IMPROVED INSECT PEST MANAGEMENT
FOR CRISPHEAD LETTUCE
GROWN IN S.W. BRITISH COLUMBIA

by

John Reginald Mackenzie

BSc., University of British Columbia, 1975

A PROFESSIONAL PAPER SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF PEST MANAGEMENT

in the Department

of

Biological Sciences

SIMON FRASER UNIVERSITY

March 1986

Approval

Name: John R. MacKenzie

Degree: Master of Pest Management

Title of Professional Paper: Improved Insect Pest Management for Crisp Head Lettuce Grown in S.W. British Columbia

Examining Committee:

Chairman: Prof. T. Finlayson

Dr. H. R. MacCarthy, Senior Supervisor

Dr. J. E. Rahe

Mr. Jack Arrand, Director of Crop Protection, B.C. Ministry of Agriculture & Food, External Examiner

Date Approved: 7 March 1986

PARTIAL COPYRIGHT LICENSE

Title of ~~Thesis~~/Project/Extended Essay / PROFESSIONAL PAPER

Improved Insect Pest Management for Crisp Head Lettuce Grown in S.W. British Columbia

Author:

(signature)

John R. MacKenzie

(name)

7 March 1986

(date)

ABSTRACT

Since 1981, the European lettuce aphid, *Nasonovia ribisnigri* (Mosley) (Homoptera: Aphididae), has become a serious pest of crisphead lettuce grown in the lower Fraser Valley of B.C. A program of improved management was started, based on assessment of available insecticides, identifications of pests, an understanding of pest development and ecology, efficient monitoring methods, and more effective controls.

On a typical commercial farm, plantings of lettuce were monitored weekly and the status of the pests was reported to the grower with recommendations for their control. For better timing of pest management, the growth of the crop was closely monitored by sampling blocks of lettuce planted successively during the season. Counts of leaves/plant showed that there are three physiological stages in the crop growth.

A search was conducted for alternative winter hosts of the aphid. Hosts were found at several sites, some with aphid colonies by mid-May. The economic threshold is virtually zero aphids/plant because the produce will be unmarketable if any aphids are found. Managing aphids on lettuce is thus difficult. Since aphicidal sprays had to be applied whenever aphids were detected, a sensitive monitoring method was essential. The distribution of aphids within fields and plants was plotted, showing that they appear to prefer field margins and the inner rather than outer leaves of a lettuce plant.

Alfalfa loopers, *Autographa californica* (Speyer) (Lepidoptera: Noctuidae), were also serious pests. They were monitored by plant

pheromone bait. To improve sampling, the plantings were examined and the pattern of spatial distribution of loopers was mapped. Insecticidal sprays were recommended when the loopers exceeded 0.5/plant.

Regular monitoring showed differences in the efficacy of insecticides. Results from controlled screenings of registered materials combined with a new registration of the carbamate, pirimicarb, led to an effective spray schedule. Since these measures were implemented in 1983 and 1984, there have been no major losses to the aphid, following the estimated $1 million loss incurred in 1982. Further refinements should include a registration for foliar application of the systemic, disulfoton, a reduction in the number of sprays required, standardization of optimum parameters for spray application, and diversification in the options recommended for control.

ACKNOWLEDGMENTS

I especially thank Dr. H.R. (Mac) MacCarthy my senior supervisor, who provided me with encouragement and advice. His editorial expertise and vigilence, astute and constructive criticism and great breadth of experience are very much appreciated. I thank Dr. J. Rahe for his review of this manuscript. I express thanks to Dr. R.S. Vernon for time spent in discussion with me and for his practical guidance. I also wish to thank Mr. S. Szeto and Mrs. M. Brown for determination of insecticide residues. The assistance of Mr. B. Johnston in the 1982 field work is acknowledged as is the assistance of Mss. D. Bartel, J. Brookes, D. Dyck, and Mr. G. Toews. I thank the owners of Cloverdale Produce Farms and Mr. G. Spranger, grower, for their cooperation; Ms. F. Cupples for typing; Mr. W. MacDiarmid for help with many of the figures; and Mr. C.-K. Chan for preparation of figures 3 and 4, and aphid identifications. The approval of Dr. M. Weintraub, Director; Dr. A.R. Forbes, Head of Entomology and Dr. R.S. Vernon, Research Scientist at the Vancouver Research Station of Agriculture Canada, to pursue an M.P.M. degree while under their employ and to utilize research station facilities, is sincerely appreciated. The cooperation and financial contribution of the British Columbia Ministry of Agriculture and Food (D.A.T.E. Project #99, 1982) is gratefully acknowledged.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure		Page

1. INTRODUCTION

Lettuce, Lactuca sativa L., is an important fresh vegetable crop in the lower Fraser Valley of British Columbia. The moderate climate and muck soil produce crops of extremely high quality. Nearly all lettuce grown and marketed in the Fraser Valley is of the crisphead or iceberg variety, Ithaca, which is favoured for its firm, compact head. These heads easily withstand the stress and shock associated with long distance transport to markets in Alberta and as far east as Manitoba. Most are sold in B.C., however, along with much smaller amounts of butterhead, looseleaf, and cos or romaine types which are grown mainly on small market farms (Appendix C3) or in greenhouses nearby[1].

The growing season begins in the second week of March when the first beds are either precision-seeded or transplanted. The number and size of plantings on each farm depend on the market quota assigned to the grower and to fluctuations in demand. Large growers commonly sow 24 beds (0.8 ha) every two weeks until the first week of August. The first damaging frost, usually in October, ends the growing season, which is longer than 200 days and allows two complete croppings per year on the same site.

In 1982, 25 lower Fraser Valley growers planted some 220 ha of lettuce and produced an estimated 7.8 million kg or 9.2 million heads. This amounted to almost 6% of the value of all fresh vegetables grown outdoors in southwestern B.C. in that year, or more than $2 million worth of lettuce on the wholesale market (B.C. Vegetable Marketing Board, 1982 unpub).

Acceptable management of lettuce pests is essential but has recently been difficult or impossible to achieve. Until recently, treatment of the whole range of lettuce insect pests has depended primarily on chemical sprays. Many growers simply spray at fixed interval schedules of 7 to 14 days based on label recommendations, or on intuition, past experience and casual field observations. The sprays are often applied with little information about pest populations in the field, spray efficacy, and methods of application. As a result, the grower may not use the most appropriate pesticide in the best way at the most opportune time. Sprays applied in the absence of economically damaging levels of pests is an unnecessary expense and may degrade the crop ecosystem. In California, researchers have discovered that repeated spray applications can actually reduce yields (Toscano et al. 1982a).

The cost of purchasing and applying pesticides, although fairly low in the past, has risen in recent years, a trend which will probably continue. If so, ill-timed, chosen, and applied sprays will be of increasing financial concern. Many species of insects have developed resistance to over-used pesticides, and pest resistance is likely to become an even more serious problem because few new products are currently being registered as replacements. Moreover, the imprudent use of pesticides results in the supression of beneficial predators and parasites and may lead to outbreaks of secondary pests.

The need for changes in the management of lettuce pests became increasingly urgent with the sudden appearance in 1981 of a new pest, the lettuce aphid, Nasonovia ribisnigri (Mosley) (Homoptera: Aphididae). Despite sprays applied to prevent buildups of, and to bring under control, the commonly encountered caterpillar and aphid pests, four major growers suffered severe and unexpected crop losses in September 1981.

Lettuce aphids found inside the harvested heads rendered unmarketable an estimated $80,000 worth of lettuce. Although this European aphid had been present on other plants in the area for many years (Forbes et al. 1973), no damage to lettuce crops was noted.

In 1982 the routine sprays failed again. Lettuce aphids were found in commercial plantings in late May and by the end of June were causing rejection of the infested produce. The infestation was widespread and became progressively worse. Several growers were affected and by the end of the season the industry had lost an estimated total of $1 million to this aphid, or over 40% of the expected production (Secretary, Cloverdale Lettuce and Vegetable Cooperative[2], pers. comm.). Ill-timed and imperfectly applied sprays and resistance by the aphids to certain chemicals are suspected to be among the causes of the outbreak. For these reasons, a more effective pest management program was needed.

'Pest management' is defined here as any means which prevent populations of crop-damaging pests from reaching levels which cause economic damage and are, at the same time, those least disruptive to the environment. The steps taken to suppress pest insects may be physical, cultural, biological or chemical. A grower who applies weekly insecticidal sprays alone, exercises chemical pest management. Integrated pest management (IPM) makes use of two or more different kinds of control, often simultaneously. Proper identification of pests, an understanding of their biology, then directly monitoring crops for them should be the basis of an integrated pest management program. In the Fraser Valley, pest monitoring techniques developed for the main pests of carrots (Judd 1982), onions (Vernon 1979), and potatoes, have been successfully implemented by a private pest management firm since 1979. The use of pest monitoring procedures could be advantageous in other crops as well, such as lettuce.

The main purpose of this study was to improve the management of insect pests in Fraser Valley lettuce. Towards this goal, the major pests of lettuce were identified, their life-cycles and interrelationships considered, then the pests were directly monitored on a field-by-field basis so that sprays might be applied only at critical stages or when potentially damaging pest population levels were approached. In addition, studies were conducted to find effective pesticides, application methods, and residue persistence.

2. KEY PESTS

Several pests attack lettuce in the area; some only occasionally and others, annually. Earwigs, wireworms, leatherjackets (Insecta) and slugs (Gastropoda) are important sporadic pests. The insects which caused economic damage to lettuce crops in 1982 were, in order of their appearance and increasing significance: leatherjacket larvae, *Tipula paludosa* Meig. (Diptera: Tipulidae), alfalfa loopers, *Autographa californica* (Speyer) (Lepidoptera: Noctuidae) and lettuce aphids, *Nasonovia ribisnigri*. Leatherjacket larvae appeared only in localized areas in the spring.

2.1 Miscellaneous

The European earwig, *Forficula auricularia* L. (Dermaptera: Forficulidae), is an omnivorous feeder at night and in the daytime seeks refuge in narrow crevices such as those formed by adjacent lettuce leaves. Contamination of heads can sometimes occur but generally speaking the earwig is not a consequential pest (Lamb 1974).

Wireworms, the larvae of click beetles, attack many ornamentals and vegetables, including lettuce. Several species are native to the lower Fraser Valley, but the dusky wireworm, *Agriotes obscurus* (L.) (Coleoptera: Elateridae), is a serious pest of potatoes and corn and has caused the most concern. The wireworm reaches high and destructive population levels and is still spreading (Wilkinson 1980). Damage to lettuce has recently been reported on Vancouver Island and can be expected in the lower Fraser Valley.

Slugs damage lettuce crops from time to time. They eat holes in the leaves, leave silvery slime trails wherever they crawl, and cause distress and ill will in consumers by their presence within the heads, usually as small immatures. An outbreak in 1948 resulted in 25% damage and in 1960 an unspecified loss was reported (Rollo *et al*. 1975). The most important pest species are: The banded slug, *Arion circumscriptus* (Johnston); the grey garden slug, *Deroceras reticulatum* (Muller), the spotted garden slug, *Limax maximus* (L.); the black slug, *Arion ater* (L.) - all introduced species - and the reticulated slug, *Prophysaon andersoni* (Cooper), a native species. The grey garden slug is the most abundant and economically important here (Rollo *et al*. 1975).

Damage to lettuce by slugs is usually localized and most prevalent in wet years, especially in consecutive wet years. Crops planted in poorly drained organic soils are particularly susceptible. Slugs feed on either living or decaying organic matter, mainly at night and when conditions are mild and damp. Feeding can be underground on roots or on aerial plant parts (Anon. 1973). Control can be achieved through sanitation and the application of chemicals, notably metaldehyde. Areas of long grass, weeds and trash are the usual sites for slugs to lay eggs and seek refuge. Fence-rows, headlands, and ditchbanks should therefore be kept closely cropped and clean. Metaldehyde, in bait, dust, or liquid formulations, is effective when applied where damage is observed, such as at the base of young plants. Pre-planting or headland treatment can also be effective. Baits are evenly broadcast on the soil or placed in small piles protected from rain. Not all slugs forage in a given night, therefore treatment should be repeated after five days (Wilkinson 1974).

2.2 Leatherjackets (Diptera)

Larvae of the European crane fly, *Tipula paludosa*, or leatherjackets (Fig. 1A), are native to northwestern Europe where they are a pest primarily of low-lying pasture. They were first discovered in the lower Fraser Valley in 1965 and became established in coastal B.C. mainly because of the mild, damp climate (Wilkinson and MacCarthy 1967).

Vegetable seedlings are especially vulnerable to damage since a single larva will attack several plants. The damage resembles that of cutworms and is most severe in early plantings which have been thinned or sparsely seeded, growing in newly cultivated grassland. Crop losses occurred in 1982 when several young lettuce plantings were attacked in late April and May. The stems of seedlings were cut off by larvae feeding near the soil surface. Leatherjackets were easily found near the surface at the bases of affected seedlings.

Crane fly adults have long, spindly legs, narrow bodies, a pair of halteres and transparent wings. Most of them emerge in late August and early September, mate quickly and within hours lay about 280 minute, black eggs on soil and grass. The crane flies live for about one week. The eggs hatch in about 14 days into small, grey, legless larvae which feed almost continuously on grass crowns and blades in the fall and during intervals of mild winter weather. When warm spring temperatures arrive, the larvae feed voraciously, and in March and April do their worst damage. When fully grown, leatherjackets are about 40 mm long, brownish-grey, plump and soft, yet with a tough leathery skin (Fig. 1A). At this point they stop feeding and after early July, pupate in the soil. Just before the adults are ready to emerge, the pupae squirm upwards until they protrude slightly above the soil surface. There is one generation a year (Wilkinson and MacCarthy 1967).

Natural enemies of leatherjackets are few and include European starlings, Sturnus vulgaris L., an introduced parasitic fly, Siphona geniculata (De Geer) (Diptera: Tachinidae), and several diseases. The parasite has been present only at low levels but starlings provide some control in heavily infested pasture.

If grassland is converted to lettuce production it should be tested for leatherjackets before seeding. To do so, 1 L of diazinon spray or

Figure 1. (A) last instar European crane fly larva, Tipula paludosa Meig.; (B) alfalfa looper, Autographa californica (Speyer); (C) the lettuce aphid, Nasonovia ribisnigri (Mosley), was found in the blisters on the under sides of leaves of black current, Ribes nigrum L.

A

B

C

1/2 L of gasoline is applied to 1,000 cm^2 of soil and if an average of more than one larvae/m^2 wriggle to the surface, control steps are probably justified. If several ha require testing, 10 to 15 tests should be made. The recommended control in vegetables is a single, preventative spray application of diazinon or parathion during the period from October 1 to two weeks before ploughing or rotovating the land. Where damage has been heavy in previous years, lettuce may be seeded after the larvae have pupated in late June and July and will escape damage. In 1982, sprays which were applied after damage was apparent were not highly effective. A more detailed discussion of damage in 1982 is found in section 3.

2.3 Caterpillars (Lepidoptera)

Several species of caterpillars inflict economic damage on lettuce crops in the Fraser Valley. These include cutworms and loopers, which are the larvae of moths in the Family Noctuidae. Their feeding habits vary according to species but all have wide, overlapping host ranges. Climbing cutworms and loopers feed on stems and leaves but soil-inhabiting cutworms feed mainly on roots or stems close to the soil surface. Mature larvae range from 25 to 50 mm long, lack conspicuous hairs, and vary greatly in pattern and color. Cutworms and loopers overwinter as partially developed eggs, early instar larvae, or adults, but mostly as pupae in the soil. Early in the spring, the moths emerge from overwintered pupae and lay eggs on the soil or on host plants. Meanwhile the dormant larvae resume feeding and overwintered eggs hatch. There may be one to several generations per year (Essig 1958).

Three species of climbing cutworms are occasional, but potentially serious, pests of lettuce. These are the black army cutworm, *Actebia fennica* (Tauscher); the bertha armyworm, *Mamestra configurata* Walker; and the variegated cutworm, *Peridroma saucia* (Hübner). Although none was found in 1982, infestations may result in complete defoliation of localized areas virtually overnight. Mature climbing cutworms vary in color from green to grey, brown, or black and are about 40 mm long. Moths of the variegated cutworm have dark mottled forewings with a metallic lustre and a wingspan of about 45 mm (Berry 1978).

Hymenopterous parasites and viral diseases have some regulating effects on bertha armyworm populations, but applications of insecticides are sometimes necessary. Chemical sprays are most effective against climbing cutworms when the caterpillars are small, so that proper timing of treatments is important. Regular monitoring for young larvae should begin in the early spring. The insecticide is best applied in the evening to intercept the larvae, which feed at night.

A complex of soil cutworms exists, in which two species are sometimes of concern, namely: the redbacked cutworm, *Euxoa ochrogaster* (Guenée) and the darksided cutworm, *E. messoria* (Harris). Little or no damage was reported in 1982, but in some years plants are chewed at or below the soil surface, and at night, even the aerial parts may be eaten (Banham 1978).

Although the genus *Euxoa* is extremely variable, mature redbacked cutworms can be distinguished by a dull, reddish brown dorsal stripe divided and bordered by dark lines. The appearance of the moth is also variable and ranges from a warm tan marked with dark brown to dark brownish-red variably marked with black. The hind wings are smoky brownish grey and the forewings span about 40 mm (Berry 1978, Hardwick, 1965). First instar larvae of both species overwinter inside the egg in the soil. Eggs hatch when the soil becomes sufficiently warm in the spring and the larvae immediately start feeding. Crop damage, which does not usually appear until the larvae are about half-grown, is worst between mid-May and the end of June. Mature caterpillars pupate in the soil and the moths emerge from late July to early September. The eggs are laid in late August and early September on leaves of cultivated plants and weeds. There is one generation per year.

Soil cutworms, because of their underground habits, are difficult to control. Weeds provide shelter for egg laying and food for young larvae. Crops sown in land previously infested with weeds are more susceptible to damage than those sown in areas kept weed free. Weed control, and the ploughing under of crop debris before late August, can reduce the number of eggs laid. Cutworms are monitored by sampling the soil around the base of host plants in the spring. Since one larva can cut off the stems of several seedlings in a row, a single cutworm in 25 samples may justify insecticide treatment (Berry, 1978). Protective insecticides are sometimes incorporated in the soil or placed on the surface with bait before planting.

The alfalfa looper, Autographa californica, is the main looper pest of lettuce in the region, but the cabbage looper, Trichoplusia ni (Hübner), and the celery looper, Anagrapha falcifera (Kirby), also cause occasional damage. Loopers are foliage feeders and lettuce is made unmarketable by ragged-edged holes from feeding and the attendant contamination.

Moths of the cabbage and alfalfa loopers are similar in size and body color; both have wingspans of about 30 mm and the wings are mottled silvery-grey with scalloped margins. But their forewing markings differ. The forewing of the cabbage looper tends to be sandy-brown and has a figure 8-shaped stigma near the centre, whereas the alfalfa looper forewing is silvery-grey with a white, hook-shaped stigma. Larvae of both species are about 25 mm long and green, generally with dorsal and sub-dorsal lines (Fig. 1B). Both species have three pairs of abdominal prolegs.

In May, the moths of the loopers emerge from pupae which overwinter in soil and trash. Small, round, pale-yellow eggs are laid singly on weed and crop leaves through the spring and summer. In 1982, widespread crop damage was caused by the alfalfa looper from late May to early July. When mature, loopers pupate inside white mesh cocoons attached to leaves. Crop damage may occur through the season, as there are several overlapping generations per year (Berry 1978).

Predators, parasites, nuclear polyhedral virus diseases, and applied Bacillus thuringiensis (or B.t.), may reduce some looper infestations, but the natural occurrence of these biocontrol agents is unpredictable and often too late to be useful in a fast-growing annual crop. Results from spray applications of B.t. depend not only on the target species of looper, but also on the methods used and the conditions during application.

Traps baited with sex pheromones can be used to monitor the emergence of male moths and, in some cases, to time insecticide applications. For example, Berry (1978) states that insecticides should be applied 10 days after the first appearance of cabbage looper moths in traps. Lures are available for several species of cutworms and loopers, but the trap catches indicate only the presence or absence of male moths of the species baited and not damaging larval populations. Since the moths are strong fliers and relatively long-lived, their progeny may appear some time later and a long way away. Usually, direct larval counts are the most effective means of reaching decisions to apply insecticidal sprays. Such decisions are best made when the larvae are small.

Another option for control of loopers on lettuce has already been investigated. Lettuce hybrids with some apparent resistance to feeding by cabbage loopers have resulted from crosses of cultivated varieties with the wild species, Lactuca saligna L., and these interspecific crosses may eventually lead to resistant commercial varieties (Whitaker 1974).

2.4 Leafhoppers and Aphids (Homoptera)

The aster leafhopper, Macrosteles fascifrons (Stål) (Cicadellidae), is a vector of lettuce yellows, a disease which causes economic loss in lettuce. Although the problem has warranted study in other parts of Canada (Westdal 1960; Thompson 1967) it has not done so here.

Several species of aphids (Aphididae) infest field-grown crisphead lettuce in southwestern B.C. These are: the lettuce root aphid, Pemphigus bursarius (L.); and the foliage feeders, the foxglove aphid, Aulacorthum solani (Kltb.); the shallot aphid, Myzus ascalonicus Doncaster; the potato aphid, Macrosiphum euphorbiae (Thos.); the green peach aphid, Myzus persicae (Sulz.); and most importantly, the lettuce aphid, Nasonovia ribisnigri.

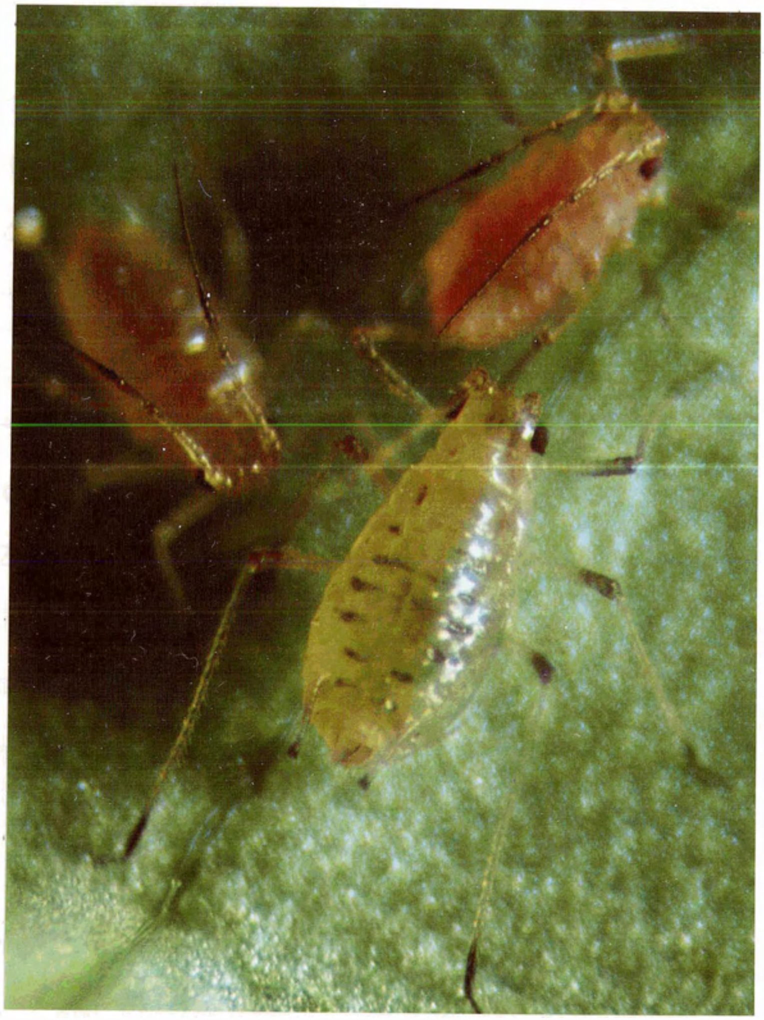
The lettuce root aphid, P. bursarius is not an important pest of commercially-grown lettuce in the lower Fraser Valley, but severe damage by the related species, P. betae Doane, has been reported in backyard gardens (Chan, C-K., Res. Stn. Agric. Canada, Vancouver, B.C., pers. comm.). Damage by root aphids is most likely to occur in the summer when infested plants are subject to heat stress and drought, which leads to collapse and death. Lombardy and black poplars are the primary hosts upon which over-wintering eggs are laid, although in mild enough winters the summer morphs may remain active in the soil. To control lettuce root aphids, growers should avoid planting near poplar trees; rotate crops in infested areas; irrigate when wilting appears; and in intensively cropped soil, use soil insecticides where needed.

Of the foliage-feeding aphids found on lettuce only M. persicae and N. ribisnigri have been economically important to B.C. growers.

M. persicae is commonly found on a very wide range of hosts, including lettuce. Outside lettuce leaves are the preferred feeding sites of this aphid and although feeding damage is minimal, M. persicae can transmit several virus diseases. Overwintering occurs in the egg stage on peach and nectarine and, in mild winters, as apterae on herbaceous weeds and crop remains.

For the past three years however, the lettuce aphid has been the most important insect pest (Fig. 2). Even small numbers of lettuce aphids may cause economic damage, because this aphid tends to colonize leaves inside the developing heads, making them unacceptable for market. Once in the formed heads, the aphids are virtually impossible to reach with foliar, contact sprays. Large populations, of course, cause direct damage by their feeding and deposits of honey dew but the damage is primarily cosmetic. Although N. ribisnigri is reported to be unable to transmit lettuce mosaic

Figure 2. The lettuce aphid, *Nasonovia ribisnigri* on lettuce.



virus, it is a potential threat as a vector of cucumber mosaic and perhaps also of beet western yellows (Kennedy et al. 1962).

N. ribisnigri (Figs. 2, 3 A and B) is a medium-sized (2-3 mm long) olive-green aphid with a distinctive dorsal sclerotic pattern, especially in the winged form (Fig. 3B). Its antennae are long with secondary sensoria on the basal 1/4 - 3/4 of segment III in apterae (Fig. 4A) and all along segment III in alatae (Fig. 4B). Its cornicles are cylindrical, with a distinct preapical annular circumcision (Fig. 4C). Its cauda is finger-shaped, usually with 7 hairs (Fig. 4D). Both Hille Ris Lambers (1949) and Heie (1979) give detailed morphological descriptions of the various morphs of the aphid. I have also collected and reared a pink form of N. ribisnigri in B.C.

This is an heteroecious aphid (Fig. 5) with its primary hosts in Ribes and secondary hosts in the Compositae and several other plant families (see Mackauer 1962 and Fig. 1C). In England during mild winters some of the aphids are able to continue to breed on lettuce outdoors throughout the winter. This probably occurs in the Fraser Valley as well and could result in sizeable populations of lettuce aphid being present on overwintered lettuce and other secondary hosts ready to infest newly seeded crops in the spring.

In Canada, this aphid has been previously recorded in B.C., Quebec and New Brunswick (Smith and Parron 1978). In the eastern United States it has been collected in New York, Vermont, Pennsylvania, New Jersey, District of Columbia and possibly North Carolina (Ibid 1978); in the western United States in Montana, (Ibid 1978) and Oregon (Leonard 1974). It has not, however, been previously documented as a pest in North America. In Britain

Figure 3. The lettuce aphid, Nasonovia ribisnigri (A) aptera; (B) alate.

