days, life cycle completed in 13–19 days. The egg, larval, and pupal stages took 6, 8, and 7 days, respectively. Males lived from 3 to 12 days and females from 3 to 20 days (Nugaliyadde and Heinrichs, 1984).

Figure 2.3 The adult rice thrips and silvery feeding marks

ETL

- one plant per sq. m showing chlorosis and scorching in nursery;
- three needle-like leaves per hill in main field; and
- 60 thrips per 12 wet hand sweeps in nursery.

Control measures

- Spray Azadirachtin 0.15 percent w/w 1.5-2.5 L or Lambda-Cyhalothrin 2.5 EC 500 ml or Lambda-Cyhalothrin 5 EC 250 ml in 500 L water/ha.
- Grow resistant cultivars after consulting with DOA or DAR.
- Flooding the field to submerge rice for 2 days is an effective control strategy for rice thrips.
- If the field cannot be flooded then thrip numbers can be reduced by dusting the seedlings with wood ash at a rate of 0.3kg/m2 in the morning. The wood ash breaks down the skin of the thrip.
- Adult thrips can also be reduced by catching them using a fine net such as a mosquito net or scarf. Drag the net lightly over the surface of the plants and kill any thrips collected.
- Rice seedlings normally recover from thrip damage provided water and fertilizer are supplied. After thrips infestation, use Nitrogen fertilizer (0.2 kg/m2) to improve tiller growth.
- Encourage establishment of biological control agents: predatory thrips, coccinellid beetles, anthocorid bugs, and staphylinid beetles.
- Seed treatment and soil application of granules of cartap and disulfoton after transplanting gave effective control of larvae and adults.
- Uproot and burn the plants with leaves curling inward which is the symptom of thrips infestation.

2.2.4 Plant hoppers

Brown planthopper, *Nilaparvata lugens* (Stal)
White-backed planthopper, *Sogatella furfcifera*

Figure 2.4 Different life stages of brown plant hoppers

Eggs Nymphs Short-winged Adult Long-winged Adult

Figure 2.5 Different life stages of white-backed plant hoppers

Eggs Nymphs Short-winged Adult Long-winged Adult

In Indonesia, the insect predators that feed on rice pests - dragon-flies, wasps, spiders, pond skaters and many others - are wiped out by heavy pesticide applications. In the absence of the natural enemies, the population of BPH will multiply exponentially leading to outbreak. Fields with heavy infestations of BPH can become entirely parched - an effect known as "hopper burn" - cutting the harvest to zero. However, Natural enemy destruction was a minor factor (Chelliah, 1979). When resurgence-inducing insecticides were applied in the field, these chemicals stimulated BPH population growth regardless of their relative toxicity to natural enemies.

In Shwebo, brown plant hoppers attack the fields just before the rice shoots come out in the majority of the fields. The synthetic pyrethroids deltamethrin and cypermethrin, and organophosphates such as methyl parathion, diazinon, azinphos ethyl, and quinalphos are reported to cause BPH resurgence (Heinrichs *et al.,* 1978). In rice, paddy water application of granular formulations of carbofuran, isazophos, ethoprop, and acephate significantly increases plant height (Heinrichs *et al.,* 1979). The phytotonic effect (healthy, green plants) of certain insecticides may attract more macropterous hoppers immigrating into rice fields. The alighting followed by increased feeding, reproduction, and longevity would increase BPH resurgence.

Figure 2.6 Making space for better ventilation and spraying to control the brown planthopper

Figure 2.7 Brown planthoppers at the base of the hill and the hopper burn in paddy field

With the outbreak of brown planthopper, there are different opinions by different researchers.

(a) Natural enemy destruction was a minor factor (Chelliah 1979, Chelliah and Heinrichs 1980; Heinrichs *et al.,* 1982).

(b)The phytotonic effect (healthy, green plants) of certain insecticides may attract more macropterous hoppers immigrating into rice fields. The alighting followed by increased feeding, reproduction, and longevity would increase BPH resurgence.

(c) To save money, farmers are using low insecticide doses. Chelliah (1979) reported that low doses of resurgence-inducing insecticides increased the reproductive rate of the BPH and reduced the nymphal duration, eventually leading to resurgence.

(d) Insecticides causing resurgence include some synthetic pyrethroids, organophosphates, and carbamates. No single class of insecticide has been identified to be free from resurgence-inducement (Chelliah, 1979).

(e) Foliar spraying induced more BPH resurgence than root zone placement and broadcasting.

(f) Cypermethrin, deltamethrin, bifenthrin and lambda cyhalothrin resulted in a sex ratio in favour of a greater number of females (Kumar *et al.,* 2019).

2.3 Some insect pests found in the field

Figure 2.8 Yellow stem borer and Rice leaffolder

Figure 2.9 Rice leaf butterfly larva and rice skipper larva

Figure 2.10 Stink bug and the leaf hopper, *Cofana* species

Figure 2.11 ***Spodoptera litura*** **larva and short-horned grasshopper**

Figure 2.12 Rice earbug, ***Leptocorisa varicornis***

Figure 2.13 ***Amsacta*** **sp egg mass and newly hatched larva**

Chapter 3

Plant diseases of paddy in Myanmar

3.1 The common diseases of paddy in Myanmar

Although CPC (2007) listed 29 diseases of paddy in Myanmar, PPD (2014) mentioned only 14 diseases of national importance from the current list of 17 diseases. Among them, only three diseases were reported as serious problem for the paddy growers of the project area (CFAVC, 2019).

Table 3.1 Diseases of paddy in Myanmar

Sr. no.	Important diseases in Myanmar	Important diseases in project area
1	Rice blast, *Pyricularia oryzae*	
2	Sheath rot, *Acrocylindrium oryzae*	
3	Sheath blight, *Rhizoctonia solani*	
4	Brown leaf spot, *Drechslera oryzae*	
5	Narrow brown leaf spot, *Cercospora janceana*	
6	False smut, *Ustilaginoidea virens*	False smut, *Ustilaginoidea virens*
7	Stem rot, *Magnaporthe salvinii*	Stem rot, *Magnaporthe salvinii*
8	Bakanae disease, *Fusarium moniliforme*	
9	Bacterial blight, *Xanthomonas oryzae* pv *oryzae*	Bacterial blight, *Xanthomonas oryzae* pv *oryzae*
10	Bacterial leaf streak, *Xanthomonas oryzae* pv *oryzicola*	
11	Bacterial foot rot, *Erwinia chrysanthemi*	
12	Rice ufra disease, *Ditylenchus angustus*	
13	White tip disease, *Aphelenchoides besseyi*	
14	Rice root knot disease, *Meloidogyne incognita*	

Source: PPD. 2014. Bacterial leaf blight of rice, Pest Management Decision Guide: Green and Yellow list, CAB International, UK

3.1.1 Bacterial blight *Xanthomonas oryzae* pv. *oryzae*.

3.1.1.1 Symptoms

This disease has three types of symptoms, blight, kresek and pale-yellow symptoms.

Blight symptom: The blight symptom appears commonly on leaf blades, and sometimes on leaf sheaths and glumes. The symptom usually begins at the leaf margin near the tip. At first, tiny water-soaked lesions appear on the leaf margin. The lesions enlarge both in length and width, have a wavy margin, and turn yellow within a few days. On the surface of young lesions, milky or opaque dew drops (bacterial ooze) may be observed in the early morning.

Kresek symptom: The kresek symptom may be observed 1 or 2 weeks after transplanting. The leaves turn to grayish-green, suddenly wither and rollup and some of them float on the water. When the crown is cut longitudinally, it shows a soft rot that is filled with yellowish bacterial slime.

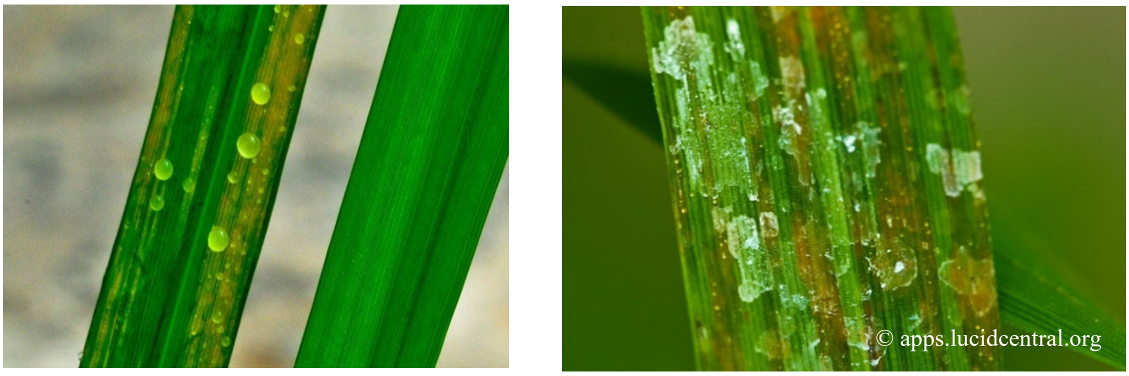
Pale yellow symptom: Pale yellow symptom is found in mature plants. While the older leaves are normal and green, the youngest leaf is uniformly pale yellow or has a yellow or greenish-yellow broad stripe on the blade. No bacteria can be detected in the yellow leaves, but they are numerous in the crown of the stem and in the internodes immediately below infected leaves.

3.1.1.2 Host range

Cyperus rotundus and *C. difformis* are reported as the weed hosts of *X. oryzae* pv. *oryzae* from India as being alternative hosts found infected in nature. Several other weed hosts have also been reported.

