Crucifer insect pest problems: trends, issues and management strategies

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Abstract

Crucifer vegetables are important cultivated crops and are widely grown in many parts of the world, including the highlands in most tropical countries. They are frequently attacked by a number of important insect pests. Some have been a problem for a long time while others have become important only recently. For many, trends are apparent pertaining to their changing status, including other aspects and strategies associated with efforts to counter them. In some cases, they are also closely associated with other agricultural developments and agronomic practices which are driven by commercial interests in vegetable production.

Among the major trends recognised are: (1) A number of pests persisting to be important (e.g., Plutella xylostella or diamondback moth (DBM), Pieris rapae, Hellula undalis), (2) Negative impacts of pesticides continuing to be of major concern where DBM remains a serious problem, (3) Some pests becoming more important, either independently of DBM suppression (e.g., leafminer and Spodoptera exigua) or as a consequence of effective DBM control (e.g., aphid and Crocidolomia binotalis), (4) DBM becoming increasingly resistant to Bacillus thuringiensis, and (5) New cultivation practices emerging, such as rain shelter and hydroponic systems. All these have generated new concerns, additional issues and challenges, and have demanded a review of crucifer cultivation and the associated pest problems, including their management practices and approach. Some major ones include issues of weak extension support, lack of holistic approach in research, incongruence of scientific research with farmers’ needs, limited efforts in biological control, increased interest in integrated pest management programmes, organic agriculture, and others.

This paper examines the changing trends and possible reasons, including the management approaches being developed to deal with current chemical control practices. Related issues are appraised along with their implications and follow-up strategies proposed to deal with them are discussed.

Key words: Crucifer pests, trends, issues, management strategies

Introduction

Many cultivated crucifers are important vegetables. They are widely grown in many parts of the world, including the highlands of the tropics. A number of important insect pests frequently attack them (Lim and Di, 1990; Talekar, 1992). Some have been problems for a long time while a few are newly emerging pests. For many of these pests, trends are apparent in relation to their changing status, including other aspects associated with efforts to counter them. In some cases, they are also closely associated with changing agricultural developments driven purely by intensified commercial interests. On the other hand, counter pressures from environmental concerns have played a key role to cushion the impacts from such unilateral commercial interests.

This paper examines the changing trends in the status of crucifer pests and their management, and underlines the possible reasons with particular focus on situations in the developing tropics in Asia. The trends involve mainly those of persistent and emerging insect pests, including trends of pest management approaches being developed to deal with the pests and the escalating problems associated with current chemical control practices. Related issues are appraised along with their implications and the follow-up strategies proposed to deal with them are discussed.

Trends in pest situations

Persistence of major pests

Among the major trends recognised is the persistence of several key pests on crucifers. An excellent example is Plutella xylostella or the diamondback moth (DBM) which occurs widely in both the hot and cool areas. Another important pest is the cabbage white butterfly, Pieris rapae, which is confined to the cooler locations.

However, in the hot tropical lowlands, the webworm Hellula undalis has persisted as an important pest in many places. Several other species have also been reported to be important, viz, cutworm (Agrotis ypsilon), armyworm (Spodoptera litura), cabbage head worm (Crocidolomia binotalis), flea beetle (Phyllotreta spp), and aphids (Myzus persicae, Brevicoryne brassicae) (Table 1). However, these do not constantly inflict serious damage, although their presence is often noticeable.

The reasons may differ for different species as to why some of these pests are important. For some, an
important reason is because they are exotic pests without their full complements of effective natural enemies. Specific examples include DBM and the cabbage white butterfly. Even in situations where the natural enemies have been successfully introduced, there exist many cases where the parasites are unable to exert their full impacts due to excessive use of harmful insecticides. Examples are situations of the Cordillera Highlands in the Philippines from 1989–93 and that of the Cameron Highlands in Malaysia in recent years. In general, most of the pests have persisted because of poor understanding of the pest ecology in the tropics, including a lack in ecological approach to managing them. Control efforts have all along been devoted to using and finding more and more effective chemical pesticides. This has led to pesticide treadmills occurring in most vegetable areas and the pest problem persisting to be critical. Some newly emergent pests (e.g., leafminers) in several countries (e.g., Indonesia, Malaysia, Philippines, Vietnam) appear to have also fallen into the same condition (Table 1, see also subsection on other recent pests).

**Emergence of other pests as a consequence of DBM control**

Some pests have become more important, apparently as a consequence of effective DBM control. Prominent among these are aphids and the cabbage head worm, *C. binotalis*. Farmers in the Cordillera Highlands (Philippines) have reported that these species are posing a bigger problem after DBM has been successfully suppressed by the parasite, *Diadegma semiclausum*, in conjunction with Farmer Field Schools (FFS). This phenomenon is also recently noted elsewhere (e.g., Indonesia, Malaysia) where some success of DBM control have been achieved.

The reasons for both aphids and the cabbage head worm becoming more important is presently unclear. It could truly be a case of successions by both the species moving into the niche previously occupied by DBM, now that competition of the latter is eliminated. Alternatively, it could be a shift in focus by the farmers to the next important pest problem now that DBM has become less or is no more serious. Or probably, it is a combination of both. Whatever may be the actual reason, the reality is that both these species are becoming increasingly more important and this trend cannot be ignored (Table 1). Appropriate research efforts are thus needed to develop pragmatic control measures for them, including suitable supporting extension activities to implement them.