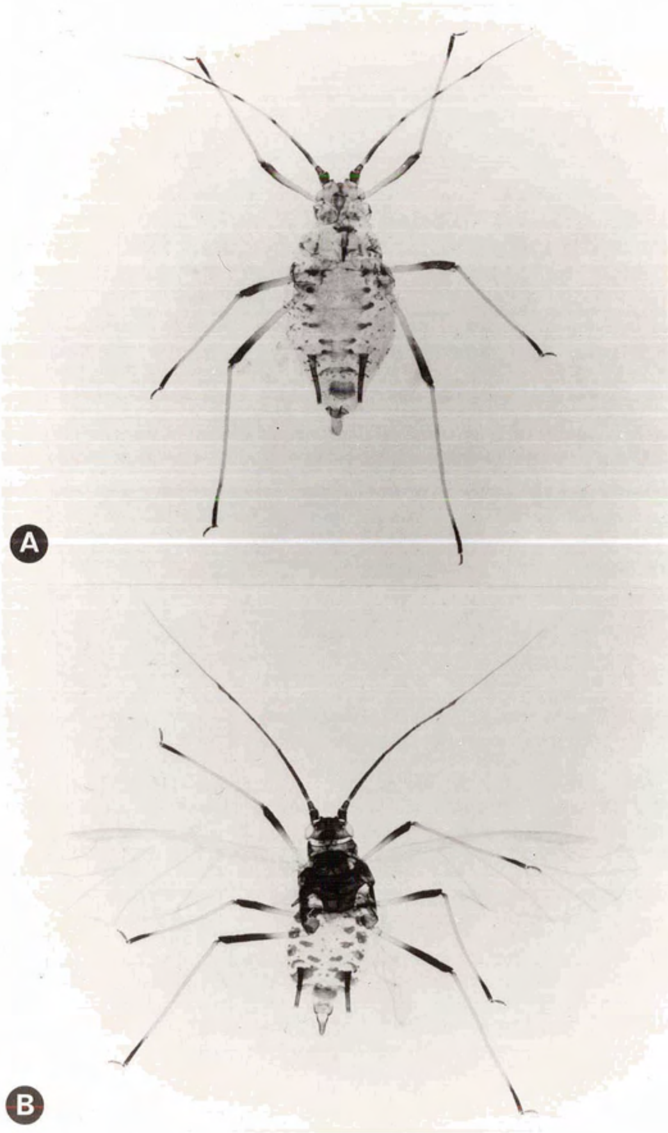

A
B

Figure 4. Electron micrographs of *N. ribisnigri*: (A) secondary sensoria on the basal 1/4-3/4 of segment III of antenna in apterae; (B) secondary sensoria all along segment III of antenna in alatae; (C) cylindrical cornicle with a distinct pre-apical annular circumcision; (D) finger-shaped cauda.

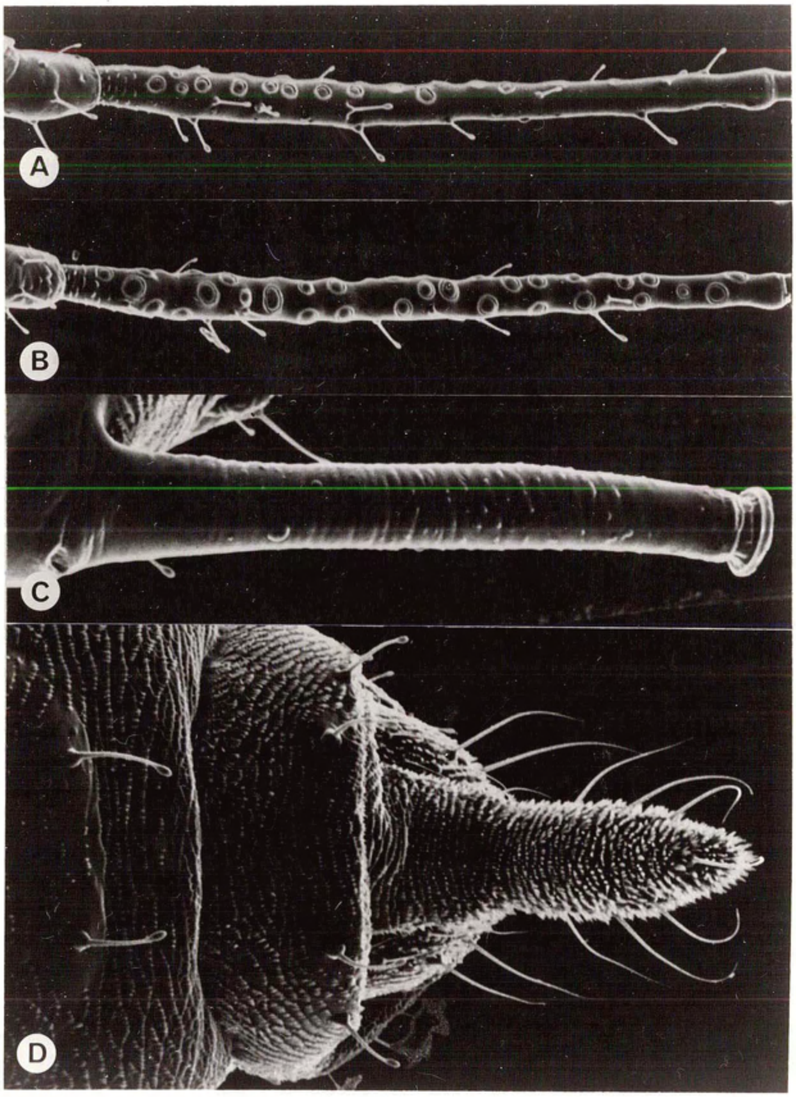
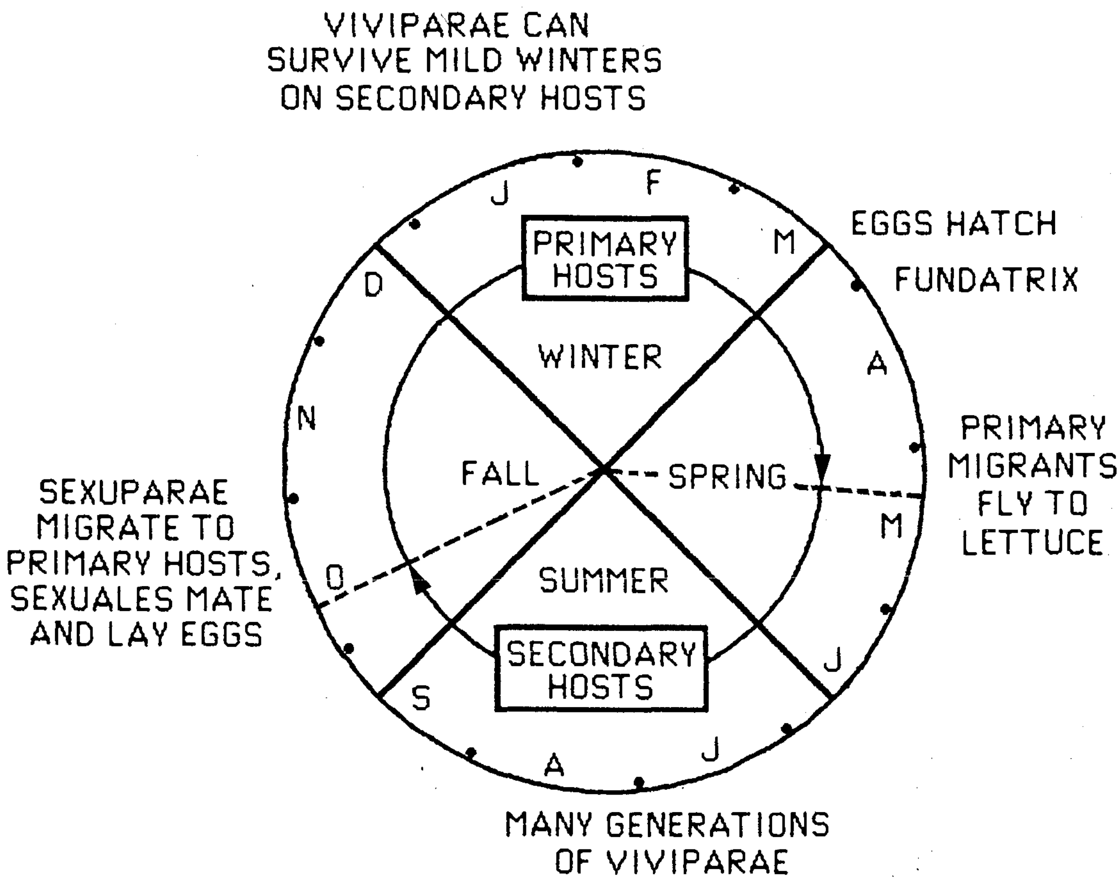

A
B
C
D

Figure 5. Life cycle of the lettuce aphid in B.C.



LIFE CYCLE OF THE LETTUCE APHID IN B.C.

it is recognized as probably the most important aphid pest of lettuce both out-of-doors and under glass (Ministry of Agriculture, Fisheries and Food 1978).

Prior to 1983, insect pest control on lettuce was based primarily on the application of insecticial sprays (Veg. Prod. Guide 1982) chosen and timed by individual growers. Such lettuce pest management was unable to bring under control the outbreak of the lettuce aphid in 1981 and 1982.

The following section, with an emphasis on the two main pests, alfalfa loopers and lettuce aphids, sets out to establish a basis on which to improve lettuce pest management decisions. The factors considered are: crop growth characteristics; the pests' biologies; economic injury levels; pest population thresholds for control action; monitoring techniques; and information transfer.

3. MANAGEMENT OF PESTS

3.1 Introduction

My proposal for improved lettuce pest management was based on the development and implementation of a monitoring program. Before routine monitoring could begin, however, some basic research was necessary.

For a start, the crop itself had to be studied. The physiological age of the crop affects the pest population level at which economic loss occurs, i.e. the economic injury level. In some instances the tolerated economic injury level may be much higher when the crop is young than when mature. For example, on young plants, leaf damage to non-head, basal leaves caused by alfalfa loopers may be inconsequential since only heads are harvested.

The effectiveness of control measures will also be influenced by the physiological age of the crop. An aphicidal spray with contact action will be more effective when applied to very young plants, on which leaf feeding pests are relatively exposed, than to mature plants where aphids or small slugs are mostly protected inside the developing heads. The success of biological control through timed release of parasites or predators will depend on the target pest population, which might in turn depend on crop age.

Attempts at pest control must not interfere with normal crop production practices carried out by the farmer. For example, thinning crews are dispatched to fields as the stage in crop growth dictates, and planning is thus required to ensure that pest control recommendations do not disrupt this husbandry.

For improved lettuce pest management, better identification and a good knowledge of the pests' local life-cycle are required. Control measures are usually most effective at particular stages of pest development, perhaps on non-crop alternative hosts. With a knowledge of the pest's life cycle, its first appearance on the crop can often be predicted. A survey was conducted in and around the main lettuce-growing area for the early detection and mapping of N. ribisnigri on its primary host, Ribes, before the aphids migrated to lettuce. Details of the survey are given in the following section.

Simple, inexpensive, and reliable monitoring methods had to be evaluated to account for as many pests as possible. For maximum efficiency in monitoring, the distribution of loopers and aphids within commercial plantings and aphids within individual plants was investigated, so that monitoring could then focus on the parts of fields or plants most likely to harbour the pests.

Thresholds of population levels for control had to be determined for each pest. Thresholds may be dictated by market demands for insect-free or undamaged produce and may vary with crop age.

For effective pest management, the extension agent, the grower's co-operative, the grower, and the pest manager must all interact freely and effective control options must be available. Channels for conveying up-to-date information to the growers about the status of pests on their crop and the pest manager's recommendations were well established but the chemical controls were in need of re-evaluation.

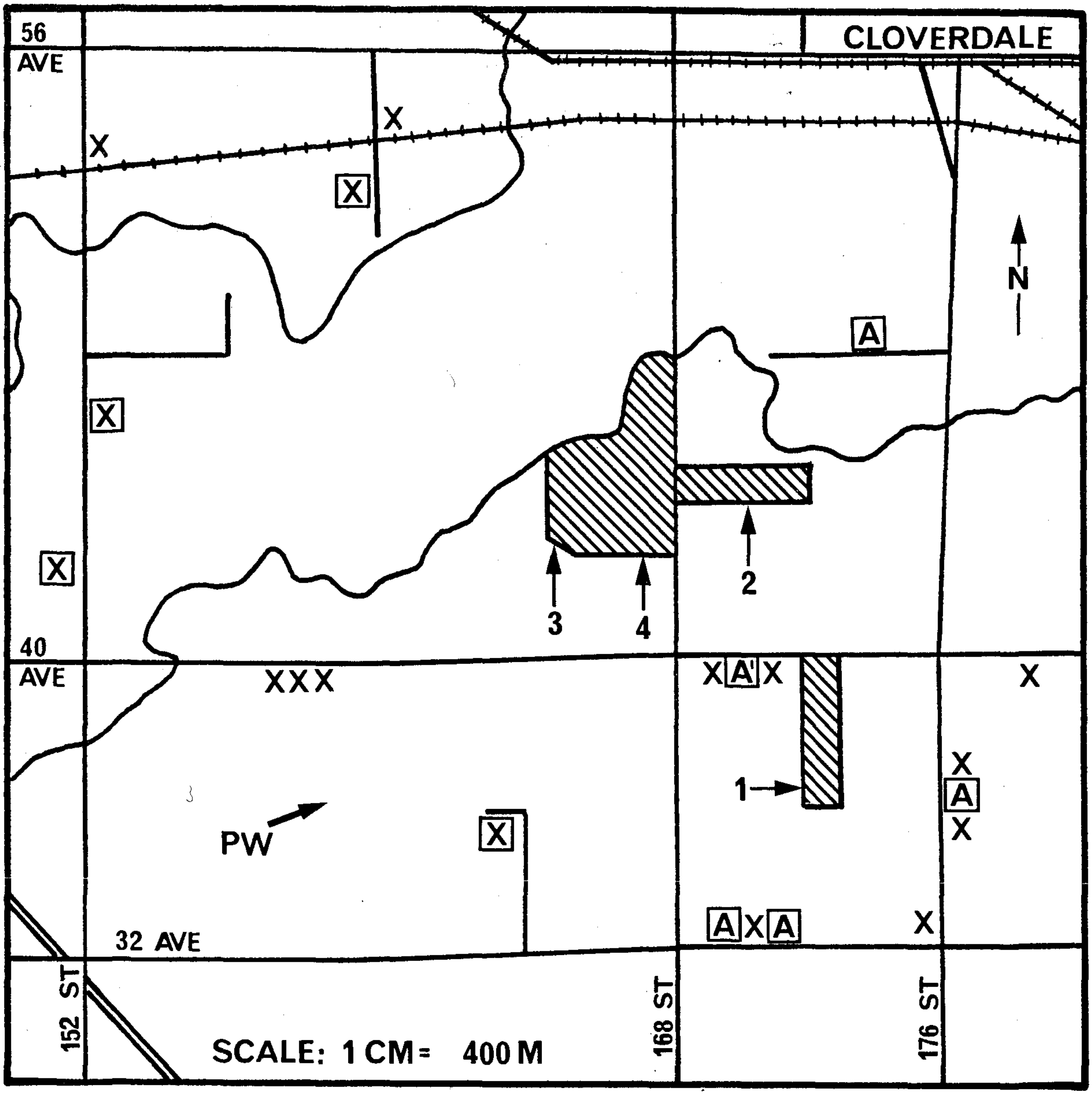
Most importantly, monitoring should be conducted on a frequent and continuing basis for the detection of rapid or unexpected changes in pest populations. This practice is necessary in order to take effective control measures. Control may be increasingly difficult or impossible when pests are allowed to become established undetected. Ongoing monitoring provides a prompt evaluation of any control measures taken which can then be modified and re-applied if necessary.

3.1.1 The Demonstration Farm

A cooperating lettuce grower in the Clover Valley offered his lettuce fields for the trial implementation and demonstration of a monitoring program (Fig. 6). Throughout the 1982 season, a total of 16.2 ha (40 acres) of lettuce on his farm were monitored weekly for insects (Fig. 7 and 8, Table 1).

The most important pest encountered was the lettuce aphid, followed by the alfalfa looper and a localized infestation of leatherjackets. None of the other pests of lettuce were present in damaging numbers in that year. The fungal disease, drop or watery soft rot, *Sclerotinia sclerotiorum* (Lib.), was widespread and prevalent.

Figure 6. Area map of regional survey conducted in 1982 for *N. ribisnigri* and its primary hosts. Diagonal shading shows Cloverdale Produce Farm.



CLOVERDALE PRODUCE FARMS

X PRIMARY HOST

STICKY APHID TRAP

A _NASONOVIA RIBISNIGRI_ EX. PRIMARY HOST

PW..PREVAILING WIND

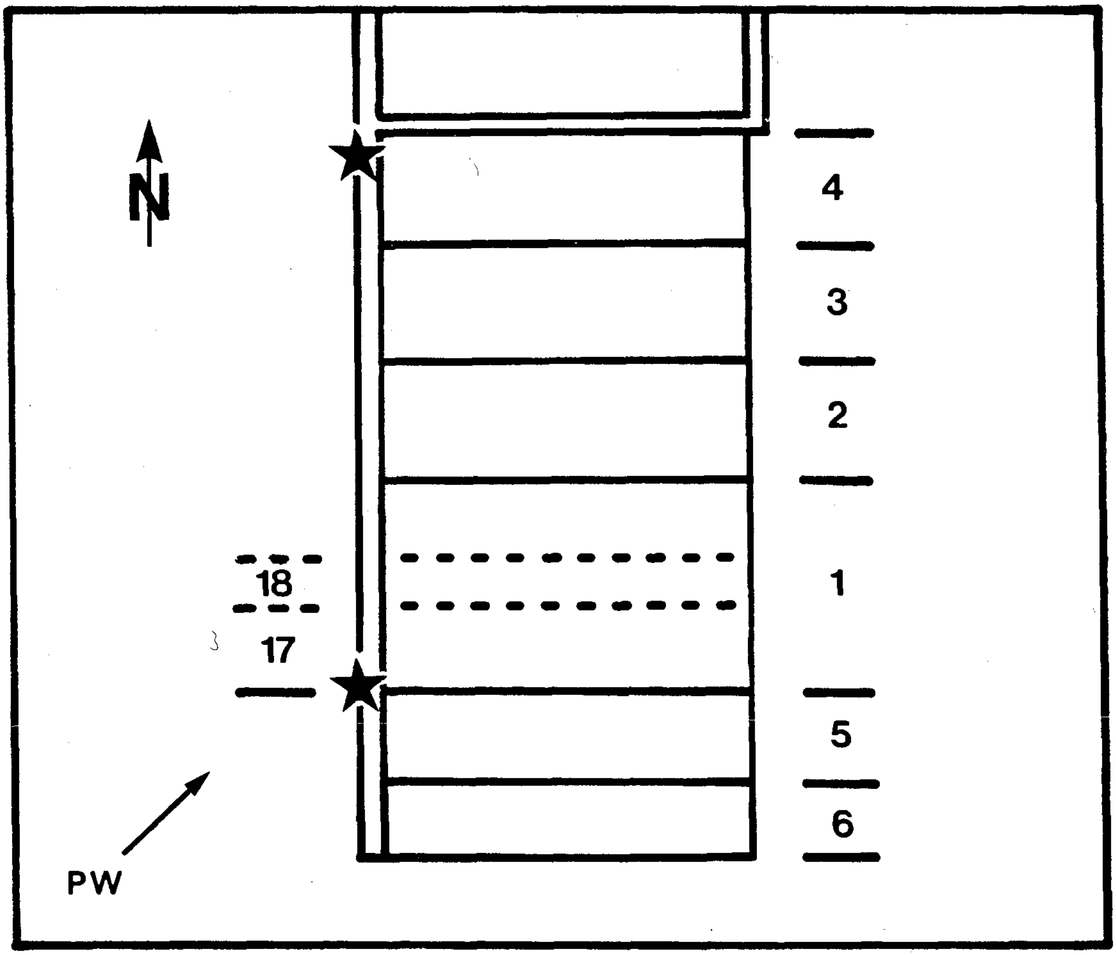
1..PLANTINGS 1-6, 17, 18

2 7-13

3 14-16

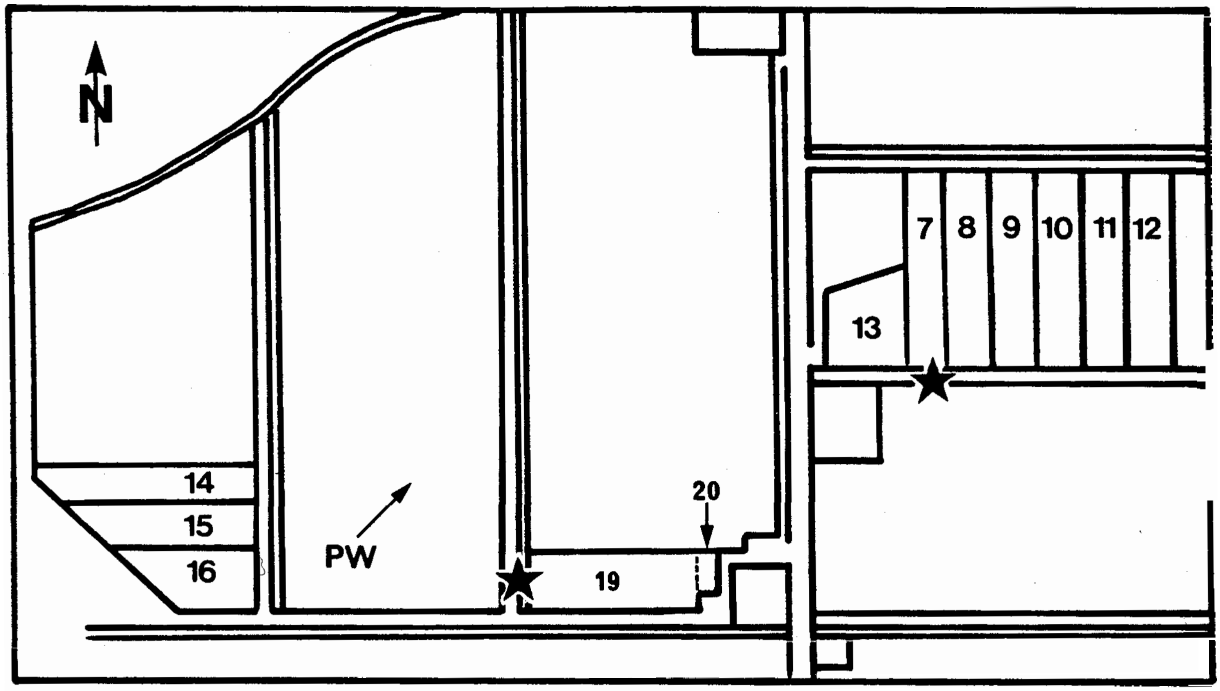
4 .... 19, 20

Figure 7. Lettuce planting numbers 1-6 monitored on Cloverdale Produce Farm, 1982. Planting numbers 17 and 18 were seeded after the harvest of planting number 1.



★ _ _PHEROMONE BAITED TRAP
PW_ _PREVAILING WIND
TOTAL AREA ~6.7 ha

Figure 8. Lettuce planting numbers 7-16, 19 and 20 monitored on Cloverdale Produce Farm, 1982.



★...PHEROMONE BAITED TRAP

PW...PREVAILING WIND

TOTAL LETTUCE CROPPING AREA: ~ 7.5 ha

Table 1. Lettuce plantings monitored on Cloverdale Produce Farm, 1982

Planting	Planting: Size (beds)*	Area (ha)	Seeding date	Harvest date	Days from seeding to harvest
1	60	1.89	March 9	June 17	115
2	34	1.07	March 22		
3	36	1.13	April 2		
4	37	1.16	April 16	July 1	76
5	24	0.76	April 22	July 8	77
6	22	0.69	May 1	July 9	69
7	24	0.81	May 7	July 12	66
8	24	0.81	May 13	July 14-21	61-68
9	24	0.81	May 20	July 21	62
10	24	0.81	May 27		
11	24	0.81	June 3		
12	13.5	0.46	June 8		
13	45	0.65	June 12		
14	20	0.55	June 17		
15	25	0.53	June 23		
16	34	0.50	June 30		
17	25	0.79	July 6		
18	13	0.41	July 16		
19 (1st)	31	0.65	April 27		
(2nd)	31	0.65	July 16		
20 (1st)	21	0.12	April 27		
(2nd)	21	0.12	July 16		
TOTAL	612.5	16.18			

* A bed consists of 4 rows, 35 cm apart (see Fig. 13).

3.2 Plant Examination and Sampling

A simple way of estimating the physiological age of a lettuce planting was sought first, one that could be used by growers and pest managers alike. One possibility was a calculation of biomass based either on regularly measured heights and widths or on weights of plants. But when height and width measurements were attempted, they proved to be somewhat subjective and very time-comsuming. Weight measurements would have required the use of scales which, in a field situation is difficult to use, especially if insects must be counted between weighings or if the weather is wet. The following method, however, was found to be convenient. Selected plants were uprooted or, when too large to pull, cut off at ground level and closely examined. Examination called for stripping off and counting each leaf, including head leaves, while inspecting for pests and damage. In this way the physiological age of the crop could be ascertained through leaf counts while the pests and their damage were directly monitored and recorded. In addition, the roots were periodically checked for soil pests and their damage.

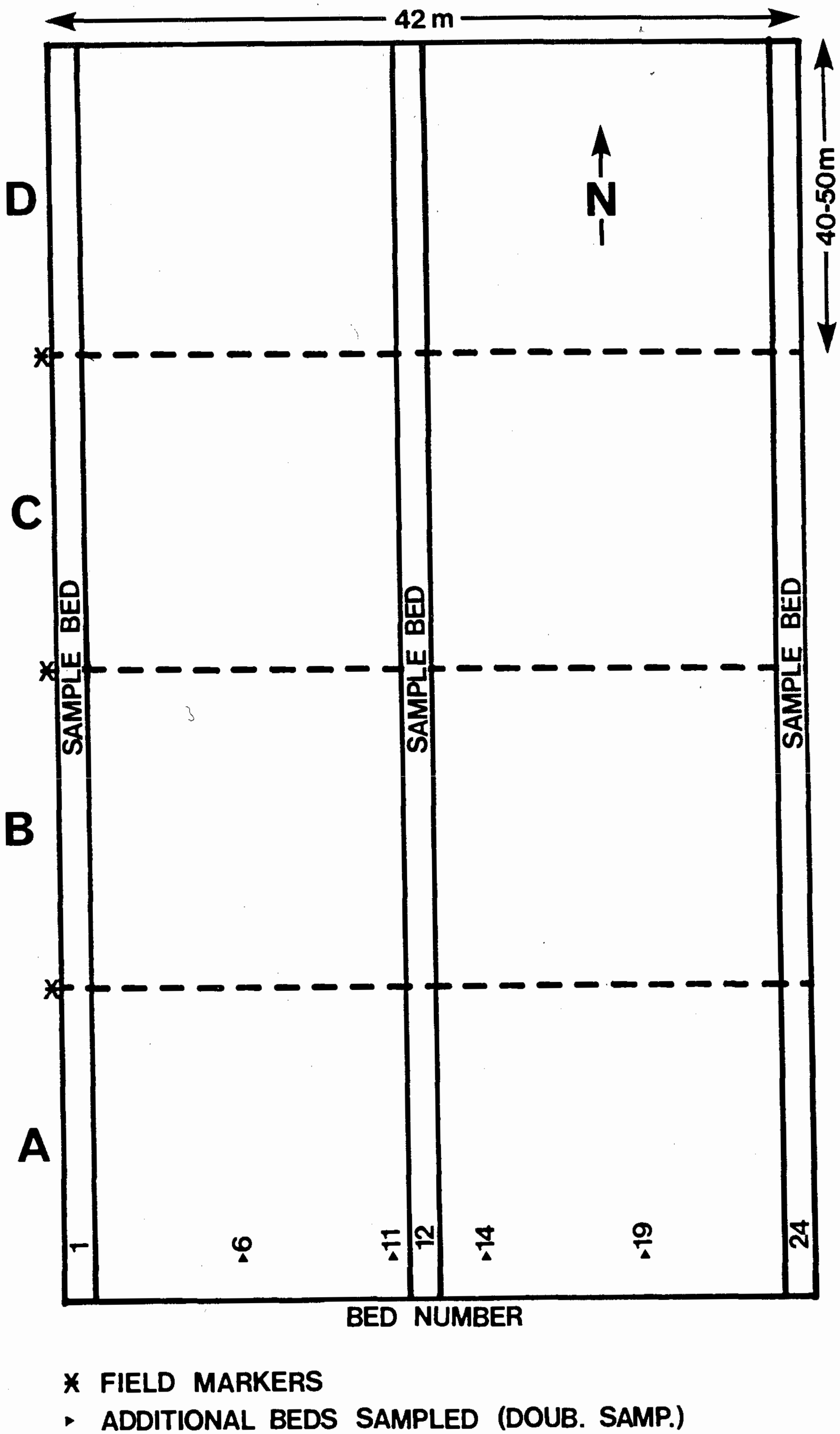
The plants examined were selected as follows: Beginning in one corner of a planting I walked 50 long paces (1 pace = .94 m) along the bed (a bed consists of 4 rows, 35 cm apart, see Fig. 13), then hammered into the soil a broom handle marked with fluorescent surveyor's tape at the top. Since most plantings were about 200 paces (about 188 m) long, three broom handles marked four 47 m long sampling blocks across the field. Then one plant was selected at random within each block, from the two outer beds of the planting and from the centre bed, i.e. four plants were taken from planting (Fig. 9). Most of the commercial plantings monitored consisted of 24 beds so within these plantings, beds 1, 12, and 24 were sampled. Many plantings varied from 20 to 60 beds in width, but at least 13 plants/ha were sampled regardless of planting size. If no aphids were found just prior to the initiation of heading, then to verify the first field sampling, twice the usual number of plants were inspected.

