Insect Problems in Crops for Processing*

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The differing motives of growers, processors and the public for controlling pests are discussed, and effects of changes in crop production systems are noted.

For each crop/pest/market problem, damage by particular pests has a unique importance and can be expressed as the frequency of occurrence of damaged crop produce ("units") and the amount of damage done to each. By reference to pests of vegetables, damage is classified according to whether it prevents the plant reaching maturity, or affects the unmarketed or the marketed part of the plant.

A distinction is made between the efficiency and the effectiveness of control measures. Their limitations and associated problems are also discussed.

1. Introduction

Processing crop produce is expensive, representing a large investment relative to the production costs of the crop. Its value therefore increases several-fold between the farm-gate and the retail price of the canned, quick-frozen or freeze-dried commodity. Most processed produce, however, competes directly with the pre-packaged or fresh market equivalents which tend to set ceiling retail prices for processed commodities. The housewife and the catering industry are therefore the final arbiters of what constitutes an acceptable price differential to pay for the convenience of the processed product. Consequently production costs are closely scrutinised at all stages, including the growing of the crop, and there is therefore a strong incentive to optimise pest control operations to achieve a maximum cost/effectiveness.1

Only crop produce of the highest quality is worth processing and even slight damage, whatever the cause, can greatly increase grading costs and assume an importance out of all proportion to the actual amount of damage done. The significance of pest damage to crops for processing, and to vegetables in particular, has been discussed at length2-5 and the more important pest problems in the United Kingdom have also been described.5-6 Ideally, the basic requirement is to protect plants until harvest and so ensure that supplies of blemish-free produce of the correct form and quality are available to meet factory processing schedules. Many present-day control measures using insecticides cannot protect crops sufficiently to meet the stringent tolerances now being placed on pest-damage incidence in crops for processing,7 but it is very questionable whether some objectives set for pest control measures are realistic.1-8

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In this paper, damage by pests of vegetables is described as a generalised concept, and classified according to its impact on crop production. Aspects of insecticide usage which effectively limit standards of pest control in vegetables are discussed to illustrate some present difficulties.

2. Pest control motives and crop production systems

The motives for undertaking pest control operations on crops destined for processing are not always obvious. Different motives influence the actions and points of view of the growers, the processing organisations and the public, but economics, and not yield, is usually the dominant consideration.

Pest control operations are only one of the many factors which interact to determine modern systems of crop production. Some intensive agricultural systems, which have developed directly as a result of appropriate chemicals being available for pest, disease and weed control, are reducing the effectiveness of the very chemicals on which the systems depend, thereby increasing the problems. 6, 8

2.1. Motives for pest control

The grower seeks primarily to guarantee the profitability of his enterprise, and hence his income. He is increasingly forward-contracting, committing himself to obtaining good yields of high quality crops of the form specified in the contract. A low yield, or a crop of mis-shapen, blemished produce, may be valueless even though edible. The present inability to predict those crops which will be significantly damaged by pests or diseases compels the grower to resort to insurance-type treatments, even when there is only a low probability that significant damage will occur. Some unnecessary expenditure on pesticides is therefore inevitable until methods for forecasting pest incidence improve.

The processor has a large investment in processing plant and equipment, and also some social obligation to maintain employment of labour. A steady daily intake of raw produce in accordance with a pre-determined time-table is essential to guarantee full productivity for the factory while a succession of crops will be processed. Variations in quality attributable to pest damage, or to the presence of pest organisms in the produce, can greatly impede production and increase costs alarmingly. Seeking always the highest quality of produce, the processor is liable to vary acceptance tolerances and, unfortunately, is generally reluctant to specify precise standards for accepting or rejecting produce. Growers are often puzzled by decisions based on fluctuating criteria and the research worker or advisor has difficulty in deciding how effective pest control methods need to be; optimum pest control strategies cannot therefore be easily devised or recognised if attainable objectives are not first set. 1 When sold, a processed product almost invariably bears a brand name and must conform to the requirements of the relevant Food and Drug Act Regulations which make it illegal to sell unwholesome food for human consumption. The processor is responsible for excluding pests and their debris from the finished product, as well as for ensuring that pesticide residues are either absent or do not exceed stated concentrations. To maintain sales of the finished product, taints, off-flavours or losses of flavour arising from pesticide or other treatments must also be avoided.
Insect problems in crops for processing

Until recently, the public has been primarily concerned with obtaining a low-priced, high quality product but public interest has now broadened to include concern about the possible adverse consequences of pesticide usage on the environment. Without pesticides, crop production systems would have to become less intensive, production costs would increase and quality would certainly decline. With research development and marketing costs for a new pesticide now estimated to be £2 million to £3 million, and increasing, few new chemicals with only limited applications are likely to be developed. It is in the interests of all parties concerned, therefore, to ensure that the present range of insecticides is used rationally and economically so that their useful life is not curtailed before there are satisfactory alternative methods of pest control.