Figure 3.1 Bacterial leaf blight symptoms

Figure 3.2 Bacterial ooze and dried up bacterial ooze



3.1.1.3 Management

Pest management decision guide: Green and yellow list for Bacterial leaf blight by CABI is as follows:

Prevention	Monitoring	Direct control	Direct control	Restrictions
-Plant the resistant variety Sin Thu Kha Plant 8″ x 6″ spacing to avoid overlapping leaves - Plant 8″ x 6″ spacing to avoid overlapping leaves -Early planting: Sow in 1st week of June-July - Do not overuse nitrogen fertilizer (urea 46 percent); 112 lb. per acre - Use 28 lb. per acre of potassium as basal dressing (45 percent K2O) - Remove infested plants, weeds, debris, which can serve as host of bacteria - Burn rice straw left from previous crop	-20 days after transplanting, check the field for yellow wavy line symptom at the tip of the leaves near the margin -For hybrid variety: take action when 30 percent damage of leaf area -For Sin Thu Kha variety: take action when 50 percent damage of leaf area -Check for wilting and yellowing of leaves, or wilting of seedlings	-Follow good irrigation practices, i.e., avoid draining water from infected fields to uninfected fields.	-Spray copper hydroxide 400–500 grams per acre when 30 percent–50 percent damage of leaf area (Veg) or 20 percent damage of flag leaf area (Heading)	-WHO Class II (Moderately hazardous). Apply a maximum of three times per season

Source: PPD, 2014

3.1.2 Rice blast

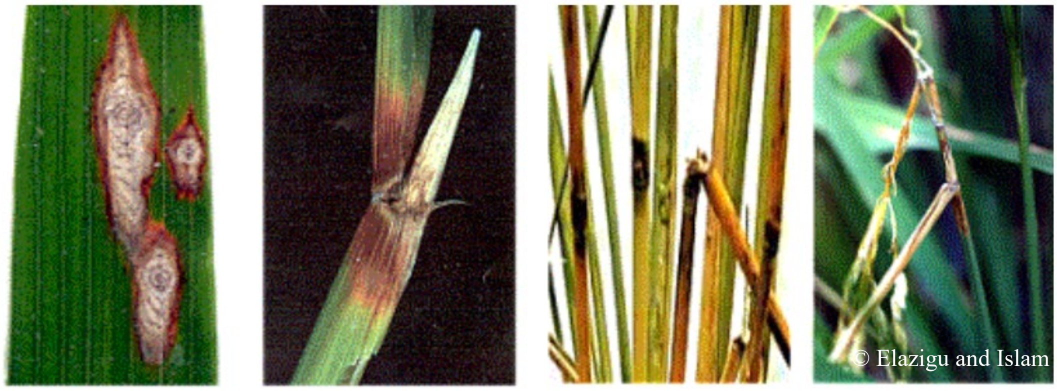
3.1.2.1 Occurrence and economic importance

Although blast is capable of causing very severe losses of up to 100 percent, little information exists on the extent and intensity of actual losses in farmers' fields in Myanmar. Thresholds and estimates for losses have been calculated that for every 10 percent of neck blast, there was a six percent yield reduction and a five percent increase in chalky kernels, which lowered the rice quality by one or two classes. The gross income loss was estimated at 7–9 percent (Heinrichs and Muniappan, 2017).

3.1.2.2 Symptoms

Formerly, rice blast was recognized in relation to the rice growth stage affected: seedling blast, leaf blast and neck and node blast. Seedling blast occurs in seedbeds. Infected leaves have many small, brown, oval lesions. At advanced stages, leaves and leaf sheaths are dead. Severe infections result in the death of large patches of seedlings. In leaf blast, lesions appear on the leaves, particularly near the upper end. Collar blast is commonly found and leaves may break from the sheath as a result of rotting at the junction of leaf and sheath. Collar blasted leaves also seem to have a shorter lifespan than unaffected leaves. Neck and node blast occur in nearly mature plants. No grain is formed when these lesions develop early. Later development of lesions results in the production of poorly developed grain. These are the most destructive forms of disease.

Figure 3.3 Different kinds of rice blasts



Leaf blast **Collar blast** **Node blast** **Panicle blast**

3.1.2.3 Forecasting

Blast-forecasting systems have been successfully developed in Japan and Republic of Korea based on meteorological data. Various methods of forecasting blast disease have been made based upon information on the fungus, the host plant and the environment. For example, the number of blast lesions was estimated by the numbers of trapped spores and the wetting period of leaves. Besides information on inoculum and climate, the predisposition of the rice plant has also been used for blast forecasting. Often one method works well for one region but does not function at another place.

3.1.2.4 Hosts

Rice blast affects other host grasses. Besides the grass hosts reported by many workers, the pathogen has been found on a number of other plant species, including ginger, banana, barley, sugarcane, maize and sedges.

3.1.2.5 Resistant crop cultivars

In Myanmar, Sin-thu-kha - 2, Sin-thwe-latt and Shwe Myanmar are found to be resistant to rice blast.

3.1.2.6 Chemical control

Current major products are mainly systemics with a residual activity of at least 15 days. The modern blasticides include isoprothiolane, probenazole, pyroquilon and tricyclazole and are applied as foliar sprays, as granules into water or seed-box treatments (irrigated lowland rice), or as seed dressings for upland rice. First applications of most products are recommended as protective applications before or shortly after the onset of leaf blast. Panicle blast treatment should be preventative rather than curative. In Japan, up to five foliar applications may be necessary.

3.1.2.7 Cultural control

- Restricted nitrogen fertilizer applications are needed to avoid serious outbreaks of blast.
- Control of irrigation water has also been used to reduce blast damage.
- Close spacing also often increases the severity of the disease.
- Field sanitation and synchronized planting reduce carryover and/or spread of disease.

3.1.3 Rice false smut *Ustilaginoidea virens*

3.1.3.1 Symptoms

Rice false smut causes yellowish to orange small balls to develop on the grains which later turn black. The incidence of false smut is increasing more and more among rice growers, especially among small seed productive farmers. This is due to changing weather conditions and continuous rice cropping (IRRI Rice Knowledge Bank). False smut affects not only the yield but also reduces grain quality.

False smut is a soil, seed and air borne fungal disease. It causes reduced rice quality and means farmers get a low market price. The pathogen that causes false smut can survive in soil from harvesting time to flowering time of next crop. But we can control this problem easily with prevention methods. But we can control this problem easily with prevention methods.

Figure 3.4 Spore balls are initially orange and turn greenish black when mature

3.1.3.2 Management

Latt Latt Khaing (2014) gives some preventive measure for Myanmar farmers as follows:

- deep plough to at least six inches and practise sun drying the field during the summer;

- use certified disease-free seeds;
- dpray a fungicide 5–7 days before flowering stage only once (carbendazim, hexaconazole) (carbendazim is about to be banned in Myanmar); and
- temove alternative hosts, including grassy weeds, especially Common barnyardgrass (*Echinochloa crus-galli*) and Jungle rice (*Echinochloa colona*).

When using a pesticide, always wear protective clothing and follow the instructions on the product label, such as dosage, timing of application, and pre-harvest interval.

3.1.4 Rice stem rot *Magnaporthe salvinii*

3.1.4.1 Symptoms

The symptoms are generally observed after mid-tillering stage. The disease appears as small, irregular black lesions on the outer leaf sheath near water level. As the disease advances, the lesions enlarge and the fungus moves inwards and rots the stem. This may result in lodging, unfilled panicles and chalky grains. Severe infection causes tiller death. Infected stem rots produce numerous tiny white and black sclerotia and mycelium inside the infected culms as the plants matures.

Sclerotia of H. *sigmoideum var. irregulare*. Sclerotia spherical or nearly so, black at maturity, surface nearly smooth, at times covered with cottony weft of white mycelium; 180–280 µm, mostly 230–270 µm. Sclerotia found in the infected tissues are diagnostic.

3.1.4.2 Management

- Plough the land frequently before sowing or transplanting.
- Applications of lime have been used to reduce soil pH.
- Periodically, drain the fields to reduce the number of sclerotia.
- Use the correct balance between nitrogen and potassium fertilizers. It is best to split applications.
- Collect straw and other debris after harvest and burn it with the stubble, or plough everything into the soil.
- Rotate with forage or legume crops.

3.1.4.3 Resistant varieties

There are no highly resistant varieties, although there are differences in ability of varieties to withstand lodging.

3.1.4.4 Chemical control

PPD has recommended some fungicides such as propiconazole, chlorothalonil, thiophanate methyl, benomyl at the start of the disease is said to be effective, but careful consideration should be given to the economics of this method of control. The possible association of the disease with insect attack by brown plant hopper and armyworm, or with nutritional imbalance should be considered before application of fungicides.

When using a pesticide, always wear protective clothing and follow the instructions on the product label, such as dosage, timing of application, and pre-harvest interval.

Figure 3.5 Stem rot symptom caused by *M. salvinii* and sclerotia

DAR has reported some paddy cultivars resistant to rice diseases as follow:

Table 3.2 Paddy varieties resistant to diseases

Variety	Bacterial blight	Rice blast	Sheath blight
	Xanthomonas oryzae pv. *oryzae.*	*Magnaporthe grisea*	*Rhizoctonia solani*
Htunthiri		R	
Kalargyi		R	
kaukhnyinhmwe		R	
Khaukphephan		R	
Manawthukha		R	MR
Meegauk			MR
MR-230	R		
Namathalay		R	
Pyilonechanthar		R	
Sabarnet		R	
Sannigyan		R	
Seinyin		R	
Sinayar-1		R	
Sinayar-2		R	
Sinthukha	R		
Shwemyanmar	R		MR
Shwepyitan			MR
Shwethweyin	R		
Sinakari-3		R	
Sinnweyin	R		
Sintheingi	R		MR
Yadanartoe	R	R	MR
Yar-2 Htun		R	
Yar-8		R	
Yar-9		R	MR
Yayanaelo-1		R	
Yebawsein		R	
Yezin-1		R	
Yetkoesae	R		
Yezin lonethwe			MR

Source: DAR. 2019. Research outcomes after 65 years of DAR's effort (in Myanmar), Department of Agricultural Research, Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw

Chapter 4

The role of pesticides in crop protection

4.1 Introduction

Insecticides are the most powerful tool available for use in pest management. They are highly effective, rapid in curative action, adaptable to most situations, 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 method of application 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
e. direct hazards from insecticide use.

4.4 The use of pesticides on selected crops in Myanmar

Prior to the introduction of the modern varieties, the rice crop survived for centuries with traditional varieties with robust plant type but low yield. The farmers started applying higher doses of fertilizers in general and nitrogen in particular and resulted in an altered micro-climate, which led to the accentuation of the insect pest and disease problems. Many diseases such as sheath blight, sheath rot, false smut and leaf scald have become severe in several parts of the country. Yield-losses ranging from 21 to 51 percent have been estimated due to moderate to serious 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 for realizing yield potential of rice, development of suitable Integrated Pest Management (IPM) strategy is important.

But as the farmers have been mostly confident on chemical control for managing the pests, it has become imperative to develop a holistic system of tackling pests, which is environment-friendly, economically viable and socially acceptable. Time, money, patience, short- and long-term planning, flexibility and commitment are required for any IPM programme 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 are was 2.303 million ha (about 25.1 percent). The use of pesticides on five selected crops was as shown in table.

Table 4.1 The amount of pesticide 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. Myanmar Agriculture at a Glance. Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw

The trend of pesticide use is changing these days. In the past the volume of insecticides was the largest but herbicide use becomes more and more popular to solve the farm-labour shortage due to migration to neighboring countries. The most widely used pesticides were 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

4.5 Problems with pesticides

Although pesticides are used to combat the pests in the crop, it may not be necessary all the time. Based on their survey in ten Asian countries (Myanmar is not included), Heong and Escalada (1997) pointed out that farmers usually overreacted 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 and there were some initiations in Myanmar to get awareness and to change the perceptions of farmers through a variety of media such as Farmer Channel, PPD app from the government sector as well as Greenway and Htwettoe apps from private sector.

According to Indonesia 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 to control golden snail, shatter the ecological balance of the fields. The insect predators that feed on rice pests - dragon-flies, 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 practicing PM rarely use pesticides. Consequently, BPH predators flourish and healthy rice plants continue to grow in their field.