A useful outcome of the leaf counting exercise was the identification of three distinct stages in the physiological development of head lettuce (Fig. 10). The first stage extended from the time of seeding to thinning, when an average of about five leaves/plant was attained. The second stage was the interval between thinning and the initiation of head formation, when plants consisted of close to 15 leaves. The third and final stage was the time from head initiation to harvest, by which time the plants consisted of 30 or more leaves. Although the length of each interval depended on the rate of growth, which in turn was related to seasonal changes in growing conditions, the leaf count at the transition between stages was similar regardless of growth rate. An estimate of crop physiological age by average leaf count is a good gauge for the timing of pest control measures.

When plantings seeded early, midway and late in the season were compared (Fig. 11), the March 9 seeding needed 115 days to mature, the May 13 seeding needed only 61-68 days, whereas the July 16 seeding was never harvested because of early frost damage.

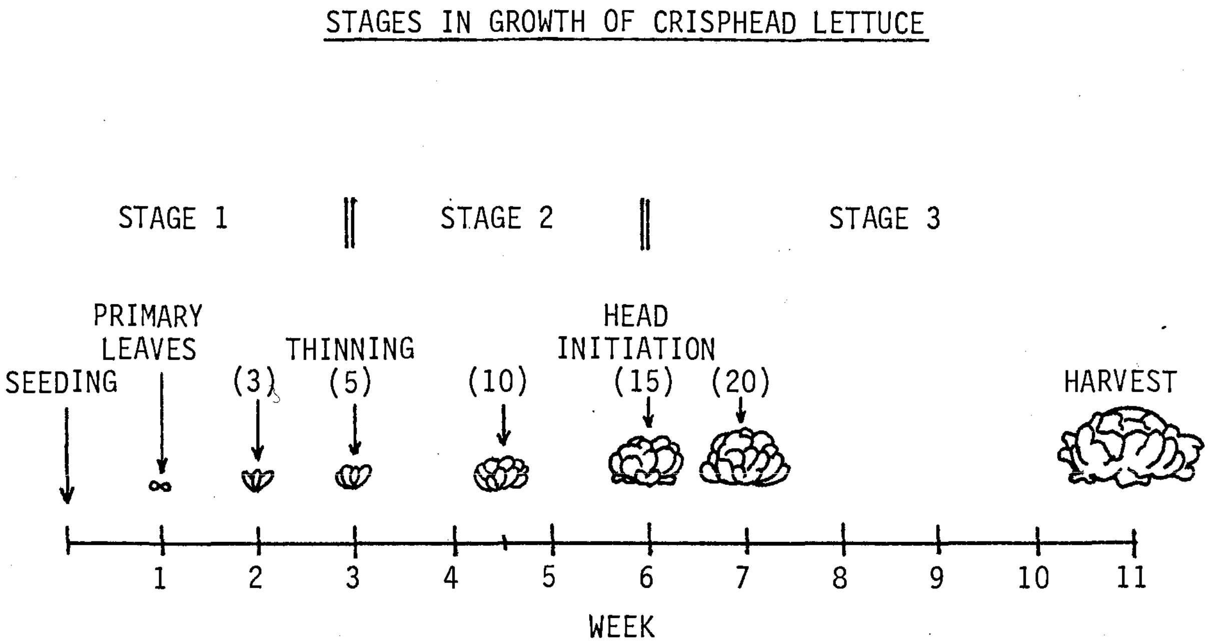
If the crop sampling method described here were to be used on a larger scale, area-wide, lettuce monitoring program, then the economics of such a use must be worked out. Labour and time spent in sampling are important economic considerations. With this in mind, two persons sampled twelve

Figure 9. Plan of a typical planting of lettuce and the sampling procedure used in 1982.



42 m
40-50m
N
D
C
B
A
SAMPLE BED
SAMPLE BED
SAMPLE BED
1
6
11
12
14
19
24
BED NUMBER
FIELD MARKERS
ADDITIONAL BEDS SAMPLED (DOUB. SAMP.)

Figure 10. Stages in the growth of crisphead lettuce.



(N) = APPROXIMATE NUMBER OF LEAVES/PLANT

Figure 11. Profiles of lettuce growth from early- (March 9), mid- (May 13) and late- (July 16) season seedings, 1982.

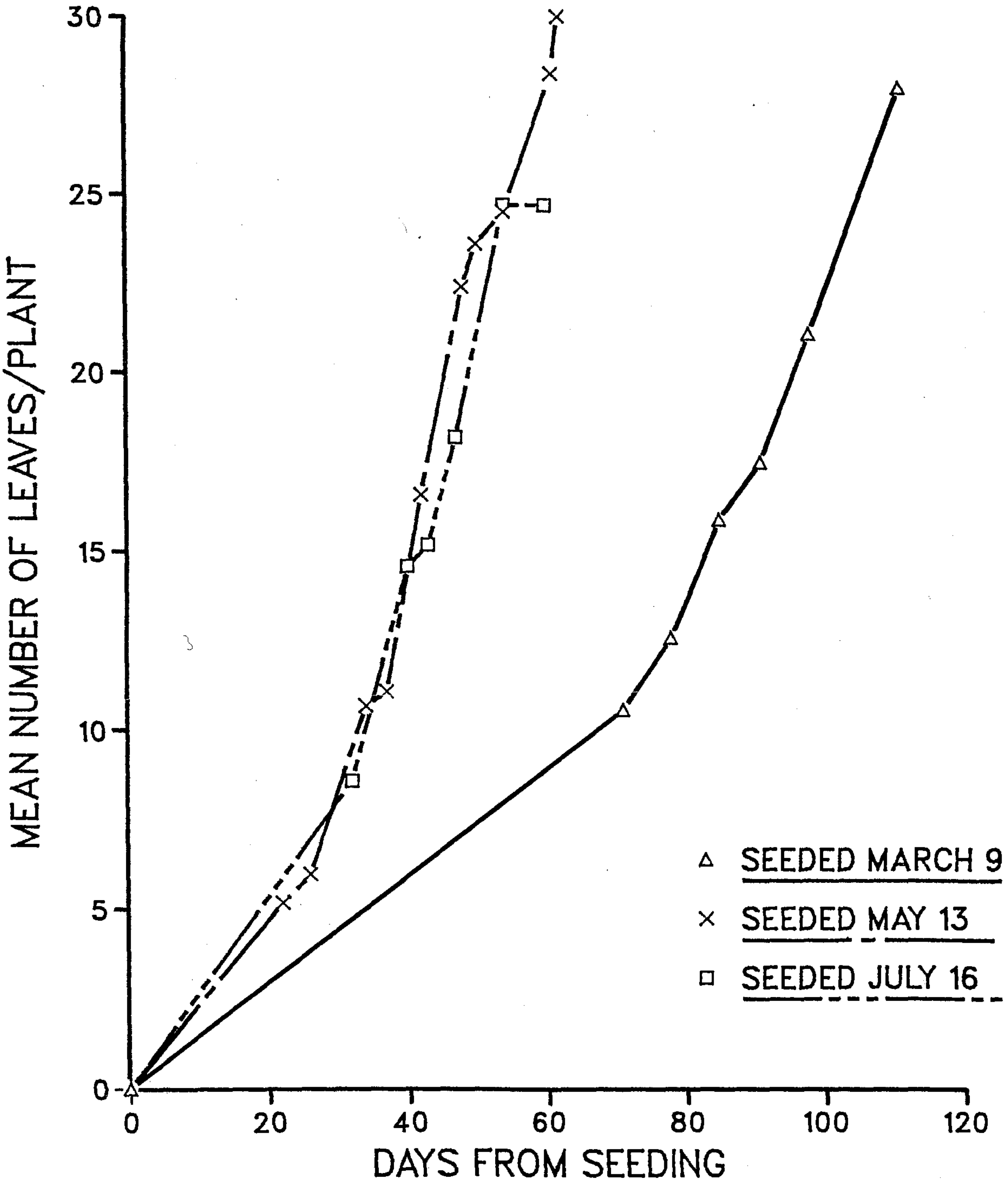

MEAN NUMBER OF LEAVES/PLANT
DAYS FROM SEEDING
SEEDED MARCH 9
SEEDED MAY 13
SEEDED JULY 16
0
5
10
15
20
25
30
0
20
40
60
80
100
120

Figure 12. Approximation of the time required for two persons to monitor 0.8 ha of lettuce from the start of stage 2 to just before harvest. Stages 2 and 3 refer to stages in crop growth.

TIME SPENT MONITORING .8 ha

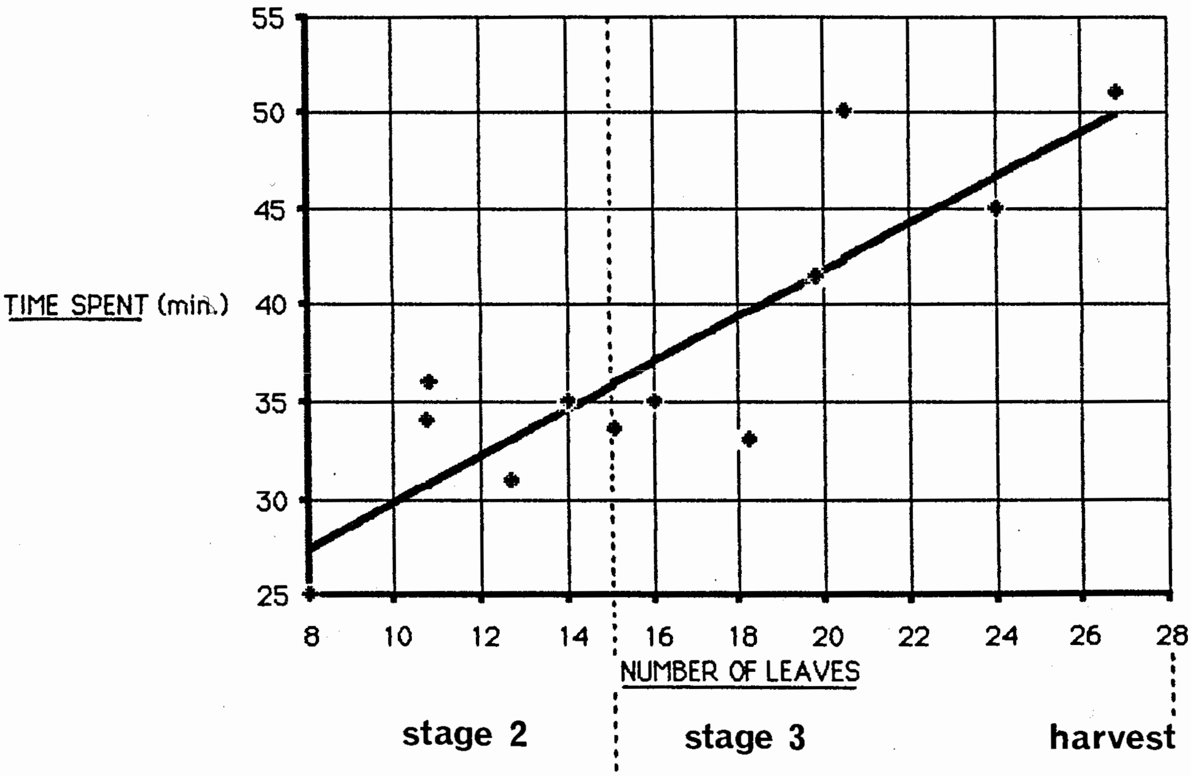


Table 2. Approximation of time required/2 persons to monitor 0.8 ha of lettuce from stage 2 to just before harvest.

Weeks from seeding (approx.)	Number of leaves/plant	Time required for sampling by 2 persons (minutes)
3	5	24
4	9	29
5	13	34
------------ start of heading ------------		
6	17	38
7	21	44
8	25	48
9	29	53
harvest		
TOTAL 7 weeks		

Note: Sampling after the end of week five is not generally economic. Total time required for sampling to the 13 leaf stage is 87 minutes (1.45 hrs)/2 persons/0.8 ha, or 2.9 hrs/person*/0.8 ha, or 3.6 hrs/person/ha.

*One person may take more than twice as long as two persons to sample the same area.

use must be worked out. Labour and time spent in sampling are important economic considerations. With this in mind, two persons sampled twelve plantings of different physiological ages and recorded the time taken to complete the task. The results (Fig. 12) indicate that when two persons sampled plantings of 0.8 ha (24 beds wide, 194 m long) as described, approximately 25 minutes were required when plants were at the 5-leaf stage of growth and 36 minutes when they were at the 15-leaf stage, i.e. at the start of head formation (Table 2). The efficiency would likely be less if one were working alone but time could be saved if only the presence or absence of aphids was recorded or if, instead of marking out the field with stakes in advance, intervals between samples were either paced or measured as sampling progressed. In a large scale program, even more time would be saved since sampling does not normally continue past the end of stage 2 in crop growth.

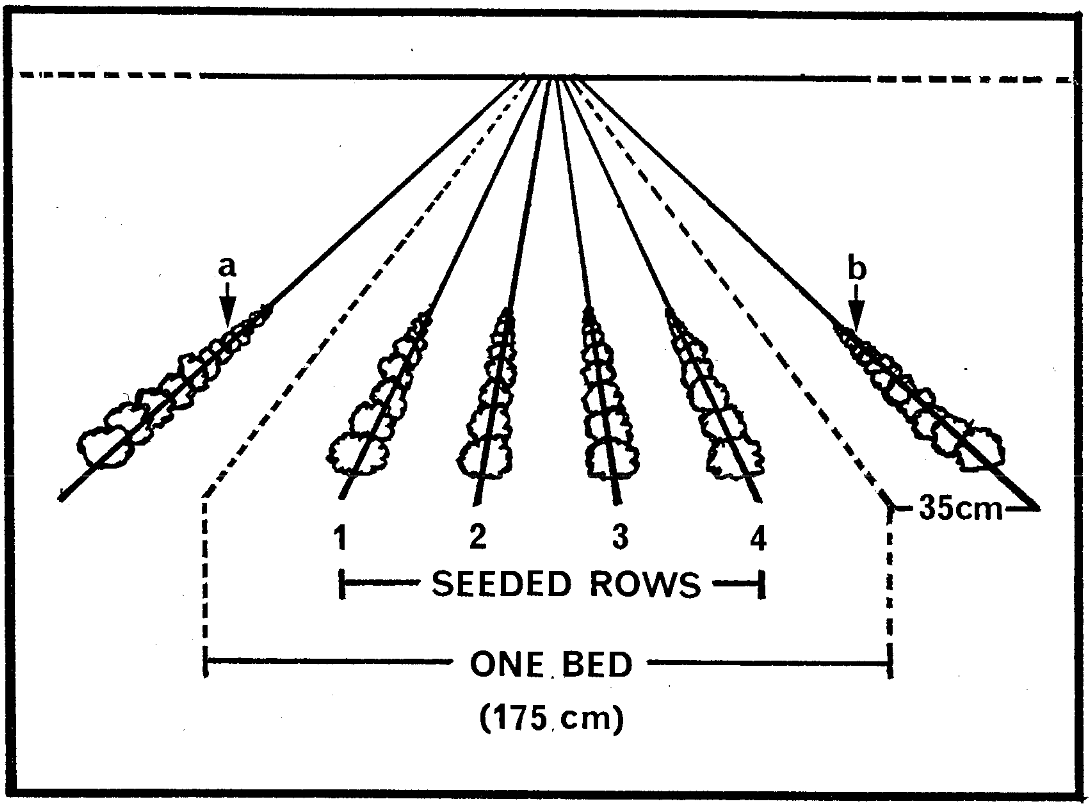
These timing trials did not include the time taken to position and remove the stakes - a total of about 6 minutes. Once positioned, however, the stakes usually served several contiguous plantings and so in a calculation of total sampling time, the 6 minutes would be averaged over however many adjacent plantings were sampled. Table 2 represents an estimation, from the data plotted in Fig. 12, of the time required for 2 persons to monitor 0.8 ha of lettuce from the start of stage 2 to just before harvest. The timing exercise reported here, although not wholly adequate for calculating the economics of sampling in a large-scale program, does give an estimate of the amount of time sampling might consume. A more detailed analysis of the cost of monitoring is outlined by Dun (1984).

3.3 Leatherjackets

On 23 April, 1982 leatherjackets were found killing lettuce seedlings in planting numbers 5 and 6 (Fig. 7). A soil spray of parathion was recommended and applied in the evening and no further damage was reported. On 25 May, leatherjackets were found again, this time in planting 19 (Fig. 8) and so it was decided to conduct a damage and population assessment in that field. On 27 May, damage was assessed in planting 19 by counting damaged and undamaged plants in beds located near the margins and in the middle of the field. Comparable numbers of damaged plants and larvae were found in all the beds examined and an overall average of 30.6% of plants were killed by what were confirmed, in many instances, as leatherjackets. On the same date, a similar count was taken in the small field 20. Leatherjackets were distributed in low numbers thoughout the field, but the overall damage level was estimated at only 8.3%.

To estimate the population of leatherjackets, diagonal lines were surveyed between the corners of the field so that they intersected at the centre. Five equidistant sites in field 19 and three in field 20 were chosen along each of the two diagonal lines with a shared site at the intersection. Sites at the ends of the lines were not less than 5 m from the field margin. On 27 May, mini-plots of 1,000 cm^2 at each site were drenched with 1 L diazinon mixture using a Solo manual backpack sprayer. The purpose was to induce larvae to wriggle to the surface where they could be counted. In garden crops, control measures are advised at least two weeks before the field is prepared for seeding if an average of one or more larvae are seen on the surface (Wilkinson 1983). Nineteen hours after the

Figure 13. Dimensions of a typical bed of lettuce on a commercial farm.


a
b
35cm
1
2
3
4
SEEDED ROWS
ONE BED
(175 cm)

drenches were applied, the sites were examined. Only one larva was seen, dead, on the soil surface. However, at more than one site in field 19, excavation of the soil around killed seedlings revealed living leatherjackets at a depth of about 5 cm. No larvae were found in field 20. The soil was dry to a depth of about 1.5 cm in both fields which might have explained why larvae were not found on or near the surface. Leatherjackets normally prefer damp conditions but after the damage was first detected, the weather turned warm and dry. The surface soil became dry, and feeding activity was confined to depths below 1.5 cm. Irrigation of field 19 followed by a spray of parathion was recommended to the grower on 27 May and carried out the next day. But on the 29 May, a follow-up examination of the field revealed live larvae - the parathion application was ineffective. A recommendation to reapply the parathion but increase the volume of spray mix to at least 1000 L/ha covering 10 cm on either side of plants in the row was issued to the grower on 1 June. This second spray, the continuation of dry, warm weather, a cessation in feeding by full grown larvae, or a combination of these factors resulted in no further damage that season.

3.4 Alfalfa Looper

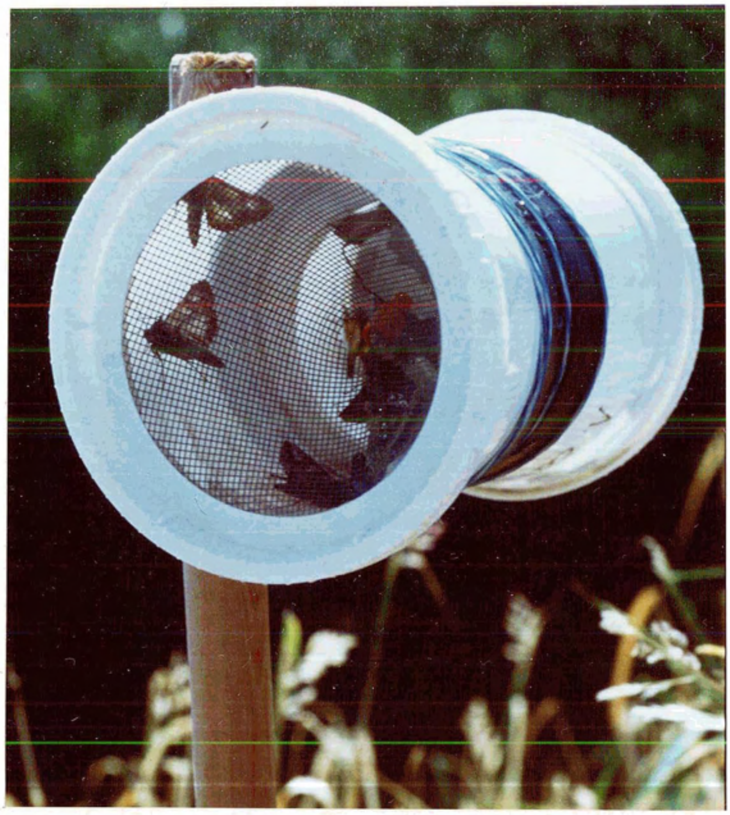
3.4.1 Monitoring

The alfalfa looper, *Autographa californica* (Speyer), was monitored in two ways: by direct examination of lettuce plants for larvae, eggs, and pupae; and by trapping. To monitor the numbers of *A. californica* male moths between fields and to follow general trends in the population of males through the season, experimental female moth sex pheromone traps were used. The pheromone chemical was impregnated into red rubber septae for lures and suspended mid-way inside cone-typed traps (Fig. 14). Both the lures, pre-baited with phermone, and the four cone traps were donated by the National Research Council of Canada9. The traps were tied horizontally to broom handle stakes 1 m above ground, at evenly-spaced locations on the cooperator's farm, so that one trap was set out for each 3.2 ha (7.9 ac) of lettuce grown (Figs. 7 and 8). The prevailing wind was from the southwest so the traps were placed upwind of fields, *i.e.* in their southwest corners and aligned so that the long axis of the trap was parallel with the prevailing wind vector.

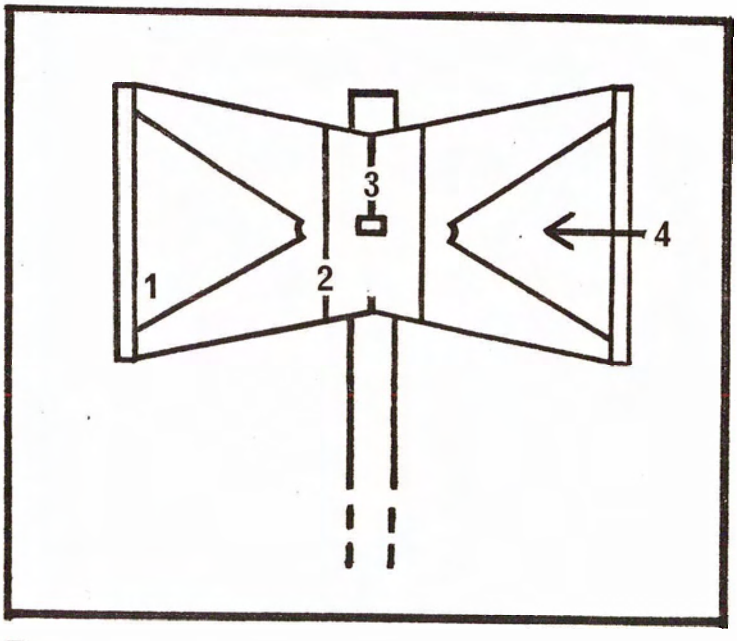
Trap catches were identified, counted, and recorded on standard forms (Appendix A2) at least once/week but usually twice/week. Moths were removed from the traps after each count and the traps and lures were checked and maintained. Lures were replaced every 4 weeks. Trapping began in early May and continued until the end of September.

When the numbers of moths caught in individual traps were compared between fields, no trends were apparent, but when the catches of all four

Figure 14. (A) cone trap baited with *Autographa californica* female moth sex pheromone showing trapped males, 1982; (B) components of same trap: 1, cone of wire mesh; 2, adhesive tape; 3, pheromone impregnated rubber septa centrally suspended on short wire; 4, intended air flow.

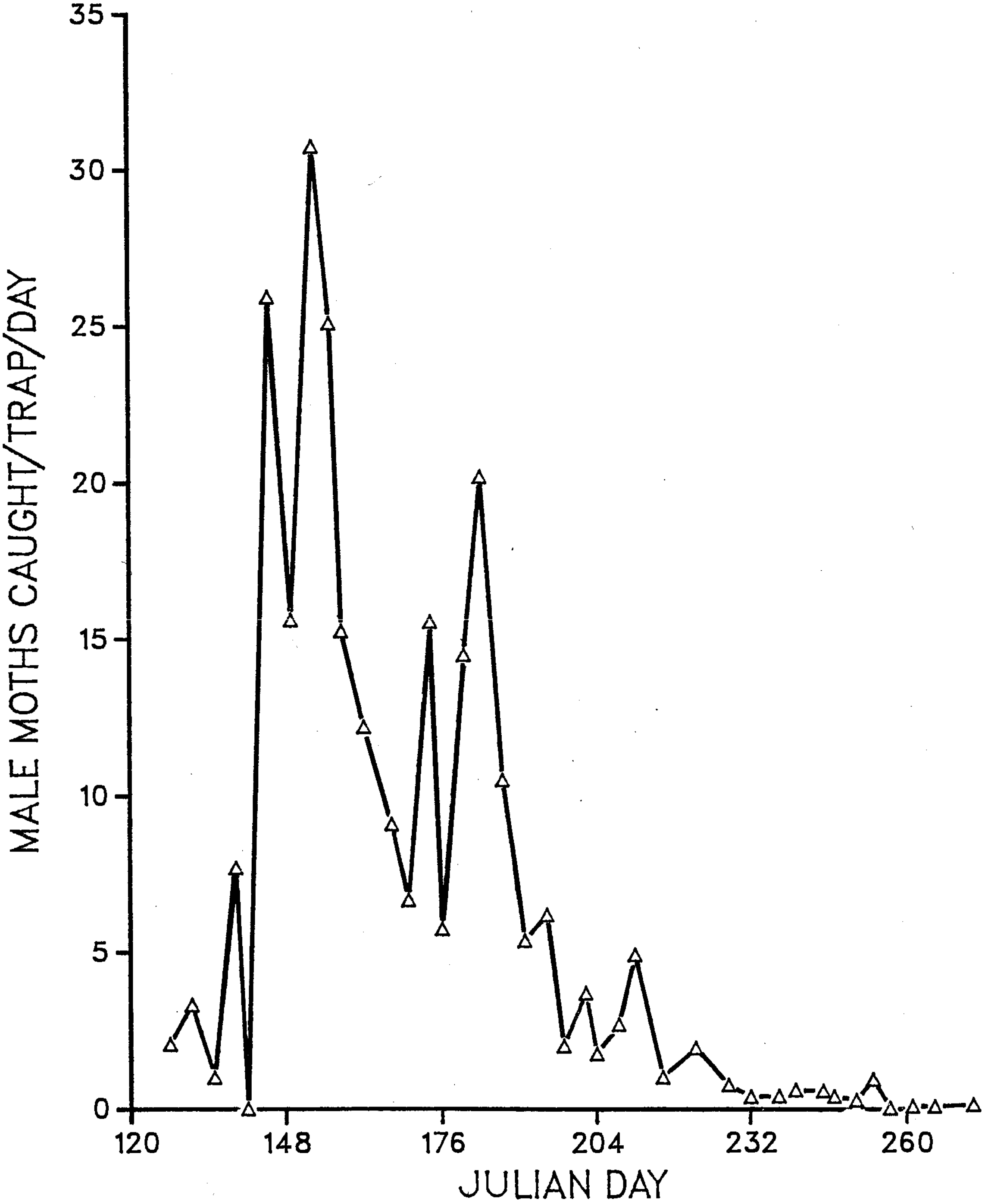


A



B

Figure 15. Number of male *Autographa californica* moths caught/trap/day in female sex pheromone baited traps located on Cloverdale Produce Farm, 1982.