2.2. Crop production changes

Vegetables for processing are grown almost entirely on a farm rather than a small, horticultural scale. Modern production systems rely on herbicides for weed control, permitting great freedom to use different plant arrangements and densities to achieve the required size grades and yields of produce. Extensive mechanisation of production involves large capital inputs, large-scale crop production methods and consequently specialisation in only a few crops. Even for a large farm exceeding, say, 500 acres, this implies that rotations will be short, if indeed any significant rotation is possible from the viewpoint of the separation distances necessary to counter the mobility of some pest populations. Technical problems, including pests, are recognised as inevitable and seem often to be unique to a particular holding, locality or system or production in accordance with the developed agro-ecology. Research on each situation is not feasible. It is therefore essential to develop sound, broad-based principles of pest control which can be applied readily and still guarantee supplies of produce for processing. Entomologists agree that no single method of pest control will provide a complete solution to all pest problems and that total reliance on insecticides is not a wise strategy.9

3. Pest damage

Damage by insect pests is usually described and classified according to their feeding habits or behaviour. The descriptions do not usually relate to the economic impact of the pest damage and more practical classifications need to be based on the effects on the crop and the produce rather than any particular attributes of the causal organisms.

3.1. Basic concept

The status of a pest in a particular crop/market problem seems to be determined by two parameters, namely the proportion of crop units (the whole plant or the saleable commodity such as the potato tuber, the cauliflower curd, the apple, the pea and so on) affected and the severity of damage to each affected unit. This concept has been represented graphically using linear scales1 but, in crops for processing, pest damage tolerances tend to approach zero and so most interest centres on the zone near the origin. If logarithmic axes are used (Figure 1), small amounts of damage are emphasised. This is more helpful and also avoids the implications that pest damage can be
completely prevented, or that zero tolerances for pest damage can be attained economically. Using this concept, specifications for pest damage could be stated quantitatively to provide standards against which to measure the performance of pest control methods.

Figure 1. Unifying concept of pest damage relating the percentage of damaged crop “units” (see text) to the amount of damage on each. Modified after Wheatley and Coaker (1970). A = zone of total crop loss; B = zone typical of Type 1 damage; C = zone of minimal damage for Type 3 problems involving crops for processing; D = zone typical of Type 2 problems in which small amounts of damage are permissible on a high proportion of the crop plants or “units”.

3.2. Classification of pest damage

The types of damage of practical significance to vegetable crops are classified in Table 1 which summarises and extends previous descriptions. Examples of pests perpetrating the different types of damage are also shown in the Table.

