SYSTEMIC INSECTICIDAL CONTROL OF THE ASTER LEAFHOPPER (*MACROSTELES FASCIFRONS*, STÅL) AND ASTER YELLOWS IN CARROTS AND CELERY IN MANITOBA

A Thesis

Submitted to the Faculty

of

Graduate Studies

The University of Manitoba

by

George Brian Ure

In Partial Fulfillment of the

Requirements for the Degree

of

Doctor of Philosophy

Department of Plant Science

October 1981

SYSTEMIC INSECTICIDAL CONTROL OF THE ASTER LEAFHOPPER (MACROSTELES FASCIFRONS, STÅL) AND ASTER YELLOWS IN CARROTS AND CELERY IN MANITOBA

BY

GEORGE BRIAN URE

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to Dr. L. J. LaCroix, Department of Plant Science for his continued support and guidance; to Dr. C. C. Bernier, Department of Plant Science for his advice; to Dr. P. H. Westdal, Agriculture Canada, Research Station, Winnipeg, for his counsel and permission to use greenhouse facilities; to Dr. J. F. Moore, former Director of Research, Campbell Soup Company Ltd., for his constructive criticisms regarding the field studies and to Mrs. M. Henderson and Mrs. S. Armstrong for their conscientious typing of this manuscript.

The financial assistance of the National Science and Engineering Research Council and the Campbell Soup Research Fellowship is gratefully acknowledged.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table

Table

Page

Table

Page

APPENDIX

Table

Table

Table

LIST OF FIGURES

Figure

Page

Figure

Page

ABSTRACT

Ure, G. Brian. Ph.D., The University of Manitoba, February, 1982. Systemic Insecticidal Control of the Aster Leafhopper (Macrosteles fascifrons, Stål) and Aster Yellows in Carrots and Celery in Manitoba. Major Professor; L.J. LaCroix.

In Manitoba, aster yellows (AY) disease, as transmitted by the aster leafhopper, Macrosteles fascifrons, Stål, often results in reduced yield and quality of celery and carrots. The incidence and severity of the disease, which may reach epidemic proportions, are directly related to spring influxes of migrant leafhoppers which represent the major source of disease inoculum. A critical situation thus exists, when large numbers of an efficient vector, a certain percentage of which are persistently infectious, invade an area when many susceptible crops are in the seedling stage.

Due to the lack of adequate control programs, replicated field trials were conducted over a period of 3 years at Portage la Prairie. The efficacy of contact spray materials, as compared to several foliar and granular systemic insecticide treatments, for control of the aster leafhopper and aster yellows disease in celery and carrots

was assessed. Foliar sprays of carbaryl (1.7 kg/ha ai), methoxychlor (1.7 kg/ha ai) and oxydemeton-methyl (0.6 kg/ha ai) were applied weekly, while granular treatments (3.4 kg/ha ai) were applied in-furrow at planting. The aster leafhopper population was monitored by weekly sweep net counts, just prior to application of foliar treatments.

In individual trials, and over the 3 year period, foliar contact sprays, systemic foliar applications and systemic granular in-furrow treatments were found to have increasing orders of efficacy. Applications of carbaryl resulted in minimal crop protection. Leafhopper control averaged 30% and disease incidence was only slightly reduced in carrots. Methoxychlor treatments were equally ineffective. Oxydemeton-methyl applications were more effective when the leafhopper population was stable, than during periods of migrant influxes. The maximum carrot yellows reduction achieved with oxydemeton-methyl was 60%.

Of the granular materials evaluated, disulfoton was ineffective for leafhopper or disease control in either crop. Phorate, carbofuran and aldicarb treatments had increasing orders of efficacy. The duration of activity of phorate was 7-8 weeks. Carbofuran treatments effectively controlled the early-season leafhopper population and reduced AY disease incidence. The maximum celery yellows reduction was 75%. Aldicarb was the most effective and consistent treatment tested. Early-season leafhopper control was 60-70%.

Maximum carrot and celery yellows reductions were 72 and 66%, respectively. The duration of insecticidal activity of aldicarb was 9-12 weeks but a longer period of efficacy was often noted.

Linear correlation analysis, of the trial variables, revealed the importance of early seedling protection. Early season leafhopper populations were better correlated with AY incidence at harvest and decreased yield than other variables.

The persistence and fate of aldicarb in carrots was investigated. Residues of toxic aldicarb equivalents in carrot roots, determined by gas chromatography, ranged from 0.06 to 0.21 ppm, 70 days after in-furrow applications at rates of 1.7 to 6.7 kg/ha ai. Residues did not accumulate in the root, were found to be rate related and declined to 0.04 to 0.10 ppm at harvest, 130 days after application. Residue levels in the leaves, 51 days following aldicarb applications, ranged from 1.4 to 6.9 ppm. Leaf residues declined rapidly at first, then more slowly, and at day 99 ranged from 0.16 to 0.62 ppm. Leaf residues were also rate related. Furthermore, the proportion of toxic aldicarb metabolites in the leaf relative to the root was also rate related.

The metabolism of S-methyl-^{14}C-aldicarb in carrot following 12 hours of root uptake from nutrient solution containing 11.25 ppm aldicarb was studied. Uptake was rapid (30% in 12 hrs) resulting in an initial concentration of aldicarb equivalents in the plant of 38.5 ppm. Plants were

sampled over time (0.5 to 45 days) and analysed for total aldicarb metabolites in the root, and toxic and non-toxic metabolites in the leaves. Elimination of activity from the root, leaves and plant was approximated by first order kinetics.

Translocation of aldicarb metabolites to the leaves was rapid. Radio activity was evenly distributed in leaves and stems but concentrated in the leaf tips. The half-lives of aldicarb metabolites in the root, leaves and whole plant were 6.5, 17.8 and 13.9 days, respectively. Toxic aldicarb metabolites were rapidly degraded/eliminated from the leaves (half-life, 8.7 days). The level of toxic metabolites in the leaf, as a percentage of total plant ^{14}C, declined slowly over the duration of the experiment.

In bioassay experiments, infectious leafhoppers were fed on plants containing a range in concentration of toxic aldicarb equivalents (0.7 - 15.4 ppm). Subsequent mortalities ranged from 5-89% in 24 hr and 26-100% in 48 hr. The LC_{50} values for 24 and 48 hr were found to be 3.44 and 1.24 ppm, respectively, and correspond to toxic aldicarb concentrations in field leaf samples, 7 weeks following in-furrow aldicarb applications. The LC_{95} value (48 hr) was 16.7 ppm while the LC_{95} (24 hr) was extremely high. Low leaf residuals and rapid degradation in the plant do not explain the long duration of leafhopper control in the field. These results, as well as an apparent avoidance from feeding in bioassay

tests, are suggestive of a repellent action for aldicarb in the plant.

The major benefits of effective granular in-furrow treatments are: elimination of a critically timed spray program, early seedling protection, persistent activity and ease of application. The maximum yellows reduction expected as a result of in-furrow treatments is 60-75%.

INTRODUCTION

This thesis contains the results of a study of the insecticidal control of aster yellows disease and its primary vector the aster leafhopper, Macrosteles fascifrons (Stål) in vegetable crops in Manitoba.

Insect pests of plants may be controlled with a wide range of insecticides. With respect to non-vectors or non-infectious vectors, crop protection requires only that the insect population be reduced below a certain critical level. That is, damage is usually proportional to the number of insects and the length of the feeding period (Carter, 1973). If the insect is also a vector of a plant virus, however, the problem is compounded and factors arise which are not directly related to the effectiveness of the insecticide (Mathews, 1970). Although disease incidence may be reduced, application of insecticide does not guarantee prevention of disease spread. In fact, a specific vector may be controlled but the spread or incidence of disease may not be reduced (Broadbent, 1957). Since a vector carrying a stylet-borne virus rapidly loses infectivity, insecticidal applications are not expected to reduce primary infection or spread of the disease to the same extent as is possible with a persistently borne virus (Burt, 1960). The requirement for a latent period in the vector before transmission can occur

imposes a time limitation on the acquisition and spread of a persistent virus. However, once the vector becomes infectious it is doubly dangerous.

A critical situation thus occurs when a vector population carrying a persistent disease agent invades a crop. This is the case with the aster leafhopper and the transmission of aster yellows disease to susceptible crops in Manitoba. Migrant leafhoppers from the southern United States generally arrive in mid-May with 1% to 5% of the population typically being infectious (Chiykowski and Chapman 1965, Westdal 1969a). The importance and biology of the insect and disease in Manitoba have been reported in a number of studies (Lee and Robinson 1958; Sackston 1957; Westdal 1969a; Westdal et. al. 1961). Preferred host plants include cereals, flax, lettuce, celery and carrots. Disease incidence varies from year to year and may reach epidemic proportions depending on population influxes, percentage of infectious leafhoppers and environmental conditions (Westdal and Richardson 1963). Such conditions may be the limiting factor(s) to the production of lettuce and celery and can result in significant yield loss in carrots (Chapman and Libby 1971).

Although the causal organism had not been isolated, aster yellows disease was, until 1967, considered to be the result of a virus infection. At that time electron microscopy studies of the phloem elements of yellows infected plants by Doi et. al (1967) combined with the therapeutic effect of

tetracycline antibiotics (Ishie et. al. 1967) culminated with the implication of a mycoplasma or chlamydia-like organism as causal agent of the disease. Subsequent reports confirming the similarity between the presumed yellows agent found in diseased plants and infectious vectors, and members of the order Mycoplasmatales were first reviewed by Maramorosch et. al. (1970), Whitcomb and Davis (1970), and Davis and Whitcomb (1971).

Although antibiotic treatments can suppress or delay symptom development in the plant and result in reduced efficiency of vector transmission (Sinha and Peterson, 1972), practical disease control in annual crops remains a problem of vector control. When this study was initiated only the contact insecticides, carbaryl and malathion were recommended for aster leafhopper control in vegetable crops in Manitoba. Even with a diligent spray program involving frequent applications, a high disease incidence could occur (Henne 1970). Persistent insecticides, especially those which move systemically through the plant offer more hope for disease control. As well, systemics offer savings in time, material and labour; protect the crop in the critical early stages of growth; and, reduce the hazards of environmental contamination. A number of studies have reported systemic insecticidal control of the aster leafhopper on carrots(Chiykowski 1958; Thompson 1965) and lettuce (Chiykowski 1958; Thompson and Rawlins 1961; Thompson 1964, 1965, 1967; Richardson and Westdal 1964;

Rawlins and Gonzalez 1966). A limited amount of information is available regarding the control of aster yellows in carrots (Henne 1970) and celery in Manitoba.

The objectives of this study were:

(1) To determine the efficacy of a number of granular and foliar systemic insecticides for aster leafhopper and aster yellows control in carrots and celery;

(2) To compare the relative efficiency of granular systemics applied at planting, with standard contact spray programs;

(3) To monitor levels of the granular systemic insecticide aldicarb in carrot roots and foliage during the season and at harvest;

(4) To monitor uptake, translocation, degradation and elimination of ^{14}C-aldicarb from carrot roots and leaves; and,

(5) To develop a bioassay with respect to leafhopper mortality from, and disease transmission to, aldicarb treated carrots.

LITERATURE REVIEW

Introduction

A basic knowledge of the factors affecting the epidemiology of a plant disease is a prerequisite to the design of an effective control program. The purpose of this review is to summarize those factors affecting the incidence and spread of aster yellows disease. The interactive contributions of the vector, causal organism, host and environment are discussed with respect to possibilities for insecticidal control of the vector and reduction of disease incidence.

The arthropod-borne plant viruses are among the most economically important and most widely distributed disease agents in the world (Maramorosch 1963). Typically,but not exclusively, the vectors of any one virus disease are limited to one of the major taxa (Black 1959). Of the many vectors of plant viruses, the Homopterous insects, including the aphids and leafhoppers are of primary importance.

The Aphidae is the largest group of insect vectors from the standpoint both of numbers of viruses, as well as species of aphids involved (Carter 1973). Second in importance are the leafhopper transmitted plant viruses. In fact,the first plant virus shown to be insect transmitted was one transmitted by a leafhopper. This disease,called rice dwarf,was first noted in

Japan in 1883 (Fukushi 1969). Since that time,numerous other virus diseases have been found to be leafhopper vectored until today when more than 120 species of leafhoppers are implicated in plant virus transmission (Nielsen 1968, 1979).

In addition to group specificity in the transmission of a virus disease,two other broad generalizations occur with respect to aphid and leafhopper vectors. Whereas mosaic type diseases are associated with the former, the general categorization of "yellows" diseases has been attributed to leafhopper vectors (Bennett 1967). Yellows diseases typically result in a disturbance to the vascular system, primarily the phloem and result in yellowing, dwarfing, streaking, curling, rosette formation or a proliferation of axillary growth, but rarely induce mottling. Secondly,leafhopper transmitted viruses are, with one exception, characterized by persistence in the insect and in many cases are propagative. The tungro disease of rice transmitted by Nephotettix impicticeps Ish. is non-persistent (Ling 1966). In addition,leafhopper transmitted viruses are not readily juice transmissable nor are they seed transmitted (Frazier and Posnette 1957).

Many widely distributed diseases of economic importance to a number of food, forage and horticultural crops are included in the "yellows" group (Maramorsch et. al. 1970, Whitcomb and Davis 1970). Characteristic symptoms,in addition to the above, include: abnormalities to flower parts including virescence and phyllody, vein clearing, chlorosis, reduction in leaf lamina and

secondary shoot formation. Sterility is often induced. Crop quality may be particularly affected as with the formation of stunted twisted petioles in celery or the formation of stunted "woody" carrots with excessive adventitious root growth (Davis and Gordon 1977). In the latter cases, the plant is also predisposed to secondary rot organisms.

Much of the accumulated evidence, from over fifty years of research, indicated a viral etiology for many of the yellows-type diseases. Factors considered included: transmission of the disease by leafhoppers, grafting and dodder, filterability of the infectious agent, interference of strains, sensitivity to heat treatment, resistance to penicillin and the absence of other causal organisms (Maramorosch et. al. 1968).

However, attempts to isolate, purify and characterize the infectious agent met with considerable difficulties. Since the AY agent passed through bacterial filters with difficulty and sedimented rapidly at low centrifugal speeds, Black (1943) suggested that the agent must be large. Lee and Chiykowski (1963) using homogenates of infectious leafhoppers recovered fractions containing the infectious agent by differential centrifugation. However, infectivity appeared in the low and high speed supernatant fractions, and they were unable to concentrate or determine the size of the agent. Purification attempts by Steere (1967) using differential centrifugation and agar gel filtration were also unsuccessful. As well, attempts to identify virus particles by electron microscopy met with

failure (Maramorosch et. al. 1968).

In 1967, electron micrographs of phloem cells of plants infected with mulberry dwarf disease revealed the presence of pleomorphic bodies which were interpreted as being "mycoplasma-like" organisms (Doi et. al. 1967). The observed bodies were bound by a single unit membrane, devoid of a cell wall and were highly pleomorphic. The presence of similar structures in plants infected with Japanese aster yellows, potato witches' broom, and Paulownia witches'-broom provided support that the causal organism was in fact non-viral in nature. In a concurrent report, Ishie et. al. (1967) demonstrated a partial remission of symptoms in dwarfed mulberries treated with tetracycline antibiotics. Subsequently, similar pleomorphic bodies were described in plants infected with several other yellows diseases, and in their insect vectors (Hirumi and Maramorosch 1969). These earlier reports have been reviewed by Maramorosch et. al. (1970) and Whitcomb and Davis (1970).

The list of plant diseases, previously thought to be viral in nature but subsequently associated with a "mycoplasma-like" organism, grew rapidly. In 1973, Carter (1973) listed 63 plant diseases for which mycoplasma-like organisms had been shown to occur in infected plant tissue. Today, however, pathogenicity as defined by Koch's postulates has been demonstrated only for the corn stunt (Chen and Liao 1975; Williamson and Whitcomb 1975) and citrus stubborn diseases (Cole et. al.

1973; Daniels et. al. 1973). Helical, mycoplasma-like organisms known as spiroplasmas were found to be the causal agents of these yellow-type diseases. Although a spiroplasma has also been suggested as the causal agent of aster yellows, pathogenicity has not been positively confirmed (Kaloostian et. al. 1979). Despite the uncertain etiology of aster yellows, however, much of the past research on the disease remains valid and should not be affected by the indication of a mycoplasma-like organism as the causal agent (Hampton 1972).

A number of reviews have been published regarding mycoplasmas, spiroplasmas and rickettsia-like organisms as plant pathogens (Maramorosch et. al. 1970; Whitcomb and Davis 1970; Davis and Whitcomb 1971; Hampton 1972; Maramorosch 1974; Nienhaus and Sikora 1979; Whitcomb 1980).

Aster Yellows

Aster yellows as a disease of plants in North America has been known since the early 1900's when Smith (1902) described it as a destructive disease of asters in Massachusetts. Since no causal organism could be found he suggested that the disease was due to a virus.

Much of the early developmental research on aster yellows (AY) was carried out by Kunkel (1926) who demonstrated that the disease could be transmitted by grafting but was not mechanically transmissable. As well, he showed aster yellows disease to be the result of an infectious agent that was transmitted by a leafhopper, Macrosteles fascifrons Stål (Kunkel

1924). After an acquisition feeding period on diseased plants, a latent period of about 9 days was required before leafhoppers become transmitters. This latent period, corresponding approximately in length to the incubation period in the plant required for symptom expression, suggested to Kunkel that the disease agent multiplied in both the vector and the host. This conjecture was further supported by the fact that heat treatment of leafhoppers (36°C) and plants (44°C) permanently cured the host of aster yellows, while lower temperatures delayed subsequent transmission or symptom development (Kunkel 1937, 1941, 1943).

The first bioassay technique was developed by Black (1940), who was successful in mechanically transmitting the disease agent to leafhoppers by needle inoculation. Filtration experiments showed that passage through bacterial filters occurred only with difficulty and was accompanied by the passage of unidentified bacteria. Infectivity was associated with a large sized agent which was labile and presumed to form aggregates. The inoculation technique was used by Black (1941) to demonstrate multiplication of the causal organism in leafhoppers.

It remained for Maramorosch (1952) to conclusively show, by serial passage of the infectious agent through 10 groups of insects, that multiplication did in fact occur. Dilution over the 10 passages was 10^{-40}, but measured concentrations at the final passage equalled that of the first. He concluded that multiplication of the pathogen adequately explained the latent

period and retention of infectivity for life.

Moreover the length of the incubation period varied with the dosage of the inoculum. It was subsequently shown that the length of the latent period in the plant, as well as in the vector, is a function of dosage (Maramorosch 1953). Due to rapid multiplication during the logarithmic phase, this dosage effect was less noticable in the plant than in the insect. As well, Kunkel (1954) has shown that length of acquisition feeds only slightly affects future transmission.

More recently, Sinha and Chiykowski (1967) used the injection technique to transfer the disease agent, from different organs of infectious leafhoppers at various times after acquisition, to test leafhoppers. They concluded that the alimentary canal was the initial site of multiplication and that the hemocytes were the main sites of multiplication of the causal organism.

In comparing the distribution of a CAYA strain in various organs of Macrosteles fascifrons, an efficient vector, with distribution in Athysanus argentarius a less efficient vector, Chiykowski (1979) concluded that multiplication must occur in the salivary glands and a certain threshold level must be attained before transmission can occur. The low efficiency of transmission by A. argentarius was attributed to recovery of only low concentrations of the causal agent from the salivary glands.

The aster yellows agent is thus propagative and circulative in the aster leafhopper. These terms are not mutually exclusive

and propagative transmission is considered to be a form of circulative transmission (Maramorosch 1964). On the basis of overt symptomatology, Maramorosch (1952) initially suggested that the yellows agent was better adapted to its vector than to its host. In a subsequent study, however, cytological effects upon the fat bodies were observed. The effect was most pronounced in male leafhoppers infected with an eastern aster yellows strain (Littau and Maramorosch 1960).

Kunkel (1953) also elucidated the uniquely wide host range of aster yellows. At that time ,at least 300 species in 48 families were known to be susceptible to aster yellows. Today more than 350 species in 54 families have been recorded as hosts of the aster leafhopper and/or aster yellows (Peterson 1973).

For many years cereals were used to rear noninfectious or healthy leafhoppers. In 1960, however, Bantarri and Moore (1960) showed that barley was susceptible. It is now well established that barley (Chiykowski 1965); wheat, Triticum aestivum L. and T. durum (Chiykowski 1963, 1967; Richardson 1967); oats, Avena sativa L and Avena fatua L. (Westdal and Richardson 1969; Chiykowski and Wolynetz 1981); rye, Secale cereale L. and Triticale (Westdal and Richardson 1969) are susceptible to infection by aster yellows disease to varying degrees. The higher degree of susceptibility of oats to NCAY as opposed to CAYA has been demonstrated (Westdal 1969b; Chiykowski and Wolynetz 1981). As well, brome grass, Italian

rye grass and annual canary grass have been indicated as hosts of AY disease (Banttari 1966).

That more than one strain of AY exists was demonstrated by Kunkel (1932) in transmission trials with eastern AY and an AY isolate from California (Severin 1929) which infected zinnia and celery which were previously thought to be immune. In this and a subsequent trial (Severin 1934), celery was resistant to all isolates except those from California or Utah. Even though Kunkel (1955) demonstrated that zinnia and celery could be infected with eastern AY, by confining large numbers of infectious insects on young plants, celery has consistently been utilized as a differential host. AY isolates were correspondingly referred to as western or celery infecting (CAYA) and eastern or non-celery infecting (NCAY). Recently, Chiykowski (1978) reported a high infection rate (74%) of celery with an eastern AY strain and suggested that due to the delay in symptom expression (115.7 days vs 40.6 days for CAYA) the infection of celery has gone unnoticed.

Eastern and western strains can be distinguished, however, by symptom expression in several differential hosts including Nicotiana rustica L. and Zinnia elegans Jacq. Rosette formation is typical of infection by CAYA; whereas, NCAY is characterized by profuse axillary growth (Kunkel 1955). Furthermore NCAY is transmitted only by Macrosteles fascifrons Stål, whereas CAYA strains are transmitted by at least 31 species of leafhoppers including the aster leafhopper (Carter 1973). However, of the

vectors capable of transmitting CAYA, Macrosteles fascifrons has been shown to be the most efficient (Hirumi and Maramorosch 1963; Sinha and Chiykowski 1967). In addition, Aphrodes bicinctus and Athysanus argentarius have recently been shown to be vectors of CAYA in North America (Chiykowski 1977, 1979).

The ability to distinguish these aster yellows strains according to symptoms enabled Kunkel (1955) to demonstrate for the first time the cross-protection reaction in both host and vector. When one strain became established, leafhoppers were unable to acquire and transmit the second strain. The NCAY and CAYA strains completely protected against each other, indicating a close relationship between the two. Cross protection may not always be complete, however, and depends on the strains and combinations tested (Freitag 1958; Maramorosch 1958). As well, the dual transmission of a "mycoplasma-like" organism (AY) and a virus (OBDV) has been demonstrated (Hsu and Banttari 1979).

During his studies on thermolability of the AY agent, Kunkel (1937) isolated several mild or attenuated strains of aster yellows. Various degrees in severity of infection occurred on test plants; however, no correlation between length of heat treatment and mildness of strains was shown. Reversion to the parent strain did not occur in subsequent transmissions. Although the incubation period in the insect was not affected, incubation periods in plants infected with mild strains were slightly longer.

Following Kunkel's observation of variants resulting from heat treatments, the widespread occurrence of natural strains of aster yellows was reported (Freitag 1969; Richardson 1967; Granados and Chapman 1968; Westdal 1969b; Westdal and Richardson 1969; Gill et. al. 1969). Mutant forms, with properties favouring persistence and/or spread, may significantly affect disease epidemiology (Bennett 1967).

Epidemiology and Control

The incidence and severity of aster yellows in Manitoba varies from year to year and may cause severe losses in many vegetable and field crops. In most years, aster yellows is the limiting factor in the production of lettuce (Richardson and Westdal 1963). Following an epidemic of the disease in 1957, Westdal and Richardson (1966), compared the yields of susceptible crops in that year, to the average yields over a 30 year period. Estimated yield reductions, representing a crop value of $167,000,000, were 14% in rapeseed, potatoes and buckwheat; 25 to 34% in barley and sunflowers, respectively and 55% in flax. The yield for crops resistant or immune to AY was near the 30 year mean.

The first instance of actual feeding injury resulting in destruction of some susceptible crops was recorded in 1963 (Westdal and Richardson 1963). The aster leafhopper population reached a peak of 3,000 - 4,000/100 sweeps as monitored by sweep net counts. The incidence of AY disease in carrots and celery was 33% and in lettuce was near 100%.

The incidence of aster yellows infection in barley (6.5%) in 1966 was the highest on record for commercial barley fields in Manitoba (Gill and Westdal 1966). Westdal and Richardson (1971) have demonstrated the relation between percentage of sterile heads and yield loss in barley. They estimated that appreciable yield loss could result from a low level of head infection (5%).

Under somewhat similar conditions in Wisconsin, AY disease is often the limiting factor in the production of lettuce and celery. Disease levels of 95% in carrots and 75% in potatoes have been reported (Chapman 1959).

Annual fluctuations in AY disease incidence in Manitoba, as in Wisconsin, may be attributed to a large extent, to the biology and ecology of the aster leafhopper. Macrosteles fascifrons has a wide geographical range through different life zones extending from Mexico and Puerto Rico to Alaska (DeLong 1971). The adult does not normally overwinter in the northern United States. Although both eggs and adults may overwinter in the southern United States, in Manitoba Macrosteles fascifrons overwinters in the egg stage only (Westdal et. al. 1961). Nymphs after hatching normally pass through five instar stages. Under Canadian conditions, the adults have a life expectancy of 30 to 50 days during the growing season (Miller and Delyzer 1960). Further, the epidemiology of AY disease is complicated by: the degree of local and long distance movement of the vector, the seasonal sequence of plant host selection, the

many different strains of the pathogen that occur and the very wide plant host range of both the pathogen and the vector.

Of primary importance is the fact that in central North America, the aster leafhopper migrates long distances northward from breeding grounds in northwestern Louisiana and northeastern Texas. Feeding on successively emerging cereal crops, the migration proceeds through Kansas and Missouri into Wisconsin, the Dakotas and Manitoba (Chiykowski and Chapman 1965; Drake and Chapman 1965). Since the egg is the only overwintering stage in Manitoba, migrants are the first leafhoppers to appear and are the primary source of disease inoculum (Westdal et. al. 1961; Gill and Westdal 1967). Migrant influxes are dependent on wind direction, time of movement, and temperature. Few leafhoppers take flight below 15°C (Chapman 1959). Thus adults generally begin to arrive in Manitoba on strong south winds from mid-May until early June. With ideal conditions, four generations may occur during a season but since these overlap, distinct broods are not apparent. The percentage of infectious adults often declines in July and August as the local population increases (Westdal et. al. 1961).

Host plant preferences of the aster leafhopper have been discussed by DeLong (1971) and Peterson (1973). Winter cereal crops, bromegrass, bluegrass, quackgrass and timothy provide sites for overwintering eggs and serve as early spring hosts for leafhopper migrants. Small grains, including oats, rye, barley and wheat are also important breeding hosts during the early-

summer. As cereal crops mature, a shift in hosts to lettuce, parsley, carrot, celery and flax may occur. Certain host plants, such as potato, tomato and onion, are used for feeding but are not considered favourable for breeding. As well, AY diseased plants have been shown to be more suitable breeding hosts than healthy plants (Severin 1946). Within the vegetable crops, lettuce, carrots, celery and potato have decreasing orders of susceptibility (Shultz 1973). Information on the genetics of resistance to AY in carrot and celery is limited and breeding programs offer limited potential for the development of resistant cultivars.

Reference has been made to a number of naturally occurring strains of the AY pathogen. A consideration of these strains is necessary to account for the variation in crop damage which often occurs.

In Manitoba, three distinct strains of the AY pathogen, two celery infecting and one non-celery infecting were isolated by Richardson (1967). These strains were differentiated on the basis of symptoms in aster and wild tobacco and differential transmission to 13 hosts. One celery infecting strain was similar to one isolated by Granados (1965) in Wisconsin. Since the vectors in Manitoba and Wisconsin may have a common source, a similar strain complex in the two regions was suggested.

Also, Westdal (1969a) isolated the AY pathogen from 67 of 72 barley plants exhibiting typical "yellows" symptoms. Forty-four percent of these were celery infecting. On the basis of

symptom expression the isolates were divided into 8 groups and three were chosen for further characterization. Two isolates, S-14 and S-15 were of the "eastern type" but infected oats (50%) and wheat (40%). The third strain, S-72, was celery infecting and infected oats only to a small degree (4%). Further isolations in 1968 showed common wheat, oats and rye among other hosts to be susceptible to three of six strains which were characterized. The strains that infected cereals were non-celery infecting; whereas, those that did not infect cereals were celery infecting. Prior to the report of Banttari and Moore (1960), however, members of the Gramineae were thought to be immune to infection by AY disease. Subsequent attempts by Westdal (1969) to infect oats with celery or non-celery infecting strains maintained in the greenhouse for several years, were unsuccessful. Furthermore, an increased incidence of celery yellows, beginning in 1953 was noted in Wisconsin (Chiykowski 1958) and in Manitoba (Sackston 1959). Apparently, a change in the strain complex resulted in a change in the host range of AY disease.

The design of an effective control program for aster yellows disease is thus complicated primarily by the long distance migration of the aster leafhopper. Of the control measures described by Broadbent (1969), those with most potential in this circumstance include:timed plantings, and chemical control of the vector in combination with forecasts of migrant influxes and disease severity.

Since plants are most susceptible in the seedling stage, early planting prior to migrant influxes, offers some potential for disease control. Plant age at infection has been demonstrated by Hao (1970) as being more critical than vector numbers. In Manitoba, early maturing crops generally escape severe aster yellows infection; whereas, a high incidence may occur in later crops (Westdal 1961).

Higher plant populations, accomplished by higher seeding rates and decreased row widths, have been shown to decrease the incidence of virus infection in sugar beets, when the virus was introduced from outside the crop (Hull, 1965). However, in the case of AY, this may not be true. In Wisconsin, leafhoppers have been reported as congregating in areas of dense stands and greater growth, especially in spring grain fields (Chapman 1973).

Several weed species have been shown to be a source of the aster yellows pathogen in Manitoba (Westdal 1961). These include stinkweed (Thlaspi arvense L.), flixweed (Descurainia sophia (L.) Webb) and groundsel (Senecia vulgaris L). However, under conditions of migrant influxes, the control of weeds in close proximity to susceptible crops has little potential for control (Duffus 1971).

Antibiotics have also been evaluated as a control measure since Ishiie (1967) demonstrated the remission of symptoms in infected mulberry plants. Treatment with achromycin and aureomycin was shown by Freitag and Smith (1969) to result in a remission of symptoms of three AY strains in aster, plantain and

celery. As well, transmission rates of leafhoppers were reduced after feeding on treated plants.

Oxytetracycline, tetracycline and doxycline, as foliar sprays, resulted in a suppression of AY and clover phyllody symptoms in aster but the plants were not cured (Chiykowski 1972). In a series of experiments, Sinha and Peterson (1972) showed that oxytetracycline was absorbed from solution by the roots of aster plants, thus resulting in a remission of clover phyllody symptoms. Antibiotic was not detected in the plant following foliar sprays or application to the soil. As well, healthy asters did not become infected when subjected to root treatment immediately before or soon after inoculation. As the interval between inoculation and treatment was increased, the eventual number of diseased plants increased. Until more effective treatments are developed, the use of antibiotics to reduce AY disease incidence in annual field crops is impractical.

Elimination of the vector by use of insecticides, thus remains as the basis for reducing the incidence of aster yellows in commercial carrot and celery fields in Manitoba. Since elimination of the vector at the source is impractical, forecasts of leafhopper influxes and predictions of levels of infectivity, together with early crop planting where possible, are also elements of an effective control program.

In Wisconsin, the severity of AY disease in a particular year may be predicted by the use of previous knowledge on

general migration patterns and early spring movements of the aster leafhopper. Leafhopper surveys across the migration path, to determine the magnitude of the migrant population and the percentage of infectious adults, followed by recommendations to growers regarding timing of sprays, have been effective in reducing AY incidence (Chapman 1956).

On the other hand in Manitoba, Henne (1969) concluded that frequent insecticidal applications of contact materials were necessary to protect carrots from AY. Even with a diligent spray program disease incidence could be high.

The problem of reducing non-vector populations to non-injurious levels is simple (Eskafi, F.M. and Van Schoonhoven 1981) as compared to the prevention of disease spread by vectors. Further, insecticidal applications to control vectors of a stylet-borne virus are not expected to reduce disease incidence to the same extent as is possible with a persistently borne virus (Burt 1960).

The pertinent factors with respect to incidence and spread of AY in carrots and celery in Manitoba include: crop susceptibility to strains of the disease present, migrant entry when the crop is in the seedling stage, an efficient vector with a short inoculation threshold for transmission (Lee 1961), and influxes of migrants, a certain percentage of which are already persistently infectious. Furthermore, the actual numbers of insects are less important than the percentage of infectious insects and their degree of mobility (Chapman 1959). Thus,

to maximize disease control, insecticides are best applied prior to entry, and activity or knockdown must be rapid. (Chiykowski and Chapman 1958, Chapman 1959).

Systemic insecticides applied to the soil, have shown promise in reducing the incidence of plant diseases transmitted by leafhoppers. Of seven granular systemic insecticides applied in-furrow to corn at planting (Bhirud and Pitre, 1972) carbofuran was the most effective for control of Dalbulus maidus followed, in order of efficacy by aldicarb, phorate, disulfoton and fenthion. Insect control was reflected in subsequent reductions in the incidence of corn stunt disease. Maximum reductions of 80% were attained with carbofuran.

The epidemiology of maize streak disease in relation to population densities of Cicaduline spp. has been studied by Rose (1974). With low numbers of migrants, disease incidence increased arithmetically over time, while large populations resulted in an exponential increase in disease incidence. In-furrow treatments of aldicarb with the seed effectively protected the crop from maize streak infection.

In a trial to evaluate insecticidal control of the aster leafhopper in carrots in Manitoba, Henne (1969) found carbofuran, as an in-furrow treatment, equivalent to 6-8 sprays of carbaryl in reducing carrot yellows. Although carbaryl and oxydemeton foliar applications provided the best control of the aster leafhopper, these treatments did not result in the lowest disease incidence. Carbofuran, applied as a foliar spray was

ineffective in control of aster leafhoppers.

With respect to lettuce yellows in Manitoba, Richardson and Westdal (1964) reported malathion as being more effective than phorate for leafhopper control, but less effective in preventing aster yellows infection. In a second trial, although some treatments partially protected the spring lettuce crop from infection, all treatments were ineffective in protecting the summer crop.

The incidence of sterile heads in barley, due to AY infection, has been correlated with barley yield reductions by Westdal and Richardson (1972). Further, those treatments providing reasonably good leafhopper control during the seedling stage of growth resulted in disease control and yield increases nearly equivalent to treatments with a longer duration of control. Thus the importance of seedling protection was demonstrated.

Eckenrode (1973) compared a number of foliar applications for duration of control of local populations of the aster leafhopper, in New York State. Carbofuran effectively reduced the leafhopper populations for a period in excess of 10 days. Carbaryl was slightly more effective than methoxychlor, one week after application.

To determine length of effectiveness, in relation to application interval, Shultz (1976) applied weekly and bi-weekly sprays of carbofuran, methomyl and malathion to carrots. For control of the aster leafhopper, 1 kg/ha ai weekly or 2 kg bi-weekly of carbofuran or methomyl were equivalent to or better than 2 kg/ha ai of standard malathion applied weekly.

MATERIALS AND METHODS

This section includes a description of the methodology utilized in conducting field trials as well as laboratory and greenhouse studies. In addition to monitoring several characteristics of the migrant aster leafhopper population, field studies included replicated insecticide trials and a survey of the leafhopper population and aster yellows disease incidence in local carrot and celery fields. Laboratory and greenhouse studies included an analysis of aldicarb residues in carrot leaves and roots by gas chromatography. As well ^{14}C-aldicarb was utilized to study uptake, translocation, degradation and persistence of this compound in carrots and to calculate an LC_{50} for aldicarb in carrot leaves in relation to aster leafhopper mortality.

Field Studies

Insecticide Trials

At Portage La Prairie, Manitoba, field trials were conducted from 1970 to 1972 to determine the effect of several insecticidal treatments on the aster leafhopper population, aster yellows incidence and yield in carrots and celery. The site utilized for the plots consisted of a clay loam soil (pH 6.5), and 5% organic matter. The plots were irrigated as required to provide approximately 1.25 cm of water

per week. A randomized complete block design with four replications was utilized for each crop. To minimize the effect of leafhopper mobility relatively large plots were utilized with a buffer zone between areas of data collection. Carrots, cultivar "Danvers 126" were sown in plots 5.4 m x 30.5 m. Each plot consisted of three beds (1.8 m wide) with four rows of carrots per bed. Plant spacing was 4-5 cm. Celery, cultivar "Tall Utah 52-70R" was transplanted into plots 5.4m x 9.1m consisting of three beds (1.8m) with 3 rows of celery per bed. Plant spacing was 15 cm. Since the celery transplants were imported from California a random sample was grown in the greenhouse and aster yellows incidence was found to be less than 0.5%. All data were collected from the centre bed of each plot thus allowing for a 3.6 m buffer zone between plots.

The following insecticides were evaluated.

Granular systemic formulations: aldicarb (Temik 10G), 2-methyl-2-(methylthio) propionaldehyde o-(methylcarbamoyl) oxime; carbofuran (Furadan 10G), 2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate; disulfoton (Di-Syston 15G), 0,0-diethyl S-[2-(ethylthio) ethyl] phosophorodithioate; phorate (Thimet 10G), 0-0-diethyl S-(ethylthio)methyl phosphorodithioate.

Foliar systemic formulation: oxydemeton-methyl (Meta-Systox R,2.4EC), 0,0-dimethyl S-[2-(ethylsulfinyl) ethyl] phosphorothioate.

Foliar contact formulations: carbaryl (Seven 50 WP),

1-naphthyl methyl carbamate; methoxychlor (Methoxychlor 50 WP), 1,1[1]-(2,2,2-trichloroethylidene) bis (4-methoxybenzene).

Carrots were seeded and granular insecticide formulations were applied with a seeder/granular applicator unit comprised of four Planet Jr. seeders and four cone seeders. The cone seeders were used to apply a measured amount of insecticide evenly to each row of each plot. Thus the seed and insecticide were simultaneously placed at a depth of 1.25-1.5 cm. in a furrow approximately 3 cm wide opened by a double disc and closed with a packing wheel.

For the celery trials the cone seeder units were utilized to apply the granular treatments in three bands per plot as described above but at a depth of 5.0 cm. Celery seedlings were transplanted into the bands immediately after application.

Foliar insecticide treatments were applied with a boom sprayer equipped with conical nozzles in a volume of 842 L of water per hectare at a pressure of 2450 KPa. Treatments were commenced when leafhoppers were first detected in the field, and were subsequently applied on a 7 to 10 day schedule.

Except for the insecticide treatments, standard crop production practices were followed for all trials. Maintenance fungicide, herbicide and fertilizer treatments are listed in Table 37, (Appendix) along with dates of planting, harvest, insecticide application etc.

A relative measure of the number of aster leafhoppers

present in each plot was obtained by regular sweeping with an insect net (30 cm diam.). Fifty and 25 sweeps/plot were utilized for the carrot and celery trials, respectively. Population counts were taken just prior to foliar insecticide applications, on a calm day and preferably when the previous day had also been calm.

The incidence of aster yellows disease in the plots was monitored at mid-season and at harvest and expressed as a percentage of plants infected per total number of plants examined. For celery, all plants in the centre bed of the plot were examined (ca. 150 plants). For carrots, 300 plants/plot (50 consecutive plants at six random locations in the centre bed) were evaluated for foliage symptoms at mid-season. At harvest aster yellows incidence and yield data were derived from the entire center bed in celery plots and by harvesting two centre rows of carrots, 6 m long, at two random locations in the plot.

Field Surveys: Migrant Leafhopper Population and Disease Incidence

In conjunction with field insecticide trials several characteristics of the migrant aster leafhopper population were monitored in the vicinity of Portage La Prairie. These included, dates of first arrival and major influxes, date of appearance of nymphs and percentage of infectious leafhoppers. This was accomplished by sweeping headlands and ditchbanks in close proximity to the trial area as well

as sweeping fields of winter cereals (predominantly fall rye) in the vicinity of Portage La Prairie. The infectivity level of the leafhopper population was determined by Agriculture Canada personnel in Winnipeg using aster as an indicator plant.

In addition, the leafhopper population and aster yellows incidence in several local commercial carrot and celery fields was monitored during the summers that insecticide trials were conducted. Aster leafhopper population levels were determined at these locations by taking sweep net counts (several hundred per site) on a weekly basis. As well, in two of the three years that surveys were conducted sticky board traps were located in the fields in the area that sweeps were taken. The traps were 22 x 20 x 2 cm plywood, painted bright yellow, divided into quadrants, coated with a sticky material (Tack Trap) and mounted in the field at the height of the crop. Leafhopper counts were taken weekly on a per trap (8 traps per site) basis prior to cleaning and replacement of the adhesive. Aster yellows incidence was determined according to foliage symptoms at mid-season and according to leaf and root symptoms at harvest. Insecticidal sprays and dates of application are indicated in the appropriate Results tables.

Field Evaluation of Aldicarb 10G

One trial was initiated in 1973 at the University of Manitoba field plot site to determine crop tolerance, aster

yellows incidence and yield of carrots treated with aldicarb 10G at 1.68, 3.36, 5.04 and 6.72 kg/ha ai. This site consisted of a clay loam soil with a pH of 7.1 and an organic matter content of 5 %.

A randomized complete block design with six replications was utilized for this trial. Each plot (1.8 m x 9.1 m) consisted of four rows of carrots 35 cm apart with plants thinned to ca. 3.5 cm apart within the row. A four row V-belt seeder unit was utilized to apply aldicarb in a 5 cm band slightly below the seed (cv. "Danvers 126") which was also planted with the V-belt seeder at a depth of 1.25 - 1.50 cm.

The trial was initiated on May 9 and harvested September 16. One center row of each plot was harvested for yield data. As well,the incidence of aster yellows infection was noted and symptoms classified as slight (rootlet hair growth stimulated but easily sloughed off), moderate (rootlet hair growth heavy but root size and development normal), and severe (heavy rootlet hair growth and retarded root development often with secondary rot organisms present).

From the remaining rows in the plot,samples were collected for residue analysis. Leaf samples (50 gm) were randomly collected from at least 25 plants/plot on June 28, July 8 and 17, August 1 and 16. Carrot roots (at least 20/plot) were harvested on July 17, August 1, 16, 28 and September 16. Root samples were thoroughly washed, diced without peeling and a 50 g sample reserved. All samples were

packaged in polyethylene bags and stored in a freezer (-10 °C) for subsequent analysis.

Laboratory and Greenhouse Studies

Analysis of Aldicarb Residues in Carrot Leaf and Root Samples

Residue levels of aldicarb in carrot leaf and root tissue sampled at various times from the aldicarb rate trial were determined by gas chromatography. With some modification, a method developed by Union Carbide Corporation was utilized for the analysis (Anon, 1973). The procedure is applicable for determination of total toxic aldicarb residues consisting of aldicarb and the major metabolites aldicarb sulfoxide and aldicarb sulfone. The nontoxic oxime and nitrile metabolites of aldicarb as well as the further degraded metabolites are removed by a cleanup procedure to avoid interference. The specificity of the method has been tested against most of the presently registered sulfur containing pesticides and none have been found to interfere.

Apparatus. A Varian 1400 gas chromatograph equipped with a Tracor flame-photometric detector (1440-10) with a 394 nm filter selective for sulfur containing compounds was utilized. A teflon column (32 mm O.D.), 130 cm long and packed with 3% EGSS-X on Gas Chrom Q (80/100 mesh) was used. An 8 cm section of stainless steel tubing lightly packed with glass wool was attached to the oven injection port and extended about 2.5 cm into the oven to serve as heat insula-

tion for the column packing. The gas chromatograph conditions were as follows:

Injection port temperature, 300°C.