35
30
25
20
15
10
5
0
MALE MOTHS CAUGHT/TRAP/DAY
120
148
176
204
232
260
JULIAN DAY

first peak occurred between 22 May (Julian day (JD) 142 on Fig. 15) and 19 June (JD 170) and the second between 19 June and 10 July (JD 170 and 191). Eggs and larvae of the alfalfa looper were first found on the crop on 25 May (JD 145) and pupae were found in the field on 29 June (JD 180). Trap catches were somewhat related to the looper populations actually encountered in field sampling. They were an especially serious pest in June and this is reflected in the trap catches. However, crop damage was observed and loopers were present on the crop throughout the remainder of the season. From the middle of July through the first half of September moths were routinely caught, albeit in relatively low numbers, while crop damage was less than in June.

I think that considering the relatively small scale of the lettuce cropping practiced in the lower Fraser Valley, compared to, for example, California, trapping with pheromone is neither accurate nor practical enough for monitoring alfalfa loopers for local pest management. The indirect nature of the monitoring, variability between catches, and the area over which the pheromone draws moths, make the traps more useful for investigating the biology and migrations of the pest than for predicting short-term crop damage.

3.4.2 Threshold for Control Action

The seriousness of the threat of crop damage by the alfalfa looper is related to the stage of crop growth. When the plants are very small, only a little leaf feeding will defoliate and kill seedlings. Larger plants are able to sustain more feeding, but as plants approach heading and harvest, less damage is tolerated by consumers.

In a California study, maximum harvest yields were obtained when levels below 0.5 larvae/plant were maintained during stage 2. The lettuce heads then had to be kept insect-free during stage 3 in order to ensure a marketable product (Toscano, *et al*. 1982b). Although some of the species of caterpillars encountered in the California study were different from those found in B.C., the same treatment thresholds were applied here (see Appendix B2 for summary of recommendations).

A. californica larvae were monitored by direct examination of lettuce plants in the field and their numbers were recorded on standard forms (Appendix A1). Upon completion of examinations, the counts of larvae, eggs and pupae were totalled and the larval population was expressed as the number of loopers/plant. The threshold of <0.5 loopers/plant in stage 2 of crop growth proved satisfactory since effective insecticides such as methomyl and methamidophos were available.

Reports of incomplete control from spray applications of parathion were received and checked out. On June 10, 1982, parathion failed to control loopers on one farm. Inspection of the grower's field suggested either pest resistance or improper application during hot, sunny weather, hence rapid detoxification of the insecticide by volatility and U.V. degradation was probable. Use of outdated spray concentrate was another possible factor in the lack of control. The grower was advised to apply another spray but in the evening when the wind was calm and to use a different insecticide. He applied carbaryl (Sevin) and achieved satisfactory control.

3.4.3 Within-field Distribution of the Alfalfa Looper

If the monitoring of lettuce is to be practical on a large-scale, then sampling must be efficient. The objective is to obtain a reliable estimate of the looper population in the field with the fewest possible samples.

The sampling of lettuce fields is constrained by the physical layout of the plantings. Lettuce is usually seeded in blocks or plantings of several long beds, each bed containing four rows 35 cm apart (Fig. 13). The beds are 1.75 m across and as the plants grow it becomes increasingly difficult to walk across the beds within the field without damaging the plants or sinking into the soft organic soil. With this in mind, the easiest way to sample a lettuce field is to take samples along the length of beds or to take them from across the ends of the rows or headlands, while walking just outside the planted area.

One way of reducing the number of samples would be to sample only the two beds bounding the length of the planting and the ends of beds across the planting's width. Samples from within the block would be eliminated. However, in order to reduce the number of samples in this way, one must have data depicting the distribution of loopers in several fields. Such data might show whether loopers and their eggs are usually found in clumps or pockets of infestation, at a particular directional end of the fields, or mainly along the margins. They may show no "typical" distribution at all, but if the liklihood of finding loopers is the same anywhere within the field, then perhaps the easiest samples, i.e. those taken only from the field margins, would provide the same information as more difficult, in-depth sampling.

With the above rationale in mind, four commercial fields of lettuce were intensively sampled (Appendix D1). The method used to sample field 3L is given here as an example (see Appendix D2 for graphed results). Field 3L was .56 ha of lettuce in stage 2 of growth (5 leaves) and was bounded on the north and south sides by one-week younger and one-week older plantings of lettuce respectively. The prevailing wind was from the southwest. On 28 May, 1985, the field was surveyed for loopers and their eggs by selecting at even intervals, six of the 25 beds and examining four plants at every 18 m interval along the selected beds. Examination meant gently prying open the leaves of plants and taking note of the numbers of eggs and loopers observed.

The distribution profile of eggs in field 3L appears biased to the east and north sides (Appendix D2). Field 4L shows a similar trend, but from south to north no trends appeared. In both fields the numbers of loopers were fairly even regardless of direction. Field 1L shows a higher number of eggs towards the eastern border and a uniform number of loopers from east to west. No trends were obvious in either the number of eggs or loopers in the south to north direction. In field 2L, inspected in August, the counts appear to vary more than in the other fields, but the highest count of nearly 1.4 larvae/plant (at 45 m in the west-to-east direction) is comparable to the magnitude of counts in the other fields.

With the exception of field 2L, field inspections were done in late May. The May inspections showed a much higher number of A. californica eggs/plant than loopers/plant, while the August 18 examination showed the reverse. In 1982, pheromone-baited traps were set out on 3 May and during the first four days, an average of two male moths were caught/trap/day. Assuming that females were also active, then mating and egg laying had started by early May. Eggs and first instar loopers were found on the crop for the first time on 25 May. Field inspections late in May correspond to a time when pheromone-baited traps caught 26 male moths/trap/day, the second highest catch of the season. These coincidental notes suggest that the first generation of loopers was just getting underway. The lower egg count in August could reflect a tapering off of egg laying for that season. Since insecticides directed against loopers are more effective when larvae are in their early instars (Berry 1978), late May and early June are probably a good time to consider insecticide application for this pest. The decision is made more difficult, however, since the size of the crop, thus the potential for the alfalfa looper to cause economic damage to the harvestable portion must also be taken into account.

In all of the fields examined, the numbers of loopers/plant were above Toscano's (1982b) threshold of 0.5 larvae/plant. Sampling only the outside margins of the fields would have correctly led to the decision to apply an insecticidal spray - except in field 1L. If only the southernmost and northernmost beds of that planting had been sampled, an incorrect decision not to apply a spray would have been made. Although the numbers of loopers within the field were not extremely high, they were, nevertheless above what was considered as the economic threshold. Whether or not the mid-way bias in looper infestation pattern in this one field is cause for real concern can only be answered by more field sampling.

3.5 Lettuce Aphid

3.5.1 Regional Survey

In 1982, a survey was carried out to investigate the biology of N. ribisnigri. The purposes of the survey were: to gain experience in the identification of primary (winter) and secondary (summer) hosts; to locate possible areas with primary hosts as harbourage for the aphids; and to determine when the fundatrigeniae hatch and the spring migrants disperse. The survey was conducted within the boundaries of a 30 km^2 area from which is produced 95% of the lettuce grown in the lower Fraser Valley (Cloverdale Lettuce and Vegetable Cooperative, unpub., 1983)[3] (Fig. 6). From 5 May to 16 June and from 4 to 29 September, field headlands, ditchbanks, home-owners' yards (Appendix C2), unused lands, and forested areas within the survey boundaries were surveyed weekly. Plant and aphid samples were collected for identification, and sites of primary host plants were mapped.

To determine when the spring migrants of the lettuce aphid fly from primary woody hosts (Ribes spp.) to summer herbaceous hosts, the use of colour-attractive aphid traps was attempted. Several authors have successfully captured aphids in the field using yellow-coloured sticky or water pan traps (Heathcote 1957; Lamb 1958; Kennedy et al. 1961; Gonzalez and Rawlins 1968; Moericke 1969; McCalley and Lange 1969; and locally, Wright et al. 1970). The following important points emerged from these studies.

The effectiveness of a trap to monitor aphids depends on the target species, its physiological condition for flight, the characteristics of the trap, the ambient air temperature and the wind speed. In the present study, lettuce aphid was the intended target and the assumption was that primary migrants would be ready for spring flight between mid-May and mid-June.

The decision to use either sticky traps or water pan traps to monitor the migration was based on the following considerations. Moericke water pan traps have caught more aphids than sticky traps (Heathcote 1957), but were subject to loss of catch by overflow flooding from rain, and drying out or decomposition of specimens. Sticky traps collected fewer aphids, but they had the advantage of needing less attention, and were therefore chosen here.

Trap colour was another consideration. Kennedy (1961) cited Moericke (1952, 1953, 1955a,b, and c), as reporting yellow to be more attractive to aphids in the field than the other colours tested. Later researchers found the most attractive yellows to be unsaturated[4], capable of reflecting ultraviolet light and of high intensity[5]. Unfortunately, the yellows tested were largely non-specific in their attractiveness. In this study, a yellow paint containing lead was obtained locally (industrial lead base yellow, no. 76025, Cloverdale Paint Ltd.)[7]. A plot of the percent reflectance of this yellow at wavelengths from 300 to 700 nanometers (nm) is given in Appendix C1.

The construction of the traps was slightly modified from a design formerly used successfully to monitor the onion maggot, Delia antiqua (Meig.), in a local onion pest management program (Vernon 1979). To make the traps, cardboard (4-ply Railroad Board, Domtar Fine Papers, Toronto, Ont.) was painted yellow and cut into 15 cm squares. Stickem Special® (Seabright Enterprises, Emeryville, CA)[8] was applied evenly to one side and the squares were clipped, sticky side up, to plywood platforms of the same area. To raise the sticky surface 38 cm above ground, the platforms were mounted on the ends of wooden dowels of 2 cm diam. driven into the soil. The trapping surface was horizontal to ensure that any aphids trapped were ready to land and not merely windblown. Heathcote (1957) considered that aphids are unable to fly independently of winds greater than 2.5 km/h which would mean that alate aphids responding to colour do so only during calm weather. Temperature and moisture are likely to affect the trap catch also. Sticky traps were set up at sites of primary host plants and checked for catch weekly (Fig. 6).

Several sites were located around the lettuce-growing area where primary host plants were growing and possibly harbouring the lettuce aphid (marked "X" on Fig. 6, also see Appendix C2 for addresses). I collected adult fundatrices and fundatrigeniae (mostly alate) on black currant, <u>Ribes nigrum</u> L., in May, 1982, designated as "A" on Fig. 6. The first record of the year was on 11 May and is marked "A^1" on the map. Migration to lettuce and presumably to other secondary hosts, took place in late May and June as lettuce aphids were first noticed on the crop on 27 May. Late summer and fall return of aphids to <u>Ribes</u> was not witnessed, but probably it takes place in September and October.

In addition to the survey near Cloverdale, small, local market producers in south Burnaby were questioned about their lettuce pests (see Appendix C3 for addresses and comments).

3.5.2 Monitoring with Sticky Traps

Yellow sticky traps were assessed on the farm as a means of monitoring incoming migrant alates of lettuce aphid. Six traps were positioned in planting 1 (about 3 traps/ha) (Table 1 and Fig. 7). The traps were 80 m apart along the two outermost beds which themselves were slightly more than 100 m apart. Data were recorded weekly and the traps maintained between 26 April and 12 June.

The results were discouraging. Traps placed within the field were frequently knocked over by tractors and obscured by either splashing or blowing soil. In wet weather the sticky film turned milky making identification of the few trapped aphids very difficult. Traps were non-specific in their catches. The species caught included the shallot aphid, *Myzus ascalonicus* Donacaster, *Aulacorthum solani* Kaltenbach, *N. ribisnigri*, *Fimbriaphis* spp., and a species of *Periphyllus*. These appeared sporadically in low numbers, however, and the initial flight of the lettuce aphid from primary hosts to the crop was not detected by the traps. The sticky trapping of aphids in commercial plantings was not nearly so useful a monitoring technique as direct examination of plants. The first appearance of the lettuce aphid on the crop was detected in that way since the plant examinations were necessary anyway for keeping abreast of the size of the alfalfa looper population.

3.5.3 Thresholds for Control Action

In the lettuce plantings, aphid pests were monitored in the same way as alfalfa loopers - by direct examination of plants in the field. The aphids were identified, counted and recorded on standard forms (Appendix A1). Initially, the numbers of alates, apterae and nymphs were recorded separately and the density of aphids in the planting was expressed as the total number of individuals of all morphs/leaf and/plant. A look-out was kept for any parasites and predators of the lettuce aphid, but in the Cloverdale area, none was seen.

At the start of the 1982 season, an appropriate threshold for numbers of aphids causing economic damage, especially lettuce aphids was not known. Between the start of head formation and harvest (stage 3), it seemed logical to assume that a threshold of 0 aphids/plant was necessary because lettuces infested with even one or two aphids had been rejected in the previous season; but the number of aphids which could be tolerated on plants prior to heading was in doubt. This threshold had to be approximated through trial and error.

From mid-May until the first week of July, a spray was recommended (Appendix B2) when a threshold of 0.5 aphids/plant was recorded in stage 2. This threshold was retained until the first week of July when infestations in excess of 25 aphids/plant were suddenly encountered. Aphid density then had to be considered in a different way. Counting large numbers of individual aphids became much too time-consuming, so it was decided to express the population density more simply as percent infestation, i.e. the number of aphid-infested plants encountered divided by the number of plants examined. It also became apparent that, considering the effectiveness of the control measures available, a threshold of 0.5 aphids/plant in stage 2 was too high. If lettuce plants were infested with aphids at the start of heading, then satisfactory control was extremely difficult and more likely impossible.

With 2.6 ha of lettuce on the cooperator's farm about to head by early July and 6.8 additional hectares in successive plantings, the threshold of aphid density at which sprays were recommended had to be lowered. It was not known at this point whether any aphids could be tolerated in plantings prior to head initiation, but with so much at stake and because of the uncertainty, a zero threshold was reluctantly adopted. If a planting was within one week of stage 3, and the routine plant examinations indicated that it was free of aphids then, to verify the original count, twice the number of plants per hectare were examined.

After completion of a direct examination of plants in each planting, the density of aphids and loopers was calculated and entered in a master table for all plantings (Appendix A6). In this way decisions were made easier, either to act or defer action on pest control. Examination dates, pest controls and the physiological age of the plantings were all overseen.

Two scenarios in lettuce arise depending on whether or not pest monitoring is available. Monitoring will indicate when the first spray should be applied and whether subsequent sprays are warranted. On the other hand, growers whose fields are not monitored must rely on published control schemes that are based on the pest's life-cycle and judged best by experimentation and past experience.

A threshold of zero percent aphid-infested plants largely precludes integrated management of the pest. Instead, monitoring can only tell us when to apply the first spray of insecticide, and unless the spray is 100% effective, subsequent monitoring will only evaluate the sprays, since other sprays will be needed until all the aphids are eradicated within the field. The concept of only applying control measures when monitoring indicates levels of pests above threshold, does not readily apply when extremely low numbers of pests are perceived economically damaging.

The option of withholding sprays and thus saving money by reducing the number of sprays applied/season, is open only until monitoring indicates the presence of the pest. Once the pest is found, considerable effort, i.e. energy, is required to eradicate it within the field. In lettuce, eradication of the lettuce aphid must be achieved before the end of stage 2 of crop growth to prevent the contamination of heads with insect corpses. Chemical control must therefore be customized to be effective in accord with the stage of crop growth. This topic will be discussed further in Section 5.

3.5.4 Distribution of Lettuce Aphids within Commercial Fields

In 1982, most of the monitoring of commercial lettuce fields was dedicated to the lettuce aphid, therefore an efficient and reliable method for monitoring the aphid was needed. A major goal in the development of any monitoring scheme is to obtain an acceptable estimate of the pest population in a field with the greatest economy. If typical patterns of aphid distribution do occur within fields, and are known, then those areas most likely to harbour aphids could be sampled first, and an estimation of the action threshold could be obtained without sampling all parts of the field.

The following studies attempted to show any tendency for aphids to colonize one part of a field rather than another. The physical layout of lettuce fields restricts easy access to pathways between beds and across headlands, therefore comparisons were made in north-to-south and west-to-east directions (Appendices D3 and 4).

Factors which might influence aphid distribution include the size of the field, the adjacent ground cover, the prevailing wind, the stage of crop growth and the examination date. These factors are summarized for each field in Appendix D3. Sampling was carried out the same way as in section 3.4.3, Within-field Distribution of the Alfalfa Looper. In field 1A aphids were counted and expressed as the number of aphids/plant, whereas in sampling fields 2A, 3A and 4A, only the presence or absence of aphids was recorded and expressed in percent as the number of infested plants in the total number of plants examined.

In six of the eight infestation profiles presented (Appendix D4), the highest infestation levels were found along an outermost margin of the field; however, no orientation was apparent toward any direction, an adjacent ground cover or the prevailing wind. When considered alone, field 1A showed its highest levels of infestation along the western (29 aphids/plant) and northern (26 aphids/plant) margins. However, the entire field was heavily infested. Field 2A, a relatively large field, showed a bimodal peak in a west-to-east direction and a higher percentage of infested plants along the southern and northern margins adjacent to mature and earlier plantings of lettuce respectively. Twenty-six percent of plants examined in the bed adjacent to a planting of mature lettuce were infested, compared with 20% in the bed adjacent to earlier seeded lettuce. Field 3A also showed a higher percentage of infested plants along north and south sides. Forty-seven percent of examined plants were infested in the northernmost bed adjacent to a planting of mature lettuce. The highest level of infestation, 53%, was on the upwind side (west) of the field, next to a field of onions. In field 4A, the infestation was higher in the western and easternmost beds. From the south-to-north ends of the field, the profile of percent infestation was bimodal with a bias towards the margins.

It can be concluded from these results that monitoring only the marginal beds of a lettuce planting and across the headlands should provide a conservative estimate of the overall infestation level without sampling the middle of the field.

Monitoring lettuce was first implemented on a large scale in 1983 (Dun 1984) and is discussed in Section 5.

3.5.5 Distribution within Plants

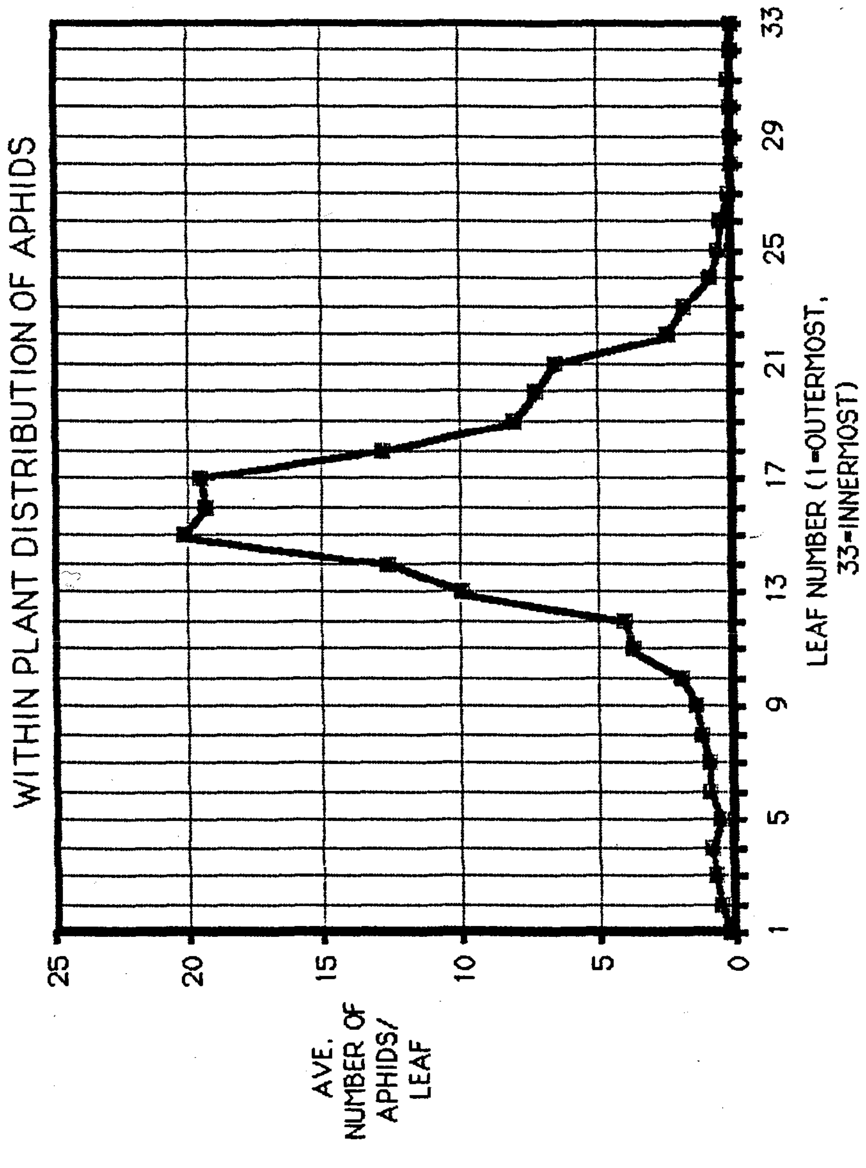
Unlike the green peach aphid, Myzus persicae (Sulzer), the potato aphid, Macrosiphum euphorbiae (Thomas), and other lettuce-infesting species of aphids which feed mainly on the outer leaves, the lettuce aphid feeds primarily on the innermost leaves. Alates of N. ribisnigri and their progeny which colonize lettuces when heads are forming, are well protected from foliar sprays of contact and locally systemic insecticides by the infolding leaves of the head. A preference of N. ribisnigri for the youngest leaves of lettuce plants was suspected, but since there were no data to confirm the suspicion, a study was undertaken.

On 22 June, 1984 crisphead lettuce, cv. Ithaca, was seeded in beds 1.75 m wide each consisting of 4 rows of lettuce, 35 cm apart (Fig. 13) to simulate lettuce seeded on commercial farms. The 0.12 ha experimental field was divided into blocks and within blocks, plants were selected at random, marked, and on 5, 9, 13 and 16 July inoculated with about 5 aphids/plant. All inoculations were made in stage 1 of growth, i.e. before the plants had developed 5 secondary leaves. No insecticides were applied during the season. At harvest, 29 August, 6-7 plants were uprooted in each block and each stripped of its leaves, one at a time while the number of aphids on each leaf were counted and recorded. A total of 26 plants were examined in this manner. An additional 81 plants were uprooted on August 28 and 29 but only the outer wrapper leaves, i.e. those leaves not from the head, were counted. The number and distribution of aphids found on each of the 26 plants examined was averaged (Fig. 16).

Eighteen of the plants were made up of 33 or more leaves while the fewest number of leaves found on any of the plants was 27. The average number of wrapper (outer, non-head) leaves/plant was 12.0. A cumulative total of 430 lettuce aphids (12% of total aphids) were found on the first 12 leaves examined compared to 3,005 (84% of total) on leaves numbered 13 to 21 inclusive.

These results dramatically show a preference of lettuce aphids for feeding sites just inside heads of crisphead lettuce, rather than on the wrapper leaves or in the very centre of mature heads. This finding will influence continued research into control practices such as the development of improved application methods for insecticides and selection of those which can reach the pest. Whether aphid preference for specific feeding sites is affected by the stage of crop growth and the impact of the timing of initial aphid colonization in relation to these stages should be investigated. Such information would improve the timing of controls and their effectiveness.

Figure 16. Average distribution of lettuce aphids within 26 plants, Abbotsford, 1984.


WITHIN PLANT DISTRIBUTION OF APHIDS
AVE. NUMBER OF APHIDS/ LEAF
25
20
15
10
5
0
1
5
9
13
17
21
25
29
33
LEAF NUMBER (1=OUTERMOST, 33=INNERMOST)

3.6 Recent Developments in Plant Examination and Sampling

Since 1982, monitoring has been introduced on an area-wide scale. In 1983 and 1984, funds were made available to this project by the B.C. Ministry of Agriculture and Food (B.C.M.A.F.) through an extension of the "Demonstration of Agricultural Technology and Economics" (D.A.T.E.) project no. 99 under the supervision of Dr. H. Gerber[10] and the contracted services of Mr. W. Dun. Mr. Dun was mainly responsible for monitoring the lettuce fields and reporting the results to growers who would then follow the control program according to the pest situation. Under the monitoring program, no pest-related crop losses occurred in 1983. The program was successfully continued in 1984 by the same agency and, although lettuce aphids were more prevalent than in 1983, only 0.5% of the total crop was rejected because of aphid contamination (Dun 1984). In 1985, the B.C.M.A.F. discontinued its provision of monitoring services and the responsibility was assumed by the Cloverdale Lettuce and Vegetable Cooperative[2] which contracted the services of a field scout.

The lettuce aphid appeared for the first time as a serious pest on lettuce in 1981, therefore little was known about how it should be be monitored and controlled. A good start towards its management was made in 1982, but modifications and refinements to the program, especially the sampling technique, have been found necessary through actual application on a large scale. For example, in 1982 sampling was carried out through plant stages 2 and 3 of crop growth, i.e. from thinning to harvest, but in 1983 it was found that sampling after stage 2 was impractical. Therefore, in the 1983 and 1984 programs, sampling took place only in stage 2, i.e between thinning (5 leaves/plant) and the start of heading (about 15 leaves/plant).

Within-field distribution studies have also resulted in modifications to sampling. Firstly, they have shown that lettuce aphids tend to colonize the margins of fields, and secondly, in fields of young lettuce planted next to fields of mature lettuce most aphids were usually found along the field edge closest to the mature lettuce. These two observations led in 1984 to the sampling of only the outside edges of plantings not adjacent to other plantings of lettuce; and in plantings situated next to an older planting on one side, sampling only the edge nearest to the older plantings.

In plantings that were situated side-by-side with those of a different age, the third bed in from the edge of the planting was sampled rather than the outermost bed, to avoid sampling the area along the edge prone to over- or under-spray. This is a consideration since some growers use spray booms which reach across several beds, usually five. The number of beds in a planting are not always multiples of five and consequently the outermost bed or couple of beds may be left over after the grower has completed his last full five-bed pass. He then either decides to leave the leftover beds unsprayed or to spray them along with three beds in the next planting. He might even stay within the original planting in order to spray the leftover beds and consequently double spray the three beds in the last five-bed swath. Each of these possible actions affect the aphid population found along borders between plantings, therefore extreme border areas, where aphid numbers may not be representative of the remainder of the field, were not sampled.

The way in which plants were examined in the large scale monitoring was also modified from the method used in 1982. Instead of cutting plants off and stripping their leaves, they were left in place in the row and their leaves gently pried apart and inspected for aphids and loopers. This method of observation was less precise for counting aphid numbers, but was adequate for detecting their presence or absence. It was also faster, hence more plants were examined, i.e. four plants were inspected at ten-pace intervals along the length of bed, one plant from each row in the bed at each sample site.

4. INSECTICIDE EVALUATION

When used properly, insecticides can be a valuable tool in the management of pests. This is especially true in the case of the lettuce aphid. In fact to produce aphid-free lettuce in B.C., the use of pesticides is virtually unavoidable. The available insecticides were in need of evaluation so that only those effective and safe could be recommended. Timing and method of treatment were factors in the evaluation process. Besides the assessment of previously-registered aphicides, a strategy was needed for an effective spray schedule. Insecticides with differing chemistry were favoured for inclusion in the schedule to reduce the chance of resistant populations arising from repeated use of a particular insecticide for several seasons.

To improve the spray program, insecticides with species-specific activity were chosen for testing, notably pirimicarb (Pirimor®) and disulfoton (Di-Syston®). Pirimicarb has several desirable attributes: it degrades rapidly in the environment, has a low mammalian toxicity, appears non-phytotoxic to lettuce, and is highly specific in its toxicity to aphids but has little effect on non-target organisms such as aphid parasites and predators (Simonet 1980).

