RESISTANCE OF BARLEY VARIETIES TO THE APHID
Rhopalosiphum padi (L.)

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Sze-Jih Hsu

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ABSTRACT

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A series of preliminary tests were made between September 1959 and September 1960 to assess the possibility of finding resistance in barley varieties to the birdcherry oat aphid, *Rhopalosiphum padi* (L.). The results were so encouraging that seed samples of 468 varieties from the Canadian Genetic Stock of Barley Varieties were tested during the following two years. The two components of resistance tested were antibiosis (effect of the plant on the insect) and tolerance (effect of the insect on the plant). Antibiosis was determined by counting the number of young produced during five days from one wingless female aphid, caged on one plant, replicated ten times for each variety. Tolerance was measured by infesting each plant of ten plants of each variety with ten aphids, and then counting the number of plants alive at the end of six weeks, under cages.

All 468 varieties were tested in the greenhouse. Only those which showed either antibiosis or tolerance in the greenhouse were retested in the field. In greenhouse

tests 47 varieties showed both antibiosis and tolerance, 35 showed antibiosis only, 45 showed tolerance only, and 341 showed no resistance.

Of the 127 varieties planted for field tests, 43 showed both antibiosis and tolerance, 46 showed antibiosis only, 25 showed tolerance only, and 13 showed no resistance. An interesting finding was that a few varieties, particularly Rojo and C.I. 3906-1, which are known to be resistant to barley yellow dwarf virus, are also resistant to the vector *R. padi*.

Some observations on the biology of *R. padi* are given, along with records of breeding colonies on summer hosts for *R. padi*, the greenbug, *Schizaphis graminum* (Rondani), the English grain aphid, *Macrosiphum avenae* (Fabricius), the corn leaf aphid, *Rhopalosiphum maidis* (Fitch), the quackgrass aphid, *Sipha agropyrella* Hille Ris Lambers, and four other species of minor importance.

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TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Since the end of the Second World War there has been a tremendous advance in the development and use of insecticides as a method of chemical control of insect pests. However, this method is usually costly and resistance of insects to many insecticides has developed. In addition, insects attack the whorls, head boots, leaf sheaths, bore into the stems or live on the roots of the plants, where insecticides are difficult to apply. Sometimes the application of insecticides for insect control causes a complicating result, giving rise to a tremendous increase in the populations of other insects or arthropods.

Cultural practices and biological control methods are not always dependable, so it is necessary to seek a more satisfactory solution. Evidences of the differences in the responses of plant varieties to insect attack, and the interrelationships of plants and insects have been studied by many workers. Based upon these relationships, resistance in crop plants has been successfully used as a control measure for a number of insects. The world literature on insect resistance in crop plants was reviewed by Painter (1951), and other authors have discussed various aspects of insect resistance in plants.

The problem

Painter (1958 a) outlined the three basic components of resistance of plants to insects, namely non-preference, antibiosis and tolerance.

Non-preference means that insects keep away from, or at least are not attracted to a significant degree to a particular plant for oviposition, food or shelter.

Antibiosis concerns the adverse effects of the plant on the biology of the insect. These effects are usually reduced fecundity, decreased body size or weight, abnormal life span or increased mortality rate. These effects of antibiosis suggest that the food is ingested and that it contains toxic substances, or it may be unsatisfactory in quality or quantity for a normal rate of growth, development or reproduction.

Tolerance is the ability of a plant to withstand, without appreciable damage, the attacks of an insect population.

A plant may be markedly resistant to insect attack in terms of antibiosis, but its tolerance may be so low that even a light infestation of insects may cause serious injury. Conversely, a plant may have little adverse effect on insects, but its tolerance may be such that it can support a relatively large population of insects without being seriously injured.

The purpose of this study was to find barley varieties which show antibiosis or tolerance to the aphid, Rhopalosiphum padi (L.) under greenhouse and field conditions. Temperature and other factors which might influence the resistance of barley varieties will be discussed in the following chapters.

Importance of the study

The birdcherry oat aphid, *Rhopalosiphum padi* (L.) is regarded as an efficient vector of some strains of barley yellow dwarf virus which infects barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.), wheat (*Triticum aestivum* L.) and other Gramineae (Slykhuis *et al.*, 1959 and Watson and Mulligan, 1960).

Infestations of barley by *R. padi* may cause direct feeding damage, or indirectly introduce the barley yellow dwarf virus into plants. The economic importance of barley yellow dwarf virus has been discussed by Bruehl (1961).

Barley varieties resistant to aphids would solve the problem of direct feeding damage and by reducing aphid populations would help to prevent further spread of the virus.

Organization of the thesis

In the spring of 1960 264 miscellaneous varieties of barley plus 9 varieties commonly grown in Western Canada were used in preliminary tests to develop techniques and to assess the possibility of finding varieties with resistance to *R. padi*. The results are reported in Chapter V. The names of the 264 varieties are given in the Appendix.

The results of these tests were sufficiently encouraging that a decision was made to continue this line of research, and to assess the possibility of finding resistant varieties in all available material from the Canadian Genetic Stock of Barley, held at the Central Experimental Farm, Ottawa, Ontario.

The main experiments of this study were therefore conducted from September, 1960 to August, 1962, and are reported separately by years in Chapters VI and VII.

During the three years of this research project some notes on the biology and life history of *R. padi* were compiled, and these are presented in Chapter IV.

During the summer of 1962 large populations of other species of aphids on cereal grains and grasses developed, and many host records were obtained. These records are presented in Chapter VIII.

CHAPTER II

REVIEW OF THE LITERATURE

The most important literature dealing with the resistance of plants to insects, up to 1951, was reviewed by Painter (1951). Most of the studies were attempts to find resistance in certain varieties of plant species. Some workers investigated the environmental factors which influence resistance. Other workers emphasized the relationships of insects and host plants.

Resistance of plants to aphids has been reported more frequently than to any other group of insects. Varieties of gooseberry showing resistance to the gooseberry aphid, *Myzus houghtonensis* (Troop), were studied by DeLong and Jones (1926). Raspberry varieties resistant to the raspberry aphid, *Amphorophora rubi* Kalt., were reported by Winter (1929). Huber and Schwartze (1938) and Le Pelley (1932) found that the woolly apple aphid, *Eriosoma lanigerum* (Hausman), would not reproduce on the Northern Spy variety of apple. Variations in infestations and populations of greenbug, *Toxoptera graminum* (Rondani) on different varieties or hybrids of wheat, oats, and barley were shown by Wadley (1931), Fenton and Fisher (1940), Walton (1944), Atkins and Dahms (1945), Dahms (1948) and Dahms and Johnston (1955). Painter and Peters (1956) described a method for screening wheat varieties for testing resistance to the greenbug and concluded that most of the varieties were more susceptible than Pawnee. About four per cent of the varieties appeared to carry some resistance. Wood (1961 a) studied the tolerance of small grains in the greenhouse to greenbug by allowing the aphids to migrate freely from artificially infested plants to other plants, and showed that some varieties of wheat from 8,000 lines of the World Wheat Collection have a high degree of tolerance.

The reproductive ability of the pea aphid, *Macrosiphum pisi* (Kalt.) differed on different alfalfa varieties and even between the flowering and vegetative branches of the same plant and this aphid reproduced more rapidly and had a lower mortality rate on susceptible varieties of alfalfa than on resistant varieties (Dahms and Painter, 1940). A satisfactory progress in breeding a pea aphid-resistant alfalfa, of the common Chilean type, was made by Jones *et al*., 1950. The red clover variety Dollard is more resistant to pea aphid than the variety Wegener, because of non-preference and antibiosis (Wilcoxson and Peterson, 1960). Selection of healthy seedlings of alfalfa after a pea aphid infestation is a rapid and practical method for locating resistant plants (Ortman *et al*., 1960).

Harvey and Hackerott (1956) pointed out that the spotted alfalfa aphid, *Therioaphis maculata* (Buck.), could not survive on Lahontan variety of alfalfa. Howe and Smith

(1956, 1957) found that there were three varieties of alfalfa resistant to the spotted alfalfa aphid, Pterocallidium sp. Dobson and Watts (1957) found that New Mexico 16 and Lahontan were significantly better in resistance to spotted alfalfa aphid than New Mexico Common. Peters and Painter (1957, 1958) showed that there were twelve species of four legume plant genera, Medicago, Melilotus, Trifolium and Trigonella, which were immune to the yellow clover aphid, Pterocallidium trifolii (Monell), spotted alfalfa aphid and sweet clover aphid, Myzocallidium riehmi Börner. Alfalfa varieties and breeding lines differing in resistance to the spotted alfalfa aphid and sweet clover aphid were studied by Howe and Pesho (1960), and Manglitz and Gorz (1961).

Solanum polyadenium is able to escape infestation by the green peach aphid, Myzus persicae (Sulz.) (Stringer, 1947). Three varieties of tobacco, which are more susceptible than other varieties were found by Thurston (1961).

A considerable difference in the injury and degree of infestation by the corn leaf aphid, Aphis maidis (Fitch) among seventeen varieties of sorghum was mentioned by McColloch (1921). The variety Piper Sudan showed a high level of resistance while Milo sorghum proved highly susceptible when studied by Howitt and Painter (1956) in a search for resistance in 595 varieties of sorghum.

Plant resistance to insects may be modified by both intrinsic or physiological, and extrinsic or ecological factors. Müller (1958) found that Aphis fabae (Scop.) in selecting its host plants was strongly dominated by two antagonistic reactions, the flying impulse and the infesting impulse, both of them being influenced contrarily by factors of environment. Coon (1959 a,b) concluded that the efficiency of a grass species in maintaining an aphid population depends upon (1) the ability of the adult aphid to obtain required nutrients from the host over a period long enough to produce progeny, (2) the ability of progeny to feed and mature on the host and (3) the satisfaction of stimuli necessary to result in reproduction. Harvey et al., (1960) indicated that the increase of populations of spotted alfalfa aphid depended on these factors: (1) presence of initial infestation, (2) abundance of predators and parasites, (3) temperature and (4) type of rainfall. A rain of an inch or more usually reduced aphid populations but lighter rains were rarely effective in reducing populations unless they were dashing, or spreading out more or less continuously over several days.

That plant resistance to insects is due to the inherent characteristics of plants rather than to environmental conditions has been concluded by Snelling et al. (1940), Walter and Brunson (1940), Huber and Stringfield (1942), Painter (1954), Smith (1954) and Chada (1959).

The presence of insect biotypes emphasizes the importance of finding as many sources of resistance as possible. The relationships of the biotypes of insects to plant resistance have been shown by Cartier and Painter (1956), Pathak and Painter (1958 a,b) and Wood (1961 b).

There is some evidence which demonstrates the effects of ecological factors on resistance in the host plants. Painter (1954) cited various examples of this phenomenon. Generally, the degree of resistance in plants is less at low than at high temperatures in the spotted alfalfa aphid and the pea aphid (Dickson et al., 1955, Harpaz, 1955, Painter, 1954 and Hackerott and Harvey, 1959). The reverse is true of greenbugs on wheat (Painter, 1958 b).

The reactions of the spotted alfalfa aphid on resistant, intermediate and susceptible alfalfa plants are different at different temperatures (Hackerott et al., 1958). Cartier (1957) showed that at 60°F. corn leaf aphids were not moving; at 75°F. they were always active and excreting honeydew, and could withstand temperatures as high as 110°F. in the greenhouse. McMurtry (1962) concluded that the change in resistance of alfalfa to the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), is effected by a change in temperature, but the apparent change in resistance may be an expression of the response of the aphids or plants to temperature changes.

The effect of photoperiod on resistance in plants to aphids usually interacts along with the effects of temperature.

The length of life of the adult of the pea aphid increased as the photoperiod increased and temperature decreased (Kenten, 1955). Davidson (1925) explained that the reduction of populations of bean aphid, Aphis rumicis L. on English broad bean might be due to a response to plant physiology. Emery (1946) showed that short daylight would cause susceptible alfalfa plants to become unattractive and unsuitable to the pea aphid. However, McMurtry (1961) proved that differences in photoperiod had no effect on survival and reproduction of the spotted alfalfa aphid on alfalfa plants.

Emery (1946), Barker and Tauber (1954), Kennedy et al. (1958) and Kennedy and Booth (1959) have shown that the lower water content of the tissues of plants would increase the degree of resistance to aphids. Müller (1958) found that high temperatures and high humidity increase the flying impulse, whereas lower temperatures and lower humidity increase settling down in insects. This flying impulse is one of the reactions which determines host preference. The degrees of infestation are influenced by food conditions resulting from the biochemical reactions of the plant to temperature and moisture and under conditions of low temperature and deficiency of moisture the food condition will be unfavorable to aphids (Emery, 1946). McMurtry (1962) concluded that there were no significant differences in reproduction of the spotted alfalfa aphid on watered or unwatered alfalfa plants under two different temperatures. The drought condition could not be shown to affect the aphid populations on either the resistant or susceptible clones of alfalfa.

Relationships between plant nutrition and insect infestation were stated by Painter (1951) as: "each species of insect in relation to its host plant, may be affected by soil conditions in respect to one or more factors of resistance."

Greenbug populations varied inversely with the amount of nitrogen applied to plants (Arant and Jones, 1951, Bleckenstaff _et al_., 1954 and Daniels, 1957). Conversely, that a sufficient supply of nitrogen to plants will produce a higher degree of susceptibility has been shown by Mumford (1931), Evans (1938), Isely (1946), Maltais (1951), and Barker and Tauber (1951 a, b). Taylor _et al_. (1952) showed that plants treated heavily with a balanced fertilizer were able to withstand an aphid attack and produce a better yield than were plants grown on soil with inadequate nutrients. McMurtry (1962) indicated that phosphorus-deficient alfalfa varieties C-84 and C-902 became more resistant, while potassium deficiency resulted in plants being less resistant. But plants watered with a nitrogen-deficient solution did not vary in resistance or susceptibility compared with plants watered with a nondeficient solution.

Viale (1950), and Taylor _et al_. (1952) showed that the application of different combinations and rates of fertilizer did not produce a noticeable change in resistance or susceptibility of plants and that there were no significant differences in the reproductive capacity of aphids on the plants.