Column temperature, 140°C.

Carrier gas (nitrogen), 85 mL/min.

Detector gases - hydrogen (150 mL/min), oxygen (16 mL/min), air (100 mL/min).

Injections were made through a high temperature silicone-teflon lined 9.5 mm gas chromatographic septum (Pierce #13252).

Standard Curve. Aldicarb residues were extracted from the crops by blending the sample with a mixed solvent (acetone: water, 3:1). The aldicarb residues were oxidized to aldicarb sulfone by addition of peracetic acid to the extracting solvent. Following appropriate cleanup of the extract on a Florisil column, the pesticide residues were determined as aldicarb sulfone. The residue was quantitated by reference of the peak height to a previously prepared calibration curve derived from injection of aldicarb sulfone standard solutions.

Therefore, using technical grade aldicarb sulfone (99.0%), standard solutions in acetone ranging in concentration from 0.9 ug/mL to 18 ug/mL were made and utilized in developing standard curves. For a 3 uL injection, nanogram amounts of aldicarb sulfone per injection therefore ranged from 2.7 to 36.0 ng. A calibration curve was prepared daily

for each sample run and checked periodically with injections of standard.

Extraction Procedure. The following outline summarizes the referenced method of extraction (Anon, 1973).

Aldicarb residues were extracted from the plant samples with 3:1 acetone:water in a blender, and oxidized by the addition of 40% peracetic acid. Following vacuum filtration and washing of the filter cake the volume of the extract was measured and one-half retained for cleanup and quantitation of residues. The extract was stirred (15 min) in the original flask prior to adding 10% sodium bicarbonate and stirring (30 min) to neutralize residual acid.

The neutralized extract was transferred to a separatory funnel and extracted four times with chloroform. The extracts were combined by each time draining the chloroform layer through a bed of anhydrous granular sodium sulfate in a funnel into an Erlenmeger flask. The sodium sulfate bed was washed and allowed to drain. Using a vacuum manifold with the flask immersed in a 40 - 50°C water bath the extract was evaporated to a volume of 2 - 5 mL and subsequently to dryness or a slightly oily residue with a gentle stream of air.

A glass chromatography column (13 mm I.D.) was prepared by placing a cotton plug in the bottom and covering with 10 cm of Florisil (60/100 mesh, PR grade). The column was prewet with chloroform. The residue was then dissolved in

chloroform, poured on the Florisil column, eluted in rapid drops and the eluate discarded. Fraction I, containing aldicarb oximes and nitriles, which would interfere with subsequent quantitation of the carbamate residues, was eluted with 5% acetone in ethyl ether. Fraction II containing the carbamate residues was eluted with 50% acetone in ethyl ether and collected in an Erlenmeyer flask. With the flask in a 40 - 50°C water bath the solvent was evaporated with a gentle stream of air and the flask removed immediately after attaining dryness.

After chilling the flask in an ice bath, 1 ml of 0°C acetone was added. The flask was stoppered and swirled to dissolve all the residual pesticide. A 3 mL sample was injected into the chromatograph and the residue quantitated by reference of the peak height to a standard curve derived from injection of aldicarb sulfone standards. If necessary the sample was further diluted with a known volume of acetone to bring it on scale at the attenuation used to derive the standard curve. Sample calculation:

$$\frac{\text{ug aldicarb sulfone} \times D}{50 \times 0.5} = \text{ppm total toxic aldicarb residues expressed as aldicarb sulfone.}$$

Where D = mL of 0°C acetone, needed for final dilution of the sample for injection.

^{14}C-Aldicarb Studies in Carrots

The experiments utilizing radiolabeled aldicarb had

two objectives. Firstly to study the uptake, translocation, and degradation of aldicarb in carrots over time. And secondly to develop an LC_{50} in ppm of aldicarb (and toxic metabolites) in carrot leaves with respect to mortality of the aster leafhopper as a result of feeding on treated plants.

^{14}C-Aldicarb Standard Solutions. The ^{14}C-aldicarb utilized in the following experiments was S-methyl-^{14}C-aldicarb [2-methyl-2-(methyl-^{14}C-thio) propionaldehyde 0-(methylcarbamoyl) oxime]. A 26.8 mg sample (1.0 mCi) was obtained from the manufacturer (Union Carbide Inc.).

The labelled sample was dissolved in 100 mL of acetone to form a stock solution (268 ug/mL; 0.0373 uCi/ug). Subsequently by fortifying a volume of the stock solution with cold technical aldicarb, two standard solutions were made at concentrations of 125 and 500 ug/mL of aldicarb, each with a specific activity of 0.004 uCi/ug.

Determination of Radioactivity. Radioactivity was determined with a Nuclear Chicago liquid scintillation counter (Model 724) utilizing an external standard channels ratio system for quench correction. Organic extracts were counted in a solution of toluene containing 4 gm of 2,5-diphenyloxazole (PPO) and 50 mg of p-bis-2-(5-phenyloxazolyl) benzene (POPOP) per litre of solution. Aqueous extracts were counted in Aquasol. Ten milliliters of the scintillation mixture were employed per sample. Background and ^{14}C-standard vials were included at each counting.

Plant Raising, Dosing and Harvest. Carrots, cultivar "Danvers 126" were seeded in sand and at the cotyledon stage (first true leaf just emerging) were carefully removed and suspended in 1/4 strength complete nutrient solution (pH 6.7) in 1.1 L Mason jars wrapped with aluminum foil and aerated in the greenhouse. At the 3 - 4 true leaf stage uniform plants were selected, suspended in test tubes containing nutrient solution and preconditioned in a growth room for 24 hours under continuous light (2,000 ft. candles) at 22°C and 50% relative humidity.

The first experiment was designed to examine uptake, translocation and degradation of aldicarb over time with all plants receiving an equal dose at zero time. Following the preconditioning period all plants were transferred to test tubes containing 40 mL of 1/4 strength nutrient solution plus 450 ug of ^{14}C-aldicarb and were subsequently maintained in the growth room for a period of 12 hours. The plants were then removed from the treatment solution, the roots were rinsed and the plants returned to the greenhouse (1/2 strength nutrient solution). At the end of the treatment period i.e. 12 hours and at 1, 3, 7, 15, 30 and 45 days, seven plants were sampled as follows:

(a) One plant was separated into root and shoot and each part pressed with Kodak NS-54T no screen medical X-ray film in order to visualize by radioautography the distribution of radioactivity in the plant. The samples were frozen for the duration

of the exposure period.

(b) Three plants were placed in 10 cm pots and 30 - 40 leafhoppers were caged on the plants utilizing clear solid plastic cages. Leafhopper mortality was recorded at 24 and 48 hours.

(c) Three plants were separated into root and shoot, fresh weights recorded, and the parts frozen for subsequent analysis. One control plant was included at each sample date. Uptake of ^{14}C-aldicarb was determined by counting and subtracting the amount of radioactivity remaining in the treatment solution plus the amount in the rinse solution from the total amount originally placed in the treatment tubes.

For the second experiment (LD_{50} determination) plants were grown and preconditioned as above. Using leafhopper mortality in experiment 1 as a guide, plants were treated with a range of ^{14}C-aldicarb concentrations (0, 12.5, 50, 75, 100, 200, 300 and 500 ug/40 mL of nutrient solution). Thirteen plants per treatment were utilized; 10 for the bioassay and 3 for analysis. After the 12 hour exposure period the plants were planted in 10 cm pots and placed in the greenhouse. Mean uptake of ^{14}C-aldicarb for each treatment was determined as indicated above.

In the early morning on the fifth day after treatment and following a 12 hour starvation period, 15 - 20 infectious leafhoppers were caged on each plant. Mortality was

determined at 24 and 48 hours. The plants were subsequently maintained in the greenhouse for evaluation of disease incidence. Leafhoppers utilized in the bioassay were taken from a population of nymphs and young adults previously confined for one week on diseased aster and subsequently for 25 days on holding oats prior to the bioassay. The asters were infected with an eastern strain of AY disease.

Determination of ppm of aldicarb and toxic metabolites (aldicarb sulfoxide and aldicarb sulfone) was conducted by gas chromatography (previously described) of the three plants per treatment retained for analysis. The leaves were removed, fresh weights recorded and the samples frozen for analysis at initiation of the bioassay.

Extraction and Analysis. Root samples were analysed for total radioactivity as follows. After thawing at room temperature the roots were homogenized in a Wareing blender with 50% aqueous ethanol. For larger samples 5 - 10 mL/gm fresh weight was used while for smaller samples sufficient solvent to allow proper homogenization was utilized (ca 150 mL). The insoluble plant material was removed from the homogenate by filtration through Whatman No. 1 filter paper in a suction filter, reblended in a minimal amount of solvent and refiltered. After washing the plant residue twice with 50% ethanol, the volume was reduced under vacuum at 40°C sufficiently for counting. Two aliquots of 0.1 mL each were removed from each extract and successively counted for act-

ivity determinations (Andrawes et. al. 1971).

Leaf samples were extracted as indicated above for roots except the filtrate was concentrated to a viscous syrup. The residue was then taken up into 50 mL of water and following the addition of an equal volume of acetonitrile was extracted successively 5 times with chloroform (1 x 50 mL and 4 x 25 mL). The organic fraction was reduced to a volume of 10 mL. Total radioactivity in each phase, organic and aqueous, was determined as above (Bartley et. al. 1970).

Aster Yellows Transmission

One trial was conducted to assess transmission of aster yellows to carrots by the aster leafhopper as affected by length of feeding. A population of aster leafhoppers (nymphs and young adults) was raised on disease-free Rodney oats. A sufficient number of hoppers to conduct the trial was transferred to asters infected with an eastern strain of the AY pathogen and allowed an acquisition feeding period of 7 days. The leafhoppers were then transferred to healthy oats for a holding period of 18 days. Subsequently, single leafhoppers were caged on healthy aster (2 - 3 leaf stage) for a period of 48 hours following which the leafhoppers were serially transferred to carrots (2 - 3 leaf stage) for feeding periods of 1, 2, 4, 8, 12, 24, and 48 hours. Finally, the hoppers were serially transferred to flax. All plants were maintained in the greenhouse for a period of time sufficient for symptom development.

RESULTS AND DISCUSSION

The results of this thesis are presented and discussed in two main sections. The first includes the results of three years of field trials designed to evaluate several insecticide treatments for control of the aster leafhopper and aster yellows in carrots and celery. The results of surveys conducted to monitor the aster leafhopper population and disease incidence in commercial carrot and celery fields are also reported. The second section contains the results of laboratory and greenhouse studies conducted to determine

(a) The fate of aldicarb in carrots,

(b) Aldicarb leaf concentrations required for leafhopper mortality (LC_{50}, 24 and 48 hour), and

(c) The persistence of aldicarb in carrot leaves and roots as a result of granular treatments applied in-furrow at planting.

Field Studies

With respect to insect transmitted plant diseases, a thorough understanding of the pathogen-vector relationship is necessary before control measures can be established. Further, information regarding the identity and source of the pathogen and vector, host susceptibility and vector ecology and behaviour is essential. In addition, a knowledge of the

relationship between vector density and disease incidence is useful in forecasting crop injury and conducting control programs (Ling, 1972).

To briefly summarize, in Manitoba the primary aster leafhopper population results almost entirely from adults migrating into the area, beginning about mid-May, on warm air streams from the southern United States (Chiykowski and Chapman, 1965). Although some local weeds are a source of the aster yellows pathogen the migrants usually arrive with 1 to 5% of the population already being infectious. The non-migrant population results in part from overwintering eggs but mostly from eggs laid by migrants. From 2 to 4 overlapping generations normally occur in one season. The early migrants generally infest emerging fields of fall rye and subsequently move on to preferred hosts including other cereals, flax, lettuce, carrots and celery. The severity of the disease varies from year to year and may, as in 1957, 1963 and 1966 reach epidemic proportions (Westdal and Richardson, 1963; Gill and Westdal, 1966). As such, aster yellows disease may be the limiting factor in the production of lettuce and celery and can result in substantial yield reductions in carrots and other susceptible crops (Chapman, 1959; Westdal and Richardson, 1963, 1966). The actual incidence of aster yellows in any year is dependent on numerous factors. These include time and level of population influxes, percentage of infectious leafhoppers, strains present and environmental conditions.

Therefore,in the years that insecticide trials were conducted, it was of interest to monitor some of these variables. As part of a graduate course project a very preliminary investigation of strains present in carrots and celery was conducted. The findings are admitedly cursory and are included only to suggest a relatedness of the strains found, to those previously described as a result of more detailed studies. As a source of the pathogen, six infected carrot and three infected celery plants were collected from commercial fields at Portage La Prairie. Utilizing standard procedures the AY pathogen was transferred from the six carrots to aster and flax. In two transmission trials 89% and 74% of the aster indicator plants became infected. Symptom expression was similar on all diseased asters. In addition to typical symptoms of chlorosis and vein clearing, plants were moderately stunted but retained an upright growth habit. A "bushy" appearance resulted from the proliferation of chlorotic weak axillary shoots that are indicative of infection by eastern strains of AY (Kunkel, 1926; Granados and Chapman 1968). As well, one of the AY infected carrot hosts was also shown to be a carrier of oat blue dwarf virus. Forty percent of the flax test plants exposed to leafhoppers infected from this carrot exhibited symptoms of OBDV. Westdal(1969) first indicated carrot as a host of this disease.

As well, following suitable acquisition access and latent periods, leafhoppers from each celery host plant were transferred singly to aster. The AY pathogen was not transmitted

as readily from celery to aster as from carrot to aster. In two tests 30% and 35% of the indicator aster plants developed symptoms of AY. Furthermore,symptom expression in aster infected from celery was quite different from asters infected from carrot. Plants developed typical chlorotic symptoms but lacked the proliferation of axillary shoot growth. Extreme stunting occurred with new growth formed into a tight rosette, indicative of infection by a celery or "western" AY strain. Two further tests were conducted. Leafhoppers confined on six of the asters infected in the latter trial were transferred singly to oats and serially to celery. Subsequently ,celery plants infected in this test were used as hosts and leafhoppers transferred singly to oats and serially to aster and celery (Table 36, Appendix). The results of these tests suggested a similarity between the strain infecting celery and the S-72 isolate described by Westdal (1969), which was transmissable to celery (30%) but oats were infected only to a small degree (4%). He further elucidated the strain complex by characterizing 79 isolates collected from various plants in the field. Approximately half (44%) were of the CAY type.

In addition to the above results, and since the incidence and severity of aster yellows in Manitoba is directly related to the migrant leafhopper population, field surveys were conducted during the three year period of trials at Portage La Prairie. The variables monitored included, first date of aster leafhopper arrival, dates and size of major population influxes, date of appearance of nymphs and the percentage of infectious leafhoppers from early to mid-season (Table 1).

TABLE 1. Characteristics of the aster leafhopper population in the vicinity of Portage La Prairie, Manitoba for a 3 year period.

Variable	Year		
	1970	1971	1972
Date of arrival	May 5	May 7	May 19
Major influxes (#/100 sweeps)	June 4 (60/100) July 9 (300/100) August 7 (400/100)	July 6 (50/100)	July 7 (25/100) July 11 (100/100)
Appearance of nymphs	June 7	June 22	June 30
Infectious adults (%)	June 30, 4.5% July 22, 6.6%	May 27, 9.0% June 15, 5.5%	May 23, 10.0% June 1, 8.0% June 20, 3.0%

In 1970, aster leafhoppers first appeared about May 5, with population levels remaining low (1 to 5/100 sweeps) until strong south winds resulted in an influx of migrants on June 4 (20 to 100/100 sweeps). A further large influx of migrants occurred about July 9. This population along with the development of the local population (1st - 3rd instar nymphs detected June 7) resulted in high numbers of leafhoppers being present for the remainder of the season. Population samples collected for infectivity tests indicated a relatively consistent proportion of leafhoppers transmitting the aster yellows agent (4.5 - 6.6%).

In 1971, leafhoppers arrived at about the same time as in 1970 (May 7) but in larger numbers (15 to 40/100 sweeps) through May and June. This fact, together with the high percentage of the population (9.0%) which was capable of transmitting the AY agent in May, resulted in forecasts of epidemic levels of AY. However, cool, wet spring weather slowed leafhopper and pathogen development such that disease incidence did not reach expected levels. The appearance of nymphs was delayed (June 22) and the percentage of infectious adults declined to about 5% through June. Population levels remained relatively consistent throughout the season.

In 1972, the arrival of adults and the appearance of nymphs was delayed. Although the percentage of adults transmitting AY was initially high (8 - 10%), this level dropped rapidly to about 3% through June. Two major influxes occurred on July 7 and July 11. The late spring arrival and relatively

low early population levels resulted in predictions of a reduced incidence of AY in 1972.

In conjunction with the above surveys, the aster leafhopper population and AY incidence in commercial carrot and celery fields was monitored throughout the season over a three year period (Table 2, 3 and 4). Weekly sweep net counts (3 years) and sticky board traps (2 years) were utilized to survey the population. Aster yellows incidence in carrots was severe in 1970 (12 - 26%) and less so in 1971 (4.0 - 7.3%) and in 1972 (4.5 - 8.0%). Disease incidence in celery was about 8% in 1970 and 1971 but declined to 3.0% in 1972.

As expected variation is high between sites and between sweep net and trap counts within sites. This variation can be attributed to many factors including: timing of insecticidal applications, field size and location, adjacent crops, planting date and environmental conditions. It is not intended that specific conclusions be drawn as a result of the surveys: however, some general remarks can be made. For comparative purposes, Table 5 contains cumulative mean number of leafhoppers/100 sweeps/week and aster yellows (AY) incidence in control plots of carrots and celery insecticide trials conducted in the years of the surveys. Carrot Site 3 and Celery Site 1 were located within 0.5 km and 1.5 km respectively of the trial area while the remaining sites were at a distance of 8 to 10 km.

In 1970, a lack of concern or awareness on the part of the growers resulted in a minimal number of carbaryl applica-

TABLE 2. Aster leafhopper population and aster yellows incidence in commercial carrot and celery fields in the vicinity of Portage La Prairie, Manitoba, 1970.

Location		Mean number of leafhoppers per 100 sweeps[1] at each date											AY incidence (%)	
		25/6	4/7	9/7	16/7	22/7	28/7	$\bar{x}^2$	13/8	21/8	26/8	$\bar{x}^3$	leaf 28/7	root 10/9
Carrot site	1	30	19	103	115	129	105	83	210	150	85	105	2.3	12.0
	2	43	14	17	250	98	125	91	350	190	75	129	4.4	16.5
	3	88	25	19	200	131	240	117	560	210	80	173	17.8	26.0
Celery site	1	10	5	18	110	56	30	38	190	100	--	71	5.9	8.4 (leaf)

1. Mean of several hundred sweeps at each location. 2. Mean to 28/7. 3. Mean 25/6 to 26/8.

Note: Carbaryl (Seven WP) 1.7 kg/ha ai applied at Carrot Site 1, 19/6, 2/7, 14/7; Site 2, 6/7; Site 3, 6/7; and at Celery Site 1, 20/6, 3/7.

TABLE 3. Aster leafhopper population and aster yellows incidence in commercial carrot and celery fields in the vicinity of Portage La Prairie, Manitoba, 1971.

		Mean number of leafhoppers per 100 sweeps at each date													AY incidence (%)	
		24/6	2/7	9/7	16/7	23/7	30/7	$\bar{x}^1$	5/8	20/8	26/8	2/9	10/9	$\bar{x}^2$	$\bar{x}^3$	leaf 5/8	root 15/9
Carrot site	1	5	9	44	45	35	15	26	45	46	250	1000	250	318	176	2.3	4.0
	2	7	8	30	60	25	42	24	30	82	600	400	100	242	123	3.1	5.8
	3	4	7	35	20	14	22	17	26	200	110	1200	120	331	159	2.1	4.8
	4	8	12	50	45	20	40	29	35	100	750	1600	90	515	249	3.5	7.3
Celery site	1	6	4	21	14	10	24	13	12	35	60	150	11	54	31	4.0	7.5(leaf)

		Mean number of leafhoppers per trap[4] at each date														Insecticide treatment[5]
Carrot site	1	42	76	150	120	110	95	98	250	190	210	260	50	192	141	21/6 29/6 10/7 19/7
	2	45	47	172	38	100	70	79	50	100	150	70	20	78	87	28/6 5/7 12/7 20/7
	3	40	67	97	48	122	40	69	92	150	275	390	40	190	141	23/6 2/7 14/7 21/7
	4	63	53	98	68	35	60	84	190	200	300	700	130	304	184	25/6 3/7 12/7 22/7
Celery site	1	50	35	80	30	90	24	52	60	65	110	150	70	91	70	21/6 17/7

1. $\bar{x}$ to 30/7 2. $\bar{x}$ 5/8 to 10/9 3. $\bar{x}$ total 4. 10 traps per site 5. Carbaryl 1.7 kg/ha ai at each date

TABLE 4. Aster leafhopper population and aster yellows incidence in commercial carrot and celery fields in the vicinity of Portage La Prairie, Manitoba, 1972.

		Mean number of leafhoppers per 100 sweeps at each date													AY incidence (%)	
		29/6	6/7	12/7	20/7	27/7	$\bar{x}^1$	4/8	11/8	18/8	24/8	31/8	$\bar{x}^2$	$\bar{x}^3$	leaf	root
															4/8	15/9
Carrot site	1	20	28	65	35	55	41	130	225	275	156	50	167	104	3.0	6.5
	2	50	4	80	5	5	29	60	102	450	82	73	153	91	5.2	7.5
	3	4	1	160	90	90	52	400	350	610	90	67	303	178	4.8	8.0
	4	7	8	5	30	30	11	35	90	180	17	25	69	40	2.0	4.5
Celery site	1	3	0	7	4	5	4	5	14	20	6	8	11	8	1.5	3.0 (leaf)
		Mean number of leafhoppers per trap[4] at each date													Insecticide treatment[5]	
Carrot site	1	60	105	184	117	324	135	240	101	120	120	46	125	130	16/6	23/6 30/6 7/7 14/7
	2	115	106	167	119	102	107	50	70	98	159	161	108	108	24/6	1/7 7/7 15/7
	3	105	14	179	85	360	135	38	147	160	200	98	129	132	28/6	4/7 11/7 14/7
	4	54	18	61	49	136	63	58	34	80	330	82	117	90	22/6	28/6 5/7 12/7
Celery site	1	47	122	217	105	65	111	45	52	50	75	65	57	84	5/6	4/7

1. $\bar{x}$ to 27/7 2. $\bar{x}$ 4/8 to 31/8 3. $\bar{x}$ total 4. 10 traps per site 5. Carbaryl, 1.7 kg/ha ai at each date

TABLE 5. Leafhopper population and aster yellows incidence in control plots of celery and carrot aster yellows insecticide trials for a three year period.

Year	Celery					Carrot				
	$\bar{x}$ #/100 sweeps/week[1]			AY incidence, %		$\bar{x}$ #/100 sweeps/week			AY incidence, %	
	E	M	L[2]	M	L	E	M	L	M	L
1970	11	19	57	6.0	9.2	10	30	72	3.9	25.6
1971	13	14	25	5.7	13.1	33	39	83	5.0	13.1
1972	16	9	9	0.5	2.0	130	94	97	1.5	9.1

1. Cumulative mean number of leafhoppers per 100 sweeps per week = sum of the weekly means to each observation date - number of observation dates.

2. E = early season; M = mid-season; L - late season.

tions for aster leafhopper control. Generally the leafhopper population and disease incidence was high in carrots and somewhat less so in celery. Generally over the three years, population levels and disease incidence were less in celery as compared to carrots. This may be attributed to several factors including feeding preference, host susceptibility, strains present in the migrant population and size and location of fields. At carrot site 1, carbaryl was applied earlier and more frequently than at other carrot sites and also had a lower disease incidence. Over the three years, sweep net counts to mid-season appear to bear a relation with AY incidence at harvest, thus suggesting the importance of early control. Trap counts which were expected to result in a more accurate estimate of the weekly population tend to follow a similar pattern although this is not always the case. Environmental conditions when sweep counts were taken and timimg of influxes at each site are key factors affecting the relative numbers of leafhoppers indicated by sweeps net and trap counts. In 1971 and 1972, carbaryl applications in carrots were applied earlier and more frequently than in 1970 and AY incidence at harvest was less. However, AY severity in general was less in these years as compared to 1970. Although carbaryl applications appeared to offer some crop protection, spray programs as applied by the growers were considered to be inadequate (Tables 2, 3 and 4).

In general these conclusions support the statement of Henne (1970) that frequent applications of contact materials are necessary in order to minimize aster yellows incidence and that even with a diligent spray program disease incidence may often be high. At the time only malathion and carbaryl were recommended for aster leafhopper control in carrots and celery in Manitoba. Improved crop protection with these materials would be expected if spray application took place prior to a vector acquiring a persistently-borne disease agent or at least prior to completion of the required latent period. However, when infectious vectors, with the ability to infect a crop in a short time, migrate into the crop, a critical situation exists. In this case non-persistent contact insecticides offer only limited protection and spray applications must be timed with migrant influxes to be beneficial.

In the case of aster yellows in Manitoba the advent of systemic insecticides therefore offered increased possibilities for crop protection. Based on a number of prior studies, systemic control of aster leafhoppers on lettuce (Chiykowski 1958; Rawlins and Gonzalez 1966; Richardson and Westdal 1958; Thompson 1964, 1965, 1967; Thompson and Rawlins 1961), carrots (Thompson 1965; Henne 1970) and celery (Chiykowski and Chapman 1958) was achieved.

Due to the severity of the disease and lack of adequate control programs and due to the importance of carrots and celery to the local fresh market and processing industry a

project was initiated with the following objectives:

(1) To determine the efficacy of a number of soil applied granular and foliar applied systemic insecticides for aster leafhopper and aster yellows control in carrots and celery, and

(2) To compare the relative efficiency of granular and foliar systemics with standard contact spray programs.

It was of particular interest to examine the degree of disease reduction that could be obtained by utilizing a granular systemic insecticide at planting to effect control of a foliar feeding vector of a persistently borne pathogen that could be transmitted during short feeding periods.

The compounds selected for evaluation and applied as granular in-furrow treatments at planting included the carbamates aldicarb and carbofuran as well as the organophosphate compounds disulfoton and phorate. In addition oxydemeton-methyl,an organophosphate, and carbaryl,a carbamate as well as methoxychlor,were evaluated as foliar sprays.

Two insecticide trials were conducted in each of three years to evaluate the above compounds for control of the aster leafhopper and aster yellows disease in carrots and celery. For each trial the data are presented in three tables, supplemented with figures where appropriate to assist interpretation. Population data by treatment are listed as the mean number of leafhoppers per 100 sweeps at each observation date (4 replications). As well, in order to

evaluate each treatment over a longer period of time and to reduce the week to week variability in population counts the data are presented as a cumulative mean number of leafhoppers per 100 sweeps per week (i.e. the sum of the weekly means by treatment to each observation date ÷ the number of observation dates). Both weekly and cumulative means are considered together in interpretation of results, with caution being exercised with the cumulative means, since one week of high leafhopper counts may somewhat distort the cumulative mean for the remainder of the season. Weekly population data by replication are indicated in the Appendix. Where analysis of variance is reported for cumulative population data, the cumulative means by replication were determined for use in the analysis.

In the first celery trial, weekly aster leafhopper counts in control plots ranged from about 10/100 sweeps early in the season to about 150/100 sweeps in late August (Table 6). Over the same period the cumulative population mean rose from 11/100 to 57/100 sweeps (Table 7). Pertinent information regarding dates of application, planting etc. are included in Table 37 (Appendix). Granular (G) formulations were applied in-furrow and foliar sprays were commenced when leafhoppers were first detected in the plots by sweep net or sticky board traps. Weekly foliar applications were continued until late August to allow further comparisons of treatment effectiveness. Since the main effect of the aster leafhopper is disease transmission as opposed to

feeding injury,the time required for symptom development would preclude the necessity of commercial applications at this late stage.

With respect to the four granular treatments applied at planting,disulfoton G and phorate G provided aster leafhopper control on a weekly basis to about July 5 and on a cumulative basis,to July 9 (Tables 6 and 7). That is, control was short lived and of approximately 6 weeks duration. Aldicarb G and carbofuran G, however,were the most effective treatments in the trial with aldicarb G being more effective during weeks of high leafhopper counts. The weekly population data would indicate that carbofuran G provided leafhopper control to about July 16 - July 28 or about 8 weeks after application. Weekly populations in aldicarb G plots remained at less than 50% of control levels throughout the season (Table 6). In this trial,weekly populations late in the season resulting from aldicarb G and carbofuran G treatments are lower than one might expect as a result of granular applications at seeding. This effect is relatively consistent throughout the trials especially in weeks of high leafhopper counts and is more prevalent with aldicarb than with carbofuran G. The cumulative mean population levels as a result of granular in-furrow treatments compared with control are plotted in Figure 1 and show the short duration of control achieved with disulfoton G and phorate G and the extended activity of aldicarb G and carbofuran G.

Foliar applications of carbaryl and methoxychlor offer-

TABLE 6. Weekly populations of the aster leafhopper in celery as affected by various insecticide treatments, 1970.

Treatment	Rate kg/ha ai	Mean[1] number of leafhoppers/100 sweeps at each date[2]								
		26/6	5/7	9/7	16/7	22/7	28/7	7/8	14/8	26/8
Aldicarb G	3.4	7	4	3	16	5	11	36	39	52
Carbofuran G	3.4	3	1	4	32	10	21	56	45	28
Disulfoton G	3.4	9	3	20	36	44	36	178	138	73
Phorate G	3.4	7	5	16	24	31	33	118	117	72
Oxydemeton-methyl	0.6	2	1	13	21	12	27	139	63	24
Methoxychlor	1.7	8	2	11	13	27	22	117	77	16
Carbaryl	1.7	5	1	7	14	17	35	133	118	22
Control	---	17	4	11	35	21	24	162	97	144

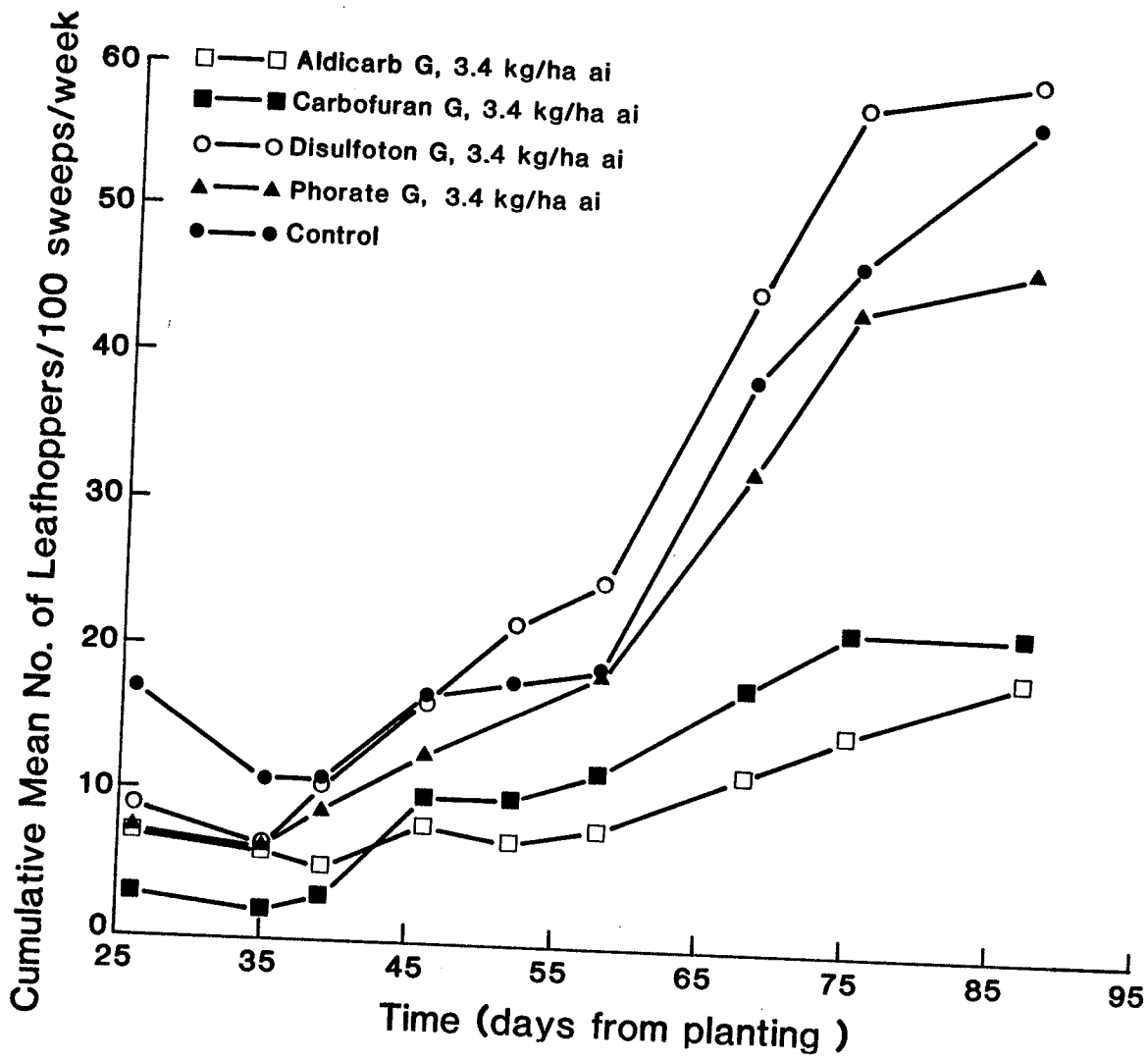
1. Average of 4 replications rounded to nearest whole number.
2. Replicated data are included in Table 38, (Appendix).

TABLE 7. Cumulative mean population levels of the aster leafhopper in celery as affected by various insecticide treatments, 1970.

Treatment	Rate kg/ha ai	Cumulative mean[1] # of leafhoppers/100 sweeps/week							
		5/7	9/7	16/7	22/7	28/7	7/8	14/8	26/8
Aldicarb G	3.4	6	5	8	7	8	12	15	19
Carbofuran G	3.4	2	3	10	10	12	18	22	22
Disulfoton G	3.4	6	11	17	22	25	47	58	60
Phorate G	3.4	6	9	13	16	19	33	44	47
Oxydemeton-methyl	0.6	2	5	9	10	13	31	35	34
Methoxychlor	1.7	5	7	9	12	14	29	35	33
Carbaryl	1.7	3	4	7	9	13	30	41	39
Control	---	11	11	17	18	19	39	47	57

1. Average of 4 replications rounded to nearest whole number.

Figure 1. Cumulative mean population levels of the aster leafhopper in celery as affected by several granular insecticides applied as in-furrow treatments at planting.


Aldicarb G, 3.4 kg/ha ai
Carbofuran G, 3.4 kg/ha ai
Disulfoton G, 3.4 kg/ha ai
Phorate G, 3.4 kg/ha ai
Control
Cumulative Mean No. of Leafhoppers/100 sweeps/week
0
10
20
30
40
50
60
25
35
45
55
65
75
85
95
Time (days from planting)

ed some early leafhopper control but subsequently tended only to prevent large population increases. As a foliar sytemic, oxydemeton-methyl resulted in superior control for the first few weeks but subsequent control was about equal to carbaryl. The cumulative mean population levels in carbaryl, oxydemeton-methyl and aldicarb G plots are compared with control in Figure 2.

Overall, aldicarb G was the single most effective treatment for leafhopper and disease control, with carbofuran G being slightly less efficacious (Table 8). Treatment with aldicarb G resulted in 59% and 66% control of the aster leafhopper as indicated by the cumulative population means to mid and late-season, respectively. Aster yellows was reduced by about 50% and yield increased by 17%. Disulfoton G and phorate G, as in-furrow treatments at planting, were ineffective with respect to insect or disease control. Methoxychlor and carbaryl treatments were inadequate for early leafhopper control and resulted in high levels of AY at harvest. Oxydemeton-methyl tended to reduce AY incidence at harvest but otherwise was equivalent to carbaryl in activity. All treatments with the exception of carbofuran G and disulfoton G resulted in a yield increase as compared to control.

In the carrot trial (1970), weekly leafhopper population counts were high from July 16 to the end of the season with major influxes on July 16 and August 7 (Table 9). These conditions no doubt contributed to variability in data and make interpretation difficult. In an effort to reduce wide vari-

Figure 2. Cumulative mean population levels of the aster leafhopper in celery as affected by insecticidal treatments applied weekly as a foliar spray, (carbaryl, oxydemeton-methyl) or as a granular in-furrow treatment at planting, (aldicarb G).1970.

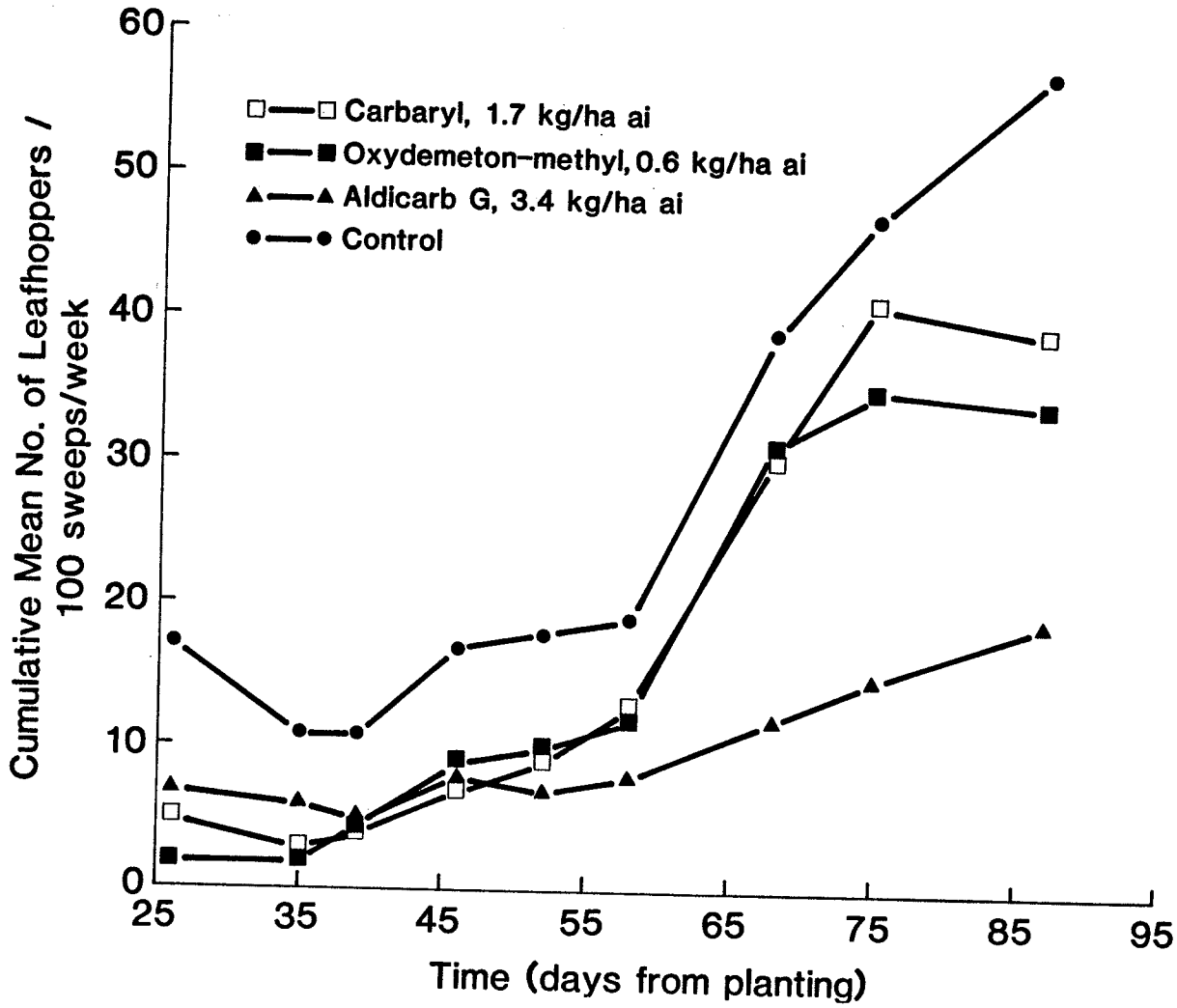

Carbaryl, 1.7 kg/ha ai
Oxydemeton-methyl, 0.6 kg/ha ai
Aldicarb G, 3.4 kg/ha ai
Control
Cumulative Mean No. of Leafhoppers / 100 sweeps/week
0
10
20
30
40
50
60
25
35
45
55
65
75
85
95
Time (days from planting)

TABLE 8. Aster leafhopper population, aster yellows incidence and yield in celery as affected by various insecticide treatments, 1970.

Treatment	Rate kg/ha ai	Mean # of leafhoppers/ 100 sweeps/week (% control)[2]		Aster yellows incidence %[2]		Yield t/ha[2]
		28/7	26/8	4/8	23/9	
Aldicarb G	3.4	7.7(59) a[1]	19.2(66) a	3.3 ab	4.5 a	49.1 b
Carbofuran G	3.4	11.8(37) ab	22.2(61) a	2.2 a	6.2 ab	47.7 ab
Disulfoton G	3.4	24.7(-32) d	59.7(- 4) d	7.8 e	10.5 c	45.7 ab
Phorate G	3.4	19.3(- 3) cd	47.0(18) cd	7.2 de	11.4 c	51.5 b
Oxydemeton-methyl	0.6	12.7(32) abc	33.5(41) b	4.2 bc	6.2 ab	51.5 b
Methoxychlor	1.7	13.9(26) bc	32.5(43) b	3.2 ab	10.2 c	49.7 b
Carbaryl	1.7	13.2(29) bc	39.1(32) bc	5.4 cd	11.3 c	51.5 b
Control	---	18.7(0) bcd	57.2(0) d	6.0 cde	9.2 bc	41.9 a

1. Means followed by the same letter are not significantly different D.M.R.T. (.05).
2. ANOVA and replicated data are included in Table 39 (Appendix).

TABLE 9. Weekly populations of the aster leafhopper in carrots as affected by various insecticide treatments, 1970.

Treatment	Rate kg/ha ai	Mean[1] number of leafhoppers/100 sweeps at each date[2]								
		26/6	5/7	9/7	16/7	22/7	28/7	7/8	14/8	26/8
Aldicarb G	3.4	0	0	6	182	33	11	285	180	206
Carbofuran G	3.4	1	1	15	397	89	34	807	260	752
Disulfoton G	3.4	3	3	20	535	81	38	595	250	512
Phorate G	3.4	3	1	7	302	37	28	537	170	530
Oxydemeton-methyl	0.6	1	0	9	552	59	27	635	380	82
Methoxychlor	1.7	2	2	9	212	53	48	507	190	168
Carbaryl	1.7	3	1	17	445	55	35	600	250	392
Control	---	4	3	24	410	86	33	602	280	512

1. Average of 4 replications rounded to nearest whole number.
2. Replicated data are included in Table 40 (Appendix).

ations in the population data,the cumulative means included in brackets in Table 10 were calculated by omitting weeks of major influxes. With respect to leafhopper control,aldicarb G was superior to other treatments especially during the aforementioned influxes. Contrary to the results of the celery (1970) trial,phorate G appeared to provide relatively good control.

Leafhopper population, disease incidence and yield data are summarized in Table 11. Aldicarb resulted in 67% and 47% leafhopper control to mid and late season,respectively. In addition,the incidence of AY was reduced at harvest although only by about 10%. Although yield increases appeared to be effected by some treatments,variability was high in this trial and differences were not significant.

In 1971,the disulfotan G and phorate G treatments were excluded from the celery trial due to poor performance in 1970. Further, a treatment consisting of aldicarb G at planting followed by 2 foliar sprays of oxydemeton-methyl in mid to late season was included. The weekly population and cumulative mean population data are indicated in Tables 12 and 13,respectively. A relatively stable leafhopper population in 1971 as indicated by control plot leafhopper counts resulted in lower coefficients of variability and allowed more accurate treatment comparisons. Carbaryl and methoxychlor were only partially successful in controlling the early season leafhopper population with carbaryl being the superior of the two treatments. Oxydemeton-methyl

TABLE 10. Cumulative mean population levels of the aster leafhopper in carrots as affected by various insecticide treatments, 1970.

