X crop revenue are not linear. When pests are attacking the actual crop product very low populations could only be tolerated. However, if vegetative parts are attacked and if the plant or variety has adequate capacity or in a suitable growth stage to compensate the damage, then very dense populations could be tolerated. ii. When a number of pest species attack a crop, it is difficult to estimate the effects of combined populations. iii. The ET levels vary according to the crop variety. iv. Economic thresholds change at different stages of crop development at different seasons. Heavy tillering varieties of rice can tolerate during early stages moderate levels of stem borer. v. The control action thersholds are also substantially influenced by marketing standards and market prices. vi. ET levels also vary depending on whether the crop had been previously treated with an insecticide or not. Because of elimination of natural enemies in related fields the ET level would be less than in the untreated. vii. ET levels have to be constantly reviewed and changed considering new varieties, new marketing standards and systems, new pests, new insecticides, etc.

CP176

PRINCIPLES AND METHODS OF PEST MANAGEMENT IN PULSES

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Pulses are subjected to severe depredations by several pest species, resulting in losses which may range from moderate to very heavy. In India, pulses are attacked by pests which may fall into five major categories : (a) flower and pod feeders, (b) stem/leaf tissue borers, (c) defoliators, (d) sap feeders, and (e) subterranean pests. In this presentation, I prefer to concentrate upon the pest problems and their management on pigeonpea and chickpea.

PESTS AND THE LOSSES CAUSED IN PIGEONPEA

In India, there are several scattered reports on the losses caused by pests on this crop which were reviewed by Davies and Lateef (1978) and Saxena (1978). There is no doubt that very many species of insects can cause significant damage to the crop in some areas and seasons. However, the pigeonpea plant can recover from substantial pest damage, particularly during its early growth, and substantial yield loss is likely to be caused only at the flowering and fruiting stage. Even at that stage it is possible for a plant to lose most of its fruiting points and produce a later crop, if climatic conditions are favourable. Lateef and Reed (1983) mentoined of estimates of 'avoidable losses' ranging from 6 to 64 per cent in large, unreplicated plot comparisons and from 8 to 78 per cent in small, replicated plot tests across different locations in India.

Pest damage surveys conducted in India by ICRISAT in co-operation with national scientists during 1975-81 have revealed the situation in relation to pod damage (Table 1). It is evident that lepidopterous borers dominate in the south, while podfly contributes to most damage in the north. These differences may be a result of differences in agroclimatic conditions, the late varieties common in north tending to be more infested by the podfly which picks up more activity during Jan-Mar/Apr, due to which most early varieties tend to escape its severe attack. The other pests which may become important include bud/flower feeders, while defoliators are rarely of concern. The eriophyid mite *(Aceria cajani)* can cause problems by transmitting sterility mosaic disease, leading to serious yield losses.

Table 1 : Insect pests damage to pigeonpea pods in various zones in India recorded during sample surveys from 1975 to 1981 (Lateef and Reed, 1983).

Zones	Percent pod damage				
	Borer[a]	Podfly[b]	Bruchid[c]	Hymn.[d]	Total
North-West Zone					
Punjab, Haryana, Delhi (early maturing pigeonpea) (n = 49)	29.7	14.5	0.05	0.03	44.0
North Zone					
Above 23°N (Late maturing pigeonpea) (n = 359)	13.2	20.8	0.2	0.5	33.8
Central Zone					
20°-23°N (Mid and late maturing p.pea) (n = 446)	24.3	22.3	2.2	1.6	48.0
South Zone					
Below 20°N (early and mid maturing pigeonpea) (n = 443)	36.4	11.1	6.7	2.2	49.9

n = no. of samples analysed for pest damage

a = Borer = All lepidoptera like *Heliothis, Exelastis, Maruca, Adisura, etc.*

b = Podfly = *Menolagromyza obtusa* (Agromyzidae : Diptera)

c = Bruchid = Mostly *Callosobruchus* spp. (Bruchidae : Coleoptera)

d = Hymn. = *Tanaostigmodes* sp. (Tanaostigmatidae : Hymenoptera)