In Indonesian, some 800 X 10^3 ha of rice were treated for yellow stem borers by aerial applications of phosphamidon (Dimecron 50; Ciba Geigy Ltd., Switzerland) from 1968 through 1970 (Mochida 1978). Government subsidy on pesticide for about 20 percent of actual cost (van der Fliert 1993). Subsidies for insecticides increased yearly, and by the mid-1980s the annual subsidy averaged USD 120 X 10^6. Prior to 1970 and the mass spraying of phosphamidon, the rice brown planthopper was not reported as a pest in Indonesia. By 1974 a new pest, the rice brown planthopper, *Nilaparvata lugens* (Stal), was emerging in many of the areas sprayed as a pest far 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. In the following seasons, farmers responded to this stem borer outbreak by overusing pesticides, which killed beneficial insects, thereby inviting more problematic ones. In the following 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 have to double their use of pesticides to tackle the problem but further aggravated rather than solving 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, and number of insecticide applications and the level of varietal resistance to BPH (Chelliah and Heinrichs, 1980).

Foliar spraying is the most common method of applying insecticides in Myanmar. *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 develops resistance to insecticides in areas where they have been used excessively.

Buprofezin 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 the majority of the field population are second or third instar. Overuse of insecticide applications including the use of 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 is calling for the use of integrated pest management rather than solely relying on chemical pesticide 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 the crop protection. It also allows certain biopesticides to get provisional registration and import so that to combat invasive pest like the fall armyworm threatening maize industry in Myanmar. At the same time PPD banned some of highly hazardous pesticides and announce the restricted to use list after getting approval from the Pesticide Registration Board. So far, 54 pesticides are banned in Myanmar as of July 2020.

4.6 Banned and restricted pesticides in Myanmar

Pesticide registration board chaired by the Deputy Minister of has regular meeting and allows or rejects registration of 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	Remarks
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 wild life, other chronic effect, long residual effect, 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 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

No	Active Ingredients	Reason	Usage	Remarks
32.	Mirex	Carcinogenicity, persistent in environment, biomagnifications in food chain	Insecticide	POP List
33.	Parathion ethyl	Toxic to aquatic organisms, high acute toxicity	Insecticide, Acaricide	PIC List
34.	Pentachlorophenol (PCP)	Highly acute toxicity, persistent in 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 organism, 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	Insecticid e	
45	Terbufos	Highly acute toxicity, inhibition of brain cholinesterase, reproductive effects	Insecticid e	
46	Borax decahydrate	Reproductive effects, fetotoxicity, possible liver carcinogen	Insecticide	

No	Active Ingredients	Reason	Usage	Remarks
47	Hydramethylnon	Reproductive effects, highly acute toxicity, possible human carcinogen	Insecticide	
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 toxicities to humans, cholinesterase inhibitor, neurotoxin, highly toxic to vertebrates and birds	Insecticide	PIC List
52	Carbendazim	Mutagenecity, reproductive effects, teratogenicity, hepatocellular 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 tumors	Fungicide	-
54	Glufosinate-ammonium	Reproductive effects, neurotoxicity cardiovascular and CNS adverse effects, inhibit glutamine synthetase, persistent through soil	Herbicide	-

Source: MOALI. 2018. Agricultural Development Support Project, Ministry of Agriculture, Livestock and Irrigation, Myanmar

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

Source: MOALI. 2018. Agricultural Development Support Project, Ministry of Agriculture, Livestock and Irrigation, Myanmar

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 illiteracy** 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 pesticides used in Myanmar and most of them have been already banned in EU (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 EU 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 EU 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**

Source: Rothschild, G. 2020. Comprehensive literature review and information gathering , Powerpoint presentation at the Myanmar Plantwise National Forum, 11 November, 2020

Table 4.6 The comparison of fungicides and herbicides used in EU and Myanmar

FUNGICIDES

Table 4.5 The comparison of insecticides in EU and Myanmar

Pestic			474 total	337 total	+IFDC- 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**

Source: Rothschild, G. 2020. Comprehensive literature review and information gathering , Powerpoint presentation at the Myanmar Plantwise National Forum, 11 November, 2020

Chapter 5

Precaution measures for safe handling of pesticides and container disposal

5.1 Introduction

Pesticides are toxic to both pests and humans. It is necessary to take precaution not to harm people, livestock and non-target organisms. Careless handling and application of pesticides will pose hazard not only to the user but also 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 with 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.

Using pesticides safely depends on many things. Some of the most important factors include selecting the appropriate product, and using that product according to the label directions. The label directions are written to minimize the risk of problems and to define the *legal* uses for the product.

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

Some basic pesticide safety principles

Always read and follow label directions before buying or using a pesticide.

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 are not going to 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. Transport pesticides in the trunk or truck bed, separate from passengers, groceries or animal feed, and secure the containers to prevent spills.
5. Store pesticides in a locked cabinet or secure area, away from food, feed, or personal protective equipment.
6. Measure and mix pesticides in a well-ventilated area away from children, pets, toys, and food.
7. Calibrate and maintain application equipment so that the amount of pesticide applied will be accurate, uniform, and legal.
8. Keep pesticides on target – use untreated buffers if necessary or delay the application if conditions favor off-target movement due to wind or water.
9. Identify sensitive areas and organisms that could be affected by the application, and take all necessary precautions.
10. Do everything possible to prevent spills and leaks, and always have an absorbent material such as cat litter or sawdust readily available.
11. Wash slightly contaminated work clothes separately before re-use, and follow all directions on care and disposal of personal protective equipment.
12. Dispose of the pesticide properly, as well as any excess spray mixture, empty containers, and contaminated cleanup material and clothing.

5.2 Reducing pesticide risk

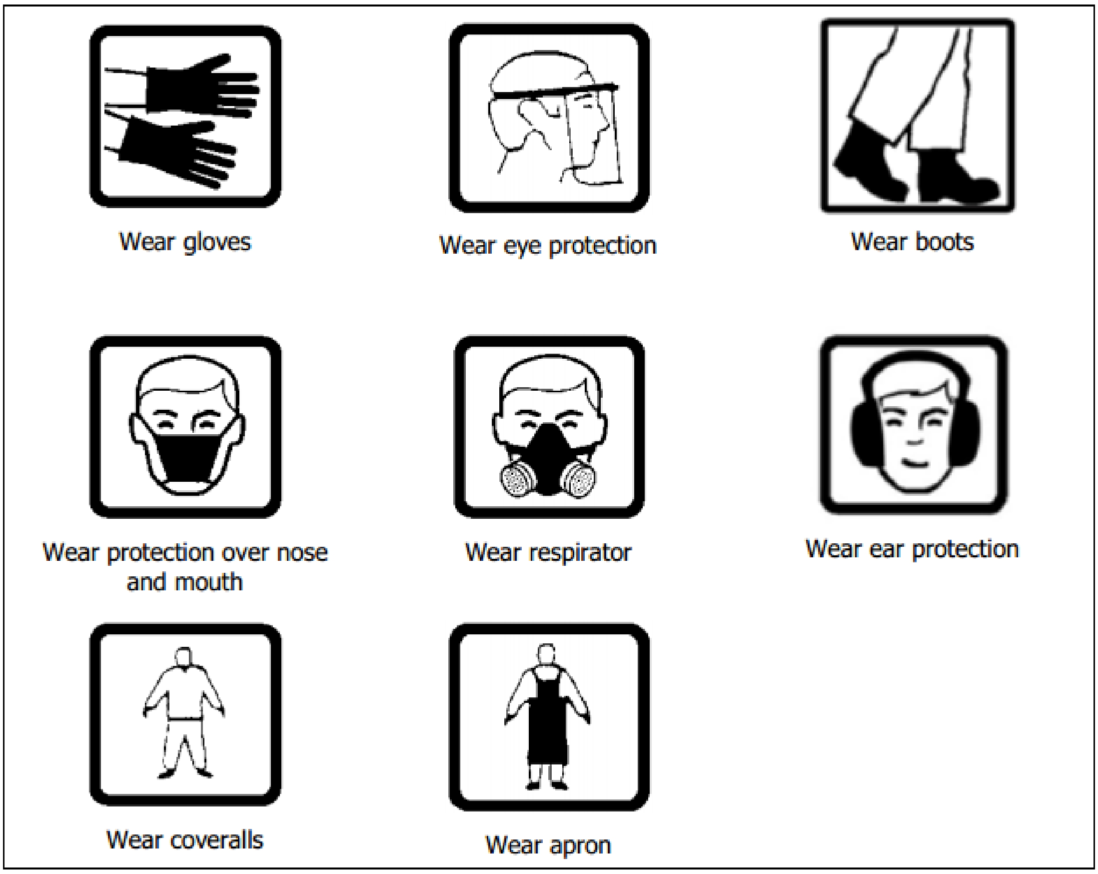
Risk is defined as the product of hazard (i.e., chemical property) and exposure (i.e., intensity and duration). Risk reduction can be achieved by reducing hazard and/or reducing exposure (Walter-Echols, 2007). Hazard can be reduced by selecting less toxic products (when pesticide use is justified), while exposure is reduced by using fewer pesticides (reducing reliance on pesticides in favor 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 spilled over the body part, blurred eyes and one said that he was collapsed while spraying. One farmer said that he had problem with poisoning and had to be operated 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 becomes an advocate for using PPE. In Myanmar, most of the famers 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 A farmer spraying pesticides in the field and getting wet after spraying

Figure 5.3 Examples of common PPE pictograms for pesticide use



Source: FAO and WHO. 2020. Guidelines for personal protection when handling and applying pesticide – International Code of Conduct on Pesticide Management

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:

- Make sure kids, pets, and anyone non-essential to the application is out of the area before mixing and applying pesticides.
- Be sure to wear clothing that will protect you when using pesticides. Consider wearing a long sleeve shirt, long pants, and closed-toe shoes in addition to any other protective clothing or equipment required by the label.
- Mix pesticides outdoors or in well-ventilated areas.
- Mix only what you need to use in the short term to avoid storing or disposing of excess pesticide.
- Be prepared 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.
- After using pesticides, wash your hands before smoking or eating.

5.3 Disposal of pesticides

Pesticides need to be disposed of properly to prevent accidents and to protect the environment. If you have unwanted pesticide products, store them safely and dispose of them as soon as you can.

- 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 neighbor 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 empty pesticide container 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; and
- 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!

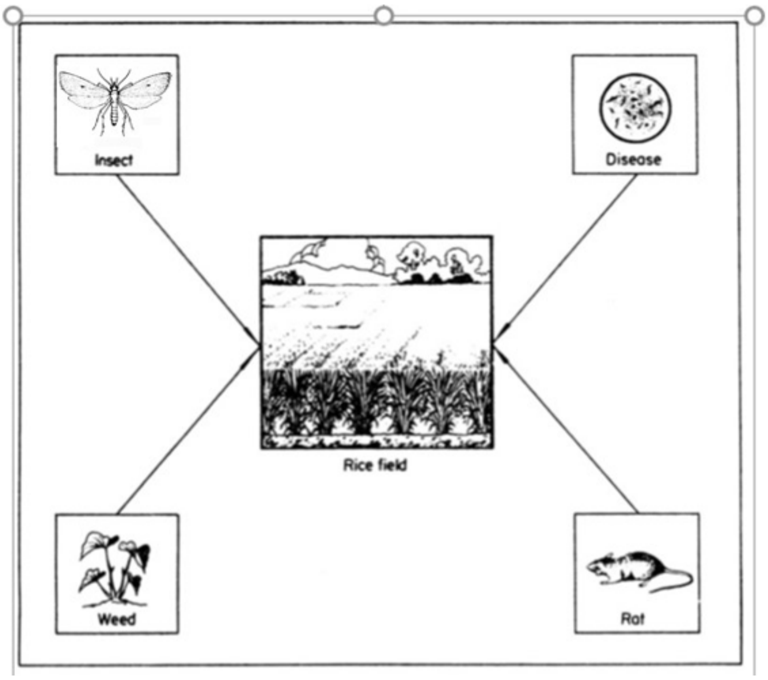
Chapter 6

Integrated pest management

6.1 Introduction

A pest is defined as any species, strain or biotype of plant, animal or pathogenic agent injurious to plants and. plant products, materials or environments and includes vectors of parasites or pathogens of human and animal disease and animals causing public health nuisance (FAO/WHO, 2014).