**Other recent pests**

In recent years, a few pests were observed to have become more important in a number of countries, independent of DBM suppression. The more prominent ones include the complex of leafminers comprising mainly *Liriomyza huidobrensis* (and other *Liriomyza spp*) and *Chromatomyia horticola* (Sivapragasam et al., 1992) and *Spodoptera exigua* (Hussan, pers. comm) (Table 1). The latter has recently been found to attack legumes and brassicas in Malaysia and is a key pest in Thailand. A wide range of insecticides are applied repeatedly against them. Like DBM, many of these chemicals will soon become ineffective, suggesting rapid development of resistance to the products. Also, in many places the problems have increased with more intense use of chemical

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<th>Relative importance</th>
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| Very important      | *Hellula undalis*  
*Phyllotreta spp.*  
*Pieris spp. particularly *P. rapae*  
and *P. brassicae*  
*Plutella xylostella* | Occur in abundance most of the time. Farmers spray regularly with many kinds of insecticides against them. Usually very difficult to control. Serious problem encountered with insecticide resistance development. [Note: In some cool highland areas where parasites (particularly *Diadegma semiclausum*) are providing good control, *P. xylostella* has become unimportant]. |
| Moderately important| *Agrotis ypsilon*  
*Crocidolomia binotalis*  
*Spodoptera litura*  
*Aphids (mainly *Myzus persicae* and *Brevicoryne brassicae*) | Present most of the time but peaks of abundance are sporadic. Farmers commonly spray insecticides to control them. |
| Becoming more important recently | *Leafminers (mainly *Liriomyza spp.* and *Chromatomyia spp.*)*  
*Spodoptera exigua* | Believed these are spread around rapidly and widely by increasing movements of trade and people in recent times. Farmers spray heavily against them. |
| Becoming more important following effective suppression of *Plutella xylostella* by parasites | *Aphids*  
*Crocidolomia binotalis* | These have been observed to increase recently in areas with effective IPM programmes against *P. xylostella*. Believed to be a case of pest succession where the niche previously occupied by *P. xylostella* is now taken over by these species. |
insecticides, indicating that their buildups may be insecticide-induced.

These emerging pests are also believed to be introduced species. They probably have escaped quarantine and are spread around by the increased agricultural trade and other global activities of transnational travellers in recent years. Whatever the means of entry, these exotic pests can only be effectively managed if there also exist their complement of effective natural enemies. Numerous parasites of leafminers have been recorded (Waterhouse and Norris, 1987). However, these parasites are presently not fully exploited for leafminer problems in the Asian region. Efforts should be made to explore the possibility of utilising them, particularly after confirming the absence of useful indigenous natural enemies. Focusing on Pacific countries, Waterhouse and Norris (1987) suggested that because of the wide host range as well as the need to consider the wide range of cultivated plants at risk, it is probably desirable to introduce a wide range of parasites. They pointed out that no harm will result from this and, if it is done, there seems to be good prospects for bringing about biological control, provided insecticide application for the control of other pests is selective or carefully restricted. Species of particular promise are Chrysocoris parksi, Chrysonotomyia punctiventris, Diglyphus begini, D. intermedius and Gansaspis dium hunteri.

Besides introductions of effective parasites, there is also a need for more vigilant enforcement of quarantine measures to prevent further spread of these pests into those countries where they are still not present.

**Trends in pest control**

**Growing list of negative impacts of pesticides**

Because many insects continue to persist as major pests leading to many undesirable problems from pesticide treadmills, the growing negative impacts of pesticides have become an increasing concern. For example, where DBM remains a serious problem, as is the case in most parts of the developing tropics, many of the undesirable impacts of pesticides are now widespread. In many countries, the problems continue to escalate, especially where DBM has persisted and where the pesticide industry is very active and numerous kinds of insecticides are easily obtained. However, for some areas in a few countries where DBM is successfully controlled by parasites (e.g., Indonesia, Philippines, Taiwan), there have been reports of drastic reductions in pesticide inputs in those areas (Ooi et al. 1992; Talekar, 1992; AVRDC, 1995; IIBC, 1996).

The negative impacts and the implications arising from excessive use of pesticides on vegetables are numerous and now well known as shown in Appendix 1. They include the effects on pest ecology, effects on domestic species, wildlife and other living organisms, reduction and loss in biodiversity, pesticides in food and food chain, contamination of the environment, impacts on human, and their hormonal effects. These negative impacts may escalate as pesticide use in the region continue to increase (RENPAP, 1994).

**Increasing resistance to Bacillus thuringiensis by DBM**

For a long time it was assumed that insects, including DBM, would not become resistant to Bacillus thuringiensis (Bt) because it is a biological agent. An experimental study by Devriendt and Martouret (1976) initially lent support to this. However, as field populations of DBM were repeatedly exposed to commercial Bt sprays in Hawaii, high levels of resistance appeared, nullifying the pathogen’s usefulness (Tabashnik et al., 1992). There are now signs that resistance to the Bt has also developed in various parts of the world where Bt is used fairly extensively (Shelton and Wyman, 1992; Hama 1992; Syed, 1992). However, the cases of resistance reported appear to be mainly against the HD-1 isolate of the kurstaki serotype and to some extent the aizawai serotype (Wright et al., 1996). There seems also to be some cross-resistance between both the serotypes (Tabashnik et al., 1992).

Recent research has suggested that resistance to Bt could evolve much faster than previously anticipated. Numerous strains of the bacterium produce many different Bt toxins. It has been assumed that each would evolve independently and the process complex and long. But it is now confirmed that a single and common recessive gene can confer resistance to four different Bt toxins (Cry1Aa, Cry1Ab, Cry1Ac and Cry1F). Crosses between a field population that had been heavily exposed to Bt toxins and a susceptible laboratory population produced offsprings which not only survived exposure to just one toxin but also developed resistance to all four, suggesting that the resistance may have been the consequence of a single gene mutation. In the study, 21% of individuals in the susceptible laboratory population were heterozygous across the whole resistance gene as compared with an expected frequency of 1 in 10 000.