The species specific action of disulfoton is attributed more to its systemic properties than to direct toxicity. Once in the vascular system of a plant, only those organisms which feed directly on the plant sap will receive the toxicant. Parasites and predators might be affected by direct contact during application, but with disulfoton, extended aphid control even in remote parts of the plant which are protected from direct spray contact should be possible without affecting transient, non-target organisms.

Before a "minor-use" registration can be granted for any insecticide, residue data must support a safe treatment-to-harvest interval for the intended use. In 1983, a minor-use registration of primicarb was approved after submission of the efficacy and residue results presented here.

4.1 Evaluation of Registered Aphicides

The relative efficacy of the commonly used aphicides registered in Canada as foliar sprays for aphid control on lettuce, and of pirimicarb, were assessed at two locations in 1982. Site 1 was a 27-bed planting of lettuce on a commercial farm near Cloverdale (Mackenzie et al. 1982, p. 114) and site 2, an experimental plot at the Abbotsford, B.C. substation of Agriculture Canada (Mackenzie et al. 1982 p.115).

At site 1, treatment plots were 120 m long and two beds wide, replicated three times in a randomized complete block design. Control plots were single beds to minimize crop loss caused by aphids. Normal commercial cultivation was practised during the trials. The sprays included the following:

pirimicarb - Pirimor 50 WP wettable powder,

demeton - Systox 2.4 SC, spray concentrate,

methamidophos - Monitor 4 L, liquid,

dimethoate - Cygon 4 EC, emulsifiable concentrate

The sprays were applied on 20 August, 5 weeks after seeding and about 1 week before heading, with a tractor-mounted 'Pak-tank' sprayer fitted with three D2 cone-type nozzles spaced 46 cm apart over each bed. Rates of application are given in Table 3. A pressure of 1000 kPa delivered 500 L of water/ha. The entire field was subsequently sprayed with methamidophos on 2 September at a rate of .90 kg ai/ha just after the start of heading, followed by dimethoate on 13 September at a rate of .30 kg ai/ha one and a half weeks before harvest. Both methamidophos and dimethoate were applied in 900 L of water/ha at 1000 kPa. Spreader-sticker (Super Spread®) was added to all treatments. Efficacy of the treatments was assessed by pulling plants, stripping off their leaves and counting the number of aphids on each leaf. Three plants in each replicate of a treatment were sampled for a total of 9 samples/ treatment. Breakdown of insecticidal residues in the crop was monitored by gas-liquid chromatography (G.L.C.).

At site 2, lettuce was direct seeded on 25 May, using a hand-propelled Stanhay precision seeder. The plots consisted of 7.5 m long rows paired 60 cm apart and replicated 4 times in a randomized block design. Cultivated strips 2 m wide were maintained between blocks. The plants were thinned to 30 cm spacing about 3 weeks after seeding. To make sure the field infestation of N. ribisnigri was evenly distributed, laboratory-reared aphids were released at equidistant points within the field 2 weeks before treatments were applied. The sprays included the following:

Safer's Insecticidal Soap® - 50.5% formulated esters of fatty acid salts;
parathion 8 E - emulsifiable;
dimethoate - Cygon 4E;
methamidophos - Monitor 4 L;
pirimicarb - Pirimor 50 WP;
endosulfan - Thiodan 4 E

These were applied on 22 July, about 2 weeks before the plants started heading and again on 11 August, about 1 week from harvest. Sprays were applied with a Solo® manual back-pack sprayer which delivered 1900 L of water/ha. Rates of application are given in Table 4. Spreader-sticker (Super Spread®) was used with all treatments. Efficacy of treatments was assessed in the same way as at site 1, by pulling plants, stripping off the leaves and counting the number of aphids on each leaf. Two plants in each replicate of a treatment were sampled for a total of 8 samples per treatment. Breakdown of dimethoate, methamidophos and pirimicarb residues in lettuce tissue was monitored by G.L.C. analysis.

At site 1 (Table 3), both demeton and methamidophos reduced lettuce aphid numbers to levels significantly lower than those in untreated plots despite the low volume of water and the resultant coverage without runoff. Only methamidophos, however, was able to reduce numbers of green peach aphids significantly. When the entire field was sprayed with methamidophos, numbers of green peach aphids were reduced to zero in most plots whereas lettuce aphids protected within the developing heads were not immediately affected. The entire field was subsequently sprayed with dimethoate on 13 September. Neither the methamidophos nor the dimethoate spray reduced the numbers of lettuce aphids to a level acceptable for market, hence the crop was unmarketable.

It was again noted that while the lettuce aphid fed mainly on the young, innermost leaves, the green peach aphid fed mainly on the undersides of the old, outer leaves.

At site 2 (Table 4), the variability in the numbers of aphids from plant-to-plant within and between treatment plots made conclusions from

Table 3. Efficacy of aphicides foliar applied against aphids infesting lettuce, site 1 - Surrey, B.C. 1982.

Treatment (applied 20/8)	Rate (kg ai/ha)	Average number of lettuce or green peach aphids on 10 leaves — Examination date, day/month: 24/8 N.r.*	24/8 M.p.*	3/9 N.r. (I ↓)	3/9 M.p.	10/9 N.r.	10/9 M.p.	17/9 N.r. (II ↓)	17/9 M.p.
Pirimicarb	.14	8 bc	53 b***	4	0	4	0	10	0
Demeton	.56	0 a	42 b	3	0	1	0	2	0
Methamidophos	.90	0 a	1 a	2	0	0	0	6	0
Dimethoate	.30	3 ab	128 c	6	2	2	0	30	0
Control**	-	12 c	76 bc	17	0	3	0	2	0

* N.r. = Nasonovia ribisnigri, M.p. = Myzus persicae.

** Field population of aphids on 18 August prior to any spray application was 17 N. ribisnigri/10 leaves and 104 M. persicae/10 leaves.

*** Values followed by the same letter are not significantly different at the 5% level (Duncan's multiple range test). For analysis, values were transformed: $(X = \sqrt{x + .5})$.

I: Entire field was sprayed with methamidophos, 2/9, just after the start of heading.

II: Entire field was sprayed with dimethoate, 13/9, one and a half weeks before harvest.

Table 4. Efficacy of aphicides foliar applied against lettuce aphids infesting lettuce, site 2 - Abbotsford, B.C. 1982.

Treatment (applied 22/7)	Rate (kg ai/ha)	Average number of lettuce aphids on 10 leaves* Examination date, day/month 24/7	26/7	29/7	5/8	9/8		13/8	Average of all dates
formulated esters	1% sol'n	15	12	18	16	18	I	3	14 d***
of fatty acids salts	2% sol'n	2	32	11	5	11	↓	5	11 cd
Parathion	.34	0	3	1	6	4		2	3 ab
	.68	0	1	13	2	4		1	3 ab
Dimethoate	.15	1	1	3	3	3		3	5 ab
	.30	5	1	1	6	19		5	6 bc
Methamidophos	.45	1	1	2	3	8		1	3 ab
	.90	0	1	4	2	5		1	2 ab
Pirimicarb	.14	0	0	0	3	4		2	1 a
	.28	0	0	1	1	5		1	1 a
Endosulfan	.40	0	4	1	11	2		2	3 ab
	.80	4	1	1	1	6		2	2 ab
Control**	-	1	7	7	7	7		4	6 bc

* All values are rounded to the nearest whole number.
** The overall field population prior to aphid release, 7 July, was 2 aphids/10 leaves and prior to the first application of treatments, 21 July, 4 aphids/10 leaves.
*** Values followed by the same letter are not significantly different at the 5% level(Duncan's multiple range test). For analysis, values were transformed: $(X = \sqrt{x + .5})$.
I: All treatments were reapplied 11 August.

individual examination dates speculative at best. However, when all the examination dates were averaged significant differences were evident. Pirimicarb then emerged as the only treatment which reduced the number of lettuce aphids to a level significantly lower than that in untreated plots. Complete control was not achieved in any of the treatment plots when the second spray was applied after the heads had begun to form.

4.1.1 Residue Analyses

Samples of lettuce tissue were taken for the determination of insecticide residues at both sites 1 and 2. At site 1, six plants were randomly selected for sampling in each of the three replicates of only the pirimicarb treatment. Nine leaves were taken from the outside and nine from the inside of the 18 plants, one leaf/plant to form a composite sample for the determination of residues. At site 2, two whole plants were collected from each of the four replicates of dimethoate, methamidophos, and pirimicarb treated plots before and after foliar spray treatments were applied. The two whole plants collected from each treatment replicate made up a composite sample for residue determination.

At sites 1 and 2, pirimicarb metabolized rapidly in lettuce to its toxic metabolites, formyl methylamino pirimicarb and methylamino pirimicarb, both of which almost disappeared in 14 days (Szeto et al. 1982. pp. 341 and 348). At site 2, dimethoate was partially oxidized to its oxon in lettuce (Szeto et al. 1982 p. 346). Most residues were detected in the outer leaves and very few in the head. Both the parent compound and the oxon were degraded rapidly under field conditions. The total residues disappeared almost completely in about 14 days. Similarly, methamidophos was detected mostly in outer leaves (Szeto et al. 1982, p. 347). Residues in the inner leaves of all samples tested were well below the tolerance of 1.0 ppm.

4.2 Pirimicarb Trials

Pirimicarb was tested alongside disulfoton (Di-syston® 8EC, 72% ai) in two separate trials on a commercial farm near Cloverdale, in 1982 (Mackenzie et al. 1982, pp. 117, 118).

Trial 1, which included demeton, was 20 beds wide and 35 m long. Plots were single beds, replicated 4 times in a randomized complete block design. Commercial cultivation was practiced for the duration of the trial. Sprays were applied on 20 August, about 5 weeks after seeding and about 1 week before heading, with a tractor-mounted 'Pak-tank' sprayer fitted with three D2 cone-type nozzles spaced 46 cm apart over each bed. A pressure of 1000 kPa delivered 500 L of water/ha. The entire field was subsequently sprayed with methamidophos on 2 September at a rate of .90 kg ai/ha just after the start of heading followed by dimethoate on 13 September, at a rate of .30 kg ai/ha 1 1/2 weeks before harvest. Both methamidophos and dimethoate were applied in 900 L of water/ha at 1000 kPa. Spreader-sticker (Super Spread) was added to all treatments. Efficacy of the treatments was assessed as in previous trials, by pulling plants, stripping off their leaves, and counting the number of aphids on each leaf. Two plants in each replicate of a treatment were sampled for a total of 8 samples/treatment.

In trial 2, lettuce was direct-seeded on 4 August using a hand-propelled Stanhay precision seeder. Plots consisted of 3 rows 44 cm apart and 7.5 m long and were replicated 4 times in a randomized block design. Cultivated strips 2 m wide were maintained between end-to-end plots. Plants were thinned to 30 cm spacings about 3 weeks after seeding. To make sure the field infestation of N. ribisnigri was evenly distributed, laboratory-reared aphids were released on marked plants one week before treatments were applied. Foliar sprays were applied on 21 September, just before the plants started to form heads. Sprays were applied with a Solo manual back-pack sprayer which delivered 2300 L of water/ha. As in trial 1, spreader-sticker (Super Spread) was used with all treatments. Efficacy of treatments was assessed by the same method used in trial 1. Two marked plants in each replicate of a treatment were sampled for a total of 8 samples/treatment on each examination date.

In both trials 1 and 2, the breakdown of insecticide residues in the crop was monitored by G.L.C. analysis.

In trial 1 (Table 5), all treatments had, after 4 days, reduced the numbers of lettuce aphids to levels significantly lower than those in untreated plots, despite the low volume of spray mix applied (500 L/ha) and the coverage without runoff which resulted. The systemics, demeton and disulfoton at both rates tested, were more effective than pirimicarb, but only pirimicarb was able to significantly reduce the numbers of green peach aphids. At heading, after the entire field was sprayed with methamidophos, numbers of lettuce aphids were low in all treatments, although in the original control plots the spray had no apparent effect on lettuce aphids protected within the developing heads. The numbers of green peach aphids

Table 5. Efficacy of pirimicarb and two systemic insecticides applied 20 August to foliage against aphids infesting lettuce; Trial 1, Surrey, B.C. 1982.

Treatment 20/8	Rate (kg ai/ha)	Average number of lettuce and green peach aphids on 10 leaves*									
		Examination date, day/month									
		24/8			3/9		10/9			17/9	
		N.r.**	M.p.**		N.r.	M.p.	N.r.	M.p.		N.r.	M.p.
				I					II		
Disulfoton	.56	<1 a+	49 b		<1 a	<1	1 a	0		2 a	0
Disulfoton	1.12	0 a	29 b		<1 a	0	1 a	0		2 a	0
Demeton	.56	<1 a	33 b		2 ab	0	2 a	0		6 a	0
Pirimicarb	.14	2 b	12 a		6 b	<1	9 a	0		8 a	0
Control++	--	8 c	41 b		13 c	0	11 a	0		9 a	0

* All values are rounded to the nearest whole number.
** N.r. = *Nasonovia ribisnigri*, M.p. = *Myzus persicae*.
\+ Values followed by the same letter are not significantly different at the 5% level(Duncan's multiple range test). For analysis, values were transformed: (X = /x + .5).
++ The overall field population of aphids on 17 August, prior to any spray application, was 14 *N. ribisnigri*/10 leaves and 90 *M. persicae*/10 leaves.
I: Entire field was sprayed with methamidophos just after the start of heading, 2/9.
II: Entire field was sprayed with dimethoate one and a half weeks before harvest, 13/9.

In trial 2 (Table 6), the number of lettuce aphids was significantly less in plots treated with as little as 1 kg ai/ha of disulfoton, when compared with untreated plots six days after application. The number of aphids was still significantly reduced in plots treated with the lower rate of either disulfoton or pirimicarb when compared with untreated plots 13 days after application. No lettuce aphids were found in the plots treated with 4 kg ai/ha of disulfoton on either of the two plant examination dates.

Table 6. Efficacy of pirimicarb and disulfoton applied 21 September to foliage against lettuce aphids infesting lettuce; Trial 2 Surrey, B.C. 1982.

Treatment (applied 21/9)	Rate (kg ai/ha)	Average number of lettuce aphids on 10 leaves	
		Examination date, day/month	
		27/9	4/10
Disulfoton	1.0	0 a*	.1 a
Disulfoton	2.0	0 a	.1 a
Disulfoton	4.0	0 a	0 a
Pirimicarb	.14	.1 a	.5 a
Pirimicarb	.28	.3 ab	.5 a
Control	--	1.4 b	17.3 b

* Values followed by the same letter are not significantly different at the 5% level (Duncan's multiple range test). For analysis, values were transformed: $(X = \sqrt{x + .5})$.

4.2.1 Residue Analyses

In both trials 1 and 2, samples of lettuce tissue were taken for determination of pirimicarb residues.

In trial 1, four plants were selected at random in each replicate of the treatment plots and sampled before and 0, 3, 7, 14, and 21 days after application of insecticides. A total of four leaves, one/plant, were collected alternately from the outside and the inside of plants to form a composite sample for the determination of insecticide residues.

From each of the four replicates of treatments in trial 2, two plants were selected at random and sampled 1 and 6 days after the application of sprays. As in trial 1, one leaf/plant was collected alternately from the outside and inside of plants at each sampling to form a composite sample for analysis. Thirteen days after the application of sprays, two whole lettuce heads were collected from each treatment plot to form a composite sample for residue analysis.

In both trials, pirimicarb rapidly metabolized in lettuce to its toxic metabolites (Szeto et al. 1982, pp. 342, 343). In trial 1, the total residues, i.e., the parent compound and its metabolites, almost disappeared in 14 days and in trial 2, the total residues almost disappeared in 13 days.

4.3 Disulfoton Trials

Soil application of disulfoton at seeding for systemic control of aphids on lettuce is currently a registered use for the granular formulation, Di-Syston® 15G (15% ai), and emulsifiable concentrate, Di-syston® 8 EC (72% ai) formulation. The granular may be applied at the rate of 11 g ai/100 m row and the EC in a drench of 10 g ai/100 m row on organic soils. Further conditions prevail concerning this use (Compendium of Pest Control Products Registered in Canada 1984). It was not previously known how effective in controlling the lettuce aphid either formulation would be in the lower Fraser Valley. I was also interested in knowing how effective disulfoton was as a foliar spray and how persistent were the residues. To try to answer these questions, several field trials were conducted in 1982 on a commercial farm near Cloverdale, and another in 1985 at the Abbotsford substation of Agriculture Canada.

In 1982, the insecticide was applied to the soil at seeding either as granules in a band or drenches containing EC. Experimental plots for band treatment and soil drench consisted of 3 rows 44 cm apart and 7.5 m long, replicated 4 times in a randomized complete block design. Cultivated strips 2 m wide were maintained between end-to-end plots. Crisphead lettuce (cv. Ithaca) was direct-seeded with a hand-propelled Stanhay® precision seeder on 4 August. Disulfoton granular was applied in a band 10 cm wide and 2 cm deep over the row at seeding. A geared applicator was attached to the seeder with the delivery fan in front of the seed coulter which thoroughly incorporated the granules into the organic muck soil with the seeding action.

Disulfoton drenches were applied along the rows in 1300 L of water/ha with a Solo® manual back-pack sprayer immediately after seeding. Twenty-two days later, the plants were thinned to 30 cm spacings. Efficacy was assessed weekly during stage 2 of crop growth i.e. from thinning to heading, by counting the number of aphids present on two plants collected randomly from each replicate of the treated and control plots for a total of 8 plants/treatment. Residues of disulfoton and its metabolites in lettuce were monitored by gas-liquid chromatography.

The experimental plots for the foliar spray trials were set up in the same manner as for band treatment and soil drench. To ensure infestation, ten laboratory-reared lettuce aphids were transferred to each of 4 marked plants in each replicate plot one week before foliar applications. On 21 September, 1982, just before the plants started to form heads, foliar sprays of disulfoton in 2,300 L of water/ha were applied with a Solo® manual back pack sprayer. Super Spread®, a spreader-sticker, was added to all sprays. On 27 September, and 4 October, i.e. 6 and 13 days after foliar sprays were applied, efficacy was assessed by counting the number of aphids present on two of the 4 marked plants in each replicate for a total of 8 marked plants examined/treatment on each examination date. Samples of lettuce tissue for determining the residues of disulfoton and its metabolites were collected in the same manner as described previously, 1, 6, 13 and 23 days after spray applications. Samples were analyzed by gas-liquid chromatography.

Foliar sprays of disulfoton (Di-Syston 8 EC), oxydemeton-methyl (Metasystox-R® EC, 24% ai), demeton (Systox® EC, 24% ai), and endosulfan (Thiodan 4 E) were assessed in 1985 at the Abbotsford sub-station

(Vernon *et al*. 1985). Lettuce (cv. Ithaca) was seeded on 2 July in beds of dimensions used in commercial plantings. Beds were seeded in blocks 4 m long and each bed was randomly assigned a different treatment. A 1 m wide cultivated strip separated adjacent beds. In each bed, 6 plants were selected for aphid inoculation, one from each of the two outside rows and 2 from each of the inside rows. Selection was according to the size and shape of the plants, *i.e*. very small or misshapen plants were not selected. Small flags made of surveyors tape tied to the ends of 15 cm long lengths of coat-hanger wire were used as markers pushed into the soil beside the inoculated plants. About 8-10 lab-reared aphids were introduced to each of the 24 marked plants in each treatment on 13 August and again on 16 August. Aphids were allowed 4 days to acclimatize before the evening of 20 August, 1985 when spray treatments were applied (see Table 9 for rates). Sprays were applied with a hand-pushed CO2 pressurized boom sprayer equipped with 3, D4 hollow cone nozzles. The insecticide was delivered in 610 L of water/ha at a pressure of 690 kPa. When the sprays were applied, plants were at the 18 leaf stage (average of 144 plants examined), thus the heads had begun to form. Marked plants were examined for aphids and their predators as described previously. Treatments were assessed on 22 and 23 August.

Sampling for residue determination was done as follows: one head was taken at random from each of the four rows in the treatment plots (beds). This provided a composite sample of four heads/replicate or 16 heads/ treatment. Only the three outermost wrapper leaves were collected for samples so that the residues detected represented the highest probable concentration of insecticide in the crop. Additional experiments for the

Table 7. Efficacy of disulfoton granular and drench applied to the soil against aphids infesting crisphead lettuce, Cloverdale, 1982.

		Average number of lettuce aphids on 10 leaves*									
		Examination date, day/month									
		Nasonovia ribisnigri					*Myzus persicae*				
Disulfoton (applied 4/8)	Rate (kg ai/ha)	26/8	2/9	9/9	16/9	Average all dates	26/8	2/9	9/9	16/9	Average all dates
15% granular	.9	0 a**	0 a	4 a	2 a	1 a	4 a	9 ab	13 a	3 a	7 ab
15% granular	1.9	2 a	3 ab	<1 a	<1 a	1 a	5 a	12 ab	9 a	4 a	7 ab
72% emulsifiable concentrate	1.1	1 a	5 ab	1 a	9 a	3 a	4 a	8 ab	5 a	3 a	5 a
72% emulsifiable concentrate	2.3	<1 a	3 ab	3 a	3 a	2 a	2 a	5 a	7 a	8 a	5 a
Control	--	2 a	6 ab	8 a	8 a	6 a	9 a	23 b	21 a	11 a	11 ab

* All values are rounded to the nearest whole number.

** Values followed by the same letter are not significantly different at the 5% level(Duncan's multiple range test). For analysis, values were transformed: $(X = \sqrt{x + .5})$.

determination of persistence of disulfoton and its metabolites as well as for oxydemeton-methyl and its metabolites were carried out in a similar manner at Abbotsford in 1985 (Szeto, et al. 1985).

Results

Disulfoton applied to the soil at seeding in a drench at the recommended rate, and in the granular formulation at 76% of the recommended rate failed to significantly reduce the number of lettuce aphids below that in untreated plots according to weekly plant inspections between thinning and heading, i.e. stage 2 of crop growth (Table 7). Some control of green peach aphids occurred in the drench-treated plots, especially at 4 weeks after seeding, in plots treated with the higher rate.

In the foliar spray trial conducted in 1982, plots treated with disulfoton at the lowest rate tested, 1 kg ai/ha, had, six days after treatment, significantly fewer aphids than untreated plots (Table 8). One week later there were still fewer aphids in the disulfoton-treated plots. Plots treated with the lower rate of Pirimor also had significantly fewer aphids than untreated plots. No lettuce aphids were found in plots treated with 4 kg ai/ha of disulfoton on either of the two plant examination dates.

Although the aphid counts taken in sprayed plots 13 days after application were significantly lower ($P < 0.05$) than those in control plots it is not known if this difference could be attributed to residual activity of disulfoton. The spray trial was conducted in late summer and early fall and so re-infestation of sprayed plots by migrating virginoparae is considered unlikely. This may account for the low number of aphids in

Table 8. Efficacy of disulfoton foliar applied 21 September, against lettuce aphids infesting lettuce, Cloverdale, 1982.

Treatment (applied 21/9)	Rate (kg ai/ha)	Average number of lettuce aphids on 10 leaves — Examination date (day/month)	
		27/9	4/10
Disulfoton	1	0 a*	.1 a
Disulfoton	2	0 a	.1 a
Disulfoton	4	0 a	0 a
Pirimicarb	.14	.1 a	.5 a
Pirimicarb	.28	.3 ab	.5 a
Check	--	1.4 b	17.3 b

* Values followed by the same letter are not significantly different at the 5% level (Duncan's multiple range test). For analysis, values were transformed: $(X = \sqrt{x + .5})$.

Table 9. Efficacy of various insecticides foliar applied 20 August against lettuce aphids infesting cripshead lettuce, Abbotsford, 1985.

Treatment (applied 20/8)	Rate (kg ai/ha)	Number of lettuce aphids (22,23/8)			Percent aphid mortality
		Alive	Dead	Total	
Disulfoton	0.56	13 a*	43 ns*	56 ns	76.8
Disulfoton	1.12	4 a	71 ns	75 ns	95.0
Oxydemeton-methyl	0.56	8 a	54 ns	62 ns	87.1
Endosulfan	0.84	22 ab	47 ns	69 ns	68.1
Demeton	0.56	13 a	35 ns	48 ns	72.9
Control		65 b	8 ns	73 ns	11.0

* Numbers followed by the same letter are not significantly different at the 5% level;
ns: not significantly different at the 5% level (Duncan's multiple range test).

plots for almost two weeks after treatment, whereas in untreated plots, a substantial increase in aphid population occurred during the same period. Aphids placed on marked plants in control plots were apparently able to continue their natural rate of reproduction without interruption.

In the 1985 trial, all treatments except endosulfan significantly reduced the number of living aphids found on aphid-inoculated lettuce plants (Table 9). Disulfoton applied at 1.12 kg ai/ha caused the highest percent mortality of aphids, followed closely by oxydemeton-methyl applied at 0.56 kg ai/ha. Many of the released aphids were unaccounted for in the total of living and dead aphids found. Predation by syrphid larvae (Diptera: Syrphidae) may have been partially responsible for the discrepancy since an average of 0.7 larvae/plant were found in the check plots, and dead syrphid larvae were often found in the treated plants. In the check plots, inoculated plants that had syrphid larvae rarely had any surviving aphids.

In conclusion, it is apparent that given the conditions under which lettuce is grown in B.C., disulfoton is more effective as a foliar spray than as a soil treatment.

4.3.1 Residue Analyses

In 1982, disulfoton residues were monitored in the lettuce grown in soil treated with either the granular or drench formulation. Twenty-two days after seeding and application of insecticide, two young plants were randomly selected for sampling from each of the four treated plots and one leaf/plant was collected to form a composite sample for residue determination. Additional samples were collected to form a composite sample for analysis 29 and 36 days after insecticide application.

After application of disulfoton granular at 2.0 kg ai/ha at seeding, the insecticide was translocated from the soil into the young plants (Szeto et al. 1982, p. 345). The plant tissue residues consisted of the parent compound, the sulfoxide and the sulfone of the parent compound, and the oxygen analogue. The oxon was not detected in any of the lettuce tissue samples taken. Twenty-two days after application total residues were 1.60 ppm, but after 36 days, a total of only 0.02 ppm in residues remained. This rapid dissipation could be related to many factors (Szeto et al. 1983). The growth rate of lettuce is rapid in stages 1 and 2, i.e., between emergence and heading, and may have diluted the total residues/ fresh weight of plant tissue. A second factor may have been the growth of lettuce roots beyond the treated volume of soil, thus causing a gradual decline in the root uptake of disulfoton and its toxic metabolites. Another factor could have been the physical movement of granules out of the original treated band, or degradation of toxicants to non-toxic or unavailable metabolites. Total residues in lettuce grown in plots treated with the high rate of soil drench reached only 0.58 ppm after 22 days, and after 36 days, only a trace was detected.

After foliar spray application in the 1982 trial near Cloverdale, disulfoton rapidly oxidized in lettuce tissue to its sulfoxides and sulfone and its oxygen analogue sulfoxides and sulfones (Szeto et al. 1983). After application at 2 and 4 kg ai/ha the parent compound persisted in lettuce only for about 6 days and after 13 days, none was detected. At the lowest rate, 1 kg ai/ha, total residues were 2.99 ppm the day after application.

This level was higher than any detected in either the band or soil drench treatments and might account for the superior efficacy of the foliar spray. Total residues subsequently decreased to 50% of day 1 levels in 3-4 days and to 10% in 12-13 days regardless of application rate. At harvest, 23 days after application of disulfoton, even at the highest rate, total residues were below the Canadian tolerance level of 0.5 ppm, which applies only to residue of the parent compound.

In light of the analytical techniques worked out by Szeto (1982) which can detect all six toxic metabolites of disulfoton, the Canadian tolerance level should be changed to account for all of them. It would then provide a more realistic and meaningful safeguard for consumers against potential harmful residues in disulfoton-treated commodities. Officials of Agriculture Canada have been notified of the inadequacies in the tolerance requirements and are in the process of reviewing them.