The effects of plant growth regulators on fecundity of aphids were studied by Maxwell and Harwood (1960) and Robinson (1961).

Potter (1960) showed that infestations of *Aphis fabae* on beans are usually greater in thin stands of plants, on which the populations of aphids also increase faster than on thicker stands of plants.

Chemicals in plants are also concerned as factors which affect resistance. Davidson (1925) and Emery (1946) studied the bean aphid, *Aphis rumicis* L., on English broad bean and the pea aphid on alfalfa and concluded that as the populations of aphids increased the carbohydrate content in plants decreased. Haber and Gaessler (1942) concluded that the infestation of tassels on corn by corn leaf aphids is not the result of a high sugar content of the pollen. However, Auclair and Maltais (1950) with the pea aphid and Alikhan (1960) with black bean aphid showed that susceptible plant varieties contain a higher concentration of amino-acids. Maltais (1951) reported that the rate of development and reproduction of pea aphids were closely related to the amounts of sugars and amino-nitrogen present in the cell sap of the various host plants, and this report has been supported by Davidson (1925) and Evans (1938). Mumford and Hey (1930) pointed out that a highly nitrogenous diet stimulates reproduction in insects. Thus the resistance or susceptibility to insect attack is closely related to the protein value in the plant.

Insect resistance in host plants is sometimes affected by the different stages of plant growth. This aspect has been discussed by Patch (1942), Patch *et al.* (1942), Beard (1943), Patch and Deay (1948), and Turner and Beard (1950) in their studies on the resistance of corn to the European corn borer. Viale (1950) showed that all the corn seedlings are resistant to the corn leaf aphid until they are more than a month old. Differences in population density of the bean aphid, *Aphis fabae* Scop. and the green peach aphid, *Myzus persicae* (Sulz.), on different-aged leaves of spindle trees and sugar-beet plants were shown by Kennedy *et al.* (1950). The feeding preferences for young leaves and senescing leaves, and fecundity, of *Aphis fabae* Scop. in relation to the age and kind of spindle tree were shown by Kennedy and Booth (1951). Ibbotson and Kennedy (1950) showed that the leaves of sugar beet were very suitable to bean aphid, *Aphis fabae* Scop., when young, became unsuitable as they matured, became suitable again just after maturity and then unsuitable again as they senesced. A very detailed description of the relation of the infestation by spotted alfalfa aphid to the ages of four varieties of alfalfa plants was made by Howe and Pesho (1960 a, b). The tolerance of barley varieties to the corn leaf aphid varies with the date of seeding. Little damage was done when the aphids attacked barley that had advanced to the late stages of stem elongation (Wells and McDonald, 1961). Manglitz and Gorz (1961) showed that older plants demonstrated the greatest resistance, among some sweetclover varieties, to sweetclover aphid. The senescing leaves of a resistant wild species of tobacco were much more susceptible to the green peach aphid than the young or mature leaves (Thurston, 1961).

Some aphids prefer damaged or virus-infected plants. This phenomenon has been studied by Baker (1960), and MacKinnon (1961).

During studies of the resistance of plants to insects, some workers found that morphological construction of the plants affected the resistance capacity of plants (Howe, 1949 and Johnson, 1953). In discussing insect resistance in plants Thorsteinson (1960) stated: "Morphological resistance is rarely if ever, independent of other types of resistance and it is to be noted that Painter does not recognize morphological resistance as one of the primary mechanisms."

Techniques used in studying the resistance of plants to aphids include either large or small cages, or screens to confine the aphids in a limited space, both in the greenhouse and field. The most useful cages which have been adopted by workers are a clip-on leaf cage (Kennedy et al. 1958 and Noble, 1958), a dialyzing tube cage (Dahm and Painter, 1940, Cartier and Painter, 1956 and Howitt and Painter, 1956), organdy cylinder cage (MacGillivray and Anderson, 1957) and cellulose nitrate cage (Pathak and Painter, 1958).

Wood (1961 a) used a non-cage method for studying the tolerance of small grains to the greenbug. The insects were allowed to migrate freely from plant to plant.

Resistance to aphids is usually measured by the percentage of infestation of the plant, or the development, longevity, reproduction, or mortality rate of the aphids (Painter, 1951). Cartier and Painter (1956) and Painter (1958 a) used the fecundity, weight of adults, and the length of adult and nymphal life as criteria for measuring resistance. Auclair (1958 a, b), Mittler (1957, 1958), and Banks and Nixon (1959) mentioned that the rate of excretion is a good index of the aphid feeding rate. Hackerott and Harvey (1959) and McMurtry (1962) indicated that the fecundity of adults is a better criterion than the mortality rate, for resistance studies.

Wood (1961 a) showed that the number of days the plants remain alive can be used as a measure of tolerance. The measurement of dry root weight and dry leaf weight (Ortman and Painter, 1960) and an estimate of chlorosis of leaves are also commonly used for infestation indices.

The measurement of resistance has been discussed by Painter in his excellent book "Insect Resistance in Crop Plants" (1951). He stated that for relative measurements one should use a susceptible or a well known variety as standard. There are usually two ways to measure: some form of count of insect populations, or some kind of estimate of the amount of damage. If the susceptible variety is absent, then some independent measure of an insect population should be found.

There are several studies on the biology of *Rhopalosiphum padi* (L.). In 1917, Patch described the general biology under the title "The Aphid of Chokecherry and Grains." Baker and Turner (1919) gave a brief report of the life-history of this aphid by using the name *Rhopalosiphum prunifoliae* (Fitch). A very detailed description of this aphid has been done by Rogerson (1947), in England. Other recent papers include those by Bruehl (1961), Müller (1961), Orlob (1961 b), Orlob and Medler (1961) and Forbes (1962). Richards (1960) gave a general description of this aphid in his monograph "A Synopsis of the Genus *Rhopalosiphum* in Canada."

CHAPTER III

MATERIALS AND METHODS

Aphids used for this study were identified by Dr. W. R. Richards, Entomology Research Institute, Ottawa, Ontario, as Rhopalosiphum padi (L.). They were all descendents from one apterous viviparous female isolated in September, 1959 in the greenhouse, and maintained as viviparous females, and there were therefore no problems of males, oviparous females, or biotypes. All aphids used for the experiments in both greenhouse and field may be regarded as a clone.

The stock cultures were reared on Swan variety of barley in screened cages under greenhouse conditions. Possible infection of plants by barley yellow dwarf virus was also eliminated by this caging technique.

Both aphids and plants appeared to thrive despite fluctuations in greenhouse temperatures which occasionally reached 110°F. in summer months. However, temperatures in the greenhouse never fell below 60°F. Transfer of aphids on plants was done with an aspirator. The technique was developed and described by Robinson (1961). All the aphids used for each test were apterous viviparous females, approximately the same age (7-8 days old). This was achieved by placing apterous females on plants in screened cages for 48 hours and then removing the adults. By this means the difference in age of progeny left on the plant would be at most only 48 hours.

Preliminary studies were conducted in the spring of 1960 to develop techniques and to determine the feasibility of continuing the project.

These studies were on antibiosis only. Seeds of 264 varieties of barley were obtained from the Canada Department of Agriculture Research Station, Winnipeg. Ten seeds of each variety were hand-seeded in hills in the field. Two weeks after seeding, two adult apterous viviparae of R. padi were placed on one plant in each hill and covered with a fine-mesh organdy cage, 20 inches high and 3 inches in diameter, supported by a rigid wire frame. The other plants in the same hill were kept uncaged under natural conditions. Counts of progeny produced on the caged plants were made at the end of seven days. Plant antibiosis in terms of aphid fecundity was measured in six groups 0-20, 21-40, 41-60, 61-80, 81-100 and 100+ of total aphids found on each caged plant at the end of seven days.

In addition to these preliminary field tests begun in the spring of 1960, tests were also started in the greenhouse, and during the summer of 1960, 39 of the above mentioned 264 varieties were investigated for antibiosis. Two seeds of each variety were planted in soil in each of ten 5-inch clay pots, and when the plants were two to three inches high the weaker of the two seedlings was removed. One adult apterous vivipara was caged on a single plant, replicated five times for each variety, and progeny were counted at the end of seven days. Counts on fecundity were also grouped into six categories, 6-15, 16-25, 26-35, 36-45, 46-55, 56-65. In addition to the field and greenhouse tests outlined above, nine barley varieties commonly grown in Western Canada were seeded in the spring of 1960 in the field in single rows nine feet long. When the plants were at the four-leaf stage, ten single plants of each variety were infested each with two adult apterous viviparae, and covered with organdy cages. At the end of five days the number of young was counted, and then the same procedure was repeated using two new aphids on a new plant. After the second count, two aphids were again put on fresh plants at five-day intervals, but records of progeny were related to plant growth stage and kept separate from the first two counts. The purpose of this procedure was to assess possible relationships between varietal resistance and stage of plant growth.

Results of the three preliminary investigations outlined above were sufficiently promising that a decision was made to begin in September, 1960 a survey for possible resistance (both antibiosis and tolerance) in all available varieties of the Canadian Genetic Stock of Barley. The aphid, R. padi, had proved easy to handle under both greenhouse and field conditions; it is a native species which overwinters in

Manitoba; and it is a known vector of some strains of barley yellow dwarf virus. Therefore it was chosen as the test insect for the investigations which followed. Four hundred and sixty-eight varieties from the Canadian Genetic Stock of Barley were received from Dr. R. Loiselle, of Canada Department of Agriculture, Ottawa. All varieties were first tested in the greenhouse, and those varieties which demonstrated resistance, in terms of either antibiosis or tolerance, were retested under field conditions in the summers of 1961 or 1962.

In the greenhouse, methods were the same as the preliminary tests outlined above, except that only one aphid was placed in a cage on one plant, and counts on fecundity and mortality were made at the end of five days. Five days was chosen to ensure that none of the progeny could become adult and start reproducing. Swan variety was used as a standard variety for comparison. In the field tests a row of each variety was planted, and ten healthy plants selected from the row. Rows were 18 inches apart, and the ten selected plants were approximately 18 inches apart.

In both greenhouse and field tests the procedure was identical. One apterous adult female of R. padi 7-8 days old was placed on the base of the stem of each plant when 2 to 3 inches high and fine-mesh organdy cloth cages were placed over each plant (Figures 1 and 2). At the end of five days mortality and fecundity of aphids were recorded for each of

FIGURE 1

SECTION OF GREENHOUSE BENCH SHOWING CAGED PLANTS USED IN TESTS FOR ANTIBIOSIS AND TOLERANCE

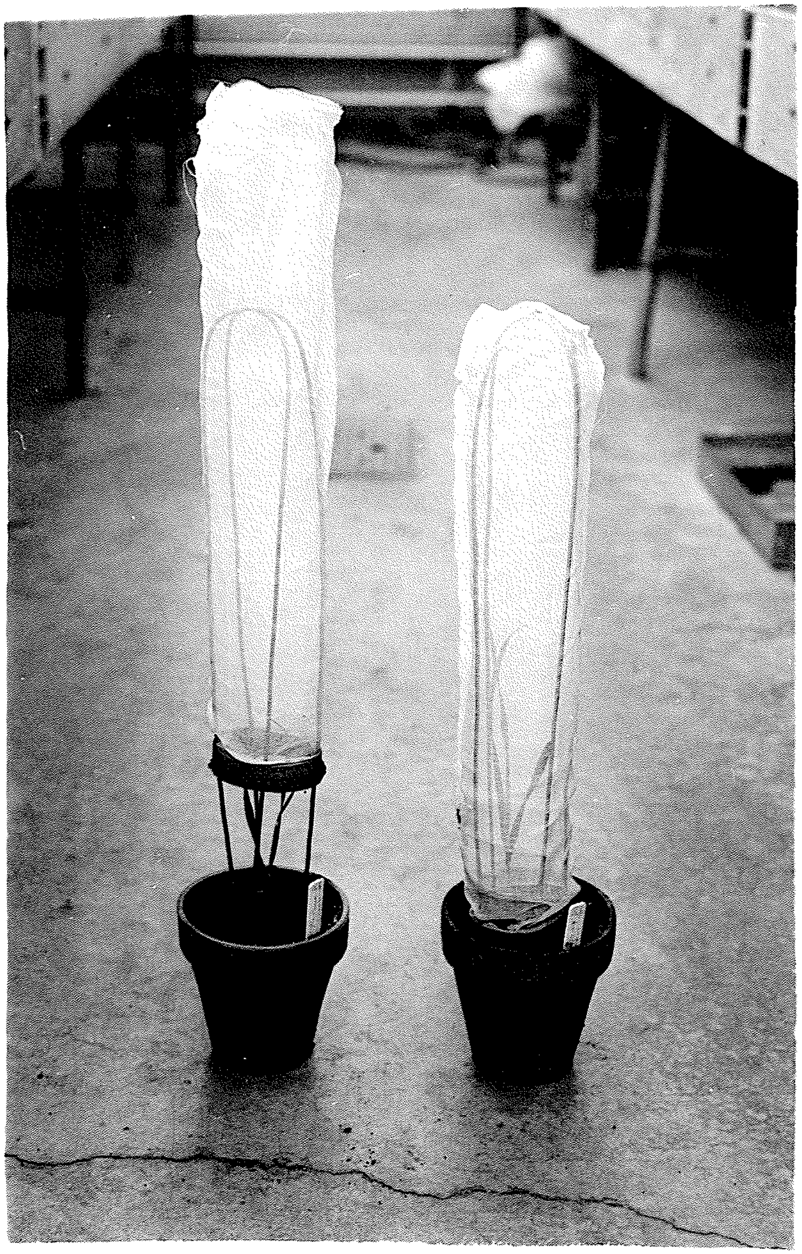

FIGURE 2

ILLUSTRATION OF ORGANDY MESH CAGES USED IN TESTS FOR ANTIBIOSIS AND TOLERANCE IN THE GREENHOUSE the ten replicates. This was the measure of resistance in terms of antibiosis. The aphids were then removed, and ten last instar nymphs of R. padi from the stock culture were placed on each plant, and allowed to reproduce freely for a maximum of eight weeks. Resistance of the plants in terms of tolerance to the resulting infestations was measured by noting death or survival of the plants at weekly intervals.