That resistance to Bt could evolve much faster than previously anticipated has many implications. The most critical is whether resistance management strategies can practically be developed for effective implementation by small crucifer farmers, and in time, before the valuable resource of Bt toxins in pest control is lost.

**Efforts in alternative pest management**

Largely because of the negative impacts of pesticides and increasing difficulties encountered in controlling many vegetable pests, much efforts have in recent years been devoted to find alternative approach in dealing with them. Different strategies are adopted by different interest groups. At the farm level, some farmers are pioneering into cultivation under large plastic rain shelters or net houses. Researchers, governments and donors are focusing into integrated pest management (IPM) research. In IPM implementation, extension workers have explored.
several methods. More recently, the non-formal, bottom-up and self-discovery approach of the Farmers Field School (FFS) has been receiving increasing support, both by some governments, donors and NGOs. A third approach is pursued mainly by other environmental concerned or/and health conscious groups, comprising largely those practising organic or ecological farming.

Cultivation under protected environment (netted structures)

In parts of some countries in the Asian region (e.g., China, Philippines, Malaysia, Thailand, Vietnam), particularly in areas where strong winds are not a recurring problem, cultivation of crucifers and other vegetable crops under protected environment is being practised. Essentially, two kinds of netted structures are used; those that are covered completely with a net (ca. 256 mesh) and those with nets on the side and a plastic sheet on top. One major reason for such a practice is to exclude insect pests, hence avoiding or minimising the use of chemical insecticides. Other advantages include avoiding damage from direct impact of rain, wash-off of applied chemicals against diseases, soil spillage onto crops, better fertilizer use, and less weed problems.

Although the netted structures afforded some protection, many insect pest problems could not be excluded as was found in Malaysia (Loke et al., 1996). The major insect problems as indicated by respondent farmers in a survey were, in order of importance, *P. xylostella*, *H. undalis*, *S. litura*, *A. ypsilon* and flea beetles (*Phyllotreta* spp). Sometimes, aphids posed a problem. Initially, the problems were usually rare, but they would normally build up from the third planting onwards. Like insects, disease problems were also generally less within the netted structures than outside.

A wide range of insecticides continued to be used, mostly Bt, cypermethrin and methamidophos. On average, about 50% of the growers sprayed 2–5 times per crop in the netted structures compared to 5–10 times outside. They used 10–70% (av: 41%) less insecticides, although the concentrations used were the same. A similar situation was also found for the case of disease control where fungicides were substantially reduced. Normally, growers would mix insecticides with fungicides and foliar fertilizers in a single spray operation.

An IPM programme has been developed and evaluated (Loke et al., 1996). Although preliminary results have shown it to be promising, further refinements are needed to improve its overall effectiveness and practical applications. Some measures of success have also been reported in Thailand (Vattanatangum, 1990).

Emphasis on IPM

In principle, IPM attempts to integrate the available pest control methods to achieve a farmer’s most effective, economical, and sustainable combination for a particular local situation. Emphasis is placed on biological control, plant resistance, cultural control, and other non-polluting methods. Pesticides are used only when necessary as a last resort and only when cost/benefit analyses show that their use is truly justifiable and acceptable alternatives are lacking. There are now many IPM success stories reported for several crops in the region, including vegetables (Hansen, 1987; Tait and Napompheth, 1987; Teng and Heong, 1988; Talekar, 1992; Ooi et al., 1992; ADB, 1994). In addition, there exist numerous experimental efforts and successes in many parts of the world that need further verification on a larger scale at the farm level (Wiebers 1991).

To date, the successful IPM programmes have produced many benefits (Hansen, 1987; Tait and Napompheth, 1987; Teng and Heong, 1988; Talekar, 1992; Ooi et al., 1992; ADB, 1994). These include: (1) lower production costs (at farm level) compared with the conventional pest control method with its high inputs of pesticides, (2) enormous savings for governments from pesticide imports and reduced subsidies for pesticide use, (3) reduced environmental pollution, particularly improvement of soil and water quality, (4) reduced farmer and consumer risks from pesticide poisoning and related hazards, and (5) ecological sustainability by conserving natural enemy species, biodiversity and genetic diversity. At a more general level, the stability that IPM provides to agricultural production enhances political stability in a country where agriculture is a dominant sector of the economy. In the rural areas, it is important in developing local self-reliance through farmer empowerment (Kenmore et al., 1994). Thus, IPM can achieve broad and long-lasting socioeconomic benefits far beyond plant protection activities. Many of these benefits are well illustrated by the example of vegetable IPM in the Cordillera highlands of the Philippines (IIBC, 1996). In this case, the parasite, *D. semiclausum*, reduced DBM to a level that was insignificant economically. Pesticide use by FFS farmers were reduced by 80%, including a big shift towards using only less toxic insecticides where needed. Fungicides alone were cut by 50–70% and fertilizers also reduced. The economic benefits included bigger cabbages and higher harvests because of improved crop husbandry practices, as well as, savings in production costs amounting to an average of 37%. Farmers who adopted IPM practices reported a return on investment of >400%, compared to 250% for those who did not. The reduced spraying also led to a noticeable increase in a wide variety of beneficial arthropods. The prerequisites for success were a proven IPM programme, a team of skilled FFS trainers, trained extension staff and adequate support for the season-long weekly sessions.