Figure 6.1 Rice IPM and Pests



Source: Reissig, W. H., Heinrichs, E. A., Litsinger, J. A., Moody, K., Fiedler, L., Mew, T.W., Barrion, A.T. 1986. Illustrated guide to integrated pest management in rice in tropical Asia, International Rice Research Institute, Manila

In phrases such as "integrated pest management" and "pest control", the term pest is used in a broader sense to mean all harmful organisms including 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

There are many definitions of Integrated Pest management (see Bajwa and Kogan, 2002). Initially, it was referred as Integrated Control and defined by FAO in 1967 as:

> "Integrated control is a pest management system that in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economic injury" (FAO, 1967).

In the International Code of Conduct on the Distribution and Use of Pesticides, which was adopted by the FAO Council 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 discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce 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 favourable economic, ecological and sociological consequences. The practice of pest management has been described by Geier (1966) as: (1) determining how the life system of a pest needs to be modified to reduce its number to a tolerable levels, that is, below the economic threshold, (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 economic 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 use of pest-resistant crop varieties, modifying agronomic practices to reduce pest incidence, biological control along with other innovative approaches to pest suppression and need-based judicious use of chemical pesticides.

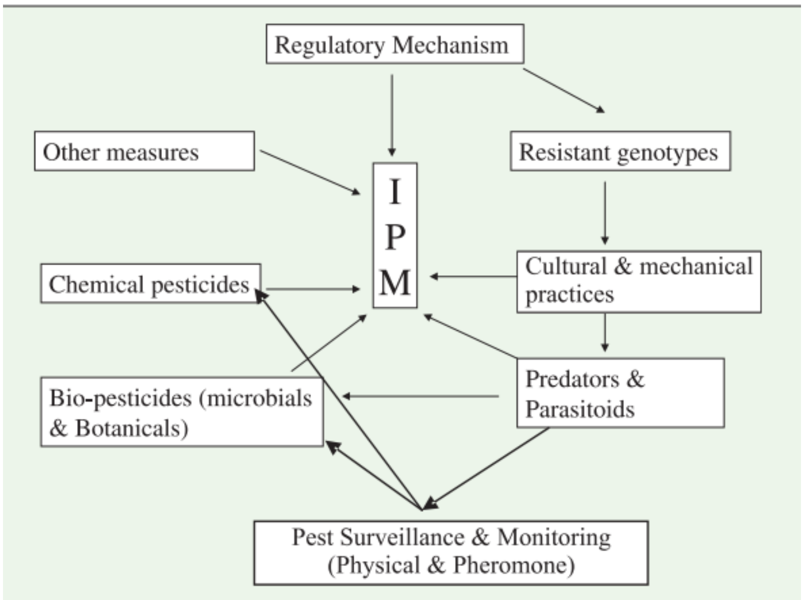
These IPM principles and practices are combined to create IPM programs. While each situation is different, five major components (Stein, 2006) are common to all IPM programs:

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 in a way that minimizes economic, health, and environmental risks with the help of pest scouts. Prakash *et al.,* (2014) explained the components of IPM as in the following figure.

Figure 6.2 Diagrammatic representation of IPM components



Source: Prakash, A., Bentur, J.S. Prasad, M.S., Tanwar, R. K., Sharma, O.P., Bhagat, S., Sehgal, M., Singh, S.P., Singh, M., Chattopadhyay, C., Sushil, S.N., Sinha, A.K., Asre, R., Kapoor, K.S., Satyagopal, K., Jeyakumar. P. 2014. Integrated Pest Management for Rice

IPM is not just a simplified insecticide application program based on the economic threshold concept. It will consider the ecology of 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 host plant, pests and natural enemies. The coevolution of insect and plant, 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 does often try to assist and augment the efficacy of natural enemies by limiting the impact of pesticide on their populations and provide 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 Prakash *et al.* (2014) is worth to mention here.

6.3 Pest monitoring

a. Survey/field scouting

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

1. **Roving survey:** - Undertake roving survey at every 10 km distance at 7–10 days intervals (depending upon pest population). Everyday 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.

Majority of insect population can be monitored by fixing and positioning of pheromones or light traps at appropriate stage of crop. PPD can initiate this action at strategic locations at 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** - 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 for 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. Asynchronous 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.

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.

6.5 Host plant resistance

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

6.6 Chemical control as a component of IPM

Currently rice protection from insect pests solely depends on chemical pesticides which have tremendous impact on biodiversity, environment, animal, and human health. According to the Bangladesh experience, there exists a technique that can reduce 75 percent of insecticide usage in rice field (Ali *et al.,* 2017). They found that predatory insects were higher in numbers in IPM plot than that of insecticide treated fields and they conclude farmers should refrain insecticide applications up to 30–40 days after transplanting to enhance higher predatory arthropod population numbers, which might check pest populations in rice field. Insecticide application should be done based on ETL. Myanmar famers 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 rice pests in Myanmar although some other countries have their own, for example, Bangladesh as mentioned in Table 6.2.

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. In the following seasons, farmers responded to this stem borer outbreak by overusing pesticides, which killed beneficial insects, thereby inviting more problematic ones. In the following 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 in 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 the perception of farmers influenced by the media.

Table 6.2 Economic threshold level (ETL) of rice insect pests in Bangladesh

Sr. No.	Insect pest	Economic threshold level (ETL)
1	Yellow stem borer	01 Adult/Sweep
		10–15 percent Dead heart or 5 percent white head
2	Rice hispa	35 percent Leaf damaged or 4 adults/hill or 05grubs/tiller
3	Leaffolder	25 percent Leaf damaged
4	Grasshoppers	25 percent Leaf damaged
5	Long horned cricket	25 percent Leaf damaged
6	Green leafhopper	01 Hopper/sweep
7	Brown planthopper (BPH)	04 Gravid adults/plant or 10 nymphs/plant
8	White backed planthopper (WBPH)	04 Gravid adults/plant or 10 nymphs/plant
9	Rice gall midge	05 percent Onion shoot
10	Case worm	25 percent Leaf damaged
11	Swarming caterpillar	25 percent Leaf damaged
12	Rice bug	02–03 Bugs/hill
13	Ear-cutting caterpillar	02–05 caterpillars/10m^2 rice field

Source: ***Ali, M.P., Haque, S., Kabir, M., Ahmed, N., Bari, N. & Zaman, M. 2017. Rice Production without Insecticide in Smallholder Farmer's Field. Frontiers in Environmental Science, 5. https://doi.org/10.3389/fenvs.2017.00016***

The threshold level is further divided based on crop growth stage in India as follows:

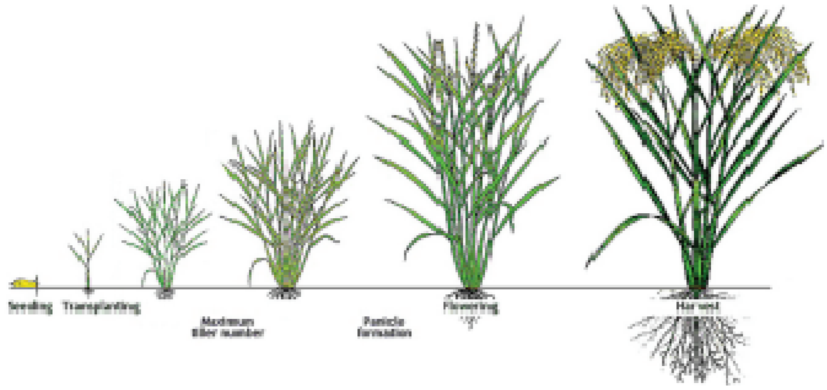
Table 6.3 Economic threshold level (ETL) of major pests of rice crop stage wise

Crop stage	Pest/Disease	Economic Threshold Level (ETLs)
Nursery	Yellow stem borer 1 egg	mass/m^2
	Root-knot nematode	1 nematode/g soil
	BLB: Kresek Phase	2–3 plants/m^2
Early to late tillering	Leaf-folder	2 Fully damaged leaves (FDL) with larva/hill
	Stem borer	2 egg-mass/m2 or 10 percent dead heart or 1 moth/m2 or 25 moths/trap/week
	Gall midge	1 gall/m2 or 10 percent Silver shoot
	Brown planthopper/ WBPH	10–15 hoppers/hill
	Rice hispa	2 adults or 2 dead leaf /hill
	Rice caseworm	2 FDL/hill
	Swarming caterpillar	1 damaged tiller/hill or 2 larvae/ m^2
	Foliar blast	3–5 lesions/leaf
	Brown spot	2–3 spots/leaf & 2–3 infected plants/ m^2
	Sheath blight	Lesions of 5–6 mm in length & 2–3 infected plants/m^2
	Sheath-rot	Lesion length 2–3 mm on sheath & 3–5 infected plants/ m^2
	BLB	2–3 infected leaves/m^2
	Tungro	1 Tungro infected plants/m2 & 2 GLH/hill (in fungus endemic areas)
Panicle initiation to booting	Stem borers	2 egg-mass/m2 or 1 moth/m2 or 25 moths / trap / week
	Leaf-folders	2 FDL/hill
	BPH/WBPH	15–20 hoppers/hill
	Swarming caterpillar/cut worm	1 damaged tiller/hill or 2 larvae/ m^2
	Neck blast	2–5 neck infected plants/m^2
	Sheath-rot	5 infected plants/m^2
Flowering to milky grain	Rice ear bug	2 bugs/hill
	Rice panicle mite	No ETL*

Source: Prakash, A., Bentur, J.S. Prasad, M.S., Tanwar, R. K., Sharma, O.P., Bhagat, S., Sehgal, M., Singh, S.P., Singh, M., Chattopadhyay, C., Sushil, S.N., Sinha, A.K., Asre, R., Kapoor, K.S., Satyagopal, K., Jeyakumar. P. 2014. Integrated Pest Management for Rice

* If mite appeared in previous season, it requires prophylactic control measures in the current season

Bateman (2016) has presented the action thresholds for key pests of rice: with changes during the main stages of crop development based on Mekong delta situation as follows:

Crop stage	vegetative phase: first 40 days	40 days (tillering) to booting	booting to flowering	ripening	** last 14
Key: Pesticide application: Avoid if possible or unlikely to be effective; Do not apply pesticides. **Pest:**					
Plant-hoppers: BPH, WBPH		2–3 insects /tiller if virus diseases are not present on farm (see box 1).			
BPH, GLH & other hoppers: **virus risk**	ONLY in response to warnings from local authorities (agricultural officers) or when symptoms seen in fields				
Leaf-folder and other leaf feeders *		100 living insects per m²	40 living insects per m²		
Stem borers		2 egg masses per m² (see parasitism)	one egg mass per 2 m²	Too late for effective control	
Thrips		**Insecticides mostly ineffective or not economic to control**			
Gall midge					
Panicle rice mite/ sheath rot		**Identify problem** if > 5% flag leaves with lesions (pesticides probably not effective)		Too late for effective control	
Rice blast (with **susceptible varieties**)	Progressive scouting method (in text): increasing signs of lesions on 10% of leaves: 10 leaf samples in 4 sides of the field		Spray max. 2 X for neck blast if disease present and humid	Max. 3 sprays / season	
Bacterial leaf blight		Chemical controls have limited efficacy: only apply at early stage of disease			
Late season pests: especially **rice bugs**			10 insects per m²: at milky stage (7–10d after flowering)		
Herbicides	If direct seeded				
Golden Apple Snails	GAS: 10 /m² if >1 ha				
Rodents	Community strategy at early stage			Not effective	

Source: Bateman, R. 2016. The Role of Pesticides in SE Asian Rice IPM: a View from the Mekong Delta, Outlooks on Pest Management – April 2016, Research Information Ltd. www.pestoutlook.com

Notes: *1. The PPD recommends that insecticide sprays are not normally warranted for the first 40 days after seeding. Numerous tests have shown that 50 percent loss of leaf area (or 'whitening' of leaves with leaf-folder and hispa) causes little crop loss; other defoliators include: cutworms, caseworms, grasshoppers, among others. ** observe the pre-harvest interval (PHI): NO pesticides to be applied within 7 days before harvest: and they are probably unnecessary within the last 14 days.

6.7 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 ton)
I = Crop injury per pest density
D = Damage per unit injury (ton 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 expressed in insect numbers, ETL is, in fact, a time parametre, with pest numbers being used as an index for determining when to implement management strategies. 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 that necessary control measures are initiated at this level to contain the pest population reaching EIL.

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 twenty to twenty five at booting stage can cause yellowing in lower leaves then wilting and death in the susceptible varieties like TN-1 and Karma Mahsuri while the other varieties like Ptb-33 is not affected because of its high level of resistance to BPH under the glasshouse in India (Kushwaha *et al.,* 2016).

(c) Limitations of economic threshold level

- The terms EIL and ETL are themselves misleading because both are defined in terms of population densities, while the former represents an injury level and the latter the right time for implementation of control measures. This limitation may be overcome by defining these levels in terms of injury 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 on the basis of definition by Stern *et al.* (1959).
- Decision levels for management of some types of pest cannot be determined with EILs. Besides medical and veterinary pests, it includes most 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, in spite of these limitations, the EIL and ETL concept offers a practical approach to pest-related decision-making.

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 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. AESA-based IPM is being promoted by FAO.

The AESA approach can be gainfully used by extension functionaries and farmers to analyse field situations with regard to pests, defenders, soil conditions, plant health and climatic factors, and their interrelationship for a healthy crop. A critical field analysis will help in taking 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 on the basis of the AESA, which uses IPM components like release of defenders, application of neem formulations and other safe pesticides for specific pest situations. This exercise can be repeated by extension functionaries 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 on their field. 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 takes only the pest population into account, but farmers have to 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, one being that 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 produce 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 1 hover fly larva".

This is why 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 as well as their economic and social situation.

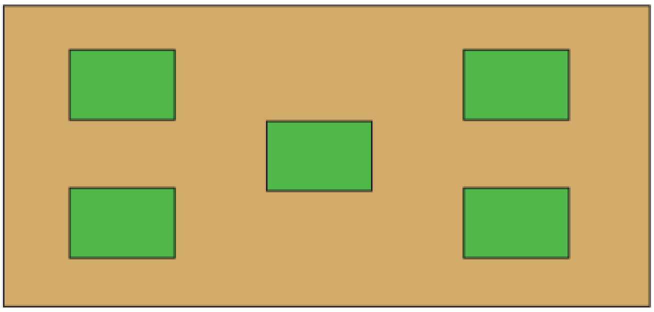
Another important consideration is that good crop management does not only depend on pest control, but even more on the prevention of pests. IPM specialists have realized the limitations of the ETL and gradually developed the AESA as a more flexible tool for crop management decisions.

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' experience.

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 fie 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 (Total 20 hills/field).



Data recording

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

- keep records of what has happened; and
- help us making 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 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).

7.5 Important instructions while taking observations

- While walking in the field, manually collect insects in plastic bags. Use a sweep net to collect additional insects. Collect plant parts with disease symptoms.
- Find a shady place to sit as a group in a small circle for drawing and discussion.
- If needed, kill the insects with some chloroform (if available) on a piece of cotton.
- 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 as 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 on another side.
- Write the number next to each insect. Indicate the plant part where the pests and defenders were found. Try to show the interaction between pests and defenders.
- Each group will discuss the situation and make a crop management recommendation.
- The small groups then join each other and a member of each group will now present their analysis in front of all participants.
- The facilitator will facilitate the discussion by asking guiding questions and makes sure that all participants (also shy or illiterate persons) are actively involved in this process.
- Formulate a common conclusion. The whole group should support the decision on what field management is required in the AESA plot.
- Make sure that the required activities (based on the decision) will be carried out.
- Keep the drawing for comparison purpose 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)

Identifying the number of pests and beneficial insects helps the farmers to make appropriate pest management decisions. Sweep net, visual counts etc. can be adopted to arrive at the numbers of pests and defenders. The P: D ratio can vary depending on the feeding potential of natural enemy as well as the type of pest. 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: Prakash, A., Bentur, J.S. Prasad, M.S., Tanwar, R. K., Sharma, O.P., Bhagat, S., Sehgal, M., Singh, S.P., Singh, M., Chattopadhyay, C., Sushil, S.N., Sinha, A.K., Asre, R., Kapoor, K.S., Satyagopal, K., Jeyakumar. P. 2014. Integrated Pest Management for Rice.

7.8 Ecologically sustainable strategies for pest management

IPM strategies are different for each crop, for a country, for a region, even for one location, depending on local varieties used, local agronomic practices and various crop protection options available. IPM can never be delivered in a "package"; it needs to be developed, adapted and tailor-made to fit local requirements. Designing and practicing effective IPM systems is about learning and continuously finding solutions to changing field situations and problems.

The best control for pests and disease problems is prevention. 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 they will create field conditions that favor 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, associations, and cultural practices that minimize the pressure and maximize biological prevention of pests and diseases.
- Maintain regular and quantitative assessment of the balance status between pest and disease and beneficial organisms of all crops.
- Apply pest and disease forecasting techniques where available.
- Understand and use non-chemical pest and disease management practices.
- Decide on interventions following consideration of all possible methods and their short- and long-term effects on farm productivity and environmental implications in order to minimize the use of agrochemicals, in particular promote integrated pest management (IPM).
- Store and use agrochemicals according to legal requirements, e.g. registration for individual crops, rates, timings, and pre-harvest intervals.
- Assure that agrochemicals are only applied by specially trained knowledgeable persons.
- Assure that equipment used for the handling and application of agrochemicals complies with established safety and maintenance standards.
- Maintain accurate records of agrochemical use.
- Avoid any point source pollution from agrochemicals resulting from use, storage, cleaning and disposal of products or application equipment.
- Avoid impact on non-target areas of any pest and disease management activity.

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 1 401 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 use against caterpillars.
- The fungus *Beauveria bassiana* for use 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 *Bacillus thuringiensis* as an insecticide and *Trichoderma harzianum* against root pathogens. In Myanmar, Trichoderma is used for the prevention and control of 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.

Tichoderma was tested for the control of sesame black stem, chilli wilt, root rot and rice sheath blight. It can reduce the death rate of plant by 25 percent for chilli wilt, 30 percent for sesame black 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 popularization of biopesticides is very slow as compared to chemicals and only two percent biopesticides are available in India.

Among them, *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. are also known to suppress plant parasitic nematodes (root-knot nematodes).
- lower cost and longer efficacy than fungicides
- does not lead to development of resistance in plant pathogens
- no phytotoxic 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** that are derived from plants and minerals, that have naturally occurring defensive properties. Also, they have proven to be more useful 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 all over the world from synthetic pesticides to non-synthetic ones and this is large because of the widespread awareness of the side effects of these synthetic pesticides not only on plants but also on other living organisms. However, the commercialization of new botanical insecticides can be hindered by a number of issues as pointed out by Isman (1997). The principal barriers to commercialization of new botanicals are (i) scarcity of the natural resource; (ii) standardization and quality control; and (iii) registration.

In Myanmar, neem trees, *Azadirachta indica* are naturally grown mostly in upper Myanmar. The insecticide, neem oil is commercially produced from Paleik factory in Mandalay region. The seeds are commonly available in summer time. There is a good chance to make neem seed kernel extract for the control of insect pests. Neem insecticide is reported to be effective to control beetle larvae, butterfly and moth caterpillars, stalk borers, true bugs, plant and leaf-hoppers, adult beetles, thrips, fruit flies, scale insects, mealy bugs etc.

Process of neem seed kernel extract from neem seeds

Neem seed kernel extract is prepared from dried neem seeds. 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. Make sure the neem fruits are yellow (not greenish-yellow or yellowish-green) before harvesting. Put a plastic sheet under the neem tree and beat the branches with a stick. Collect the fallen fruit from the plastic sheet. Throw away bad or moldy ones. Remove the pulp of the fruit by twisting the Neem fruit between thumb and index finger. The seeds must be milky white. Dry them upside down on a mat or sheet in the shade for 2 or 3 days. They must not be exposed to rain or direct sunlight. Store the seeds in well-aerated baskets or gunnysacks (not in plastic bags) they must be kept dry. The seeds used to make the kernel extract should be between 3 to 7 months old.

Making neem insecticide (TNAU, 2014)

For preparation of 100 litres of 5 percent NSKE solution, following material are 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 required quantity of neem seed kernel (5 kg);
2. grind the kernels gently to powder it;
3. soak it overnight in ten litres of water;
4. stir with wooden plank in the morning till solution becomes milky white;
5. filter through double layer of muslin cloth and make the volume to 100 litres;
6. add 1 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.

Things to be taken care

- Collect the Neem fruits during 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 hence 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 kernel is sufficient. If the seeds are old, 5 kg are required.
- Pound the kernel gently and tie it loosely with a cotton cloth. Soak this overnight in a vessel containing ten 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 discouraging 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 10 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 fairly 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, make sure that they are properly dried and are stored in an airy container (never use plastic container), away from direct sunlight and moisture. Make sure that they are with homemade free from molds before using them.
3. Do not use cooking and drinking utensils for the extract preparation. Clean properly all the utensils every time after using them.
4. Do not have a 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 becomes more and more popular due to its safety, species specific and long-term action on the target pests. Unlike chemical method, which kills non target species, cause detrimental health effects to human beings and pollute 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 predator, parasites and parasitoid 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 required 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 filed. 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 prey are required for the development of each predator.