Very few of the aphids produced more than 30 young in five days. In the tests for antibiosis the varieties were regarded as showing resistance to R. padi if the average number of nymphs produced per female in five days was less than 15. Varieties with an average number of nymphs per female of 15 to 30^{+} were classed as susceptible. In the tests for tolerance those varieties which had five or more plants out of ten surviving at the end of six weeks were classed as resistant, and less than five plants still alive as susceptible.

No fertilizers were applied to the soil either in the greenhouse or the field. Plants in the field were watered by hose four times under the drought conditions of the summer of 1961.

Data were analyzed by transforming the means by the formula $\sqrt{x + 0.5}$ (Goulden, 1945) because of possible zero counts; by Duncan's multiple range test, or by general analysis of variance and t test.

Collections of aphids were made on possible overwintering hosts such as _Prunus virginiana_, _Prunus pennsylvanica_, _Crataegus_ sp., _Malus_ sp., and _Cotoneaster_ sp.

Along with observations in the field on the biology of _R. padi_ a test was made to determine the difference in fecundity between alate and apterous viviparous females. This test was conducted in the greenhouse, using ten individuals of each morph on Swan barley. Daily records of fecundity were taken until the end of each female's life.

In the summer of 1962 extensive collecting was done on cereal grains and grasses to try and determine the relative abundance of _R. padi_ on these summer hosts, and to compare its host records with those of other species of aphids on cereal grains and grasses.

CHAPTER IV

NOTES ON BIOLOGY OF *Rhopalosiphum padi* (L.)

Synonyms of *Rhopalosiphum padi* (L.) found in the literature are *Aphis padi*, *Aphis prunifoliae*, *Aphis avenae*, *Aphis pseudoavenae*, *Siphocoryne avenae* and *Siphocoryne splendens* (Hills Ris Lambers, 1960, Richards, 1960 and Rogerson, 1947).

R. padi is common in Europe, where it is known as the birdcherry oat aphid, but in America it is usually confused with the apple grain aphid, *R. fitchii* (Sand.). Therefore, Orlob (1961 a) used the term "*padi*-*fitchii* complex". Richards (1960) recognized *R. padi* and *R. fitchii* as two distinct species.

In life history studies on *R. padi* it has been found that Rosaceae are its primary or winter hosts and Gramineae are secondary or summer hosts. The general biology has been studied by Patch (1917), Baker and Turner (1919), Rogerson (1947), Orlob (1961 b) and Orlob and Medler (1961). In Canada the eggs overwinter on various species of *Prunus*, and hatch in April. Alienicolae appear on grasses and cereal grains in late spring, where both winged and wingless forms occur until autumn. Fall migrants and sexuales occur on the winter host from the middle of September to the end of October (Richards 1960). The major summer host in New Brunswick is oats (Orlob 1961). In Vancouver, B. C. it may overwinter as eggs but also overwinters as viviparae on winter wheat and possibly on other Gramineae (Forbes, 1962). No detailed studies on _R. padi_ have been done in Manitoba. Our records show that the fundatrigeniae and spring migrants occur on _Prunus virginiana_ L. and _P. pennsylvanica_ L. approximately May 15 to June 30, and males and fall migrants have been taken in flight during October. Twenty-two summer host plants were found for _R. padi_ (Table I). The other species of aphids listed in Table I will be discussed in Chapter VIII. _R. padi_ was found mostly on the lower portion of the stem of cereal grains and grasses. It prefers the young stage of barley to the old stages. However, seedlings of corn, _Zea mays_, less than one month old caused heavy mortality to _R. padi_, whereas old corn plants were favorable as a host. Observations also indicated that the mortality of wingless adults was higher than that of the winged, and that all the progeny from alates grew better on the young corn plants than those from apterae.

A study of development of _R. padi_ was conducted in the greenhouse as follows: ten adults of each form (winged and wingless) which had not yet produced progeny were placed one on each of twenty Swan barley plants, and covered with organdy cages. Observations were made daily, and length of adult life, total progeny produced and average number of progeny per day are shown in Table II or Figures 3 and 4.

TABLE I

HOST PLANT LIST OF APHIDS FOUND ON GRASSES AND CEREALS IN MANITOBA
(* indicates record of a breeding colony)

Host plant	*Schizaphis graminum*	*Macrosiphum avenae*	*Rhopalosiphum padi*	*Rhopalosiphum maidis*	*Sipha agropyrella*	*Metopolophium dirhodum*	*Hyalopterus pruni*	*Hysteroneura setariae*	*Forda olivacea*
Aegilops sp.	*	*	*		*				
Agropyron cristatum (L.) Gaertn.		*	*		*				
Agropyron intermedium (Host.) Beauv.	*	*							
Agropyron repens (L.) Beauv.	*	*	*		*				
Agropyron trachycaulum (Link) Malte	*	*			*				
Agropyron trichophorum (Link) Richt.	*	*			*				
Agrostis scabra Willd.		*							
Agrostis stolonifera L.	*	*	*	*	*				
Alopecurus aequalis Sobol.			*						
Alopecurus pratensis L.	*	*	*	*					
Andropogon gerardi Vitman		*							
Avena fatua L.	*	*							
Avena sativa L.	*	*	*	*		*			
Bromus inermis Leyss	*	*	*	*	*				*
Dactylis glomerata L.	*								
Danthonia sp.	*								
Echinochloa crusgalli (L.) Beauv.	*		*	*					

TABLE I (continued)

Host plant	*Schizaphis graminum*	*Macrosiphum avenae*	*Rhopalosiphum padi*	*Rhopalosiphum maidis*	*Sipha agropyrella*	*Metopolophium dirhodum*	*Hyalopterus pruni*	*Hysteroneura setariae*	*Forda olivacea*
Elymus sp.	*	*							
Elymus junceus Fisch	*	*	*						
Elymus striatus sensu Hitchc. not Willd.		*	*	*					
Festuca pratensis Huds.	*		*	*		*			
Hordeum jubatum L.	*	*	*	*	*				
Hordeum vulgare L.	*	*	*	*	*	*			
Lolium perenne L.	*					*			
Panicum miliaceum L.	*	*							
Phalaris arundinacea L.	*		*	*		*			
Phalaris canariensis L.				*					
Phleum pratense L.	*	*	*	*	*				
Phragmites communis Trin.							*		
Poa pratensis L.	*		*	*					*
Secale cereale L.	*	*	*						
Setaria sp.		*		*					
Setaria italica (L.) Beauv.		*	*	*					
Setaria viridis (L.) Beauv.	*	*	*	*	*				
Sorghum sudanense (Piper) Stapf		*							
Triticum aestivum L.	*	*	*		*	*		*	
Typha latifolia L.		*							
Zea mays L.			*	*					

TABLE II

DEVELOPMENT AND FECUNDITY OF THE PROGENY OF TEN APTERAE AND ALATAE OF *Rhopalosiphum padi* (L.) IN THE GREENHOUSE

Source of young	Average length of adult life (days)	Total progeny of ten females	Average number of progeny per female per day
Wingless females	29.0	870	2.97**
Winged females	23.7	325	1.41

**Significant at the 1 per cent level

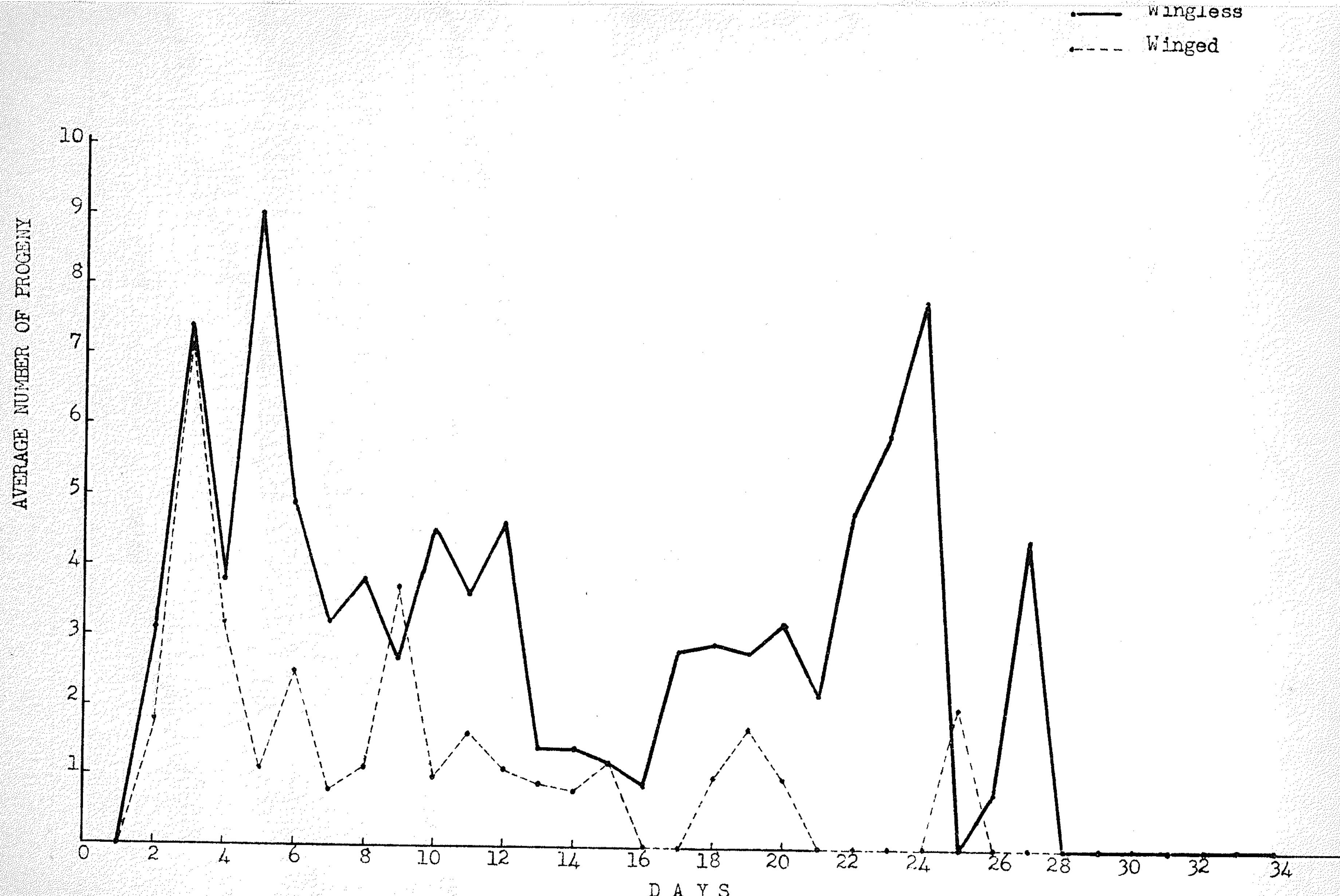

FIGURE 3

AVERAGE NUMBER OF PROGENY PRODUCED PER FEMALE PER DAY BY TEN ADULT WINGED AND TEN ADULT WINGLESS Rhopalosiphum padi (L.) IN GREENHOUSE

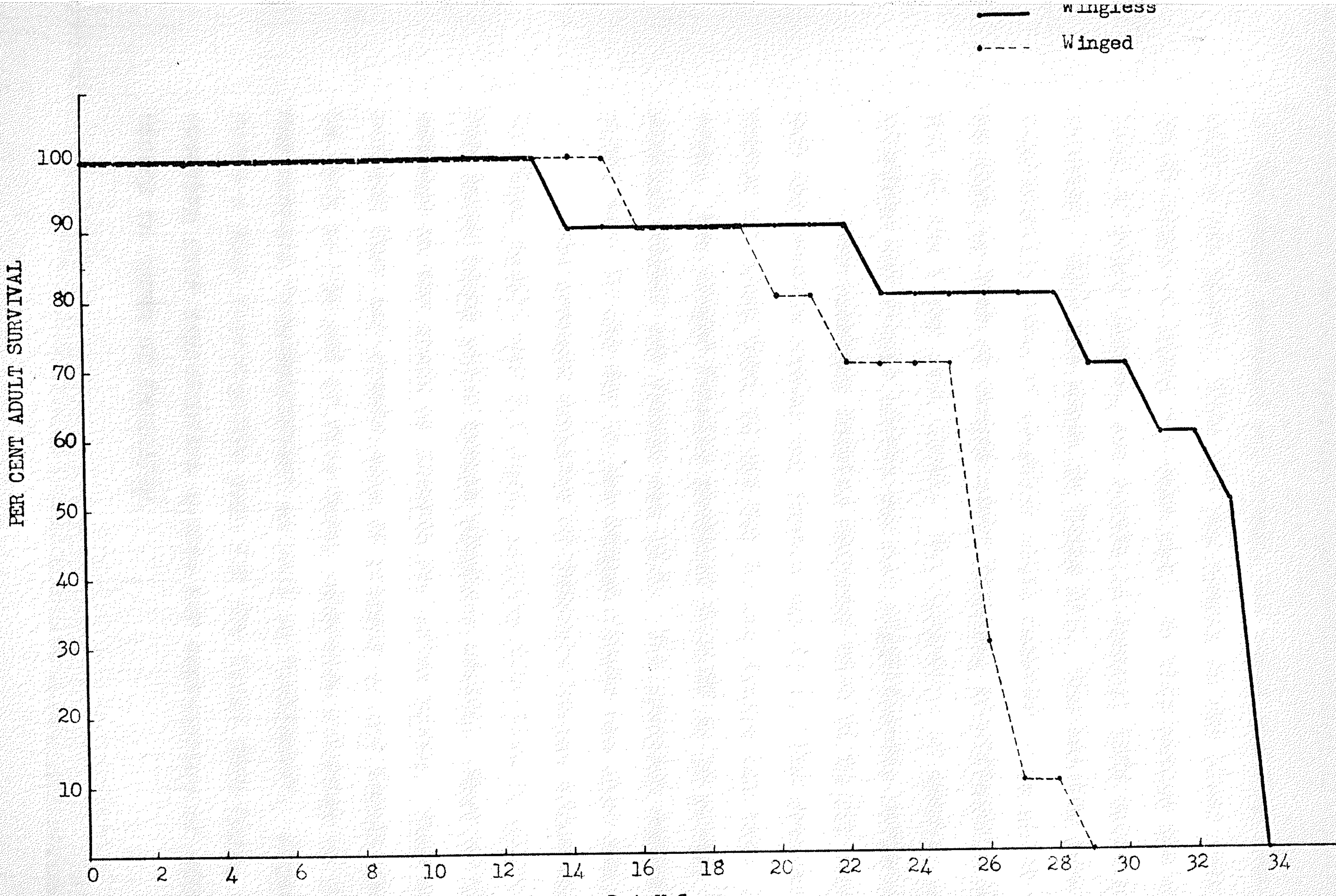

FIGURE 4

LONGEVITY OF ADULT WINGED AND WINGLESS FEMALES OF Rhopalosiphum padi (L.) IN THE GREENHOUSE EXPRESSED IN TERMS OF PER CENT SURVIVAL PER DAY

If the adult produced any young, the adult was then removed onto a new plant. Thus all the nymphs on one plant were within 24 hours of being the same age. By this method the duration of every instar, and length of nymphal life could be studied. Data are shown in Table III. The results show the reproductive rate of wingless adult females to be about twice as high as that of winged adult females, significantly different at the 1 per cent level. The longevity of nymphs, and of wingless and winged adults was not significantly different.