In general, IPM is a sustainable system and has many benefits, although the impacts may vary with different programmes. It can, and should, replace the current conventional agriculture which relies solely on intensive agrochemical inputs that have caused much unwanted problems. Many individuals and
organisations have recognised this, including many national governments, donors and NGOs. Consequently, there is now seen a stronger movement towards IPM in many of the countries in the region. Donor support and NGOs’ activities in vegetable IPM are also more evident, as may be illustrated by some samples of recent programmes in vegetable IPM, viz: ADB-AVRED support programmes of AVNET, SAVNET and CLVNET which include Bangladesh, Cambodia, India, Indonesia, Laos, Malaysia, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam; World Bank loan support programme for the Agricultural Rehabilitation Project in Vietnam; FAO Inter-country Programme for IPM in Vegetables covering Bangladesh, Laos, Philippines and Vietnam; ACIAR-assisted programme for vegetable IPM in China, ADB-IIBC Project for Highland Vegetables in Cordillera, Philippines; German-support Bread for the World programme in Vietnam; CARE programme in Bangladesh, and World Education in Indonesia. Because vegetables are important food crops and massive amounts of pesticides are rampantly used in their cultivation, it is envisaged that IPM programmes for them would continue to receive strong support. These will have important role in alleviating many of the problems now experienced with vegetable cultivation in the region.

Growing interest in ecological farming and unorthodox practices
In recent years, more and more interest is seen for food production and security to be viewed in the context of a healthier, environmental friendly, and sustainable agriculture, and need for investment in low external input and non-chemical alternatives. Many sustainable agriculture initiatives and approaches based on these principles have been pioneered and pursued, albeit by small concerned groups, comprising mainly those practising organic or ecological farming.

In practice, numerous models exist and are advocated. For the most part the farms exclude synthetic chemical inputs (pesticides and fertilizers) and approach a “closed fertility system” management. Examples of the different “schools” of organic/ecological agriculture include biodynamic agriculture, permaculture, farming with effective microorganisms (EM), ecological/natural farming, and indigenous/traditional agriculture (Tompkins and Bird, 1973; Tebecis, 1982; Fukuoka, 1985; Mollison, 1988; Higa, 1989; Parr and Hornick, 1989; Reijntjes et al., 1992; Lampkin and Padel, 1994; Ong, 1994; Perlas III, 1994; Redfield, 1994). It relies on the science of ecology and respect the wisdom and practices of indigenous farmers.

Among these practitioners, some “schools” believe that most current farming endeavours, even including many organic farmers, have little understanding of life because most believe the farming processes to be purely chemical. Affirming that purely chemical and materialistic explanations of life have collapsed, such “schools”, however, are pioneering a “second scientific revolution”. The new science sees nature as alive and ensouled, and spirit as active in nature and the universe. It incorporates studies on non-material and spiritual properties of life and expands the meaning of ecology to include exploring and working with divine and cosmic forces that nurture the quality and nutritional value of food crops. Examples of such “schools” include Yoko Farming (Tebecis, 1982), biodynamic farming (Perlas III, 1994), and others (Tompkins and Bird, 1973; Redfield, 1994).

Presently, practitioners of organic/ecological agriculture, including those of unorthodox practices, comprise only a small minority of the farming communities. But the numbers appear to be growing steadily, particularly with increasing demand by consumers for organic food free of chemical pesticides. Despite the lack of governmental support for such produce, many small and independent groups have emerged in the Asian countries (e.g., India, Japan, Malaysia, Philippines, South Korea, Thailand) to produce and market them. Initially, many were concerned with organic vegetables and fruits, but expanding into others later. In some of these countries, commercial companies, stores and special sections in some supermarkets, have even been set up in recent years to trade in such products. A few have labels to identify such special eco-products. Guided by this trend, it appears that the organic agriculture industry will continue to grow and expand further in the future, particularly as consumers are becoming more affluent and health conscious due to more and more countries in the region becoming industrialised with improved standard of living.

Related issues, concerns, and what may be done
Some of the above trends observed in crucifer cultivation are truly a cause for concern, in particular, the large number of persistent pests and the heavy reliance on chemicals for their control. That these problems have persisted for a long time, with some becoming even more acute, clearly reflect the weakness of current approaches in dealing with them. Besides, a few new ones have also emerged. All these, along with the other trends noted, have generated new concerns, additional issues and challenges, and have demanded a review of present practices in crucifer cultivation, particularly the pest management strategies and approach. Aspects demanding immediate consideration include various aspects of research, extension and also those relating to policy support.

Research
Ecological and holistic approach in research
With some exceptions, much of the research on crucifer pests until now lacks an ecological and a holistic approach. Each pest is usually considered by itself. Research on control also tends to focus on short term measures, predominantly on chemical pesticides. Hence, researchers and extension workers feel confident only in recommending pesticides. Consequently, farmers know only pesticides as a

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means to deal with pests. This situation is further aggravated by the pesticide industry which is able to push chemical pest control hard, mainly because few alternatives can be offered by researchers and the extension workers. Under such conditions, it is not difficult to understand why farmers have become ‘trapped’ in the pesticide treadmill and there are now many undesirable problems of pesticides.

In nature, each crucifer pest does not occur in isolation by itself. Usually, several different pests may occur together with some overlaps, although each may sometimes peak at different stage of the crop. Some may also concentrate in different parts of the plant. As such, a particular control measure made against any one pest will tend also to affect others, except in the use of specific agents such as parasites (e.g., D. semiclausum targeting only DBM). Applications of Bt against DBM can however also affect other lepidopteran pests on the crop, e.g., H. undalis. Likewise, spraying chemical insecticides against other pests may also adversely affect any successful ongoing IPM programmes where DBM is kept under control by its parasites. As such, research must therefore consider the overall pest complex on the crucifer crop and should aim to deal with them together. A holistic approach is necessary, taking into consideration both the pest-natural enemy ecology and the crop agroecosystems. The latter is important since crucifers are often planted alone or in rotation with other crops, some of which also having a number of common pests. A truly holistic approach, however, should also include diseases, weeds, and other aspects which normally are a part and the process in crucifer production. The strategy, in practice, should be geared towards integrated crop management (ICM).