Type 1 damage prevents the crop plant from maturing, usually killing it at an early stage of growth. The primary effect is to reduce plant density erratically, leave a “patchy” stand of crop and make the surviving plants less uniform so that an adequate yield of produce of the desired form and quality is not obtained. This effect can occur if large numbers of carrot seedlings are killed by carrot fly maggots (Psila rosae F.). Type 1 damage is usually of most concern to the grower in his attempts to meet contracts profitably. The processor is only concerned if the damage is sufficiently widespread to limit supplies of the produce meeting his specifications. Subtle effects on quality, such as minor changes in flavour, may affect most if not all supplies but would probably not be noticed. The importance of Type 1 damage is increasing as growers come to rely
<table>
<thead>
<tr>
<th>Damage Effect</th>
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<tbody>
<tr>
<td>Destroys plant before maturity</td>
</tr>
<tr>
<td>“Uneven plant stand”; yield reduction; undesirable compensatory growth</td>
</tr>
<tr>
<td>To unmarketed part of the plant</td>
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<tr>
<td>Plant vigour suppressed; affects earliness, quality and ultimately yield</td>
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<tr>
<td>To marketed part of the plant</td>
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<tr>
<td>Reduces marketable yield; increases sorting/grading costs</td>
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<table>
<thead>
<tr>
<th>Standard of pest control required</th>
<th>High</th>
<th>Moderate</th>
<th>Very high</th>
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<tbody>
<tr>
<td><strong>Aphids</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Willow-carrot (Cavariella aegopodii Scop.)</td>
<td>Y</td>
<td>X</td>
<td>—</td>
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<tr>
<td>Pea (Acrlyrphilon pismum Harris)</td>
<td>Y</td>
<td>X</td>
<td>—</td>
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<tr>
<td>Black bean [Aphid fabae (L.)]</td>
<td>—</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cabbage [Brevicoryne brassicae (L.)]</td>
<td>—</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Caterpillars</strong></td>
<td></td>
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<td></td>
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<tr>
<td>Pea moth (Laspeyresia nigricana Steph.)</td>
<td>—</td>
<td>—</td>
<td>X</td>
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<tr>
<td>Cutworms (Noctuidae)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cabbage moth [Mamestra brassicae (L.)]</td>
<td>—</td>
<td>—</td>
<td>X</td>
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<tr>
<td>Silver-Y moth [Plusia gamma (L.)]</td>
<td>—</td>
<td>—</td>
<td>X</td>
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<tr>
<td><strong>Root maggots</strong></td>
<td></td>
<td></td>
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<tr>
<td>Cabbage root fly [Erioischia brassicae (Bouché)]</td>
<td>Y</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Carrot fly (Psila rosae F.)</td>
<td>X</td>
<td>—</td>
<td>X</td>
</tr>
<tr>
<td>Onion fly (Delia antiqua Meig.)</td>
<td>X</td>
<td>—</td>
<td>X</td>
</tr>
<tr>
<td>Bean seed fly (Delia platura Meig.)</td>
<td>X</td>
<td>—</td>
<td>X</td>
</tr>
<tr>
<td><strong>Leaf miners</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Spinach (Pegomyia betae Curt.)</td>
<td>—</td>
<td>—</td>
<td>X</td>
</tr>
<tr>
<td>Calabrese (Phytomyza rufipes Meig.)</td>
<td>—</td>
<td>—</td>
<td>X</td>
</tr>
<tr>
<td>Pea (Agromyzidae)</td>
<td>—</td>
<td>X</td>
<td>—</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pea midge (Contarinta pisi Winn.)</td>
<td>—</td>
<td>X</td>
<td>—</td>
</tr>
<tr>
<td>Wireworms (Elateridae)</td>
<td>Y</td>
<td>—</td>
<td>X</td>
</tr>
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X, Most, Y, least important effect.
more on precision seeding to achieve plant densities appropriate to each commodity and hence require a 95% assured stand of plants. The principal pests causing Type 1 damage on crops grown in the U.K. for processing are the carrot fly maggot, the willow-carrot aphid (*Cavariella aegopodii* Scop.), the pea aphid (*Acyrthosiphon pisum* Harris), the bean seed fly maggot (*Delia platura* Meig), the onion fly maggot (*Delia antiqua* Meig.), the cabbage root fly maggot [*Erioischia brassicae* (Bouché)], cutworms (larvae of *Noctuidae*) and wireworms (larvae of *Elateridae*).

Type 2 damage occurs on the unmarketable parts of the plants, usually suppressing their growth and vigour although not necessarily in proportion to the degree of attack. Plants can often withstand appreciable amounts of damage before the yield of marketable produce is measurably affected. For example, cabbage root fly larvae must usually destroy more than one-third of the roots of Brussels sprout plants before the yield of sprouts is measurably reduced. The effects vary with weather and soil conditions, being much less evident when the soil is moist and when evapo-transpiration is minimal. Fertiliser practice also affects the importance of Type 2 pest damage. When only Type 2 damage is involved, and small amounts can be tolerated, very high levels of control are not necessary. However, some pests also cause other types of damage to the same or adjacent crops necessitating more effective control than might otherwise be necessary. Aphids may not themselves always cause severe Type 2 damage but even small numbers on the crop can introduce and spread viruses which impair crop growth yield. A specific strategy is needed for each pest.

