Chapter 29

Insect Biodiversity in Nepal and Its Value for Integrated Pest Management Systems

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Pests (including insects, diseases, weeds, rodents, and mites) are the major biotic constraints to increasing agricultural production. Infestation by pests has been identified as one of the main causes of low food production. Exact figures are not available, but the National Planning Commission of Nepal has estimated that pests cause a loss in food production of about 15-20 per cent (Baker and Gyawali 1994). Bunting (1972) suggested that, in developing countries, about one fifth of the possible output was lost because of field pests and another fifth because of post harvest pests. Current estimates of loss caused by pests is around 30 per cent of potential food production (NRI 1991). Insects alone cause more than one third of the total damage done by pests. Therefore pest control alone can contribute a lot to food sufficiency. This paper aims to discuss some of the issues related to pest management, in general, and the use and promotion of biological control systems against insects in pest control strategies in particular. Pest control will contribute to ensuring the long-term sustainability of agriculture in mountain areas.

Pests and Pest Control Options

Any organism that interferes with our health and comfort, the quality and quantity of our food supply, our cultivated plants, our forests and buildings, our domestic animals, or any other aspects of the quality of our environment may be considered a pest (Waterhouse and Norris 1987). From the agricultural perspective, we would include among pests organisms that induce disease (fungi, bacteria, viruses, nematodes) or that damage crops in the field or in storage (such as insects, mites, rodents, birds, mammals) or compete with them for space, nutrients, light, or water (weeds).

Traditional agriculture is characterised by the adoption of stabilised land races (low productivity but higher ability to compensate for loss), low external input, low cropping intensity, and long fallow periods. There used to be a wide range of crop diversity within the same piece of land (through mixed cropping), or deliberate use of a mixture of varieties. Pesticides were neither available, nor were they felt to be necessary because of the subsistence nature of production. This further enhanced the role of natural enemies and pests were mostly controlled naturally or by traditional farming operations.

In modern agriculture, efforts have been made to boost productivity by using high-yielding varieties with a high degree of assimilation efficiency, increased cropping intensity, and increasing external inputs such as irrigation, fertilizers and pesticides. Traditional and environmentally adapted practices were replaced and efforts were made to change the environment in favour of the crop variety so as to maximise production. Monocropping replaced mixed cropping, and so called 'miracle varieties' replaced varietal diversity. This practice encouraged some pest species to grow to economically important levels. Application of pesticides to control these pests disturbed the natural balance of the ecosystem, leading to further outbreaks of secondary pests.

Before the discovery of DDT as an insecticide, insect control was largely by nature, cultivation practices, and some biological control agents. Since the development of DDT and other synthetic insecticides, insect control has mainly been based on the use of chemical pesticides. Soon after they became widespread, environmental mishaps began to be observed. Pesticide residues were reported in several foodstuffs, bio-accumulation resulted in the death of animals of higher tropic level, and the whole ecosystem was greatly disturbed. The long-term effects of pesticides on human and animal health were studied in detail. At the same time several insects developed resistance to pesticides and outbreaks of pests became more common than in the past. Awareness of pesticide misuse supported the campaign against pesticides and Stern et al. (1959) proposed an integrated control concept combining chemical pesticides with biological control agents. The idea received wide acceptance and, further developed with wider applicability, was given the name 'Integrated Pest Management (IPM)'.

Pest Control Approaches

There are few problems with insect/pests in natural ecosystems because of the balance between carnivorous and herbivorous insects. Subsistence agriculture supports a slightly lower level of insect diversity. The expansion of crop monocultures worsens insect pest problems considerably because of the decrease in local habitat diversity (Alieteri 1987).