The wingless females produced from 36 to 111 young, but the average number per female was 93.1. The greatest number of young born in one day to one female was ten. However, the winged females produced from 26 to 39 young, the average number per female was 33.6. The greatest number of young born in one day to one winged female was also ten.

The average duration of immature stages (from birth to final moult) was 6.5 days, ranging from five to eight days, for those young which became wingless adults. Most of them matured on the sixth or seventh day after birth. Thus it is evident that any counts made on progeny of one female should be made at the end of five days, otherwise colonies on plants may contain "grandchildren" as well as "children". Figure 3 shows a high reproductive peak for the first five days, thus ensuring good reproductive counts for expressions of antibiosis in terms of fecundity.

TABLE III

DEVELOPMENT IN THE GREENHOUSE OF IMMATURE STAGES OF *Rhopalosiphum padi* (L.), PRODUCED BY APTEROUS OR ALATE FEMALES

Source of young	Number of aphids studied	Average length of nymphal development (days)	Number of instars
Wingless	10	6.5	4
Winged	10	6.9	4

Counting progeny was somewhat simplified by the fact that the young tended to congregate around the mother aphid. This species excretes very little honeydew, so plants rarely became sticky and difficult to handle, nor was there any problem with fungus growing on honeydew.

CHAPTER V

PRELIMINARY EXPERIMENTS, 1959-1960

The data reported in Chapter V are from various miscellaneous and exploratory tests conducted prior to September, 1960. In one project 264 varieties of barley were tested by placing two apterous viviparae on one plant of each variety, in the field under cages. Plant resistance in terms of antibiosis was measured by recording aphid fecundity in six groups. Results are shown in Table IV. The data indicated that 142 varieties (Group 1) were more resistant than 64 varieties in Group 2 and 15 varieties in Group 3, and that varieties in Groups 4, 5 and 6 were quite susceptible, based on the high number of progeny produced by two aphids in seven days. The 264 varieties are listed alphabetically in the Appendix. The grouping according to Table IV is indicated by the group number in parenthesis after the variety name.

The same aphids were allowed to remain on the plants in the cages, and total counts of aphids present when plants headed out were recorded. Counts were also made on single plants not enclosed in cages, which had become naturally infected. The populations on uncaged plants were vulnerable to attacks by parasites and predators. Because of very large populations present on some plants, plant resistance in terms of aphid fecundity was measured as N = no aphids present,

TABLE IV

RESISTANCE AMONG 264 VARIETIES OF BARLEY TO <u>Rhopalosiphum padi</u> (L.), AS SHOWN BY THE NUMBER OF PROGENY PRODUCED BY TWO FEMALES CAGED FOR SEVEN DAYS ON SINGLE PLANTS IN THE FIELD

Group	Number of nymphs per plant after seven days	Number of varieties in group
1	0-20	142
2	21-40	64
3	41-60	15
4	61-80	11
5	81-100	3
6	100^+	29

S = less than 100 aphids, M = 100 to 200 and L = more than 200 aphids (or none, small, medium and large). These data are recorded in Table V. The grouping according to Table V is indicated in the alphabetical list of varieties in the Appendix after the variety name, by NC, SC, MC, or LC in parenthesis for "aphid caged", and by NNC, SNC, MNC, or LNC for "aphids not caged".

The four varieties under N in Table V (aphids caged) are Quinn C.I. 1024, C.I. 4219, Smooth Awn X Manchuria 11-21-15, and Paso C.I. 5047. They also occur in Group 1 of Table IV. The variety Paso also occurs under Group N (aphids not caged) and the other three varieties occur under Group S (aphids not caged) of Table V.

Table VI shows the total results of two five-day counts of antibiosis conducted in the field in 1960 on nine commercial varieties of barley commonly grown in Western Canada, based on fecundity of two adult wingless female aphids per plant, ten plants for each variety, with aphids and plants changed after the first count. Table VII shows the results obtained from counts made at five-day intervals from the four-leaf to headed stage on the nine commercial varieties. It is evident from Table VII that populations reach a peak at the 5-6 leaf stage, and then rapidly decline as the plant matures.

Population counts were also made at harvest time on the other plants of nine commercial varieties which had not

TABLE V

RESISTANCE AMONG 264 VARIETIES OF BARLEY TO *Rhopalosiphum padi* (L.), AS SHOWN BY TOTAL COUNTS OF APHIDS PRESENT WHEN PLANTS WERE HEADED OUT, ON BOTH CAGED AND UNCAGED SINGLE PLANTS IN THE FIELD

	Aphids caged				Aphids not caged			
	Group				Group			
	N	S	M	L	N	S	M	L
Number of varieties in group	4	151	32	77	23	172	33	36

N = no aphids present
S = small (less than 100 aphids)
M = medium (100 to 200 aphids present)
L = large (more than 200 aphids)

TABLE VI

FECUNDITY OF Rhopalosiphum padi (L.) ON NINE COMMERCIAL VARIETIES OF BARLEY IN FIELD TESTS IN 1960, COUNTS MADE ON TWO APHIDS CAGED PER PLANT ON TEN PLANTS, AT TWO FIVE-DAY INTERVALS

Variety	Average number of progeny	Transformed average[1]	Duncan's multiple range test[2]
Vantage	6.7	2.34	│
Herta C.I. 8090	6.8	2.69	│
O.A.C.21, C.I. 1470	11.0	3.29	
Montcalm	16.4	3.96	│
Husky	17.3	3.97	│
Traill	17.7	3.99	│
Parkland	18.6	4.21	│ │
Swan	27.0	4.72	│
Gartons	42.3	6.02	│

[1]Transformed by formula $\sqrt{x + 0.5}$

[2]Any two means not enclosed by the same bracket are significantly different at the 5 per cent level

TABLE VII

POPULATION COUNTS OF *Rhopalosiphum padi* (L.) ON NINE COMMERCIAL VARIETIES OF BARLEY, ACCORDING TO STAGE OF PLANT GROWTH, COUNTS MADE AT FIVE-DAY INTERVALS

Time counts made	Plant stage	Total number of aphids present
1	4-5 leaf	850
2	5-6 leaf	1823
3	5-6 leaf heading	1350
4	6 leaf heading	1682
5	7 leaf heading	984
6	heading	900
7	headed	900

been used for cage experiments and which had become naturally infested. Numbers of aphids present were rated as High = more than 200 aphids per plant, Intermediate = 100-200, and Low = less than 100 aphids per plant. Results are shown in Table VIII.

These natural infestations were vulnerable to parasites and predators. Comparing the data in Tables VI and VIII, there is a remarkably close correlation between resistance of varieties whether caged or uncaged.

In a further preliminary test, to determine the feasibility of testing resistance of barley in the greenhouse, 39 varieties of the 264 mentioned above were planted in pots in the greenhouse. Numbers of progeny from one apterous adult female caged per plant, replicated five times and counted at the end of seven days are recorded in Table IX by groups.

All seven of the varieties in the 6-15 group in Table IX also occur in the 0-20 group of varieties with high resistance shown in Table IV. These varieties are Danish Island, Glabron C.I.4577, Colsess C.I.2792, Danubian C.I.6525, Club Mariout C.I.261, Chile Brewing C.I.657 and Black Barbless C.A.N.11. Of the four varieties in the 56+ group of Table IX, three occur also in the high susceptibility 100+ group of Table IV. The three varieties are Blue Hulless C.I.4848, Austrian Hannast 66 and Duckbill C.I.1916.

TABLE VIII

RESISTANCE OF NINE COMMERCIAL VARIETIES OF BARLEY TO *Rhopalosiphum padi* (L.), AS INDICATED BY TOTAL POPULATIONS PRESENT AT HARVEST TIME FROM NATURAL INFESTATIONS

Low (0-100)	Intermediate (101-200)	High (200+)
Vantage	Husky	Gartons
Herta	Montcalm	Swan
	O.A.C.21	Parkland
		Traill

TABLE IX

RESISTANCE OF 39 VARIETIES OF BARLEY IN THE GREENHOUSE TO *Rhopalosiphum padi* (L.), BASED ON NUMBER OF PROGENY COUNTED AT THE END OF SEVEN DAYS FROM FIVE FEMALES

Total number of nymphs present at end of 7 days	Number of varieties per category
6-15	7
16-25	8
26-35	11
36-45	3
46-55	6
56+	4

After the aphids reported on in Table IX had been counted they were allowed to remain on the plants and reproduce freely inside cages until the barley headed out. Table X shows the results with S = less than 100 aphids per plant, M = 100-200, and L = more than 200 aphids per plant. Two varieties, Glabron and Danubian shown under S in Table X also occur in the 0-20 group of Table IV and the 6-15 group of Table IX showing high resistance to the aphids. Of the four varieties under L in Table X, two varieties Duckbill and Blue Hulless also occur in the 100+ group of Table IV and the 56+ group of Table IX as being highly susceptible.

The preliminary experiments outlined above indicated: (a) that varieties of barley differed in resistance to the aphid species used in the tests, both in the greenhouse and the field, and (b) that the most reliable counts of progeny were obtained from one caged adult apterous female on one plant, at the end of five days of reproduction.

TABLE X

RESISTANCE OF 39 VARIETIES OF BARLEY IN THE GREENHOUSE TO Rhopalosiphum padi (L.), BASED ON TOTAL PROGENY WHEN PLANTS WERE HEADED OUT

Total number of aphids per plant	Number of varieties per category
S (0-100)	2
M (101-200)	33
L (200+)	4

CHAPTER VI

RESULTS OF GREENHOUSE AND FIELD EXPERIMENTS, 1960-1961

As a result of the information gained from the tests outlined in the previous chapter, it was decided to test all the available varieties of the Canadian Genetic Stock of Barley held at the Central Experimental Farm, Canada Department of Agriculture, Ottawa, for resistance (both antibiosis and tolerance) to the aphid *Rhopalosiphum padi* (L.). Starting in September, 1960, 137 varieties of barley were tested in the greenhouse for both antibiosis and tolerance by the spring of 1961. Forty-nine varieties showed some resistance in the greenhouse and they were selected for field tests on the basis of 20 showing both antibiosis and tolerance, 19 because of antibiosis only and 10 because of tolerance only. Eighty-eight varieties demonstrated no resistance in the greenhouse tests. The susceptible varieties were compared to the variety Swan, because Swan was used for rearing stock cultures, and was known to be susceptible. Table XI shows the results of greenhouse tests on these 88 varieties, with average number of progeny transformed by the formula $\sqrt{x = 0.5}$, and compared with Swan. Analysis of variance with the transformed means of the 88 varieties showed that 10 of the varieties were less susceptible than Swan, and the remainder were more susceptible, or the same. Variety Astra appeared as the most susceptible to *R. padi*.

TABLE XI

APHID MULTIPLICATION AND FEEDING DAMAGE IN 88 SUSCEPTIBLE VARIETIES OF BARLEY INFESTED WITH *Rhopalosiphum padi* (L.) IN THE GREENHOUSE IN 1960-1961

Variety	Average number progeny in 5 days	Trans- formed average	No. of plants alive at the end of weeks							
			1	2	3	4	5	6	7	8
Abyssinian C.I.668	15.4	3.94**				2	4	2	2	
Abyssinian C.I.4220-1	25.0	5.04			1	2	4	3		
Arequipa C.I.1256	17.6	4.24			4	3	2			1
Astra B 653	34.2	5.87			3	7				
Atlas 46 C.I.7323	17.3	4.19			2	4	2		2	
B 162 B 8925	27.9	5.31			2	3	2	1		2
B 185 Common 6 rowed	18.6	4.36				4	5	1		
B 220 German Brewing	19.4	4.43				1	5	4		
Bay C.I.7113	18.0	4.27		1	3	4	1			1
Betzes C.I.6398	17.1	4.18		1		2	4	3		
Brandon M 57-754	18.1	4.30				1		5	3	1
Brant C.I.10073	22.6	4.75		3		3	1		3	
Byng C.I.6089	17.9	4.27			4	1	1			4
Canadian Thorpe C.I.740	16.7	4.13*			2	1	4	2		1
Cape 6 rowed C.I.1386	25.8	5.11			2	3		2		3
Carlsbery II C.I.7621	17.7	4.26		1	3	1	3	2		
Cebada Cape C.I.6193	16.2	4.08*			1	4	2		1	2
Charlottetown 80 C.I.2732	20.1	4.47		1	2	1	3		2	
C.I.2542	20.5	4.41			2	1	2	1		4
C.I.4402	18.3	4.32					6	2	2	
Clemson Hooded C.I.7042	17.3	4.19			1	3	3		3	
Coast C.I.276	19.8	4.48				3	4	1	2	
Danish Island C.A.N. 1002	17.3	4.21			5	5				
Duckbill C.I.1916	18.7	4.29		1		4	3		2	
Edda II	18.5	4.32			4	2	1	1	2	
Erie C.I.5050	20.1	4.50				2	5		3	
Fort	26.7	5.21		1		4	3	1	1	
Franken II B 28	21.5	4.68					1	5	3	1
Franken III B 29	27.0	5.24			4	3	2	1		