In 1985, higher levels of total disulfoton residues were found in the outer wrapper leaves of lettuce heads, which were in direct contact with the spray compared with the samples which included a 2.54 cm thick longitudinal cross-section of the heads (Szeto et al. 1985, Study I). Samples which included only the three outermost wrapper leaves are therefore considered a better estimate of the maximum concentration of pesticide residue in the edible portion of the crop. Despite the higher residue levels found in the outer wrapper leaves, total disulfoton residues were well below 0.5 ppm after 23 days when applied either at the recommended rate or twice the rate. In a similar experiment, total residues were below 0.5 ppm in the outside wrapper leaves only 15 days after treatment with the recommended rate (Szeto et al. 1985, Study II). These results clearly show the rapid dissipation of disulfoton and its toxic metabolites after foliar application to lettuce.

Experiments were set up in the same way as for disulfoton to determine the persistence of oxydemeton-methyl after foliar spray application at either 0.56 or 1.12 kg ai/ha. The results indicated that residues of oxydemeton methyl sulfone were slightly above 0.1 ppm 23 days after its application at both rates. Residue was higher in the plots treated with oxydemeton-methyl with spreader-sticker added compared with plots which received the same rate of oxydemeton methyl but without spreader-sticker. At another site, residues of oxydemeton-methyl sulfone fell to neglibible levels (<.1 ppm) within 28 days of application (Szeto et al. 1985, Study II). Thus oxydemeton methyl sulfone appears to be slightly more persistent in and on lettuce than are the residues of disulfoton.

The insecticide evaluations conducted here were purposeful in four main ways. Firstly, they re-evaluated the relative efficacy of the insecticides (Veg. Prod. Guide 1982, p. 38) recommended for aphid control over the previous five or more years. Secondly, the importance of timing and method of applying treatments was realized. Thirdly, the mission yielded an effective schedule of treatments which must now be receptive to on-going modification, such as the introduction of different insecticides. Fourthly, residues of registered materials and candidates for minor use registrations were monitored to ensure safe treatment to harvest intervals.

As a product of this work, several changes have taken place since 1982 in the overall recommendations for aphid control. The first change was a warning that spraying for aphids should commence before heads begin to form (Veg. Prod. Guide 1982), but in 1983 the recommendations were almost completely re-written to reflect results of the previous season. A schedule of sprays (Fig. 17) was drafted which tied in with the stages of crop growth (Fig. 10). Methamidophos was found most effective against both aphids and loopers and was the backbone of the schedule. Application of Systox was timed to provide systemic aphid control just after the start of heading, and non-residual chemicals with contact activity were chosen for the clean-up of migrates just before harvest. This schedule was effective, but relied too heavily on one chemical: methamidophos. If methamidophos were to lose its effectiveness, so would the schedule. The application for minor use registration of pirimicarb, found to be an excellent aphicide, was approved in time for inclusion in the schedule for 1984 (Fig. 17). In addition, the monitoring routine was outlined in the 1984 edition of the Vegetable Production Guide (B.C. Min. Agric. and Food 1984). The most recent amendment to the control recommendations has been a mention that when aphid or looper populations are either low or absent, as determined by regular monitoring, the first two sprays of the schedule may be omitted. Further changes to the recommendations are proposed in the next section.

Figure 17. Schedule of sprays recommended for control of the lettuce aphid, 1984.

1984 Spray Schedule For Lettuce Aphid Control

Stage of crop growth	Weeks from seeding (approx.)	Ave. no. of leaves /plant	Recommended Insecticide	Spray no. /season
1	2			
		3		
	3			
		5 (thinning)	1	1
2	4			
		8	1 or 2	2
	5			
		12	1	3
	6			
		15 (start of heading)		
3	7		4	4
		20		
	8			
			1 or 2	5
	9			
			1	6
	10			
			2,3 or 5	7
	11			
		harvest		

Insecticides: 1=Monitor (methamidophos); 2=Pirimor (pirimicarb); 3=Phosdrin (mevinphos); 4=Systox (demeton); and 5=Cygon (dimethoate).

5. DISCUSSION

Pest management is a dynamic science. By necessity, pest management programs must be adaptable and respond to changing forces in natural systems. Such has been the case in the management program for the current main pest of lettuce, the lettuce aphid. For convenience, management of the lettuce aphid can be thought of as a development through several distinct phases. Aphid management on lettuce in the decade or more prior to 1982 might be considered as a first phase in development. At this time, aphid control was based almost entirely on aphicides applied at the growers' discretion. Without pest monitoring, the sprays could have been applied without enough information about aphid populations and as a result may have been badly timed, poorly chosen, and unnecessary.

The appearance in 1981 of the lettuce aphid as a pest on lettuce, despite routine sprays, was a forewarning of the urgent need for change in the management practised thus far. As a new threat, the lettuce aphid necessitated a marked change in approach to the control of insects on lettuce in 1982. This represents the start of a second phase in lettuce pest management. At the start of this phase the appearance of the aphid caused a virtual panic in the lettuce growing industry. The problem was publicized from the beginning, so that consumers were aware and intolerant of the presence of aphids on marketed lettuce. Representatives of the export market also became sensitive to aphids on lettuce; in short, nobody wanted any aphids at all, in or on the produce. At the lettuce growers' cooperative, regular inspections of shipments for aphids were invoked and if even a very few were found, the entire truckload could be refused.

In response to the demand for aphid-free lettuce, drastic measures were taken in 1982. These included the emergency development of monitoring techniques, assessment of available aphicides and, with the results of pesticide screening, the implementation of an effective spray program (Fig. 17). In 1983 and 1984, monitoring was available on most farms, with the main purpose initially of insuring the spray program was properly followed. Monitoring also provided an ongoing evaluation of the effectiveness of the program on a commercial scale and an on-site check of the way in which growers applied their sprays, i.e. timing of sprays, rates of application, and spray settings. This approach proved to be effective in maintaining a supply of aphid-free lettuce. However, growers were still having to apply sprays almost on a weekly basis. Acceptable control of aphids was attained, but with no reduction in the amount of spraying from the previous phase. Nevertheless, the atmosphere of urgency may be changing towards one of more rational, long-term management which would allow for some aphids on the crop in its early growth, albeit very low numbers.

In 1985, the alfalfa looper predominated as the main pest until well into the season, while the lettuce aphid was found only in low numbers. The spray program was still enforced by monitoring, but the emphasis was on the selection of insecticides most effective against loopers. It became apparent that proper management of lettuce pests required flexibility in the spray program. The management program had reached a second major turning point, and if monitoring is available in 1986, a third phase should be entered. Experience thus far has identified effective insecticides and yielded a practical and effective monitoring method. The means necessary for acceptable managment of the lettuce aphid are now available and in the next phase, should be incorporated with other improvements as they become available. Monitoring is a vital component of future programs, but should, in my opinion, be slightly modified. The within-field distribution studies reported here showed that, in most cases, only the margins of fields need to be sampled. The number of samples taken in each field might therefore be best expressed in terms of the number of plants examined/length of field margin instead of /area. For example, if 200 plants were to be sampled/ha (100 m x 100 m) this would be carried out as 50 plants/100 m of margin, i.e. approximately 4-5 plants/10 long paces or one plant/2 paces.

In 1986, the program for management of the lettuce aphid could be further improved by a reduction, wherever possible, in the total number of sprays applied in the season. Although the market's low tolerance for aphids poses a formidable obstacle to this proposal, there exists a possibility for the elimination of up to 3 sprays in the early part of stage 2 in crop growth (Fig. 18 and 19). Stage 2 is an interval of about 3-4 weeks from thinning to the start of heading (Fig. 10), when the plants have few leaves, the upper surfaces of which are relatively exposed. As growth continues to the start of heading, the leaves become more tightly arranged and provide increasing protection for colonizing aphids. At the begining of heading, the innermost leaves start to infold. These are the leaves which eventually form the harvested head. Aphids colonizing infolding leaves are well protected from contact sprays and therefore control is most easily achieved before infolding of leaves begins. We know that to prevent aphid infestation of the heads or their contamination with dead insects, the plants must be free of aphids at the end of stage 2. At this point the threshold of aphid-infested plants must be zero. But if low numbers of aphids are present one week before the start of infolding and can be eliminated with a spray, then at two and three weeks prior to heading, equivalent or even higher infestation levels could be tolerated. It makes logical sense that the tolerance of aphids could be higher when plants are small, aphids are more exposed, and time is available for sprays between the examination date of the plants and heading. With this rationale in mind, a decreasing threshold of percent aphid-infested plants from thinning to the start of heading has been suggested (Vernon, R.S. pers. comm.). For example, one week before the start of heading, the threshold could possibly be 1% infested plants; two weeks before, i.e. one week after thinning, 2%, and at thining 3% (Fig. 19). If less than an average of 3 infested plants were found in 100 plants examined at thinning, then a recommendation could be made to withhold the scheduled spray. Two or three weeks would still be available for sprays to be applied if the number of infested plants were to exceed the threshold before the onset of heading, when control is much more difficult. Since the head itself does not form until the start of stage 3, any dead aphids on lettuce leaves as a result of aphid mortality from sprays applied in stage 2 will be displaced by the new leaves of the developing head and will not contaminate the harvested crop.

This scheme of graduated infestation levels could operate with a sequenced field sampling. For example, at thinning, sampling would continue until at least 100 plants/400 m of field margin were examined or until 3 aphid-infested plants were found (Fig. 19). As soon as the 3% threshold of aphid-infested plants was reached, sampling could stop. Instead of having to sample a fixed number of plants every time, the number of samples could be reduced when the threshold was reached before a predetermined minimum number of plants was sampled. This would be the case in the sampling of highly infested fields. If, on the other hand, pest numbers were very low and below threshold, then all of the predetermined number of samples would have to be taken, but scheduled sprays could be witheld. The main advantage associated with the kind of field sampling proposed here is the potential for reducing the number of samples needed. The main advantage associated with the graduated scale of infestation levels is the potential for reducing the number of sprays applied/season. Both reductions amount to a direct saving of labour and materials.

This proposed management scheme would also have to take account of pests other than the lettuce aphid such as the alfalfa looper. Sampling would have to continue until the threshold for each target pest was reached, before a reduction in the number of samples could be realized.

As the time shortens before the start of head formation, an increase in the predetermined number of samples, i.e. number of plants examined, is proposed. More samples close to heading are insurance against misjudgement in the actual level of aphid-infested plants. Confidence in the results from sampling has not yet been firmly established, but as heading is approached, one must be increasingly confident that the infestation level is below threshold and that no infested plants will be present at the start of heading. If, one week before the start of heading, the field is free of target pests, then up to 200 plants would be sampled, but the pest manager would be more confident of his results than at thinning when less confidence can be afforded. In the current management program, fields are not sampled beyond stage 2. Sampling in stage 3 is impractical since each

Figure 18. Proposed schedule of sprays for control of the lettuce aphid.

Proposed Spray Schedule For Lettuce Aphid Control

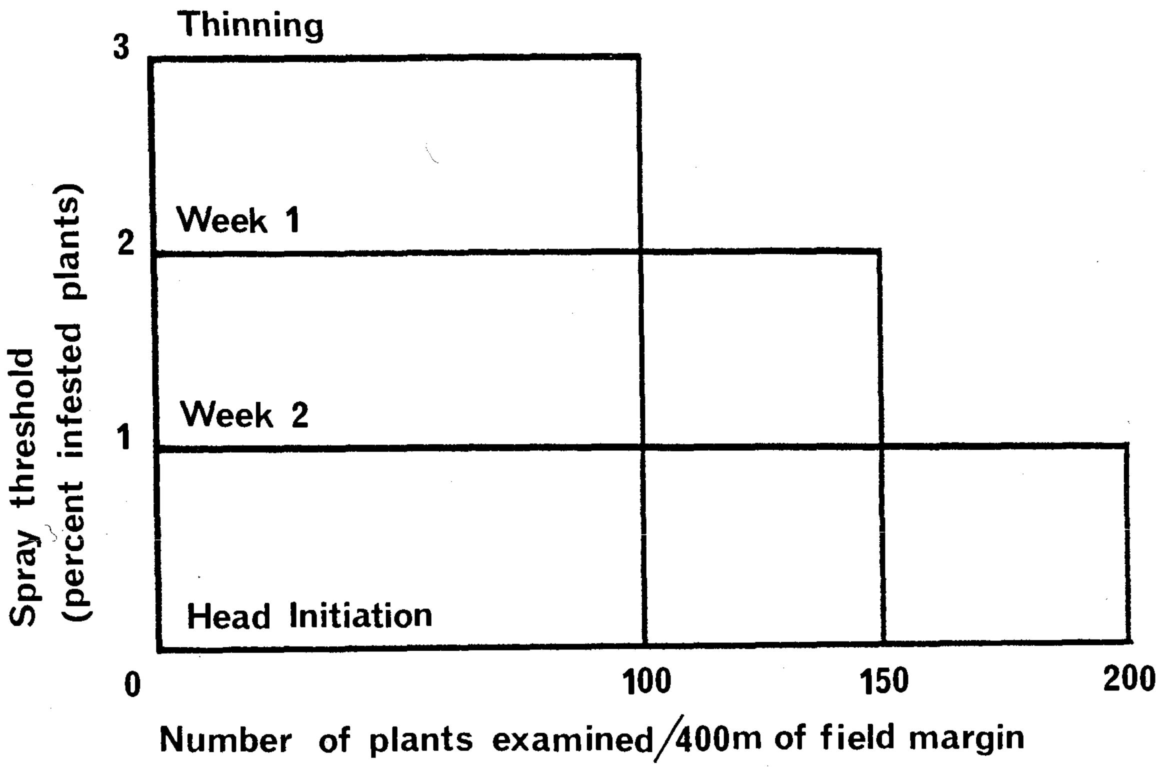
Stage of crop growth	Weeks from seeding (approx.)	Ave. no. of leaves /plant	Recommended Insecticide	Spray no. /season
1	2			
		3		
	3			
		5 (thinning)	1,2, or 3	1*
2	4			
		8	1,2, or 3	2*
	5			
		12	1 or 2	3*
	6			
		15 (start of heading)		
3	7		4**	4
		20		
	8			
			1 or 2	5
	9			
			1	6
	10			
			2,3 or 5	7
	11			
		harvest		

Insecticides: 1=Monitor (methamidophos); 2=Pirimor (pirimicarb); 3=Phosdrin (mevinphos); 4=Systox (demeton); and 5=Cygon (dimethoate).

*May be eliminated if monitoring shows infestation below threshold.

**May be replaced with Di-Syston (disulfoton) in the 1987 season pending the approval of an application for its "minor use" registration.

Figure 19. Proposed spray thresholds and sampling scheme for management of the lettuce aphid.


Thinning
Week 1
Week 2
Head Initiation
3
2
1
0
100
150
200
Spray threshold
(percent infested plants)
Number of plants examined/400m of field margin

plant has an average of 20 or more leaves, many of which are tightly infolded. Detection of aphids under these conditions is extremely difficult, time consuming, and destructive to the plants. Therefore, to ensure control of aphids which may have gone undetected inside the heads of lettuce, a spray of the systemic, Systox, becomes mandatory just after the start of heading (Fig. 17 and 18). To maintain a clean crop, and control any aphids migrating into the field after sampling ends, sprays are recommended weekly until just before harvest. This policy will prevail in the coming season, but in 1987, demeton may be replaced by disulfoton pending its approval for a minor use registration.

The proposed management scheme would result from a revised spray schedule which would stress the alternation of different insecticides between successive applications (Fig. 18). For example, at thinning, a choice could be made between a spray of methamidophos, pirimicarb or mevinphos, depending on the degree of infestation and the presence of leaf-feeding pests such as loopers. If alate aphids were found in low numbers i.e. they had recently migrated into the field and had not yet colonized the plants, and loopers were above threshold, then mevinphos would probably be the best choice since it has rapid, non-residual toxic activity against both loopers and aphids and is cheaper than the other two products. But if aphids were above threshold, aphid predators were observed and loopers were below their threshold, pirimicarb would probably be the best choice. Pirimicarb has little activity against beneficial insects and loopers but is an effective aphicide. If both aphids and loopers were well over their respective thresholds and the aphids appeared to be well established on the inside leaves of the plant, then methamidophos would probably be the micarb has little activity against beneficial insects and loopers but is an effective aphicide. If both aphids and loopers were well over their respective thresholds and the aphids appeared to be well established on the inside leaves of the plant, then methamidophos would probably be the insecticide of choice. Methamidophos is locally systemic and is effective against both loopers and aphids.

Further development of the spray schedule beyond 1986 can be considered as the fourth phase in the development of a management program. For this phase, a minor use registration of the systemic, disulfoton (Di-Syston), as a foliar spray is anticipated.

Other requirements in future pesticide research include the development and introduction of additional species-specific insecticides, but with extended residual activity. The monitoring of residues in the crop would accompany any such innovation. It is hoped, however, that not all further developments will be restricted to pesticides, but embrace a wide variety of strategies.

Some potential for control of the lettuce aphid may exist through its other hosts. It has been suggested that a control program be launched to treat or eliminate the primary woody hosts. Many of these grow on homeowners' property so that gaining permission to spray or remove blackcurrant and gooseberry bushes could be difficult. Such an exercise might be futile anyway, since primary hosts are very widespread and migrant aphids can be carried over long distances by wind. Many of the sites where winter host plants were first located have since been cleared, and yet the aphid problem still persists.

the vicinity of commercial lettuce fields. Spraying the headlands with insecticide or selectively managing the weed populations warrants further investigation.

The management of pests on lettuce is complex. Experience has taught us that regular application of insecticides to protect crops and constantly suppress pests to often unreasonably low levels, without being aware of the continuous and often subtle changes in the crop ecosystem, leads to several undesirable consequences. Research in California has now shown that multiple applications of pesticide can actually lower crop yields by phytotoxicity (Toscano et al. 1982), yet another reason to strive for reduced spraying. Monitoring is a means of keeping informed about the many pests of lettuce and must continue for the further development and operation of an integrated approach to their management. Present and anticipated computer technology should be exploited for needed support in handling the rapidly increasing base of information about all aspects of crop production and to effectively tap this information for delivery of relevant custom-tailored recommendations to individual growers. The chance of radical fluctuations occurring in the quality of future lettuce pest management will, in this way, be minimized.

LIST OF REFERENCES

Footnote

1 Western Lettuce Now, Inc., 7092 Glover Road, Langley, B.C. (604) 888-3758.

2 Cloverdale Lettuce and Vegetable Co-operative, 5590- 152nd Street, P.O. Box 1185, Surrey, B.C. V3S 4P6. (604) 576-9101.

3 Of low reflectance in the blue violet region of the spectrum (360-480 nm).

4 Containing white.

5 No black added.

6 Cloverdale Paint and Chemicals Ltd., 6950 King George Highway, Surrey, B.C., V3W 4Z1. (604) 596-6261.

7 Seabright Enterprises, 5749 Langregan Street, Emeryville, California, U.S.A. 94608. (415) 655-2733.

8 D. Gangloff, T. Singh, T. Warhurst, Cloverdale Produce, 4623 - 168 Street, Surrey, B.C. (604) 576-2733.

9 Courtesy of Dr. W. Stick, Prairie Regional Laboratory, National Research Council of Canada, 110 Gymnasium Road, University Campus, Saskatoon, Sask. S7N 0W9.

10 Entomologist, Crop Protection Branch, B.C. Ministry of Agriculture and Food, 17720 - 57th Avenue, Surrey, B.C., V3S 4P9. (604) 576-2911.

BIBLIOGRAPHY

Anonymous. 1973. Slugs and snails. Min. Agr. Fish, Food (Brit.) Adv. Leaflet 115: 9pp.

Anonymous. 1978. Lettuce aphids. Ministry of Agriculture, Fisheries and Food, United Kingdom. HVD 55. 7pp.

Anonymous. 1982, 1983, 1984, 1985. Vegetable Production Guide for Commercial Growers. British Columbia Ministry of Agriculture and Food Publication, Victoria, B.C.

Anonymous. 1984. Compendium of pest control products registered in Canada, arthropod and mollusc controls. Pesticides Division, Plant Health and Plant Products Directorate, Agriculture Canada, Ottawa.

Banham, F.L., and J.C. Arrand. 1978. Recognition and life history of the major insect and allied pests of vegetables in British Columbia. British Columbia Ministry of Agriculture and Food Publication 78-18: 43pp. Victoria, B.C.

Berry, R.E. 1978. Insects and mites of economic importance in the Northwest. O.S.U. Bookstores, Inc. Publication, Oregon State University, Corvallis, Ore.

Dun, W. 1984. The application of IPM to lettuce production in B.C. D.A.T.E. Project #99, unpub. report. B.C. Ministry of Agriculture and Food, Cloverdale, B.C.

Essig, E.O. 1958. Insects and mites of western North America. Revised Ed., The Macmillan Company, New York.

Forbes, A.R., B.D. Frazer, and H.R. MacCarthy. 1973. The aphids (Homoptera: Aphididae) of British Columbia. 1. A basic taxonomic list. J. entomol. Soc. B.C. 70:43-57.

Gonzalez, D., and W.A. Rawlins. 1968. Aphid sampling efficiency of Moericke traps affected by height and background. J. econ. Ent. 61: 109-114.

Hardwick, D.F. 1965. The ochrogaster group of the genus Euxoa (Lepidoptera: Noctuidae), with description of a new species. Can. Ent. 97: 673-78.

Heathcoate, G.D. 1957. The comparison of yellow cylindrical, flat and water traps, and of Johnson suction traps for sampling aphids. Ann. appl. Biol. 45:133-139.

Heie, O.E. 1979. Revision of the aphid genus Nasonovia Mordvilko, including Kakimia Hottes and Frison, with keys to descriptions of the species of the world (Homoptera: Aphididae). Entomologica Scandinavica. Supplement No. 9. 105pp.

Hille Ris Lambers, D. 1949. Contributions to a monograph of the Aphididae of Europe. IV. Temminckia 8: 182-324.

Judd, G.J.R. 1982. Development and implementation of a pest management program for carrot production in the lower Fraser Valley. Master of Pest Management Professional Paper, Dept. of Biol. Sciences, Simon Fraser University, Burnaby, B.C.

Kennedy, J.S., C.O. Booth, and W.J.S. Kershaw, W.J.S. 1961. Host finding by aphids in the field. III. Visual attraction. Ann. appl. Biol. 49: 1-21.

Kennedy, J.S., M.F. Day, and V.F. Eastop. 1962. A conspectus of aphids as vectors of plant viruses. Commonwealth Institute of Entomology, London. 114 pp.

Lamb, K.P. 1958. Alate aphids trapped in Auckland, N.Z. using Moericke colour traps. New Zeal. J. Sci. 1: 578.

Lamb, R.J. 1974. Earwig travel in relation to habitat. PhD. Thesis. Dept. of Plant Science, University of British Columbia, Vancouver, B.C.

Leonard, M.D. 1974. A list of the aphids of Oregon (Homoptera: Aphididae). U.S. Dep. Agr., Agr. Res. Service Mimeo. 116pp.

Mackauer, M.J.P. 1962. Monoctonus crepidis (Haliday) (Hymenoptera: Aphidiidae) an aphid parasite new to North America. Can. Ent. 94: 1089-1093.

Mackenzie, J.R., R.S. Vernon, S. Szeto and M.J. Brown. 1982. In: Expert Committee on Pesticide Use in Canada (ECPUA), Pesticide Research Report (PRR). pp. 114-118.

Moericke, V. 1969. Hostplant specific colour behaviour by Hyalopterus pruni (Aphididae). Ent. exp. & appl. 12: 524-534.

McCalley, N.F., and W.H. Lange. 1969. A practical aphid trap for field studies. California Agriculture. 23(10):18.

Rollo, C.D., and W.G. Wellington. 1975. Terrestrial slugs in the vicinity of Vancouver, British Columbia. The Nautilus, 89(4):107-15.

Simonet, D.E. 1980. Strategies for aphid control on field-grown leaf lettuce. Ohio Report. May-June:44-46

Smith, C.F., and C.S. Parron. 1978. An annotated list of Aphididae (Homoptera) of North America. N.C. Agr. Exp. Sta. Tech. Bul. No. 255. 428pp.

Szeto, S.Y. and M.J. Brown. 1982. Gas-liquid chromatographic methods for the determination of disulfoton, phorate, oxydemeton-methyl, and their toxic metabolites in asparagus tissue and soil. J. Agric. Food Chem. 30:1082-1086.

Szeto, S., J.R. Mackenzie, M.J. Brown, and R.S. Vernon. 1982. In: Expert Committee on Pesticide Use in Canada (ECPUA), Pesticide Research Report (PRR). pp. 341-348.

Szeto, S., J.R. Mackenzie, M.J. Brown, and R.S. Vernon. 1983. The degradation of disulfoton in lettuce after applications for control of the lettuce aphid, Nasonovia ribisnigri (Mosley). J. environ. Sci. Health, B18(6):725-734.

Szeto, S., R.S. Vernon, and J.R. Mackenzie. 1985. Residues of disulfoton in lettuce after foliar application - Study I and II. Expert Committee on Pesticide Use in Canada (ECPUA), Pesticide Research Report (PRR). In press.

Szeto, S., R.S. Vernon, and J.R. Mackenzie. 1985. Residues of oxydemeton-methyl in lettuce after foliar application - Study I and II. Expert Committee on Pesticide Use in Canada (ECPUA), Pesticide Research Report (PRR). In press.

Thompson, L.S. 1967. Reduction of lettuce yellows with systemic insecticides. J. econ. Ent. 60(3):716-718.

Toscano, N.C., F.V. Sances, M.W. Johnson, and L.F. LaPre. 1982a. Effect of various pesticides on lettuce physiology and yield. J. econ. Ent. 75:738-741.

Toscano, N.C., R.A. van Steenwyk, K. Kido, N.F. McCalley, W.W. Barnett, and M.W. Johnson. 1982b. Yield responses in lettuce plants at various density treatment levels of lepidopterous larvae. J. econ. Ent. 75(5): 916-920.

Vernon, R.S. 1979. Population monitoring and management of Hylemya antiqua and Thrips tabaci in British Columbia onion fields, with observations on other root maggot populations. Master of Pest Management Professional Paper, Dept. of Biol. Sciences, Simon Fraser University, Burnaby, B.C.

Vernon, R.S., and J.R. Mackenzie. 1985. Efficacy of insecticidal sprays against the lettuce aphid infesting crisphead lettuce. Expert Committee on Pesticide Use in Canada (ECPUA), Pesticide Research Report (PRR). In press.

Westdal, P.H., C.F. Barrett, and H.P. Richardson. 1961. The six-spotted leafhopper, Macrosteles fascifrons (Stal.) and aster yellows in Manitoba. Can. J. Plant Sci. 41:320-31.

Whitaker, T.W. 1974. Lettuce: Evolution of a weedy Cinderella. HortScience 9(6): 512-14.

Wilkinson, A.T.S. 1974. Control of slugs. Agriculture Canada Publication 1213: 4pp.

Wilkinson, A.T.S. 1980. Wireworms in British Columbia. Canada Agriculture. Spring, 1980.

Wilkinson, A.T.S., and H.S. Gerber. 1983. Description, life-history, and control of leatherjackets. B.C. Ministry of Agriculture and Food Publication, Victoria, B.C.

Wilkinson, A.T.S., and H.R. MacCarthy. 1967. The marsh crane fly, Tipula paludosa Mg., a new pest in British Columbia (Diptera: Tipulidae) J. entomol. Soc. B.C. 64: 29-34.

Wright, N.S., H.R. MacCarthy, and A.R. Forbes. 1970. Epidemiology of potato leaf roll virus in the Fraser River delta of British Columbia. Am. Potato J. 47(1):1-8.