Understanding the role of insects in the ecosystem is necessary before developing a pest management strategy against the important pests. Plants are the universal producers. Herbivore insects constitute the second trophic level, and their parasites and predators the third trophic level. Insects are the largest group of living organisms and are distributed widely throughout all ecosystems. They play a very vital role in agricultural ecosystems as well. Not all insects present in agriculture are economically important. Some insects are identified as good friends because of their economic benefit to farmers (honeybees, silk worms, lac insects, scavenging insects), some are known as notorious pests and disease vectors, and others as their enemies. Most insects may not have any direct significance)

In Nepalese hill agriculture, weeds are managed by cultivation and human labour. Most of the diseases of field crops are controlled by using the host plant resistance through breeding programmes. Insect pests in most crops, and diseases (mostly fungal) in many high-value crops such as vegetables, have become the targets of pesticides. The accumulation of pesticides in the environment, and its effects on the health of humans and livestock, and on non-targetted organisms, have made pesticides more problematic than the pests themselves.

Pest management research receives low priority. In order to promote the adoption of modern agricultural technologies, both for cereals and in high-value commodities, HMG/N has been providing subsidies for pesticides and sprayers (through special programmes). Over-reliance on pesticides is a result of (i) the orientation of technicians and commercial growers towards chemical control because of its quick action, (ii) easy access to pesticides and lack of regulations to control pesticide misuse, and (iii) lack of alternative pest control methods.

Using pesticides can have many advantages if sufficient care is taken (and that is the reason why they are so popular in the developed world). The developed countries are the biggest users of pesticides, but pesticide-related hazards and accidents are most common in the developing countries (Dahal 1995). The most common patterns of pesticide misuse in mountain agriculture have been documented by Baker and Gyawali (1995). They are mostly related to improper selection, storage, handling, dosages of pesticides, and failure to observe the required waiting periods. These problems are caused by the low literacy rate, lack of proper information about pesticide hazards, limited access to safety measures, inadequate legislation and weak enforcement of existing rules, and lack of awareness about pesticides. Less than five per cent of the pesticide applicators wear protective clothing, and none applies masks to cover the mouth and nose (Baker and Gyawali 1995).

There are no properly recorded data on the quantity of pesticides used by hill farmers in Nepal or on their ill effects on human health. This is largely because of the involvement of the private sector, which has no obligation to maintain records, in the pesticide business (Dahal 1995). Nepal imported pesticides worth NRs 42.394 million in 1989, insecticides alone accounted for NRs 42.167 million (Baker and Gyawali 1995), indicating their dominance. Most of the insecticides applied in Nepal belong to the organo-chlorine or organo-phosphate groups. The most popular insecticides are BHC (Class II, moderately hazardous, banned in 28 countries) and metacid (Class 1a, extremely hazardous, banned in five countries) (Dahal 1995). Mountain farmers are ignorant about the unwanted effects of pesticides, and the greater the toxicity, the wider the range of insects killed, and the longer the residual effects of a pesticide, the more likely they are to rate it as 'good'.

Integrated Pest Management (IPM)

Because of the failure of chemical pest control (Box 29.1) and the increasing concerns related to health and environment all over the world, emphasis has been given to research into alternative methods of pest control. IPM has been recognised as the best strategy for pest management. It is defined as a pest

Box 29.1

Failure of Chemical Pest Control in Nepal

- The rice bug *Leptocorisa orotorius* is considered to be a major pest for rice. Farmers use pesticides to control the pest. Outbreaks of brown plant hopper (*Nilapervata lugens*) were observed in Jholunge Phant in Gorkha District and in Rishing Patan in Tanahu District in 1992, following the application of contact insecticides, such as metacid or malathion, to control the bug.

- Citrus green stink bug (*Rhynchocorris humeralis*) is an easily visible pest of citrus which causes fruit drop in mandarin oranges. Several species of scale insects are also associated with mandarin oranges. Application of cypermethrin to control the citrus green stink bug has increased the problem of scale insects in Hyangja in Kaski District and Bandipur in Tanahu District. In both cases the scale insect problem gradually declined once pesticide spraying was abandoned .