TABLE XI (continued)

Variety	Average number progeny in 5 days	Transformed average	No. of plants alive at the end of weeks							
			1	2	3	4	5	6	7	8
Gartons 108 C.I.6615	19.7	4.44			1	5	3			1
Gateway C.I.10072	23.2	4.85		4	1	4	1			
H 4808 B 294	20.4	4.54		3	3	2	2			
Hanna C.I.30	19.0	4.40				1	4	2		3
Hanna C.I.906	15.5	3.99		1	3	4		1	1	
Hartan	17.8	4.27			7				1	2
Hannchen C.I.531	24.7	4.99		3	2	3	2			
Heines Haisa B 34	25.5	5.09			3	3	3		1	
Herta	22.8	4.80			4	1	2	1	2	
Himalaya	21.2	4.63		3	3		2			2
Husky C.I.9537	21.0	4.61				3		3	1	3
Kenate	22.3	4.76		1	2	3	1	1		2
Lion C.I.923	20.1	4.52			1	4		3		2
Manchuria C.I.244	25.8	5.10				1	5	2	1	1
Manchurian	20.3	4.78			3	2	1	4		
Manchuria C.I.956	24.0	4.92				4	2	4		
Manchurian C.I.739	26.7	5.18					2	5	1	2
Marco C.I.5647	22.1	4.73				5	1	1	1	2
Mensury Ott. 60	17.4	4.21			1	3	1	5		
Minerva L.G.51 B 230	21.9	4.72		1	1	3	4			1
Montcalm C.I.7149	25.6	5.07				2	6		2	
Newal C.I. 6088	21.6	4.70		1	1			4		4
Oat Collection	24.1	4.93				2	4	1	1	2
O.B.C. 3 (4811-18-2-3)	16.0	4.04*				2	5	2		1
Oderbrucker C.I.940	17.5	4.18				4	4	2		
Olli	17.8	4.24				4	2	2	2	
Opal B.C.I.6617	17.6	4.27				3	4		3	
Orge Marcaine O 17	20.3	4.54			1		6		3	
Orge 227 Schribaux	17.6	4.22				4	4	1	1	
Ott. 3643 B (Vel. X Olli X Peatland X Pulper)	17.8	4.27				4	2	3	1	
Parkland C.I.10001	23.8	4.90			1		7	2		
Peruvian Sl.19 C.I.6568	18.5	4.27			5	2		1	2	
Peruvian 1 C.I.5912	16.3	4.09*			1	3	1	1	1	3

TABLE XI (continued)

Variety	Average number progeny in 5 days	Transformed average	No. of plants alive at the end of weeks							
			1	2	3	4	5	6	7	8
Pillsbury C.I.7166	17.8	4.21		2	3	2	1	1	1	
Plumage Archer C.I.5033	18.8	4.49		5	3	2				
Pontiac C.I.4849	17.7	4.25		2	1	2		2		3
Prize Prolific C.I.169	19.0	4.40		3	2	2	1			2
Prospect C.I.6339	29.5	5.44			1	2	2	1		4
Psaknon C.I.6305	28.9	5.39			1	7		1		1
Rabat C.I.4974	16.9	4.13*				3	3		1	3
Rex C.I.1388	23.5	4.85		2	1	2	2	2		
Regal C.I.5030	19.8	4.50				2	4	3	1	
Rika	16.8	4.12*			3	4	2	1		
SC. 235	19.0	4.40					1	5	2	2
Sanalta C.I.6087	26.1	5.13				3	1	2		4
Spray C.I.5477	18.0	4.29		1	4	2	2	1		
Staller C.I.9871	16.6	4.11*		3		3	1	2		1
Texan C.I.6499	19.3	4.40					4	2	2	2
Titan C.I.7055	29.0	5.42			4	1	3			2
Trebi C.I.936	24.8	5.02			2	3	3		2	
Vantmore C.I.9555	22.1	4.72		1	3	1	1			4
Velvet C.I.4252	18.0	4.29		1	1	5	2	1		
Warrior C.I.6991	15.7	4.00*				4	2	2	2	
Wisc. Ped. C.I.5028	16.6	4.10*			1	7	2			
Wolfe C.I.10071	23.2	4.83		1	3	1		1	1	2
4813-193-2-1	28.8	5.41			1	5	2	1	1	
4813-193-10-1	17.2	4.18					6	2		2
4813-227-4-3	21.2	4.62				4	4	1		
Swan (as check)	21.6	4.66				3		4	1	2

** Significantly different in lower susceptibility at the 1 per cent level compared with Swan

* Significantly different in lower susceptibility at the 5 per cent level compared with Swan

The reaction of the 49 varities which showed resistance in the greenhouse tests is shown in Table XII, with data from both greenhouse and field tests. In the field tests 30 varieties exhibited antibiosis only, 1 showed tolerance only, 4 showed neither antibiosis nor tolerance and 14 varieties demonstrated both antibiosis and tolerance.

Table XIII shows the average number of progeny produced per female in five days, and the number of plants alive at the end of six weeks in field tests for the 14 varieties which exhibited both antibiosis and tolerance. Analysis of variance and Duncan's multiple range test showed no significant difference among the 14 varieties.

Eight of the 49 varieties showed both antibiosis and tolerance in both the greenhouse and field tests (Table XIV).

It is interesting to compare the data from the tests conducted in 1960 with the tests conducted in 1961. The following varieties which showed antibiosis in 1960 continued to show some degree of resistance to R. padi when included among the varieties used in the 1961 tests: Black Barbless C.A.N.11, C.I.4219, Colsess C.I.2792, Danubian C.I.6525, Chile Brewing C.I.657, Glabron C.I.4577, Paso C.I.5407, Quinn C.I.1024, Smooth Awn X Manchuria 11-21-15 and Club Mariout C.I.261. Of this group C.I.4219, Black Barbless C.A.N.11, Colsess C.I.2792 and Danubian C.I.6525 were rated sufficiently high to be included in Table XIII, and must be regarded as

TABLE XII

REACTION OF 49 VARIETIES OF BARLEY TO POPULATIONS OF THE APHID *Rhopalosiphum padi* (L.) IN BOTH GREENHOUSE AND FIELD TESTS

Variety	Reaction[1]			
	Antibiosis		Tolerance	
	Green-house	Field	Green-house	Field
Abyssinian C.I.2192	*	*	*	
Alpha C.I.959		*	*	
Barboff C.I.7148	*	*	*	
Black Barbless C.A.N.11	*	*	*	*
Brandon M.57-680	*	*	*	
Carre 26 C.I.3386		*	*	
Chile Brewing C.I.657	*	*	*	
Chinese Black C.I.1969	*	*		
C.I.2376	*	*	*	
C.I.3906-1	*	*	*	*
C.I.4219	*	*		*
Club Mariout C.I.261	*			
Colsess C.I.2792	*	*	*	*
Compana C.I.5438	*	*		
Danubian C.I.6525	*	*		*
Feebar C.I.7260		*	*	
4811-68-2			*	
4811-70-1	*	*	*	
4813-193-3-1	*	*	*	
Galore C.I.7150	*	*	*	*
Gatami C.I.2276	*	*		
Glabron C.I.4577	*	*	*	
Herta C.I.8097	*			*
Hooded Spring C.I.716	*	*	*	
July C.I.4289	*	*		
Kindred C.I.6969		*	*	
Kwan C.I.1016	*	*	*	
Lynch C.I.919		*	*	
Mechnos Moroc C.I.1379	*	*		
Mianwali C.I.3400	*	*	*	*

TABLE XII (continued)

Variety	Reaction[1] Antibiosis Greenhouse	Antibiosis Field	Tolerance Greenhouse	Tolerance Field
Multan C.I.3401	*			
Nigrate C.I.2444	*	*		
Nobarb C.I.6120			*	
O.A.C.21 C.I.1470	*	*	*	*
Odessa C.I.934		*	*	*
Paso C.I.5047	*	*		
Peatland C.I.5267	*	*		*
Plush C.I.6093	*	*	*	
Quinn C.I.1024	*	*		
Rojo C.I.5401		*	*	*
Smooth Awn X Manchuria 11-21-15	*	*		
Star C.A.N.748	*	*		
Success C.I.1775	*	*		*
Valentine C.I.7242		*	*	
Vantage X Jet Br. 5209-7	*	*	*	*
Vantage X Jet Br. 5209-29	*	*	*	*
Velvon 11 C.I.7088	*	*		
Wong C.I.6728	*	*	*	
White Anoidium C.I.7269	*	*		

[1] * (Antibiosis) = Average number of nymphs fewer than 15 per female in 5 days

* (Tolerance) = 5 or more plants out of 10 survived 6 weeks

TABLE XIII

APHID MULTIPLICATION AND FEEDING DAMAGE IN 14 RESISTANT VARIETIES OF BARLEY INFESTED WITH *Rhopalosiphum padi* (L.), FIELD TESTS

Variety	Average number of progeny in 5 days	Transformed average[1]	Duncan's multiple range test[2]	Number of plants alive at end of 6 weeks
Rojo C.I.5401	15.2	3.94	│	5
(Vantage X Jet)Br. 5209-7	13.8	3.72	│	5
Danubian C.I.6525	13.4	3.68	│	5
Galore C.I.7150	13.0	3.63	│	5
C.I.4219	12.9	3.53	│	5
Colsess C.I.2792	11.7	3.47	│	5
Success C.I.1775	11.4	3.42	│	7
Mianwali C.I.3400	11.1	3.39	│	5
Peatland C.I.5267	11.0	3.37	│	9
O.A.C.21 C.I.1470	11.1	3.37	│	7
Black Barbless C.A.N.11	10.6	3.32	│	8
(Vantage X Jet) Br.5209-29	10.5	3.29	│	7
Odessa C.I.934	9.8	3.16	│	6
C.I.3906-1	9.4	3.12	│	6

[1]Transformed by the formula $\sqrt{x + 0.5}$

[2]There are no significant differences between varieties within the groups indicated by the vertical line

TABLE XIV

APHID MULTIPLICATION AND FEEDING DAMAGE IN EIGHT RESISTANT VARIETIES OF BARLEY INFESTED WITH *Rhopalosiphum padi* (L.), GREENHOUSE AND FIELD TESTS

Variety	Greenhouse tests			Field tests		
	Average number of progeny in 5 days	Trans-formed average	Number of plants alive at end of 6 weeks	Average number of progeny in 5 days	Trans-formed average	Number of plants alive at end of 6 weeks
Black Barbless C.A.N.11	12.3	3.57	8	10.6	3.32	8
C.I.3906-1	14.2	3.85	10	9.4	3.12	6
Colsess C.I.2792	8.6	3.00	8	11.7	3.47	5
Galore C.I.7150	8.5	2.97	7	13.0	3.63	5
Mianwali C.I.3400	13.5	3.72	7	11.1	3.39	5
O.A.C.21.C.I.1470	10.2	3.28	6	11.1	3.37	7
(Vantage X Jet) Br.5209-7	13.6	3.75	10	13.8	3.72	5
(Vantage X Jet) Br.5209-29	13.4	3.71	7	10.5	3.29	7

resistant varieties on the basis of consistent performance over two summers of field tests. However, it must be pointed out that the data on varieties are not strictly comparable between Table IV and Table XIII, because of difference in years and in stages of plant growth at the time aphids were put on the plants.

Of the nine commercial varieties, O.A.C.21 which showed intermediate resistance in the field tests of 1960, (Table VIII) exhibited resistance in all tests in 1961. The variety Herta showed only tolerance in both greenhouse and field tests in 1961. Vantage, which appeared to show resistance as well as Herta in 1960 tests failed to qualify in the 1961 tests, although it is represented in the two hybrid crosses with Jet in Table XIII.

CHAPTER VII

RESULTS OF GREENHOUSE AND FIELD EXPERIMENTS, 1961-1962

This chapter reports the results from testing the remaining varieties (331) of the Canadian Genetic Stock of Barley, not reported in Chapter VI, for resistance to *R. padi*. All varieties were first tested in the greenhouse between May, 1961 and May, 1962. Two hundred and fifty-three showed susceptibility and 78 varieties demonstrated resistance in terms of either antibiosis or tolerance. The procedures were identical to those used for the varieties reported on in Chapter VI.

The 253 susceptible varieties were compared with Swan variety by using the method of Goulden (1945). Results (Table XV) indicate that 27 varieties are significantly different to Swan at the 5 per cent level, and 142 at the 1 per cent level. These varieties might therefore be considered as less susceptible than Swan. Eighty-four varieties were more susceptible than Swan.

The 78 resistant varieties from the greenhouse tests were based on 27 varieties showing both antibiosis and tolerance, 16 because of antibiosis only and 35 because of tolerance only. These varieties were tested in the field in the summer of 1962. The reaction of these varieties in both greenhouse and field tests is shown in Table XVI.