PESTS AND THE LOSSES CAUSED IN CHICKPEA

Chickpea has relatively few pests. The most important pest is *Heliothis armigera*. Besides being a pod borer, this pest can attack chickpeas in the vegetative stage also, resulting in severe defoliation. Nevertheless the plants can recover well after defoliation and the delay in harvest by 2-3 weeks may be the main effect rather than any marked yield reduction. The pod damage by *Heliothis* is marked by a distinct circular hole made by the larva when boring into the pod. Another pod damaging insect is the semilooper *(Plusia)*. Pod damage may also be caused by birds such as parakeets and also by rodents. Sithanantham *et al.* (1983) calculated that avoidable losses in India ranged from 2 to 74 per cent based on AICPIP trials in several locations, while large plot tests at Patancheru showed losses ranging from 6 to 38 per cent across 7 years of experimentation between 1975 and 1982. Out surveys in India indicate that the pod damage across different states is around 5 to 15%, though individual locations have shown more than 50 per cent damage in several instances (Table 2). In general, chickpeas in Andhra Pradesh, Madhya Pradesh and Uttar Pradesh seem to suffer greater pod damage than in others.

Cutworms may result in plant mortality in some pockets as in Bihar and Rajasthan. Termites may affect plant stands as in Haryana. Aphids may become important, by transmitting 'stunt' disease, in some areas in north India.

PRINCIPLES AND METHODS

There are several papers relating to pest management in pulses embracing principles and/or methods including those by Saxena (1978), Srivastava (1979), and Reed *et al.* (1979, 1980). The options on principles relating to pulse crops in India may be as below : 1. The crops are largely grown under limitations of natural and fiscal resources-hence the inputs/practices should be less expensive and less risk borne. 2. The pulse crops are grown more as 'intercrops' than as sole crops and so the pest management should fit into the crop husbandry system adopted. 3. Essentially the pest attacks are important in the flowering and fruiting phase, excepting disease spread by vectors which can be important in the earlier phases of the crops. Monitoring of the pests concerned, is of vital importance in developing relevant strategies to manage the pests. We are still at a stage where we can propose adequate and complete integrated pest management strategies for these crops. I am describing the state of knowledge on the principal components of management, largely based on our experience at ICRISAT, as below.

Table 2: Summary of ICRISAT pest damage surveys at maturity stage of chickpeas in India, during 1977-82 (Sithanantham *et al.*, 1983)

States	No. of fields surveyed (No. of years)	Mean % pods damaged by pests			Mean % pls killed by pests*
		Borer	Birds	Total	
Andhra Pradesh	14 (4)	15.1	0.0	15.1	0.7
Bihar	22 (1)	5.7	0.6	6.3	0.0
Gujarat	10 (2)	5.9	0.3	6.2	0.6
Haryana	47 (3)	1.2	1.4	2.6	2.6
Karnataka	25 (3)	3.1	0.0	3.1	0.1
Madhya Pradesh	105 (3)	13.2	0.5	13.7	3.6
Maharashtra	117 (4)	4.7	0.04	4.8	0.4
Orissa	4 (2)	5.4	0.0	5.4	0.0
Punjab	40 (3)	2.5	0.01	2.6	3.1
Rajasthan	63 (4)	8.2	1.1	9.3	1.9
Tamil Nadu	2 (1)	7.0	0.0	7.0	0.0
Uttar Pradesh	192 (5)	8.4	0.3	8.7	1.0
West Bengal	6 (1)	2.4	0.0	2.4	0.0
Overall	647	7.33	0.41	7.76	1.55

Plants recorded to have been killed by cutworms, termites, whitegrubs, etc.

1. PEST MONITORING : This constitutes one of the essential components in effective pest management. Economic and efficient use of resources for pest control should be based on the occurrence and then the intensity of pest infestations. Simple systems of detecting the presence of eggs, early instars or adults should be made known to the farmers and/or field workers to be able to warn about impending pest attacks. The value of monitoring of pests relating to legume pest management has been rightly emphasised

by Irwin (1978) in his review on soybeans in USA and by Singh *et al.* (1978) relating to cowpeas. The need to obtain relevant ecological information, to help forewarn 'pest invasi on' has been pointed out by Van Emden (1978). There is a basic need to undertake a range of biological and ecological studies on the key pests of pulses, based on a recent review of such studies on *Heliothis* by Jayaraj (1982). Truly, ecology studies need more emphasis in our overall pest management planning.