Research to address farmers’ needs

Although research has contributed much to the advancement of agricultural science, it has for too long also been done with focus for research sake, often in the scientist’s own pet area and to satisfy his/her academic curiosity. Usually, insufficient attention is given to address the real problems of farmers; consequently many pest problems have remained unsolved. This is accentuated by the research approach being normally top-down and lacking accurate or direct feedbacks from farmers of their problems.

In recent years, there is increasing appreciation in the weakness of such a research approach. Consequently, some scientists are initiating research efforts in a bottom-up manner by working closely with farmers and undertaking research which matches the farmers’ needs. Some of these have been effectively achieved through researchers-extensionists-farmers cooperative activities as exemplified by the farmer participatory action research (PAR) activities in FFS. Because of their efficiencies, PAR should continue to be given emphasis and expanded. Also, agricultural scientists who do not undertake PAR should be mindful of their responsibilities in helping farmers and to make more effort in reorienting their research approach towards achieving this objective. They should ensure that their research is aligned with the needs of farmers.

More efforts in biological control

Many crucifers now widely cultivated in the developing Asian countries are exotic vegetables. So also are many of their pests. The latter are posing serious problems because the natural enemies which keep them under natural control in their original homelands are absent. Where these have been successfully introduced, as in the case of DBM parasites, the pest has become unimportant in those areas where there are no or little use of chemical insecticides, whereby the parasites can exert their full impacts (e.g., in Australia, Indonesia, New Zealand, Malaysia, Philippines, Taiwan).

Currently, many of the pests have remained important because few natural enemies appear to exist. Where some indigenous ones do occur, their impacts have normally been inadequate. Consequently, many farmers have continued to resort to relying heavily on chemical insecticides. The successes with introduced parasites for the control of DBM and the persistent failures in controlling many other crucifer pests by conventional means should provide a good lesson on the benefits of classical biological control and in encouraging similar attempts of such an ecological approach to deal with most of the remaining important crucifer pests.

The present inability to satisfactorily handle many of the crucifer pests is a clear reflection of the lack of ecological and biological control efforts towards managing the current pest problems. This is especially so since biological control has been the cornerstone of many successful IPM programmes. Future strategies should therefore include a more concerted effort to search for and import appropriate natural enemies against the major pests now afflicting crucifer vegetables in the region. Incorporating good biological control agents will help in providing the basis for other control tactics to build on and also paving towards the formulation of a good IPM programme. Also, these successes can greatly enhance FFS activities, without which, the benefits from FFS may be less significant. Likewise, FFS activities should be encouraged to educate farmers on the benefits of biological control agents so as to gain their full cooperation in ensuring and expediting the establishment of these beneficial agents. Many attempts at classical biological control in the past have failed because farmers did not clearly understand the efforts. They continued to spray, thereby creating conditions which are not conducive for the introduced beneficial agents.

Research into alternative control methods

Although there are research efforts on alternative control methods (biological control, agronomic and cultural techniques, planting systems, etc) and ecological studies, these are relatively limited. Consequently, understanding of these aspects in relation to crucifer cultivation is still very poor. In contrast,
much exist on the use of chemical insecticides; hence, recommendations focusing on chemical control are aplenty. Consequently, we can expect to continue to immerse in the unwanted problems of pesticide use, including facing persistent pest problems caused by pesticide threadmills.

Under such a situation, what choice then do farmers have? Little, but continue to spray repeatedly! Unless recommendations on alternatives can be offered, their approach of “chemical farming” can never change. Also, unless there are substantially more research efforts devoted into ecological studies and alternative methods, sound recommendations on suitable alternative control cannot be developed. It is therefore clear that scientists must reorientate themselves towards an ecological approach and reallocate more efforts to develop and recommend pest management measures alternative to chemical pesticides. This is crucial if the present scenario of conventional farming practices is to give way to a more ecological and environmentally-friendly farming system, such as IPM and other forms of ecological/ organic agriculture.

**Hidden costs of pesticides**

Although much evidence exist on the unwanted effects of many pesticides, there is little effort made by way of relating them to costs, e.g., costs to human health, environment, natural ecology, etc. Such data are unavailable in most parts of the world. However, in the United States, Pimentel et al., (1993) have computed the overall environmental and social costs for agriculture. The total estimated annual costs amounted to US$ 8 billion. Even this is believed to be underestimated (Pimentel et al., 1993).

In the developing Asian countries, the environmental and social costs can be very high, particularly when the negative impacts of agrochemicals are increasingly being reported. Presently, because such data are lacking, much arguments exist about their hidden costs. There is therefore an urgent need to gather the much-needed information. Since massive amount of pesticides are normally used in vegetable cultivation, in particular crucifers, initial studies made in this environment would appear apt. The data generated could help support and promote the need for alternative control strategies.

**Extension and IPM implementation**

Although extension is aimed at transferring useful research findings for implementation by farmers, generally little of this happens in practice. This is largely due to poor communication or cooperation between researchers and extension workers. Also, it is partly because these separate functions are handled by different agencies. Often, another contributing factor is due to the research findings being not practicable or are of little relevance to the needs of farmers. Hence, farmers do not adopt them. For effective extension, therefore, the basic requisites must include a close working relationship between researchers and extension workers plus relevance of the research to farmers’ needs. Even if these conditions are fulfilled, the extension approach must still be appropriate and effective.

Experiences of IPM extension through FFS have shown such an approach to be highly effective. Although most studies are in rice, there are increasingly more and more in vegetables (e.g., in Bangladesh, India, Indonesia, Philippines, Vietnam). What the FFS entails and the processes involved have been lucidly described by Kenmore et al (1994). Accordingly, an FFS is usually attended by about 25 farmers from the same village or the same area. It is season-long. Once a week an IPM facilitator visits the FFS to help farmers conduct field experiments to understand IPM.