Appendix A. Standard forms used to record pest and crop data:

1. caterpillar counts
2. pheromone trap catches
3. aphid counts
4. catches on sticky aphid traps
5. miscellaneous pests
6. table of insect population levels

A1. LETTUCE IPM PILOT PROJECT PLANT EXAMINATION RECORD SHEET	DATE DA/MO	EXAMINER	FIELD	EXAM NO.	PAGE NO./OF
LEPIDOPTERA					

			SP:							SP:							SP:							
PLANT #	BED	ROW	EGGS	I 1	I 2	I 3	I 4	PUP	TOTAL	EGGS	I 1	I 2	I 3	I 4	PUP	TOTAL	EGGS	I 1	I 2	I 3	I 4	PUP	TOTAL	GRAND TOTALS
TOTALS																								
TOT/PLANT																								

COMMENTS

A2. LETTUCE IPM PILOT PROJECT	EXAMINER	SPECIES	PAGE NO./OF
PHEROMONE TRAP RECORD SHEET			

TRAP	DATE						TOTAL
TOTAL							
TOT/TRAP							
T/TR/DAY							

LETTUCE IPM PILOT PROJECT	EXAMINER	SPECIES	PAGE NO./OF
PHEROMONE TRAP RECORD SHEET			

TRAP	DATE						TOTAL
TOTAL							
TOT/TRAP							
T/TR/DAY							

LETTUCE IPM PILOT PROJECT	EXAMINER	SPECIES	PAGE NO./OF
PHEROMONE TRAP RECORD SHEET			

TRAP	DATE						TOTAL
TOTAL							
TOT/TRAP							
T/TR/DAY							

A3. LETTUCE IPM PILOT PROJECT PLANT EXAMINATION RECORD SHEET	EXAM NO.	PAGE NO./OF

GROWER	EXAMINER	FIELD	CULTIVAR

DATE DA/MO	TIME AM/PM	PPTN IN PAST 24 HRS O L M H	SOIL D M W	PLANTS D W

APHIDS

PLANT #	BED	ROW	NASONOVIA RIBISNIGRI									TOTAL	MISC. PREDOMINANT:									TOTAL	TOTAL APHIDS	TOTAL LEAVES	
			ALATA			APTERAE			NYMPHS				ALATA			APTERAE			NYMPHS						
LOCATION			O	H		O	H		O	H			O	H		O	H		O	H					
LOCATION TOTAL																									
MORPH TOTAL																							TOT/PLANT		
GRAND TOTAL																							TOT/LEAF		

O: OUTER, H: HEAD LEAVES

A4. LETTUCE IPM PILOT PROJECT APHID TRAP RECORD SHEET	DATE DA/MO	EXAMINER	FIELD	VARIETY	PAGE NO./OF

REF TO PLANT EXAM NO.	DAYS IN TRAP SESSION	

TRAP NO.	SPECIES*						TRAP NO.	SPECIES						
	Nr	Mp	Me			TOTAL		Nr	Mp	Me			TOTAL	REPLACE
														TOTAL
														TOT/TRAP
														T/TR/DAY

* Nr NASONOVIA RIBISNIGRI
Mp MYZUS PERSICAE
Me MACROSIPHUM EUPHORBIAE

EXAMINER	GROWER	FIELD	

A5. LETTUCE IPM PILOT PROJECT PLANT EXAMINATION RECORD SHEET	DATE DA/MO	EXAMINER	FIELD	EXAM NO.	PAGE NO./OF

MISCELLANEOUS PESTS AND DISEASES

PLANT #	BED	ROW	SLUGS	DOWNY MILDEW	BACTERIAL SLIME ROT	VIRUS	OTHER	COMMENTS
TOTALS								
TOT/PLANT								

COMMENTS

A6. LETTUCE I P M PILOT PROJECT - TABLE OF INSECT POPULATION LEVELS FOR CONTROL ACTION

DATE																					COMMENTS
FIELD	APHIDS		LOOPERS		MISC.	NO. LVS	SPRAY DATE	PRO-DUCT	SEE PAGE	FIELD	APHIDS		LOOPERS		MISC.	NO. LVS	SPRAY DATE	PRO-DUCT	SEE PAGE		
	/P	/L	/P	/L							/P	/L	/P	/L							

Appendix B. Control recommendations:

1. recommendation form
2. summary of recommendations for alfalfa looper
3. summary of recommendations for lettuce aphid control
4. notice to all lettuce growers

Appendix B.1. Recommendation Form, 1982.

Lettuce IPM Pilot Project

Pest Report

Grower ____________________

Date ________________ Field __________________ Crop ____________________

Examiner __________________

Pest Status: ____

____

____

____

____

____

Recommendation: ____

____

____

____

____

____

Pest situation is:

___ urgent (follow recommendation within 24 hours)

___ potentially dangerous (follow recommendation within 2 days)

___ not of immediate concern

This form has been read by __________________________

Date ________________

Appendix B 2. Summary of recommendations for alfalfa looper control on the cooperator's farm, 1982.

Recommendation Number (of the year)	Date	Planting Number	Insecticide	Comments
1(2)	May 27	19(1st)		looper first detected (in low numbers)
2(4)	June 3	1	Malathion or Monitor	apply within 2 days
3(5)	June 4	7,8	Monitor	apply within 24 hours
4(6)	June 11	2,3	Monitor	apply within 24 hours
5(7)	June 16	5,6	Monitor	price of pesticide was given
6(8)	June 17	8-10 20(1st)	 Sevin	
7(9)	June 21	8	Monitor	
8(10)	June 23	1-3		harvest as soon as possible and plough under refuse
9(11)	June 23	7,11 19,20	Monitor, Thuricide or Lannate	tips for most effective spray application given
10(12)	June 28	7,11	Lannate or Monitor	
11(13)	June 30	8-10	Monitor	
12(14)	July 6	7-9		pest below threshold, grower update
13(15)	July 8	9	Lannate	
14(17)	July 28	15	Monitor	
15(18)	July 31	16	Monitor	
16(20)	August 17	18	Monitor	presence of loopers noted (below threshold), spray for aphids

Appendix B 3. Summary of recommendations for lettuce aphid control on the cooperator's farm, 1982.

Recommendation Number (of the year)	Date	Planting Number	Suggested Treatment	Comments
1(14)	July 6	7,9		first warning to grower of aphid presence
2(16)	July 20	9-14	Cygon	
3(17)	July 28	12,13	Cygon	
3(17)	July 28	14,15	Monitor	
4(18)	July 31	11-14	Cygon	
4(18)	July 31	15-18	Monitor	
5(19)	Aug. 6	12,13		plough under crop remains
5(19)	Aug. 6	14	Cygon	within 3 days
5(19)	Aug. 6	15-18	Monitor	within 24 hours
6(20)	Aug. 17	14,15	Cygon	
6(20)	Aug. 17	16	Systox	
6(20)	Aug. 17	17,18	Monitor	
7(21)	Aug. 25	15		no aphids found
7(21)	Aug. 25	16	Monitor	
7(21)	Aug. 25	17	Systox	
7(21)	Aug. 25	18	Monitor	
8(23)	Sept. 10	19,20(2nd)	Cygon	

Appendix B4. Notice to all lettuce growers

August 26, 1982 (replaces "Growers Notes" issued August 5, 1982)

IMPORTANT NOTICE TO ALL LETTUCE GROWERS

RE: THE LETTUCE APHID

As a result of continuing research into more effective control procedures for the lettuce aphid, the recommendations made on August 5 at a Cloverdale Lettuce and Vegetable Cooperative Directors' Meeting have been revised as follows:

Inspect all plants starting with those nearest to harvest.

Procedure:

a) Walk down the outside beds and up the centre bed examining four (4) heads at equal intervals within each bed. Examining means stripping the head and inspecting each leaf for aphids. If aphids are found, contact George Rush, Director, Cloverdale Lettuce and Vegetable Cooperative, or Jim Conroy, District Horticulturist, B.C.M.A.F. and leave a message if necessary.

b) Plants between the thinning and heading stage should be inspected weekly. If a single aphid is found apply Monitor at 1.1-2.3 L/hectare (30 fluid ounces per acre) at weekly intervals until plants reach the 15 leaf stage (this will be just prior to heading). One application of Systox S.C. should be applied at this point (at least 21 days before harvest) followed a week later with one final Monitor spray (at least 14 days before harvest). Systox S.C. should be applied at 2.25 L/hectare (30 fluid ounces per acre). For maximum control a spreader-sticker should be added to the spray mix.

Note:

1. Ploughing under or rotovating infested plantings will prevent the spread of aphids to younger plantings and adjacent fields. Plant material should be throughly covered with soil to ensure maximum aphid control.

2. Proper application of spray mix is essential for effective control. If the spray boom is too high, or nozzles are not spraying plant centres directly, control may be inadequate. Use 700-900 liters of water/hectare (60-80 gallons of water per acre) at a pressure of at least 1000 kPa (150 psi). For best results, sprays should be applied in the evening and when winds are CALM.

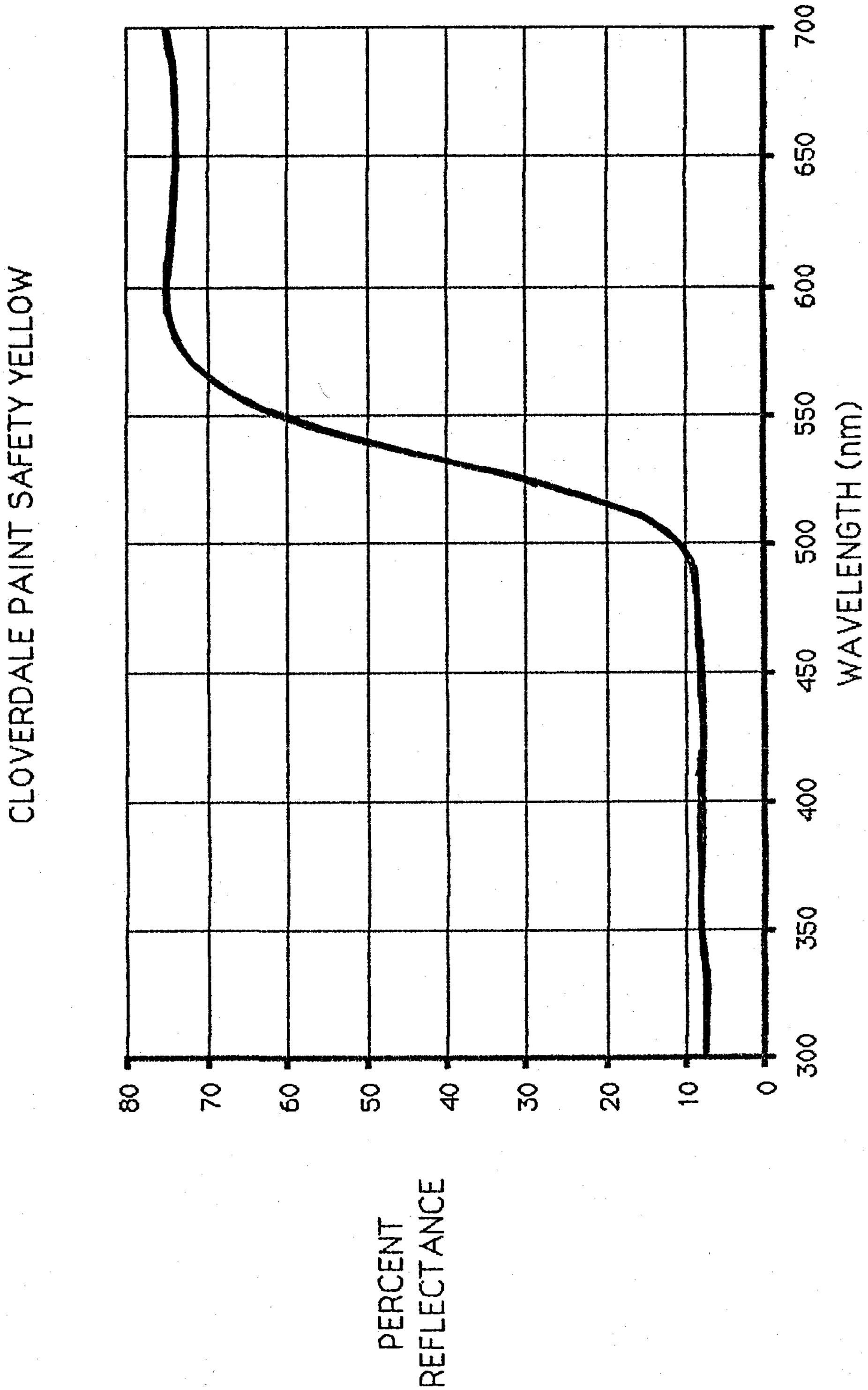
J.R. Mackenzie
Technician, Crop Entomology
Research Branch, Agriculture Canada
Vancouver, B.C.

J.F. Conroy
District Horticulturist
B.C. Ministry of
Agriculture and Food,
Surrey (Cloverdale), B.C.

Appendix C. Lettuce aphid survey:

1. percent reflectance curve of "Industrial yellow, No. 76025"[2] used in field and survey aphid monitoring with sticky traps.
2. addresses visited within the survey boundaries, Surrey, B.C.
3. market growers visited in Burnaby, B.C.

Appendix C1.



CLOVERDALE PAINT SAFETY YELLOW
80
70
60
50
40
30
20
10
0
PERCENT REFLECTANCE
300
350
400
450
500
550
600
650
700
WAVELENGTH (nm)

Appendix C 2. Lettuce aphid survey, Surrey, B.C., 1982.

	Address	Comments
1	16332 - 36 Avenue	had lettuce, but no aphid problems last year, wild Ribes and gooseberry, Ribes divaricatum, found behind Spranger's farm.
2	16982 - 40 Avenue	red currant, Ribes rubrum L.
3	16966 - 40 Avenue	red currant, black currant (Ribis nigrum L.), gooseberry
4	16952 - 40 Avenue	N. ribisnigri, i.d. May 11/82 on black currant, gooseberry, aphids present, samples taken
7	15739 - 40 Avenue	gooseberry, black currant
8	15777 - 40 Avenue	black currant
9	15756 - 40 Avenue	gooseberry, red currant
10	4612 - 152 Street	gooseberry, red and black currant
11	15328 - 48 Avenue	currants of different varieties, dark-colored aphids found
12	opposite 5224-160 St.	large patch of currant bushes
13	5468 - 160 Street	black currants
15	5340 -152 Street	red and black currant, one gooseberry, N. ribisnigri fundatrix, and nymphs found.
16	5355 - 168 Street	
17	5097 - 168 Street (Johnson Farms)	owner planted some lettuce last year, intends to plant 1-2 rows of fancy lettuce this year.
18	4636 - 168 Street (across from Cloverdale Produce)	2 red currant bushes, 1 gooseberry bush.

Appendix C 2. (continued)

	Address	Comments
19	17305 - 48 Avenue	about 12 currant plants, both red and black varieties, aphids present.
20	3810 - 168 Street	red currant
21	17017 - 32 Avenue	red, black, and white, _Ribes nigrum_ L., variety of currant aphids present.
22	17075 - 32 Avenue	black currant
23	17139 - 32 Avenue	red currant, aphids found
24	4375 - 152 Street	field of red currant
25	3445 - 180 Street	black currant
26	3962 - 176 Street	gooseberry and lettuce but no aphids
27	3738 - 176 Street	gooseberry at front driveway
28	3610 - 176 Street	white, black, and red currant varieties, many aphids present, owner had problems with aphids last year, 20-30 bushes total
29	3255 - 176 Street	red currant
30	3277 - 176 Street	black currant
31	17952 - 40 Avenue	2 gooseberry and 3 black currant bushes, 1 apterae found

Appendix C 3. Lettuce aphid survey, Burnaby, B.C., 1982.

	Farm	Address	Comments
1	Sun Tai Sang	4886 Marine Drive	- no problems with aphids in the past - operator grows only fancy lettuce, no iceberg - farm about 5 acres in size
2	C.Y. Chan	4888 S.E. Marine Drive	- has not had any major aphid problems, although some aphids were found and collected from his lettuce - both green and pink forms of <u>Nasonovia ribisnigri</u> present - grows fancy lettuce only
3	Wing Wong	between C.Y. Chan and Hop on	- no aphid problems apparent, but farmer was not contacted personally - only fancy lettuce grown
4	Hop On	5624 Marine Drive	- had an aphid problem last year, possibly a result of not spraying early enough in the season - this year sprays of Thiodan were applied earlier and no problems have yet appeared
5	West of Sun Tai Sang		- not visited due to language difference

Appendix C 3. (continued)

	Farm	Address	Comments
6	Quin On Farm	7487 Meadow Street	- about 2.5 acres lettuce grown/year - fancy lettuce only - no major problems, although grower had noticed a few earlier in the season and dusted with Thiodan
7	Kwang Lee Yuen	6060 Marine Drive	- sizable farm - no English spoken
8	Wongs Garden	6320 14th just off Marine Drive	- about 2-3 acres fancy lettuce grown/year - no aphid problems in the past - operator sprays with Thiodan when aphids are found - crop was not inspected

There are many very small farms down Byrne Road which were not visited.

Appendix D. Within-field distributions of alfalfa loopers and lettuce aphids

1. Within-field distributions of alfalfa loopers: field descriptions

2. Within-field distributions of alfalfa loopers: density profiles of looper distributions in commercial lettuce fields 1L, 2L, 3L and 4L.

3. Within-field distributions of lettuce aphids: field descriptions.

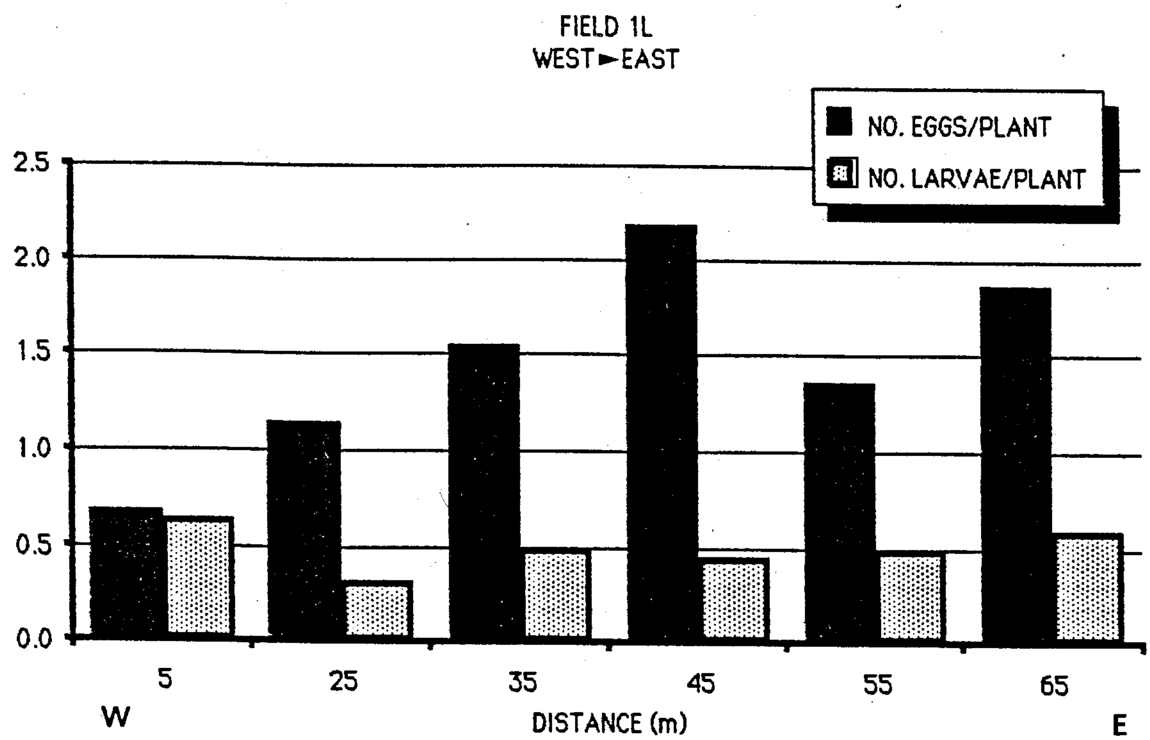
4. Within-field distributions of lettuce aphids: density profiles of aphid distributions in commercial lettuce, fields 1A, 2A, 3A and 4A.

Appendix D 1. Within-field distributions of alfalfa loopers - field descriptions.

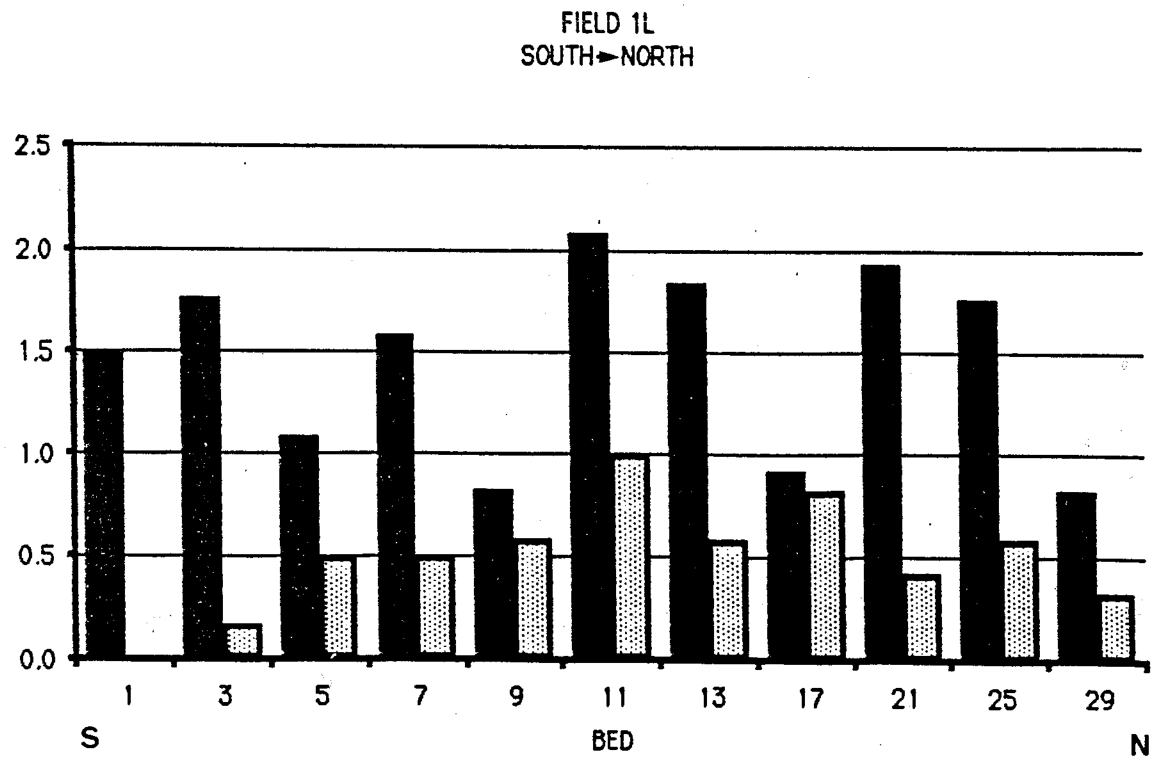
Field	Date of plant exami-nation	Field			Ground cover adjacent to field				Average no. of leaves per plant*	Total no. of plants examined
		Length (m)	Width (m)	Area (ha)	West side	South side	East side	North side		
1L	28/5/82	120	54	.65	road, ditch	road, ditch	service yard	carrot field	7	132
2L	18/8/82	120	54	.65	road, ditch	road, ditch	service yard	carrot field	9	66
3L	28/5/85	127	44	.56	road, ditch	older planting of lettuce	road, ditch	younger planting of lettuce	5	192
4L	28/5/85	188	49	.92	older planting of lettuce	road	younger planting of lettuce	road	5	216

* On the day of plant examination

Appendix D2.

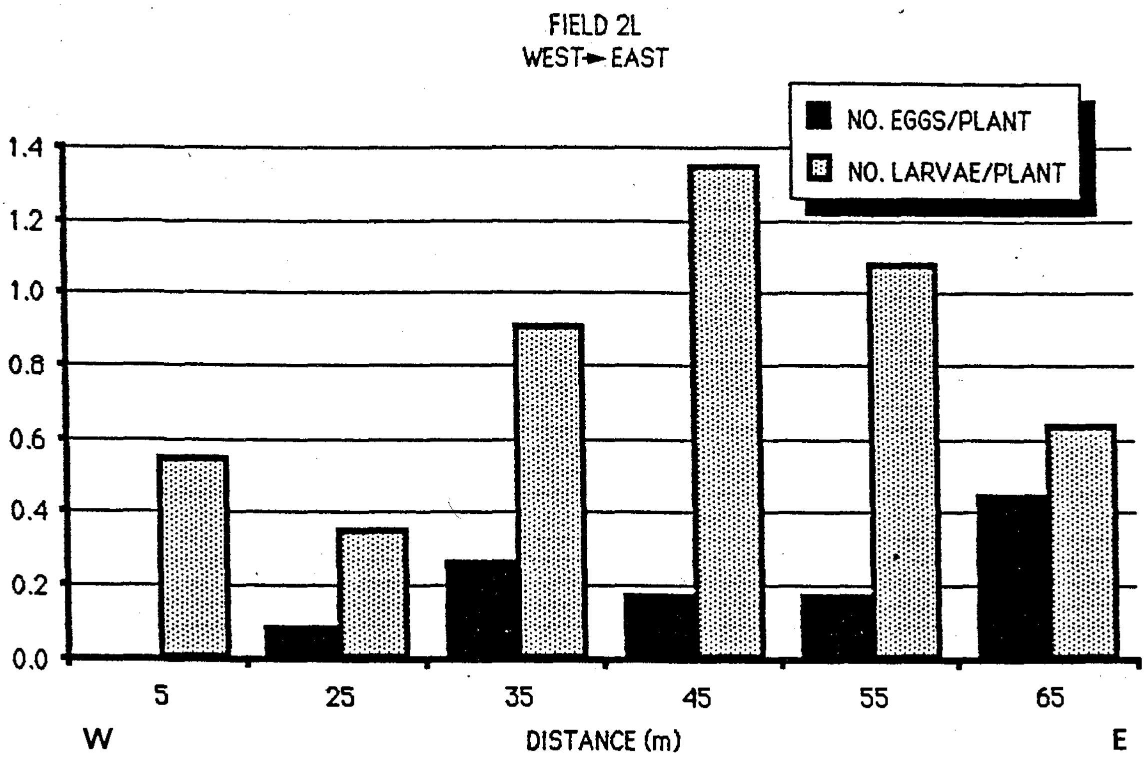


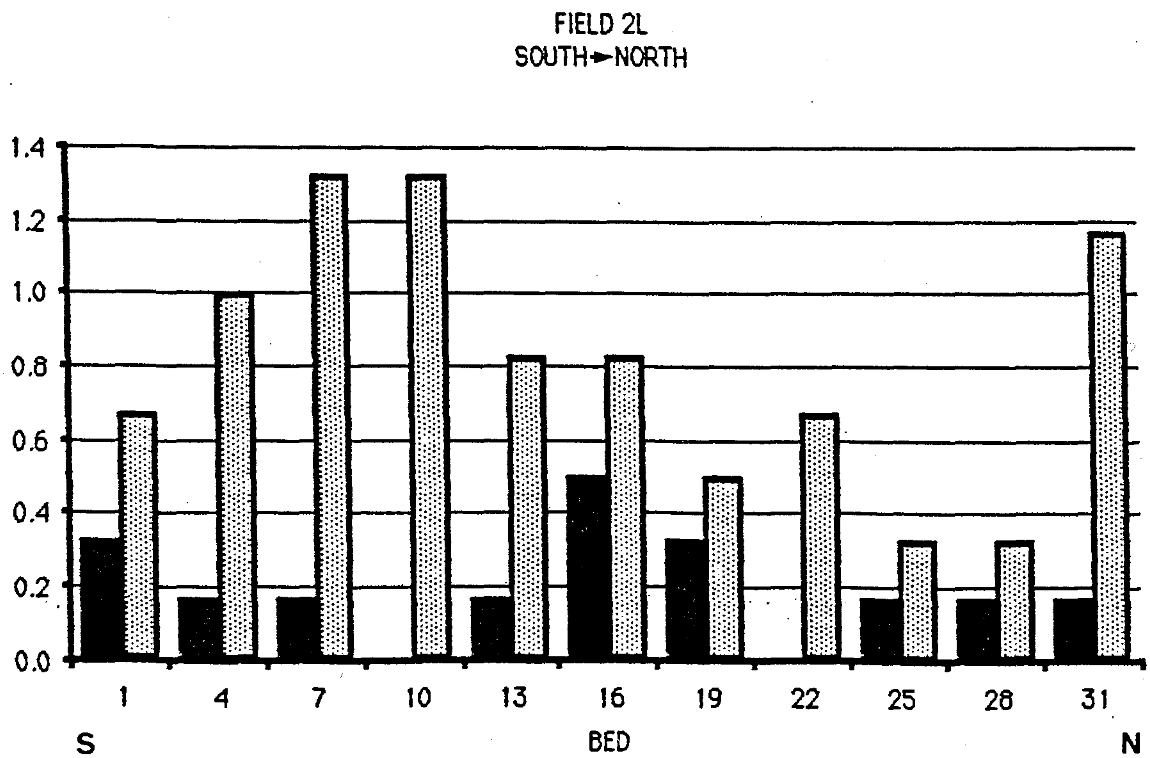
FIELD 1L
WEST►EAST
NO. EGGS/PLANT
NO. LARVAE/PLANT
2.5
2.0
1.5
1.0
0.5
0.0
5
25
35
45
55
65
W
DISTANCE (m)
E