8.2.1 Spiders

The most important predator in rice fields is the wolf spider *Pardosa pseudoannulata* (Boes. and Str.) of the family Lycosidae. Recognize the adult male by the large black pedipalps near the mouth, and the female by the egg sac it carries. *P. pseudoannulata* does not spin webs; it hunts its prey in the rice fields. It is often found near the base of the rice plants. It attacks many kinds of rice insect pests, especially hoppers and moths.

Atypena formosana (Oi.) - The smallest of all rice field spiders. It has a strong preference for young instar nymphs of hoppers. It can kill at least fifty second instar nymphs of green leafhoppers per day. *Atypena* belongs to the family Linyphiidae commonly known as dwarf spiders.

Figure 8.1 *Pardosa pseudoannulata* and *Oxyopes javanus*

Oxyopes javanus (Thorell) - common name lynx spider, is a member of the family Oxyopidae. It is an excellent hunter of immature and adult rice insect pests because of its hexagonal eye pattern. An adult consumes two to three leaf folder moths per day.

Tetragnatha virescens (Okuma) *and* ***Tetragnatha javana*** (Thorell) –

Six *Tetragnatha* species are common in rice fields. All are web builders belonging to the family Tetragnathidae. Of these, *T. virescens* Okuma and *T. javana* (Thorell) are the most common during the early vegetative growth stage of the rice plant.

Figure 8.2 *Atypena formosana* and *Tetragnatha virescens*

8.2.2 Green lace wing: *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 potential to feed 12 aphids per day on average or about 120 aphids during the entire developmental period.

Figure 8.3 Green lace wing: *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 8.4 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 for the suppression of *A. craccivora* on groundnut.

Figure 8.5 Ladybird beetle: *Cheilomenes sexmaculata* (egg, larva, pupa and adult)

8.2.4 Ground beetle

Ophionea nigrofasciata, the insect is always found within the folded leaf made by the leaffolder larvae. It can prey on 3 to 5 larvae per day. It also feeds on planthoppers. O. nigrofasciata is common in both wetland rice bunds and dryland fields where it also pupates.

Figure 8.6 Ground beetle *Ophionea nigrofasciata* adult

8.3 Some predator found in the paddy fields of Myanmar

Figure 8.7 Spiders – Wolf spider and Long jawed orb weaver

Figure 8.8 Spiders *Atypena formosana* and assassin bug

Figure 8.9 Egg mass of spider and newly hatched spiderlings

Figure 8.10 Ladybird beetle adult and grub

Figure 8.11 Cannibalism in dragon flies

8.4 Parasitoids

A parasitoid is an organism that has young that develop on or within another organism (the host), eventually killing it. Parasitoids have characteristics of the predator and parasites. Most insect parasitoids only attack a particular life stage of one or several related species. The immature parasitoid develops on or within a pest, feeding on body fluids and organs, eventually leaving the host to pupate or emerging as an adult. The life cycle of the pest and parasitoid can coincide, or that of the pest may be altered by the parasitoid to accommodate its development.

The life cycle and reproductive habits of beneficial parasitoids can be complex. In some species, only one parasitoid will develop in or on each pest while, in others, hundreds of young larvae may develop within the pest host. Overwintering habits may also vary. Female parasitoids may also kill many pests by direct feeding on the pest eggs and immatures (Hoffmann and Frodsham, 1993).

Major characteristics of insect parasitoids

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

Figure 8.12 Parasitoids – *Apanteles* sp. and unknown sp

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 starts 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 are glued that harbor the wasps at a stage close to emergence. A 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 do not leave any residues in food;
- helps protecting other natural enemies in the fields, ecosystem balance and the environment;
- does not pose any thread 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.

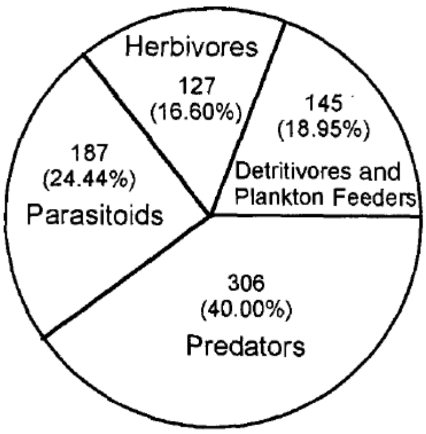
Figure 8.13 An adult of *Trichogramma* sp. (egg parasiotoid)

Figure 8.14 An official from DAR educating farmers how to use *Trichogramma* parasitoids in paddy field

8.5 The role of predators and parasitoids in 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 plankton-feeding insects, whose populations consistently peak and decline in the first third of the season.

Figure 8.15 Number of species and (percentage) recorded in lowland irrigated rice in Indonesia



Source: Settle, W.H., Ariawan, H., Astuti, E.T., Cayhana, W., Hakim, A.L., Hindayana, D., Lestari, A.S., Pajarningsih, S. 1996. Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. Ecology 77(7): 1975-1988.

8.6 Feeding/egg laying potential of different parasitoids/predators

Predators/Parasitoids	Feeding potential/ Egg laying capacity
Lady bird beetle	One adult lady bird beetle eats 50 aphids per day 1st & 2nd nymphal instars can consume 1 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
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 whitefl 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	Predatory rate of 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 field.
- Natural biocontrol agents such as spiders, dryinids, water bugs, mirid bugs, damsel flies, dragonflies, meadow grasshoppers, staphylinid beetles, carabids, coccinellids, *Apanteles, Tetrastichus, Telenomus, Trichogramma, Bracon, Platygaster* etc. should be conserved.
- Collection of egg masses of borers and putting them in a bamboo cage-cum-percher till flowering which will permit the escape of egg parasites and trap and kill the hatching larvae. Besides, these would allow 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 of flowering weeds like marigold, sun hemp increases beneficial natural enemy population and also reduces the incidence of root knot nematodes. Provide refuge like straw bundles having charged with spiders to help in buildup spider population and to 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 host for pests and diseases, (c) reducing crop yield and quality.

9.2 Weed classification

Weeds can be classified as annual weed (e.g., barnyard grass, Echinochloa) biennial weed (e.g. wild carrot) and perennial weed (e.g., nut sedge) according to their life span.

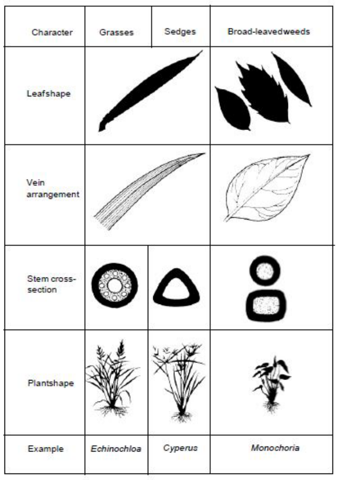
According to their morphological features, weeds are classified as follows:

(a). Grasses: Their leaves are narrow with parallel venation. They possess fibrous root system. Stems or culms are round. The leaf comprises of 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., pickerel weed, Monochloria).

Figure 9.1 Weed classification (left) and (right)



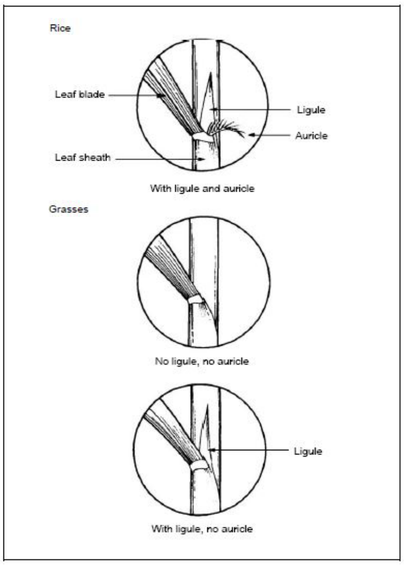
Grass

Sedge

Differences between rice and grasses

It is difficult to distinguish weeds and rice plants at seedling stage as the morphological characters of leaves are quite similar. However, they can be distinguished by looking at the ligule area. The top one is rice where the ligule and auricle can be seen clearly. There is no ligule in barnyard grass, *Echinochloa crus-galli* (the middle one). The ligule is seen but there is no auricle in red sprangletop, *Leptochloa chinensis* (the bottom).

Figure 9.2 The difference between a young rice plant and weed (left) and (right)



Rice with ligule and auricle

Weed no ligule and no auricle

9.3 The dirty dozen in the rice fields of Asia

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

Sedges are troublesome and farmers apply post-emergence herbicides such as "Nominee Gold" (Bispyribac-sodium 10 percent w/v) and "Complete" (Bispyribac-Sodium ten percent WP). Farmers perceive that yield loss caused by this weed is at 50 percent (MOALI, 2018).

Figure 9.3 *Cyperus iria* and *Cyperus difformis*

Figure 9.4 *Echinochloa colona* and *Echnichloa crus-galli*

Figure 9.5 ***Eclipta prostrata*** **and** ***Fimbristilis miliacea***

Figure 9.6 ***Ischaemum rugosum*** **and** ***Leptoochloa chinensis***

Figure 9.7 ***Ludwigia hyssopifolia*** **and** ***Scirpus grossus***

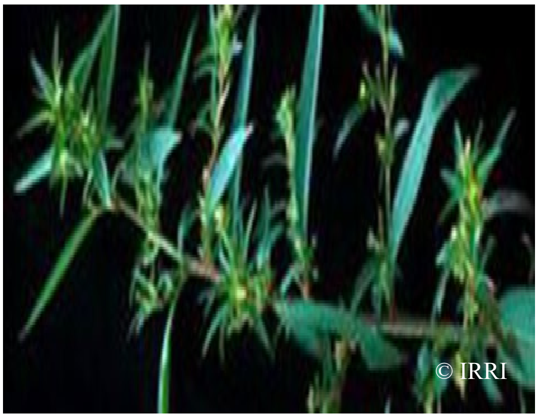
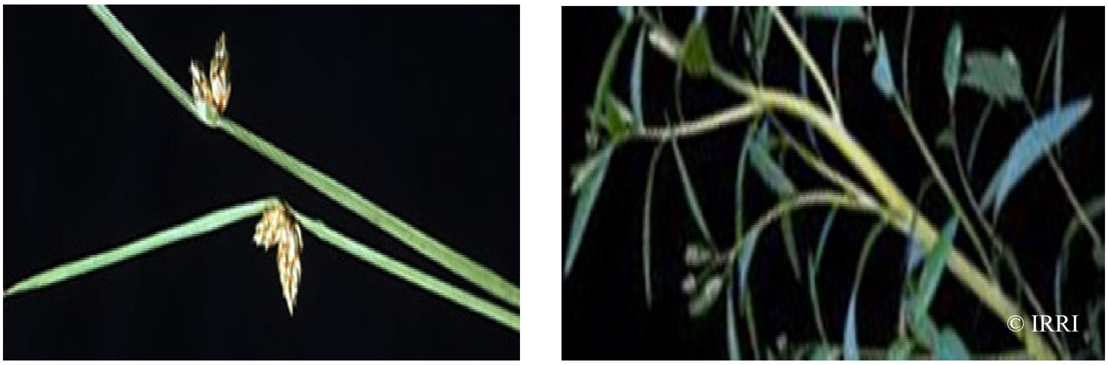


Figure 9.8 ***Schoeoplectus juncoides*** **and** ***Spheoclea zeylanica***



9.4 Some weeds found in rice fields of Myanmar

Figure 9.9 Wild rice and ***Echinochloa colona***

Figure 9.10 ***Cyperus difformis*** **and** ***Cyperus iria***

Figure 9.11 ***Fimbristilis miliacea*** **and** ***Scirpus grossus***

Figure 9.12 Leptoochloa chinensis and Schoeoplectus juncoides

Figure 9.13 ***Echnichloa crus-galli*** **and** ***Cleome viscose***

9.5 Reproduction and dispersal

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

Sexual reproduction requires pollination of flowers and subsequently formation of seeds. Most of the annual weeds flowering start as early as five weeks after sowing. This coincides with maximum tillering period. Then the duration of 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, 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 digestive tract;
(c) wind;
(d) irrigation water;
(e) manure from weed-infested area; and
(f) transport the use of farm implements.