Treatment	Rate kg/ha ai	Cumulative mean[1] # of leafhoppers/100 sweeps/week							
		5/7	9/7	16/7	22/7[2]	28/7[2]	7/8	14/8[3]	26/8
Aldicarb G	3.4	0	2	47	44(10)	39(10)	74	87(38)	100
Carbofuran G	3.4	1	6	104	101(27)	90(28)	192	201(67)	262
Disulfoton G	3.4	3	9	140	128(27)	113(29)	182	191(66)	226
Phorate G	3.4	2	4	78	70(12)	63(15)	131	136(41)	179
Oxydemeton-methyl	0.6	1	3	141	124(17)	108(19)	183	199(79)	186
Methoxychlor	1.7	2	4	56	56(16)	54(23)	119	124(51)	129
Carbaryl	1.7	2	7	116	104(19)	93(22)	165	176(60)	200
Control	---	3	10	110	105(29)	93(30)	166	181(72)	217

1. Average of 4 replications rounded to nearest whole number.
2. Means in brackets omit 16/7.
3. Means in brackets omit 16/7 + 7/8.

TABLE 11. Aster leafhopper population, aster yellows incidence and yield in carrots as affected by various insecticide treatments, 1970.

Treatment	Rate kg/ha ai	Mean # of leafhoppers/ 100 sweeps/week (% control)[2]		Aster yellows incidence %[2]		Yield t/ha[2]
		28/7	14/8	4/8	26/9	
Aldicarb G	3.4	10(67) a[1]	38(47) a	2.1	16.3 b	45.0
Carbofuran G	3.4	23(7) cd	67(7) cd	1.5	22.8 ab	49.5
Disulfoton G	3.4	29(3) d	66(8) cd	3.6	22.1 ab	45.9
Phorate G	3.4	15(50) ab	41(43) ab	2.5	21.1 ab	44.1
Oxydemeton-methyl	0.6	19(37) bc	79(-10) d	3.9	18.7 ab	42.1
Methoxychlor	1.7	23(23) bcd	51(29) abc	2.3	21.0 ab	50.0
Carbaryl	1.7	22(27) bcd	60(17) bcd	3.1	23.7 ab	39.9
Control	---	30(0) d	72(0) cd	3.9	25.6 a	41.7
				N.S.D.		N.S.D.

1. Means followed by the same letter are not significantly different D.M.R.T. (.05).
2. ANOVA and replicated data are included in Table 41 (Appendix).

TABLE 12. Weekly populations of the aster leafhopper in celery as affected by various insecticide treatments, 1971.

Treatment	Rate kg/ha ai	Mean[1] number of leafhoppers/100 sweeps at each date[3]											
		21/6	28/6	6/7	13/7	20/7	26/7	3/8	9/8	18/8	23/8	30/8	7/9
Aldicarb G	3.4	1	0	4	1	8	6	4	1	8	17	44	13
Carbofuran G	3.4	0	0	6	0	11	5	0	0	11	29	63	12
Aldicarb G + oxydemeton-methyl	3.4 + 0.6[2]	0	2	3	7	2	6	1	2	9	13	42	10
Oxydemeton-methyl	0.6	3	2	13	2	6	5	0	0	6	16	24	5
Methoxychlor	1.7	7	1	14	6	5	23	2	4	24	40	52	12
Carbaryl	1.7	7	1	15	2	3	11	2	0	19	30	24	14
Control	---	13	2	24	8	6	29	8	4	43	59	85	21

1. Average of 4 replications rounded to nearest whole number.
2. Foliar applications, 23/8 and 30/8.
3. Replicated data are included in Table 42 (Appendix).

TABLE 13. Cumulative mean population levels of the aster leafhopper in celery as affected by various insecticide treatments, 1971.

Treatment	Rate kg/ha ai	Cumulative mean[1] # of leafhoppers/100 sweeps/week										
		28/6	6/7	13/7	20/7	26/7	3/8	9/8	18/8	23/8	30/8	7/9
Aldicarb G	3.4	1	2	2	3	3	3	3	4	5	9	9
Carbofuran G	3.4	0	2	2	3	4	3	3	4	6	11	11
Aldicarb G + oxydemeton-methyl	3.4[2] + 0.6[2]	1	2	3	3	3	3	3	4	5	8	8
Oxydemeton-methyl	0.6	3	6	5	5	5	4	4	4	5	7	7
Methoxychlor	1.7	4	7	7	7	9	8	8	10	13	16	16
Carbaryl	1.7	4	8	6	6	7	6	5	7	9	10	11
Control	---	8	13	12	11	14	13	12	15	20	26	25

1. Average of 4 replications rounded to nearest whole number.
2. Foliar applications, 23/8 and 30/8.

resulted in improved early and late season leafhopper control in comparison to other foliar treatments and with superior performance to the previous years results. As well, in-furrow treatments with aldicarb G or carbofuran G provided excellent leafhopper control. Leafhopper counts in these treatments approached control numbers on the July 20 sample date but subsequently remained below control levels for the duration of the season. Foliar applications of oxydemeton-methyl following aldicarb G at seeding did not enhance the activity of aldicarb G alone and were likely applied too late. The cumulative mean population over time as affected by foliar applications of carbaryl and oxydemeton-methyl as well as aldicarb G are compared to control in Figure 3.

In summary,the cumulative population means for control plots were 13.7 and 25.2 leafhoppers/100 sweeps/week at mid and late-season,respectively (Table 14). Aster yellows incidence of 5.7% at mid season rose to 13.1% at harvest and the plots yielded 42.8 t/ha. Granular in-furrow treatments substantially reduced the early season leafhopper population with percent control being approximately 75%. This degree of control resulted in reduced mid-season incidence of AY (carbofuran G) and subsequently lower levels of AY at harvest (carbofuran G and aldicarb G). The mean reduction in AY as compared to control was 69%.

In contrast,6 applications of methoxychlor or carbaryl applied weekly up to July 26 resulted in limited early season control of the aster leafhopper (32 and 53%,respect-

Figure 3. Cumulative mean population levels of the aster leafhopper in celery as affected by insecticidal treatments applied weekly as a foliar spray (carbaryl, oxydemeton-methyl) or as a granular in-furrow treatment at planting (aldicarb G). 1971.

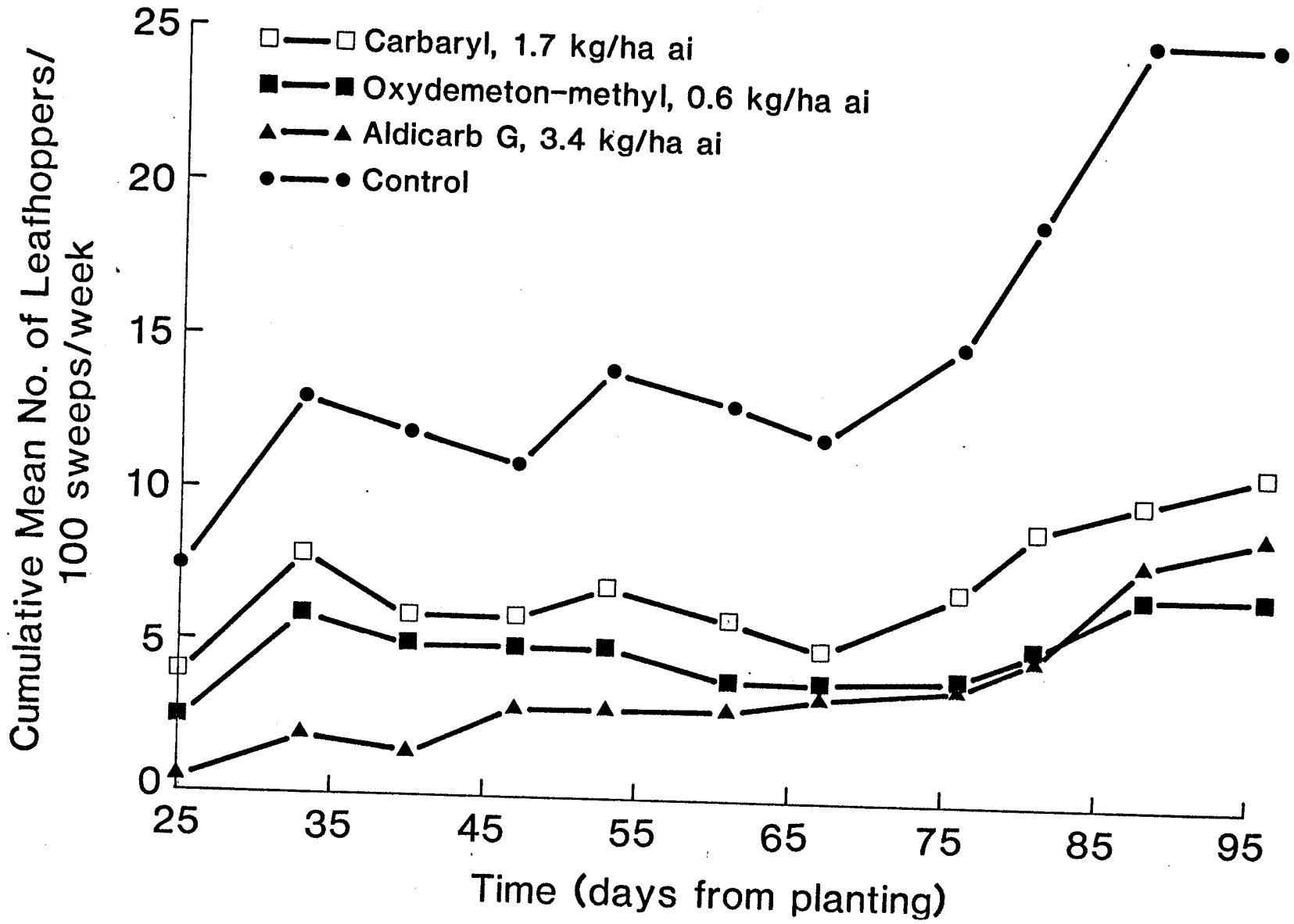

Carbaryl, 1.7 kg/ha ai
Oxydemeton-methyl, 0.6 kg/ha ai
Aldicarb G, 3.4 kg/ha ai
Control
Cumulative Mean No. of Leafhoppers/ 100 sweeps/week
0
5
10
15
20
25
25
35
45
55
65
75
85
95
Time (days from planting)

TABLE 14. Aster leafhopper population, aster yellows incidence and yield in celery as affected by various insecticide treatments, 1971.

Treatment	Rate kg/ha ai	Mean # of leafhoppers/ 100 sweeps/week (% control)[3]		Aster yellows incidence %[3]		Yield[3] t/ha
		26/7	7/9	27/7	9/9	
Aldicarb G	3.4	3.3(76) a[2]	8.9(65) ab	3.7 ab	4.4 ab	59.6 b
Carbofuran G	3.4	3.7(73) ab	11.4(55) b	2.6 b	3.0 a	66.5 b
Aldicarb G + oxydemeton-methyl	3.4[1] + 0.6[1]	3.3(76) a	8.1(68) a	2.6 b	4.6 ab	62.5 b
Oxydemeton-methyl	0.6	5.2(62)bc	6.8(73) a	4.8 ab	5.7 b	60.5 b
Methoxychlor	1.7	9.3(32) d	15.8(38) c	4.4 ab	9.2 c	60.5 b
Carbaryl	1.7	6.5(53) c	10.7(58) b	3.7 ab	9.1 c	49.1 a
Control	---	13.7(0) e	25.2(0) d	5.7 a	13.1 d	42.8 a

1. Foliar applications, 23/8 and 30/8.
2. Means followed by the same letter are not significantly different, D.M.R.T. (.05).
3. ANOVA and replicated data are included in Table 43 (Appendix).

ively), and twice the incidence of AY at harvest as compared to granular treatments. The activity of oxydemeton-methyl in relation to mid season population levels and disease incidence at harvest was intermediate to carbaryl and carbofuran. These combined results tend to stress the importance of continuous protection in the early stages of crop growth. All treatments, with the exception of carbaryl, resulted in a yield increase, with the maximum increase of 55% resulting from the carbofuran G treatment.

In the 1971 carrot trial, two treatments were added; aldicarb G, 1.7 kg/ha ai at planting plus aldicarb G, 1.7 kg/ha ai applied as a sidedress application in mid-season and aldicarb G, 3.4 kg/ha ai at planting followed by 2 applications of oxydemeton-methyl in August. The disulfoton G treatment was dropped due to lack of efficacy in 1970 (Table 15).

Weekly leafhopper counts in control plots were relatively stable in 1971, rising gradually from 20/100 sweeps on June 21 to 80 - 100/100 sweeps towards the end of the season (Table 15). A major influx of leafhoppers into the trial area occurred on August 30. Granular in-furrow treatments of aldicarb G, carbofuran G and phorate G (3.4) were especially effective in controlling the early leafhopper population with duration of control extending to the end of July or about 11 weeks following application. In-furrow treatment with aldicarb at the half rate (1.7 kg/ha) was equivalent to the full rate (3.4 kg/ha) of aldicarb to mid-season. Following a sidedress application (July 22), populations de-

TABLE 15. Weekly populations of the aster leafhopper in carrots as affected by various insecticide treatments, 1971.

Treatment	Rate kg/ha ai	Mean[1] number of leafhoppers/100 sweeps at each date[4]										
		21/6	28/6	6/7	13/7	20/7	26/7	9/8	18/8	23/8	30/8	7/9
Aldicarb G	1.7[2]+ 1.7[2]	7	4	21	8	12	24	21	29	28	153	37
Aldicarb G	3.4	3	4	15	4	14	34	47	55	39	292	80
Aldicarb G + oxydemeton-methyl	3.4[3]+ 0.6[3]	3	1	9	5	10	19	15	51	26	352	74
Oxydemeton-methyl	0.6	10	8	22	2	6	11	11	44	17	95	26
Carbofuran G	3.4	3	7	19	8	30	17	57	100	48	60	123
Phorate G	3.4	5	9	29	6	11	26	39	93	40	304	77
Methoxychlor	1.7	11	6	51	41	34	48	28	90	33	106	41
Carbaryl	1.7	9	11	57	10	14	25	7	53	23	224	43
Control	---	20	21	59	29	61	45	57	101	46	390	84

1. Average of 4 replications rounded to nearest whole number.
2. 1.7 kg applied at planting plus 1.7 kg as a sidedress on 22/7.
3. Foliar applications, 23/8 and 30/8.
4. Replicated data are included in Table 44 (Appendix).

clined below that of aldicarb alone at seeding (Figure 4). Weekly foliar applications of oxydemeton-methyl also effectively reduced the leafhopper population with the exception of the first two weeks when leafhopper counts were equivalent to those in carbaryl and methoxychlor plots. Leafhopper control,with weekly applications of the latter two compounds,was variable. Oxydemeton-methyl applications following aldicarb at planting were made too late to be beneficial.

On the basis of the full-season cumulative population means, oxydemeton-methyl weekly applications were superior to other treatments with the exception of aldicarb G, 1.7 + 1.7 kg/ha (Table 16). As well,a single application of aldicarb G resulted in superior control compared to 8 applications of carbaryl applied to August 9 (Figure 5). Further carbaryl appeared to provide inadequate early control with a tendency only to limit large population increases. Early season control was best achieved with treatment of oxydemeton-methyl or aldicarb G, followed closely by carbofuran G and phorate G.

In control plots.the cumulative population mean rose to 51.9 leafhoppers/100 sweeps/week in September, AY incidence was 5.0% and 13.1% at mid-season and harvest, respectively, and yield was 42.3 t/ha (Table 17). Excellent reductions in the leafhopper population as a result of granular in-furrow treatments are shown by the percent control in mid-season and during late season (aldicarb sidedress). In addition, oxydemeton-methyl resulted in excellent season-long control.

Figure 4. Weekly population levels of the aster leafhopper in carrots as affected by insecticidal treatments applied weekly as a foliar spray (carbaryl) and as a granular in-furrow treatment (aldicarb G) or as a granular in-furrow treatment (aldicarb G) plus a sidedress application (aldicarb G) in mid-season.

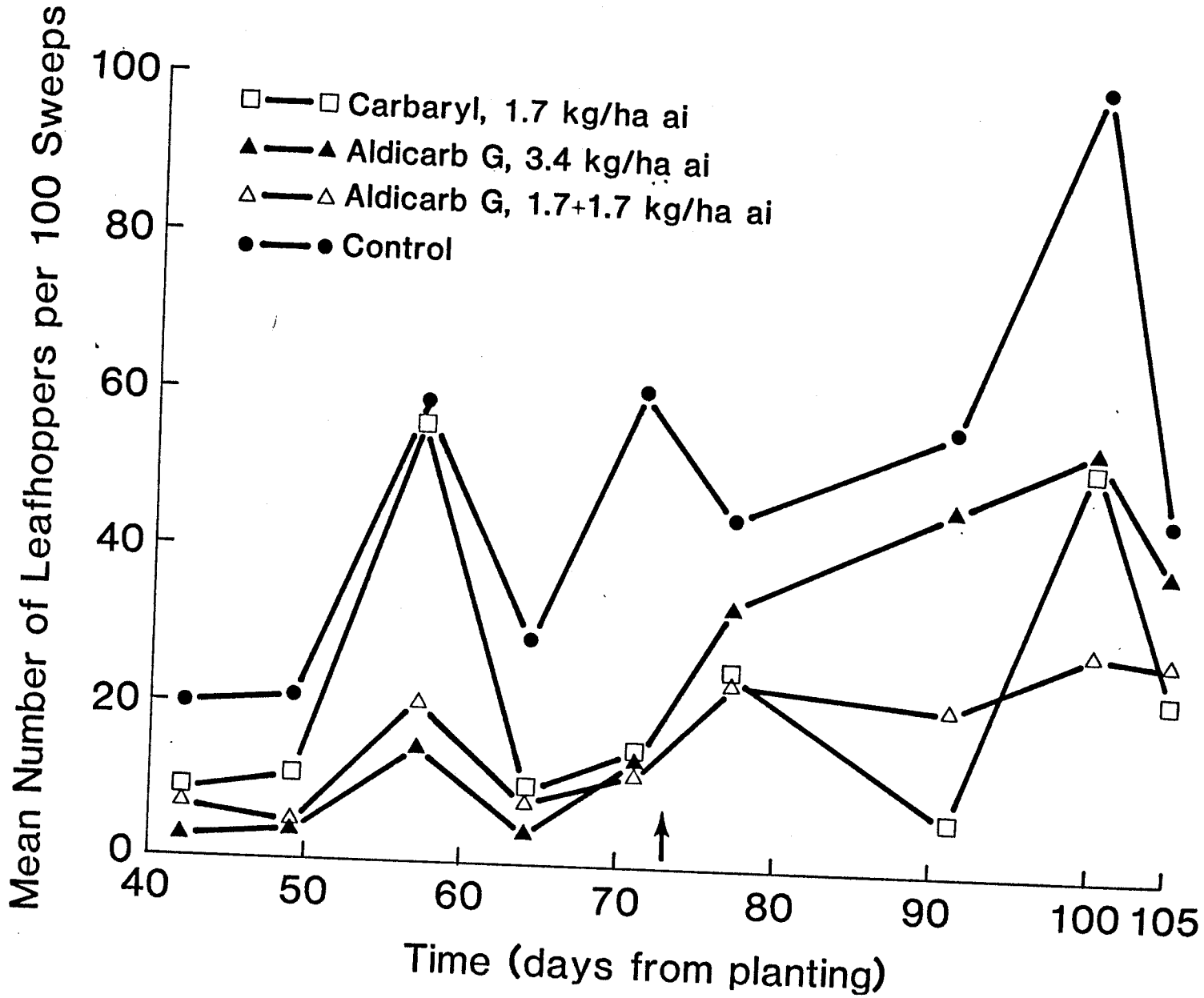

Mean Number of Leafhoppers per 100 Sweeps
100
80
60
40
20
0
Carbaryl, 1.7 kg/ha ai
Aldicarb G, 3.4 kg/ha ai
Aldicarb G, 1.7+1.7 kg/ha ai
Control
40
50
60
70
80
90
100
105
Time (days from planting)

TABLE 16. Cumulative mean population level of the aster leafhopper in carrots as affected by various insecticide treatments, 1971.

Treatment	Rate kg/ha ai	Cumulative mean[1] # of leafhoppers/100 sweeps/week									
		28/6	6/7	13/7	20/7	26/7	9/8	18/8	23/8	30/8	7/9[4]
Aldicarb G	1.7 + 1.7[2]	6	11	10	10	13	14	16	17	31	19
Aldicarb G	3.4	3	7	6	8	12	17	22	24	50	29
Aldicarb G + oxydemeton-methyl	3.4 + 0.6[3]	2	4	4	5	8	9	14	15	49	21
Oxydemeton-methyl	0.6	9	13	10	9	10	10	14	14	23	15
Carbofuran G	3.4	5	10	9	13	14	20	30	32	88	41
Phorate G	3.4	7	14	12	12	14	18	27	29	56	33
Methoxychlor	1.7	8	23	27	28	32	31	38	38	45	38
Carbaryl	1.7	10	26	22	20	21	19	23	23	43	24
Control	---	20	33	32	38	39	41	49	48	83	52

1. Average of 4 replications rounded to nearest whole number.
2. 1.7 kg applied at planting plus 1.7 kg as a sidedress on 22/7.
3. Foliar applications, 23/8 and 30/8.
4. 7/9 omits 30/8.

Figure 5. Cumulative mean population levels of the aster leafhopper in carrots as affected by insecticidal treatments applied weekly as a foliar spray (carbaryl, oxydemeton-methyl) and as a granular in-furrow treatment (aldicarb G) or as an in-furrow treatment (aldicarb G) plus a sidedress application (aldicarb G) in mid-season.

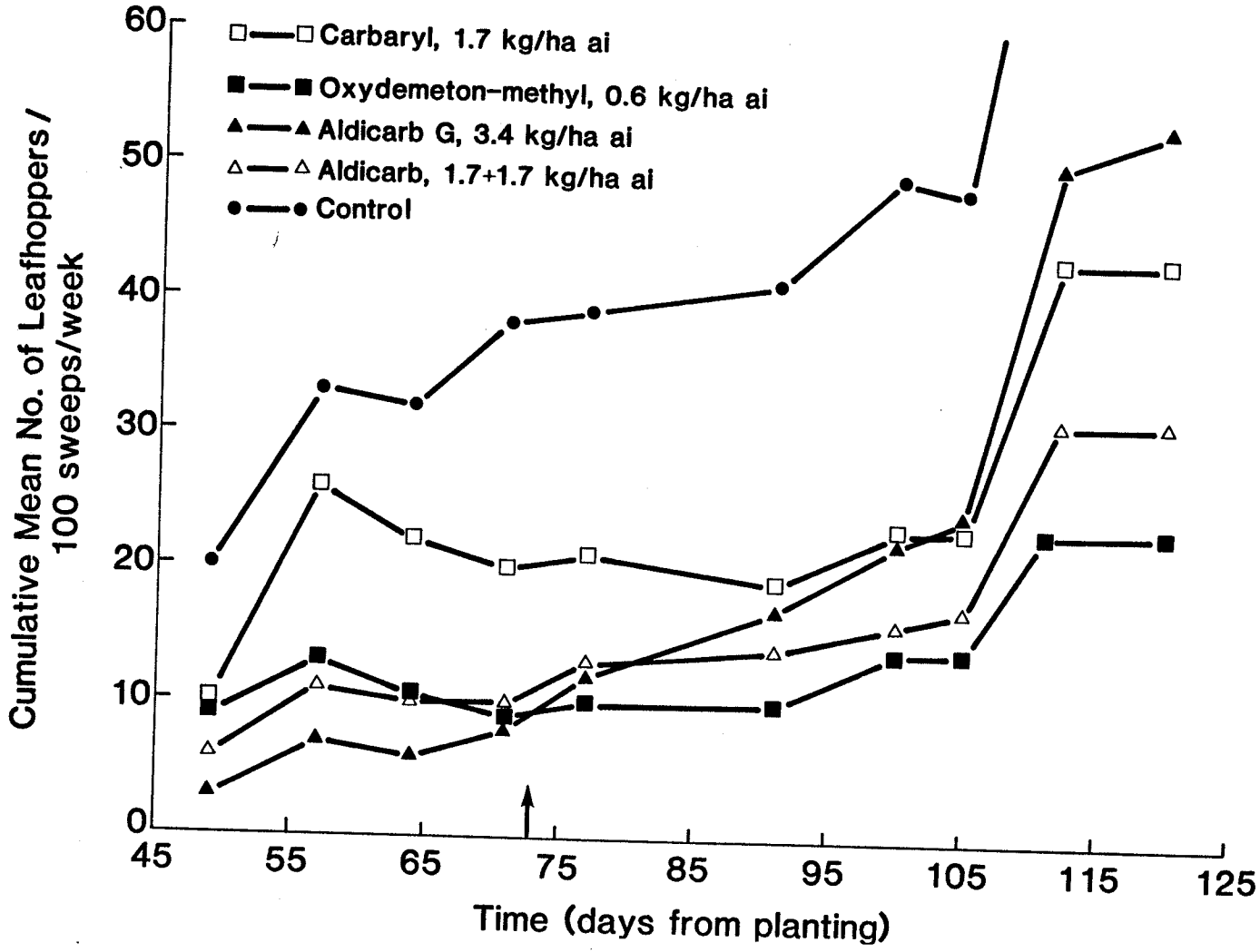

Carbaryl, 1.7 kg/ha ai
Oxydemeton-methyl, 0.6 kg/ha ai
Aldicarb G, 3.4 kg/ha ai
Aldicarb, 1.7+1.7 kg/ha ai
Control
Cumulative Mean No. of Leafhoppers / 100 sweeps/week
0
10
20
30
40
50
60
45
55
65
75
85
95
105
115
125
Time (days from planting)

TABLE 17. Aster leafhopper population, aster yellows incidence and yield in carrots as affected by various insecticide treatments, 1971.

Treatment	Rate kg/ha ai	Mean # of leafhoppers/ 100 sweeps/week (% control)[4]		Aster yellows incidence %[4]		Yield t/ha[4]
		26/7	7/9	27/7	28/9	
Aldicarb G	1.7 + 1.7[1]	12.5(68) b[3]	19.0(63) ab	4.0 bc	4.3 ab	41.7
Aldicarb G	3.4	12.0(69) ab	29.2(44) de	3.5 abc	3.7 a	47.5
Aldicarb G + oxydemeton-methyl	3.4 + 0.6[2]	7.7(80) a	21.2(59) bc	1.0 a	3.4 a	47.7
Oxydemeton-methyl	0.6	9.5(76) ab	15.5(70) a	3.0 abc	5.1 abc	43.2
Carbofuran G	3.4	13.8(64) b	41.1(21) f	3.5 abc	5.7 bc	44.8
Phorate G	3.4	14.2(63) b	33.4(36) ef	2.0 ab	5.3 abc	43.2
Methoxychlor	1.7	31.6(19) d	38.1(27) f	3.0 abc	5.1 abc	45.9
Carbaryl	1.7	20.7(47) c	24.9(52) cd	5.3 c	6.7 c	42.1
Control	---	38.8(0) d	51.9(0) g	5.0 c	13.1 d	42.3
L.S.D. (0.1)						4.6

1. 1.7 kg applied at planting plus 1.7 as a sidedress on 22/7.
2. Foliar applications, 23/8 and 30/8.
3. Means followed by the same letter are not significantly different D.M.R.T. (.05).
4. ANOVA and replicated data are included in Table 45 (Appendix).

AY incidence at harvest was reduced by all treatments as compared to control and by aldicarb treatments as compared to carbaryl. Although a significant yield increase was not evident the yield resulting from aldicarb G (3.4 kg/ha ai alone) tended to be higher with significance occurring between L.S.D. .05 and 0.1

In 1972, the leafhopper population and resultant AY incidence in the celery insecticide trial were low and resulted in a limited amount of information being derived from the trial. Leafhopper control was best achieved with aldicarb and was superior with aldicarb followed by 2 foliar applications of oxydemeton-methyl on July 21 and August 8 (Table 18 and 19). Even with a relatively low population, leafhopper control with carbaryl was poor while control with carbofuran and oxydemeton-methyl was intermediate to control with carbaryl and aldicarb. No reductions in the incidence of aster yellows or increases in yield occurred as a result of insecticide application (Table 20).

In contrast to the above trial, the leafhopper population in the 1972 carrot trial was much higher with numbers in control plots fluctuating until August 4 and thereafter remaining at about 100/100 sweeps (Table 21). The number of leafhoppers in aldicarb treated plots approached control levels on July 25, 10 weeks after planting but thereafter remained at about 50% of control. Applications of oxydemeton-methyl following aldicarb G resulted in slightly lower leafhopper counts the following week. As well, oxydemeton-methyl

TABLE 18. Weekly populations of the aster leafhopper in celery as affected by various insecticide treatments, 1972.

Treatment	Rate kg/ha ai	Mean[1] number of leafhoppers/100 sweeps at each date[4]								
		4/7	11/7	18/7	25/7	4/8	11/8	17/8	24/8	31/8
Aldicarb G	1.7[2]+ 1.7[2]	5	10	3	0	4	4	5	3	3
Aldicarb G	3.4	1	9	5	1	4	3	6	5	5
Aldicarb G + oxydemeton-methyl	3.4[3]+ 0.6[3]	2	6	0	0	3	6	8	3	4
Carbofuran G	3.4	3	15	2	2	5	6	8	4	5
Oxydemeton-methyl	0.6	2	19	5	0	6	9	4	8	4
Carbaryl	1.7	5	7	15	2	7	13	11	5	6
Control	---	9	22	4	1	8	10	17	5	8

1. Average of 4 replications rounded to nearest whole number.
2. 1.7 kg applied at planting plus 1.7 kg as a sidedress on 21/7.
3. Foliar applications applied on 21/7 and 11/8.
4. Replicated data are included in Table 46 (Appendix).

TABLE 19. Cumulative mean population levels of the aster leafhopper in celery as affected by various insecticide treatments, 1972.

Treatment	Rate kg/ha ai	Cumulative mean[1] # of leafhoppers/100 sweeps/week							
		11/7	18/7	25/7	4/8	11/8	17/8	24/8	31/8
Aldicarb G	1.7[3]+ 1.7	8	6	5	4	4	4	4	4
Aldicarb G	3.4	5	5	4	4	4	4	4	4
Aldicarb G + oxydemeton-methyl	3.4[2]+ 0.6	4	3	2	2	3	4	4	4
Carbofuran G	3.4	9	7	6	5	6	6	6	6
Oxydemeton-methyl	0.6	11	9	7	6	7	6	7	6
Carbaryl	1.7	6	9	7	7	8	9	8	8
Control	---	16	12	9	9	9	10	10	9

1. Average of 4 replications rounded to nearest whole number.
2. Foliar applications applied on 21/7 and 11/8.
3. 1.7 kg applied at planting plus 1.7 kg as a sidedress on 21/7.

TABLE 20. Aster leafhopper population, aster yellows incidence and yield in celery as affected by various insecticide treatments, 1972.

Treatment	Rate kg/ha ai	Mean # of leafhoppers/ 100 sweeps/week (% control)[4]		Aster yellows incidence %[4]		Yield t/ha[4]
		25/7	31/8	31/7	5/9	5/9
Aldicarb G	1.7 + 1.7[2]	4.5(50) ab	4.1(56) a	0.2	1.8 bc	55.1
Aldicarb G	3.4	4.0(56) ab[3]	4.3(54) ab	0.3	1.8 bc	58.0
Aldicarb G + oxydemeton-methyl	3.4 + 0.6[1]	2.0(78) a	3.5(62) a	0.3	0.5 c	58.1
Carbofuran G	3.4	5.5(39) bc	5.5(41) abc	0.3	2.2 b	50.2
Oxydemeton-methyl	0.6	6.5(28) bc	6.3(32) bc	0.5	2.2 b	58.7
Carbaryl	1.7	7.3(19) bc	7.9(15) cd	0.5	4.0 a	52.9
Control	---	9.0(0) c	9.3(0) d	0.5	2.0 bc	56.0
				N.S.D.		N.S.D.

1. Foliar applications applied on 21/7 and 11/8.
2. 1.7 kg applied at planting plus 1.7 as a sidedress on 21/7.
3. Means followed by the same letter are not significantly different D.M.R.T. (.05).
4. ANOVA and replicated data are included in Table 47 (Appendix).

TABLE 21. Weekly populations of the aster leafhopper in carrots as affected by various insecticide treatments, 1972.

Treatment	Rate kg/ha ai	Mean[1] number of leafhoppers/100 sweeps at each date[4]								
		4/7	11/7	18/7	25/7	4/8	11/8	17/8	25/8	31/8
Aldicarb G	3.4	2	42	38	22	30	31	63	41	45
Aldicarb G + oxydemeton-methyl	3.4 + 0.6[2]	3	91	26	12	33	43	36	35	40
Aldicarb G	1.7 + 1.7[3]	3	78	41	17	35	38	31	31	52
Carbofuran G	3.4	7	81	34	41	71	67	54	90	88
Oxydemeton-methyl	0.6	6	88	18	6	30	26	20	30	21
Carbaryl	1.7	15	231	36	2	71	82	53	99	78
Control	---	20	240	81	35	104	95	80	115	101

1. Average of 4 replications rounded to nearest whole number.
2. Foliar applications applied on 21/7 and 11/8.
3. 1.7 kg applied at planting plus 1.7 kg as a sidedress on 21/7.
4. Replicated data are included in Table 48 (Appendix).

applied alone on a weekly basis achieved excellent leafhopper control. Carbofuran G effectively controlled the early season leafhopper population with a duration of activity slightly less than that of aldicarb G. Leafhopper control with carbaryl sprays was variable. On the basis of cumulative means to August 31, leafhopper control with aldicarb and oxydemeton-methyl treatments was superior to treatment with carbofuran G or carbaryl (Table 22).

The incidence of aster yellows at harvest was reduced by all insecticide treatments as compared to control (9.1%); the lowest levels resulting from those treatments with a high percent leafhopper control (Table 23). Aldicarb alone at planting was the sole treatment to reduce the incidence of AY in mid season. The highest disease reduction (68%) resulted from weekly oxydemeton-methyl applications. With respect to yield effects, carbofuran G resulted in the highest increase followed by aldicarb G (1.7 + 1.7 kg/ha) and oxydemeton-methyl.

The interpretation of results of field insecticide trials investigating disease control via vector control is complicated by the high degree of variability that often occurs. This is especially true when the insect of study has a high degree of mobility as does the aster leafhopper. Variable and fluctuating populations, influxes of migrants as well as local mobility are key factors leading to a high degree of variation in experimental results. Extremely high leafhopper counts, in addition to week-to-week fluctuations

TABLE 22. Cumulative mean population levels of the aster leafhopper in carrots as affected by various insecticide treatments, 1972.

Treatment	Rate kg/ha ai	Cumulative mean[1] # of leafhoppers/100 sweeps/week							
		11/7	18/7	25/7	4/8	11/8	17/8	25/8	31/8
Aldicarb G	3.4	22	27	26	27	28	33	34	35
Aldicarb G + oxydemeton-methyl	3.4 + 0.6[2]	47	40	33	33	35	35	35	36
Aldicarb G	1.7 + 1.7[3]	40	40	35	35	35	35	34	36
Carbofuran G	3.4	44	41	41	47	50	51	56	59
Oxydemeton-methyl	0.6	47	37	30	30	29	28	28	27
Carbaryl	1.7	123	94	71	71	73	70	74	74
Control	---	130	114	94	96	96	93	96	97

1. Average of 4 replications rounded to nearest whole number.
2. Foliar applications applied on 21/7 and 11/8.
3. 1.7 kg applied at planting plus 1.7 kg as a sidedress on 21/7.

TABLE 23. Aster leafhopper population, aster yellows incidence and yield in carrots as affected by various insecticide treatments, 1972.

Treatment	Rate kg/ha ai	Mean # of leafhoppers/ 100 sweeps/week (% control)[4]		Aster yellows incidence %[4]		Yield t/ha[4]
		25/7	31/8	31/7	3/10	
Aldicarb G	3.4	26(72) a[3]	35(64) b	0.4 c	3.6 a	44.1 bc
Aldicarb G + oxydemeton-methyl	3.4[1] + 0.6[1]	33(65) ab	36(63) b	1.5 ab	4.8 a	48.2 abc
Aldicarb G	1.7[2] + 1.7[2]	35(63) ab	36(63) b	0.6 bc	3.5 a	49.7 ab
Carbofuran G	3.4	41(56) b	59(39) c	0.8 abc	5.1 a	53.5 a
Oxydemeton-methyl	0.6	30(68) ab	27(72) a	1.6 ab	2.9 a	49.1 ab
Carbaryl	1.7	71(24) c	74(24) d	1.0 abc	5.3 a	41.7 bc
Control	---	94(0) d	97(0) e	1.5 ab	9.1 b	40.8 c

1. Foliar applications applied on 12/7 and 11/8.
2. 1.7 kg applied at planting plus 1.7 kg as a sidedress on 21/7.
3. Means followed by the same letter are not significantly different D.M.R.T.(.05).
4. ANOVA and replicated data are included in Table 49 (Appendix).

(carrots 1970) and, on the other hand, populations too low to make significant comparisons (celery 1970), are examples of problems encountered. The large plot size and buffer zones utilized in these trials in an attempt to minimize, at least to some degree, this type of variation, was outlined in the Materials and Methods section.

Prior to making summary result statements and to assist in the interpretation of the trial results, an analysis of variance was conducted over the three year period using the method described by Little and Hills (1975) to compare the four treatments which were included in each trial in each year. The four treatments included aldicarb and carbofuran G applied in furrow at planting as well as oxydemeton-methyl and carbaryl applied as weekly foliar sprays (Table 24 and 25).

The following summary result statements therefore take into consideration the individual trials, the three year means for appropriate treatments, the high variability in the 1971 carrot trial and the low leafhopper population in the 1972 celery trial.

Firstly with respect to carbaryl and methoxychlor, aster leafhopper control as indicated by weekly counts was variable and generally considered to be inadequate in both celery and carrots. An average of 6 to 7 weekly applications beginning when leafhoppers were first detected in the trials resulted in only 30 to 40% control, based on cumulative population means to mid-season. Subsequent applications tended only to

TABLE 24. Three year means for aster leafhopper population, aster yellows incidence and yield in celery as affected by various insecticide treatments.

Treatment	Rate kg/ha ai	Mean # of leafhoppers/ 100 sweeps/week (% control)		Aster yellows incidence %		Yield t/ha[6]
		Mid-season[2]	Harvest[3]	Mid-season[4]	Harvest[5]	
Aldicarb G	3.4	5.1(63) a[1]	10.7(65) a	2.4 b	3.6 a	55.6 a
Carbofuran G	3.4	7.1(49) b	13.0(57) ab	1.7 a	3.8 a	54.8 a
Oxydemeton-methyl	0.6	8.2(41) bc	15.7(48) ab	3.2 b	4.7 b	56.9 a
Carbaryl	1.7	8.9(36) c	19.2(37) b	3.2 b	8.1 c	51.2 ab
Control	---	13.9(0) d	30.5(0) c	4.1 c	8.1 c	46.9 b

1. Means followed by the same letter are not significantly different D.M.R.T. (.05).
2, 3, 4, 5, 6. ANOVA and replicated data are included in Table 50 - 54 (Appendix) respectively.

TABLE 25. Three year means for aster leafhopper population, aster yellows incidence and yield in carrots as affected by various insecticide treatments.

Treatment	Rate kg/ha ai	Mean # of leafhoppers/ 100 sweeps/week (% control)		Aster yellows incidence %		Yield t/ha[6]
		Mid season[2]	Harvest[3]	Mid-season[4]	Harvest[5]	
Aldicarb G	3.4	16(70) a[1]	34(54) a	2.0 a	7.9 a	45.5 b
Carbofuran G	3.4	28(48) b	56(24) b	1.9 a	11.2 b	49.3 c
Oxydemeton-methyl	0.6	20(63) a	41(45) a	2.8 b	8.9 a	44.8 b
Carbaryl	1.7	38(30) c	53(28) b	3.1 b	11.9 b	41.2 a
Control	---	54(0) d	74(0) c	3.5 b	15.9 c	41.6 a

1. Means followed by the same letter are not significantly different D.M.R.T. (.05).
2, 3, 4, 5, 6. ANOVA and replicated data are included in Table 55 - 59 (Appendix) respectively.

limit large population increases. Of the two treatments, applications of carbaryl tended to be slightly more efficacious (1971 trials). In regards to disease control, although reductions in incidence did occur in some trials, these were generally minimal as compared to more effective treatments. Averaged over three years, carbaryl applications reduced AY incidence in carrots by 25% while no disease reduction in celery occurred. The three year means show no effect of carbaryl on yield.

Eckenrode (1973) showed methoxychlor and carbaryl to have a duration of activity in carrots of approximately 8 and 12 days respectively. This study, however, was conducted in the absence of a migrant population. Henne (1970) obtained good leafhopper control with weekly carbaryl applications but carrot yellows incidence was not correspondingly reduced. He concluded that even with a diligent spray program, disease incidence could be high. Variable results with carbaryl on lettuce and carrots were obtained by Thompson (1965, 1967). In the 1965 report, malathion or carbaryl sprays equaled granular phorate treatments in reducing lettuce and carrot yellows, while in the latter trials carbaryl was less effective than phorate.

Oxydemeton-methyl applied as a weekly foliar spray generally resulted in excellent aster leafhopper control (carrots 1971, 1972, celery 1971) although results were somewhat inconsistent (carrots and celery 1970). Since leafhopper control was superior in 1971 when the leafhopper population

was relatively stable, as compared to a fluctuating population in 1970, the variable control may in part be attributable to time of application in relation to population influxes. Weekly leafhopper counts in aldicarb G plots receiving foliar oxydemeton-methyl applications in mid-season, however, would indicate a duration of activity of 5 to 7 days. During the three year period that oxydemeton-methyl was tested, seasonal leafhopper control averaged about 50% (Tables 24 and 25). Aster yellows reductions at harvest ranged from 30 to 50% in the 1971 and 1972 trials, and averaged 43% over the three year period. Significant yield increases in individual trials as well as in the three year comparison resulted from oxydemeton-methyl applications. Variable results with oxydemeton-methyl were also reported by Henne (1970). He found that although the leafhopper population was greatly reduced a corresponding yellows reduction did not occur. Thompson (1967) reported oxydemeton-methyl as less efficacious than granular treatments and attributed the superior performance of the latter to early seedling protection. A closely related compound, demeton, was reported by Chiykowski (1958) as providing excellent reductions in both the leafhopper population and aster yellows in carrots.

Disulfoton G, included in the first trial year failed to adequately control the aster leafhopper or reduce aster yellows incidence and therefore was not included in subsequent trials. Rawlins and Gonzalez (1966) suggested that poor results with disulfoton could be due to placement of the

granules below the seed. Disulfoton failed to control lettuce yellows when applied in this manner (Richardson and Westdal, 1964). However, in the studies reported here placement in the furrow with the seed (carrots) was not an effective treatment.

Lack of efficacy in celery (1970) and uncertain performance in carrots (1970) resulted in phorate G being included only in the 1971 carrot trial. Early season leafhopper control (63%) and a subsequent reduction in aster yellows (58%) were achieved. Phorate was not fully evaluated but appeared less persistent than aldicarb and carbofuran. The duration of leafhopper control was about 7 to 8 weeks.

Richardson and Westdal (1964) found the activity of phorate to be equivalent to malathion in regard to reduction of lettuce yellows when leafhopper populations and the percentage of infectious adults were relatively low. Under more severe conditions,phorate was the superior treatment. In subsequent trials with lettuce and barley, phorate was shown to be effective for about 5 weeks after crop emergence. As well,oviposition and nymphal development were prevented. The reduced leafhopper population was associated with a reduced incidence of aster yellows in barley, flax and lettuce and an increased seed yield of barley (Westdal and Richardson 1971). Although leafhopper populations were not monitored, Thompson (1975) found phorate to have twice the activity of disulfoton in reducing lettuce yellows. As well phorate at seeding was about equivalent to regular carbaryl or malathion spray

programs. One-half the rate of phorate at seeding plus one-half applied as a side-dress application was no more effective than the total amount applied at seeding (Thompson 1964, 1967).