2. ECONOMIC INJURY LEVELS (EIL) : With a wide ranging cropping and climatic variation in the areas grown to pulses in India, we may not benefit by a simplistic approach for fixing EIL. Examples, however, are available as develcped for several pests in soybeans (Irwin, 1978) and for *Heliothis* in crops like chickpea in India (cited by Sithanantham *et al.*, 1983). We should attempt to develop empirical values for EIL for the key pests in our pulse crops, largely experimenting on locally adapted cultivars in the near future.

3. HOST PLANT RESISTANCE : Our national pulse project (AICPIP) by extensive tests has identified several resistant varieties for a number of pests on our pulse crops and details are available in the Annual Reports. At ICRISAT the search for host plant resistance in pigeonpeas has been against the lepidoptera (mainly *Heliothis)* and the podfly *(M. obtusa)*. Over 10,000 lines have been screened during 1976-82. Some selections such as PPE-45-2, ICP-2223-1, PPE-38-2 and ICP-7537 have been found to be consistently 'less susceptible' to lepidopteran borers, while ICP-7349-I-S4, 7941.7194-1-S4* and ICP-6840 are 'less susceptible' to podfly. Studies on the mechanisms of resistance, genetics of inheritance of resistance and multilocation testing are in progress. In chickpeas, the progress has been more impressive. We found that for the last 4 seasons, the variety ICC - 506 has recorded lower pod damage and greater yield than the locally popular cultivar 'Annigeri'. During 1980-81 Rabi season, we found that ICC-506 and IC-7394-18-2-1P-BP yielded significantly more than Annigeri under pesticide-free conditions. Two more selections (IC-738-8-1-1P-BP and IC 73103-10 2-1P-LB-BP) also recorded less borer damage and greater yield than the local check. We are looking at both early and late maturity groups and also commencing

multilocation testing to assess their consistancy of low susceptibility.

4. BIOLOGICAL CONTROL: At ICRISAT, we find that *Heliothis* on pigeonpea is attacked more by dipteran parasitoids, while on chickpeas, the hymenopteran parasitoids seem to be more common. Nevertheless there are also exceptions. An imported Dipteran parasitoid of *Heliothis* (*Eucelatoria)* was found to be more active in pigeonpea than on chickpeas. We are looking into the various aspects of augmentation of natural enemies for possible biocontrol steps. We also know that predators such as spiders, coccinellids, lacewings, ants and birds, can assume importance in natural regulation of pest numbers. But, except in cases like *Chrysopa* (lacewings) which can be mass multiplied in the laboratories, it is difficult to exploit them for directed regulation of pest populations.

In the case of pathogens, the viruses, particularly a Nuclear Polyhedrosis Virus (NPV) for *Heliothis* can be useful. However, the safety standards for field use and also their cheap production need be fulfilled, if only these are to find a role to play in practical pest management.

A recent review by Bhatnagar *et al.* (1983) details the state of knowledge and scope for manipulation of natural control in pigeonpea and chickpea. A status paper on biological control of major pests of legumes by CIBC also provides related information. Biocontrol of *Heliothis* in India, was reviewed recently by Nagarkatti (1982), which outlines the scope for this approach in our situation.

5. CHEMICAL CONTROL: The situations where pesticide use seems economical have been very limited in grain legumes, mainly due to more than one pest group being important which require a different timing and/or type of pesticide. For instance, in pigeonpeas, endosulfan is found useful against moth borers, but gives little control of podfly. Also, their timing of activity tends to differ, the latter being more important in late cultivars. The surveys by ICRISAT during 1975-80 have revealed that in both these crops, less than 15% of the farmers apply any pesticide and when used, the pesticides are mostly DDT and/or BHC. This may

be largely on cost considerations. Again, problems in application are considerable. The bushy and tall canopy in pigeonpeas calls for either altered plant type or application system. A controlled droplet application (CDA) system seems promising, particularly in situations where water is not often readily available (Raheja, 1978).

6. CULTURAL METHODS : In the case of rainfed cropping of these pulses, which is the dominant system in India, we expect very liltle scope for costly inputs to be of importance in both crop production and protection. Our studies on seed rate (plant density) in both pigeonpea and chickpea indicated that we are likely to collect more *Heliothis* per unit area by closer plant spacing, but still the percent pods lost to pests does not change appreciably. As such, subject to moisture being not limiting, under unprotected (pesticide-free) conditions an increase in plant density could be considered to provide a marginal increase in yield.