9.6 Crop-weed competition

Weeds compete with crop in many cases such as, competition for light, water and nutrient. The most serious damage by weeds is reduction in yield. This is due to interference in the acquisition of 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 may 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 weed 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 weeding at 30 and 60 DAE would prevent unacceptable yield losses from weeds in chickpea. The critical period of weed control for some crops are 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. 1972. The influence of crop-weed competition. Indian J. Weed Sci., 4 (2) (1972), pp. 120-123; Duary, B. & Hazra, D. 2013. Determination of critical period of crop-weed competition in sesame. , 45: 253–256.

9.7 Methods of weed control

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

We control methods are listed below.

(a) Hand pulling:

- pulling weeds by hand is a manual method of control; and
- hand pulling takes a lot of time.

(b) 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 under water.

(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, timely operation is beyond the capacity of a famer only possible when weather conditions are favorable.

(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.

9.8 Classification of herbicides

(i) Based on formulation

Herbicides are formulated according to their solubility and the manner in which they are applied. The formulation can have an effect on 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 application.

(ii) Based on 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 to place the chemical in the zone where needed.
- Preemergence - application to the soil surface before emergence of the crop or the weeds. (e.g., butachlor).
- Post emergence - Any treatment made after emergence of a particular crop or weeds. (e.g., 2, 4-D). Time of application is very important 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 moist condition. For upland crops, spraying in the dust is 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 site of application.
- *Translocated (systemic) herbicides* - capable of movement inside the plant and kill the whole plant. (e.g., Glyphosate and 2, 4-D)

9.9 Integrated weed control

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

The weed common in transplanted rice (*Monochoria vaginalis, Echinochloa crus-galli, Cyperus iria, and Scripus maritimus*) are in general highly competitive. They have discontinuous germination and rapid growth and are adapted to aquatic conditions. Weeds grow and infest an irrigated field if optimum water depth is not maintained. In poorly flooded rice fields, most semi-aquatic lowland rice weeds can germinate and survive.

Lowland weeds such as *Echinochloa crus-galli, Ischaemum rugosum, Leptochloa chinensis, Cyperus difformis, Fimbristylis miliaceae, and Scripus maritimus* are adapted to the wet conditions of direct seeded flooded rice.

Weeds in rice seedling nurseries can cause the complete failure of the nursery. Propanil, thiobencarb, butachlor, quinclorac, bensulfuron, pretilachlor+ fenclorim, and pendimethalin give good weed control in rice seedling nurseries.

The yield losses due to weeds ranged from 2 to 46 percent in transplanted rice and 3 to 62 percent in direct seeded rice (wet method). The yield losses may vary with cropping season. It was 32 percent in summer rice and 17 percent in monsoon rice. The yield losses may also vary with rice cultivars/varieties, for example, 14 percent in Sinnweyin and 35 percent in Manawthukhs in summer rice. Rice cultivars differ in life duration, plant vigour, plant type, plant height, tillering power and leaf position so that their ability to compete with weeds from one cultivar to another. Yield losses in Manawthukha ranged between 5 and 48 5 (31 percent in average), in Sinthukha from 9 to 19 percent (14 percent in average) and in Theehtutyin 13 to 31 percent (22 percent in average) (DAR, 2019).

Weed control is important to prevent losses in yield and production costs, and to 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 next cultivation. In addition, a level field helps retain a constant water level that controls weeds.

Hand weeding - The first six weeks after transplanting is the critical time of 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 seedling at such an early stage. Two or three timely weeding will provide adequate weed control. Hand weeding requires about 120 labor-hours ha^{-1}.

Herbicides - Rice herbicides show maximum selectivity in transplanted rice because of differences in growth between rice seedlings transplanted at the 3-to-6 leaf stage and the germinating weed. Hand weeding is difficult in direct seeded flooded rice, chemical weed control combined with other cultural practices (such as water control) is an alternated that may be practiced to reduce weed competition, crop losses, and labour costs. Several herbicides and herbicide combinations can be used in transplanted rice. Some important rice herbicides and their times of application in irrigated transplanted rice are given in Table below.

Table 9.2 Herbicides for general use

1	Glyphosate	Annual grass, Sedge and Broadleaf weed	Pre-plant application for existing weed on all crop 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 crop and inter-row application. (Remark-Do not contact green parts of plants.)

Table 9.3 Herbicides recommended to control weeds in rice by PPD, Myanmar

Sr	Herbicide	Weed	Remark
1	Cyhalofop-butyl	Annual grass, Perennial grass	
2	Fenoxaprop-p-ethyl	Annual grass, Perennial grass	
3	Bensulfuron-methyl	Broadleaf and Sedge	Apply at 6-8 DAS /3-5 DAT
4	Bispyribac sodium	Grass, Sedge and Broadleaf weed	
5	Metsulfuron-methyl	Sedge and Broadleaf weed	

6	Ethoxysulfuron	Sedge and Broadleaf weed	
7	Pyrazosulfuron-ethyl	Sedge and Broadleaf weed	
8	Pendimethalin	Annual grass, Sedge and Broadleaf weed	Up to 6 DAS/ 4 DAT
9	2,4-D	Sedge and Broadleaf weed	Apply 3-4 weeks after seeding
10	Propanil	Annual grass, Sedge and Broadleaf weed	Apply post emergence at the 2 to 5 leaf stages. Drain flooded fields 24 hr before application and reflood 3-5 days after treatment.
11	Oxyfluorfen	Annual grass, Sedge and Broadleaf weed	
12	Oxadiazon	Annual grass, Sedge and Broadleaf weed	Apply at 6DAS
13	Quinclorac	Annual grass, Sedge and Broadleaf weed	Direct seeded rice at 6–8 DAS/ transplanted rice at 3–5 DAT
14	Butachlor	Annual grass, sedge and certain broadleaf weed	Direct seeded rice at 6 DAS and remain nonflooded for 3 days after application. / Transplanted rice at 3–6 DAT.
15	Pretilachlor	Annual grass, sedge and broadleaf weed	Direct seeded rice at 3 DAS/ transplanting rice
16	Thiobencarb	Grass and sedges	Apply about 6 DAS, when grasses have 1–2 leaves but before the 3 leaf stage of grasses and sedges.

9.10 Problems with herbicide application

As smallholder farmers have little knowledge about herbicides, they encountered a number of problems when applying herbicides. Most of the 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 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 provide good effect on 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 1970's 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 the use of spraying equipment have advantages for the small farmer and have become established practice in many areas.

One thing to bear in mind is the fact that frequent use may create resistant problem as experienced in the United States of America. For example, 30 years of propanil use resulted in resistant *Echinochloa* sp., and 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 herbicide are often not used at appropriate times or dosages, which may hasten the development of resistance (Johnson, 1996)

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

Since farmers generally use the most effective and the least expensive herbicide, resistance involves cost increases (Orson, 1999; Preston *et al.,* 2006). Thus, prevention is seen as an obligatory measure to if one wishes to have the best control strategy for a longer period of time.

Resistance prevention requires adopting an integrated weed management approach, since no single control strategy can effectively and sustainably eliminate resistant weeds (Storrie, 2006).

Chapter 10

Rodent management

10.1 Introduction

Rodents are mammals belong to the order Rodentia which consist of 2 277 (about 42 percent) of the 5 419 mammalian species. They are characterised by two continuously-growing incisors in the upper and lower jaws which must be kept short by gnawing hard objects. With their sharp incisors, they use 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 rodent 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 at 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 in an effort 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 agriculture 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 attacks stored grain. There are about 8-9 offspring per delivery. They peak breeding season is from booting stage to ripening stage in rice crop (Nyo Me Htwe, 2013).

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 the mud walls of huts, and in backyards and gardens. It also consumes soil invertebrates like earthworm and insects.

Figure 10.2 Larger bandicoot

10.2.3 Roof rats (*Rattus rattus*) are small sized with a body weight of 80-120 g. Their bicoloured and ringed tail is longer than the combined length of the head and body. Living in 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 traveling range. Other rodent species such as *Bandicota savilei*, *Mus musculatus* and *Mus cerivcolor* 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 in close association 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 5 weeks can breed. 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 usually consist of 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 5 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 (Singleton, 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).

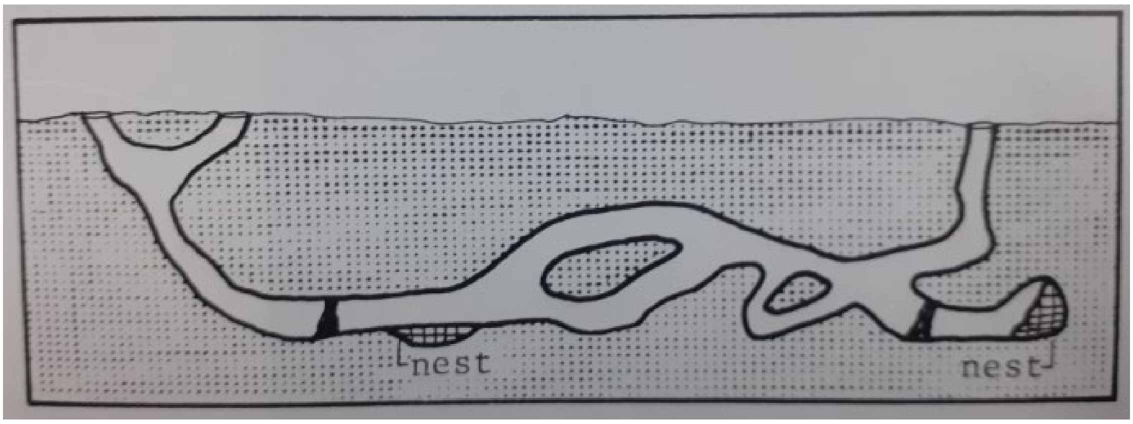
According to the survey of 350 farmers from ten villages in Mandalay, Bago and Yangon Divisions between 2003 and 2005, farmers believed that rodents were one of the main pests causing the most damage in their crops, monsoon rice, summer rice and mung bean (Brown *et al.,* 2008). Recent survey in 2018 also showed that they cause significant damage to ground nut pods in the field. Apart from that, they are minor problem with rice production. Farmers in Yinmabin township said that rodents are a minimal problem especially at panicle initiation to grain filling stage. However, some outbreaks occur in some part of Myanmar.