The damage classified as Type 3 is undoubtedly of most importance to the processor since it affects the marketed part of the crop plant. The problem may be the blemishes or holes caused by the feeding activities of the pest (Type 3A), for example cutworm or wireworm holes in carrots or potatoes. The pest itself, or its debris, may be present in a proportion of the crop units (Type 2B) as in the case of dipterous larvae in carrots, Brussels sprouts, calabrese, spinach, etc. Even when affected units can be graded-out, it is costly. Not all pests can be detected, for instance cabbage root fly maggots in Brussels sprouts, and it has become necessary recently to restrict the period when sprouts can be accepted for quick freezing. During late summer, Brussels sprout crops can harbour maggots of the cabbage root fly in a small proportion, often less than 1% of the developing sprout buttons. The recommended control involves spraying trichlorphon at weekly intervals starting one month before harvest but, if more than about 1.5% of the Brussels sprout buttons are attacked, this treatment will not reduce the incidence sufficiently to meet the usual tolerance (<0.4% infested sprouts at harvest) to prevent the crop being rejected. By the end of October most of the larvae have left the sprouts and those damaged can be seen and graded out before quick-freezing.

Crops of peas have been rejected on occasion because of the occurrence of pupae of the hover fly, the larvae of which are important predators of the pea aphid. Although the pupae are readily visible among the peas, they are approximately the same shape. Consequently they behave similarly in the grading machinery and cannot be readily separated from the peas in bulk by mechanical methods. The presence of pest debris such as the faeces of caterpillars or cast skins of aphids is similarly unacceptable in the processed commodity.

A zero tolerance is usually stipulated as an ideal objective for several Type 3 damage
problems but, as has been emphasised,\(^1\) this is not a realistic objective for pest control. It cannot be attained by present methods and, in any case, the detection of low (not zero) incidence damage is not likely to be reliable, a typical quality control problem. It is difficult to agree acceptable and realistic tolerances because of emotive influences and, indeed legal requirements. Recently, a processing firm was found guilty and fined for selling an unwholesome article of food, a can of peas which contained a caterpillar, although it was acknowledged that all reasonable precautions had been taken to prevent such an occurrence.\(^1\)

Type 3C damage, caused by the entry of secondary infective organisms through primary lesions caused by the pests, is mainly relevant to the keeping qualities of produce in store. Most produce, however, is processed quickly after being harvested and Type 3C damage is not an important problem in all processed commodities. Since storage is costly, only undamaged produce is worthwhile storing. Fortunately, post-harvest treatment of crops such as carrots with fungicides can now greatly reduce losses arising from secondary infections.\(^1\)

### 3.3. The pests

Many pests, and particularly soil-inhabiting species of dipterous larvae, are responsible for more than one type of damage to the same crop (Table 1). Separating damage on the basis discussed here emphasises the need to consider the influences and interactions of pest activities between generations both within a crop and between adjacent host-crops. Cabbage root fly maggots will kill unprotected brassica plants in the seed bed (Type 1). They also attack the plants after transplanting, killing some and stunting others (Types 1 and 2), they will damage radish and swedes (Type 3A) and some invade a small proportion of developing Brussels sprout buttons (Type 3B) during late summer and autumn. With such a wide range of host crops, co-ordination of pest control measures will obviously be necessary before cabbage root fly populations could be suppressed even locally since the insect is now known to disperse for distances in excess of a kilometre between generations. Plant spacing also affects the microclimate within a crop,\(^6\) influencing pest infestations in ways that are not yet understood. Recent research has indicated that the crop cultivars can differ appreciably in their susceptibility to some pests so that the choice of cultivar will also be involved in determining the level of subsequent infestations and hence influence the effectiveness of pest control operations, as discussed below. Even for short-term vegetable crops, it is obvious that a much longer-term and broader view of pest control must be taken than is now usual in order to achieve an overall suppression of pest populations.

Studies of population dynamics are beginning to reveal the key factors regulating pest populations. The mathematical models involved should enable the likely impact of different pest control strategies to be explored theoretically. The models are not yet complete. For instance, none takes account of the important local effects of host-plant density. They are, however, likely to emphasise the importance of the beneficial predatory and parasitic organisms, such as the beetle predators of the cabbage root fly, and as the models are further developed it should become possible to anticipate many problems. In general terms, we are now aware that insecticidal control measures which interfere least with the natural enemies of pests are generally to be preferred to those
which kill friend and foe alike, but it should be possible, eventually, to make quantitative predictions and perhaps to manipulate pest populations more readily once the interactions of the key factors are understood.

Insecticides are able to control some types of damage more easily than others. In the case of carrot fly maggots attacking carrot seedlings, the Type 1 damage is readily prevented by a wide range of insecticides, including some applied as seed dressing. However, protection of the growing carrot steadily diminishes as the residues of the insecticide are degraded and the carrots mature.\textsuperscript{13} Damage increases progressively during the late autumn and winter, gradually reducing the yield of marketable produce, increasing the costs of grading-out damaged carrots and eventually making the crop uneconomic to market.