The results obtained with carbofuran G may be distorted somewhat by the first year's trial when leafhopper and disease control were relatively poor. With this exception carbofuran, applied as an in furrow treatment, provided 50 to 60% early season leafhopper control in both crops with efficacy extending for a period of about 10 weeks after application. Reductions in celery yellows ranged from 30 to 75% in individual trials and averaged 53% over 3 years (Tables 24 and 25). Reductions in carrot yellows were somewhat less (35 to 45%). Yield increases were evident in celery (16.8%) and especially in carrots (18.5%) as a result of carbofuran G treatment. In other trials, Henne (1970) found foliar applications of carbofuran WP to be ineffective in control of the aster leafhopper. However, application of carbofuran G below carrot seed was equivalent in performance to 5 foliar applications of carbaryl or oxydemeton-methyl. More recently, Schultz and Chapman (1976) reported carbofuran as a weekly or bi-weekly foliar treatment as equivelent to or better than standard malathion applications for control of carrot and lettuce yellows. Applied as a granular treatment the efficacy of carbofuran was about equivalent to phorate.

In-furrow treatments of aldicarb G with the seed or transplant consistently resulted in excellent early-season

leafhopper control in individual carrot and celery trials. As well, cumulative population means to mid-season show a 63 to 70% control of the aster leafhopper (Tables 24 and 25). Duration of control appeared to be in the area of 9 to 12 weeks from application; or, on an activity basis equivalent or superior to 6 to 8 applications of carbaryl. However, weekly leafhopper counts from mid to late-season, often in the range of 50% of control levels, tend to indicate a longer duration of activity. Also aldicarb consistently reduced the incidence of aster yellows in carrots and celery.

The maximum disease reduction resulting from aldicarb G (3.4 kg/ha ai) alone at planting was 66% in celery and 72% in carrots. Over three years of trials the average reduction in both crops was 50%. Application of one-half the aldicarb rate at planting plus one-half as a sidedress application in mid-season effectively prolonged the duration of leafhopper control in 1971 but had no advantage in 1972. As well sidedress applications had no effect on AY incidence at harvest, thus reinforcing the importance of early protection as opposed to prolonged duration of activity. Likewise, applications of oxydemeton-methyl in mid-season, following an aldicarb treatment at planting, resulted in a slight increase in late-season leafhopper control but did not affect disease incidence. Single applications of aldicarb G at planting resulted in a mean yield increase of 18.6% in celery and 8.6% in carrots over three years.

Related to the aforementioned problem of variability in

field trials investigating disease control via vector control is the often apparent lack of consistency between the size of the insect population, disease incidence and yield. For example Henne (1970) reported that although carbaryl and oxydemeton-methyl treatments provided the greatest reduction in leafhopper numbers they did not result in the lowest incidence of aster yellows in carrots. The key factors to consider are the short inoculation threshold for transmission of AY by the aster leafhopper as well as the rapidity of knockdown and duration of activity of the insecticide. Furthermore as stated by Chapman (1959), the actual number of vectors is less important than the percentage of infectious vectors and the degree of movement that occurs.

To investigate the degree of relatedness of cumulative leafhopper population means, aster yellow incidence and yield of carrots and celery in the trials reported here, linear correlation analysis was performed over all treatments in each crop in each year. In addition the three year means for each crop (Tables 24 and 25) were analysed separately. In each case the data, by replication, were used in the analysis.

The high degree of variability in the 1970 carrot trial as a result of a very large and fluctuating leafhopper population is reflected in the low coefficient of correlation (r) values (Table 26). As well the low insect and disease levels in the 1972 celery trial resulted in generally less correlation between the variables tested as compared to other years.

TABLE 26. Relatedness of cumulative mean leafhopper populations, aster yellows incidence and yield in carrots and celery as determined by linear correlation analysis.

	Individual trials						Three year means	
	Celery trials			Carrot trials				
	1970	1971	1972	1970	1971	1972	Celery	Carrot
1-2*	0.86	0.86	0.85	0.66	0.74	0.91	0.94	0.79
1-3	0.56	0.65	0.30	0.07	0.41	0.27	0.61	0.52
1-4	0.54	0.90	0.57	0.30	0.68	0.80	0.78	0.74
1-5	-0.39	-0.56	0.15	-0.03	-0.18	-0.50	-0.63	-0.39
2-4	0.58	0.79	0.48	0.06	0.59	0.72	0.84	0.64
2-5	-0.30	-0.43	0.03	-0.08	0.01	-0.41	-0.65	-0.19
3-4	0.60	0.68	0.32	0.02	0.39	0.25	0.68	0.26
3-5	-0.14	-0.25	-0.19	-0.15	-0.39	-0.33	-0.35	-0.62
4-5	-0.14	-0.63	-0.03	0.21	-0.29	-0.40	-0.61	-0.10

* Numbers refer to variable comparisons as follows:

1. Cumulative mean leafhopper population (mid-season).
2. Cumulative mean leafhopper population (late-season).
3. AY incidence (% at mid-season).
4. AY incidence (% at harvest).
5. Yield (t/ha).

As expected the cumulative population means to mid and late-season (i.e. 1-2) are strongly correlated throughout the trials. Further, the mid-season population means are more closely related to AY incidence at mid-season (1-3) in celery than in carrots. In comparing relative r values the generally stronger correlation between the cumulative mean population (mid-season) and % AY at harvest (1-4) as opposed to % AY in mid-season (1-3) indicates the expected progressive development of disease symptoms. Of more interest is the generally stronger association between mid-season population means and % AY at harvest (1-4) as compared with the late-season population mean and % AY at harvest (2-4). The importance of crop protection early in the season is emphasized. Further, there appears to be a stronger correlation between mid and late-season AY incidence (3-4) in celery than in carrots.

Negative correlation of the observed variables with yield was stronger in celery than carrots. However, in both crops decreased yield was more closely related to the population mean to mid-season and AY at harvest as compared to other variables, with the exception of the carrot three year means. Here decreased yield is better associated with % AY in mid-season than at harvest. This may in part be due to disease ratings in mid-season according to foliage symptoms only as opposed to foliage and root symptoms at harvest.

Rates of Aldicarb G

One trial was initiated to evaluate aldicarb G as an in-furrow treatment, over a rate range of 1.68 to 6.72 kg/ha ai in carrots (Table 27). Of the rates tested 3.36 kg/ha was considered as the likely X rate for commercial use with 1.68 kg/ha and 6.72 kg/ha therefore being the one-half X and 2X rates respectively. Possible phytotoxicity at the 2X rate and degree of aster yellows reduction over a rate range were variables of primary interest. Further,the trial was planned such that samples of carrot leaves and roots could be sampled at various times during the season for subsequent residue analysis. The leafhopper population in this trial was not monitored.

Aster yellows incidence in control plots totalled 21.7% (Table 27). All aldicarb treatments significantly reduced total disease incidence with aldicarb at 5.04 kg/ha resulting in the maximum percent reduction (55.8%). Infected roots were graded according to the degree of adventitious root growth and stunting that occurred. Disease incidence in each category, was reduced by all treatment rates with the exception of 1.68 kg/ha. For the rate range tested,aldicarb did not reduce emergence, plant stand or plant vigour. Yield increases resulted from aldicarb at rates of 5.04 and 6.72 kg/ha. Reductions in yellows incidence and increases in yield were apparently rate-related with the exception of the maximum treatment rate.

TABLE 27. The effect of aldicarb on aster yellows incidence and yield in carrot.

Treatment	Rate kg/ha ai	Aster yellows incidence %				Yield[6] t/ha
		Slight[2]	Moderate[3]	Severe[4]	Total[5]	
Aldicarb G	1.68	9.3 bc[1]	3.9 b	2.0 ab	15.2 a	68.3 ab
Aldicarb G	3.36	6.7 ab	3.6 ab	2.5 ab	12.7 ab	71.2 ab
Aldicarb G	5.04	5.7 a	2.9 a	1.0 a	9.6 b	76.8 a
Aldicarb G	6.72	5.2 a	2.9 a	2.7 b	10.7 b	74.4 a
Control	----	10.9 c	6.3 c	4.4 c	21.7 c	58.0 b

1. Means followed by the same letter are not significantly different, D.M.R.T., p = .05.
2, 3, 4, 5, 6. ANOVA and replicated data are included in Table 60 - 64 (Appendix) respectively.

Laboratory and Greenhouse Trials

Since superior results were achieved in the field trials with aldicarb regarding both aster leafhopper and aster yellows disease control, further research was initiated to investigate the activity of this compound.

In plants and soil, aldicarb is rapidly transformed to aldicarb sulfoxide and at a much slower rate to aldicarb sulfone. The sulfoxide, which has a toxicity about equal to aldicarb, is the primary metabolite responsible for insecticidal activity (Coppedge et. al. 1967). The half-life of aldicarb in soil is less than 1 week and for total toxic aldicarb equivalents (aldicarb, aldicarb sulfoxide and aldicarb sulfone) is 2 to 3 weeks in coarse, and 4 to 5 weeks in fine soil. Moisture is required to activate aldicarb and rainfall directly affects dissipation rate (Andrawes et. al. 1971a). The metabolism of aldicarb has been most extensively studied in cotton (Bartley et. al. 1970; Andrawes et. al. 1973) and potatoes (Andrawes et. al. 1971b). In the foliage of these plants aldicarb has a half-life of about 24 hours due to rapid oxidation to aldicarb sulfoxide. At application rates necessary for insect control, significant quantities of the sulfoxide are present for up to 8 weeks with the ratio of aldicarb sulfoxide to aldicarb sulfone approximately 1:1 about 30 days following application. Little insecticidal activity is attributed to the sulfone. Although the metabolic degradation pathway has not been completely delineated, a major percentage of applied aldicarb is thought to be eliminated from the plant as

volatile metabolites and carbon dioxide, with water soluble conjugates being the major metabolites present at harvest. The only residues of toxicological significance at harvest are aldicarb sulfoxide and aldicarb sulfone (Maitlen et. al. 1968).

Due to the apparent and unusually long effectiveness of aldicarb applications in controlling the aster leafhopper, the following experiments were designed to examine the fate and persistence of this compound in carrots. Carrot was chosen as the test plant to facilitate determination of aldicarb residues in an edible root crop while at the same time monitoring leaf concentrations with respect to insecticidal activity.

The specific objectives with regard to aldicarb in carrot included:

(a) a determination of toxic aldicarb equivalents in the leaf in relation to duration of insecticidal activity in the field,

(b) analysis of aldicarb residues in the root,

(c) an examination of uptake, translocation, distribution and persistence in the plant,

(d) an examination of degradation of total toxic aldicarb and equivalents to non-toxic metabolites, and,

(e) an LC_{50} calculation for total toxic aldicarb equivalents in the leaf with respect to mortality of feeding aster leafhoppers.

Residue analysis of aldicarb in carrot

As previously described in the Materials and Methods

section, the aldicarb rate trial was designed to provide samples of carrot leaves and roots for residue analysis. Five sample dates were used for leaves early in the season (June 28, July 8, 17 and August 1, 16) and for roots late in the season (July 17, August 1, 16, 28 and September 16). Gas chromatographic analysis of total toxic aldicarb equivalents (aldicarb, aldicarb sulfoxide, aldicarb sulfone) was conducted for all samples at each date.

Verification of methodology. Standard curves were developed using injections of technical grade aldicarb sulfone in acetone over a concentration range of 0.9 ug/uL to 12 ug/uL. Originally three standard curves were compared: log ng vs log area; log ng^2 vs log area and log ng vs log peak height. Linear regression analysis to determine the line of best fit showed no difference in accuracy between the standard curves. High correlation coefficients ($r = 0.99$) were obtained. Subsequently peak height was used as the measure of concentration in analysis of the samples.

To ensure the accuracy of the method and in particular to evaluate the oxidation and column separation steps in the procedure, several tests were conducted. In the absence of plant tissue, known quantities of technical grade aldicarb, aldicarb sulfoxide and aldicarb sulfone were carried through the extraction and clean-up procedures. Subsequent gas chromatographic analysis showed the resultant percent recoveries to be high (93 to 105%). Injections of aliquots from fraction I of the

column separation further indicated the absence of toxic metabolites in this fraction. Finally samples of carrot leaves and roots spiked with aldicarb sulfone, aldicarb and aldicarb sulfoxide were analysed and percent recoveries recorded (Table 28 and 29). A tendency towards higher percent recoveries resulted at the lower concentrations. For the range of toxic aldicarb equivalents in the samples,however, the percent recoveries were 88 to 97% for leaves and 96 to 114% for roots. The detection limit was approximately 0.03 ppm.

Toxic aldicarb residuals in carrot leaves and roots. In carrot leaves, total toxic aldicarb residues ranged from 6.86 ppm to 0.16 ppm over the duration of the sample period (Table 30). Residue levels resulting from the high treatment rate (6.72 kg/ha) were 6.86 ppm 51 days after application (and planting), and 0.62 ppm 99 days after application. For the corresponding period, leaf residues as a result of the lowest treatment rate, were 1.41 and 0.16 ppm. A rapid decline in leaf residue levels occurred between the first and second sample days. Over all treatments, an average of 82% of the residue present at day 51,was lost during the next 10 days. The decline in leaf residue levels from day 61 to day 99 averaged 48%.

These results are in agreement with those reported by Andrawes et. al (1973). In the foliage of field grown cotton plants, aldicarb sulfoxide represented the major portion of recovered metabolites during the first 22 days following an in-furrow treatment of ^{14}C-aldicarb. The maximum concentration of

TABLE 28. Recovery of aldicarb (T), aldicarb sulfoxide (T1) and aldicarb sulfone (T2) from carrot leaf samples.

T, T1, T2			
Sample size	Amt.Added	Final conc.	$\bar{x}$ Recovery
g	ug	ppm	%
50	0.75 T2	0.015	135
50	1.5 T2	0.03	112
50	3.0 T2	0.06	105
50	6.0 T2	0.12	97
50	45.0 T2	0.90	94
50	600.0 T2	12.00	88
50	1000.0 T	20.0	82
50	10.0 T	0.18	102
50	10.0 T1	0.16	96
50	10.0 T + 10 T1	0.34	97

TABLE 29. Recovery of aldicarb (T), aldicarb sulfoxide (T1) and aldicarb sulfone (T2) by GLC from carrot root samples.

T, T1, T2			
Sample size	Amt.Added	Final conc.	$\bar{x}$ Recovery
g	ug	ppm	%
50	1.5 T2	0.03	120
50	2.0 T2	0.04	114
50	3.0 T2	0.06	109
50	4.5 T2	0.09	103
50	6.0 T2	0.12	98
50	45.0 T2	0.90	96
50	120.0 T2	2.4	91
50	7.5 T	0.18	97
50	7.5 T	0.16	95
50	7.5 T + 7.5 T1	0.34	94

TABLE 30. Residue levels of total toxic aldicarb equivalents in carrot leaves.

Treatment	Rate kg/ha ai	Total toxic aldicarb equivalents (ppm)[1]				
		Days from planting				
		51	61	70	84	99
Aldicarb G	1.7	1.41	0.31	0.29	0.19	0.16
Aldicarb G	3.4	3.80	0.56	0.48	0.31	0.32
Aldicarb G	5.0	6.13	0.89	0.82	0.57	0.47
Aldicarb G	6.7	6.86	1.37	1.22	0.57	0.62

1. ANOVA and replicated data are included in Table 65 (Appendix).

147 ppm reached at 9 days, subsequently declined rapidly to 45 ppm at 22 days and to 0.7 ppm at 72 days. Concentrations of aldicarb sulfone increased at a slower rate, to a maximum of 39 ppm at 22 days followed by a slow decline. The maximum concentration of aldicarb per se was 2.2 ppm 9 days after planting. He further found foliage concentrations of total aldicarb equivalents to be 209 ppm, at 9 days. Following an initial increase, total aldicarb equivalents declined to 2.4 ppm 86 days after planting. The relative proportions of these metabolites from field grown plants are similar to those reported by Bartley et. al. (1970) as a result of ^{14}C-aldicarb root feeding studies.

At 84 and 99 days after applications both root and leaf samples were analysed (Table 30). At these times, the concentration of toxic aldicarb equivalents in the leaf was 3 to 5 times greater than in the root. Moreover, leaf concentrations at these times were rate related. The leaf/root concentration ratios from low to high treatment rates at day 99 were 3.2, 3.5, 3.9 and 5.0

Rouchand et. al. (1980) conducted a detailed field study of the distribution of ^{14}C-aldicarb in sugar beets following an in-furrow treatment at 3 kg/ha ai. In actively growing plants, 99 days after application, higher concentrations of total aldicarb equivalents were found in external leaf blades (3.16 ppm) and petioles (0.5 ppm) versus internal leaf blades (0.63 ppm) and petioles (0.15 ppm). At the same time the concentration in the root was 0.16 ppm. A similar distribution

of toxic aldicarb equivalents occurred.

Further with respect to beet, Steele (1979) placed transplants in pots containing 1 to 5 ug of aldicarb/g of soil. After 20 days, foliage residues were proportional to root residues but 20 times greater. The proportions of aldicarb, its sulfoxide and sulfone present in foliage at that time were 8.7, 81.6 and 9.8%, respectively.

In carrot roots residue levels of toxic aldicarb equivalents ranged from 0.06 to 0.21 ppm 70 days following application (Table 31). Roots did not accumulate aldicarb and its toxic metabolites. At harvest the residue levels had declined to a range of 0.04 to 0.10 ppm. A slow rate of decline in root residuals is apparent. The concentration of toxic metabolites resultant from the two lower application rates declined by about 32% over the duration of the sample period. At the same time root residues, resulting from the higher treatment rates, declined by about 52%. Residues at harvest were related to the rate of application.

Low residual levels of aldicarb and its toxic metabolites have been reported in other root crops. Rouchand et. al. (1980) found no detectable toxic residues in sugar beets 196 days following an in-furrow application at 3.0 kg/ha ai. In potato no aldicarb was detected 128 to 174 days after treatment at 5 kg/ha ai (Smelt et. al. 1977). During the same period aldicarb sulfoxide and aldicarb sulfone concentrations ranged from 0.02 to 0.77 ppm, with the sulfoxide accounting for

TABLE 31. Residue levels of total toxic aldicarb equivalents in carrot roots.

Treatment	Rate kg/ha ai	Total toxic aldicarb equivalents (ppm) [1]				
		Days from planting				
		70	84	99	111	130
Aldicarb G	1.7	0.06	0.06	0.05	0.05	0.04
Aldicarb G	3.4	0.10	0.10	0.09	0.08	0.06
Aldicarb G	5.0	0.14	0.12	0.12	0.12	0.07
Aldicarb G	6.7	0.21	0.13	0.12	0.11	0.10

1. ANOVA and replicated data are included in Table 66 (Appendix).

42 to 76% of the total. Residues in the peel were 11% higher than in peeled potatoes. As well, cooking or storage at 2°C for 2 months, decreased the residue by 42 - 55%.

Further, Carey and Helrich (1970) found aldicarb sulfoxide concentrations of 0.09 and 0.11 ppm in potato 5 months after in-furrow and broadcast aldicarb applications at 3.36 and 5.6 kg/ha ai, respectively.

George et. al. (1975) sampled potatoes at various times during the season following a 3.36 kg/ha ai treatment at planting. Residues in the tubers peaked early in the season and declined to a range of 0.04 to 0.38 ppm at harvest.

Since moisture and soil type directly affect the degradation and persistence of aldicarb in soils (Andrawes et. al. 1971; Smelt et. al. 1978), direct comparisons of the above results cannot be made. In all cases, however, levels of toxic aldicarb equivalents resulting from field applications were low in roots at harvest, and in the order of 0.1 ppm. Residues did not accumulate in the root even though leaf concentrations were proportionally higher.

Studies with ^{14}C-aldicarb

Following the analysis of residual toxic aldicarb equivalents in carrot roots and leaves, a more detailed study was initiated to investigate the fate of aldicarb in carrot with respect to duration of control of the aster leafhopper.

The first of two experiments utilizing radio-labelled ^{14}C-aldicarb was designed to investigate uptake and trans-

location as well as distribution and persistence of aldicarb and resultant metabolites in carrot over time, following a single dose root application of ^{14}C-aldicarb. Further, the degradation of total toxic aldicarb and equivalents (organo-soluble) to non-toxic water soluble metabolites was monitored. Of the 7 plants harvested at each sample time (12 hour, 1, 3, 7, 15, 30 and 45 days) one plant was used for autoradiography and 3 plants were used in a bioassay test to estimate leaf concentrations required for 50 and 100% mortality of feeding aster leafhoppers. The remaining plants were analysed for total radioactivity in the roots as well as total radio-activity in both the organic and aqueous leaf extracts. Since the degradation of aldicarb in carrots was rapid, calculated ug amounts based on the specific activity for ^{14}C-aldicarb (0.004 u Ci/ug), represent total aldicarb and metabolites and are referred to as aldicarb equivalents.

At zero time, all test plants were suspended in test tubes containing 450 ug ^{14}C-aldicarb per 40 mL (i.e. 11.25 ppm) of nutrient solution. Mean uptake during the subsequent 12 hour feeding period was 132.2 g or 29.4% of applied radio-activity (Table 32). This rapid rate of uptake of aldicarb from the nutrient solution resulted in an initial concentra-tion of aldicarb and equivalents on a whole plant (F.W.) basis of 38.5 ppm.

Following uptake, translocation from root to shoot was also rapid. At 12 hours,ug amounts of aldicarb equivalents in the shoot and root were 71.0 and 58.0 respectively. The

TABLE 32. Fate of aldicarb in carrot roots and leaves over time following a single dose root application of ^{14}C-aldicarb.

Time (days)	$\bar{x}$ uptake (ug)	^{14}C-aldicarb equivalents (ug)[1,5]					Distribution % of total[3]		Distribution % of total leaf[4]		Leaf organic % total plant ^{14}C
		Leaf[2]			Root	Plant					
		Organic	Aqueous	Total	Total	Total	Leaf	Root	Organic	Aqueous	
0.5	143.4	63.8	7.2	71.0	58.0	129.0	55.1	44.9	89.9	10.1	49.5
1	159.8	65.8	15.5	81.3	50.2	131.5	61.8	38.2	80.9	19.1	50.0
3	143.4	43.7	18.1	61.7	31.6	93.3	66.1	33.9	70.8	29.2	46.8
7	103.5	20.8	15.2	36.0	14.1	50.1	71.9	28.1	57.8	42.2	41.5
15	116.3	19.5	20.6	40.1	8.4	48.5	82.7	17.3	48.6	51.4	40.2
30	128.6	6.0	13.5	19.5	4.2	23.7	82.3	17.7	30.8	69.2	25.3
45	130.4	2.7	11.6	14.3	0.7	15.0	95.3	4.7	18.9	81.1	18.0
	$\bar{x}$. = 132.2 (29.4%)										

1. $\bar{x}$ of 3 plants/treatment. 2. Aldicarb equivalents (ug) present in organic (org.) and aqueous (aq).
3. % of total recovered ^{14}C in leaf and root. 4. % of total leaf ^{14}C in organic and aqueous extracts.
5. Replicated data are included in Table 67 (Appendix).

total amount (129.0 ug) represented a 90% recovery of original uptake. Radioactivity in the roots subsequently declined, rapidly at first, then more slowly over the duration of the experiment (Figure 6). Rapid upward movement was followed by a loss of activity from the leaves at a somewhat slower rate than from the roots. Thus from Day 15 to Day 45 only low levels of radioactivity were found in the roots in relation to the amount available in the whole plant, suggesting that little downward movement occurs and is likely a passive process. At Day 45 only 0.5% of original uptake was recovered from the roots as compared to 11.6% from the leaves.

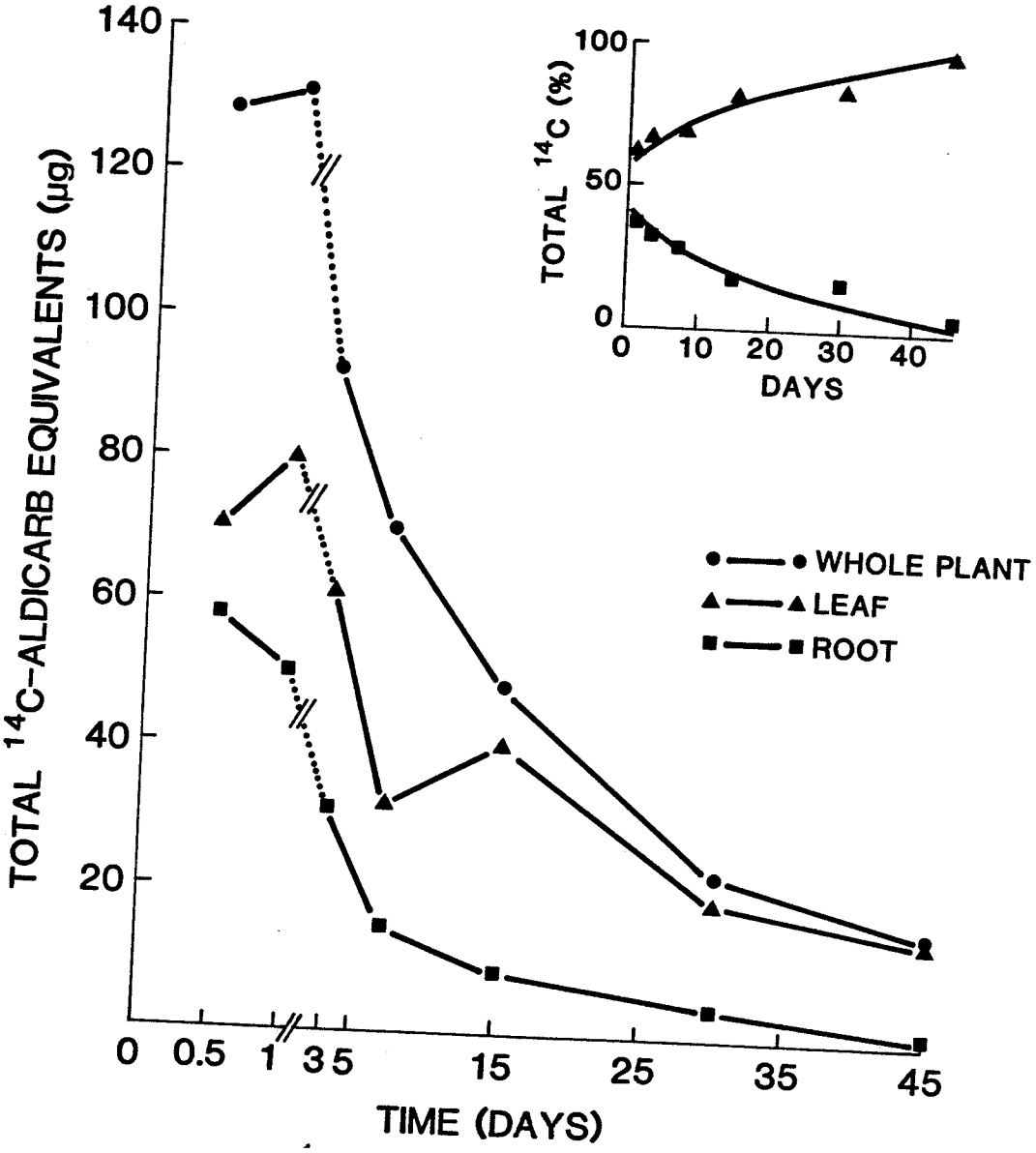
These results are approximated by a first order rate equation. When the logarithms of ug amounts remaining in the roots are plotted over time the resultant curve approximates a straight line. Thus the rate of elimination from the root and subsequently the plant is dependent upon the first power of the concentration and a rate constant may be calculated (Barrow 1961, Smelt et. al. 1978). In this experiment the rate constants for elimination of aldicarb equivalents from carrot roots and leaves were determined to be 0.11 day^{-1}, and 0.04 day^{-1} respectively. In addition the half-life of aldicarb equivalents in the root was 6.5 days and in the leaves was 17.8 days.

Aldicarb and equivalents were not persistent in the carrot plant. Of the radioactivity taken up during the feeding period (129 ug aldicarb equivalents) 90% was recovered

Figure 6. Total ^{14}C-aldicarb equivalents remaining in carrot roots and leaves over time, following a single dose root application of ^{14}C-aldicarb.

A change in scale of the X axis and thus a change in slope of the curves between days 1 and 3 is shown as.. .....

Insert. Percentage of total recovered ^{14}C-aldicarb equivalents present in carrot leaves and roots over time following a single dose root application of ^{14}C-aldicarb.


TOTAL ^{14}C-ALDICARB EQUIVALENTS (µg)
140
120
100
80
60
40
20
0
0.5
1
3
5
15
25
35
45
TIME (DAYS)
WHOLE PLANT
LEAF
ROOT
TOTAL ^{14}C (%)
100
50
0
0
10
20
30
40
DAYS

at 12 hours (Table 33). The percent remaining declined rapidly over the 45 day duration of the experiment. At 45 days only 12.1% of uptake was recovered. Conversely 87.9% of ^{14}C activity was eliminated from the plant in 45 days. The rate constant for loss of aldicarb equivalents from the whole plant was found to be 0.05 day^{-1}. Subsequently the half-life of aldicarb and equivalents following a single dose root feeding as described, was calculated at 13.9 days.

With respect to distribution of aldicarb equivalents in the plant, approximately equal proportions of uptake were recovered from the root (41.6%) and shoot (49.4%) at the 12 hour sample time. Expressed as a percentage of total recovered ^{14}C, at 12 hour 44.9% and 55.1% were found in root and shoot respectively (Figure 6, Insert). Over the duration of the experiment, an increasingly greater percentage of total plant ^{14}C was found in the leaves, until at the completion of the experiment, 95.3% was recovered from the leaves as compared to 4.7% in the roots. These results therefore concur with the residual studies previously discussed.

Rapid translocation from the root combined with a sharp decline in leaf radioactivity indicates that aldicarb is quickly degraded and/or eliminated from carrot foliage. Of the total ^{14}C-aldicarb equivalents remaining in the leaf at 12 hours (71.0 ug), the majority was organo-soluble metabolites (63.8 ug) as compared to water soluble or aqueous metabolites (7.2 ug) (Table 32). Degradation of organo-solubles to water

TABLE 33. Distribution of radioactivity and leafhopper mortality at various times following single dose root feeding of carrots with ^{14}C-aldicarb.

Time (days)	^{14}C-aldicarb equivalents remaining (% of uptake) [2]							
	Leaf			Root		Leaf	Leafhopper Mortality (%)	
	Organic	Aqueous	Total	Organic + Aqueous	Total	Organic/Aqueous	24 hr.	48 hr.
0.5	44.4 (35.8) [1]	5.0 (4.4)	49.4	40.6 (37.4)	90.0	8.9	100	100
1	41.7 (24.2)	9.9 (5.8)	51.6	31.3 (20.0)	82.9	4.2	100	100
3	30.3 (13.6)	12.7 (5.8)	43.0	22.1 (12.3)	65.1	2.4	100	100
7	19.6 (5.6)	14.2 (4.1)	33.8	14.2 (4.9)	48.0	1.4	76.4	100
15	16.9 (1.5)	17.3 (1.8)	34.2	6.9 (1.0)	41.1	1.0	43.9	87.8
30	5.0 (0.3)	11.0 (0.7)	16.0	3.1 (0.5)	19.1	0.5	8.3	15.0
45	2.3 (0.07)	9.3 (0.3)	11.6	0.5 (0.014)	12.1	0.2	----	----

1. Figures in brackets are concentration (ppm) of ^{14}C-aldicarb equivalents remaining.
2. Replicated data are included in Table 67 (Appendix).

solubles was rapid (Figure 7). Further the early onset of degradation of toxic metabolites is shown by the decreased slope of the organo-soluble curve (12 hour to 1 day) as compared to the slope of the curve representing the amount in the leaves. Although some loss of volatile metabolites may occur, the degradation to water soluble metabolites is shown. A rate constant of 0.08 day^{-1} and a half-life of 8.7 days were calculated for degradation/elimination of metabolites recovered in the organic fraction. The aqueous curve reached a broad peak at 10 to 15 days which was followed by a gradual decline in the amount of water soluble metabolites.

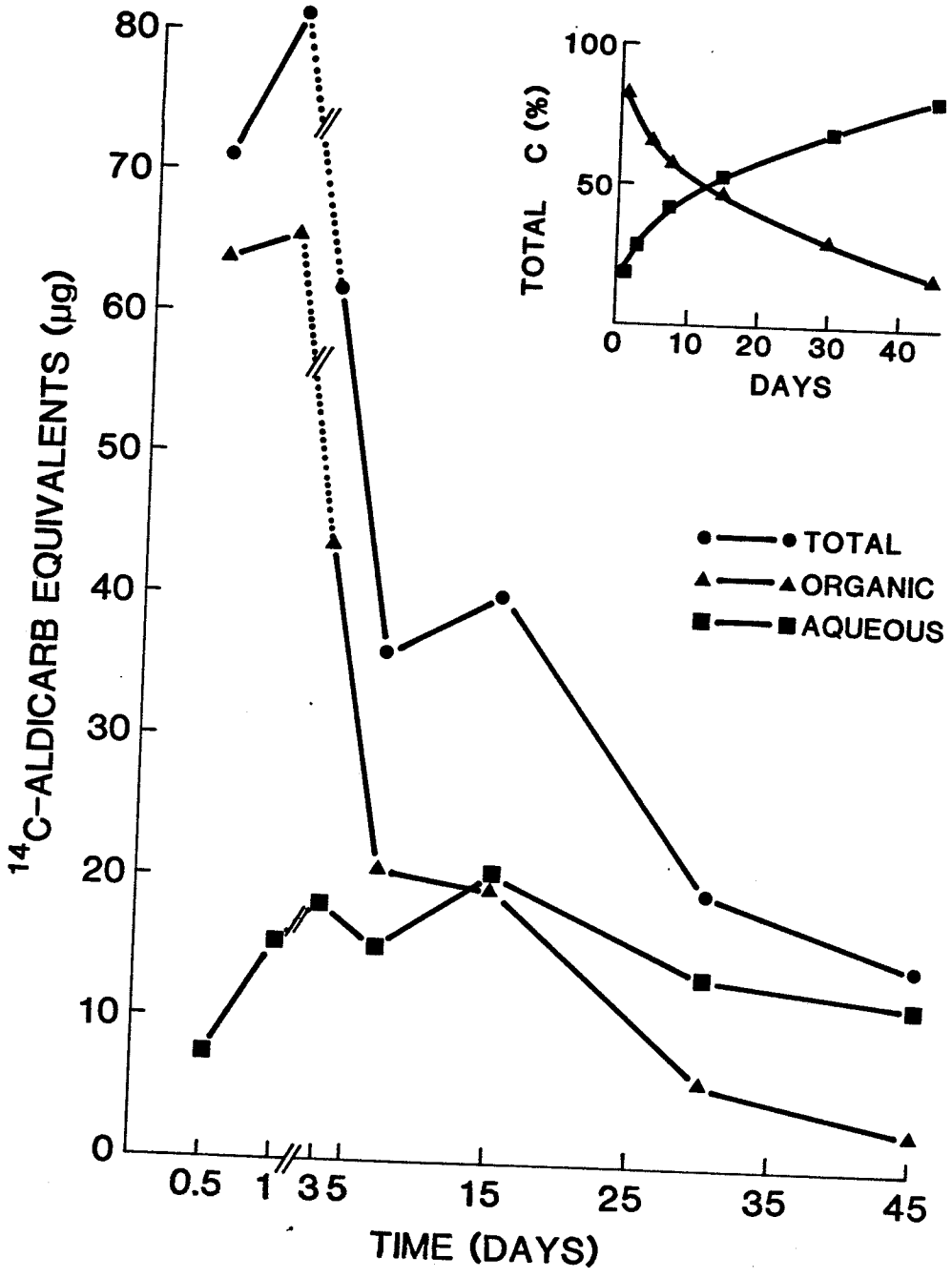
Of the total radioactivity recovered from the leaf 89.9% was found to be organo-soluble at 12 hours, while 11.1% was in the aqueous phase (Figure 7, Insert). The amount in the organic fraction declined rapidly over the duration of the experiment and was accompanied by a corresponding increase in water soluble aldicarb equivalents. The organic/aqueous partition coefficient was 1.0 at about 15 days and 0.2 at 45 days. At Day 45, 81.1% of the total leaf ^{14}C-aldicarb equivalents were present as water soluble metabolites. This rapid conversion of organo to water soluble metabolites is somewhat faster than reported by Bartley et. al. (1970) as a result of metabolic studies in cotton. However, experimental conditions were quite different.

The levels of organic and aqueous metabolites in the leaf were also examined as a percentage of uptake remaining and on a concentration basis (Table 33). On a whole plant basis, 90%

Figure 7. Organo and water soluble metabolites of ^{14}C-aldicarb remaining in carrot leaves over time following a single dose root application of ^{14}C-aldicarb.

A change of scale of the X axis and thus a change in slope of the curves between days 1 and 3 is shown as... .....

Insert. Organo and water soluble metabolites of ^{14}C-aldicarb in carrot leaves, expressed as a percentage of total ^{14}C-aldicarb equivalents recovered from the leaf over time, following a single dose root application of ^{14}C-aldicarb.


80
70
60
50
40
30
20
10
0
^{14}C-ALDICARB EQUIVALENTS (µg)
0.5
1
3
5
15
25
35
45
TIME (DAYS)
TOTAL
ORGANIC
AQUEOUS
100
50
TOTAL C (%)
0
10
20
30
40
DAYS

of ^{14}C uptake was recovered at 12 hours. Of the radioactivity present in the leaf at that time, 44.4% and 5.0% were recovered from the organic and aqueous fractions, respectively (Figure 8). At 15 days the corresponding percent recoveries were 16.9 and 17.3 (i.e. O/A partition coefficient = 0.98). Assuming the curves approximate first order kinetics, the increased percent and concentration of the water soluble metabolites are dependent on the initial high concentration of organo-soluble metabolites (also assumes organic conversion to aqueous and constant elimination). The rapid decrease in concentration of organic metabolites results from degradation and elimination as well as dilution due to plant growth. Following the initial increase in aqueous concentration, the rate constant for elimination of this metabolite from the leaf (using the ug amount data) was 0.02 day^{-1}.

Finally, the levels of organic aldicarb equivalents in the leaf, expressed as a percentage of the total plant radioactivity declined slowly from a maximum of 45.5% at 12 hours to 18.0% at 45 days (Table 32 and Figure 9). This relatively slow decline of toxic metabolites in the leaves is necessary for an extended duration of insecticidal activity in the field. Further, under constant feed conditions the level and duration of toxic equivalents in the leaves would be dependent on the amount of aldicarb applied and the rate of degradation in the soil. This conclusion as well, is supported by the results of the residue analysis. Concentrations of toxic aldicarb

Figure 8. Organo and water soluble metabolites of ^{14}C-aldicarb in carrot leaves over time following a single dose root application of ^{14}C-aldicarb. (Expressed as a percentage of uptake remaining, and concentration).

A change in scale of the X axis and thus a change in slope of the curves between days 1 and 3 is shown as..
.....

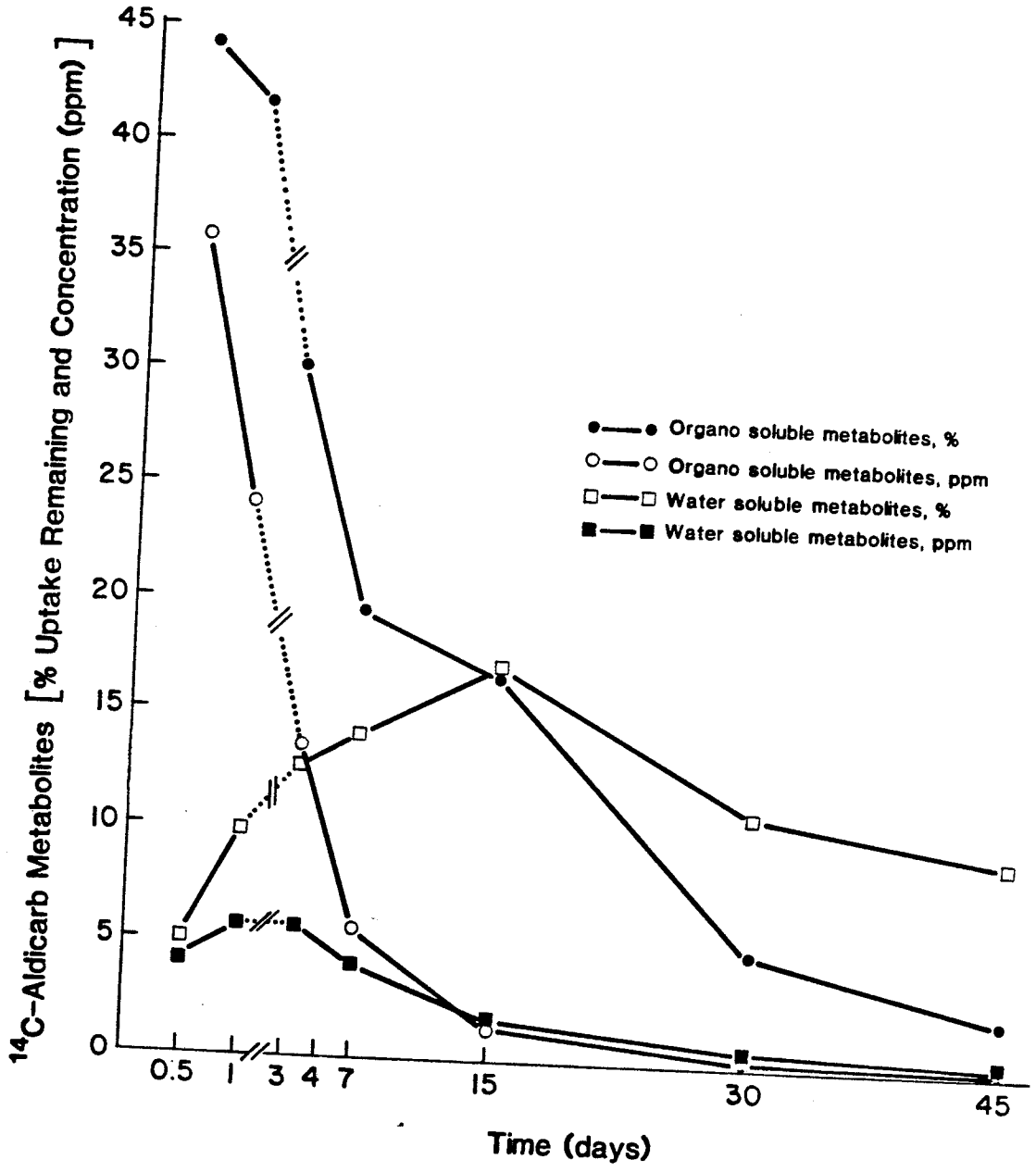
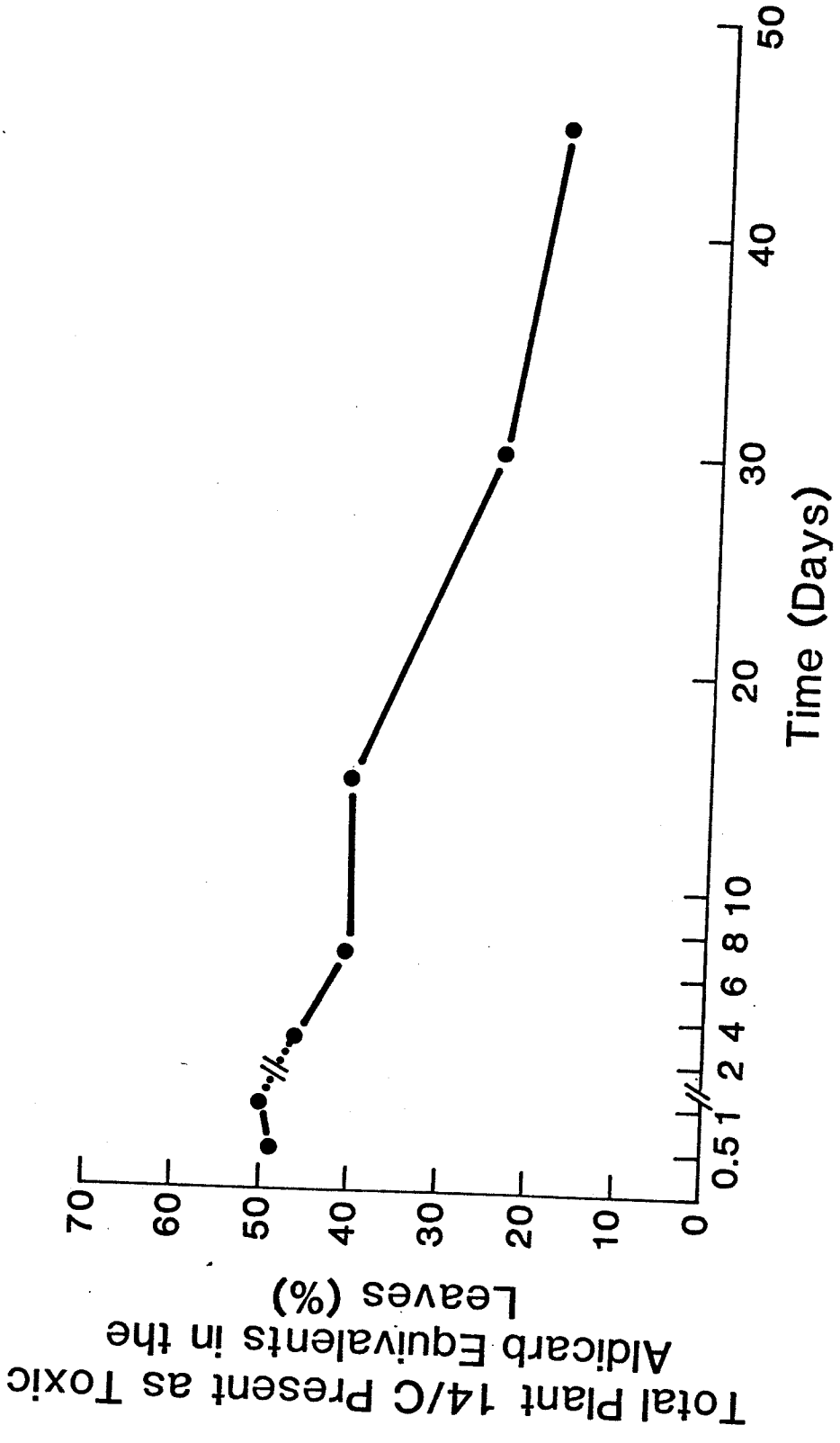

^{14}C-Aldicarb Metabolites [% Uptake Remaining and Concentration (ppm)]
45
40
35
30
25
20
15
10
5
0
0.5
1
3
4
7
15
30
45
Time (days)
Organo soluble metabolites, %
Organo soluble metabolites, ppm
Water soluble metabolites, %
Water soluble metabolites, ppm

Figure 9. Total toxic aldicarb equivalents in carrot leaves expressed as a percentage of total plant ^{14}C over time, following a single dose root application.