TABLE XV

APHID MULTIPLICATION AND FEEDING DAMAGE IN SUSCEPTIBLE VARIETIES OF BARLEY INFESTED WITH *Rhopalosiphum padi* (L.), GREENHOUSE TESTS, 1961-1962

Variety	Average number progeny in 5 days	Transformed average	No. of plants alive at the end of weeks							
			1	2	3	4	5	6	7	8
Abacus C.I.1088	17.2	4.20**		1		4	3	1		
Abate C.I.3920	20.9	4.62			2	5	1	1	1	
Abyssinia C.I.949	20.9	4.61			1	3	1	2	2	1
Abyssinian C.I.1243	16.9	4.16**			1	2	1	4		2
Abyssinian C.I.2251	17.9	4.26*			2	1	4	2		1
Alberta Black C.I.1968	17.9	4.25**				1	5	2	2	
Algerian C.I.1179	16.0	4.05**			2	2	3	1	1	1
Algerian C.I.2974	16.9	4.17**			1	7	1			1
Anoidium C.I.7269	17.1	4.19**			2	5	1	1		1
Apalan C.I.1347	16.1	4.06**			2	4	1	1		2
Ceresia B.I.M34B654	22.6	4.77			3	2	4		1	
Australian C.I.3038	16.1	4.06**		2	6	2				
Australische 22 C.I.6314	17.4	4.21**		1	2	3		2		2
B 10 Watcho C.I.9883	19.4	4.43		1	1	1	3	1	2	1
B 11 Bonga	22.6	4.69			3	4	3			
B 17 Erectoides 12	16.7	4.13**			8	1	1			
B 18 Erectoides 13	18.2	4.31*		1	6	3				
B 19 Erectoides 16 C.I.9134	16.0	4.04**			8	1	1			
B 20 Erectoides 23 C.I.9135	16.1	4.07**				2	2	3	2	1
B 40 Donnes C.I.2535	23.7	4.94		2	2	2		1		2
B 41 Victory C.I.5077	20.2	4.54			4	4	2			
B 42 Fjola	22.3	4.76			4	5				1
B 54 *H. pyramidatum*	20.7	4.59			4	4	1		1	
B 163 *H. spontaneum* Hybrid	17.6	4.23**				4	2		1	3
B 182 Sask. 5203	33.4	5.82			3	5	2			
B 186 Alaska Black	19.9	4.51			3	3	2	1		1
B 187 Tibetan Hulless	17.9	4.85*			2	3	3			2
B 189 Male sterile	17.1	4.18**			1	4	2			3
B 190	16.9	4.17**			3	5				2
B 195	21.1	4.63				3	3	1	3	
B 217 Brage	16.3	4.09**			7	3				
B 218 U 48/54	18.1	4.29*				5	4			
B 221 Hanna C.I.1122	19.1	4.42		1	4	2	2			1

TABLE XV (continued)

Variety	Average number progeny in 5 days	Trans-formed average	No. of plants alive at the end of weeks							
			1	2	3	4	5	6	7	8
B 223 Sask. 4912	17.9	4.27*		1	2	2	1	3	1	
B 224 4675 1Ch2	24.2	4.97				6	1	3		
B 225 4675-1Ch-1	16.2	4.08**			2	5	2			
B 226 S48-2	18.4	4.30*		2	5	3				
B 228 No.11 Iowa	16.5	4.11**			1	3	6			
B 240 White Aleuroned	28.5	5.36			1	4	3		2	
B 245 <u>H. intermedium</u> C.I.2209	18.4	4.34*		2	4	3				1
B 246 <u>H. intermedium</u> C.I.2607	16.9	4.16**			2	6	1			1
B 268W C.I.4966	16.6	4.12**			2	3	4			1
B 284 <u>H. tetrastisum</u> Var. <u>Coeleste</u>	16.1	4.07**		1	4	2	1	1		1
B 529 Awned Hulless Barley	28.3	5.36		3	2	1	2	1		
B 530	18.7	4.37*			1		3	2		3
B 531	17.4	4.20**			2	5	1	2		
B 673 Eligulate	16.2	4.08**		1		5	2	1		1
Baker C.I.975	18.0	4.30*				8	1			
Balder II	16.1	4.06**		1	1	3	1	1	1	2
Barley 305 C.I.6015	16.4	4.10**			4	2	4			
Bay Brewing	16.2	4.07**			5	2		2		1
Bey C.I.5581	19.0	4.41			3	7				
Beaverdam C.I.6612	16.5	4.09**		2	3	1	1	1		1
Black Egyptian C.I.1246	19.2	4.42			2	2	2	2	2	
Black Hulless C.I.666	16.2	4.07**			4	2	1	1		2
Bolivia C.I.1257	17.9	4.28*			2	4	1			3
Bonneville C.I.7248	16.4	4.11**			4	3	1	1		1
Br. 1136	16.2	4.12**				1	3	2	2	2
Br. 1239-11	16.1	4.07**			1	2	1	4		1
Br. 3962-4	16.3	4.09**			2	5	1	1		1
Brustedt's Schladener	16.0	4.06**		1	3	2	2			1
Caballero C.I.1006	20.9	4.62			3	6	1			
Callas C.I.2440	16.2	4.08**		1		2	1	2		4
Canadian Lake Shore C.I.2750	16.4	4.11**		1	2	2	2		2	
Cape C.I.1387	16.5	4.10**				7	1	2		
Carre 180 C.I.3390	16.0	4.05**			3	3		1	1	2
Chevron C.I.1111	25.0	5.03			3	6	1			
Chinerme C.I.1079	16.0	4.06**	2		3	1		1		3

TABLE XV (continued)

Variety	Average number progeny in 5 days	Trans-formed average	No. of plants alive at the end of weeks							
			1	2	3	4	5	6	7	8
Chevalier C.I.1245	27.9	5.29		1	3	4	2			
Chosen C.I.5098	25.6	5.07			2	4	2	1		
C 13-13 Sel. from U.S. Composite Cross 13	23.4	4.87		1	2	1	3	1		2
C.I.922 Bolton	17.1	4.17**			1	3	2	2	1	1
C.I.1227	17.8	4.25**		1	1	1	2	2	1	2
C.I.1237	18.7	4.36*			2	3	2	2	1	
C.I.2376 Abyssinian	25.5	5.09			1	5	1	1	2	
C.I.3212-I	20.3	4.56			1	2	4	1	2	
C.I.3530-2	16.0	4.05**		1	3	3		2		
C.I.4193	16.4	4.14**			2	4	2		2	
C.I.4220-I Abyssinian	22.2	4.76			3	6	1			
C.I.4382	18.9	4.07*			1	3	4	2		
C.I.4396	16.7	4.14**			3	5		2		
C.I.4397	16.0	4.06**			1		1	4		4
C.I.4398	22.3	4.75			2	7	1			
C.I.4405	16.1	4.06**			2	2	1	1	1	3
C.I.4413	16.0	4.05**			2	1	3	2		2
C.I.4416	20.2	4.51			1		5	2	1	1
C.I.4419	19.8	4.45			7	2		1		
C.I.4429	16.6	4.11**		1	5	1	1		1	
C.I.4430	16.0	4.06**			2	1	2	2	1	2
C.I.4444	19.7	4.58				2	4	1	2	1
C.I.4451	16.0	4.05**		2	3			1		4
C.I.4455	16.8	4.15**			2	2	1	2		3
C.I.4456	23.3	4.85			2	3		2		3
C.I.4459	16.2	4.07**			5	4		1		
C.I.4462	17.4	4.22**			1	2	2	1		4
C.I.4466-1	16.6	4.09**			2	3	3		2	
C.I.4475	16.0	4.06**			4		1	1	1	3
C.I.4487-1	16.0	4.05**		1	5	1			1	2
C.I.4488	18.0	4.26*					5	2		3
C.I.4492	17.6	4.23**			1		3	4		2
C.I.4497	19.2	4.40		1	2	2	3	1		1
C.I.4502	22.1	4.74			4	3	1		1	1
C.I.4508	16.0	4.05**			2	1	2	2		3
C.I.4518	21.7	4.68			4	3	1			1
C.I.4525	16.3	4.09**				6	1	2		1
C.I.4559	20.6	4.59			5	1	4			
C.I.4920	19.3	4.42		1	2		2	1	2	2
C.I.4932	16.0	4.04**			5		2	1	1	1

TABLE XV (continued)

Variety	Average number progeny in 5 days	Transformed average	No. of plants alive at the end of weeks							
			1	2	3	4	5	6	7	8
C.I. 5234	21.5	4.68			3	3				4
C.I.6073	16.2	4.07**			4	4			1	1
Common Chile C.I.663	17.2	4.20**				5	3		1	1
Domen B 188	17.2	4.20**				3	1	3		3
Dorsett C.I.4821	16.0	4.03**			4	1	2	1	1	1
Drost	17.3	4.20**		4	2	3	1			
Edda B44	21.3	4.66			3	5	1		1	
Engledon India B 234	18.1	4.31*			5	3				2
Egypt C.I.3410	16.5	4.12**			3	4	2	1		
Entresol C.I.1261	17.9	4.28*			2	2	3	2		
Erika C.I.9271	17.2	4.14**	1		3	4	1	1		
Ethiops C.I.2208	16.1	4.07**		1			4	2		3
Excelsior C.I.1248	15.7	4.03**			3	2	1	2		
Featherston C.I.1118	20.4	4.55				7	2	1		
Featherston C.I.954	16.9	4.17**			2	6	2			
Firlbeck III B 26	20.0	4.50		1	5			1	2	1
Flynn C.I.1311	16.9	4.17**			3	2	3	1		1
Frontier C.I.7155	22.5	4.77				3	3	1	1	2
Gartons C.I.7016	20.1	4.53				6		1	1	2
Gatami C.I.575	20.0	4.50			7	1	2			
Gatami White C.I.920	18.2	4.31*				3	3		3	1
Gem C.I.7243	24.1	4.94				5	2		1	2
Gold C.I.1145	17.5	4.22**					3	3	2	2
Goldfoil C.I.928	25.1	5.02		1	7					1
Grenet B 283	16.7	4.14**			2	3	1	1	2	1
Grushevsky B 869 C.I.6538	16.8	4.15**		1	8					1
H III-87 C.I.9185	16.6	4.12**			1	5	1	2	1	
Heitpas 5, C.I.7124	16.9	4.16**			3	2		1	4	
Hillsa C.I.1604	21.8	4.77			1	7			1	1
Himalaya C.I.620	16.7	4.14**			1	4	3		2	
Himalaya C.I.2257	18.3	4.33*			2	3	2	2	1	
Himalaya C.I.2448	16.3	4.10**			1	2	1	3	1	2
Harbin C.I.4929	16.1	4.07**			2	6	2			
<u>Hordeum deficiens decorticatum</u> C.I.2230	16.9	4.16**			2		4		1	
<u>Hordeum spontaneum</u>	19.7	4.48		1	1	2	3	1		2
Horn C.I.926	16.1	4.07**			4	3	1	1	1	
Hulless (Nepal) C.I.1032	22.5	4.78				2	2	2		4
Iwate Mensury C, B 443	16.2	4.08**			4	1	1	1	1	2
Jubilee C.I.7540	16.1	4.07**			1	3	4	1		1

TABLE XV (continued)

Variety	Average number progeny in 5 days	Trans-formed average	No. of plants alive at the end of weeks							
			1	2	3	4	5	6	7	8
Juliaca C.I.1114	16.3	4.09**			6	2	1			
K 4061-4 (Byng X Olli)	23.0	4.84		2	2	3	2		1	
Kachidoki B 444	21.4	4.68			1	1	5	3		
Kitchin C.I.1296	16.4	4.10**				7	1		1	1
Kopeck C.I.869	21.5	4.57			2	6	1		1	
Korsbyg C.I.918	16.2	4.08**			1	2	5	2		
Krimskij 301, B 866	16.8	4.15**				5	4		1	
Kubonos B 491	17.8	4.27*			1	3	5	1		
Len 13 (Sel. from U.S. Composite Cross 13)	25.3	5.07			4	5			1	
Lenta C.I.7622	20.6	4.59		2	1	3	3	1		
Lompoc C.I.1312	18.6	4.35*		2	3	1	2	1	1	
Lopac C.I.9095	17.9	4.28*			3	1	5	1		
Luth C.I.972	22.7	4.79		1	1	3	1		3	1
Maja	20.4	4.57			6	2	1	1		
Malting C.I.1129	21.8	4.71			3	5	2			
Meloy C.I.1176	17.3	4.19**			2	3	2	2		1
Mianwali Sel. 3	21.9	4.70			3	1	3	1		1
Mianwali Sel. 4	17.6	4.23**			2	1	1	2	1	1
Modia C.I.2483	16.4	4.11**				6	1	1		1
Modjo C.I.3212	24.4	4.97			2	4	2		1	1
Modoc C.I.7566	17.4	4.22**			1		6		1	1
Montanum	21.1	4.59			6	2		2		
Moore C.I.7251	21.2	4.65			1	3	2	3	1	
Moravian C.I.7559	16.9	4.16**			2	1	3	1	1	2
Morocco C.I.3902-1	20.3	4.51			5	4				
Morocco C.I.6311	16.8	4.15**				1	7	2		
Mortoni C.I.2210	22.6	4.79			2	2	4		1	1
Murasaki Mochi C.I.5899	16.2	4.08**			1	5	2		1	1
Negra Munfredi B 564	17.8	4.24**				4	3	1	1	1
Nutans 27 B 865	19.9	4.51		1	4	3	2			
Nudi deficiens C.I.2229	19.4	4.45		1	2	5	2			
O.B.C.69 (5069-7-13-14)	17.2	4.18**			2	3	3	1		1
Odessa C.I.182	16.1	4.07**			4	3	1	2		
Ogalitso C.I.7152	16.0	4.05**			3	4	1	2		
Oral C.I.351	23.0	4.83			2	6	1			1
Osiris C.I.1622	19.6	4.46				3	3			4
Palestine C.I.939	16.6	4.12**			4	4	2			
Palliser	19.0	4.38				2	5	2	1	
Palmella Blue C.I.3609	18.4	4.33*			4	3	1		1	
Persicum C.I.2249	21.8	4.69			1	2	4	1		2

TABLE XV (continued)