There are strong indications that future recommendations for pest control will tend to become more specific and tailor-made to enable each grower to solve his particular crop/pest/market problem. Consequently generalised recommendations are likely to become less and less satisfactory, even as a basis for solving particular problems.

4. Efficiency and effectiveness of control measures

A lack of common understanding of the basic factors operating in a pest/host-crop system frequently leads to confusion when research workers, advisors and growers discuss the performances of insecticide treatments. To resolve this problem, a clear distinction will be made between the terms \textit{efficiency} and \textit{effectiveness} as they refer to pest control measures.

4.1. Efficiency of control measures

Within broad limits, insecticidal methods of pest control operate as density independent factors, reducing pest populations by fixed proportions irrespective of the numbers of the pest present. This proportional reduction of a pest population is defined as a measure of the efficiency of a treatment and it is analogous to "\% mortality" in laboratory toxicological experiments. \textit{Efficiency} is expressed as the \% reduction in numbers of the pest caused by a treatment, when compared with the numbers present in a comparable untreated population, the time and conditions of the comparison being stated and implicit in the definition.

Experiments have shown that treatment efficiencies can be surprisingly consistent, provided all aspects of the treatment (chemical, application method, soil type, etc.) are similar. The recommended bow-wave application of phorate for control of carrot fly maggots\textsuperscript{14,15} reduces carrot fly larval populations by an estimated 80 to 90\%, 12 to 16 weeks after sowing in peat soils but it achieves this efficiency for 25 to 30 weeks in light mineral soils. Dieldrin incorporated into soil for carrot fly control was estimated to be 99.0 to 99.5\% efficient in reducing the maggot infestation; it was certainly not 100\% efficient as rumour tended to imply.\textsuperscript{8} The triple sprays of trichlorphon to control cabbage root fly maggots in Brussels sprout buttons have been reported to reduce infestations by up to 88\% in experiments,\textsuperscript{16} but by only an average of 68\% in practice.\textsuperscript{17}

In appropriately designed experiments, research workers can readily determine the efficiencies of chemical treatments directly, by counting the numbers of insects on
treated and untreated plots and calculating the percentage reduction attributable to the treatment(s). Efficiencies can also be determined indirectly by assessing pest damage but this gives a reliable estimate of efficiency only if the relationship between damage and insect numbers is already understood, as in the case of carrot fly control. When the efficiencies of treatments have been determined, their relative merits are usually evident and their performance in practice, or effectiveness, can be largely predicted.

4.2. Effectiveness of control measures

The effectiveness of a treatment is of most concern to the grower and processor but it depends on factors other than the intrinsic efficiency of the treatment.

A simplified relationship for carrot fly attack on carrots is illustrated diagrammatically in Figure 2 to show how the intensity of pest attack, the population density of host-plants and efficiency interact to determine effectiveness. The intrinsic efficiency of a treatment should be characterised independently as described above and should therefore be known. The grower determines host-plant density and the area of crop (total numbers of host-plants) but, to meet particular needs, he may alter the density of carrots ten-fold from about 65–100/m² (large carrots for dicing) to 500–700/m² (small carrots for canning whole). The intensity of carrot fly attack itself depends on many factors, including local cropping history and the abundance of host-crops. Where

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**Figure 2.** Illustration of some factors and interactions relating efficiency and effectiveness of control measures for carrot fly control.
carrots are grown intensively in East Anglia, large infestations usually occur. In other areas where carrots or other host crops are grown infrequently, attacks tend to be less severe but recent surveys in East Anglia by Agricultural Development and Advisory Service entomologists have shown that light infestations of this pest are present in most if not all treated carrot crops. An infestation affecting only 1% of the carrots implies a population of at least about 10^4 larvae/ha, and crops are usually much more severely infested than this if they are left to overwinter.