Total Plant 14/C Present as Toxic
Aldicarb Equivalents in the
Leaves (%)
70
60
50
40
30
20
10
0
0.5 1 2 4 6 8 10
20
30
40
50
Time (Days)

equivalents in the leaves and roots over the duration of the sample period were rate related. Moreover, the relative proportion of toxic equivalents in the leaf increased as the rate of application increased. For the 1.7 and 6.7 kg/ha rates, concentrations in the leaf were 3.2 and 5.0 times greater, respectively, than in the root, 99 days after application.

Autoradiographs. At each sample date in the above experiment one plant was used for autoradiographic analysis. ^{14}C-aldicarb was rapidly absorbed by carrot roots and translocated to the foliage. Radiocarbon was present in stems and leaves at 12 hours (Figure 10). In addition, the distribution of activity was relatively even. Rapid movement through the xylem is suggested by the higher concentrations at the leaf tips, and to some extent at the leaf margins. With respect to ^{14}C-phorate in broadbean plants Galley and Foerster (1976) explained this observation as due to the "combined effects of evaporation and, possibly, the selective action of transfer cells in the passage of the remainder of the stream to the phloem." That redistribution does occur is illustrated by the distribution of radioactivity in new leaves of plants removed from the treatment solution 30 days previous (Figure 13). Although the autoradiographs do not suggest the nature of the metabolites present, Figure 8 shows the concentrations of aldicarb sulfoxide and sulfone to be about 13 and 6 ppm, respectively, at Day 3 (Figure 11) and 6 and 4 ppm, respectively, at Day 7

Figure 10. Distribution of radioactivity in carrot leaves immediately following a 12 hour root treatment of ^{14}C-aldicarb applied via the nutrient solution (11.25 ppm).

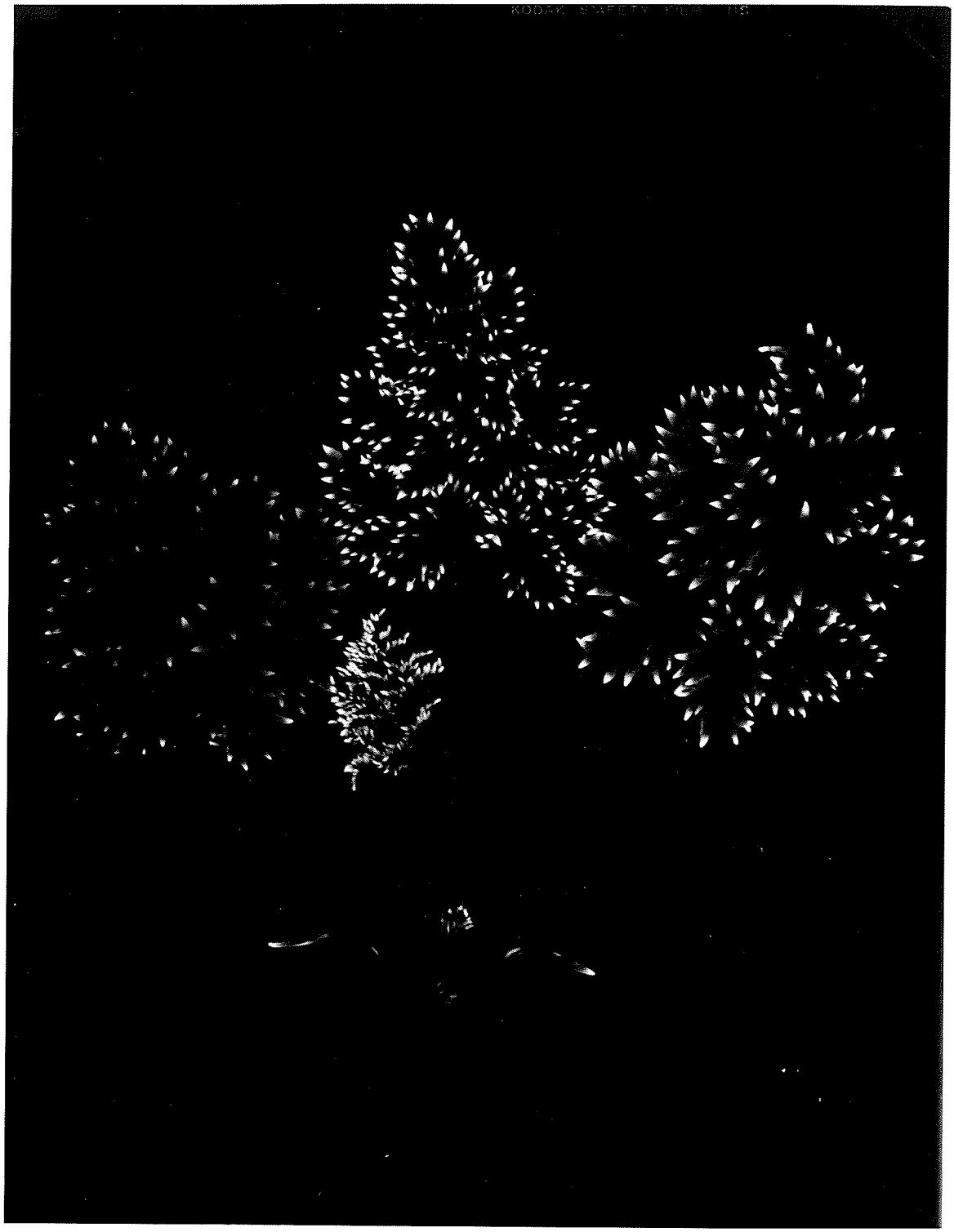


Figure 11. Distribution of radioactivity in carrot leaves 3 days following a 12 hour root treatment of ^{14}C-aldicarb applied via the nutrient solution (11.25 ppm).

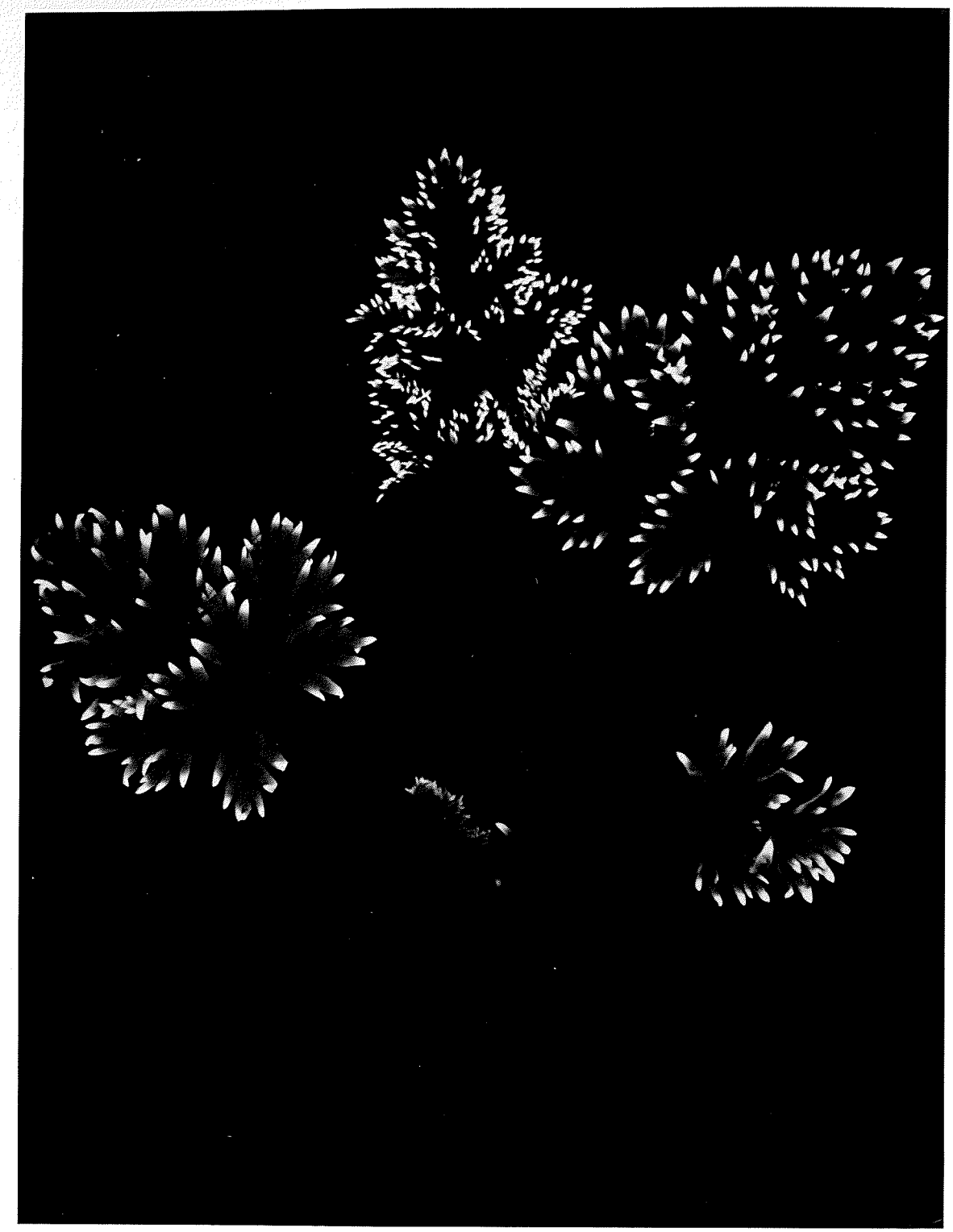


Figure 12. Distribution of radioactivity in carrot leaves 7 days following a 12 hour root treatment of ^{14}C-aldicarb applied via the nutrient solution (11.25 ppm).

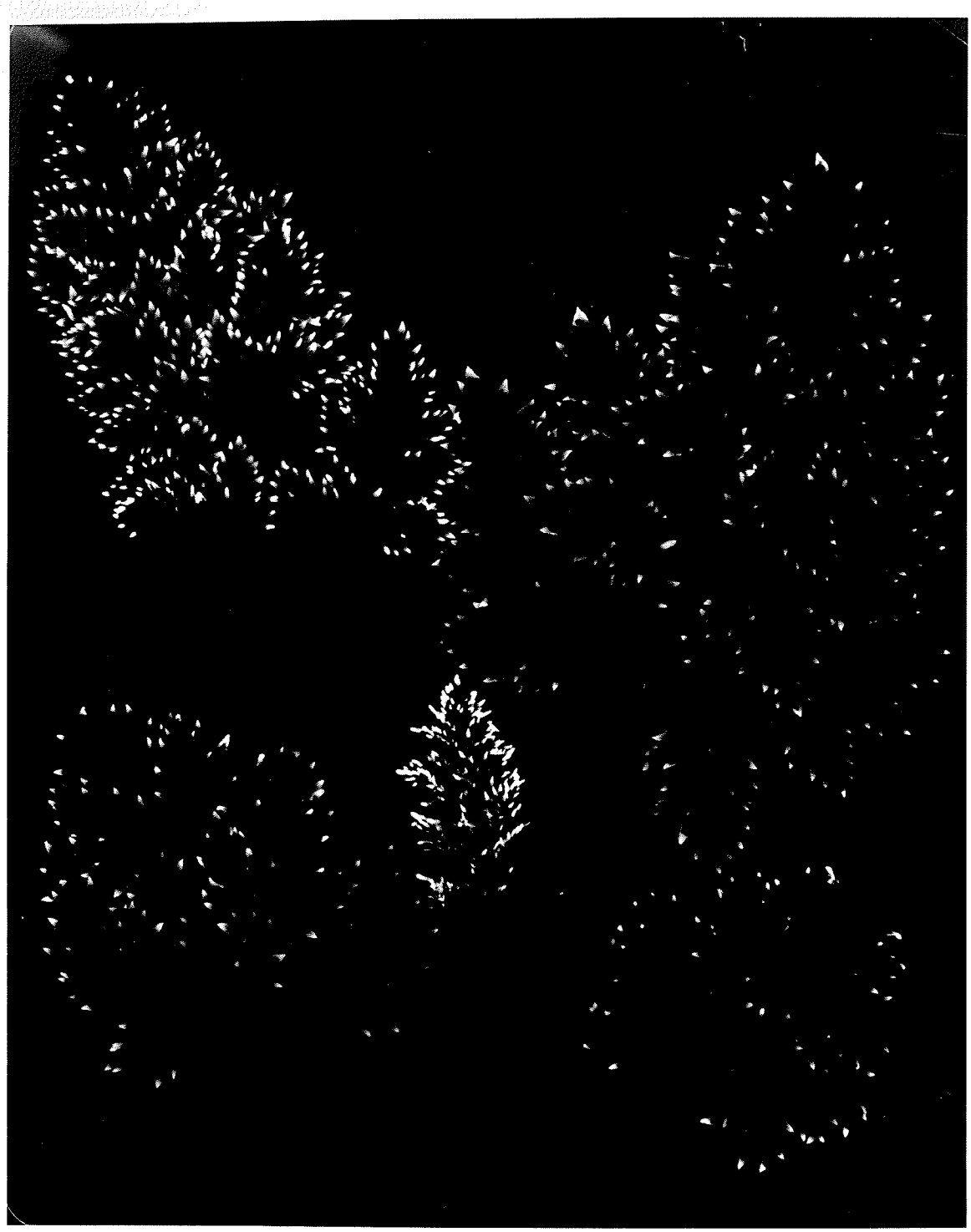
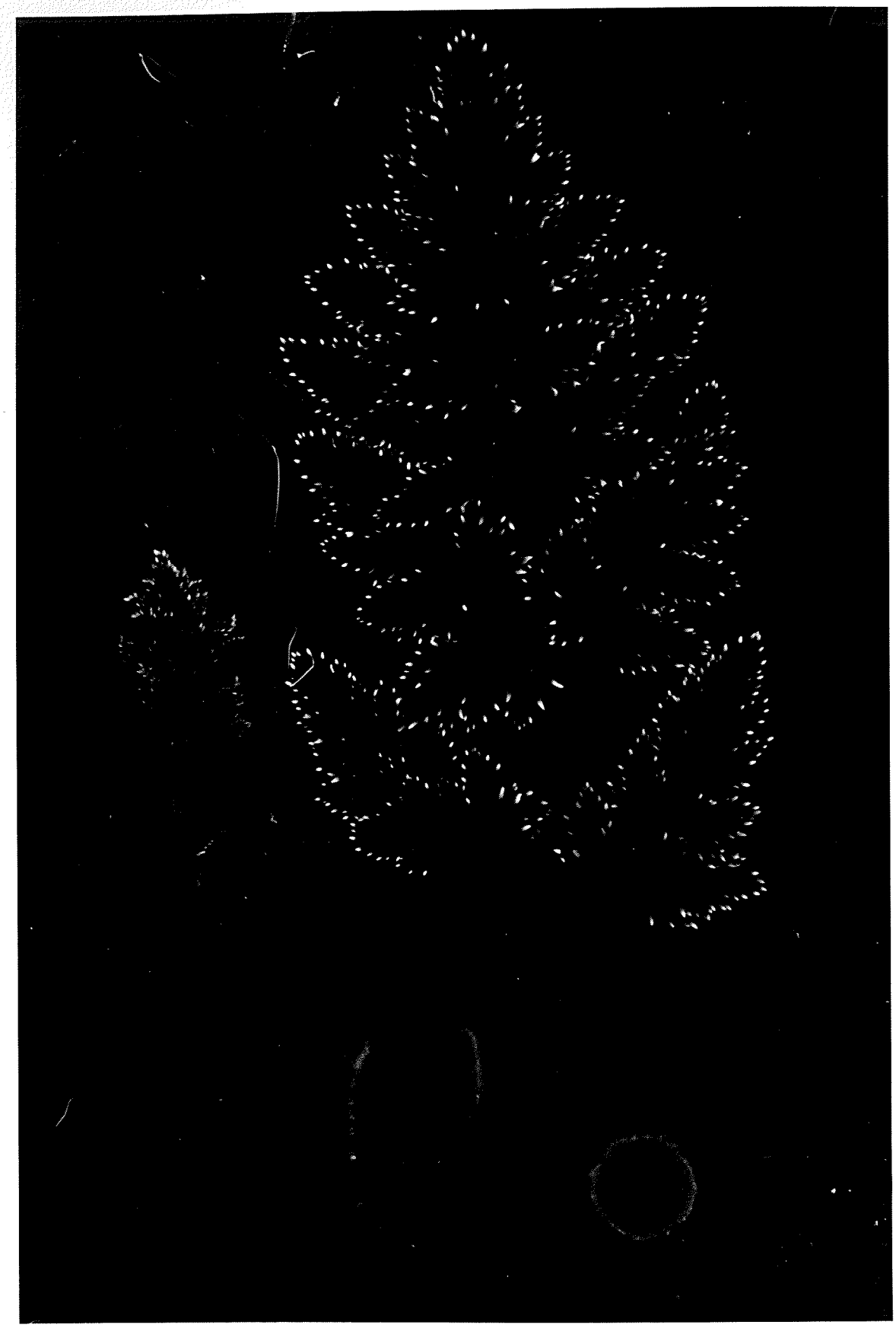


Figure 13. Distribution of radioactivity in carrot leaves and roots, 30 days following a 12 hour root treatment of ^{14}C-aldicarb applied via the nutrient solution (11.25 ppm).



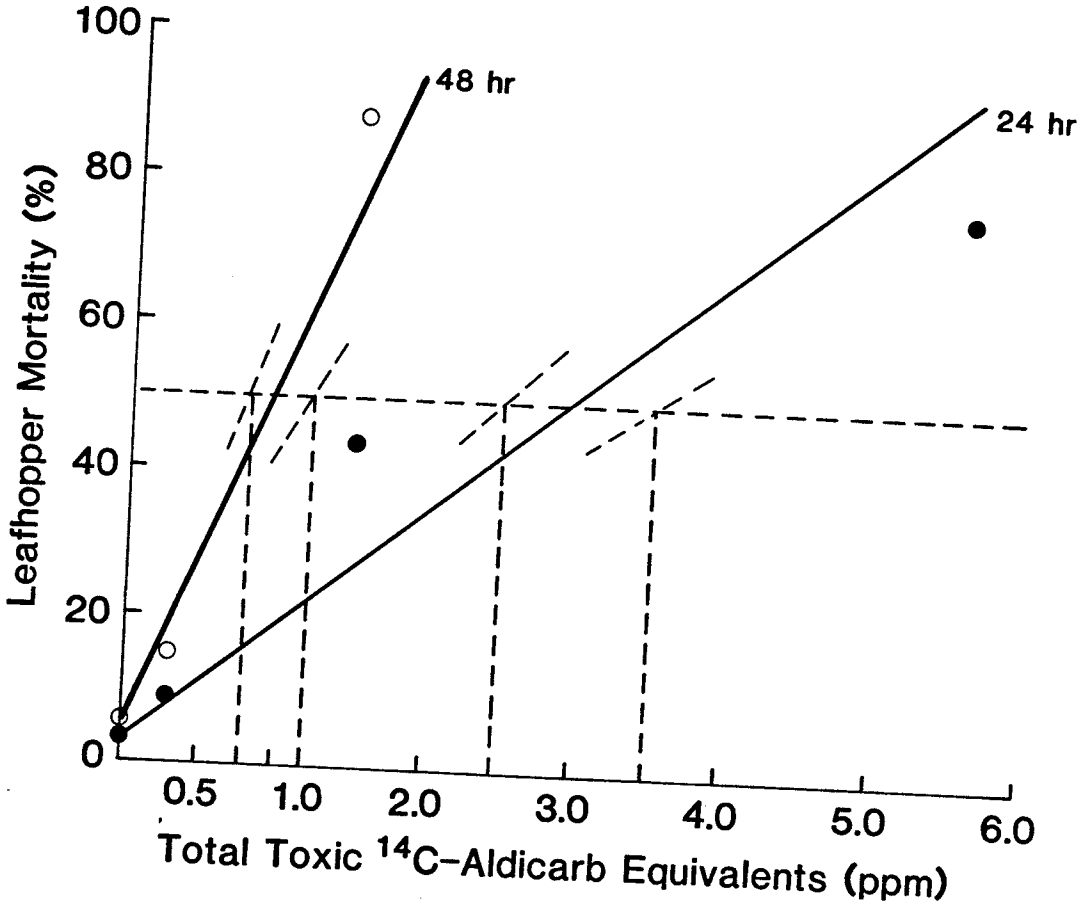
(Figure 12). In the root, radioactivity is primarily located in the cortex with residual quantities of activity present throughout the sections (Figure 13). Finlayson et. al. (1976) reported a similar distribution pattern for carbofuran, ethion and phorate in carrot roots.

LC_{50} Estimate. Prior to initiation of an experiment to determine the LC_{50} for total toxic aldicarb in carrot foliage required for mortality of feeding aster leafhoppers it was desirable to have an estimate of the concentrations necessary to achieve 50 and 90% mortality. The mortality results obtained in this preliminary test (Table 33) were used as treatment guidelines for the following experiment. The LC_{50} estimates for 24 and 48 hours were approximately 3.0 and 1.0 ppm, respectively (Figure 14).

LC_{50} Determination

According to the data in Table 33 and Figure 8 a 450 ug ^{14}C-aldicarb root treatment as described, resulted in a toxic aldicarb equivalent concentration in the leaf of 5 to 13.6 ppm at approximately Day 5. Leafhopper mortality was 76 to 100%. In the following experiment, conducted to accurately determine the LC_{50} values for 24 and 48 hours, a treatment range of 0 to 500 ug ^{14}C-aldicarb/40 mL of nutrient solution was therefore utilized. A 5 day delay between removal of plants from the treatment solution and placement of leafhoppers was allowed to avoid the sharp decline in the

Figure 14. Lethal concentration (LC) estimate of total toxic ^{14}C-aldicarb equivalents (ppm) in carrot leaves, in relation to mortality of the aster leafhopper during feeding periods of 24 and 48 hours.


100
80
60
40
20
0
Leafhopper Mortality (%)
48 hr
24 hr
0.5
1.0
2.0
3.0
4.0
5.0
6.0
Total Toxic ^{14}C-Aldicarb Equivalents (ppm)

organic aldicarb equivalent concentration shown in Figure 8.

An average uptake of ^{14}C-aldicarb from the nutrient solution of 24.1% resulted in a range of treatment concentrations in the leaf of 0.7 to 15.4 ppm toxic aldicarb equivalents (Table 34). Leafhopper mortality ranged from 4.0% to 89% in 24 hours and from 6.0% to 100% in 48 hours.

Lethal concentrations in the leaf required for 50 and 95% mortality at 24 and 48 hours, were calculated by probit analysis (Busvine, 1971). The concentrations of toxic aldicarb equivalents required for 50% mortality were 3.44 ppm in 24 hours and 1.24 ppm in 48 hours (Figure 15). Toxic concentrations in field leaf samples, as determined by residue analysis, were approximately equivalent to these calculated values 51 days following aldicarb in-furrow applications at 3.4 and 1.7 kg/ha (Table 30). Furthermore these concentration levels, at 51 days, are consistent with the expected and claimed duration of field activity of 7 - 9 weeks (Anon, 1970; Coppedge, et. al. 1967; Andrawes, et. al. 1971).

The LC_{95} (48 hours) was 16.7 ppm. Unexpectedly the LC_{95} (24 hours) was extremely high at 277.3 ppm. The corrected percent mortality was therefore plotted against the concentration of toxic equivalents as well as the logarithm (+1) of the concentration (Figure 16). The curves representing mortality in 48 hours were as expected. However, the 24 hour mortality curves are strongly skewed at high percent mortalities. This was interpreted as a lack of feeding by some of

TABLE 34. The effect of aldicarb (and toxic equivalents) on leafhopper mortality and AY disease transmission to carrot during feeding periods of 24 and 48 hours.

Treatment ug ^{14}C-aldicarb per 40 mL	Uptake		Leaf conc.	Mortality (%) [1] after		Disease incidence
	ug	%	ppm	24 hrs.	48 hrs.	%
500	92.2	20	15.4	89	100	20
300	50.3	18	7.6	76	100	40
200	46.7	25	3.6	66	97.5	30
100	27.4	29	2.8	58	93.5	10
75	18.4	26	2.1	24	87.3	20
50	12.8	26	1.1	13	38.0	30
12.5	3.3	25	0.7	5	25.5	10
0	----	--	---	4	6.0	60

1. Replicated data are included in Table 68 (Appendix).

Figure 15. Probit analysis of aster leafhopper mortality after feeding periods of 24 and 48 hours on carrot leaves containing a range of concentrations of total toxic aldicarb equivalents.

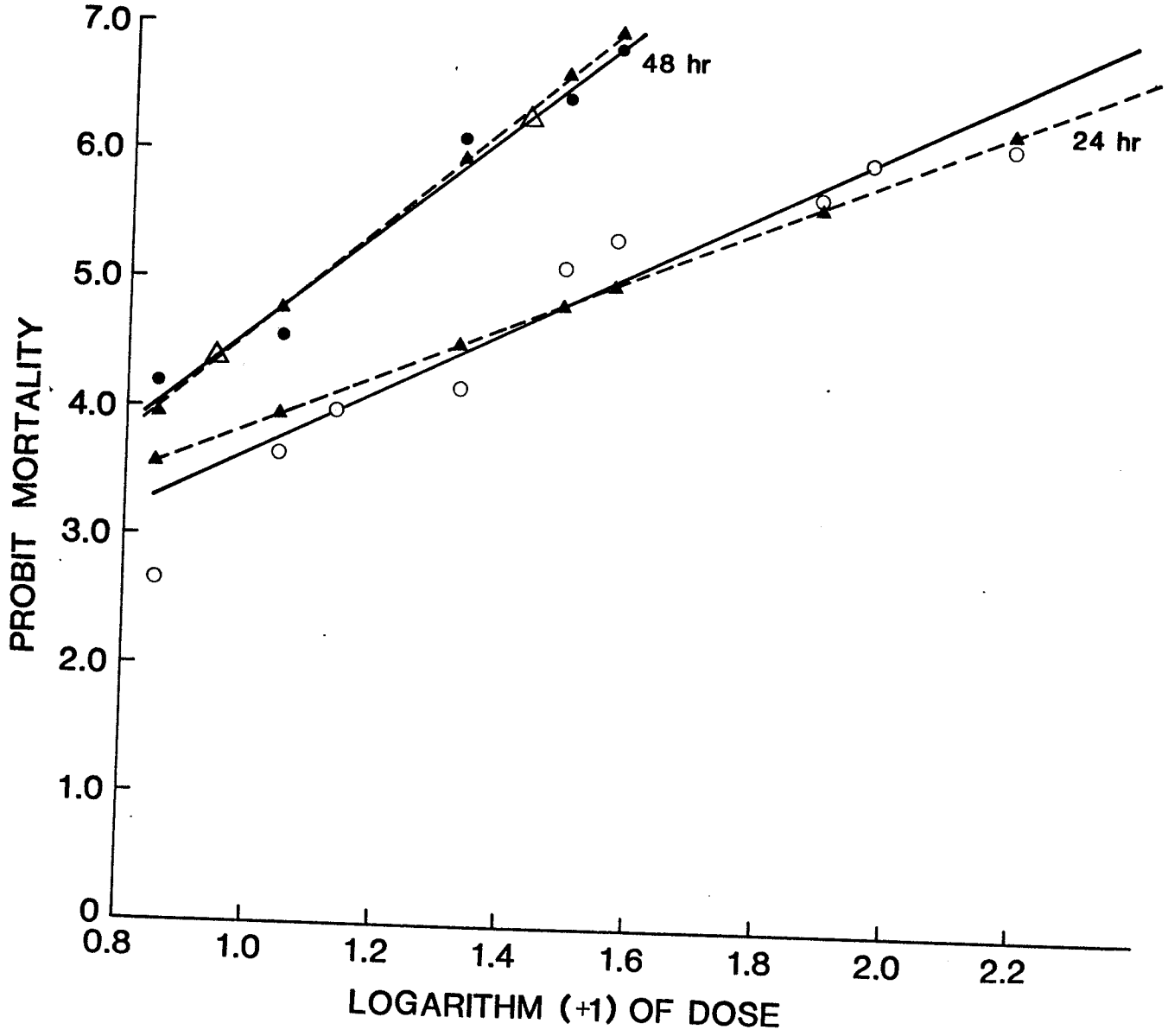
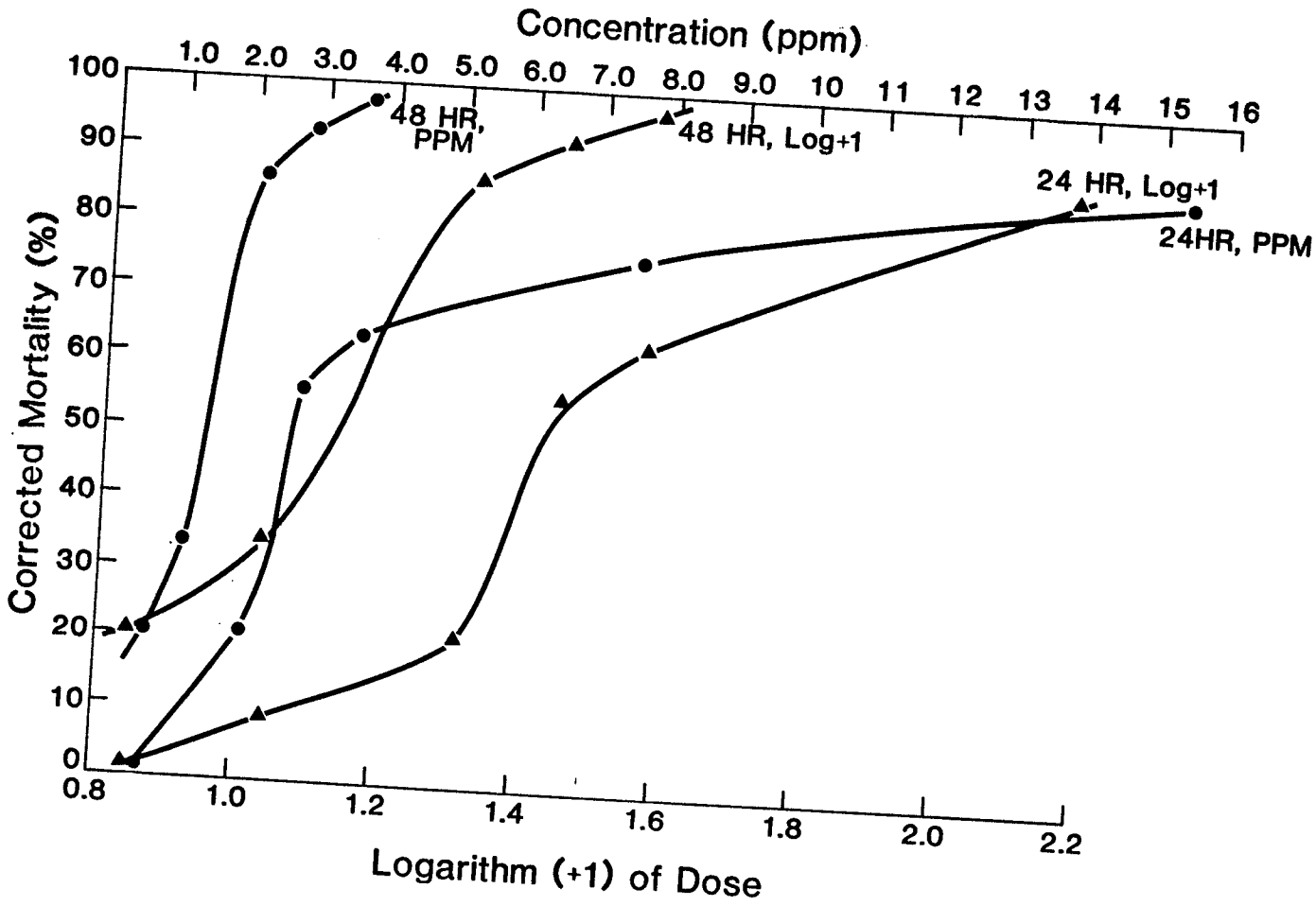

7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
PROBIT MORTALITY
48 hr
24 hr
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
LOGARITHM (+1) OF DOSE

Figure 16. Aster leafhopper mortality during 24 and 48 hour feeding periods, as a function of concentration (ppm and log (+1) ppm) of toxic aldicarb equivalents in carrot leaves.


Concentration (ppm)
1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10 11 12 13 14 15 16
100
90
80
70
60
50
40
30
20
10
0
Corrected Mortality (%)
48 HR, PPM
48 HR, Log+1
24 HR, Log+1
24HR, PPM
0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
Logarithm (+1) of Dose

the test insects. As well, the possibility of avoidance from feeding due to a repellant action of the insecticide in the plant is suggested.

Furthermore, the calculated LC_{50} and LC_{95} values are generally higher than those reported by David (1973). Utilizing a bioassay to estimate the decline in insecticidal activity of aldicarb, in 3 crop plants, the LC_{50} and LC_{95} values with respect to mortality of the aster leafhopper were 0.88 and 2.3 ppm, respectively. Concentrations of toxicant in the plant however, were not directly determined. Instead, artificial feeding through Parafilm M on various concentrations of aldicarb in glucose was used to estimate potency. Leafhopper mortality as a result of feeding on the various crops was then utilized as a measure of aldicarb concentration in the plant. Since this procedure does not take into account a possible repellent activity or the heterogeneous distribution of aldicarb in the plant (Rouchand et. al. 1980), the lethal concentrations may be underestimated. As shown in this thesis, aldicarb resulted in superior performance during three years of field trials, whereas David (1973), on the basis of bioassay studies reported aldicarb as being less potent than carbofuran and phorate.

The leafhoppers utilized in this trial were first allowed a feeding period on AY diseased plants as described in the Materials and Methods section (Aster Yellows Transmission). Although the actual percentage of infectious leafhoppers was

not determined, a random sample was caged on each plant in the test. Carrot yellows incidence in control plants was 60% (Table 34). Disease incidence was reduced in treated plants; however, no relation between leafhopper mortality and disease incidence was apparent. The mean infection of treated plants was 22.8% and the average yellows reduction was 62%.

Since the lethal concentrations were determined for periods of 24 and 48 hours and disease incidence was not related to leafhopper mortality (excluding the control), transmission trials were conducted to assess disease incidence resulting from feeding periods of 1 to 48 hours (Table 35). Disease incidence on carrot averaged 41%. No differences were noted between the inoculation access periods tested. Studies previously conducted by Chiykowski (1958) and Strong and Rawlins (1958) have demonstrated the short inoculation threshold for transmission of aster yellows by the aster leafhopper. Subsequently Lee (1961) showed AY transmission to be exponential from 7.5 minutes to 32 hours. These studies combined with the results of Maramorosch (1953) clearly show that transmission of aster yellows may occur during inoculation feeds as short as 7 to 15 minutes. In the results reported here, even though high percent mortalities resulted from leafhoppers feeding on plants containing a high concentration of toxicant, transmission still occurred.

TABLE 35. Effect of inoculation access period on transmission of AY to carrot by infectious leafhoppers.

Host	Inoculation access period hrs	Disease transmission %
Aster	48	42
Carrot	1	40
	2	44
	4	56
	8	41
	12	28
	24	44
	48	34
Flax	48	25

SUMMARY AND CONCLUSION

In Manitoba, aster yellows disease is the limiting factor in lettuce production and may result in reduced yield and quality of celery and carrots. In addition, yield reductions in susceptible field crops have occurred. The disease has the potential to reach severe or even epidemic proportions, as occurred in 1957, 1963 and 1966 and may result in significant economic loss to growers.

The incidence and severity of AY is primarily dependent on influxes of migrant leafhoppers, which first arrive in Manitoba each spring between mid-May and early June. Since the adult does not overwinter locally, the migrant population represents the main source of disease inoculum. A critical situation thus exists when efficient vectors, a certain percentage of which are persistently infectious, invade an area when many susceptible crops are in the seedling stage. Since the inoculation threshold for transmission of AY disease is short (10 - 15 min.) and since the percentage of infectious vectors is more important than the total number of insects, rapid elimination of the vector is necessary to minimize crop infection. Even with a diligent insecticidal spray program, however, disease incidence in celery and carrots may be high.

Due to the importance of celery and carrots to the local

fresh market and processing industry, and due to the lack of adequate control programs, a project was initiated to investigate the use of systemic insecticides for aster leafhopper and aster yellows control in these crops. Replicated trials were therefore conducted to assess the efficacy of recommended contact spray materials as compared to foliar and granular applications of several systemic insecticides.

On the basis of aster leafhopper control, AY disease control and increased yield, foliar contact sprays, systemic foliar applications and granular systemic in-furrow treatments were found to have increasing orders of efficacy.

In individual trials, and over a three year period, weekly foliar applications of carbaryl (1.7 kg/ha ai) provided minimal crop protection. Aster leafhopper control averaged 30 percent. Aster yellows incidence was reduced, but only slightly in carrots and not in celery. In addition, carbaryl applications did not affect total yield of either crop.

Methoxychlor (1.7 kg/ha ai), applied weekly as a foliar spray, was equal to or slightly less efficacious than weekly applications of carbaryl.

As a systemic foliar spray, applied at weekly intervals, oxydemeton-methyl (0.6 kg/ha ai) resulted in superior leafhopper control when the leafhopper population was relatively stable. Even though the duration of activity of oxydemeton-methyl was estimated at approximately 7 days, leafhopper control was less evident during major population influxes. Over 3 years of

trials, early-season leafhopper control was superior in carrots (60%) as opposed to celery (41%). The maximum yellows reduction as a result of oxydemeton-methyl application was 60% in carrots, while the mean percent yellows reduction in both crops was 43%. Significant yield increases resulted from oxydemeton-methyl applications.

Of the granular systemic materials tested, disulfoton was the least effective. In-furrow treatments (3.4 kg/ha ai), applied with the seed at planting, failed to control the aster leafhopper or aster yellows disease in carrots or celery.

Phorate (3.4 kg/ha ai), as a granular in-furrow treatment, was included in three of the six trials conducted and therefore was not fully evaluated. In carrots, early season leafhopper control of about 55% was achieved, while the duration of activity was 7 to 8 weeks. In one trial, phorate reduced carrot yellows by 58%.

The duration of activity of carbofuran,when applied as an in-furrow treatment (3.4 kg/ha ai),was found to be approximately 10 weeks. Early season leafhopper control in both crops, and aster yellows reduction in celery averaged 55%. A maximum celery yellows reduction of 75% resulted from treatment with carbofuran. Carrot yellows reductions ranged from 35 to 45%. Yield increases following treatment with carbofuran were evident in celery and espécially so in carrots.

Aldicarb (3.4 kg/ha ai) as an in-furrow treatment, with the seed at planting, was the most effective and consistent

treatment in the trials. Excellent early-season leafhopper control (60-70%), and subsequent reductions in aster yellows incidence were achieved in both crops. The maximum yellows reductions obtained with aldicarb were, 66% in celery and 72% in carrots. Yield increases were also evident following aldicarb treatments. The duration of activity of aldicarb appeared to be approximately 9 to 12 weeks. In many of the trials, however, a longer duration of control was evident.

In increasing order of activity, the granular treatments evaluated were: disulfoton, phorate, carbofuran and aldicarb. (As previously mentioned, phorate was not fully evaluated). Application of half the aldicarb rate at planting, followed by half the rate as a sidedress application in mid-season, did not significantly reduce AY incidence at harvest. Rates of aldicarb from 1.7 to 6.7 kg/ha ai, applied with the seed, were not injurious to carrots. Subsequent disease control and yield increases appeared to be rate related.

Linear correlation analysis of the cumulative mean leafhopper populations (mid and late-season), aster yellows incidence (mid-season and harvest) and yield revealed the importance of early season leafhopper control. Aster yellows incidence at harvest was generally better related to the mid-season cumulative population mean than to the late season population mean. As well,yield decreases were generally best associated with the cumulative population mean (mid-season) and percent AY at harvest. However, over 3 years, carrot

yield reductions were better associated with AY incidence in mid-season than at harvest.

Due to the apparent long duration of leafhopper control with aldicarb in-furrow treatments, further studies were initiated to investigate the fate and persistence of this compound in carrots.

Residues of toxic aldicarb equivalents did not accumulate in carrot roots and declined slowly from 70 to 130 days following application. Residues at harvest were rate related and ranged from 0.04 ppm to 0.1 ppm for the minimum (1.7 kg/ha ai) and maximum (6.7 kg/ha ai) rates of application, respectively. For the same treatment rates, total toxic aldicarb equivalent concentrations in the leaves ranged from 1.4 ppm to 6.9 ppm, 51 days after application. Degradation/elimination of toxic residues was rapid. Only 20% of the residue present at Day 51 remained in the leaves 10 days later. Leaf residues were also rate related and at harvest ranged from 0.16 ppm to 0.62 ppm. Furthermore, the proportions of toxic aldicarb equivalent in the leaf, as compared to the root, were rate related. With incremental rate increases of 1.7 kg/ha ai (from 1.7 to 6.7 kg/ha ai), leaf concentrations were 3.2, 3.5, 3.9 and 5.0 times greater than root concentrations.