Variety	Average number progeny in 5 days	Trans-formed average	No. of plants alive at the end of weeks 1	2	3	4	5	6	7	8
Peru C.I.653	16.2	4.08**			1	4	3	2		
Peruvian C.I.935	17.0	4.17**		2	4	2	1			1
Plains C.I.7250	22.4	4.75				2	2	2	1	3
Prekocius 143 B 861	17.0	4.18**			4	5	1			
Procter C.I.5961	16.5	4.12**			5	3	1	1		
Purple Hulless C.I.1415	16.3	4.09**			2	3	1	1		3
Purple Nepal C.I.1373	16.0	4.06**	1		2	3		1	1	2
Ragusa b B 36	16.1	4.06**			5	2			2	1
Ranando C.I.5170	16.0	4.06**		3	2	2	1			2
Rapur C.I.864	16.2	4.07**				2	2	3	1	2
Ricardo smoothawn C.I.6306	16.1	4.05**			3	5	1			1
Ricardo roughawn C.I.6306	16.0	4.06**			1	5	1	2		1
Rivale C.I.2345	23.4	4.88			2	2	2	1	2	1
Rokakudo C.I.5197	15.8	4.02**				3	5	2		
Rabat medium C.I.4979	16.1	4.06**			6	2	2			
Russia C.I.1371	16.6	4.13**				5	2	1	1	1
Sandrel C.I.937	23.6	4.90			6	1	2		1	
Seed stocks C.I.6614	16.0	4.03**			5	2	2	1		
Sheba C.I.4359	16.3	4.10**			2	4	2	1	1	
Silverking C.I.890	17.2	4.20**		1	7		1			
Sixty-day C.I.5031	17.9	4.27*			2	2	3	1	1	
Square head C.I.1417	17.9	4.28*				4	1	1	1	3
Stavropol C.I.90	16.0	4.03**				1	4	1		4
Stephan C.I.8051	25.0	5.04			3	5	2			
Stendelli C.I.2266	16.4	4.11**				2	2	3	1	2
Stewart C.I.6112	16.7	4.14**				4		2	1	3
Stevens 46 C.I.6608	16.3	4.08**			9			1		
Subcornutum C.I.2211	19.8	4.46			3	3	1	1		2
Sultan C.I.5577	21.7	4.71			3	1	4		1	1
Svanhals C.I.187	21.0	4.62				3	2	5		
Svansota C.I.1907	16.3	4.09**			4	4	2			
Swedish Star C.I.1701	16.3	4.09**			1	2	1	2	4	
Swiss 87 C.I.7025	16.0	4.05**			2	4		2		2
Tifang C.I.4407-1	18.2	4.31*				5		1	2	2
Tammi C.I.8345	16.0	4.05**			1	3	5	1		
Traill C.I.9538	27.7	5.29			4	3	1		1	1
Triple Awn Lemma C.I.6630	16.1	4.07**		3	1	1	2	2		

TABLE XV (continued)

Variety	Average number progeny in 5 days	Trans-formed average	No. of plants alive at the end of weeks							
			1	2	3	4	5	6	7	8
Tripoli C.I.1115	16.0	4.06**			2	3	1		1	3
Turk C.I.5611-2	19.4	4.55			2	3	2	3		
Valkie C.I.5748	26.2	5.15			1	6	2		1	
Vaughn C.I.1367	16.1	4.07**			5	3	1	1		
Vega C.I.6652	18.0	4.29*		1	1	3	1	1	1	2
Vogal's wein B 39	19.1	4.41				7	1	2		
Walpersii B 215	18.2	4.29*		1	3	2	2	1		1
Wase hosogara B 452	16.3	4.19**		1	2	3	1		2	1
Weider C.I.1021	16.2	4.08**			4	3	1		1	1
White Hulless	16.3	4.09**	1	2	1	2	1	1	1	1
Wis. H. 106	17.5	4.24**			1		3	2	2	2
Wisa B 652	16.8	4.14**			4	1	1	1	1	2
Zander-1 C.I.6610	16.2	4.07**			1	1	3	1	1	3
2 rowed deficiens C.I.3327	16.3	4.09**				2	3	1	2	2
36 Ab 6127	17.2	4.20**			1	3	4	1	1	
3110C	16.0	4.06**			2	3	5			
3110D	24.6	5.01		1	5	3	1			
4666-5 (Vantage X Rabat)	22.9	4.81			3	3	2	1		1
4668-H-1	20.2	4.54			2	5	2	1		
4668-57	22.8	4.82		1	6	3				
4675-16-3-1	18.0	4.29*		1		2	5			2
4675-16-3-7	17.7	4.25**			5	2	2		1	
4677-3-10-2	17.3	4.20**				4	2	3		1
4684-128-1	17.0	4.18**		1	2	2		2		3
4684-133-1	16.2	4.08**				2	2	2	2	2
4804-19-4-22	24.6	5.00			5	1	1	2	1	
4808-32	16.6	4.12**		1	2	5		2		
4813-67-1-1	16.0	4.05**				3	4	1	1	1
4813-193-20-5	16.4	4.10**			2		5	1	2	
Swan (Check)	22.1	4.75					3	4	1	2

** = Significant difference at the 1 per cent level, compared with Swan

* = Significant difference at the 5 per cent level, compared with Swan

In the field tests 29 varieties demonstrated both antibiosis and tolerance, 16 antibiosis only, 24 tolerance only and in 9 varieties neither antibiosis nor tolerance was observed.

Table XVII lists the 29 varieties which demonstrated both antibiosis and tolerance in field tests. Analysis of variance by the method of Goulden (1945) shows that all 29 varieties differ significantly in antibiosis at the 1 per cent level when compared with the susceptible variety Swan. Table XVII also shows the groupings of means among the 29 varieties according to Duncan's multiple range test.

Twenty-three of the 78 varieties showed both antibiosis and tolerance in both greenhouse and field tests (Table XVIII).

The 14 resistant varieties (Table XIII) which were so promising in 1961, were tested again in the field in 1962 for verification of the results of 1961. The results of both 1961 and 1962 field tests of the 14 resistant varieties are shown in Table XIX. A comparison of the data from these 14 resistant varieties indicates that the tolerance levels (number of plants alive at end of six weeks) remained very much the same in the two years. In antibiosis, the average number of progeny per female in five days was consistently lower in 1962 than in 1961.

TABLE XVI

REACTION OF 78 VARIETIES OF BARLEY TO POPULATIONS OF THE APHID Rhopalosiphum padi (L.) IN BOTH GREENHOUSE AND FIELD TESTS

Variety	Reaction[1] Antibiosis Greenhouse	Antibiosis Field	Tolerance Greenhouse	Tolerance Field
Altrada Beardless C.I.5631			*	*
Anatolian Black C.I.2970	*	*	*	*
Awnless 5067, B30			*	*
B 193	*	*	*	*
Bald Skinless C.I.6022			*	*
Barley wheat C.I.1384	*	*		
B.J.M.34, B 498		*	*	*
Bon Rudin 2 C.I.6607	*	*		
Brachytic C.I.6572	*	*	*	*
Breun's Wisa, B 287			*	
Caspian C.I.5644			*	*
Childs C.I.1326			*	
Chinese Awnless C.I.2278	*	*	*	*
C.I.2538			*	
C.I.4220-2	*	*	*	*
C.I.4273-1	*	*	*	*
C.I.4383			*	*
C.I.4388	*	*		*
C.I.4392	*	*	*	
C.I.4408	*	*	*	*
C.I.4447	*	*		
C.I.4471	*	*		
C.I.4474	*	*	*	*
C.I.4480			*	*
C.I.4517			*	*
C.I.4531	*			
C.I.4742	*	*	*	*
C.I.5324			*	
C.I.5366			*	*
Coast C.I.691			*	
Comfort C.I.4578	*	*	*	*
Duplex C.I.2433	*	*		
Edda C.I.7129	*	*	*	*
Englawnless C.I.2505	*	*	*	
4148-1	*	*	*	*
4668-9			*	*
4677-128	*	*		
4677-3-10-1		*	*	*

TABLE XVI (continued)

Variety	Reaction[1]			
	Antibiosis		Tolerance	
	Green-house	Field	Green-house	Field
Gopal C.I.1091	*	*	*	*
Gospeck C.I.9094			*	*
Granat I, B 35	*	*		
Gray Abyssinian C.I.1612	*	*		
Gujar Khan C.I.3399			*	*
Hordeum vulgare, B 227	*	*	*	*
Horsford C.I.877	*	*	*	*
Hosogara No. 1, B 442		*	*	*
Hudson C.I.8067			*	*
Hulless (Turkestan) C.I.745	*	*	*	*
Hurst C.I.1304	*	*	*	*
Ise-hadaka, B 770	*	*		
Jet C.I.967			*	
Kashu C.I.5186	*	*	*	*
Keystone C.I.10877			*	*
Kipper C.I.1291	*	*	*	*
Lyallpur C.I.3395	*	*		
Mianwali sel.7	*	*	*	
Ming C.I.4797	*	*		
Mugi C.I.5143			*	*
Nepal C.I.595			*	*
Nihonsan, B 449			*	*
Nord C.I.10635			*	*
Nutans 187, B 864			*	*
Ott. 5025-8-2	*	*		
Pasha C.I.984	*	*	*	*
Peruvian C.I.2441			*	*
Poda C.I.652	*	*	*	*
Rimpani C.I.2220	*	*		*
Seed Stocks C.I.6613	*	*	*	*
Short Head C.I.1441			*	*
Sublaxum C.I.2231	*	*		*
Sulu C.I.1022			*	*
Takeshita C.I.1374	*	*	*	*
Tennessee Winter			*	*
Tregal C.I.6359			*	
Vantage C.I.7150			*	*
Virginia Hooded C.I.648	*	*	*	
Wis. H42 C.I.7123			*	
York C.I.6090			*	*

1 *(Antibiosis) = Average number of nymphs fewer than 15 per female in 5 days
*(Tolerance) = 5 or more plants out of 10 survived 6 weeks

TABLE XVII

APHID MULTIPLICATION AND FEEDING DAMAGE IN 29 RESISTANT VARIETIES OF BARLEY INFESTED WITH *Rhopalosiphum padi* (L.), FIELD TESTS

Variety	Average number of progeny in 5 days	Trans-formed average[1]	Duncan's multiple range test[2]	Number of plants alive at end of 6 weeks
Anatolian Black C.I.2970	12.3	3.56		6
Hosogara No. 1, B 442	11.7	3.49		6
Pasha C.I.984	11.5	3.44		5
4677-3-10-1	11.1	3.41		6
Takeshita C.I.1374	11.1	3.38		5
Brachytic C.I.6572	10.4	3.29		5
Seed Stocks C.I.6613	10.1	3.24		7
4148-1	10.0	3.22		5
C.I.4474	9.8	3.18		8
C.I.4220-2	9.7	3.17		5
B.J.M.34, B 498	8.8	3.01		5
Hurst C.I.1304	8.0	2.90		5
Comfort C.I.4578	8.1	2.86		6
Kipper C.I.1291	7.9	2.81		7
Gopal C.I.1091	7.3	2.77		6
Chinese Awnless C.I.2278	6.8	2.69		5
C.I.4388	6.8	2.69		7
C.I.4273-1	6.9	2.68		10
Hulless (Turkestan)C.I.745	6.9	2.68		6
Rimpani C.I.2220	6.6	2.64		8
C.I.4408	6.5	2.61		7
Edda C.I.7129	6.2	2.56		9
Hordeum vulgare, B 227	6.4	2.52		7
B 193	6.0	2.50		5
Sublaxum C.I.2231	5.6	2.40		7
Poda C.I.652	5.0	2.30		8
C.I.4742	5.0	2.26		5
Kashu C.I.5186	4.8	2.25		8
Horsford C.I.877	4.7	2.25		6
Swan (Check)	16.4	4.10**		0

** All 29 varieties differ significantly at the 1 per cent level from the variety Swan.

1 Transformed by the formula $\sqrt{x + 0.5}$

2 There are no significant differences between varieties within the groups indicated by vertical lines (Duncan's multiple range test)

TABLE XVIII

APHID MULTIPLICATION AND FEEDING DAMAGE IN 23 RESISTANT VARIETIES OF BARLEY INFESTED WITH *Rhopalosiphum padi* (L.), GREENHOUSE AND FIELD TESTS

Variety	Greenhouse tests			Field tests		
	Average number of progeny in 5 days	Trans-formed average	Number of plants alive at end of 6 weeks	Average number of progeny in 5 days	Trans-formed average	Number of plants alive at end of 6 weeks
Anatolian Black C.I.2970	14.3	3.84	6	12.3	3.56	6
B 193	14.6	3.87	5	6.0	2.50	5
Brachytic C.I.6572	11.3	3.42	6	10.4	3.29	5
Chinese Awnless C.I.2278	12.4	3.58	5	6.8	2.69	5
C.I.4220-2	12.4	3.57	9	9.7	3.17	5
C.I.4273-1	10.1	3.24	8	6.9	2.68	10
C.I.4408	14.2	3.84	8	6.5	2.61	7
C.I.4474	7.5	2.81	6	9.8	3.18	8
C.I.4742	6.7	2.59	10	5.0	2.26	5
Comfort C.I.4578	13.8	3.80	9	8.1	2.86	6
Edda C.I.7129	14.3	3.84	5	6.2	2.56	9
4148-1	10.4	3.28	5	10.0	3.22	5
Gopal C.I.1091	9.0	3.08	7	7.3	2.77	6
Hordeum vulgare B 227	9.4	3.10	8	6.4	2.52	7
Horsford C.I.877	14.8	3.90	6	4.7	2.25	6
Hulless (Turkestan)C.I.745	10.6	3.32	5	6.9	2.68	6
Hurst C.I.1304	10.6	3.35	7	8.0	2.90	5
Kashu C.I.5186	11.9	3.53	5	4.8	2.25	8
Kipper C.I.1291	10.9	3.39	6	7.9	2.81	7
Pasha C.I.984	14.7	3.85	6	11.5	3.44	5
Poda C.I.652	10.0	3.24	6	5.0	2.30	8
Seed Stocks C.I.6613	13.4	3.70	6	10.1	3.24	7
Takeshita C.I.1374	8.4	3.02	6	11.1	3.38	5

TABLE XIX

APHID MULTIPLICATION AND FEEDING DAMAGE IN 14 RESISTANT VARIETIES OF BARLEY INFESTED WITH *Rhopalosiphum padi* (L.), FIELD TESTS 1962 COMPARED WITH FIELD TESTS 1961

Variety	Average number of progeny in 5 days		Number of plants alive at end of 6 weeks	
	1962 June 8-13	1961 June 20-25	1962	1961
Black Barbless C.A.N.11	2.7	10.6	6	8
C.I.3906-1	5.1	9.4	6	6
C.I.4219	10.3	12.9	5	5
Colsess C.I.2792	6.7	11.7	6	5
Danuvian C.I.6525	4.2	13.4	5	5
Galore C.I.7150	10.0	13.0	8	5
Mianwali C.I.3400	4.9	11.1	6	5
O.A.C.21 C.I.1470	8.2	11.1	7	7
Odessa C.I.934	7.8	9.8	6	6
Peatland C.I.5267	6.2	11.0	8	9
Rojo C.I.5401	5.2	12.2	7	5
Success C.I.1775	8.6	11.4	9	7
(Vantage X Jet) Br.5209-7	6.3	13.8	5	5
(Vantage X Jet) Br.5209-29	3.3	10.5	5	7
Swan	16.4**			

** All 14 varieties differ significantly at the 1 per cent level from Swan

When the data from these 14 from 1962 were analyzed statistically, the results showed all these varieties to be significantly different at the 1 per cent level compared with Swan.