In the FFS, farmers compare and study sprayed and unsprayed fields and conduct agroecosystem analysis by making drawings that illustrate the condition of the crop plant in the study field, the population of herbivores and key natural enemies, and the field conditions. Based on the findings, farmers make decisions on whether to carry out any interventions. This ability to make a decision is helped by carrying out simple experiments to understand the hazards of chemical pesticides, particularly insecticides, on health and natural enemies. Experiments on impact of insecticides on natural enemies and others comparing field cages with and without natural enemies help farmers become aware of the risks involved in using insecticides. In addition, farmers also learn about the number of prey eaten by each natural enemy individual, food preference, and how the natural enemy species survive when no herbivores are available. Exercises and experiments are constantly updated through new research information from national and international institutions. In this way, FFS ensures new research information reaches farmers quickly.

Basically, FFS are conducted for the purpose of helping farmers to master and apply IPM field ecology management skills. Problems are seen as challenges, not constraints. The IPM programme teaches principles. It does not promote packages which tend to discourage learning and increase the dependence of farmers on central planners. All participatory research carried out are responsive to field needs, quite unlike most conventional research programmes which drive the extension or education programme that the research should actually be serving.

To achieve this level of educating farmers, a cadre of good facilitators or extension workers is first trained. These facilitators undergo a season-long training-of-trainers programme where they learn to grow the crop and carry out experiments to learn about nonformal education, and develop a curriculum for FFS. Presently, this human resource is rather limited. Consequently, extension has been weak in many of the countries. Besides other infrastructural needs (e.g., vehicles, other materials required for field schools,
Policy support
A policy environment which discourages the indiscriminate use of pesticides is important for the development of alternative pest control strategies. This may even be a prerequisite in initiating programmes in alternative agriculture (e.g., IPM, organic agriculture). Government economic policies can often undermine a scientifically well-designed programme on alternative agriculture. For example, government technology “packages” that include substantial use of pesticides, or government subsidies for pesticides, will encourage pesticide overuse and reduce the economic incentives to use alternative pest control methods. Furthermore, in some countries, legislation concerning the regulation of pesticide imports, production, distribution, and use may be either absent of ineffective.

On the other hand, some policies may favour alternative agriculture. For example, media publicity on the dangers of pesticides, including residues in food, will encourage its demand. Since policy issues can have a great influence on the development and implementation of alternative agriculture, those involved must be aware of such issues and be able to create conditions that are conducive to it. They include key policy makers in the national governments and their scientists and extension workers, leaders and scientists in international organisations, NGOs and the donors. In general, the following policies are conducive to alternative agriculture and should be encouraged.

* Reduce or eliminate subsidies for pesticides and other credit programmes that distort economic comparisons with non-pesticide alternatives.
* Adopt alternative agriculture as a significant part of national agricultural policy.
* Reorient national research, extension and agricultural education programmes towards non-pesticide practices.
* Earmark specific and adequate funds to ensure that national agencies have the resource to carry out the national agricultural policy on alternative agriculture.
* Promote the phased implementation of alternative agriculture to ensure that sufficient time is given to develop and demonstrate non-pesticide practices that are reliable and sustainable.
* Establish a national monitoring system for pesticide residues and the health impacts of pesticide use, i.e., hidden costs, and publicise the findings.

In recent years, new pests have also emerged, apparently resulting from entry into a country with movements of trade or people. To prevent or reduce further spread, there is therefore a policy need to institute and enforce more stringently the existing quarantine control measures. This requirement will become even more important when the General Agreements on Tariff and Trade (GA TT, now W.T.O.) becomes widely and fully operational in the future whereupon trade liberalisation will increase substantially.

Discussion
The overall scenario of crucifer insect pest problems and their trends, related issues, and management strategies are summarised in Figure 1. Most of the different aspects not only are interrelated but are also influencing one another. Though all are important and need simultaneous attention, some require more effort and focused actions because of their priorities. The key area, wherein lies the root cause of the problems, is a lack in orientation and focus on an ecological and non-pesticidal approach to managing the pest problems. Even until now, negligible resources have been devoted to this area. In contrast, there has been enormous inputs into promoting the pesticide approach only. Only in recent years has there been some reconsideration because of the mounting unwanted side effects encountered in the use of pesticides. Even so, the reversal process has remained largely academic. Most proposals on alternatives agreed upon merely stay rooted in repeated debates and discussion tables, with little actually acted out. Except for a few governments, most are either unable to perceive the need for reversal (e.g., to ecological/organic agriculture, or IPM), or even if able to, are lacking in commitment to follow through. Even many donor agencies are suffering the same way. It is no wonder so many major pests of crucifers have persisted until today, not forgetting a few new ones adding on recently.

A reason commonly cited for the little effort put into ecological agriculture in the past is insufficient resources (funds, human, expertise, others). In reality, it is not so much a lack, but more of an incorrect orientation or disproportionate allocation of the existing resources. If one were to examine closely the resources allocated to pest management programmes (e.g., research, crop production activities, subsidies, promotional programmes, etc), it will at once be evident that disproportionately little has all along been devoted to activities promoting alternative agriculture. This can be clearly seen in practically all national government allocations in the region. Again, this is also true for those of many international organisations, including donor support programmes. Consequently, alternative and ecological/organic agriculture cannot be expected to grow otherwise, but only very slowly.