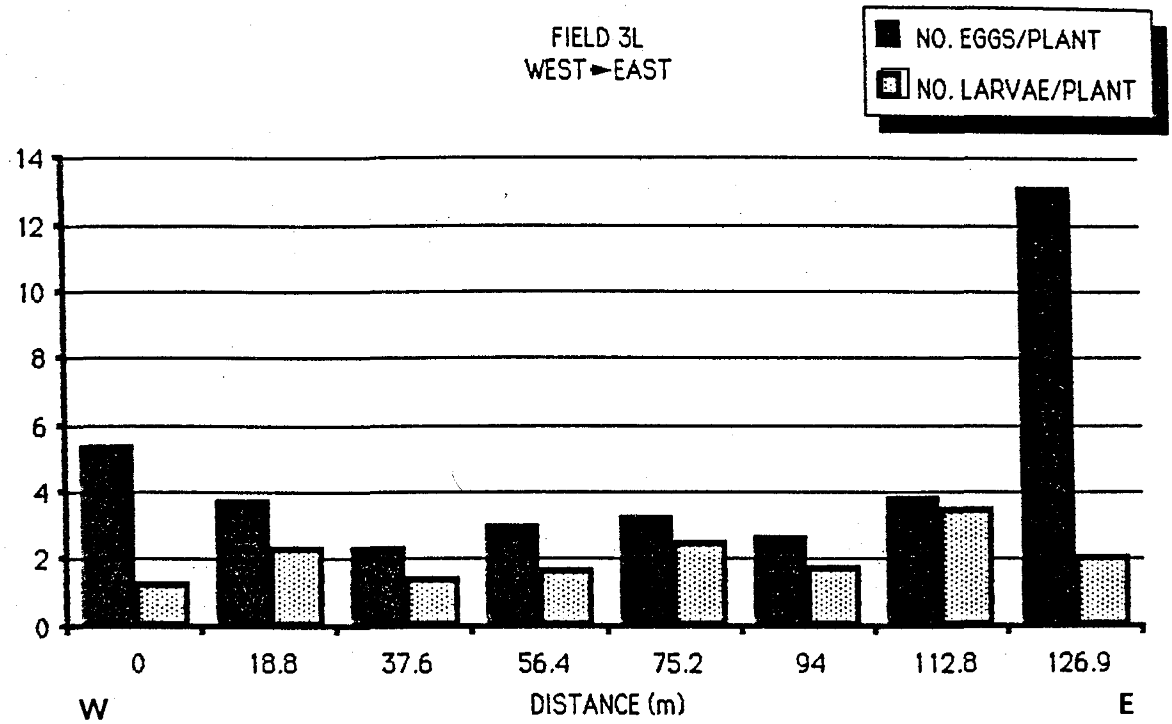
FIELD 1L
SOUTH►NORTH
2.5
2.0
1.5
1.0
0.5
0.0
1
3
5
7
9
11
13
17
21
25
29
S
BED
N

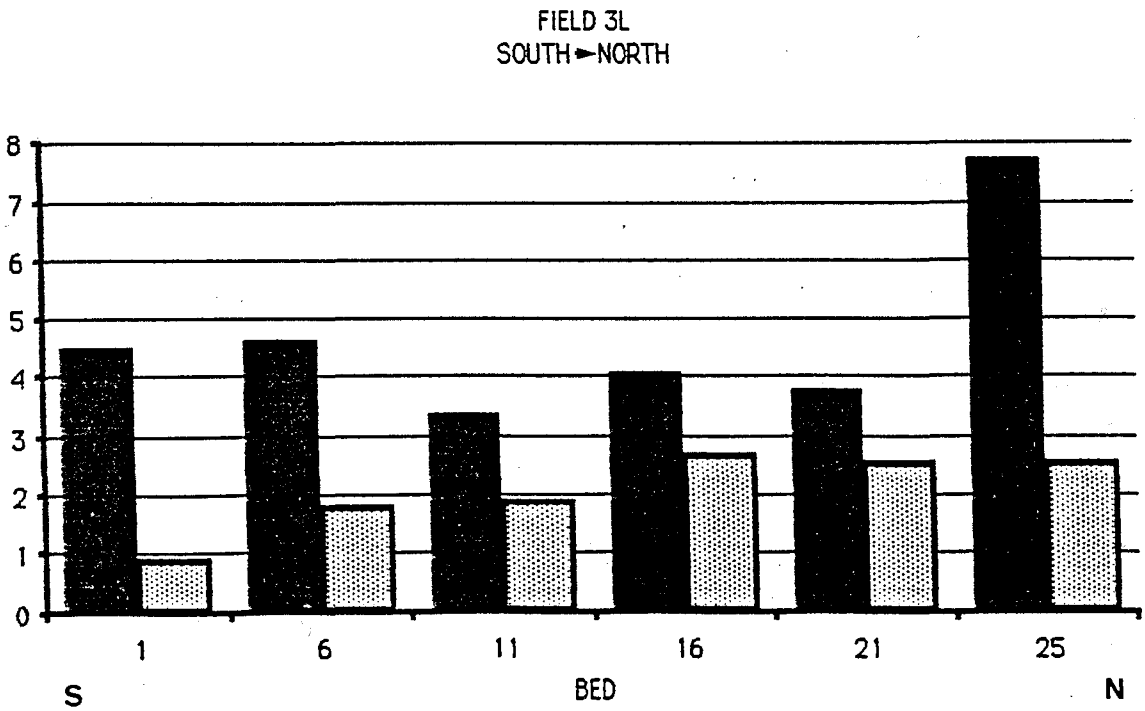
Appendix D2 (cont.)



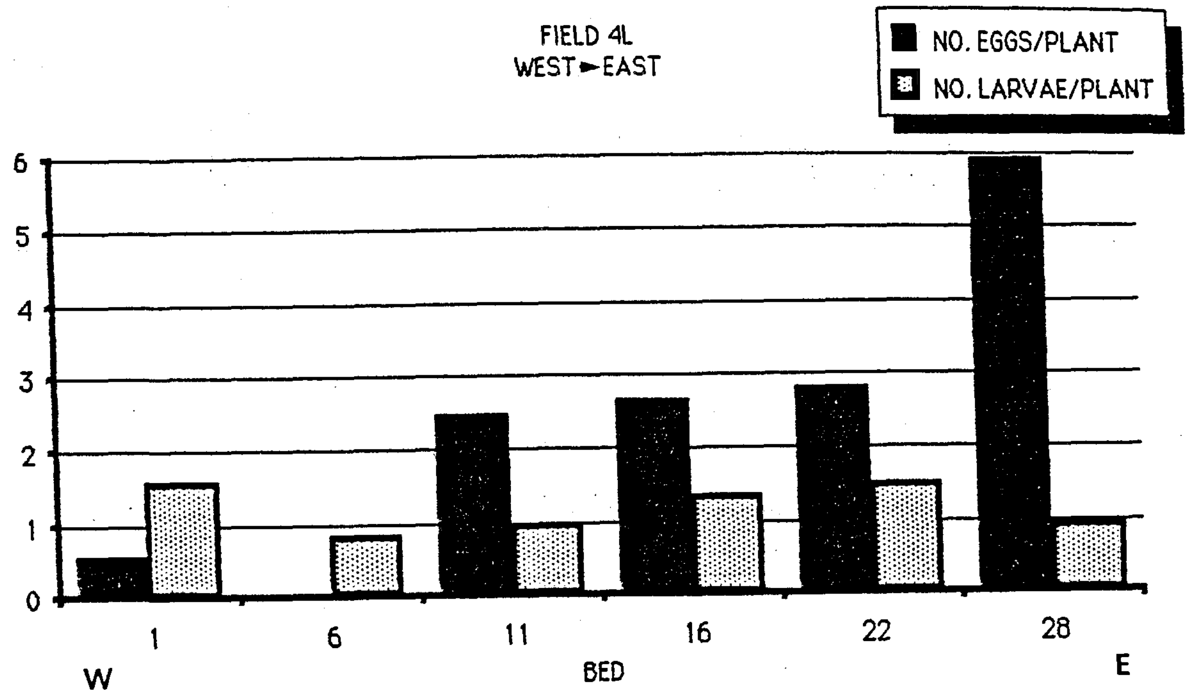


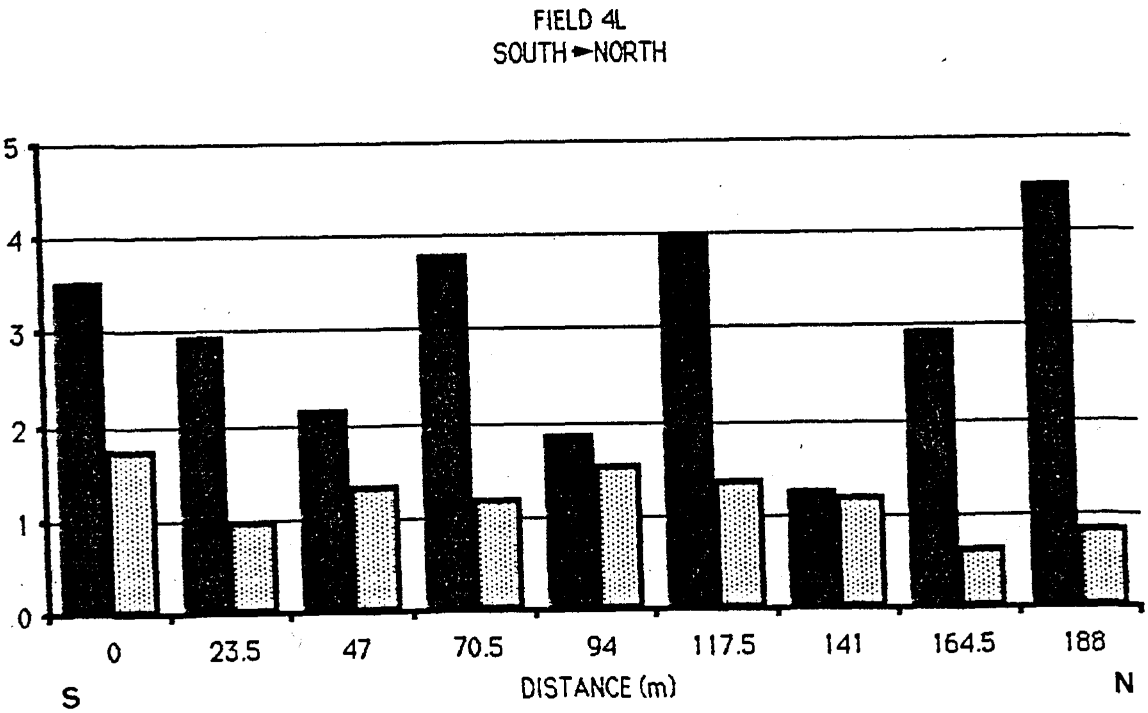
Appendix D2 (cont.)





Appendix D2 (cont.)



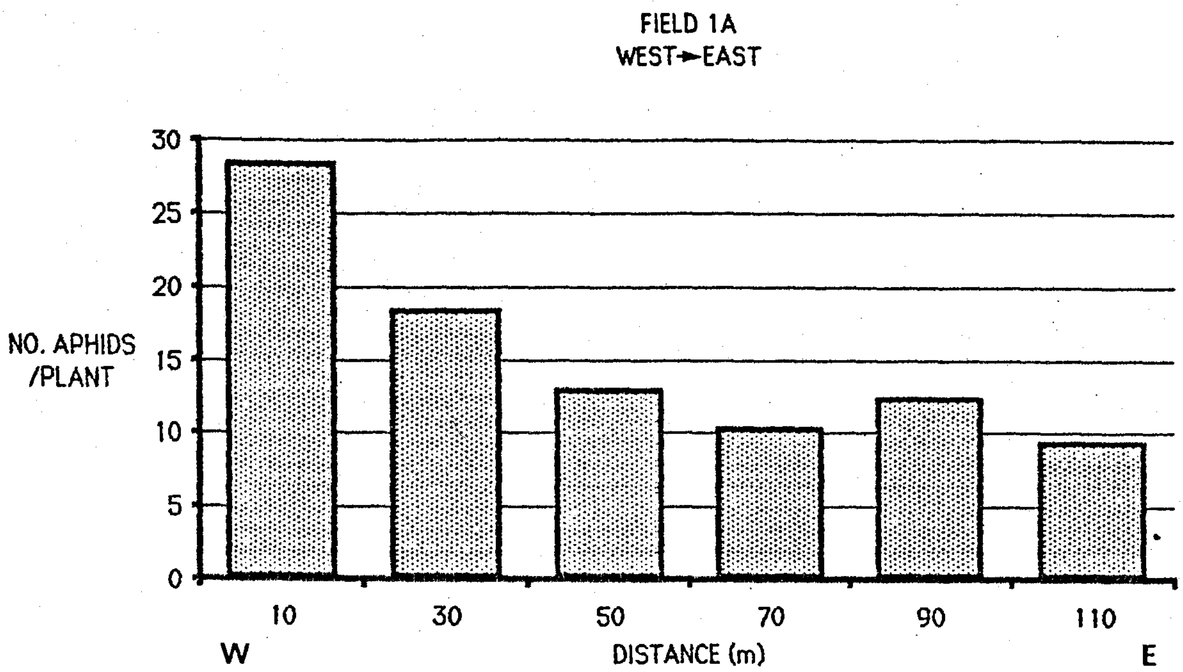


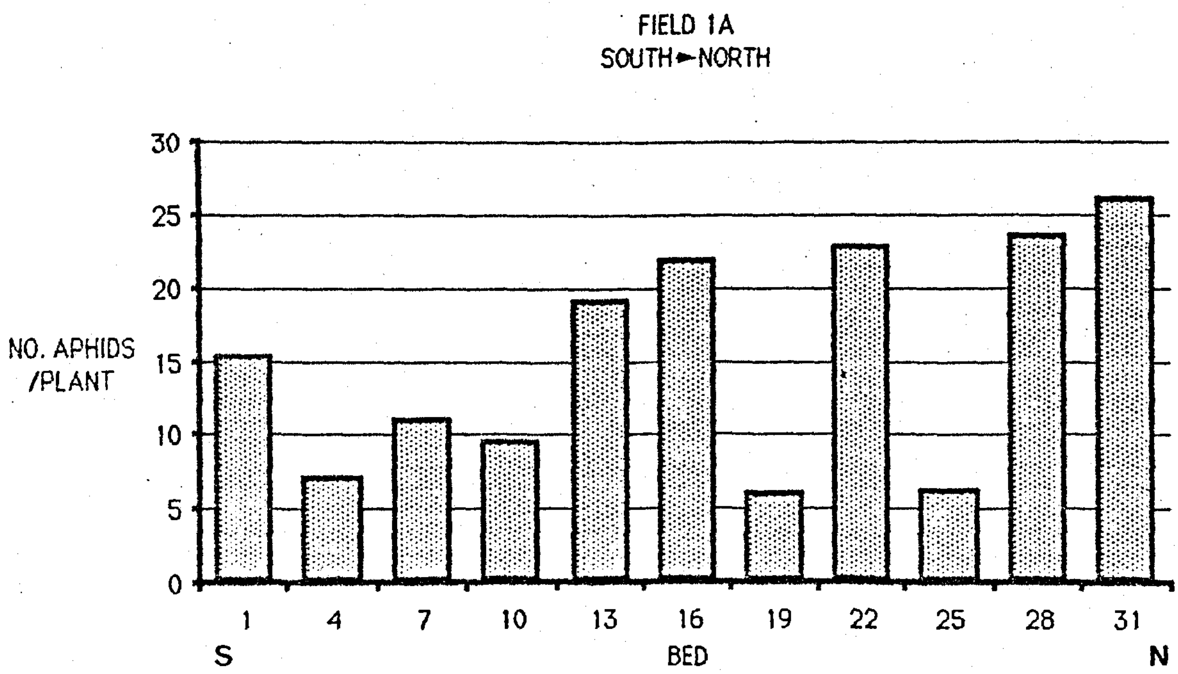
Appendix D3. Within field distributions of lettuce aphid - field descriptions.

Field	Date of plant exami- nation	Field			Ground cover adjacent to field				Average no. of leaves per plant*	Total no. of plants examined
		Length (m)	Width (m)	Area (ha)	West side	South side	East side	North side		
1A	18/8/82	120	54	.65	road, ditch	road, ditch	service yard	carrot field	9	66
2A	12/7/84	210	49	1.03	ditch, carrots	mature planting of lettuce	road	younger planting of lettuce	11	384
3A	12/7/84	160	47	.76	onions	celery	road, buildings	mature planting of lettuce	13	272
4A	17/7/84	220	37	.81	younger planting of lettuce	onions	ditch	ditch	13	460

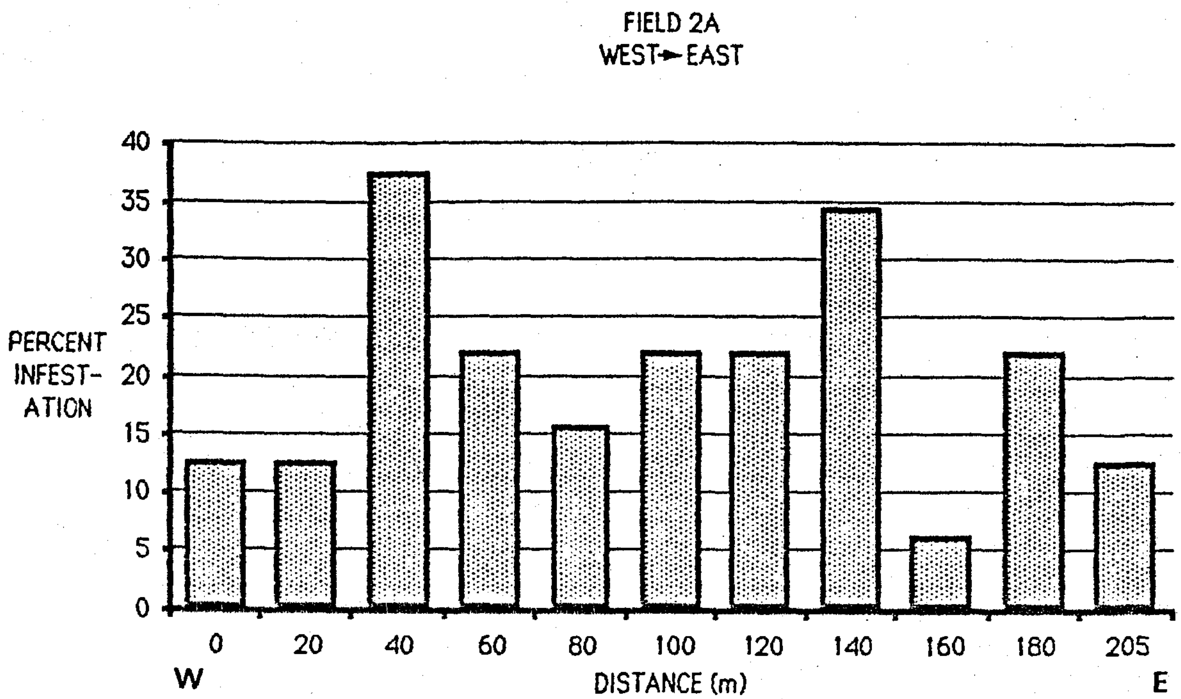
* On the day of plant examination

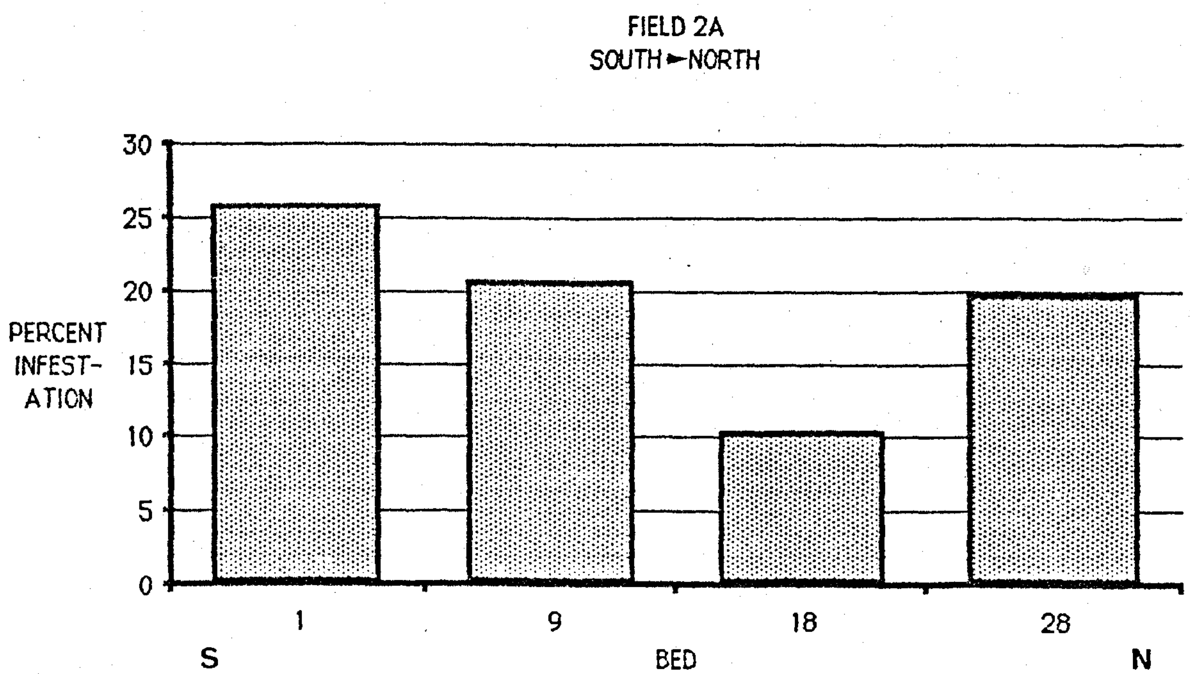
Appendix D4


FIELD 1A
WEST→EAST
NO. APHIDS /PLANT
30
25
20
15
10
5
0
10
30
50
70
90
110
W
DISTANCE (m)
E

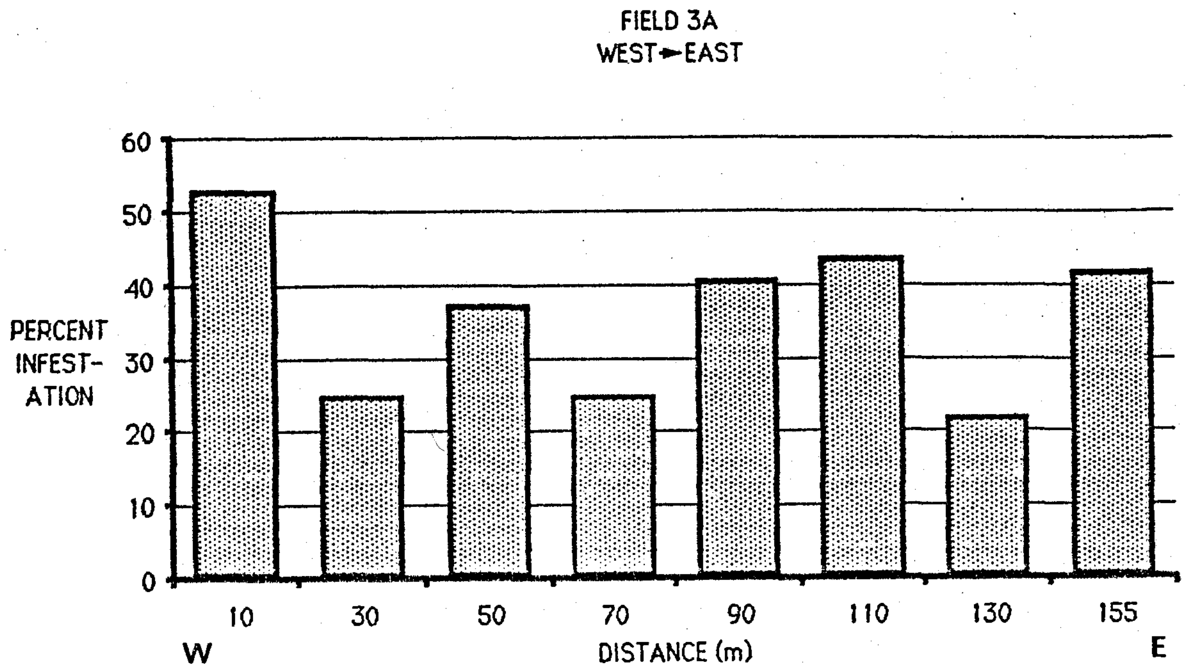

FIELD 1A
SOUTH→NORTH
NO. APHIDS /PLANT
30
25
20
15
10
5
0
1
4
7
10
13
16
19
22
25
28
31
S
BED
N

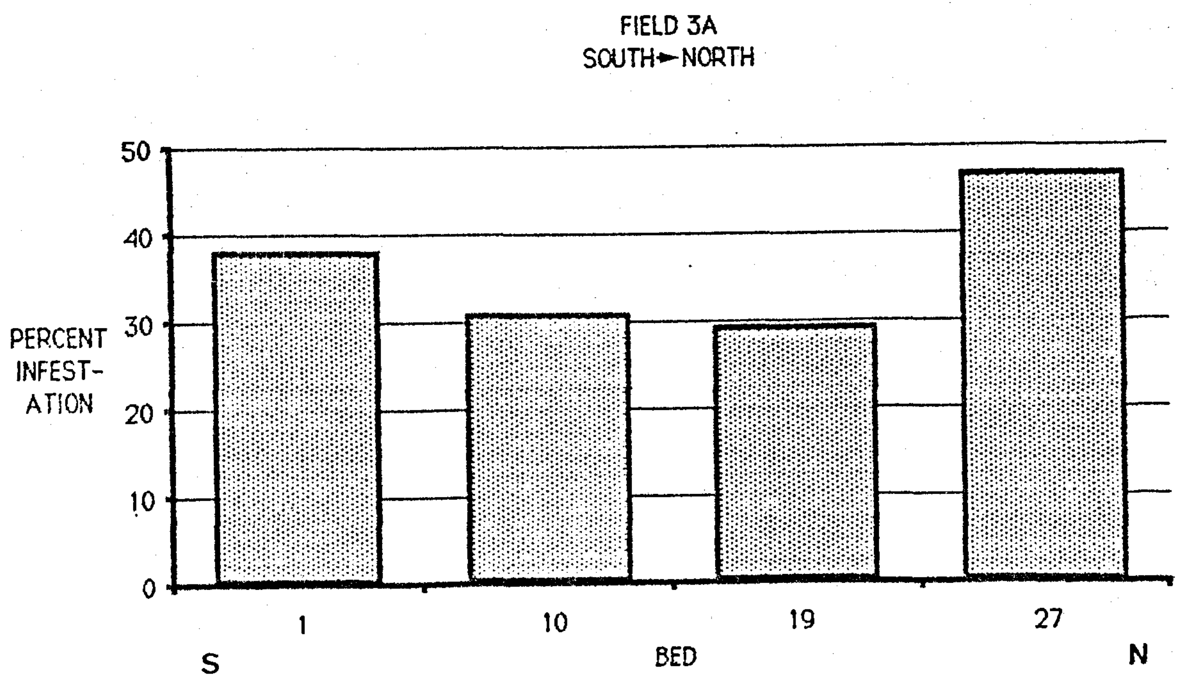
Appendix D4 (cont.)





Appendix D4 (cont.)





Appendix D4 (cont.)