It is obvious that the effectiveness of a control measure will vary from occasion to occasion, even though its efficiency may remain unchanged. Consequently comparisons of the effectiveness of different treatments are most meaningful within, rather than between, trials. Even if information is obtained on plant densities and the intensities of infestations, such data cannot yet be used quantitatively to make valid comparisons of effectiveness. False conclusions were drawn from trials during the 1960s when searches were being made for alternatives to the cyclodiene insecticides for carrot fly control. Infestations of the pest were very low at that time and rarely affected more than 10 to 15% of untreated carrots. Treatments which reduced an infestation to 3 to 5% damaged carrots were thought to be satisfactory substitutes because they apparently "controlled" the pest to acceptable levels. Their efficiencies, however, were too low and they could not protect crops adequately against the more severe attacks which arose as carrot fly populations subsequently increased.\textsuperscript{1,8,19} For carrot fly control, any treatment which is not at least 90% efficient for 20 weeks after sowing should not be accepted as a general recommendation since, in practice, it would not be sufficiently effective against even moderate attacks. Efficiencies in excess of 95% are required if at all possible.

If the concepts of efficiency and effectiveness are understood, confusion in describing the merits of treatments can be avoided. It should only be necessary to determine the efficiencies of most candidate insecticides, and this can be done readily in a few well-conducted trials. When the efficiency has been determined, the effectiveness of treatments should be largely predictable, by comparison with those for other chemicals already in use for the same purpose. Thus two chemicals with efficiencies of 90% should exhibit the same range of effectiveness in practice.

5. Associated problems

In crops for processing, controlling a pest is not an end in itself nor is the objective primarily to improve yields. Pesticides are used to control pests mainly as an aid in maximising profitability of the enterprise which implies optimising yield and automatically involves the other factors in the crop cultural systems. Growers and the processors have to ensure that the final product is acceptable and must therefore concern themselves with appearance, flavour, pesticide residues and also agronomic trends which may be economically desirable and yet work contrary to pest control requirements.

The relationships between economic return from a crop, expenditure on pest control, and the amount of pest damage are not very well understood but recent experiments at Wellesbourne have suggested that they may be even more complicated than is generally
believed. When continuous logarithmically-changing doses of insecticide were applied to cauliflowers, and Brussels sprouts or carrots, the dose-response relationships for insecticidal efficiency, crop growth or yield were not always regular trends but showed unexpected deviations indicating that there were optimum doses. There were indications that the different doses affected some, but not all, of the species of beetle predators of the immature stages of the cabbage root fly and also that some insecticides had apparently subtle effects on plant growth, affecting maturation rates of the crop, or suppressing or enhancing yields of produce in different size grades. Not all the several recommended methods for controlling cabbage root fly maggots on Brussels sprouts, for instance, are always economic alternatives. A bow-wave application of chlorfenvinphos protected an April-sown crop from root damage as well as a pre- or post-singling surface band treatment, but each method resulted in a different weight of sprouts in the freezing grade. We have very little knowledge or experience of such effects on which to base more precise recommendations at the present time.

The difficulties of achieving the very high standards of pest control being demanded by processors highlights the limited efficiencies of present methods and some residual pest damage is inevitable in crops such as carrots. Furthermore, recent attempts to improve the efficiencies of control of cabbage root fly, carrot fly, and similar pests have not been very successful, nor have the limiting factors been specifically identified.

Interpreted literally, demand for damage-free produce implies eradication of the pests concerned, but this cannot be achieved economically at present. Attempts to eliminate damage by increasing the frequency of application or the dose of insecticide are generally unsuccessful, even in experiments. Increasing pesticide usage creates residue problems and tends to shorten the useful life of chemicals by encouraging the development of resistant strains of the pests. Intensifying the use of insecticides or using highly persistent chemicals are not now accepted as practical strategies.

In the future, greater emphasis will be placed on forecasting pest incidence so that insecticides can be deployed more rationally and incisively than is now possible. However, pest control methods are likely to move away from sole reliance on insecticides as more complicated, integrated strategies are gradually adopted. The use of resistant or less susceptible crop varieties seems at present to be the most general foundation on which other methods will eventually be based.

6. Conclusions

Of the different types of pest damage to crops for processing, most difficulties arise when the pest attacks the marketed part of the plant. More intensive use of insecticides will not solve most of these problems because insecticidal methods have intrinsic limitations. Their efficiencies can be readily determined but other factors, such as host-plant density and infestation levels, interact to influence the effectiveness of control measures. Effectiveness is therefore dependent on the agricultural practices of particular areas. Risks of encouraging the development of insecticide-resistant populations of pests, of creating residue problems in processed crops and of adverse interactions of the chemicals on crop yields must necessarily prevent undue dependence on insecticides to solve pest control problems in the future.
References