If national governments, international agencies and donor support programmes were to now have a policy to support more fully organic and other
alternative agriculture, and reallocate, say, even only 50% of their pest management and crop production resources towards the support of such non-pesticide programmes, it can be envisaged that such understanding and technologies would rapidly become available within the decade, or even a shorter period, by way of alternative agriculture, particularly in ecological/organic farming. Because of policy change, hence reorientation of resources (people, funding, infrastructure, incentives, etc.), the research programmes, emphasis and focus will immediately be redirected to produce the technologies needed to develop, support and sustain alternative agriculture, including ecological/organic farming. In parallel, other undertakings to support the alternative agriculture economies would likewise receive emphasis and be developed. These would include appropriate government incentives (e.g., initial support subsidies), legislative regulatory protection (e.g., certification or eco-labelling of organic produce, or even IPM products with no detectable pesticide residues), and assistance in administrative and commercial infrastructural support (e.g., competitive commercialisation of natural enemies for pest control, easily available compost or organic fertilizers, etc). Unless such concerted efforts are directed towards developing an efficient distribution and marketing network for a viable alternative agriculture industry, it would take a very long time, or probably even impossible, to overcome the current pesticide-based agriculture that has already gained a strong foothold in most national economies.

Should the present trends persist, which are likely if there is no firm policy change towards alternative agriculture, it is probable that much of the pest and pesticide problems we now encounter with crucifer cultivation (or vegetables and other crops in general) will continue, or even escalate, well into the next millennium, proceeding in the same way of the past. We are now staring at the problems because we did not fully foresee the ecological implications and thus have failed to deal with them effectively over the past decades. But, failing to act quickly in reorienting towards the ecological approach now that we have comprehended its importance would merely mean we lack foresights, could not learn from past mistakes, or are irresponsible. If so, we therefore deserve to continue to inherit all the crucifer pest problems and others associated with pesticide-based control practices.

Judging by situations in the past, to look for a drastic change appears to hold little promise. However, there is a glimmer of hope in that several agricultural sectors have acknowledged the serious problems of pesticides and some have begun efforts to address them. For example, the Malaysian Agricultural Research & Development Institute (MARDI) has in recent years set up a unit on natural farming to develop organic agriculture. Many NGOs in the region also have such initiatives. Although there is increasing funding support towards IPM by donors, very few gave support to other forms of alternative agriculture, e.g., organic farming. These efforts, however, are relatively small in comparison with those activities which still use a lot of pesticides. At least IPM, has gained wide acceptance and is now actively being promoted in the region, including on crucifers. Although IPM still accepts a minimum amount of pesticide inputs where needed, it nevertheless can play crucial role towards reducing quite substantially the present pesticide use. It also will help slow down, but not curb, the uncaring onslaught of conventional agriculture.

Despite it being widely accepted, IPM development and implementation, particularly on a wide scale, have continued to face a number of constraints. Though many general attributes and requirements for IPM success are now known, these need to be properly addressed.

Firstly, it is important to destroy the myth that IPM is too complicated. Experience has shown that IPM can work well in developing countries and is within the reach of farmers who have received appropriate training and help in terms they can understand. For example, IPM in a number crops in many developing countries, including crucifers in Southeast Asia, has reduced pesticide applications 30–100% while yield stayed the same, or even increased. The net result may be a higher profit to the farmer.

Another important attribute is political commitment or governmental support to IPM. It can be disastrous if this is lacking. For example, a policy environment conducive to IPM will serve to discourage the use of pesticides. Adequate technical information and technologies are also important. These should meet the needs and capabilities of farmer groups. On research in IPM, it must involve extension workers and the farmers so as to ensure that cultural and social realities of farmers are included. The research must be field-oriented and geared at solving farmers’ problems while considering appropriate risk management. For insect-based IPM, emphasis on biological control is crucial. Its absence, or disruption when present, is usually the main reason for a continuous insect problem. Introducing effective biological control agents is therefore a necessary first step if these are absent. Presently, most IPM still applies to single pest/crop. A holistic or ecosystem approach is necessary. Special consideration should also be given to human resource development. In particular, farmers’ training must emphasise the hands-on and self-discovery approach because IPM is not something which is done for farmers but done by farmers. Funding is crucial, especially for implementation of selected IPM projects which have adequate support to strengthen farmers’ training.

Because IPM still permits the use of some agropesticides, unlike ecological or pure organic agriculture, IPM can be seen as a first forward step away from the current “chemical farming” and moving towards a more stable and sustainable alternative agricultural system. Ensuring its adoption over a wide scale is thus crucial and could possibly pave the way for a full reversal to alternative agriculture eventually.
Figure 1: Scenario of crucifer insect pest problems and their related issues and management strategies.

Through this process, many mutual benefits with nature can be reestablished and gainfully harmonized. Every effort, therefore, should be made by all concerned to achieve it.

References


Appendix 1. Negative impacts from excessive use of pesticides in agriculture (including crucifer vegetables)

1. **Upsetting Pest Ecology:** Insect outbreaks induced by insecticides may result because some chemicals can selectively kill the pest’s natural enemies. Without the latter, and especially where the insecticide is insufficiently effective because the pest has become resistant, then pesticide-induced outbreaks can readily occur. Applying insecticides may therefore sometimes create rather than suppress a pest problem.

Another effect on pest ecology is that pests can readily develop resistance to the insecticides used against them. Today, this is proliferating in many parts of the world. A classic example is that of diamondback moth on crucifer vegetables in Southeast Asia where the moth has become resistant to almost all kinds of insecticides introduced into the market (Lim, 1990). In Hawaii (Tabashnik et al., 1992) and elsewhere, it has even become resistant to the biological insecticide, *Bacillus thuringiensis*.

The effects of insecticide-induced outbreaks and insecticide resistance can combine to cause a phenomenon known as the *pesticide treadmill* characterised by an upward spiral of insecticide use, increasing input costs, and declining income as uncontrollable number of insects reduces yield. Today, *pesticide treadmills* have occurred on many crops, including crucifer vegetables (Hansen, 1987, Teng and Heong, 1988, Ooi et al., 1992).