- Spring tomatoes are an important off-season vegetable crop in the hills. They suffer from attacks of the fruit borer *Helicoverpa armigera*. Farmers from Tapu, Parbat District, and Dhanubase, Syangja District, have complained that Ripcord (cypermethrin) has failed to control the pest. Later this was found to be associated with the development of pesticide resistance. In Syangja, the pest has developed 56-fold resistance to cypermethrin and 53-fold resistance to Fenvalerate (Armes and Pandey 1995). Field surveys in the following years showed that the indigenous egg parasite *Trichogramma achae* was responsible for damaging a huge proportion of *Helicoverpa* eggs.

Sources: Pandey and Joshi 1996; Pandey and Rana 1992 management system in the context of the associated environment and related to the population dynamics of the pest species which uses all the suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economically unacceptable damage or loss (FAO 1986). It was only in the eighth five-year plan (1992-1997) that HMGN accepted environmentally friendly methods of pest control as a national guideline. IPM and post harvest loss control are the priorities for research in the eighth plan. The Nepal Agricultural Research Centre (NARC), as the apex body of agricultural research in the country, has also given high priority to IPM research for the development of environmentally friendly and sustainable agriculture in the country. Legislation to regulate the import, sale, and use of pesticides in the country was passed in 1994 and has recently been enforced, but not very effectively.

Because IPM is a combination of several compatible techniques of pest control methods, component technologies have to be identified and developed first. The suitability of component technologies depends on the prevailing agricultural system, socioeconomic factors, and the availability and access to alternative methods. The identification and use of the host plant resistance, modification in cultivation practices against pests and in favour of the crop and natural enemies of the pests, mechanical destruction of pests, use of other control measures such as attractants, mating disruption through pheromone traps and insect growth regulators, application of biological control agents (parasites, predators, and pathogens), and the promotion of less toxic extracts of local plant materials are key features of IPM. Chemical pesticides (either with intrinsic selectivity or selectivity resulting from application techniques) are taken as the last resort in the pest management technique (when all other techniques fail to maintain the pest population below the economic threshold level).

Insect Biodiversity

Biological control in its simplest sense is the use of insect biodiversity (one organism) to suppress pests on agricultural, forest, veterinary, or human health. The first, and very successful, use of biological control was achieved in controlling citrus scale (*Icerya purchasii*) with the help of an Australian ladybird beetle (*Rodolia cardinalis*) in the 1880s in the USA. Since then a variety of biological control programmes has been launched with mixed success. Biological control can be achieved by means of several different types of agents, commonly known as parasites, predators, and pathogens.

In the present context, biological control has become the most important component in the design of Integrated Pest Management strategies, especially those against insects. The IPM approach uses both the natural and the applied aspects of biological control. A diversity of insect species and an understanding of insect-insect relationships are crucial when determining a pest management strategy.

The association between some ants and honeydew secreting insects such as aphids and scale insects may favour the development of the latter to pest status. In contrast, predatory and parasitic insects help suppress pests in fields, and are further assisted by pathogenic organisms. Predators and parasites may themselves be attacked by predators of higher tropic level and hyper-parasites.

The most common species of predators belong to the orders *Coleoptera* (Families *Carabidae, Coccinellidae, Staphyllinidae, Cicindellidae, Cleridae, Lampyridae, Cantheridae, Meloidae, Elateridae,* and *Stylopidae*), *Dictioptera* (Family *Mantidae*), *Diptera* (Families *Syrphidae, Asilidae, Bombyliidae, Rhagionidae,* and *Empididae*) *Hemiptera* (Families *Phymatidae, Reduviidae, Nabidae, Anthocoridae, Pentatomidae,* and *Miridae*), *Hymenoptera* (Families *Vespidae, Formicidae,* and *Sphecidae*), *Mecoptera* (Families *Panorpidae* and *Bittacidae*), *Megaloptera*, *Neuroptera* (Family *Chrysopidae*) and *Odonata*. Wasps of the order *Hymenoptera* (Families *Ichneumonidae, Braconidae, Scelionidae, Eupelimidae, Trichogrammatidae,* and *Mymaridae*) and flies of the order *Diptera* (Family *Tachinidae*) are the major groups of parasitic insects.