The metabolism of S-methyl - ^{14}C - aldicarb in carrot was investigated. Root absorption of aldicarb from nutrient solution and subsequent translocation to stems and leaves was

rapid. Within the confines of the experimental procedures, the half-life of total aldicarb equivalents in the root was 6.5 days, and in the whole plant was 13.9 days. Over the duration of the experiment (45 days), an increasing percentage of the total aldicarb equivalents in the plant was found in the leaves. This finding is consistent with the results of the residue studies. The level of toxic aldicarb equivalents (aldicarb, aldicarb sulfoxide and aldicarb sulfone) declined rapidly in the leaves (half-life 8.7 days) and was equivalent to the level of non-toxic metabolites at 7 days. Furthermore,the level of toxic aldicarb equivalents in the leaf,as compared to the total aldicarb metabolites in the plant,declined slowly over the duration of the experiment. This slow rate of decline is necessary for an extended duration of insecticidal activity in the field. The rates of elimination of aldicarb and metabolites from roots and leaves, as well as the rate of degradation of toxic metabolites, were approximated by first order kinetics. The concentration of toxic aldicarb metabolites in the leaf, and subsequently the duration of insecticidal activity in the field, are therefore dependent on the concentration of toxic aldicarb equivalents in the soil.

The lethal concentrations of toxic aldicarb equivalents in carrot leaves required for 50% mortality of feeding aster leafhoppers in 24 and 48 hours were calculated to be 3.44 ppm and 1.24 ppm,respectively. These values are consistent with

leaf concentrations, as determined by residue analysis at 51 days or approximately 7 weeks following application, and correspond to the expected duration of activity.

The LC_{95} value for mortality in 48 hours was determined as 16.7 ppm, whereas, the LC_{95} for 24 hours was extremely high, 277 ppm. The combined results of the leaf residue analysis, the fate and persistence studies and the lethal concentration determinations, therefore, do not account for the apparent extended duration of leafhopper control in aldicarb treated plots. Low mid to late-season leafhopper populations resulting from aldicarb treatments, and the apparent avoidance from feeding in the lethal concentration study are therefore suggestive of a repellent action for aldicarb.

In conclusion, the above findings indicate the superiority of effective granular systemic applications, as compared to foliar sprays of contact or systemic insecticides, for control of the aster leafhopper and aster yellows in carrots and celery. In three years of trials, in-furrow applications of aldicarb or carbofuran at planting were superior to weekly sprays of carbaryl and approximately equivalent to weekly applications of oxydemeton-methyl.

The elimination of a critically timed spray program, early seedling protection, persistent activity and ease of application at planting are major benefits of granular in-furrow treatments. To warrant the use of foliar sprays, as opposed to in-furrow granular treatments, forecasts in early May would

have to indicate a low percentage of infectious leafhoppers in a small migrant population.

Finally, on the basis of field trials and lethal concentration determinations utilizing infectious leafhoppers, the maximum yellows reduction expected as a result of granular systemic treatments applied in-furrow at planting is 60-75%.

BIBLIOGRAPHY

ANDRAWES, N.R., BAGLEY, W.P. and HERRETT, R.A. 1971(a). Fate and carryover properties of Temik aldicarb pesticide, 2-methyl-2-(methylthio) propionaldehyde 0-(methylcarbamoyl) oxime in soil. J. Agr. Food Chem. 19: 727-730.

ANDRAWES, N.R., BAGLEY, W.P. and HERRETT, R.A. 1971(b). Metabolism of 2-methyl-2-(methylthio) propionaldehyde 0-(methylcarbamoyl) oxime (Temik aldicarb pesticide) in potato plants. J. Agr. Food Chem. 19: 731-737.

ANDRAWES, N.R., ROMINE, R.R. and BAGLEY, W.P. 1973. Metabolism and residues of Temik aldicarb pesticide in cotton foliage and seed under field conditions. J. Agr. Food Chem. 21: 379-386.

ANON. 1970. Technical information on Temik 10G aldicarb pesticide. Union Carbide Corporation, Salinas, California. pp. 2-10.

ANON, 1973. A method for the determination of total toxic aldicarb residues in agricultural crops by gas chromatography. Union Carbide Corporation Agricultural Products, South Charleston, West Virginia. 10 pp.

BANTTARI, E.E. 1966. Grass hosts of aster yellows virus. Plant Dis. Rep. 50: 17-21.

BANTTARI, E.E. and MOORE, M.B. 1960. Transmission of the aster yellows virus to barley. Plant Dis. Rep. 44: 154.

BARROW, G.M. 1961. Physical chemistry. McGraw Hill, New York. pp. 465-471.

BARTLEY, W.J., ANDRAWES, N.R., CHANCEY, E.L., BAGLEY, W.P. and SPURR, H.W. 1970. The metabolism of Temik aldicarb pesticide [2-methyl-2-(methylthio) propionaldehyde 0-(methylcarbamoyl) oxime] in the cotton plant. J. Agr. Food Chem. 18: 446-453.

BENNETT, C.W. 1967. Epidemiology of leafhopper-transmitted viruses. Ann. Rev. Phytopath. 5: 87-108.

BHIRUD, K.M. and PITRE, H.N. 1972. Bioactivity of systemic insecticides in corn: relationship to leafhopper vector control and corn stunt disease incidence. J. Econ. Entomol. 65: 1134-1140.

BLACK, L.M. 1940. Mechanical transmission of aster-yellows virus to leafhoppers. Phytopathology 30: 2.

BLACK, L.M. 1941. Further evidence for the multiplication of the aster-yellows virus in the aster leafhopper. Phytopathology 31: 120-135.

BLACK, L.M. 1943. Some properties of aster-yellows virus. Phytopathology 33: 2.

BLACK, L.M. 1959. Biological cycles of plant viruses in insect vectors. In The viruses (Volume 2). BURNET, F.M. and STANLEY, W.M. (Eds.) Academic Press, N.Y. pp. 157-185.

BROADBENT, L. 1957. Insecticidal control of the spread of plant virus. Ann. Rev. Entomol. 2: 334-354.

BURT, P.E., BROADBENT, L. and HEATHCOTE, G.D. 1960. The use of soil insecticides to control potato aphids and virus diseases. Ann. Appl. Biol. 48: 580-590.

BUSVINE, J.R. 1971. A critical review of the techniques for testing insecticides. (2nd ed.). Commonwealth Agric. Bureau, Slaugh, England.

CARTER, W. 1973. Insects in relation to plant disease. (2nd. ed.) Wiley,New York. pp. 479-490.

CHAPMAN, R.K. 1949. Carrot yellows disease. Proc. N. Cent. Br. Entomol. Soc. Amer. 4: 118.

CHAPMAN, R.K. 1956. The effect of variable heat treatments on the transmission of aster yellows virus by the six-spotted leafhopper. Proc. N. Cent. Br. Entomol. Soc. Amer. 11: 53-54.

CHAPMAN, R.K. 1959. Some factors affecting the insect transmission of plant viruses. Proc. Entomol. Soc. Amer. 15: 14-23.

CHAPMAN, R.K. 1971. Prediction of aster leafhopper migrations and resultant aster yellows problems in Wisconsin. Proc. N. Cent. Br. Entomol. Soc. Amer. 26: 96-98.

CHAPMAN, R.K. 1973. Integrated control of aster yellows. Proc. N. Cent. Br. Entomol. Soc. Amer. 28: 71-92.

CHAPMAN, R.K. and LIBBY, J.L. 1971. Prediction of the aster leafhopper and aster yellows problem for the 1971 season. Univ. of Wisconsin, Dept. of Entomology Bulletin. pp. 10.

CHEN, T.A. and LIAO, C.H. 1975. Corn stunt spiroplasma: Isolation, cultivation and proof of pathogenicity. Science 188: 1015-1017.

CHIYKOWSKI, L.N. 1958. Studies on migration and control of the six-spotted leafhopper, Macrosteles fascifrons (Stal), in relation to transmission of aster yellows virus. Doctoral Dissertation, Univ. of Wisconsin, 126 pp.

CHIYKOWSKI, L.N. 1963. Endria inimica (Say), a new leafhopper vector of a celery-infecting strain of aster yellows virus in barley and wheat. Can. J. Bot. 41: 669-672.

CHIYKOWSKI, L.N. 1967. Reaction to some wheat varieties to aster yellows virus. Can. J. Plant Sci. 47: 149-151.

CHIYKOWSKI, L.N. 1972. Effects of three tetracyclines and their method of application on the development of clover phyllody and aster yellows symptoms in aster. Can. J. Plant Sci. 52: 29-33.

CHIYKOWSKI, L.N. 1977. Transmission of a celery infecting strain of aster yellows by the leafhopper Aphrodes-Bicinctus. Phytopathology 67: 522-524.

CHIYKOWSKI, L.N. 1978. Delayed expression of aster yellows symptoms in celery. Can. J. Bot. 56: 2987-2989.

CHIYKOWSKI, L.N. 1979. Athysanus argentarius, an introduced European leafhopper, as a vector of aster yellows in North America. Can. J. Plant Pathol. 1: 37-41.

CHIYKOWSKI, L.N. and CHAPMAN, R.K. 1958. Control of aster yellows in lettuce, celery and carrot. Proc. North Cent. Br. Entomol. Soc. Amer. 13: 30-31.

CHIYKOWSKI, L.N. and CHAPMAN, R.K. 1965. Migration of the six-spotted leafhopper Macrosteles fascifrons (Stål). II Migration of the six-spotted leafhopper in Central North America. Univ. of Wis. Res. Bull. 261: 21-45.

CHIYKOWSKI, L.N. and WOLYNETZ, M.S. 1981. Susceptibility of oat cultivars to aster yellows isolates from eastern Canada. Can. J. Plant Pathol. 3: 53-57.

COLE, R.M., TULLY, J.G., POPKIN, T.J. and BOVÉ, T.M. 1973. J. Bacteriol. 115: 367-386.

COPPEDGE, J.R., LINDQUIST, D.A., BULL, D.L. and DOROUGH, H.W. 1967. Fate of 2-methyl-2(methylthio) propionaldehyde O-(methylcarbamoyl) oxime (Temik) in cotton plants and soil. J. Agr. Food Chem. 15: 902-910.

DANIELS, M.J., MARKHAM, P.G., MEDDINS, B.M., PLASKITT, A.K., TOWNSEND, R. and BAR-JOSEPH, M. 1973. Axenic culture of a plant pathogenic spiroplasma. Nature 244: 523-524.

DAVID, B.A. 1973. Decline of insecticidal activity in plants treated with aldicarb, carbofuran and phorate. Doctoral Dissertation, Cornell University; 196 pp.

DAVIS, E.A. and GORDON, J. 1977. Morphological comparison of two varieties of carrots, healthy and aster yellows-diseased during growth and storage: scanning electron microscopy textural profiles. Home Econ. Res. J. 6: 15-23.

DAVIS, R.E. and WHITCOMB, R.F. 1971. Mycoplasmas, rickettsiae, chlamydiae: possible relation to yellows diseases and other disorders of plants and insects. Ann. Rev. Phytopath. 9: 119-154.

DELONG, D.M. 1971. The bionomics of leafhoppers. Ann. Rev. Entomol. 16: 179-210.

DOI, Y., TERENAKA, M., YORA, K. and ASUYAMA, H. 1967. Mycoplasma- or PLT group-like microorganisms found in the phloem elements of plants infected with mulberry dwarf, potato witches' broom, aster yellows, or paulownia witches' broom. Ann. Phytopath. Soc. Jap. 33: 259-266.

DUFFUS, J.E. 1971. Role of weeds in the incidence of virus diseases. Ann. Rev. Phytopath. 9: 319-340.

ESKAFI,F.M. and VAN SCHOONHOVEN, A. 1981. Interactions of leafhopper populations, varietal resistance, insecticide treatment and plant growth on drybean yields in a tropical environment. J. Econ. Entomol. 74: 7-12.

FINLAYSON, D.G., WILLIAMS, I.H., BROWN, M.J. and CAMPBELL, C.J. 1976. Distribution of insecticide residues in carrots at harvest. J. Agric. Food Chem. 24: 606-608.

FRAZIER, N.W. and POSNETTE, A.F. 1957. Transmission and host range studies of strawberry green-petal virus. Ann. Appl. Biol. 45: 580-588.

FREITAG, J.H. 1969. Interactions of plant viruses and virus strains in their insect vectors. In Viruses, vectors and vegetation. Maramorosch, K. (Ed.) Interscience, N.Y, pp. 303-325.

FREITAG, J.H. and SMITH, S.H. 1969. Effects of tetracyclines on symptom expression and leafhopper transmission of aster yellows. Phytopathology 59: 1820-1823.

FUKUSHI, T. 1969. Relationships between propagative rice viruses and their vectors. In Viruses, vectors and vegetation. Maramorosch, K. (Ed.) Interscience, N.Y. pp. 279-302.

GALLEY, D.J. and FOERSTER, L.A. 1976. Distribution and loss of phorate residues in the foliage of broadbean plants following root uptake of ^{14}C-labelled phorate. Pestic. Sci. 7: 301-306.

GEORGE, D.A., MAITLEN, J.C., POWELL, D.M. and MCDONOUGH, L.M. 1975. Aldicarb residues in potatoes. Environ. Entomol. 4: 642 644.

GILL, C.C. and WESTDAL, P.H. 1966. Virus diseases of cereals in the eastern part of the Canadian prairies in 1966. Can. Plant Dis. Surv. 46: 110-111.

GILL, C.C. and WESTDAL, P.H. 1967. Virus diseases of cereals and populations of vectors in the Canadian prairies in 1967. Can. Plant Dis. Surv. 47: 101-103.

GRAHAM-BRYCE, I.J., STEVENSON, J.H. and ETHERIDGE, P. 1972. Factors affecting the performance of granular insecticides applied to field beans. Pestic. Sci. 3: 781-797.

GRANADOS, R.R. and CHAPMAN, R.K. 1968. Identification of some new aster yellows virus strains and their transmission by the aster leafhopper Macrosteles fascrifrons (Stål). Phytopathology 53: 1685-1692.

HAMPTON, R.O. 1972. Mycoplasmas as plant pathogens: perspectives and principles. Ann. Rev. Plant Physiol. 23: 389-418.

HAO, G.F.T. and PITRE, H.N. 1970. Relationship of vector numbers and age of corn plants at inoculation to severity of corn stunt disease. J. Econ. Entomol. 63: 924-927.

HARRIS, C.R. 1972. Factors influencing the effectiveness of soil insecticides. Ann. Rev. Entomol. 17: 177-197.

HENNE, R.C. 1970. Effect of five insecticides on populations of the six-spotted leafhopper and the incidence of aster yellows in carrots. Can. J. Plant Sci. 50: 169-174.

HILLS, O.A., CANDRIET, D.L. and BRUBAKER, R.W. 1963. Phorate treatments against the beet leafhopper on cantaloupes for prevention of curly top. J. Econ. Entomol. 57: 85-87.

HIRUMI, H. and MARAMOROSCH, K. 1963. Recovery of aster yellows virus from various organs of the insect vector, Macrosteles fascifrons. Contrib. Boyce Thompson Inst. 22: 141-152.

HIRUMI, H. and MARAMOROSCH, K. 1969. Mycoplasma-like bodies in the salivary glands of insect vectors carrying the aster yellows agent. J. Virol. 3: 82-84.

HSU, T.P. and BANTTARI, E.E.1979. Dual transmission of the aster yellows mycoplasma-like organism and the oat blue dwarf virus and its effect on longevity and fecundity of the aster leafhopper vector. Phytopathology 69:843-845.

ISHIE, T., DOI, Y., YORA, K. and ASUYAMA, H. 1967. Suppressive effects of antibiotics of tetracycline group on symptom development of mulberry dwarf disease. Ann. Phytopath. Soc. Jap. 33: 267-275.

KALOOSTIAN, G.H., OLDFIELD, G.N., PIERCE, H.D. and CALAVAN, E.C. 1979. Spiroplasma Citri and its transmission to citrus and other plants by leafhoppers. In Leafhopper vectors and plant disease agents. Maramorosch, K. and Harris, K.F. (Eds.) Academic Press, N.Y. pp. 447-450.

KUHR, R.J. 1970. Metabolism of carbamate insecticide chemicals in plants and insects. J. Agr. Food Chem. 18: 1023-1030.

KUNKEL, L.O. 1924. Insect transmission of aster yellows. Phytopathology 14: 54.

KUNKEL, L.O. 1926. Studies on aster yellows. Amer. J. Bot. 13: 646-705.

KUNKEL, L.O. 1932. Celery yellows of California not identical with yellows of New York. Contrib. Boyce Thompson Inst. 4: 405-414.

KUNKEL, L.O. 1937. Effect of heat on ability of Cicadula sexnotata (Fall.) to transmit aster yellows. Amer. J. Bot. 24: 316-327.

KUNKEL, L.O. 1941. Heat cure of aster yellows in periwinkles. Amer. J. Bot. 28: 761-769.

KUNKEL, L.O. 1943. Potato witches' broom transmission by dodder and cure by heat. Proc. Amer. Phil. Soc. 86: 470-475.

KUNKEL, L.O. 1953. Aster yellows. Yearbrook of Agric. pp. 642-645.

KUNKEL, L.O. 1954. Maintenance of yellow-type viruses in plant and insect reservoirs. In The Dynamics of virus and rickettsial infections. Hartman, F.W., Horsfall, F.L. Jr. and Kidd, J.G. (Eds.) Blakiston Co., N.Y. pp. 150-163.

KUNKEL, L.O. 1955. Cross protection between strains of yellows-type viruses. Advan. Virus Res. 3: 251-273.

LEE, P.E. 1961. Some studies on the aster-yellows virus and transmission of the six-spotted leafhopper Macrosteles fascifrons (Stål). Doctoral Dissertation, Univ. of Wisconsin, 87 pp.

LEE, P.E. and CHIYKOWSKI, L.N. 1963. Infectivity of aster-yellows virus preparations after differential centrifugations of extracts from viruliferous leafhoppers. Virology 21: 667-669.

LEE, P.E. and ROBINSON, A.G. 1958. Studies on the six-spotted leafhopper, Macrosteles fascifrons (Stål), and aster yellows in Manitoba. Can. J. Plant Sci. 38: 320-327.

LING, K.C. 1966. Non-persistence of the tungro virus of rice in its leafhopper vector, Nephotettic impicticeps. Phytopathology 56: 1252-1256.

LING, K.C. 1972. Rice virus diseases. International Rice Research Institute, Los Banos, Phillipines.

LITTAU, V.C. and MARAMOROSCH, K. 1960. A study of the cytological effects of aster yellows virus on its insect vector. Virology 10: 483-500.

LITTLE, T.M. and HILLS, F.J. 1975. Statistical methods in agricultural research (2nd. ed.) University of California, Davis. pp. 43-102.

MAITLEN, J.C., MCDONOUGH, L.M. and BEROZA, M. 1968. Determination of residues of 2-methyl-2(methylthio) propionaldehyde 0-(methylcarbamoyl) oxime (UC-21149, Temik), its sulfoxide and its sulfone by gas chromatography. J. Agr. Food Chem. 16: 549-553.

MARAMOROSCH, K. 1952(a). Direct evidence for the multiplication of aster-yellows virus in its insect vector. Phytopathology 42: 59-64.

MARAMOROSCH, K. 1952(b). Studies on the nature of the specific transmission of aster yellows and corn stunt viruses. Phytopathology 42: 663-668.

MARAMOROSCH, K. 1953. Incubation period of aster yellows virus. Amer. J. Bot. 40: 797-809.

MARAMOROSCH, K. 1963. Arthropod transmission of plant viruses. Ann. Rev. Entomol. 8: 369-414.

MARAMOROSCH, K. 1964. Interrelationships between plant pathogenic viruses and insects. Ann. N.Y. Acad. Sci. 118: 363-370.

MARAMOROSCH, K. 1974. Mycoplasmas and rickettsiae in relation to plant disease. Ann. Rev. Microbiol. 28: 301-324.

MARAMOROSCH, K., GRANADOS, R.R. and HIRUMI, H. 1970. Mycoplasma disease of plants and insects. Advan. Virus Res. 16: 135-193.

MARAMOROSCH, K., SHIKATA, E. and GRANADOS, R.R. 1968. Structures resembling mycoplasma in diseased plants and in insect vectors. Trans. N.Y. Acad. Sci. 30: 841-855.

MATTHEWS, R.E.F. 1970. Plant virology. Academic Press, New York.

MILLER, L.A. and DELYZER, A.J. 1960. A progress report on studies of biology and ecology of the six-spotted leafhopper, Macrosteles fascifrons (Stål) in Southwestern Ontario. Proc. Entomol. Soc. Ont. 90: 7-13.

NIELSON, M.W. 1968. The leafhopper vectors of phytopathogenic viruses (Homoptera, Cicadellidae). Taxonomy, biology and transmission. U.S. Dep. Agri. Tech. Bull. 1382: 1-386.

NIELSON, M.W. 1979. Taxonomic relationships of leafhopper vectors of plant pathogens. In Leafhopper vectors and plant disease agents. Maramorosch, K. and Harris, K.F. (Ed.) Academic Press, N.Y. pp. 3-28.

NIENHAUS, F. and SIKORA, R.A. 1979. Mycoplasmas, spiroplasmas and rickettsia-like organisms as plant pathogens. Ann. Rev. Phytopath. 17: 37-58.

PETERSON, A.G. 1973. Host plant and aster leafhopper relationships. Proc. N. Cent. Entomol. Soc. 28: 66-70.

PETERSON, E.A. and SINHA, R.C. 1977. Uptake, distribution and persistence of tetracycline antibiotics in various plant species susceptible to mycoplasma infection. Phytopath. Z. 90: 250-256.

PITRE, H.N.1968. Systemic insecticides for control of the blackfaced leafhopper, Graminella nigrifrons, and effect on corn stunt disease. J. Econ. Entomol. 61: 765-768.

POWELL, M.M., MAITLEN, J.C. and MONDOR, W.T. 1971. Spring migrant green peach aphid: Control on peach and apricot with systemic insecticides and resultant residues. J. Econ. Entomol. 71: 192-194.

POWELL, D.M. and MONDOR, T.W. 1973. Control of the green peach aphid and suppression of leaf roll on potatoes by systemic soil insecticides and multiple foliar sprays. J. Econ. Entomol. 66: 170-177.

RAWLINS, W.A. and GONZALEZ, D. 1966. Incidence of aster yellows in lettuce as affected by placement of systemic insecticides. J. Econ. Entomol. 59: 226-227.

READ, D.C. 1981. Adulticidal and larvacidal toxicity of aldicarb when applied as a soil insecticide. J. Econ. Entomol. 74: 40-44.

RICHARDSON, H.P. 1967. Host reactions to three strains of aster yellows virus from Manitoba. Can. J. Bot. 45: 657-664.

RICHARDSON, H.P. and WESTDAL, P.H. 1963. Control of the six-spotted leafhopper, Macrosteles fascifrons and aster yellows on head lettuce in Manitoba. Can. J.Plant Sci. 43: 12-17.

RICHARDSON, H.P. and WESTDAL, P.H. 1964. Experiments on control of the six-spotted leafhopper, Macrosteles fascifrons, and aster yellows on head lettuce with contact and systemic insecticides in Manitoba. Can. J. Plant Sci. 44: 393-396.

ROSE, D.J.W. 1974. The epidemiology of maize streak disease in relation to population density of Cicadulina spp. Ann. Appl. Biol. 76: 199-207.

ROUCHAUD, R., MOONS, C. and MEYER, J.A. 1980. Distribution of the radioactivity in sugar beet plants treated with [^{14}C] aldicarb. Pestic. Sci. 11: 83-89.

SACKSTON, W.E. 1957. Aster yellows. Proc. Man. Agron. Conf. pp. 17-18.

SACKSTON, W.E. 1959. Aster yellows. A challenging problem in plant pathology. Proc. Ent. Soc. Man. 15: 23-30.

SCHULTZ, G.A. 1973. Plant resistance to aster yellows. Proc. N. Cent. Br. Entomol. Soc. Amer. 28: 93-99.

SCHULTZ, G.A. and CHAPMAN, R.K. 1976. Reduction of aster yellows by vector control with systemic and foliar insecticides. Proc. N. Cent. Br. Entomol. Soc. Amer. 31: 46.

SEVERIN, H.H.P. 1929. Yellows disease of celery, lettuce and other host plants transmitted by Cicadula sexnotata (Fall.) Hilgardia 3: 543-582.

SEVERIN, H.H.P. 1934. Experiments with aster-yellows virus from several states. Hilgardia 8: 305-325.

SEVERIN, H.P. 1946. Longevity, or life histories of leafhopper species on virus-infected and on healthy plants. Hilgardia 17: 121-137.

SINHA, R.C. and CHIYKOWSKI, L.N. 1967. Initial and subsequent sites of aster-yellows virus infection in a leafhopper vector. Virology 33: 702-708.

SINHA, R.C. and PETERSON, E.A. 1972. Uptake and persistence of oxytetracycline in aster plants and vector leafhoppers in relation to inhibition of clover phyllody agent. Phytopathology 62: 377-383.

SMELT, J.H., HOUX, N.W.H., LEXMOND, T.M. and NOLLEN, N.M. 1977. Residues of aldicarb and its oxidation products in potato tubers after field application. Agric. Environ. 3: 337-348.

SMELT, J.H., LEISTRA, M., HOUX, N.W.H. and DEKKER, A. 1978. Conversion rates of aldicarb and its oxidation in soils. I. Aldicarb Sulfone. Pestic. Sci. 9: 279-285.

SMELT, J.H., LEISTRA, M., HOUX, N.W.H. and DEKKER, A. 1978. Conversion rates of aldicarb and its oxidation in soils. II. Aldicarb Sulfoxide. Pestic. Sci. 9: 286-292.

SMELT, J.H., LEISTRA, M., HOUX, N.W.H. and DEKKER, A. 1978. Conversion rates of aldicarb and its oxidation products in the soil. III. Aldicarb. Pestic. Sci. 9: 293-300.

SMITH, R.E. 1902. Growing China asters. Hatch Expt. Sta. Mass. Agr. Coll. Bull. 79: 1-26.

STEELE, A.E. 1979. Residues of aldicarb and its oxides in Beta vulgaris and systemic control of Heterodera-schachtii. J. Nematol. 11: 42-46.

STEEL, R.G.C. and TORRIE, J.H. 1960. Principles and procedures of statistics. McGraw-Hill, N.Y. pp. 107-109.

STEERE, R.L. 1967. Gel filtration of aster yellows virus. Phytopathology 57: 832.

STRONG, R.G. and RAWLINS, W.A. 1958. Aster yellows virus infection and transmission by Macrosteles fascifrons (Stål) with reference to lettuce yellows prevention. J. Econ. Entomol. 51: 512-515.

SUETT, D.L. 1974. Uptake of Chlorfenvinphos and phorate from soil by carrots influenced by mode of application and cultivar. Pestic. Sci. 5: 57-71.

SWENSON, K.G. 1971. Relation of age, sex and mating of Macrosteles fascifrons to transmission of aster yellows. Phytopathology 61: 657-659.

THOMPSON, L.S. 1964. Aster yellows in Prince Edward Island in 1964. Can. Plant Dis. Surv. 44: 233-235.

THOMPSON, L.S. 1965. Aster yellows in head lettuce and carrots in Prince Edward Island. J. Econ. Entomol. 58: 135-137.

THOMPSON, L.S. 1967. Reduction of lettuce yellows with systemic insecticides. J. Econ. Entomol. 60: 716-718.

THOMPSON, L.S. and RAWLINS, W.A. 1961. Systemic insecticides for six-spotted leafhopper control and reduction of incidence of lettuce yellows. J. Econ. Entomol. 54: 1173-1176.

WESTDAL, P.H. 1969(a)Blue dwarf of oats and aster yellows: Diseases of cereals transmitted by the aster leafhopper, Macrosteles fascifrons (Stål). Doctoral Dissertation, University of Manitoba. 194 pp.

WESTDAL, P.H. 1969(b)Reaction of some oat varieties to aster yellows. Can. J. Plant Sci. 49: 630-631.

WESTDAL, P.H., BARRET, C.F. and RICHARDSON, H.P. 1961. The six-spotted leafhopper, Macrosteles fascifrons (Stål), and aster yellows in Manitoba. Can. J. Plant Sci. 41: 320-331.

WESTDAL, P.H. and RICHARDSON, H.P. 1963. Aster yellows and leafhopper damage in Manitoba in 1963. Can. Plant Dis. Surv. 43: 217-218.

WESTDAL, P.H. and RICHARDSON, H.P. 1966. Importance of aster yellows virus in field crops in Manitoba. Can. Plant Dis. Surv. 46: 138.

WESTDAL, P.H. and RICHARDSON, H.P. 1969. The susceptibility of cereals and wild oats to an isolate of the aster yellows pathogen. Can. J. Bot. 47: 755-760.

WESTDAL, P.H. and RICHARDSON, H.P. 1972. Control of the aster leafhoppers in relation to incidence of aster yellows and effects on seed yield in barley. Can. J. Plant Sci. 52: 177-182.

WHEATLEY, G.A. 1972. Effects of placement and distribution on the performance of granular formulations of insecticides for carrot fly control. Pestic. Sci. 3: 811-822.

WHITCOMB, R.F. 1980. The genus Spiroplasma. Ann. Rev. Microbiol. 34: 677-709.

WHITCOMB, R.F. and DAVIS, R.E. 1970. Mycoplasma and phytarboviruses as plant pathogens persistently transmitted by insects. Ann. Rev. Entomol. 15: 405-464.

WILLIAMSON, D.L. and WHITCOMB, R.F. 1975. Plant mycoplasmas: A cultivable spiroplasma causes corn stunt disease. Science 188: 1018-1020.

TABLE 36. Reisolation of a celery infecting strain of AY from celery and serial transmission to oat, aster and celery by the aster leafhopper.

Celery host	Indicator plants		
	# of plants infected/# of plants tested		
	Oat	Aster	Celery
81-2	0/20	6/20	2/20
81-5	2/15	13/15	8/15
81-9	2/15	15/15	7/15
83-4	0/16	16/16	5/16
88-9	4/13	11/13	4/13
88-10	0/15	14/15	8/15
90-1	0/10	8/10	3/10
90-2	0/15	9/15	7/15
90-4	2/15	13/15	7/15
91-2	2/15	11/15	8/15
91-8	2/15	11/15	4/15
91-11	2/15	14/15	5/15
Total	16/179	141/179	68/179
%	9	78	38

TABLE 37. Cultural and chemical variables associated with the conduction of insecticide trials at Portage La Prairie, Manitoba, 1970-1972.

Variable	Celery trials			Carrot trials		
	1970	1971	1972	1970	1971	1972
Planting date	1/6	4/6	25/5	18/5	11/5	19/5
Harvest date	23/9	9/9	5/9	26/9	28/9	3/10
Granular insecticide applications	30/5	4/6	23/5	18/5	11/5	19/5
First foliar application	17/6	10/6	8/6	24/6	15/6	8/6
Fertilizer	11-48-0, 170 kg/ha			14-14-7, 900 kg/ha N, 33 kg/ha sidedress		
Herbicide	Gesagard 2.2 kg/ha ai pre			Treflan 1.1 kg/ha ppi + Linuron 1.5 kg/ha post.		
Fungicide	Dyrene 3.0 kg/ha ai Maneb 2.2 kg/ha ai			Maneb 2.2 kg/ha ai 2 applications		

TABLE 38. Weekly populations of the aster leafhopper in celery as affected by various insecticide treatments, 1970.

Treatment	Rate kg/ha ai	Number of leafhoppers per 25 sweeps at each date																			
		26/6					5/7					9/7					16/7					22/7				
		1	2	3	4[1]	$\bar{x}$[2]	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$
Aldicarb G	3.4	1	1	2	3	7	1	0	2	1	4	1	1	1	0	3	3	5	5	3	16	2	1	1	1	5
Carbofuran G	3.4	0	1	2	0	3	1	0	0	0	1	0	2	2	0	4	6	7	11	8	32	3	2	3	2	10
Disulfoton G	3.4	1	3	2	3	9	0	2	1	0	3	6	4	3	7	20	6	5	7	18	36	12	9	10	13	44
Phorate G	3.4	1	2	2	2	7	2	1	1	1	5	5	5	4	2	16	3	4	8	9	24	10	6	8	7	31
Oxydemeton-methyl	0.6	0	2	0	0	2	0	0	1	0	1	4	2	3	4	13	2	2	4	13	21	4	1	4	3	12
Methoxychlor	1.7	1	2	3	2	8	0	1	1	0	2	2	3	4	2	11	2	3	2	6	13	5	6	8	8	27
Carbaryl	1.7	1	1	1	2	5	1	0	0	0	1	1	1	3	2	7	5	4	2	3	14	2	6	4	5	17
Control	---	4	6	2	5	17	1	2	0	1	4	3	4	1	3	11	11	10	5	9	35	9	7	2	3	21

1. Replication 2. $\bar{x}$ #/100 sweeps

Cont'd.....

TABLE 38. (Cont'd)

Treatment	Rate kg/ha ai	Number of leafhoppers per 25 sweeps at each date																	
		28/7					7/8					14/8					26/8				
		1	2	3	4[1]	$\bar{x}$[2]	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$
Aldicarb G	3.4	2	5	1	3	11	12	8	9	7	36	7	7	10	15	39	14	6	22	10	52
Carbofuran G	3.4	4	5	8	4	21	11	14	20	11	56	6	8	16	15	45	3	8	10	7	28
Disulfoton G	3.4	8	13	7	8	36	37	40	52	49	178	20	42	39	37	138	14	11	20	28	73
Phorate G	3.4	11	8	6	8	33	28	41	19	30	118	12	21	46	38	117	38	8	14	12	72
Oxydemeton-methyl	0.6	6	5	6	10	27	34	35	26	44	139	15	13	21	14	63	10	5	2	7	24
Methoxychlor	1.7	5	6	4	7	22	15	42	31	29	117	14	22	30	11	77	5	5	4	2	16
Carbaryl	1.7	13	7	8	7	35	41	24	22	46	133	31	40	19	28	118	8	3	7	4	22
Control	---	9	7	4	4	24	38	48	40	36	162	18	12	26	41	97	42	50	16	36	144

1. Replication 2. $\bar{x}$ #/100 sweeps

TABLE 39. Analysis of variance of cumulative mean leafhopper populations (mid and late-season), aster yellows incidence (mid-season and harvest), and yield in celery as affected by various insecticide treatments, 1970.

Treatment	Rate kg/ha ai	Cumulative $\bar{x}$ number/100 sweeps/week Mid-season ($\sqrt{x+0.5}$)				
		1	2	3	4	$\bar{x}$
Aldicarb G	3.4	1.48	1.64	1.58	1.52	1.56
Carbofuran G	3.4	1.67	1.82	2.19	1.79	1.87
Disulfoton G	3.4	2.45	2.55	2.35	2.95	2.58
Phorate G	3.4	2.41	2.12	2.30	2.30	2.28
Oxydemeton-methyl	0.6	1.79	1.58	1.87	2.35	1.90
Methoxychlor	1.7	1.73	2.00	2.05	2.17	1.99
Carbaryl	1.7	2.07	1.92	1.87	1.92	1.95
Control	---	2.59	2.55	1.67	2.17	2.25

Source	d.f.	S.S.	M.S.	F
Blocks	3	0.12	0.14	
Treatment	7	2.74	0.39	6.36**
Error	21	1.29	0.06	
Total	31	4.14		

C.V. = 12.1%

Treatment	Rate kg/ha ai	Cumulative $\bar{x}$ number/100 sweeps/week Late-season ($\sqrt{x+0.5}$)				
		1	2	3	4	$\bar{x}$
Aldicarb G	3.4	2.30	2.07	2.53	2.30	2.30
Carbofuran G	3.4	2.07	2.39	2.92	2.39	2.44
Disulfoton G	3.4	3.48	3.85	4.02	4.31	3.92
Phorate G	3.4	3.56	3.30	3.54	3.65	3.51
Oxydemeton-methyl	0.6	2.97	2.77	2.81	3.33	2.97
Methoxychlor	1.7	2.43	3.24	3.19	2.81	2.92
Carbaryl	1.7	3.45	3.18	2.79	3.36	3.20
Control	---	3.94	4.09	3.35	3.97	3.84

Source	d.f.	S.S.	M.S.	F
Blocks	3	0.24	0.08	
Treatment	7	10.00	1.43	15.98**
Error	21	1.88	0.09	
Total	31	12.11		

C.V. = 9.5%

Treatment	Rate kg/ha ai	AY incidence, % (mid-season)				
		1	2	3	4	$\bar{x}$
Aldicarb G	3.4	2.7	3.3	3.3	4.0	3.3
Carbofuran G	3.4	3.3	1.3	2.7	1.3	2.2
Disulfoton G	3.4	7.3	9.3	8.7	6.0	7.8
Phorate G	3.4	6.0	6.7	8.7	7.3	7.2
Oxydemeton-methyl	0.6	3.3	4.7	4.7	4.0	4.2
Methoxychlor	1.7	3.3	4.7	2.0	2.7	3.2
Carbaryl	1.7	4.7	4.7	6.7	5.3	5.4
Control	---	4.0	7.3	4.7	8.0	6.0

Source	d.f.	S.S.	M.S.	F
Blocks	3	4.3	1.4	
Treatment	7	114.7	16.4	11.7**
Error	21	29.4	1.4	
Total	31	148.5		

C.V. = 24.2%

Cont'd.....

TABLE 39. (Cont'd)

Treatment	Rate kg/ha ai	AY incidence, % (harvest) 1	2	3	4	$\bar{x}$
Aldicarb G	3.4	4.7	4.0	5.3	4.0	4.5
Carbofuran G	3.4	6.0	4.0	8.7	6.0	6.2
Disulfoton G	3.4	10.0	11.3	9.3	11.3	10.5
Phorate G	3.4	8.0	12.7	14.7	10.0	11.4
Oxydemeton-methyl	0.6	4.7	7.3	7.3	5.3	6.2
Methoxychlor	1.7	6.7	12.0	10.0	12.0	10.2
Carbaryl	1.7	9.3	14.7	13.3	8.0	11.3
Control	---	7.3	10.0	6.7	12.7	9.2

Source	d.f.	S.S.	M.S.	F
Blocks	3	30.0	10.0	
Treatment	7	200.0	28.6	6.7**
Error	21	88.9	4.2	
Total	31	318.7		

C.V. = 25%

Treatment	Rate kg/ha ai	Yield (lbs/plot) 1	2	3	4	$\bar{x}$
Aldicarb G	3.4	192	170	204	157	180.8
Carbofuran G	3.4	183	192	157	172	176.0
Disulfoton G	3.4	164	164	180	165	168.3
Phorate G	3.4	189	185	175	211	190.0
Oxydemeton-methyl	0.6	210	183	205	162	190.0
Methoxychlor	1.7	198	178	185	174	183.8
Carbaryl	1.7	221	164	190	185	190.0
Control	---	135	155	169.	158	154.3

Source	d.f.	S.S.	M.S.	F
Blocks	3	1083.8	361.3	
Treatment	7	4502.5	643.2	2.30 N.S.D.
Error	21	5877.3	279.9	
Total	31	11463.5		

C.V. = 9.3%

TABLE 40. Weekly populations of the aster leafhopper in carrots as affected by various insecticide treatments, 1970.

Treatment	Rate kg/ha ai	Number of leafhoppers per 50 sweeps at each date																								
		26/6					5/7					9/7					16/7					22/7				
		1	2	3	4[1]	$\bar{x}$[2]	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$
Aldicarb G	3.4	0	0	0	0	0	0	0	0	0	0	4	2	3	2	5.5	85	100	70	110	182	12	25	19	10	16.5
Carbofuran G	3.4	1	0	1	0	1.0	0	1	1	0	1.0	7	4	12	7	15.0	150	150	260	235	397	26	44	64	45	44.8
Disulfoton G	3.4	2	1	2	1	3.0	1	1	2	1	2.5	5	13	8	14	20.0	210	350	300	210	535	27	50	38	47	40.5
Phorate G	3.4	1	2	2	1	3.0	1	0	1	0	1.0	5	5	2	2	7.0	150	190	135	130	302	19	35	11	10	18.8
Oxydemeton-methyl	0.6	0	0	0	1	0.5	0	0	0	0	0	7	5	3	3	9.0	245	320	240	300	552	29	32	30	28	29.8
Methoxychlor	1.7	1	2	0	1	2.0	1	1	0	1	1.5	4	7	4	3	9.0	90	100	110	125	212	35	26	17	27	26.3
Carbaryl	1.7	2	1	1	1	2.5	0	1	0	0	0.5	7	9	13	5	17.0	250	150	290	200	445	22	13	31	45	27.8
Control	---	2	2	3	1	4.0	1	2	1	1	2.5	14	16	10	7	23.5	230	215	200	125	385	47	37	36	51	42.8

1. Replication 2. $\bar{x}$ #/100 sweeps

Cont'd.....

TABLE 40. (Cont'd)

Treatment	Rate kg/ha ai	Number of leafhoppers per 50 sweeps at each date																			
		28/7					7/8					14/8					26/8				
		1	2	3	4[1]	$\bar{x}$[2]	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$
Aldicarb G	3.4	4	6	5	8	11.5	105	170	135	160	285	70	135	60	100	183	75	135	130	73	206
Carbofuran G	3.4	20	11	11	15	33.5	410	375	460	370	404	195	115	105	120	268	450	280	475	300	752
Disulfoton G	3.4	19	25	15	17	38.0	360	350	230	250	595	90	180	155	80	252	300	230	310	185	512
Phorate G	3.4	20	13	13	11	28.5	240	360	250	225	538	115	75	75	90	178	300	375	215	170	530
Oxydemeton-methyl	0.6	9	22	12	12	27.5	370	350	280	270	635	180	285	145	155	383	38	55	30	43	83
Methoxychlor	1.7	22	23	19	32	48.0	260	265	275	215	508	135	95	75	80	193	85	95	62	95	169
Carbaryl	1.7	20	14	13	23	35.0	350	320	285	300	628	160	105	90	135	245	150	220	240	175	393
Control	---	26	14	16	11	33.5	375	260	335	235	602	195	115	140	110	280	270	170	375	210	512

1. Replication 2. $\bar{x}$ #/100 sweeps

TABLE 41. Analysis of variance of cumulative mean leafhopper populations (mid and late-season), aster yellows incidence (mid-season and harvest), and yield in carrots as affected by various insecticide treatments, 1970.

Treatment	Rate kg/ha ai	Cumulative $\bar{x}$ number/100 sweeps/week Mid-season ($\sqrt{x+0.5}$)				
		1	2	3	4	$\bar{x}$
Aldicarb G	3.4	2.12	2.66	2.43	2.12	2.33
Carbofuran G	3.4	3.36	3.54	4.51	3.73	3.79
Disulfoton G	3.4	3.36	4.30	3.67	4.06	3.85
Phorate G	3.4	3.11	3.39	2.51	2.30	2.83
Oxydemeton-methyl	0.6	3.08	3.51	3.08	3.05	3.18
Methoxychlor	1.7	3.62	3.51	2.92	3.65	3.43
Carbaryl	1.7	3.27	2.85	3.48	3.91	3.38
Control	---	4.30	3.83	3.70	3.83	3.92

Source	d.f.	S.S.	M.S.	F
Blocks	3	.15	.05	
Treatment	7	8.39	1.20	7.38**
Error	21	3.41	.16	
Total	31	11.95		

C.V. = 12.08%

Treatment	Rate kg/ha ai	Cumulative $\bar{x}$ number/100 sweeps/week Late-season ($\sqrt{x+0.5}$)				
		1	2	3	4	$\bar{x}$
Aldicarb G	3.4	3.94	5.34	3.87	4.53	4.42
Carbofuran G	3.4	6.48	5.45	5.87	5.63	5.86
Disulfoton G	3.4	4.95	6.75	6.10	5.22	5.76
Phorate G	3.4	5.22	4.71	4.22	4.42	4.64
Oxydemeton-methyl	0.6	6.16	7.60	5.67	5.81	6.31
Methoxychlor	1.7	5.79	5.12	4.44	4.95	5.08
Carbaryl	1.7	5.97	4.93	5.02	5.94	5.47
Control	---	6.93	5.61	5.90	5.54	6.00

Source	d.f.	S.S.	M.S.	F
Blocks	3	1.97	.66	
Treatment	7	12.59	1.80	4.65**
Error	21	8.12	.39	
Total	31	22.68		

C.V. = 11.43%

Treatment	Rate kg/ha ai	AY incidence, % (mid-season)				
		1	2	3	4	$\bar{x}$
Aldicarb G	3.4	1.5	.5	3.0	3.5	2.1
Carbofuran G	3.4	.5	4.0	1.0	.5	1.5
Disulfoton G	3.4	0	5.5	6.0	3.0	3.6
Phorate G	3.4	2.5	2.5	2.5	2.5	2.5
Oxydemeton-methyl	0.6	3.0	3.5	7.0	2.0	3.9
Methoxychlor	1.7	.5	6.0	2.0	.5	2.3
Carbaryl	1.7	1.5	5.0	5.0	1.0	3.1
Control	---	3.0	2.5	6.0	4.0	3.9

Source	d.f.	S.S.	M.S.	F
Blocks	3	33.5	11.2	
Treatment	7	19.9	2.8	1.0 N.S.D.
Error	21	58.0	2.8	
Total	31			

C.V. = 58.1%

Cont'd.....