2. **Adverse Effects on Domestic Species, Wildlife and other Living Organisms:** The adverse impacts of pesticides have included numerous nontarget species, both domestic (usually pets, poultry and livestock) and wildlife (mostly earthworms, aquatic lives, honeybees and beneficial arthropods, and birds). In aquatic systems, they are mostly invertebrate species (such as crustaceans) and fish which may also be used as food.

Soil-inhabiting species such as springtails (Collembola), pauropods, symphylids, millipedes, centipedes and other ground dwelling arthropod predators, and earthworms, are also severely affected (Edward, 1991). They have benefitting role in crop production. Mites which occur abundantly are badly affected by acaricides, some insecticides and soil-fumigants, in particular the more active predatory species.

Effects on microorganisms are more complex and less understood because some can utilize pesticides as food sources or are involved in complex food chains. In general, any effect is relatively transient; the populations usually recovering in 2–8 weeks.

3. **Reduction and Loss in Biodiversity:** Agricultural intensification can adversely affect biological and genetic biodiversity. Heavy insecticidal use kills both insect pests and other organisms. A field freshly treated with wide-spectrum insecticides usually contains very little biological activity while even an adjacent untreated one will retain its faunal richness, both in numbers and diversity. In treated fields, biodiversity will gradually increase only if there is no further treatment. Otherwise, biological life will remain relatively very poor.

Natural enemy species used in biological pest control constitute a large component of the world’s biodiversity and are valuable to sustainable agriculture. They can often replace pesticide inputs. Topping the food chains, they play important role in regulating the balance of their preys to ensure co-existence of species by allowing none to become too abundant (CABI, 1994). Biodiversity, a property of living systems (Solbrig, 1994), is a characteristic of nature; thus, destroying biodiversity is destroying nature.

4. **Pesticide Contaminations in Food and Food Chain:** Pesticide residues are found in many market produce, particularly fresh fruits and vegetables (Lim, 1990). For example, tomatoes obtained from several local markets had residues of dithiocarbamate fungicides ranging from 0.21 mg/kg CS₂ to 15.8 mg/kg CS₂. About 65% of these contained residues in excess of the maximum residues limit of 3 mg/kg CS₂ set by FAO/WHO (1978). When permethrin was applied on *Brassica rapa* at 0.04%, the total residues may reach 10.31 ug/g. In the case of endosulfan (applied at 0.5%), the level of total residues reached was 184.28 ug/g. Ong (1990) recommended against using endosulfan on short term crops where 14-21 days waiting period cannot be practised.

High pesticide residues were also found in many market vegetables in Indonesia, the Philippines and Thailand. The widespread occurrence suggests that many currently unsurveyed produce in the region may also contain excessive residues. This has far reaching implications in trade between countries because of rejections by importing countries of the contaminated produce.

5. **Contaminating the Environment:** Enormous quantities of pesticides are used on crucifer vegetables and are increasing. The full degradation pathways or ultimate fate of many in the field are still not fully known. Many pesticides do not reach their targets but instead end up in the crops, other vegetations, animals, soils, or water. Persistent residues usually end up in soils or aquatic sediments in water bodies.
6. Impacts on Human: Pesticides also harm human health. Both acute and chronic poisonings have long been reported, although deaths may not frequently result. For example, 28.1% of 153 vegetable growers surveyed in Malaysia suffered poisoning symptoms, including headache, dizziness, nausea, and general fatigue soon after spraying operations (Ramasamy and Nursiah, 1988). Sometimes, skin rash and dermatitis are evident. Often, mild poisoning symptoms may be ignored because they are taken as signs of working too hard or due to influenza as noted in Indonesia (Mustamin, 1988). In Thailand, there were 4,046 poisoning cases in 1985 (Kritalugsana, 1988) and 824 cases in the Philippines in 1984 (Castaneda, 1988). However, not all of these are due to accidental or occupational poisonings. Substantial numbers are because of suicides.

On human health impact, the costs can be quite significant as found for rice. For example, comparative studies made in the Philippines on health status of farmers exposed to pesticides with those unexposed showed that chronic impairment of health was associated with prolonged exposure (Rola and Pingali, 1993). Farmer health costs increased by 0.74% for every 1% increase in insecticide dose. The health impairments included eye, skin, lung, cardiovascular, and neurological diseases.

More recently, there are concerns about public health risks from pesticide-induced suppression of immune system (Repetto and Baliga, 1996). Many tests revealed that a variety of organochlorine, organophosphate, carbamate, and metallic pesticides are immunotoxic and can alter the immune system’s normal structure, dis regulates and disturb immune responses, and reduce the resistance of exposed animals to antigens and infectious agents. That pesticides are immunosuppressive in humans are increasingly being suggested by both indirect and direct evidence.

7. Hormonal Effect: Recently, some pesticides with weak potential to imitate the female estrogen hormone on their own were found to become hundreds of times more potent when they are combined. For example, test of four pesticides (chlordane, dieldrin, endosulfan and toxaphene which are weakly estrogenic alone) on genetically engineering yeast cells showed the estrogenic effect was greatly enhanced when they are paired. In particular, potency in the pair of endosulfan and dieldrin increased substantially by 160-1,600 times.

The findings suggest that exposure to mixes of chemicals routinely found in the environment could be posing a much greater risk than suspected and that normal government screening of pesticides may be inadequately protecting the public from reproductive ailments and declining fertility. Evidence that “gender-warping” chemicals boost estrogen or block testosterone and damage sex organs has emerged only in recent years and the evidence is mounting steadily. Tests have shown that several manmade chemicals can damage even at low levels the sexual development of a fetus. While the adult is unaffected by the exposure, the damage is passed to the next generation through the womb. Among wildlife, many animals including alligators in Lake Apopka (Florida), birds in the Great Lakes (Michigan) and otters in Columbia River are born with super-estrogen levels, small penises or malformed testes. All these are suspected to be linked to pesticides and other industrial chemicals.