Development of a Pest Management Strategy

When developing a pest control strategy, it is necessary to understand the life cycle of the pest and factors affecting its build up. There may be many individual reasons for specific pest build up, but they can be categorised into (i) invasion, by which an organism enters into a new environment more conducive to its growth and reproduction as a result of the lack of natural enemies; (ii) ecological changes, such as adoption of high-yielding varieties, monoculture, pesticide application; and (iii) socioeconomic changes, affecting the priorities and values of the different crops grown (Stern et al. 1959).

Innundative application of biocontrol agents can be compared to pesticide application, a large number of organisms is released at one time to suppress the pest population. This practice is possible only when the cost of production is low. The best strategy against pests that have invaded a new environment, such as the tuber moth, *Phthorimaea operculellea,* in potatoes in Nepal is to search for the most efficient enemies at the place of origin and introduce them in the form of an inoculative release (as was done when *Rodolia cardinalis* was imported into California to control *Icerya purchasii*). The newly introduced species is expected to adapt to the environment and multiply using the pest, ultimately bringing the pest down to a tolerable level. Inoculation can also be practised when more efficient (compared to the indigenous) predators and parasites are available abroad for the control of an indigenous pest.

Box 29.2
Integrated Pest Management In Pakistan

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There have been several success stories of IPM in Pakistan for mangoes, apples, sugarcane, and cotton. These were made possible by introducing exotic insects such as *Cotesia flavipes* from Japan, *Apelinus mali* from the USA, *Elasmus zehntneri Ferriere* from Indonesia, *Encarsia perniciosi* from California, *Leptomastix dactylopii* from the West Indies, and *Bracon kikpatricki* from India. The identification and redistribution of natural enemies is also used as a biological control strategy in Pakistan. This approach was found to be successful in enhancing insect biodiversity as well as providing good control over various pests in sugarcane, cabbage, cauliflower, potato, and apple crops. Nevertheless, the most efficient and cost effective strategy is the conservation of natural enemies *in situ*. This requires a clear understanding of local systems and of indigenous crops and plant species and their interaction with insect pests.

The usefulness of conservation of natural enemies to control pests of sugarcane, mango, and cotton has been successfully demonstrated in Pakistan.

There is also a great diversity of insects that perform crop pollination. *Hymenoptera, Diptera, Lipidoptera, Thysanoptera*, and *Coleoptera* are the important groups of insects responsible for pollination. It is reported that more than 250,000 species of flowering plants have a complex relationship with pollinators. In Pakistan, the diversity of pollinators has been improved by the introduction of pollinators such as the honeybee (*Apis mellifera*) which was introduced in 1976 from the USSR and in 1977 from Australia. In contrast to the experiences in China, Nepal, and India, *Apis melliferra* became well established and improved seed production as well as increasing honey production.

When an indigenous pest attains pest status as a result of changes in cultivation practices (as in most vegetable farming practices in Nepal) then a good start would be to look for indigenous biocontrol agents in the same crop cultivated by traditional practice in the surrounding area and to promote these agents through changed cultivation practices or modification of the environment in their favour. This is commonly known as the 'conservation' of natural enemies. When indigenous biocontrol agents exist but are are not effective enough because of factors such as rapid population build up of the pest species, or changes in the environment such as pesticide application, then it is necessary to augment the naturally existing population by introducing additional agents of the same species. Existing insect biodiversity plays a very important role in both techniques (conservation and augmentation).

Some work on insect biodiversity has been carried out in Nepal on butterflies, beetles, and moths because of their fascinating aesthetic value, but efforts have largely concentrated on reporting the existence of a species in a given ecosystem without considering their economic role. Work on parasitic insects is very meagre, although they play a vital role in the ecological balance. The main reason behind this lack of interest is the complicated life cycle, small size, and lack of attractiveness compared to butterflies, moths, and beetles. Furthermore, the study of parasitic insects is more of a professional field for agricultural pest management personnel interested in biological control. Since biological control failed to attract the attention of national policy until recently, because of the focus on pesticides, parasitic insects remained unexplored.