In cereal crops, growth compensation has two components- tiller growth and panicle filling. Any tiller that is cut through by a rodent is likely to regrow. If this occurs before 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 maximum tillering stage, the number of panicles will be less than that of non-affected hill but the size of panicle 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 litters. The latter is used as emergency-exit but is often closed during the breeding period. Depending on the size of available location, the number of tunnels per nesting site increases during the season. At the peak of this period, 2 nests with different age of litters can be found. This height of breeding activities is closely associated with the reproductive phase of the crop. In single-cropped areas there is only one breeding cycle but if double-cropping is practiced 2 breeding cycles are common. The number of offspring ranges from 3–17 but often averages around 9 individuals (van Vreden and Ahmad, 1986).

Singleton (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 begin breeding before panicle initiation and stop when the crop ripens. If crops are planted more than two weeks apart then the rats will move to the late-planted crops and continue breeding. The rice field rat has an equivalent number of breeding-season with the number of rice planting season per year. That means one crop, one breeding season and two crops, two breeding seasons and so on.

Figure 10.4 Cross-section of nesting site of *Rattus argentiventer*



Source: Lam, Y.M. 1978. The rice field rat. Rice Research Branch, Malaaysian Argicultural Research and Development Institute, Information paper 2. 37p.

Figure 10.5 Rat burrows on the bund of a field 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 a next crop unless a neighbouring farmer plants 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 (Singleton, 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 around 15 percent of their body weight, i.e. a mouse weighing 25 g will eat 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 extremely difficult 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 a large number of 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 absolutely 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 1 m around the stack!
- Store any empty or old bags and fumigation sheets on pallets, and if possible, in 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 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 case, control measures in 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 strategy 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, has 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 natural check to rat population growth as rat breeding is linked with the growth phases of the rice crop.
   - Protect seedlings in the nursery by surrounding the seed bed 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 (Singleton, 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 - among anticoagulants, single dose of anticoagulants (bromadiolone, brodifacoum and flocoumafen) are more effective than multidose anticoagulants and are widely used.

   3. Bait preparation**:** To prepare 500 g solid bait, take 450 g (four tea cups) 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 brokens + 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 agrochemical 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).

The second-generation rodenticide such as Brodifacoum and bromadiolone were 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 for using only in closed environment, not allowed to use open environment.

The Shan State government has provided villages with hundreds of non-venomous snakes in an effort 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 labored 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 aluminum phosphide –2 pellets per burrow.
Day 14	Eliminate residual population by trapping or burrow fumigation in the case of bromadiolone 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. Soil Fertility and Fertilizer Management Strategy for Myanmar, International Fertilizer Development Center, Alabama, USA

11.2 Biofertilizers in Myanmar

During the past decade, the fertilizer market in Myanmar has grown 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 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

Crops	Sown Area	Yield	Produc-tion	Nutrient Removed by Harvest (t)			Total Nutrient Removed by Harvest plus Straw (t)		
	('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: IFDC. 2018. Soil Fertility and Fertilizer Management Strategy for Myanmar, International Fertilizer Development Center, Alabama, USA

"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 which, when applied to seed, plant surfaces (leaves), roots or soil, colonize the rhizosphere 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 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 to 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 mung bean 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 were 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 filed. 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, 8133847 packages of rhizobium fertilizer had been distributed to the farmers. In some year, the demand was as high as 250 000 packages.

The benefit of rhizobium fertilizer

1. Nitrogen needed for legume crop can be supplied with low cost.
2. Nitrogen removed from the soil by the crop can be replaced.
3. Following crop after legume can get 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. 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 super phosphate and 28–56 lb of muriate of potash as basal per acre, nodulation can be enhanced to increase yield of the crop.

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

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).

11.4 Compost preparation and use

Organic materials as fertilizer: A mixture of all kind of organic wastes such as agri-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 nutrient.

- 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 nutrient for long time;
- cost-effective; and
- environment friendly.

Composting

- Composting allows a mixture of organic materials to decompose under more or less 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. seven days after heap preparation, insert a stick to check the moisture inside (watery condition);
  d. if 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 plastic sheet;
- turn the pile upside down when it has cooled down (1st turning – after 1 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 be go down gradually.

c. One should practice turning it over, that is turning the outer portion over to inside and inner portion to 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
  - 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 soil surface;
c. base of the hole should be pressed too 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 a number of crops on the same piece of land during the given period of time 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 as (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 as 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*.

12.2 Intercropping

Principles of Intercropping

- The associating crop should be complimentary to the main crop.
- The subsidiary crop should be of shorter duration and of faster growing habits, to utilize early slow growing period of 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, machine and

power throughout the year.
• It is an insurance against drought.

12.3 Crop rotation

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 of time with an object to get maximum profit from minimum investment without impairing the soil fertility.

Principles and Advantages

If the same crop is repeatedly grown on the same land it is referred 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 in maintaining of 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, the fertility of land is utilized more evenly and effectively.
• Restorative crops like heavy foliage crops and green manure crops included in rotation increase the nitrogen and organic matter content of the soil.
• Helps in control of specific weeds like Bermuda grass, Cyperus (sedges) and *Trianthema portulacastrum.*
• Avoids accumulation of toxins and maintains physical properties of soil.
• Controls certain soil borne pests and disease.
• Reduces the pressure of work due to different farm operations in a stipulated period of time.

12.4 Cropping pattern in some project areas

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

(a) In lowland area
- 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 mid-land area
- Broadcasted paddy systems in monsoon season;
- Direct seeded paddy;
- Intercrop between pigeon pea and groundnut; and
- 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; and
   - Winter wheat, chickpea, sesame and groundnut.

Tatkon township

According to MOALI (2018) survey, in Tatkon township under the Sinthe Irrigation Scheme), farmers practiced the rice –based cropping system was practiced 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 farmer practiced double cropping patterns such as monsoon paddy-summer paddy, monsoon paddy-winter seed corn, monsoon paddy – winter groundnut and monsoon paddy-winter mung bean.

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 chick pea as 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 in May to August followed by monsoon rice, then followed by green gram. In the rainfed areas, farmers plant green gram or sesame in April to July then monsoon rice (medium or late maturing variety) in August to December.

In Yinmarpin township, the cropping patterns were; (1) monsoon paddy rice from June to October followed by chick pea as second crop grown from November to December and (2) 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.

12.5 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 the use of cultural techniques to effect habitat manipulation and to enhance biological control. The cultural practices are informed by ecological knowledge rather than on 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 and is characterized by being based more comprehensively on ecological theory and by being developed via rigorous experimentation. The process of development 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 society with its natural environment for the benefit of both, has developed over the last 30 years, and rapidly over the last ten 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 amplification of nature's ecosystem services is needed even more (Mitsch, 2012).

The concept was introduced in rice farming in China in 2008, and later on in Vietnam and Thailand. More recently, the Philippines also launched a project. 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 of the 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 for instance – then 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; and
- alternate hosts when primary hosts are not present.

Ecological engineering for pest management – Above ground

- Raise the flowering plants / compatible cash crops along the orchard border by arranging shorter plants towards 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 those are growing naturally like *Tridax procumbens*, *Ageratum* sp., *Alternanthera* sp., etc. which act as nectar source for natural enemies.
- Not to apply broad spectrum chemical pesticides, when the P: D ratio is favourable. The plant compensation ability should also be considered before applying chemical pesticides.

Ecological engineering for pest management – Below ground

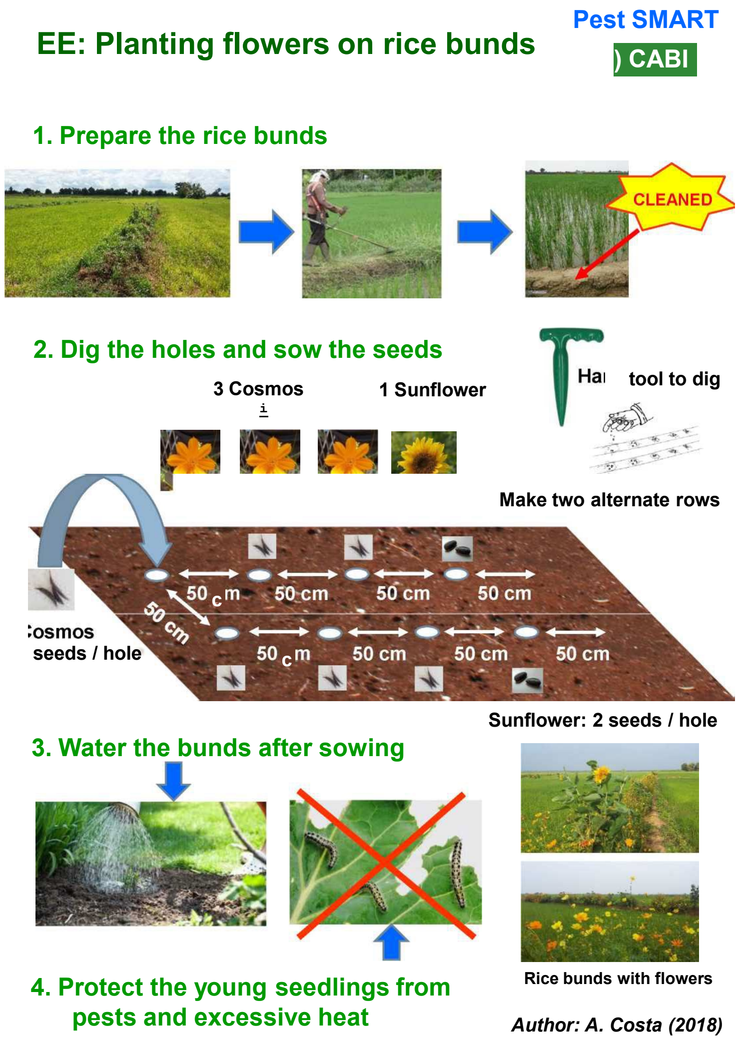
- Keep soils covered year-round with living vegetation and/or crop residue.
- Add organic matter in the form of farm yard manure (FYM), Vermicompost, crop residue which enhance below ground biodiversity.
- Reduce tillage intensity so that hibernating natural enemies can be saved.

- Apply balanced dose of nutrients using biofertilizers.
- Apply mycorrhiza and plant growth promoting rhizobacteria (PGPR).
- 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 enhancement of biodiversity by the flowering plants, parasitoids and predators (natural enemies) number also will increase due to availability of nectar, pollen, fruits, insects, etc. The major predators are a wide variety of spiders, ladybird beetles, long horned grasshoppers, Chrysoperla, earwigs, etc.

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

Cosmos and sunflower were sown on the bund in Vietnam (Costa, 2018).



Source: Costa, A. 2018. Developing pest-smart farmers in Cambodia, Climate Change, Agriculture and Food Security

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 knock down 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 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 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 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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Nay Pi Taw, Myanmar

ISBN 978-92-5-136689-9

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CC1163EN/1/08.22