TABLE 41. (Cont'd)

Treatment	Rate kg/ha ai	AY incidence, % (harvest) 1	2	3	4	$\bar{x}$
Aldicarb G	3.4	11.7	18.1	13.2	22.2	16.3
Carbofuran G	3.4	24.1	15.6	29.3	22.2	22.8
Disulfoton G	3.4	20.2	28.3	17.9	22.0	22.1
Phorate G	3.4	16.5	17.0	26.4	24.5	21.1
Oxydemeton-methyl	0.6	11.5	13.6	21.5	28.2	18.7
Methoxychlor	1.7	11.6	20.3	26.5	25.6	21.0
Carbaryl	1.7	26.7	18.3	27.4	22.4	23.7
Control	---	23.3	19.5	20.2	39.4	25.6

Source	d.f.	S.S.	M.S.	F
Blocks	3	305.9	102.0	
Treatment	7	235.7	33.7	1.1 N.S.D.
Error	21	628.2	29.9	
Total	31	1169.8		C.V. = 47.2%

Treatment	Rate kg/ha ai	Yield (lbs/plot) 1	2	3	4	$\bar{x}$
Aldicarb G	3.4	51	59	47	64	55.3
Carbofuran G	3.4	55	72	73	44	61.0
Disulfoton G	3.4	68	59	55	44	56.5
Phorate G	3.4	56	43	45	73	54.3
Oxydemeton-methyl	0.6	61	48	46	52	51.8
Methoxychlor	1.7	48	60	68	70	61.5
Carbaryl	1.7	54	43	40	59	49.0
Control	---	42	39	63	61	51.3

Source	d.f.	S.S.	M.S.	F
Blocks	3	131	43.8	
Treatment	7	566.9	81.0	.6 N.S.D.
Error	21	2641.6	125.8	
Total	31	3339.9		C.V. = 20.3%

TABLE 42. Aster leafhopper populations in celery as affected by various insecticide treatments, 1971.

Treatment	Rate kg/ha ai	Number of leafhoppers per 25 sweeps at each date																											
		21/6					28/6					6/7					13/7					20/7					26/7				
		1	2	3	4[1]	$\bar{x}$[2]	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$
Aldicarb G	3.4	0	0	1	0	1	0	0	0	0	0	2	1	1	0	4	0	0	1	0	1	2	1	2	3	8	1	1	2	2	6
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	0	0	0	0	0	0	0	1	1	2	0	0	2	1	3	0	2	2	3	7	0	0	1	1	2	2	3	1	0	6
Oxydemeton-methyl	0.6	1	1	1	0	3	0	1	0	1	2	4	3	2	4	13	1	1	0	1	2	1	1	2	2	6	0	2	1	2	5
Carbofuran G	3.4	0	0	0	0	0	0	0	0	0	0	3	0	1	2	6	0	0	0	0	0	1	2	6	2	11	2	2	0	1	5
Methoxychlor	1.7	3	1	2	1	7	0	0	0	1	1	2	5	4	3	14	1	1	1	3	6	1	1	2	1	5	6	4	5	8	23
Carbaryl	1.7	2	2	3	0	7	0	0	0	1	1	5	3	4	3	15	1	0	0	1	2	1	0	1	1	3	3	4	2	2	11
Control	---	4	4	3	2	13	1	1	0	0	2	6	8	4	6	24	2	1	3	2	8	0	3	1	2	6	7	6	10	6	29

1. Replication 2. $\bar{x}$ #/100 sweeps

Cont'd.....

TABLE 42. (Cont'd)

Treatment	Rate kg/ha ai	Number of leafhoppers per 25 sweeps at each date																											
		3/8					9/8					18/8					23/8					30/8					7/9				
		1	2	3	4[1]	$\bar{x}$[2]	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$
Aldicarb G	3.4	1	0	2	1	4	0	1	0	0	1	3	2	1	2	8	4	5	5	3	17	16	10	7	11	44	5	2	3	3	13
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	0	0	1	0	1	0	1	1	0	2	2	3	2	2	9	3	3	4	3	13	7	7	13	13	42	2	2	2	4	10
Oxydemeton-methyl	0.6	0	0	0	0	0	0	0	0	0	0	1	2	0	3	6	4	6	5	1	16	6	5	8	5	24	1	3	0	1	5
Carbofuran G	3.4	0	0	0	0	0	0	0	0	0	0	2	2	3	4	11	5	7	7	10	29	16	27	11	9	63	4	1	4	3	12
Methoxychlor	1.7	0	1	1	0	2	2	0	1	1	4	7	7	5	5	24	10	7	9	14	40	12	8	13	19	52	4	3	2	3	12
Carbaryl	1.7	0	0	1	1	2	0	0	0	0	0	3	6	4	6	19	6	11	8	5	30	5	8	5	6	24	3	4	1	6	14
Control	---	3	1	3	1	8	2	1	1	0	4	10	7	15	11	43	11	11	21	16	59	24	27	16	18	85	4	7	6	4	21

1. Replication 2. $\bar{x}$ #/100 sweeps

TABLE 43. Analysis of variance of cumulative mean leafhopper populations (mid and late-season), aster yellows incidence (mid-season and harvest) and yield in celery as affected by various insecticide treatments, 1971.

Treatment	Rate kg/ha ai	Cumulative $\bar{x}$ number/100 sweeps/week Mid-season ($\sqrt{x+0.5}$)				
		1	2	3	4	$\bar{x}$
Aldicarb G	3.4	1.14	1.00	1.30	1.14	1.15
Carbofuran G	3.4	1.22	1.10	1.30	1.14	1.19
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	0.89	1.14	1.30	1.22	1.14
Oxydemeton-methyl	0.6	1.30	1.41	1.22	1.41	1.34
Methoxychlor	1.7	1.64	1.58	1.67	1.82	1.68
Carbaryl	1.7	1.58	1.41	1.48	1.34	1.45
Control	---	1.95	2.07	2.00	1.87	1.97

Source	d.f.	S.S.	M.S.	F
Blocks	3	0.03	0.01	
Treatment	6	2.35	0.39	28.99**
Error	18	0.24	0.01	
Total	27	2.63		

C.V. = 8.21%

Treatment	Rate kg/ha ai	Cumulative $\bar{x}$ number/100 sweeps/week Late-season ($\sqrt{x+0.5}$)				
		1	2	3	4	$\bar{x}$
Aldicarb G	3.4	1.82	1.55	1.61	1.61	1.65
Carbofuran G	3.4	1.82	1.97	1.79	1.76	1.84
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	1.34	1.52	1.73	1.67	1.57
Oxydemeton-methyl	0.6	1.45	1.61	1.45	1.45	1.49
Methoxychlor	1.7	2.12	1.92	2.07	2.32	2.11
Carbaryl	1.7	1.70	1.92	1.70	1.79	1.78
Control	---	2.59	2.63	2.72	2.49	2.61

Source	d.f.	S.S.	M.S.	F
Blocks	3	0.01	0.00	
Treatment	6	3.59	0.60	34.39**
Error	18	0.31	0.02	
Total	27	3.91		

C.V. = 7.08%

Treatment	Rate kg/ha ai	AY incidence, % (mid-season)				
		1	2	3	4	$\bar{x}$
Aldicarb G	3.4	3.7	2.9	5.1	2.9	3.7
Carbofuran G	3.4	2.2	3.7	2.9	1.5	2.6
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	0.7	2.2	3.7	3.7	2.6
Oxydemeton-methyl	0.6	5.9	2.9	5.9	4.4	4.8
Methoxychlor	1.7	4.4	3.7	3.7	5.9	4.4
Carbaryl	1.7	5.1	2.9	4.4	2.2	3.7
Control	---	6.6	7.4	5.1	3.7	5.7

Source	d.f.	S.S.	M.S.	F
Blocks	3	3.6	1.2	
Treatment	6	31.7	5.3	3.0*
Error	18	31.2	1.7	
Total	27	66.6		

C.V. = 18.8%

Cont'd.....

TABLE 43. (Cont'd)

Treatment	Rate kg/ha ai	AY incidence, % (harvest) 1	2	3	4	$\bar{x}$
Aldicarb G	3.4	4.7	4.0	5.3	3.4	4.4
Carbofuran G	3.4	3.0	4.0	3.4	2.3	3.0
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	3.4	4.7	5.4	4.7	4.6
Oxydemeton-methyl	0.6	6.7	4.7	6.0	5.4	5.7
Methoxychlor	1.7	11.4	8.0	7.4	10.1	9.2
Carbaryl	1.7	8.7	8.0	10.1	9.4	9.1
Control	---	14.7	13.4	13.4	10.7	13.1

Source	d.f.	S.S.	M.S.	F
Blocks	3	1.9	0.6	
Treatment	6	305.1	50.8	34.5**
Error	18	26.5	1.5	
Total	27	333.5		

C.V. = 17.3%

Treatment	Rate kg/ha ai	Yield (lbs/plot) 1	2	3	4	$\bar{x}$
Aldicarb G	3.4	236	247	195	200	219.5
Carbofuran G	3.4	262	259	205	255	245.3
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	207	228	262	225	230.5
Oxydemeton-methyl	0.6	260	217	213	202	223.0
Methoxychlor	1.7	215	203	213	263	223.5
Carbaryl	1.7	198	208	153	164	180.8
Control	---	185	153	142	150	157.5

Source	d.f.	S.S.	M.S.	F
Blocks	3	2566.3	855.4	
Treatment	6	22807.4	3801.2	6.5**
Error	18	10481.2	582.3	
Total	27	35854.9		

C.V. = 11.4%

TABLE 44. Weekly population of the aster leafhopper in carrots as affected by various insecticide treatments, 1971.

Treatment	Rate kg/ha ai	Number of leafhoppers per 50 sweeps at each date																			
		28/6					6/7					13/7					20/7					26/7				
		1	2	3	4[1]	$\bar{x}$[2]	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	3	3	1	1	4.0	8	11	16	7	21.0	3	5	2	5	7.5	3	4	3	1	5.5	5	3	9	5	11.0
Aldicarb G	3.4	0	3	2	2	3.5	4	6	10	9	14.5	0	3	1	3	3.5	5	4	8	10	13.5	15	15	12	25	33.5
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	1	0	0	0	0.5	7	3	6	2	9.0	1	1	4	3	4.5	8	3	5	4	10.0	8	6	12	12	19.0
Oxydemeton-methyl	0.6	3	3	4	5	7.5	16	11	8	9	22.0	0	0	2	1	1.5	3	4	3	1	5.5	5	3	9	5	11.0
Carbofuran G	3.4	3	6	3	2	7.0	16	8	8	5	18.5	2	2	5	6	7.5	12	13	24	11	30.0	6	10	8	10	17.0
Phorate G	3.4	8	5	2	3	9.0	10	22	12	14	29.0	2	3	3	3	5.5	3	9	9	5	10.5	12	19	10	11	26.0
Methoxychlor	1.7	3	5	1	3	6.0	33	28	25	16	51.0	19	26	18	19	41.0	19	18	12	18	33.5	25	23	21	26	47.5
Carbaryl	1.7	8	4	8	2	11.0	25	32	30	26	56.5	4	3	5	7	9.5	7	9	6	5	13.5	13	8	9	19	24.5
Control	---	11	9	15	7	21.0	19	41	22	35	58.5	8	24	14	11	28.5	22	36	35	28	60.5	17	28	32	12	44.5

1. Replication 2. $\bar{x}$ #/100 sweeps

Cont'd.....

TABLE 44. (Cont'd)

Treatment	Rate kg/ha	Number of leafhoppers per 50 sweeps at each date																			
		9/8					18/8					23/8					30/8					7/9				
		1	2	3	4[1]	$\bar{x}$[2]	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	7	19	11	5	21.0	12	19	12	15	29.0	10	20	18	10	16.5	36	50	62	42	95	8	14	14	16	26.0
Aldicarb G	3.4	25	18	12	38	46.5	24	31	17	38	55.0	18	11	26	22	38.5	150	180	140	114	292	35	30	55	40	80.0
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	5	7	10	8	15.0	26	37	20	18	50.0	11	13	18	10	26.0	120	144	260	180	352	28	50	34	36	74.0
Oxydemeton-methyl	0.6	5	6	3	8	11.0	13	38	22	15	44.0	6	9	8	10	16.5	36	50	62	42	95	8	14	14	16	26.0
Carbofuran G	3.4	28	26	24	35	56.5	42	47	65	46	100.0	28	19	22	27	48.0	270	250	410	260	595	83	52	60	51	123.0
Phorate G	3.4	27	26	13	12	39.0	33	66	34	52	92.5	16	14	32	18	40.0	115	200	112	180	303	34	60	31	29	77.0
Methoxychlor	1.7	17	10	16	13	28.0	42	34	58	46	90.0	14	11	25	15	32.5	66	56	44	96	106	26	13	32	11	41.0
Carbaryl	1.7	2	4	3	4	6.5	38	21	18	28	52.5	8	13	10	14	22.5	72	165	120	90	223	22	14	20	30	43.0
Control	---	38	18	29	28	56.5	38	58	42	63	100.5	23	14	30	22	45.5	140	210	206	224	390	32	37	64	34	83.5

1. Replication 2. $\bar{x}$ #/100 sweeps

TABLE 45. Analysis of variance of cumulative mean leafhopper populations (mid and late-season), aster yellows incidence (mid-season and harvest), and yield in carrots as affected by various insecticide treatments, 1971.

Treatment	Rate kg/ha ai	Cumulative $\bar{x}$ number/100 sweeps/week Mid-season ($\sqrt{x+0.5}$)				
		1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	2.61	2.92	2.49	2.35	2.59
Aldicarb G	3.4	2.17	2.49	2.49	2.97	2.53
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	2.28	1.64	2.30	2.05	2.07
Oxydemeton-methyl	0.6	2.41	2.17	2.45	2.12	2.29
Carbofuran G	3.4	2.68	2.70	2.92	2.55	2.71
Phorate G	3.4	2.59	3.29	2.41	2.65	2.74
Methoxychlor	1.7	4.24	4.27	3.77	3.85	4.03
Carbaryl	1.7	3.32	3.21	3.35	3.29	3.29
Control	---	3.90	5.07	4.66	4.15	4.45

Source	d.f.	S.S.	M.S.	F
Blocks	3	0.21	0.07	
Treatment	8	20.59	2.57	28.04**
Error	24	2.20	0.09	
Total	35	23.00		

C.V. = 10.21%

Treatment	Rate kg/ha ai	Cumulative $\bar{x}$ number/100 sweeps/week Late-season ($\sqrt{x+0.5}$)				
		1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	3.07	3.62	3.15	2.74	3.15
Aldicarb G	3.4	3.63	3.59	3.86	4.39	3.87
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	3.21	3.54	3.41	3.15	3.33
Oxydemeton-methyl	0.6	2.63	3.11	2.92	2.79	2.86
Carbofuran G	3.4	4.72	4.36	4.73	4.28	4.52
Phorate G	3.4	3.90	4.85	3.83	3.94	4.13
Methoxychlor	1.7	4.57	4.23	4.67	4.20	4.42
Carbaryl	1.7	3.71	3.41	3.61	3.78	3.63
Control	---	4.73	5.32	5.17	5.02	5.06

Source	d.f.	S.S.	M.S.	F
Blocks	3	0.26	0.09	
Treatment	8	16.40	2.05	23.87**
Error	24	2.06	0.09	
Total	35	18.73		

C.V. = 7.55%

Treatment	Rate kg/ha ai	AY incidence, % (mid-season)				
		1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	4	3	2	7	4.0
Aldicarb G	3.4	3	3	6	2	3.5
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	1	1	2	0	1.0
Oxydemeton-methyl	0.6	1	3	5	3	3.0
Carbofuran G	3.4	3	5	2	4	3.5
Phorate G	3.4	3	3	1	1	2.0
Methoxychlor	1.7	4	3	1	4	3.0
Carbaryl	1.7	3	7	5	6	5.3
Control	---	3	6	6	5	5.0

Source	d.f.	S.S.	M.S.	F
Blocks	3	5.0	1.7	
Treatment	8	57.6	7.2	3.0*
Error	24	57.8	2.4	
Total	35	120.3		

C.V. = 46.2%

Cont'd.....

TABLE 45. (Cont'd)

Treatment	Rate kg/ha ai	AY incidence, % (harvest) 1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	3.2	5.7	4.2	3.9	4.3
Aldicarb G	3.4	2.8	4.6	4.6	2.8	3.7
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	4.2	3.9	2.8	2.8	3.4
Oxydemeton-methyl	0.6	4.9	3.9	6.0	5.7	5.1
Carbofuran G	3.4	6.4	3.9	7.1	5.3	5.7
Phorate G	3.4	4.9	5.3	4.2	6.7	5.3
Methoxychlor	1.7	4.6	3.9	6.0	5.7	5.1
Carbaryl	1.7	6.4	6.4	7.4	6.4	6.7
Control	---	11.0	11.3	14.1	15.9	13.1

Source	d.f.	S.S.	M.S.	F
Blocks	3	5.8	1.9	
Treatment	8	269.6	33.7	23.6**
Error	24	34.3	1.4	
Total	35	309.7		

C.V. = 20.6%

Treatment	Rate kg/ha ai	Yield (lbs/plot) 1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	59	49	52	45	51.3
Aldicarb G	3.4	53	58	65	57	58.3
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	57	52	59	67	58.8
Oxydemeton-methyl	0.6	54	47	56	56	53.3
Carbofuran G	3.4	56	54	55	56	55.3
Phorate G	3.4	53	51	60	49	53.3
Methoxychlor	1.7	62	51	63	50	56.5
Carbaryl	1.7	59	48	47	53	51.8
Control	---	59	51	50	48	52.0

Source	d.f.	S.S.	M.S.	F
Blocks	3	188.3	62.8	
Treatment	8	256.7	32.1	1.4 N.S.D.
Error	24	539.9	22.5	
Total	35	985.0		

C.V. = 8.7%

TABLE 46. Aster leafhopper populations in celery as affected by various insecticide treatments, 1972.

Treatment	Rate kg/ha ai	Number of leafhoppers per 25 sweeps at each date																								
		4/7					11/7					18/7					25/7					4/8				
		1	2	3	4[1]	$\bar{x}$[2]	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	0	1	1	3	5	4	1	2	3	10	0	0	2	1	3	0	0	0	0	0	0	1	2	1	4
Aldicarb G	3.4	0	0	0	1	1	1	3	1	4	9	1	0	2	2	5	0	0	1	0	1	0	2	1	1	4
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	0	1	1	0	2	1	1	3	1	6	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
Oxydemeton-methyl	0.6	1	1	0	0	2	3	7	6	3	19	0	1	2	2	5	0	0	0	0	0	1	2	1	2	6
Carbofuran G	3.4	0	0	2	1	3	2	5	5	3	15	0	1	1	0	2	1	1	0	0	2	0	1	2	2	5
Carbaryl	1.7	2	2	0	1	5	3	1	1	2	7	3	6	4	2	15	0	1	1	0	2	1	1	3	2	7
Control	---	2	3	3	1	9	4	5	8	5	22	1	2	1	0	4	0	0	1	0	1	3	2	2	1	8

1. Replication 2. $\bar{x}$ #/100 sweeps

Cont'd.....

TABLE 46. (Cont'd)

Treatment	Rate kg/ha ai	Number of leafhoppers per 25 sweeps at each date																			
		11/8					17/8					24/8					31/8				
		1	2	3	4[1]	$\bar{x}$[2]	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	1	0	2	1	4	0	3	0	2	5	0	1	1	1	3	0	2	1	0	3
Aldicarb G	3.4	1	2	0	0	3	1	2	2	1	6	1	2	2	0	5	1	1	2	1	5
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	2	1	3	0	6	2	1	3	2	8	0	1	0	2	3	1	2	0	1	4
Oxydemeton-methyl	0.6	1	3	2	3	9	1	1	0	2	4	1	1	2	4	8	0	1	1	2	4
Carbofuran G	3.4	2	2	1	1	6	1	2	2	3	8	2	1	0	1	4	1	2	1	1	5
Carbaryl	1.7	3	5	3	2	13	3	5	2	1	11	1	3	1	0	5	1	3	2	0	6
Control	---	3	2	2	3	10	2	5	7	3	17	2	0	3	0	5	2	3	1	2	8

1. Replication 2. $\bar{x}$ #/100 sweeps

TABLE 47. Analysis of variance of cumulative mean leafhopper populations (mid and late-season), aster yellows incidence (mid-season and harvest), and yield in celery as affected by various insecticide treatments, 1972.

Treatment	Rate kg/ha ai	Cumulative $\bar{x}$ number/100 sweeps/week Mid-season ($\sqrt{x}+0.5$)				
		1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	1.22	1.00	1.34	1.52	1.27
Aldicarb G	3.4	1.00	1.14	1.22	1.52	1.22
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	0.89	1.00	1.22	0.89	1.00
Carbofuran G	3.4	1.14	1.52	1.58	1.22	1.37
Oxydemeton-methyl	0.6	1.22	1.67	1.58	1.34	1.45
Carbaryl	1.7	1.58	1.73	1.41	1.34	1.52
Control	---	1.52	1.73	1.95	1.41	1.65

Source	d.f.	S.S.	M.S.	F
Blocks	3	0.24	0.08	
Treatment	6	1.10	0.18	5.01**
Error	18	0.66	0.04	
Total	27	2.00		

C.V. = 14.14%

Treatment	Rate kg/ha ai	Cumulative $\bar{x}$ number/100 sweeps/week Late-season ($\sqrt{x}+0.5$)				
		1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	1.05	1.22	1.30	1.34	1.23
Aldicarb G	3.4	1.10	1.34	1.30	1.26	1.25
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	1.10	1.18	1.30	1.14	1.18
Carbofuran G	3.4	1.22	1.48	1.45	1.34	1.37
Oxydemeton-methyl	0.6	1.18	1.55	1.45	1.58	1.44
Carbaryl	1.7	1.55	1.87	1.55	1.26	1.56
Control	---	1.61	1.70	1.90	1.48	1.67

Source	d.f.	S.S.	M.S.	F
Blocks	3	0.23	0.08	
Treatment	6	0.80	0.13	0.07 N.S.D.
Error	18	0.30	0.02	
Total	27	1.33		

C.V. = 9.29%

Treatment	Rate kg/ha ai	AY incidence, % (mid-season)				
		1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	0	0	1	0	0.2
Aldicarb G	3.4	0	0	1	1	0.3
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	1	1	0	0	0.3
Carbofuran G	3.4	0	1	0	1	0.3
Oxydemeton-methyl	0.6	1	1	1	0	0.5
Carbaryl	1.7	1	1	1	0	0.5
Control	---	1	0	0	2	0.5

Source	d.f.	S.S.	M.S.	F
Blocks	3	.0	.0	
Treatment	6	0.9	0.1	0.3 N.S.D.
Error	18	8.0	0.4	
Total	27	8.9		

C.V. = 116.3%

Cont'd.....

TABLE 47. (Cont'd)

Treatment	Rate kg/ha ai	AY incidence, % (harvest) 1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	.7	1.4	.7	2.7	1.8
Aldicarb G	3.4	.7	1.4	2.0	1.4	1.8
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	0	0.7	0.7	0	0.5
Carbofuran G	3.4	1.4	1.4	3.3	0.7	2.2
Oxydemeton-methyl	0.6	3.3	2.0	0.7	0.7	2.2
Carbaryl	1.7	4.7	2.7	2.0	2.7	4.0
Control	---	2.0	2.7	2.0	1.4	2.0

Source	d.f.	S.S.	M.S.	F
Blocks	3	2.0	0.7	
Treatment	6	34.9	5.8	2.8*
Error	18	38.0	2.1	
Total	27	74.9		

C.V. = 46.9%

Treatment	Rate kg/ha ai	Yield (lbs/plot) .1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	249	166	173	228	204.0
Aldicarb G	3.4	239	220	185	211	213.8
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	216	183	204	182	196.3
Carbofuran G	3.4	168	196	180	195	184.8
Oxydemeton-methyl	0.6	204	251	215	196	216.5
Carbaryl	1.7	222	187	209	161	194.8
Control	---	241	218	192	174	206.3

Source	d.f.	S.S.	M.S.	F
Blocks	3	3325.5	1108.5	
Treatment	6	3011.4	501.9	0.8 N.S.D.
Error	18	11057.2	614.3	
Total	27	17394.1		

C.V. = 12.2%

TABLE 48. Weekly populations of the aster leafhopper in carrots as affected by various insecticide treatments, 1972.

Treatment	Rate kg/ha ai	Number of leafhoppers per 50 sweeps at each date																			
		4/7					11/7					18/7					25/7					4/8				
		1	2	3	4[1]	$\bar{x}$[2]	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	1	2	1	2	3.0	25	30	45	55	77.5	18	25	17	22	41.0	8	11	10	6	17.5	12	18	25	15	35.0
Aldicarb G	3.4	1	1	0	2	2.0	26	19	29	9	41.5	14	22	19	21	38.0	11	14	13	6	22.0	11	19	8	21	29.5
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	2	1	1	2	3.0	30	60	50	43	91.5	8	15	11	17	25.5	4	8	4	7	11.5	13	24	11	18	33.0
Oxydemeton-methyl	0.6	5	2	2	3	6.0	26	55	65	30	88.0	8	15	4	9	18.0	3	5	2	2	6.0	19	13	8	19	29.5
Carbofuran G	3.4	3	4	4	3	7.0	27	50	48	37	81.0	10	15	23	20	34.0	15	24	19	24	41.0	30	33	40	38	70.5
Carbaryl	1.7	7	9	8	6	15.0	47	125	115	175	231.0	16	23	15	17	35.5	1	2	1	1	2.5	39	30	40	32	70.5
Control	---	7	13	10	9	19.5	110	85	145	140	240.0	31	37	53	40	80.5	16	20	23	10	34.5	49	60	35	63	103.5

1. Replication 2. $\bar{x}$ #/100 sweeps

Cont'd.....

TABLE 48. (Cont'd)

Treatment	Rate kg/ha ai	Number of leafhoppers per 50 sweeps at each date																			
		11/8					17/8					25/8					31/8				
		1	2	3	4[1]	$\bar{x}$[2]	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$	1	2	3	4	$\bar{x}$
Aldicarb G	1.7 + 1.7	12	25	23	16	38.0	12	20	11	20	31.5	12	20	18	12	31.0	31	29	21	22	51.5
Aldicarb G	3.4	17	21	10	14	31.0	15	25	35	50	62.5	30	17	10	25	41.0	26	21	24	18	44.5
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	28	16	15	26	42.5	15	30	12	15	36.0	20	12	23	15	34.5	15	30	21	14	40.0
Oxydemeton-methyl	0.6	7	16	12	17	26.0	10	9	15	6	20.0	15	17	15	14	30.5	6	14	10	12	21.0
Carbofuran G	3.4	40	29	39	26	67.0	15	33	37	23	54.0	44	73	45	17	89.5	44	50	36	46	88.0
Carbaryl	1.7	35	46	45	37	81.5	27	30	33	15	52.5	40	45	40	72	98.5	35	37	45	39	78.0
Control	---	59	50	41	39	94.5	55	52	23	30	80.0	85	67	28	49	114.5	61	38	45	56	100.5

1. Replication 2. $\bar{x}$ #/100 sweeps

TABLE 49. Analysis of variance of cumulative mean leafhopper populations (mid and late-season), aster yellows incidence (mid-season and harvest), and yield in carrots as affected by various insecticide treatments, 1972.

Treatment	Rate kg/ha ai	Cumulative $\bar{x}$ number/100 sweeps/week Mid-season ($\sqrt{x+0.5}$)				
		1	2	3	4	$\bar{x}$
Aldicarb G	3.4	3.67	3.81	3.97	3.16	3.65
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	3.39	4.64	4.10	4.22	4.09
Aldicarb G	1.7 + 1.7	3.67	4.18	4.34	4.67	4.22
Carbofuran G	3.4	3.78	4.88	4.90	4.74	4.58
Oxydemeton-methyl	0.6	3.32	4.45	4.34	3.39	3.88
Carbaryl	1.7	4.28	6.35	5.94	7.09	5.92
Control	---	6.44	6.28	7.64	7.09	6.86

Source	d.f.	S.S.	M.S.	F
Blocks	3	4.15	1.38	
Treatment	6	34.18	5.70	20.85**
Error	18	4.92	0.27	
Total	27	43.25		

C.V. = 11.03%

Treatment	Rate kg/ha ai	Cumulative $\bar{x}$ number/100 sweeps/week Late-season ($\sqrt{x+0.5}$)				
		1	2	3	4	$\bar{x}$
Aldicarb G	3.4	4.16	4.23	4.11	4.35	4.21
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	3.94	4.72	4.10	4.23	4.25
Aldicarb G	1.7 + 1.7	3.89	4.53	4.42	4.40	4.31
Carbofuran G	3.4	5.08	5.92	5.73	5.15	5.47
Oxydemeton-methyl	0.6	3.39	4.09	3.91	3.59	3.75
Carbaryl	1.7	5.28	6.25	6.20	6.69	6.11
Control	---	7.29	6.89	6.95	6.99	7.03

Source	d.f.	S.S.	M.S.	F
Blocks	3	0.97	0.32	
Treatment	6	35.19	5.87	65.47**
Error	18	1.61	0.09	
Total	27	37.78		

C.V. = 5.97%

Treatment	Rate kg/ha ai	AY incidence, % (mid-season)				
		1	2	3	4	$\bar{x}$
Aldicarb G	3.4	0.5	0	0.5	0.5	0.4
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	1.0	1.0	2.0	2.0	1.5
Aldicarb G	1.7 + 1.7	1.0	0.5	0.5	0.5	0.6
Carbofuran G	3.4	1.0	1.0	1.0	0	0.8
Oxydemeton-methyl	0.6	1.5	3.0	1.0	1.0	1.6
Carbaryl	1.7	0.5	1.0	1.5	1.0	1.0
Control	---	1.0	1.5	1.5	2.0	1.5

Source	d.f.	S.S.	M.S.	F
Blocks	3	0.9	0.3	
Treatment	6	23.4	3.9	3.2*
Error	18	22.2	1.2	
Total	27	46.6		

C.V. = 52.0%

Cont'd.....

TABLE 49. (Cont'd)

Treatment	Rate kg/ha ai	AY incidence, % (harvest) 1	2	3	4	$\bar{x}$
Aldicarb G	3.4	1.1	3.9	5.8	3.6	3.6
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	2.3	7.9	3.5	5.3	4.8
Aldicarb G	1.7 + 1.7	1.8	4.4	3.2	4.4	3.5
Carbofuran G	3.4	4.4	5.0	4.4	6.4	5.1
Oxydemeton-methyl	0.6	1.3	5.5	1.5	3.1	2.9
Carbaryl	1.7	3.1	6.3	4.5	7.4	5.3
Control	---	7.2	5.5	13.2	10.3	9.1

Source	d.f.	S.S.	M.S.	F
Blocks	3	32.9	10.9	
Treatment	1	101.7	16.9	5.1**
Error	18	60.2	3.3	
Total	27	194.9		

C.V. = 37.1%

Treatment	Rate kg/ha ai	Yield (lbs/plot) 1	2	3	4	$\bar{x}$
Aldicarb G	3.4	94	74	72	85	81.3
Aldicarb G + oxydemeton-methyl	3.4 + 0.6	99	87	85	84	88.8
Aldicarb G	1.7 + 1.7	86	101	89	91	91.8
Carbofuran G	3.4	112	79	97	107	98.8
Oxydemeton-methyl	0.6	95	71	91	105	90.5
Carbaryl	1.7	77	65	82	84	77.0
Control	---	81	72	77	70	75.0

Source	d.f.	S.S.	M.S.	F
Blocks	3	746.5	248.8	
Treatment	6	1791.4	298.6	3.8*
Error	18	1379.4	76.6	
Total	27	3917.4		

C.V. = 10.2%

TABLE 50. Analysis of variance of the cumulative mean leafhopper population (mid-season) in celery as affected by various insecticide treatments over a three year period.

Treatment (1970)	Rate kg/ha ai	Replication[1] 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	1.48	1.64	1.58	1.52	6.22	1.56
Carbofuran	3.4	1.67	1.82	2.19	1.79	7.47	1.87
Oxydemeton-methyl	0.6	1.79	1.58	1.87	2.35	7.59	1.90
Carbaryl	1.7	2.07	1.92	1.87	1.92	7.78	1.95
Control	---	2.59	2.55	1.67	2.17	8.98	2.25

Source	D.F.	S.S.	M.S.	F	
Blocks	3	0.03	0.01	0.14	
Treatment	4	0.96	0.24	2.84	N.S.D.
Error	12	1.02	0.08		
Total	19	2.02			

C.V. = 14.9%

Treatment (1971)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	1.14	1.00	1.30	1.14	4.58	1.15
Carbofuran	3.4	1.22	1.10	1.30	1.14	4.76	1.19
Oxydemeton-methyl	0.6	1.30	1.41	1.22	1.41	5.34	1.34
Carbaryl	1.7	1.58	1.41	1.48	1.34	5.81	1.45
Control	---	1.95	2.07	2.00	1.87	7.89	1.97

Source	D.F.	S.S.	M.S.	F	
Blocks	3	0.02	0.01	0.63	
Treatment	4	1.77	0.44	41.73	**
Error	12	0.13	0.01		
Total	19	1.92			

C.V. = 7.0%

Treatment (1972)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	1.00	1.14	1.22	1.52	4.88	1.22
Carbofuran	3.4	1.14	1.52	1.58	1.22	5.46	1.37
Oxydemeton-methyl	0.6	1.22	1.67	1.58	1.34	5.81	1.45
Carbaryl	1.7	1.58	1.73	1.41	1.34	6.06	1.52
Control	---	1.52	1.73	1.95	1.41	6.61	1.65

Source	D.F.	S.S.	M.S.	F	
Blocks	3	0.26	0.09	2.55	
Treatment	4	0.42	0.10	3.03	N.S.D.
Error	12	0.42	0.03		
Total	19	1.10			

C.V. = 12.0%

Treatment (3 Yr. Total)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	1.87	2.00	2.17	2.21	8.25	2.06
Carbofuran	3.4	2.14	2.41	2.88	2.24	9.62	2.41
Oxydemeton-methyl	0.6	2.32	2.51	2.55	2.88	10.26	2.57
Carbaryl	1.7	2.88	2.77	2.59	2.51	10.75	2.69
Control	---	3.29	3.58	3.10	3.03	13.0	3.25

Source	D.F.	S.S.	M.S.	F	
Blocks	3	0.08	0.03	0.45	
Treatment	4	3.03	0.76	12.95	**
Error	12	0.7	0.06		
Total	19	3.81			

C.V. = 9.5%

Source	D.F.	S.S.	M.S.	F	
Total (treatment x year plots)	59	114.329			
Main plots (treatment plots)	19	1.272			
Blocks	3	0.025	0.008		
Treatments (T)	4	1.012	0.253	1.265	N.S.D.
B x T [(Error(a)]	12	0.235	0.020		
Years	2	109.295	54.648	1012.	**
T x Y	8	2.140	0.268	4.96	*
B x Y	6	0.295	0.049		
B x V x Y	24	1.327	0.055		
Error (b)	30	1.622	0.054		

1. Mean number of leafhoppers/25 sweeps/week transformed to $\sqrt{x + 0.5}$

TABLE 51. Analysis of variance of the cumulative mean leafhopper population (late-season) in celery as affected by various insecticide treatments over a three year period.

Treatment (1970)	Rate kg/ha ai	Replication[1] 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	2.30	2.07	2.53	2.30	9.20	2.30
Carbofuran	3.4	2.07	2.39	2.92	2.39	9.77	2.44
Oxydemeton-methyl	0.6	2.97	2.77	2.81	3.33	11.88	2.97
Carbaryl	1.7	3.45	3.18	2.79	3.36	12.78	3.20
Control	---	3.94	4.09	3.35	3.97	15.35	3.84

Source	D.F.	S.S.	M.S.	F
Blocks	3	0.11	0.04	0.38
Treatment	4	6.11	1.53	15.94**
Error	12	1.15	0.10	
Total	19	7.37		

C.V. = 10.7%

Treatment (1971)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	1.82	1.55	1.61	1.61	6.59	1.65
Carbofuran	3.4	1.82	1.97	1.79	1.76	7.34	1.84
Oxydemeton-methyl	0.6	1.45	1.61	1.45	1.45	5.96	1.49
Carbaryl	1.7	1.70	1.92	1.70	1.79	7.11	1.78
Control	---	2.59	2.63	2.72	2.49	10.43	2.61

Source	D.F.	S.S.	M.S.	F
Blocks	3	0.04	0.01	1.28
Treatment	4	2.99	0.75	80.51**
Error	12	0.11	0.01	
Total	19	3.14		

C.V. = 5.3%

Treatment (1972)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	1.10	1.34	1.30	1.26	5.00	1.25
Carbofuran	3.4	1.22	1.48	1.45	1.34	5.49	1.37
Oxydemeton-methyl	0.6	1.18	1.55	1.45	1.58	5.76	1.44
Carbaryl	1.7	1.55	1.87	1.55	1.26	6.23	1.56
Control	---	1.61	1.70	1.90	1.48	6.69	1.67

Source	D.F.	S.S.	M.S.	F
Blocks	3	0.22	0.07	3.66
Treatment	4	0.43	0.11	5.41**
Error	12	0.24	0.02	
Total	19	0.88		

C.V. = 9.7%

Treatment (3 Yr. Total)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	2.97	2.74	3.11	2.72	11.54	2.87
Carbofuran	3.4	2.85	3.29	3.58	3.10	12.82	3.21
Oxydemeton-methyl	0.6	3.36	3.42	3.33	3.83	13.94	3.49
Carbaryl	1.7	4.02	4.04	3.48	3.87	15.43	3.86
Control	---	4.88	5.05	4.63	4.82	19.38	4.85

Source	D.F.	S.S.	M.S.	F
Blocks	3	0.03	0.01	0.13
Treatment	4	9.13	2.28	33.39 **
Error	12	0.82	0.07	
Total	19	9.97		

C.V. = 7.2%

Source	D.F.	S.S.	M.S.	F
Total (treatment x year plots)	59	208.78		
Main plots (treatment plots)	19	3.276		
Blocks	3	0.009	0.003	
Treatments (T)	4	2.993	0.748	3.28*
B x T [(Error(a)]	12	0.274	0.228	
Years	2	197.394	98.69	1591.**
T x Y	8	6.537	0.817	13.18**
B x Y	6	0.358	0.059	
B x V x Y	24	1.515	0.06	
Error (b)	30	1.873	0.062	

1. Mean number of leafhoppers/25 sweeps/week transformed to $\sqrt{x + 0.5}$

TABLE 52. Analysis of variance of the incidence of AY in celery (mid-season) as affected by various insecticide treatments over a three year period.

Treatment (1970)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	2.7	3.3	3.3	4.0	13.3	3.3
Carbofuran	3.4	3.3	1.3	2.7	1.3	8.6	2.2
Oxydemeton-methyl	0.6	3.3	4.7	4.7	4.0	16.7	4.2
Carbaryl	1.7	4.7	4.7	6.7	5.3	21.4	5.4
Control	---	4.0	7.3	4.7	8.0	24.0	6.0

Source	D.F.	S.S.	M.S.	F
Blocks	3	2.57	0.86	0.61
Treatment	4	38.13	8.53	6.83 **
Error	12	16.74	1.40	
Total	19	57.44		

C.V. = 28.1%

Treatment (1971)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	3.7	2.9	5.1	2.9	14.6	3.7
Carbofuran	3.4	2.2	3.7	2.9	1.5	10.3	2.6
Oxydemeton-methyl	0.6	5.9	2.9	5.9	4.4	19.1	4.8
Carbaryl	1.7	5.1	2.9	4.4	2.2	14.6	3.7
Control	---	6.6	7.4	5.1	3.7	22.8	5.7

Source	D.F.	S.S.	M.S.	F
Blocks	3	10.29	3.43	2.71
Treatment	4	22.97	5.73	4.54 *
Error	12	15.19	1.27	
Total	19	48.88		

C.V. = 27.6%

Treatment (1972)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	0.0	0.7	0.7	0.0	1.4	0.34
Carbofuran	3.4	0.7	0.0	0.7	0.0	1.4	0.34
Oxydemeton-methyl	0.6	0.7	0.7	0.7	0.7	2.1	0.5
Carbaryl	1.7	0.7	0.0	0.7	0.7	2.1	0.5
Control	---	0.7	0.7	0.0	0.7	2.1	0.5

Source	D.F.	S.S.	M.S.	F
Blocks	3	0.27	0.09	0.59
Treatment	4	0.15	0.04	0.24 N.S.D.
Error	12	1.81	0.15	
Total	19	2.23		

C.V. = 85.4%

Treatment (3 Yr. Total)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	6.4	10.2	9.1	6.9	32.6	8.15
Carbofuran	3.4	6.2	5.0	6.3	2.8	20.3	5.08
Oxydemeton-methyl	0.6	9.9	8.3	11.3	8.4	37.9	9.48
Carbaryl	1.7	10.5	9.6	11.8	8.2	38.1	9.53
Control	---	11.3	15.4	9.8	12.4	48.9	12.23

Source	D.F.	S.S.	M.S.	F
Blocks	3	10.42	3.47	1.00
Treatment	4	107.88	26.97	7.75 **
Error	12	41.74	3.48	
Total	19	160.04		

C.V. = 21.0%

Source	D.F.	S.S.	M.S.	F
Total (treatment x year plots)	59	269.47		
Main plots (treatment plots)	19	53.35		
Blocks	3	3.47	1.16	
Treatments (T)	4	35.96	8.99	7.75**
B x T [(Error(a)]	12	13.96	1.16	
Years	2	161.36	80.68	
T x Y	8	25.28	3.16	
B x Y	6	9.66	1.61	
B x V x Y	24	19.82	0.83	
Error (b)	30	29.48		

TABLE 53. Analysis of variance of the incidence of AY in celery (harvest) as affected by various insecticide treatments over a three year period.