Maintenance of Insect Biodiversity

Insects are the largest group of creatures on earth and are distributed throughout all habitats. Their distribution is affected, however, by the diversity of producers (plants) and other biotic and abiotic factors. Because of the ecological diversity in Nepal, there is a wide variation in natural vegetation and the crops grown (in terms of species, variety, and farming systems). This variation supports the existence of a variety of both pests and their natural enemies. The role of insects is further enhanced by the subsistence nature of agriculture in Nepal, in general, and in the hills in particular, with minimal or no use of chemical pesticides. It is important to conserve and maintain the naturally prevailing insect biodiversity for the development of IPM in hill agriculture. The 'conservation' approach would be useful against indigenous insect pests which change their status as a result of changes in agricultural practices such as a reduction in diversity, use of susceptible varieties, and application of pesticides.

Traditionally, in mixed cropping the low crop used to provide shelter and humidity for such organisms the 'natural enemies of pests'. Different crops provided flowers at different times and this benefitted many parasitic wasps. Each crop also sheltered non-specific predators that attacked the pests of the crops grown. Similarly, in modern farming, the practice adopted in the UK of leaving an unsprayed border around the crop area has not only encouraged game birds but also encouraged the growth of biological control agents (van Emden 1989).

Previously, clean cultivation free from weeds was advocated, and weed vegetation was blamed for harbouring crop pests and diseases. The orientation is now changing and the role of weeds as a home for the natural enemies of pests is receiving consideration. It now known that weedy rather than clean plots of wheat have a greater abundance of predatory beetles, and that the impact of flowers from weed flora in maintaining parasites and predators of crop pests far outweighs the detrimental influence of the weeds (van Emden 1989). Non-crop plants have been used to promote predators to control *Brassica* pests (White et al. 1995). Roadside verges, hedgerows, and nearby forests have provided food and shelter to natural enemies of crops on UK farms (van Emden 1989). It is expected that the weeds and grasses growing on the terrace risers and bunds, and the fodder and forest trees grown around the farm, could play a similar role in mountain agriculture, but this has still to be investigated. If pesticides are applied, care should be taken to choose a selective pesticide (using inherent selectivity or selectivity through the application method) so that the possible harm caused to natural enemies is minimised.

Which Agent - Indigenous or Exogenous

In Nepal, there are two ways to proceed in using insect biodiversity as a basis for finding suitable biological control agents: (a) look for our own indigenous agents and promote them, and (b) import those from abroad. The advantages of indigenous agents are that they are already adapted to the environment and there is no need to investigate their requisites to satisfy quarantine regulations. There may be some doubt as to the availability of such agents in our ecosystem, but several studies suggest otherwise. Field surveys conducted by Lumle Agricultural Research Centre have shown that several parasites exist for *Helicoverpa armigera* and the citrus green stink bug, *Rhynchocorris humeralis* (Pandey et al. 1996). Field observations have shown that a wide range of coccinellids attack aphids and scale insects. Several species of wasps attack aphids, cabbage butterflies, diamond back moth, and even grain storage pests (grain weevil) in wheat. Natural enemies for other pests attacking different crops must have existed (or still exist) in our farming system, a theory supported by the outbreaks of secondary pests following pesticide application.

The disadvantage of indigenous agents may be their efficacy; if they are already present why aren't they effective? This can only be answered by proper studies. Studies of tomato have indicated that pest build up is much faster than parasite build up after the cold winter. Here one possible solution might be to augment the prevailing biological agents, which could be achieved through release of additional agents (*Trichogramma achae* in this case) at an early stage. Such action would also help avoid interspecies competition.

Importing biological control agents from abroad would seem to be easy (because of their easy availability), but disadvantages might include problems of establishment in the new environment, problems arising from interspecies' competition with the native species, and the danger of introducing hyper-parasites and organisms pathogenic to indigenous biocontrol agents. Much more detailed and costly studies will have to be conducted on these organisms, and comparisons made with indigenous agents, if proper introductions are to be done.