In pigeonpea, intercrops can be to some extent influencing the pest activity. The spread of disease vectors such as eriophyid mites in pigeonpeas may also be influenced by the intercrops. A critical review of our konwledge of and scope for pest management in intercrop subsistance farming has been made by Bhatnagar and Davies (1979), which can constitute the base for our research/ development in pest management in pulse crops in India. Fertiliser practice can be important, but has not shown any distinct effect on pests in these two crops. Irrigation may lead to increased pest activity, but the levels are difficult to predict. Crop rotation can be important in relation to soil pests.

DIFFERENT ASPECTS OF RELATED INFORMATION

We should consider cost : benefit ratios as an important basic information, which needs to be periodically reviewed. After-all, what appeals to the farmer is the potential pay off for inputs, particularly in such predominantly rainfed, risk prone cropping of pulses as in India. Newer information relating to pest manipulation, pest avoidance, crop shifts, pest carry over should all form a constant source of refinement in perspective and planning pest management. Much of such information can be obtained from some recent publications as papers by Bhattacharya and Rathore (1977) and Kooner and Chhabra (1980), besides books such as one entitled 'Pest Control in Tropical Grain Legumes' published in 1981 by the Center for Overseas Pest Research, London; another entitled 'Pests of Grain Legumes : Ecology and Control' published in 1978 by Academic Press, London. The proceedings of a recently held workshop on *Heliothis* management published in 1982 by ICRISAT, can offer some latest reviews of the tactics and methods in pulse crops which are attacked by this polyphagous pest.

PEST MANAGEMENT EFFORTS PROPOSED : In an effort to effectively combine and exploit the different approaches, we should be able to develop the following steps in our pest control management systems : a) Choice of varieties : Depending on the importance of the pests in the region, varieties should be chosen which have proved to be resistant/less susceptible or at least tolerant. If such varieties are not available at least pest avoidance can be tried, if possible. b) Regulation of planting : Synchronous planting coupled with optimum seed rate, spacing and / or intercrop may be taken up in each location (village / watershed). c) Surveillance & Monitoring : Effective and simple systems of pest scouting and collecting information on incidence of major pests at frequent intervals (preferably weekly). d) Regulation of Control Measures : Proper combination and timing of biological, cultural and chemical methods of pest regulation to be worked out so as to derive the best impact. e) Follow up and crop sanitation : checking for the effect of the measures suggested, including any resurgence problems and also adopting crop sanitation such as control of 'carry over' through crop residues, etc, to be implemented.

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PEST MANAGEMENT IN RICE

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One of the major constraints in achieving high yield in rice is the damage caused by insect pests. In India, on an average, the yield loss in rice due to insect pests is estimated to be around 30%. Stem borers alone are estimated to cause 5 to 10% yield loss. Insect control often provides 500 to 1000 kg/ha increased yield. In attempts to control the insect pests, pesticides remain as the most important component. While sharing a major role in pest control, pesticides have also developed certain adverse effects like toxic residues in grain and straw, development of resistance by insects to insecticides, outbreak of secondary pests, resurgence of target pests, and toxicity to natural enemies of pests. However, we realise that pesticides are invariably indispensable, and it should be our endeavour to integrate chemical control with other control techniques and develop a strategy to regulate the pest population with minimum ecosystem disruption.

Initiation of a Pest Management Programme needs basic information on atleast four areas, viz natural control of pests, biology and ecology of pests, sampling methods and determination of economic population levels.

Constant monitoring of pest population/damage is essential since pest population will fluctuate with changes in the environment. If natural enemies increase or unfavourable weather prevails, the population will go down and *vice versa*. Thus pest monitoring and utilizing economic threshold levels can save the farmer money by eliminating unnecessary insecticide applications and incidentally reduces environmental pollution.

The ET for all the major pests of rice has been developed based on insect population or damage. The ET for stem borers is 10% 'dead hearts' and 2% 'white heads'; 5-10% 'silver shoots' in the field is considered as the damage threshold for the gall midge.