Treatment (1970)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	4.7	4.0	5.3	4.0	18.0	4.5
Carbofuran	3.4	6.0	4.0	8.7	6.0	24.7	6.2
Oxydemeton-methyl	0.6	4.7	7.3	7.3	5.3	24.6	6.2
Carbaryl	1.7	9.3	14.7	13.3	8.0	45.3	11.3
Control	---	7.3	10.0	6.7	12.7	36.7	9.2

Source	D.F.	S.S.	M.S.	F
Blocks	3	10.61	3.54	0.70
Treatment	4	120.03	30.01	5.96 **
Error	12	60.4	5.03	
Total	19	191.05		

C.V. - 30.1%

Treatment (1971)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	4.7	4.0	5.3	3.4	17.4	4.4
Carbofuran	3.4	3.0	4.0	3.4	2.3	12.7	3.0
Oxydemeton-methyl	0.6	6.7	4.7	6.0	5.4	22.8	5.7
Carbaryl	1.7	8.7	8.0	10.1	9.4	36.2	9.1
Control	---	14.7	13.4	13.4	10.7	52.2	13.1

Source	D.F.	S.S.	M.S.	F
Blocks	3	6.58	2.19	2.60
Treatment	4	256.51	64.13	76.07 **
Error	12	10.12	0.84	
Total	19	273.21		

C.V. = 13%

Treatment (1972)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	0.7	1.3	2.0	1.3	5.3	1.3
Carbofuran	3.4	1.3	1.3	3.3	0.7	6.6	1.7
Oxydemeton-methyl	0.6	3.3	2.0	0.7	0.7	6.7	1.7
Carbaryl	1.7	4.7	2.7	2.0	2.7	12.1	3.0
Control	---	2.0	2.7	2.0	1.3	8.0	2.0

Source	D.F.	S.S.	M.S.	F
Blocks	3	2.89	0.96	1.00
Treatment	4	6.85	1.71	1.78 N.S.D.
Error	12	11.52	0.96	
Total	19	21.27		

C.V. = 50.6%

Treatment (3 Yr. Total)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	10.1	9.3	12.6	8.7	40.7	10.18
Carbofuran	3.4	10.3	9.3	15.4	9.0	44.	11.00
Oxydemeton-methyl	0.6	14.7	14.0	14.0	11.4	54.1	13.53
Carbaryl	1.7	22.7	25.4	25.4	20.1	93.6	23.40
Control	---	24.0	26.1	22.1	24.7	96.9	24.23

Source	D.F.	S.S.	M.S.	F
Blocks	3	25.18	8.39	2.27
Treatment	4	745.54	186.39	50.35 **
Error	12	44.14	3.70	
Total	19	815.15		

C.V. = 11.7%

Source	D.F.	S.S.	M.S.	F
Total (treatment x year plots)	59	864.21		
Main plots (treatment plots)	19	271.71		
Blocks	3	8.39	2.80	
Treatments (T)	4	248.51	62.13	50.5**
B x T [(Error(a)]	12	14.81	1.23	
Years	2	380.38	190.19	
T x Y	8	134.89	16.86	
B x Y	6	11.70	1.95	
B x V x Y	24	65.53	2.73	
Error (b)	30	77.23	2.57	

TABLE 54. Analysis of variance of celery yield as affected by various insecticide treatments over a three year period.

Treatment (1970)	Rate kg/ha ai	Replication[1] 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	192	170	204	157	723	180.8
Carbofuran	3.4	183	192	157	172	704	176.0
Oxydemeton-methyl	0.6	210	183	205	162	760	190.0
Carbaryl	1.7	221	164	190	185	760	190.0
Control	---	135	155	169	158	617	154.3

Source	D.F.	S.S.	M.S.	F
Blocks	3	1526.8	508.93	
Treatment	4	3453.7	863.43	2.45 N.S.D.
Error	12	4224.7	352.06	
Total	19	9205.2		C.V. = 10.5%

Treatment (1971)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	236	247	195	200	878	219.5
Carbofuran	3.4	262	259	205	255	981	245.3
Oxydemeton-methyl	0.6	260	217	213	202	892	223.0
Carbaryl	1.7	198	208	153	164	723	180.8
Control	---	185	153	142	150	630	157.5

Source	D.F.	S.S.	M.S.	F
Blocks	3	6707.6	2235.87	
Treatment	4	19993.7	4998.43	23.1 **
Error	12	2595.9	216.33	
Total	19	29297.2		C.V. = 7.2%

Treatment (1972)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	239	220	185	211	855	213.8
Carbofuran	3.4	168	196	180	195	739	184.8
Oxydemeton-methyl	0.6	204	251	215	196	866	216.5
Carbaryl	1.7	222	187	209	161	779	194.8
Control	---	241	218	192	174	825	206.3

Source	D.F.	S.S.	M.S.	F
Blocks	3	2793.2	931.1	
Treatment	4	2837.2	709.3	1.48 N.S.D.
Error	12	5754.8	479.6	
Total	19	11385.2		C.V. = 10.8%

Treatment (3 Yr. Total)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	667	637	584	568	2456	204.7
Carbofuran	3.4	613	647	542	622	2424	202.0
Oxydemeton-methyl	0.6	674	651	633	560	2518	209.8
Carbaryl	1.7	641	559	552	510	2262	188.5
Control	---	561	520	503	482	2072	172.7

Source	D.F.	S.S.	M.S.	F
Blocks	3	21588.0	7196.0	
Treatment	4	32474.8	8118.7	9.2 **
Error	12	10572.0	881.0	
Total	19	64634.8		C.V. = 15.2%

Source	D.F.	S.S.	M.S.	F
Total (treatment x year plots)	59	58940.9		
Main plots (treatment plots)	19	21544.9		
Blocks	3	7195.9	2398.6	
Treatments (T)	4	10824.9	2706.2	9.2**
B x T [(Error(a)]	12	3524.1	293.7	
Years	2	9053.3	4526.7	
T x Y	8	15459.7	1932.5	
B x Y	6	3831.6	638.6	
B x V x Y	24	9051.37	377.1	
Error (b)	30	12882.9		

1. Lbs./plot.

TABLE 55. Analysis of variance of the cumulative mean leafhopper population (mid-season) in carrots as affected by various insecticide treatments over a three year period.

Treatment (1970)	Rate kg/ha ai	Replication[1] 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	2.12	2.70	2.45	1.87	9.14	2.29
Carbofuran	3.4	3.00	3.56	4.47	3.71	14.74	3.69
Oxydemeton-methyl	0.6	3.08	3.13	2.97	2.92	12.1	3.03
Carbaryl	1.7	2.88	2.55	3.44	3.65	12.52	3.13
Control	---	4.06	3.85	3.61	3.94	15.46	3.87

Source	D.F.	S.S.	M.S.	F
Blocks	3	0.34	0.11	.65
Treatment	4	6.20	1.55	9.00**
Error	12	2.07	0.17	
Total	19	8.60		

C.V. = 13.0%

Treatment (1971)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	2.17	2.49	2.49	2.97	10.12	2.53
Carbofuran	3.4	2.68	2.70	2.92	2.55	10.85	2.71
Oxydemeton-methyl	0.6	2.41	2.17	2.45	2.12	9.15	2.29
Carbaryl	1.7	3.32	3.21	3.35	3.29	13.17	3.29
Control	---	3.90	5.07	4.66	4.15	17.78	4.34

Source	D.F.	S.S.	M.S.	F
Blocks	3	0.20	0.07	1.07
Treatment	4	10.77	2.69	44.27**
Error	12	0.73	0.06	
Total	19	11.7		

C.V. = 8.1%

Treatment (1972)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	3.67	3.81	3.97	3.16	14.61	3.65
Carbofuran	3.4	3.78	4.88	4.90	4.64	18.2	4.55
Oxydemeton-methyl	0.6	3.32	4.45	4.34	3.39	15.5	3.88
Carbaryl	1.7	4.28	6.35	5.94	7.09	23.06	5.92
Control	---	6.44	6.28	7.64	7.09	27.45	6.86

Source	D.F.	S.S.	M.S.	F
Blocks	3	3.23	1.08	2.89
Treatment	4	30.34	7.59	20.34 **
Error	12	4.47	0.37	
Total	19	38.05		

C.V. = 12.3%

Treatment (3 Yr. Total)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	4.66	5.81	5.20	4.62	20.29	5.07
Carbofuran	3.4	5.43	6.54	7.18	6.39	25.54	6.39
Oxydemeton-methyl	0.6	5.03	5.77	5.31	3.69	19.80	5.05
Carbaryl	1.7	6.05	7.88	7.57	8.57	30.07	7.52
Control	---	8.50	8.88	9.59	9.06	36.03	9.01

Source	D.F.	S.S.	M.S.	F
Blocks	3	4.03	1.34	3.04
Treatment	4	45.68	11.42	25.89**
Error	12	5.29	0.44	
Total	19	55.00		

C.V. = 10.1%

Source	D.F.	S.S.	M.S.	F
Total (treatment x year plots)	59	655.88		
Main plots (treatment plots)	19	20.09		
Blocks	3	1.23		
Treatments (T)	4	15.65	3.91	14.48**
B x T [(Error(a)]	12	3.21	0.27	
Years	2	596.03	298.01	
T x Y	8	32.77	4.10	
B x Y	6	2.57	0.43	
B x V x Y	24	4.42	0.18	
Error (b)	30	6.99	0.23	

1. Mean number of leafhoppers/50 sweeps/week transformed to $\sqrt{x + 0.5}$.

TABLE 56. Analysis of variance of the cumulative mean leafhopper population (late season) in carrots as affected by various insecticide treatments over a three year period.

Treatment (1970)	Rate kg/ha ai	Replication[1] 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	3.94	5.34	3.87	4.53	17.68	4.42
Carbofuran	3.4	6.48	5.45	5.87	5.63	23.43	5.86
Oxydemeton-methyl	0.6	6.16	7.60	5.67	5.81	25.24	6.31
Carbaryl	1.7	5.97	4.93	5.02	5.94	21.86	5.47
Control	---	6.93	5.61	5.90	5.54	23.98	6.00

Source	D.F.	S.S.	M.S.	F
Blocks	3	1.23	0.41	0.92
Treatment	4	8.55	2.14	4.82*
Error	12	5.32	0.44	
Total	19	15.09		

C.V. = 11.9%

Treatment (1971)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	3.63	3.59	3.86	4.39	15.47	3.87
Carbofuran	3.4	4.72	4.36	4.73	4.28	18.09	4.52
Oxydemeton-methyl	0.6	2.63	3.11	2.92	2.79	11.45	2.86
Carbaryl	1.7	3.71	3.41	3.61	3.78	14.51	3.63
Control	---	4.73	5.32	5.17	5.02	20.24	5.06

Source	D.F.	S.S.	M.S.	F
Blocks	3	0.1	0.03	0.48
Treatment	4	11.38	2.85	39.62**
Error	12	0.86	0.07	
Total	19	12.35		

C.V. = 6.7%

Treatment (1972)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	4.16	4.23	4.11	4.35	16.85	4.21
Carbofuran	3.4	5.08	5.92	5.73	5.15	21.88	5.47
Oxydemeton-methyl	0.6	3.39	4.09	3.91	3.59	14.98	3.75
Carbaryl	1.7	5.28	6.25	6.20	6.69	24.42	6.11
Control	---	7.29	6.89	6.95	6.99	28.12	7.03

Source	D.F.	S.S.	M.S.	F
Blocks	3	0.54	0.18	1.46
Treatment	4	29.08	7.27	59.54**
Error	12	1.47	0.12	
Total	19	31.08		

C.V. = 6.58%

Treatment (3 Yr. Total)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	6.71	7.64	6.77	7.60	28.72	7.18
Carbofuran	3.4	9.44	9.10	9.42	8.69	36.65	9.16
Oxydemeton-methyl	0.6	6.75	9.14	7.42	7.31	30.62	7.66
Carbaryl	1.7	8.74	8.60	8.70	9.66	35.70	8.93
Control	---	11.07	10.31	10.43	10.19	42.00	10.50

Source	D.F.	S.S.	M.S.	F
Blocks	3	0.57	0.19	0.46
Treatment	4	27.62	6.91	16.67**
Error	12	4.97	0.41	
Total	19	33.16		

C.V. = 7.41

Source	D.F.	S.S.	M.S.	F
Total (treatment x year plots)	59	1067.59		
Main plots (treatment plots)	19	11.058		
Blocks	3	0.193		
Treatments (T)	4	9.211	2.302	16.88**
B x T [(Error(a)]	12	1.654	0.138	
Years	2	1009.06	504.53	1994.19**
T x Y	8	39.81	4.97	19.49**
B x Y	6	1.599	0.267	
B x V x Y	24	6.067	0.253	
Error (b)	30	7.666	0.255	

1. Mean number of leafhoppers/50 sweeps/week transformed to $\sqrt{x + 0.5}$.

TABLE 57. Analysis of variance of the incidence of AY in carrots (mid-season) as affected by various insecticide treatments over a three year period.

Treatment (1970)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	1.5	0.5	3.0	3.5	8.5	2.1
Carbofuran	3.4	0.5	4.0	1.0	0.5	6.0	1.5
Oxydemeton-methyl	0.6	3.0	3.5	7.0	2.0	15.5	3.9
Carbaryl	1.7	1.5	5.0	5.0	1.0	12.5	3.1
Control	---	3.0	2.5	6.0	4.0	15.5	3.9

Source	D.F.	S.S.	M.S.	F	
Blocks	3	18.9	6.3	2.45	
Treatment	4	18.05	4.51	1.76	N.S.D.
Error	12	30.85	2.57		
Total	19	67.8			

C.V. = 55.3

Treatment (1971)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	3	3	6	2	14	3.5
Carbofuran	3.4	3	5	2	4	14	3.5
Oxydemeton-methyl	0.6	4	3	1	4	12	3.0
Carbaryl	1.7	3	7	5	6	21	5.3
Control	---	3	6	6	5	20	5.0

Source	D.F.	S.S.	M.S.	F	
Blocks	3	6.55	2.18	0.93	
Treatment	4	16.2	4.05	1.72	N.S.D.
Error	12	28.2	2.35		
Total	19	50.95			

C.V. = 37.9%

Treatment (1972)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	0.5	0	0.5	0.5	1.5	0.4
Carbofuran	3.4	1.0	1.0	1.0	0	3.0	0.75
Oxydemeton-methyl	0.6	1.5	3.0	1.0	1.0	6.5	1.6
Carbaryl	1.7	0.5	1.0	1.5	1.0	4.0	1.0
Control	---	1.0	1.5	1.5	2.0	6.0	1.5

Source	D.F.	S.S.	M.S.	F	
Blocks	3	0.55	0.18	0.54	
Treatment	4	4.33	1.08	3.18	N.S.D.
Error	12	4.08	0.34		
Total	19	8.95			

C.V. = 55.5%

Treatment (3 Yr. Total)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	5.0	3.5	9.5	6.0	24.0	6.0
Carbofuran	3.4	4.5	10.0	4.0	4.5	23.0	5.8
Oxydemeton-methyl	0.6	8.5	9.5	9.0	7.0	34.0	8.5
Carbaryl	1.7	5.0	13.0	11.5	8.0	37.5	9.4
Control	---	7.0	10.0	13.5	11.0	41.5	10.4

Source	D.F.	S.S.	M.S.	F	
Blocks	3	40.9	13.63	2.45	
Treatment	4	67.38	16.84	3.03	N.S.D.
Error	12	66.73	5.56		
Total	19	175.0			

C.V. = 29.5%

Source	D.F.	S.S.	M.S.	F	
Total (treatment x year plots)	59	219.333			
Main plots (treatment plots)	19	58.333			
Blocks	3	13.633	4.544		
Treatments (T)	4	22.458	5.615	3.03	N.S.D.
B x T [(Error(a)]	12	22.242	1.854		
Years	2	91.633	48.817	25.8**	
T x Y	8	16.117	2.015	1.135	N.S.D
B x Y	6	12.367	2.061		
B x V x Y	24	40.883	1.703		
Error (b)	30	53.25	1.775		

TABLE 58. Analysis of variance of the incidence of AY in carrots (harvest) as affected by various insecticide treatments over a three year period.

Treatment (1970)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	11.7	18.1	13.2	22.2	65.2	16.3
Carbofuran	3.4	24.1	15.6	29.3	22.2	91.2	22.8
Oxydemeton-methyl	0.6	11.5	13.6	21.5	28.2	74.8	18.7
Carbaryl	1.7	26.7	18.3	27.4	22.4	94.8	23.7
Control	---	23.3	19.5	20.2	39.4	102.4	25.6

Source	D.F.	S.S.	M.S.	F	
Blocks	3	269.12	89.71	2.78	
Treatment	4	232.75	58.19	1.80	N.S.D.
Error	12	387.42	32.29		
Total	19	889.29			

C.V. = 26.5%

Treatment (1971)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	2.8	4.6	4.6	2.8	14.8	3.7
Carbofuran	3.4	6.4	3.9	7.1	5.3	22.7	5.7
Oxydemeton-methyl	0.6	4.6	3.9	6.0	5.7	20.2	5.1
Carbaryl	1.7	6.4	6.4	7.4	6.4	26.6	6.7
Control	---	11.0	11.3	14.1	15.9	52.3	13.1

Source	D.F.	S.S.	M.S.	F
Blocks	3	10.88	3.63	2.38
Treatment	4	213.3	53.33	34.99**
Error	12	18.29	1.52	
Total	19	242.5		

C.V. = 18.1%

Treatment (1972)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	1.1	3.9	5.8	3.6	14.4	3.6
Carbofuran	3.4	4.4	5.0	4.4	6.4	20.2	5.1
Oxydemeton-methyl	0.6	1.3	5.5	1.5	3.1	11.4	2.9
Carbaryl	1.7	3.1	6.3	4.5	7.4	21.3	5.3
Control	---	7.2	5.5	13.2	10.3	36.2	9.1

Source	D.F.	S.S.	M.S.	F
Blocks	3	22.76	7.59	1.89
Treatment	4	91.76	22.94	5.72**
Error	12	48.10	4.01	
Total	19	162.62		

C.V. = 38.7%

Treatment (3 Yr. Total)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	15.6	26.6	23.6	28.6	94.4	23.6
Carbofuran	3.4	34.9	24.5	40.8	33.9	134.1	33.5
Oxydemeton-methyl	0.6	17.4	23.0	29.0	37.0	106.4	26.6
Carbaryl	1.7	36.2	31.0	39.3	36.2	142.7	35.7
Control	---	41.5	36.3	47.5	65.6	190.8	47.7

Source	D.F.	S.S.	M.S.	F
Blocks	3	492.8	164.27	4.13
Treatment	4	1410.7	352.67	8.86**
Error	12	477.53	39.79	
Total	19	2381.02		

C.V. = 18.9%

Source	D.F.	S.S.	M.S.	F
Total (treatment x year plots)	59	4493.35		
Main plots (treatment plots)	19	795.9		
Blocks	3	166.49		
Treatments (T)	4	469.28	117.32	8.79**
B x T [(Error(a)]	12	160.13	13.34	
Years	2	3198.94		
T x Y	8	68.55		
B x V x Y	6	136.26	22.7	
Error (b)	24	293.7	12.2	
	30	429.96		

TABLE 59. Analysis of variance of carrot yield as affected by various insecticide treatments over a three year period.

Treatment (1970)	Rate kg/ha ai	Replication[1] 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	51	59	47	64	221	55.3
Carbofuran	3.4	55	72	73	44	244	61.0
Oxydemeton-methyl	0.6	61	48	46	52	207	51.8
Carbaryl	1.7	54	43	40	59	196	49.0
Control	---	42	39	63	61	205	51.3

Source	D.F.	S.S.	M.S.	F
Blocks	3	43.75	14.58	0.11
Treatment	4	350.3	87.58	0.67 N.S.D.
Error	12	1566.5	130.54	
Total	19	1960.6		

C.V. = 21.3%

Treatment (1971)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	53	58	65	57	233	58.3
Carbofuran	3.4	56	54	55	56	221	55.3
Oxydemeton-methyl	0.6	54	47	56	56	213	53.3
Carbaryl	1.7	59	48	47	53	207	51.8
Control	---	59	51	50	48	208	52.0

Source	D.F.	S.S.	M.S.	F
Blocks	3	54.6	18.2	0.92
Treatment	4	116.8	29.2	1.47 N.S.D.
Error	12	238.4	19.87	
Total	19	409.8		

C.V. = 8.24%

Treatment (1972)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	63	49	48	57	217	54.3
Carbofuran	3.4	75	53	65	71	264	66.0
Oxydemeton-methyl	0.6	63	47	61	70	241	60.3
Carbaryl	1.7	51	43	55	56	205	51.3
Control	---	54	48	51	47	200	50.0

Source	D.F.	S.S.	M.S.	F
Blocks	3	540.95	180.32	7.23
Treatment	4	716.3	179.1	7.18 **
Error	12	299.3	24.9	
Total	19	1556.6		

C.V. = 8.9%

Treatment (3 Yr. Total)	Rate kg/ha ai	Replication 1	2	3	4	X	$\bar{x}$
Aldicarb	3.4	167	166	160	178	671	167.8
Carbofuran	3.4	186	179	193	171	729	182.3
Oxydemeton-methyl	0.6	178	142	163	178	661	165.3
Carbaryl	1.7	164	134	142	168	608	152.0
Control	---	155	138	164	156	613	153.3

Source	D.F.	S.S.	M.S.	F
Blocks	3	1117.0	372.3	3.26
Treatment	4	2432.8	608.2	5.32 **
Error	12	1372.0	114.3	
Total	19	4921.8		

C.V. = 6.52%

Source	D.F.	S.S.	M.S.	F
Total (treatment x year plots)	59	4010.6		
Main plots (treatment plots)	19	1640.6		
Blocks	3	372.3	124.1	
Treatments (T)	4	810.9	202.7	5.3**
B x T [(Error(a)]	12	457.3	38.1	
Years	2	83.7	41.9	
T x Y	8	372.5	46.6	
B x Y	6	267.0	44.5	
B x V x Y	24	1646.9	68.6	
Error (b)	30	1913.9		

1. Lbs./plot.

TABLE 60. Analysis of variance of aster yellows incidence (slight) in carrot as affected by aldicarb G applied in furrow with the seed at planting.

Treatment	Rate kg/ha ai	AY incidence, % (slight) Replication 1	2	3	4	5	6	Xi	$\bar{x}$
Control	---	15.7	9.4	12.3	7.0	13.7	7.4	65.5	10.9
Aldicarb	1.7	9.3	11.5	10.0	12.3	6.7	6.0	55.8	9.3
Aldicarb	3.4	4.9	5.7	11.4	7.9	5.6	4.6	40.1	6.7
Aldicarb	5.0	3.9	4.5	7.7	6.8	4.2	7.3	34.4	5.7
Aldicarb	6.7	4.4	4.2	4.5	5.3	6.6	6.1	31.1	5.2

Source	D.F.	S.S.	M.S.	F
Blocks	5	23.25	4.65	0.75
Treatment	4	144.29	36.07	5.80**
Error	20	124.27	6.21	
Total	29	291.81	C.V. = 32.9%	

TABLE 61. Analysis of variance of aster yellows incidence (moderate) in carrot as affected by aldicarb G applied in furrow with the seed at planting.

Treatment	Rate kg/ha ai	AY incidence, % (moderate) Replication 1	2	3	4	5	6	Xi	$\bar{x}$
Control	---	5.6	5.2	8.0	6.2	7.2	5.8	38.0	6.3
Aldicarb	1.7	2.0	3.5	5.4	3.7	5.9	2.7	23.2	3.9
Aldicarb	3.4	3.2	2.7	4.1	3.7	5.0	2.7	21.4	3.6
Aldicarb	5.0	2.7	3.0	3.4	3.6	2.4	2.1	17.2	2.9
Aldicarb	6.7	1.4	3.1	3.4	2.3	3.9	3.2	17.3	2.9

Source	D.F.	S.S.	M.S.	F
Blocks	5	16.24	3.25	6.15
Treatment	4	48.81	12.20	23.11**
Error	20	10.56	0.53	
Total	29	75.61	C.V. = 18.7%	

TABLE 62. Analysis of variance of aster yellows incidence (severe) in carrot as affected by aldicarb G applied in furrow with the seed at planting.

Treatment	Rate kg/ha ai	AY incidence, % (severe) Replication 1	2	3	4	5	6	Xi	$\bar{x}$
Control	---	4.5	4.1	2.8	3.9	5.2	5.9	26.4	4.4
Aldicarb	1.7	1.3	1.8	2.9	1.5	3.0	1.5	12.0	2.0
Aldicarb	3.4	2.4	2.1	4.1	3.1	1.9	1.3	14.9	2.5
Aldicarb	5.0	0.7	1.1	1.6	1.2	0.6	1.0	6.2	1.0
Aldicarb	6.7	1.4	3.1	2.6	3.6	3.7	1.6	16.0	2.7

Source	D.F.	S.S.	M.S.	F
Blocks	5	2.57	0.51	0.6
Treatment	4	36.23	9.06	10.98**
Error	20	16.49	0.82	
Total	29		C.V. = 35.9%	

TABLE 63. Analysis of variance of aster yellows incidence (total) in carrot as affected by aldicarb G applied in furrow with the seed at planting.

Treatment	Rate kg/ha ai	AY incidence, % (total) Replication 1	2	3	4	5	6	Xi	$\bar{x}$
Control	---	25.8	18.7	23.1	17.1	26.1	19.1	12.99	21.7
Aldicarb	1.7	12.6	16.8	18.3	17.5	15.6	10.2	91.0	15.2
Aldicarb	3.4	10.5	10.5	19.6	14.7	12.5	8.6	76.4	12.7
Aldicarb	5.0	7.3	8.6	12.7	11.6	7.2	10.4	57.8	9.6
Aldicarb	6.7	7.2	10.4	10.5	11.2	14.2	10.9	64.4	10.7

Source	D.F.	S.S.	M.S.	F
Blocks	5	84.5	16.9	1.99
Treatment	4	547.4	136.8	16.17**
Error	20	169.2	8.5	
Total	29	801.1	C.V. = 20.8%	

TABLE 64. Analysis of variance of carrot yield as affected by aldicarb G applied in furrow with the seed at planting.

Treatment	Rate kg/ha ai	Yield (lbs./plot) Replication 1	2	3	4	5	6	Xi	$\bar{x}$	t/ha
Control	---	21	37	39	33	37	47	214	35.7	58.0
Aldicarb	1.7	39	30	44	43	42	54	252	42.0	68.3
Aldicarb	3.4	37	46	38	44	55	43	263	43.8	71.2
Aldicarb	5.0	48	50	48	47	34	56	283	47.2	76.8
Aldicarb	6.7	46	56	45	49	30	48	274	45.7	74.4

Source	D.F.	S.S.	M.S.	F
Blocks	5	393.9	78.8	1.41
Treatment	4	479.1	119.8	2.15 N.S.D.
Error	20	1114.5	55.7	
Total	29	1987.5		

TABLE 65. Residue levels of total toxic aldicarb equivalents in carrot leaves sampled at five dates over a fifty day period.

Treatment	Rate kg/ha ai	Total toxic aldicarb equivalents (51 days following application) 1	2	3	4	5	6	$\bar{x}$
Aldicarb G	1.7	0.98	1.44	1.52	1.61	1.62	1.30	1.41
Aldicarb G	3.4	3.33	3.08	3.80	3.55	4.79	4.28	3.81
Aldicarb G	5.0	5.19	5.76	6.82	5.27	8.30	5.44	6.13
Aldicarb G	6.7	5.98	5.63	6.64	8.35	7.52	7.03	6.86

Source	d.f.	S.S.	M.S.	F
Blocks	5	7.39	1.48	
Treatment	3	109.37	36.46	74.37**
Error	15	7.35	0.49	
Total	23	124.12		

C.V. = 15.38%

Treatment	Rate kg/ha ai	Total toxic aldicarb equivalents (61 days following application) 1	2	3	4	5	6	$\bar{x}$
Aldicarb G	1.7	0.40	0.29	0.23	0.34	0.31	0.29	0.31
Aldicarb G	3.4	0.60	0.50	0.48	0.60	0.49	0.69	0.56
Aldicarb G	5.0	0.69	0.95	1.00	0.94	0.86	0.93	0.89
Aldicarb G	6.7	1.35	1.07	1.10	1.08	1.84	1.77	1.38

Source	d.f.	S.S.	M.S.	F
Blocks	5	0.17	0.03	
Treatment	3	3.77	1.26	33.10**
Error	15	0.57	0.04	
Total	23	4.51		

C.V. = 24.88%

Treatment	Rate kg/ha ai	Total toxic aldicarb equivalents (70 days following application) 1	2	3	4	5	6	$\bar{x}$
Aldicarb G	1.7	0.402	0.250	0.182	0.392	0.212	0.296	0.289
Aldicarb G	3.4	0.558	0.340	0.493	0.488	0.382	0.595	0.476
Aldicarb G	5.0	0.918	0.998	0.723	0.635	0.749	0.891	0.819
Aldicarb G	6.7	1.442	1.340	0.876	1.296	1.593	0.755	1.217

Source	d.f.	S.S.	M.S.	F
Blocks	5	0.16	0.03	
Treatment	3	3.00	1.00	26.52**
Error	15	0.57	0.04	
Total	23	3.73		

C.V. = 27.75%

Treatment	Rate kg/ha ai	Total toxic aldicarb equivalents (84 days following application) 1	2	3	4	5	6	$\bar{x}$
Aldicarb G	1.7	0.140	0.174	0.142	0.212	0.216	0.280	0.19
Aldicarb G	3.4	0.231	0.276	0.226	0.335	0.458	0.304	0.31
Aldicarb G	5.0	0.480	0.644	0.494	0.461	0.692	0.643	0.57
Aldicarb G	6.7	0.559	0.423	0.602	0.553	0.740	0.549	0.57

Source	d.f.	S.S.	M.S.	F
Blocks	5	0.09	0.02	
Treatment	3	0.65	0.22	46.87**
Error	15	0.07	0.01	
Total	23	0.81		

C.V. = 16.64%

Treatment	Rate kg/ha ai	Total toxic aldicarb equivalents (99 days following application) 1	2	3	4	5	6	$\bar{x}$
Aldicarb G	1.7	0.213	0.095	0.210	0.141	0.198	0.115	0.16
Aldicarb G	3.4	0.201	0.486	0.313	0.366	0.306	0.272	0.32
Aldicarb G	5.0	0.360	0.622	0.582	0.328	0.612	0.316	0.47
Aldicarb G	6.7	0.552	0.700	0.523	0.842	0.650	0.471	0.62

Source	d.f.	S.S.	M.S.	F
Blocks	5	0.10	0.02	
Treatment	3	0.70	0.23	20.74**
Error	15	0.17	0.01	
Total	23	0.97		

C.V. = 26.90%

TABLE 66. Residue levels of total toxic aldicarb equivalents in carrot roots sampled at five dates over a sixty day period.

Treatment	Rate kg/ha ai	Total toxic aldicarb equivalents (70 days following application) 1	2	3	4	5	6	$\bar{x}$
Aldicarb G	1.7	0.059	0.042	0.050	0.070	0.079	0.072	0.06
Aldicarb G	3.4	0.074	0.104	0.062	0.102	0.126	0.120	0.10
Aldicarb G	5.0	0.099	0.246	0.111	0.126	0.144	0.135	0.14
Aldicarb G	6.7	0.315	0.194	0.149	0.142	0.164	0.265	0.21

Source	d.f.	S.S.	M.S.	F
Blocks	5	0.01	0.002	
Treatment	3	0.07	0.02	10.28**
Error	15	0.03	0.002	
Total	23	0.11		

C.V. = 37.06%

Treatment	Rate kg/ha ai	Total toxic aldicarb equivalents (84 days following application) 1	2	3	4	5	6	$\bar{x}$
Aldicarb G	1.7	0.047	0.051	0.058	0.053	0.067	0.068	0.057
Aldicarb G	3.4	0.079	0.069	0.091	0.098	0.138	0.099	0.096
Aldicarb G	5.0	0.086	0.158	0.158	0.108	0.093	0.112	0.119
Aldicarb G	6.7	0.075	0.119	0.127	0.103	0.152	0.174	0.125

Source	d.f.	S.S.	M.S.	F
Blocks	5	0.00	0.001	
Treatment	3	0.17	0.006	9.26**
Error	15	0.09	0.001	
Total	23	0.03		

C.V. = 24.89%

Treatment	Rate kg/ha ai	Total toxic aldicarb equivalents (99 days following application) 1	2	3	4	5	6	$\bar{x}$
Aldicarb G	1.7	0.041	0.058	0.039	0.057	0.055	0.069	0.053
Aldicarb G	3.4	0.085	0.076	0.090	0.088	0.119	0.100	0.093
Aldicarb G	5.0	0.080	0.149	0.099	0.166	0.158	0.118	0.120
Aldicarb G	6.7	0.116	0.104	0.089	0.134	0.136	0.165	0.124

Source	d.f.	S.S.	M.S.	F
Blocks	5	0.006	0.001	
Treatment	3	0.022	0.007	18.806**
Error	15	0.006	0.000	
Total	23	0.03		

C.V. = 19.70%

Treatment	Rate kg/ha ai	Total toxic aldicarb equivalents (111days following application) 1	2	3	4	5	6	$\bar{x}$
Aldicarb G	1.7	0.034	0.049	0.061	0.060	0.055	0.052	0.052
Aldicarb G	3.4	0.046	0.058	0.093	0.118	0.109	0.080	0.084
Aldicarb G	5.0	0.098	0.093	0.168	0.090	0.158	0.095	0.117
Aldicarb G	6.7	0.097	0.140	0.082	0.124	0.108	0.131	0.114

Source	d.f.	S.S.	M.S.	F
Blocks	5	0.004	0.001	
Treatment	3	0.017	0.006	8.732**
Error	15	0.010	0.001	
Total	23	0.030		

C.V. = 27.50%

Treatment	Rate kg/ha ai	Total toxic aldicarb equivalents (130days following application) 1	2	3	4	5	6	$\bar{x}$
Aldicarb G	1.7	0.059	0.048	0.040	0.054	0.030	0.039	0.045
Aldicarb G	3.4	0.053	0.076	0.073	0.068	0.041	0.055	0.061
Aldicarb G	5.0	0.087	0.057	0.061	0.077	0.049	0.065	0.066
Aldicarb G	6.7	0.132	0.074	0.115	0.084	0.125	0.070	0.100

Source	d.f.	S.S.	M.S.	F
Blocks	5	0.002	0.000	
Treatment	3	0.010	0.003	10.792**
Error	15	0.004	0.0002	
Total	23	0.016		

C.V. = 25.37%

TABLE 67. Fate of ^{14}C-aldicarb in carrot roots and leaves over time, following a single dose root feeding.

Sample time	Plant	F.W. (gm)			Uptake	^{14}C-aldicarb equivalents[1]												
						Leaf Organic			Leaf Aqueous			Leaf Total	Root Total			Leafhopper Mortality, %	
		R	S	T	ug	ug	ppm	%	ug	ppm	%	ug	ug	ppm	%	24 hr	48 hr
12 hr.	1	1.54	1.78	3.32	142.5	63.4	35.6	44.5	6.1	4.3	4.3	69.5	63.1	41.0	44.3	100	100
	2	1.45	1.87	3.32	137.9	58.9	31.5	42.7	6.5	3.5	4.7	65.4	58.2	40.1	42.2	100	100
	3	1.70	1.72	3.42	149.8	69.1	40.2	46.1	9.1	5.3	6.1	78.2	52.7	31.0	35.2	100	100
	$\bar{x}$				143.4	63.8	35.8	44.4	7.2	4.4	5.0	71.0	58.0	37.4	40.6	100	100
Day 1	1	2.83	3.20	6.03	195.1	77.0	24.0	39.5	17.8	5.6	9.1	94.8	65.9	23.3	33.8	100	100
	2	2.08	2.25	4.33	124.5	54.6	24.3	43.9	13.2	5.9	10.6	67.8	34.5	16.6	28.7	100	100
	$\bar{x}$				159.8	65.8	24.2	41.7	15.5	5.8	9.9	81.3	50.2	20.0	31.3	100	100
Day 3	1	3.24	4.81	8.05	152.4	51.3	10.7	33.7	18.6	3.9	12.2	69.9	33.7	10.4	22.1	100	100
	2	1.99	2.75	4.74	144.4	43.1	15.7	29.9	16.7	6.1	11.6	59.8	28.2	14.2	19.5	100	100
	3	2.69	2.52	5.21	133.5	36.6	14.5	27.4	18.9	7.5	14.2	55.5	32.8	12.2	24.6	100	100
	$\bar{x}$				143.4	43.7	13.6	30.3	18.1	5.8	12.7	61.7	31.6	12.3	22.1	100	100
Day 7	1	2.74	3.76	6.50	143.7	31.6	8.4	21.9	23.7	6.3	16.5	55.3	15.9	5.8	11.1	78.0	100
	2	2.36	3.60	5.96	84.3	16.6	4.6	19.7	11.7	3.3	13.9	28.3	13.8	5.8	16.4	75.4	100
	3	3.87	3.79	7.66	82.5	14.2	3.7	17.2	10.1	2.7	12.3	24.3	12.5	3.2	15.2	75.8	100
	$\bar{x}$				103.5	20.8	5.6	19.6	15.2	4.1	14.2	35.9	14.1	4.9	14.2	76.4	100
Day 15	1	9.95	15.9	25.9	145.0	26.1	1.6	18.0	26.7	1.7	18.4	52.8	10.9	1.1	7.5	51.7	83.3
	2	6.00	11.6	17.6	88.4	17.9	1.5	20.2	12.5	1.1	14.1	30.4	3.5	0.6	4.0	45.0	88.3
	3	9.1	8.7	17.8	115.4	14.5	1.7	12.6	22.5	2.6	19.5	37.0	10.7	1.2	9.3	35.0	91.7
	$\bar{x}$				116.2	19.5	1.6	16.9	20.6	1.8	17.3	40.1	8.4	1.0	6.9	43.9	87.8
Day 30	1	24.2	21.7	45.9	105.3	7.9	0.4	7.5	15.3	0.7	14.5	23.2	1.6	0.7	1.5	10.0	20.0
	2	10.2	17.6	27.8	166.1	5.1	0.3	3.1	13.6	0.8	8.2	18.7	6.1	0.6	3.7	5.0	15.0
	3	20.2	24.8	44.8	114.4	4.9	0.2	4.3	11.7	0.5	10.3	16.6	4.8	0.2	4.2	10.0	10.0
	$\bar{x}$				128.6	6.0	0.3	5.0	13.5	0.7	11.0	19.5	4.2	0.5	3.1	8.3	15.0
Day 45	1	43.6	40.6	84.2	157.6	1.5	0.04	1.0	9.5	0.2	6.0	11.0	1.3	0.03	0.8	---	---
	2	64.6	37.9	102.5	107.1	2.1	0.06	2.0	12.6	0.3	11.8	14.7	0.3	0.005	0.3	---	---
	3	80.2	43.1	123.3	126.5	4.4	0.10	3.8	12.8	0.3	10.1	17.2	0.5	0.006	0.4	---	---
	$\bar{x}$				130.4	2.7	0.07	2.3	11.6	0.3	9.3	14.3	0.7	0.014	0.5	---	---

1. ug, ppm and % of uptake in organic and aqueous leaf extracts.

TABLE 68. The effect of aldicarb (and toxic equivalents) on leafhopper mortality and AY disease transmission to carrot during feeding periods of 24 and 48 hours.

Treatment ug ^{14}C-aldicarb /40 mL	Plant	Uptake		Mortality[1]		Disease incidence	Leaf F.W. g	Total toxic aldicarb equivalents ug	Conc. ppm
		ug	%	24 hr.	48 hr.				
500	1	97	23						
	2	118	26				3.3	43.2	13.1
	3	124	27	19/20	20/20	-	2.3	40.5	17.6
	4	81	17	17/20	20/20	-			
	5	83	20	16/20	20/20	-			
	6	92	19	18/20	20/20	+			
	7	100	22	15/20	20/20	-			
	8	85	17	19/20	20/20	-			
	9	95	21	17/20	20/20	+			
	10	76	14	19/20	20/20	-			
	11	74	16	18/20	20/20	-			
	12	81	20	19/20	20/20	-			
$\bar{x}$		92	20	88.5%	100%	20%	2.8	41.9	15.4
300	1	55	28						
	2	65	22				2.8	22.1	7.9
	3	59	21	13/20	20/20	+	2.7	19.4	7.2
	4	52	17	15/20	20/20	-			
	5	69	24	17/20	20/20	-			
	6	60	23	13/20	20/20	-			
	7	51	19	18/20	20/20	-			
	8	48	12	17/20	20/20	+			
	9	45	14	14/20	20/20	+			
	10	50	15	12/20	20/20	-			
	11	59	21	18/20	20/20	-			
	12	40	14	16/20	20/20	+			
$\bar{x}$		50	18	76.5%	100%	40%	2.75	20.8	7.6

Cont'd.....

TABLE 68. (Cont'd)

Treatment ug ^{14}C-aldicarb /40 mL	Plant	Uptake ug	Uptake %	Mortality[1] 24 hr.	Mortality[1] 48 hr.	Disease incidence	Leaf F.W. g	Total toxic aldicarb equivalents ug	Conc. ppm
200	1	50	26				3.7	10.4	2.8
	2	53	28				3.2	14.1	4.4
	3	44	24	11/20	19/20	+			
	4	26	15	12/20	19/20	+			
	5	35	20	10/20	20/20	-			
	6	44	25	14/20	20/20	-			
	7	56	30	16/20	19/20	-			
	8	55	29	11/20	20/20	+			
	9	48	23	15/20	19/20	-			
	10	57	31	13/20	19/20	-			
	11	41	22	15/20	20/20	-			
	12	51	27	14/20	20/20	-			
$\bar{x}$		47	25	65.5%	97.5%	30%	3.5	12.3	3.6
100	1	29	30				4.7	10.8	2.3
	2	42	43				3.0	9.9	3.3
	3	19	21	8/20	20/20	-			
	4	23	24	12/20	18/20	-			
	5	21	22	14/20	20/20	-			
	6	22	25	8/20	19/20	+			
	7	34	34	15/20	20/20	-			
	8	24	26	10/20	17/20	-			
	9	34	35	9/20	18/20	-			
	10	33	34	13/20	19/20	-			
	11	26	27	12/20	19/20	-			
	12	25	27	15/20	17/20	-			
$\bar{x}$		27	29	58.0%	93.5%	10%	3.85	10.35	2.8

Cont'd.....

TABLE 68. (Cont'd)

ug ^{14}C-aldicarb /40 mL	Plant	Uptake ug	Uptake %	Mortality[1] 24 hr.	Mortality[1] 48 hr.	Disease incidence	Leaf F.W. g	Total toxic aldicarb equivalents ug	Conc. ppm
75	1	24	34				3.8	8.0	2.1
	2	18	25				2.8	5.9	2.1
	3	25	35	3/15	13/15	-			
	4	20	24	4/15	12/15	-			
	5	24	33	2/15	12/15	-			
	6	15	19	5/15	14/15	-			
	7	11	16	8/15	12/15	-			
	8	14	20	3/15	15/15	-			
	9	17	29	3/15	11/15	+			
	10	13	22	2/15	14/15	+			
	11	19	29	4/15	13/15	-			
	12	16	26	2/15	15/15	-			
$\bar{x}$		18	26	24.0%	87.3%	20%	3.3	7.0	2.1
50	1	17	36				5.0	4.7	0.94
	2	13	28				4.1	5.3	1.30
	3	15	31	1/20	10/20	+			
	4	10	22	2/20	9/20	-			
	5	14	29	2/20	10/20	-			
	6	11	24	4/20	6/20	-			
	7	10	21	3/20	8/20	-			
	8	15	30	3/20	7/20	+			
	9	10	20	5/20	6/20	-			
	10	11	23	3/20	6/20	+			
	11	12	18	2/20	8/20	-			
	12	16	30	1/20	6/20	-			
$\bar{x}$		13	26	13.0%	38.0%	30%	4.6	5.0	1.1

Cont'd.....

TABLE 68. (Cont'd)

Treatment ug ^{14}C-aldicarb /40 mL	Plant	Uptake		Mortality[1]		Disease incidence	Leaf F.W. g	Total toxic aldicarb equivalents ug	Conc. ppm
		ug	%	24 hr.	48 hr.				
12.5	1	3	20				2.3	1.6	0.7
	2	4	30				2.6	1.8	0.7
	3	3	22	2/20	4/20	-			
	4	4	22	1/20	7/20	-			
	5	5	36	0/20	2/20	-			
	6	3	21	1/20	5/20	-			
	7	3	25	0/20	5/20	-			
	8	3	24	2/20	6/20	-			
	9	4	29	0/20	5/20	-			
	10	3	25	2/20	4/20	+			
	11	3	23	1/20	7/20	-			
	12	2	22	1/20	6/20	-			
$\bar{x}$		3	25	5.0%	25.5%	10%	2.45	1.7	0.7
0	1								
	2								
	3			0/15	1/15	-			
	4			1/15	2/15	+			
	5			0/15	0/15	+			
	6			0/15	0/15	+			
	7			2/15	2/15	-			
	8			0/15	0/15	-			
	9			1/15	1/15	+			
	10			0/15	1/15	+			
	11			1/15	1/15	-			
	12			1/15	1/15	+			
$\bar{x}$		--	--	4.0%	6.0%	60%	---	---	---