Conclusion

The present situation in mountain agriculture is becoming favourable for the development and adoption of IPM. Government organizations (both research and extension), non-government organizations, and the donor community have shown their interest in and commitment to strengthening IPM work in the country. Public awareness about the ill effects of pesticides is increasing (both in consumers and producers). Losses due to pests are being recognised increasingly and solutions sought, and alternative methods are being demanded and accepted. Integrated Pest Management systems will help stabilise yields, increase productivity and economic benefit, and minimise applications of pesticides.

IPM is not a technology in itself but an integration of available and compatible technologies combining different aspects of agricultural science — including plant host resistance, cultivation practices, biological control agents, chemical non-pesticides, and selective (application of) pesticides. IPM can only be promoted if the component technologies to be integrated are available. The main aim of implementing IPM in Nepal is to reduce the use of pesticides. The focus of IPM programmes must be on the management of insects pests, followed by management of diseases. This is because of those farmers who use pesticides, 95 per cent use insecticides, about 41 per cent rodenticides, 38 per cent fungicides, and only 13 per cent weedicides. The insecticides used in Nepal belong to the highly persistent organochlorine group and constitute the largest volume of the total pesticides used (Dahal 1995). The total volume of rodenticides used is relatively small. IPM will help to get rid of a situation in which pest control is synonymous with pesticide, pesticide with insecticide. Rice attracts the largest volume of pesticide, whereas high value crops, such as vegetables, mustard, and cotton, receive the most intensive application (Baker and Gyawali 1994). Pest problems in these crops result from the ecological changes caused by increasing commercialisation (changes further worsened by the application of pesticides, mostly insecticides) and socioeconomic changes (high-value crops). Thus the IPM programme should first concentrate on rice and vegetables.

Insects are attacked by a wide variety of biological control agents (especially in undisturbed ecosystems), therefore emphasis should be given to the understanding of crop ecosystems in terms of pests and their natural enemies. Indigenous biological control agents need to be searched for and promoted through the adoption of various cultivation practices and other control methods that disturb natural enemies the least (such as mixed cropping, trap cropping, food lures/baits, use of pheromone traps, and demoulting hormones). In Rachel Carson's 'the other road' or 'integrated control' as proposed by Stern et al. (1959), or the modern concept of IPM in 'the context of the associated environment', the main emphasis is on the least disturbance to the biodiversity of natural enemies and the use of biological control agents. The development of resistant varieties should continue, as this is likely to be the most successful strategy against field crop diseases (as a result of the availability of vast genetic variability and the involvement of non-profit making international institutes). Identification of critical stages of crops that need special attention for protection, and development of rational spray schedules with selective and safe pesticides against important diseases and insects in commercially important crops such as vegetables, fruits, and cash crops, should also be investigated.

NGOs and environmental activists (especially journalists) have played a significant role in creating awareness against pesticides, and they should also be involved as partners in the development and dissemination of IPM. Thought must be given to managing populations of pests through biological and ecological actions; over-reliance on pesticides alone, which aims only at individual pests (Bunting 1972), must cease.

A national pest management plan needs to be developed without delay by identifying and prioritising the main pests and setting a strategy for their management. The role of different organizations should be identified and their linkages strengthened. The following are some of the areas that need immediate attention to facilitate better understanding, planning, and implementation of the IPM programme in Nepal.

- Creation of an inventory of GOs, NGOs, and other institutions that are involved in and/or can contribute to the IPM programme
- Identification of the roles of these different bodies and proper coordination
- Raising of awareness about pesticide hazards among growers and consumers
- Strengthening and enforcement of legislative measures to control pesticide misuse
- Understanding the functional role of natural enemies in maintaining the ecological balance within a given farming system through agro-ecosystem analysis
- Analysis of agricultural systems to discover the pest priorities from the farmer's perspective
- Identification of the factors affecting pest build up and development of agricultural practices to favour natural enemies
- Study of techniques for production and use of biocontrol agents
- Development of appropriate methods for the transfer of IPM technology

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