An explanation was sought for the lower average progeny (Table XIX) in 1962 compared with 1961. Weather records showed: (a) no appreciable precipitation for the 5-day periods in either year; (b) much higher mean temperatures for the 1962 period than that of 1961; (c) more hours of total bright sunshine for the 5-day period in 1961, and (d) much higher per cent relative humidity in 1962 than in 1961. These weather differences do not necessarily explain the lower means of the progeny, as these could be caused by a difference in stage of plant growth or succulence, which could not be detected by the present techniques, or the lower means could result from a difference in photoperiod. However, the demonstration of resistance over two years of tests on these fourteen varieties indicates genetic inheritance rather than some expression from environmental factors.

CHAPTER VIII

HOST PLANT RECORDS AND BIOLOGY OF OTHER APHIDS ON CEREAL GRAINS AND GRASSES IN MANITOBA

Collections of aphids on cereal grains and grasses have been made by Dr. A. G. Robinson of the Department of Entomology, University of Manitoba prior to 1959, and by myself from 1959 to 1962. Certain observations on economic damage of this group of aphids in Western Canada in recent years are also available in records such as the Canadian Insect Pest Review. In 1962 most species of aphids on Gramineae were present in unusually large numbers in Manitoba, and an excellent opportunity was afforded to obtain records of breeding colonies on 38 host plants, many of them in the Forage Plots of the Department of Plant Science, University of Manitoba. The host plants and aphids are listed in Table I. The species collected are important because of their possible economic injury to cereal crops and also because several of the species are known vectors of the barley yellow dwarf virus of barley, oats and other Gramineae. In the following paragraphs all the pertinent observations available from records or from personal knowledge are given for each species of aphid, excluding _R. padi_. Two species, _Rhopalosiphum fitchii_ and _Brachycolus tritici_ are not listed in Table I because they were not taken on summer hosts.

Schizaphis (=*Toxoptera*) *graminum* (Rondani) - The Greenbug.

There is no evidence of the overwintering of the greenbug in Manitoba. Infestations apparently arise from alate aphids blown into Manitoba by southerly winds. In 1949 and in 1962 some fields of cereal crops were sprayed with insecticides to prevent further damage by the aphids, but in most years populations remain very low. Records indicate that the greenbug is present in Manitoba approximately June 1 to September. Feeding by greenbug colonies causes very noticeable necrotic areas on the leaves of the plants.

Macrosiphum avenae (Fabricius) (=*M. granarium* (Kirby)) - The English Grain Aphid.

The English grain aphid is not known to overwinter in Manitoba, probably entering on southerly winds along with the greenbug. Populations normally remain very low, but in 1962 some wheat fields were sprayed with insecticides to destroy large numbers of this species developing on wheat heads. Records of alienicolae indicate that the English grain aphid is present in Manitoba approximately June 1 to September. Orlob (1961b) found *M. avenae* to be less prevalent on grasses than cereals. The host list for Manitoba (Table I) shows that it is able to establish colonies on plants of many of the genera of grasses, but it does occur in much larger numbers on the cereal grains.

Rhopalosiphum fitchii (Sanderson) - The Apple Grain Aphid.

Fundatrigeniae and spring migrants of *R. fitchii* have been recorded from *Crataegus* sp., *Malus* sp. and *Cotoneaster* sp. approximately May 15 to June 30, and males and fall migrants have been taken in flight or on the winter hosts September 1 to November 1. Alienicolae have not been found in Manitoba. Hille Ris Lambers (1960) states that in Europe they occur underground on various Gramineae, including cereals.

Rhopalosiphum maidis (Fitch) - The Corn Leaf Aphid.

There is no record of overwintering of the corn leaf aphid in Manitoba, and it is apparently a migrant from the south, being present as alienicolae from about June 15 until killed by frosts. It does not appear to have as wide a host range as the first three species mentioned above. Our observations show that *Hordeum vulgare* and *Echinochloa crusgalli* are preferred hosts. We were not able to rear *R. maidis* on plants of *Zea mays* less than 30 days old. Older plants of *Zea mays* often become heavily infested by the corn leaf aphid, and aphids may be found in the leaf whorls until winter. In 1955 many thousands of acres of late-seeded barley were destroyed by *R. maidis* between June 21 and July 21, in Western Canada.

Sipha agropyrella Hille Ris Lambers - The Quackgrass Aphid.

This species almost certainly overwinters in Manitoba.

Robinson (1957) reported finding large numbers of oviparae, although the host plant was not determined. MacGillivray (1956) found males, oviparae and eggs on *Agropyron repens* in New Brunswick. Orlob and Medler (1961) found that in Wisconsin it overwinters as eggs on *A. repens*. These authors believed *S. agropyrella* to be monophagous on *Agropyron*, but records of breeding colonies in Manitoba (Table I) show that it does develop successfully on other Gramineae under natural conditions. The presence of feeding colonies causes necrotic areas on plant leaves. There are no records of this species as a pest of economic importance in Western Canada.

Metopolophium (=*Macrosiphum*) *dirhodum* (Walker) - The Rose Grass Aphid.

The rose grass aphid overwinters on *Rosa* spp. in Manitoba. Fundatrices were not looked for, but fall migrants and males were found on *Rosa* spp. in October. It is not readily found during collecting and does not have a wide range of host plants (Table I). It can not be considered as of economic importance, although listed by Bruehl (1961) as a vector of barley yellow dwarf virus.

Hyalopterus pruni (=*arundinis*) (Geoffrey) - The Mealy Plum Aphid.

The mealy plum aphid overwinters on *Prunus americana* March. and *P. nigra* Ait. and hybrids or selections of these two wild species of plum. Very heavy infestations commonly occur on the undersides of leaves, well into July and August. It may be that in some cases the life cycle is spent entirely on plum, and in other cases there is a migration to the summer host, *Phragmites communis*. There is one record of unsuccessful attempted colonization of lilac, *Syringa* sp. in August.

Hysteroneura (=*Aphis*) *setariae* (Thomas) - The Rusty Plum Aphid.

This species is relatively rare in Manitoba. Alate and apterous forms have been taken on plum (*Prunus* sp.) on 7 July, and on wheat heads 28 July. No forms were found during the extensive collecting of 1962.

Brachycolus tritici Gillette - The Western Wheat Aphid.

One alate aphid was collected 6 June 1958 in a yellow water trap. No forms were found in 1962.

Forda olivacea Rohwer.

This root aphid has not been extensively looked for, but is probably quite abundant in Manitoba. It has been taken on the roots of *Bromus inermis*, *Poa pratensis* and *Poa* sp.

CHAPTER IX

SUMMARY AND CONCLUSIONS

In Chapter I the subject of insect resistance in plants is introduced. The three components of resistance, non-preference, antibiosis and tolerance are defined by reference to the monograph of Dr. R. H. Painter entitled "Insect Resistance in Crop Plants." The place of resistance among other methods of insect control is evaluated. The problems associated with the use of chemical control measures are briefly outlined, and it is suggested that in the long run more permanent and less costly control of insects may be obtained by the use of varieties of plants which are resistant to the insect pests. The present study reports a search for resistance in all the available varieties of barley in the Canadian Genetic Stock of Barley Varieties to the birdcherry oat aphid, *Rhopalosiphum padi* (L.).

Chapter II reviews the more important literature of recent years on attempts by other workers to find resistance in species and varieties of plants to insects, and especially to aphids. Included in the literature review is an appraisal of the effects of environmental factors on expressions of resistance, and also references to findings that varieties may vary in their resistance according to stage of plant growth, suggesting that the chemistry of the plant nutrients may have a profound effect on insects, especially insects such as aphids which ingest plant sap.

In Chapter III the materials and methods are described. Stock cultures of R. padi, descended from one female, were maintained in the greenhouse on Swan variety of barley, and newly moulted apterous female aphids 7-8 days old were used in most of the experiments, under cages, in both greenhouse and field tests. The first exploratory experiments from September 1959 to September 1960, led to a decision to concentrate all succeeding experiments on testing barley varieties for antibiosis and tolerance. Preference or non-preference were not tested. The measure of resistance in terms of antibiosis was mortality and fecundity of aphids caged for five days on a plant. The measure of plant tolerance to infestations was plant mortality resulting from initial introductions of ten aphids per plant, to determine how many plants could survive for eight weeks.

In Chapter IV some notes on biology of R. padi are given. This species apparently overwinters in Manitoba on Prunus pennsylvanica and P. virginiana, migrating to cereal grains and grasses for an alternate summer host. Breeding colonies of R. padi were found on 22 species of Gramineae. In greenhouse studies the following observations were made: (1) the fecundity of wingless females was more than twice that of winged females, (2) average number of young per wingless female was 93.1 and for winged females 33.6, (3) average length of adult life for wingless females was 29.0 days and for winged females 23.7 days, (4) there were four nymphal instars, (5) wingless adults took 6.5 days from birth to final moult, and winged adults took 6.9 days to reach adult stage.

A series of preliminary and exploratory experiments are reported in Chapter V. In one test 264 varieties of barley were planted in the field, and two apterous females were caged on one plant of each variety. Counts of progeny were made at the end of seven days. From this test the chief lesson learned was that only one aphid should be caged on each plant for tests on fecundity, and that counts should be made preferably at the end of five days. The total counts from each of the 264 plants were grouped into six groups, 0-20 progeny indicating a high degree of antibiosis, and at the other end of the groupings 100+ progeny indicating a high degree of susceptibility. The aphids were left on the plants after counting, still caged, and total counts were made when the plants were headed out. Because of the large infestations present the counts were recorded and plants grouped according to size of populations; no aphids present, small, medium, or large populations. At the same time, counts were made of R. padi present on uncaged plants of each variety. Because so few plants of each variety were used in these tests, the data are not very reliable. However, there was a remarkably good correlation between the varieties as to antibiosis and tolerance between one kind of test and another. So much so that it was obvious that some varieties of barley did show resistance to the aphids, and that a proper search for resistance should be made in barley varieties, using adequate samples and proper techniques.

Also reported in the same series of tests are some counts of progeny of R. padi on nine commercial varieties. Vantage and Herta appeared to be high in antibiosis, Husky, Montcalm and O.A.C. 21 were intermediate, and Gartons, Swan, Parkland and Traill were highly susceptible. This same test demonstrated that populations of aphids were highest in the 5-6 leaf and 6 leaf-heading stage of plant growth, and populations rapidly declined as the plants matured further. From this it was decided that the best time to assess tolerance was at the end of six weeks of plant growth, otherwise declining populations would adversely affect the reliability of the counts of total progeny expressed in plant mortality.

In conjunction with the field tests outlined above, tests were started in the greenhouse. Thirty-nine varieties grown in clay pots were tested for antibiosis. No problems were encountered in the greenhouse tests. As a result of all the greenhouse and field tests reported in Chapter V it was decided to proceed with an evaluation of resistance in all the varieties currently held in the Canada Genetic Stock of Barley, first testing all varieties in the greenhouse, for both antibiosis and tolerance, and then retesting in the field those varieties which demonstrated either antibiosis or tolerance in the greenhouse tests.

A total of 468 varieties of barley was obtained from the Central Experimental Farm, Ottawa, Ontario. Chapter VI reports on the tests conducted between September, 1960 and September, 1961. One hundred and thirty-seven varieties of barley were tested in the greenhouse. Of these, 49 varieties showed some resistance, and were selected for field tests on the basis of 20 showing both antibiosis and tolerance, 19 showing antibiosis only, and 10 tolerance only. Eighty-eight varieties demonstrated no resistance in the greenhouse tests. The susceptibility of these 88 varieties was compared with Swan, showing that 78 were even more susceptible than Swan.

When the 49 varieties were tested in the field, 30 exhibited antibiosis only, 1 showed tolerance only, 4 showed neither antibiosis nor tolerance, and 14 varieties demonstrated both antibiosis and tolerance. It is interesting to note that the resistant varieties Rojo and C.I. 3906-1 are also reported as resistant to barley yellow dwarf virus (Rasmusson and Schaller, 1959). Of the 49 varieties tested in the field in 1961, C.I.2376, Velvon 11, Compana, Club

Mariout and Kindred are also reported by Bruehl (1961) as showing varying degrees of resistance to the barley yellow dwarf virus. There is an indication here of a correlation between vector resistance and virus resistance in barley varieties.

Beginning September 1961 the remaining 331 varieties from the Canadian Genetic Stock were tested in the greenhouse. The results of this final year of work are reported in Chapter VII. Seventy-eight varieties were selected for field tests, based on 27 showing both antibiosis and tolerance, 16 because of antibiosis only and 35 because of tolerance only. In the field tests 29 varieties demonstrated both antibiosis and tolerance, 16 antibiosis only, 24 tolerance only, and in 9 varieties neither antibiosis nor tolerance was recorded.

The 14 varieties which had shown both antibiosis and tolerance in the field in 1961 were retested in the field in 1962. A comparison of data from the two years of tests showed that tolerance (number of plants alive at end of six weeks) remained very much the same for both years. In antibiosis, the average number of progeny per female in five days was consistently lower in 1962 than in 1961. The demonstration of resistance over two years of tests on these 14 varieties indicates genetic inheritance rather than some expression from environmental factors.

In 1962 an excellent opportunity was afforded to obtain records of breeding colonies of other species of aphids on Gramineae. These breeding records are given in Chapter VIII, along with a few notes on biology. The greenbug was found on 26 species of Gramineae, the English grain aphid on 27 species, the corn leaf aphid on 17 species and the quackgrass aphid on 12 species of cereal grains or grasses.

In conclusion, certain deductions may be made from the findings reported in this thesis. No varieties tested were completely immune to the aphids. Table XX shows the percentages of the 468 varieties which showed both antibiosis and tolerance, antibiosis only, or tolerance only, in both greenhouse and field tests. If we base our selection of resistant varieties on field tests, 43 varieties must be regarded as most suitable as parents in any future breeding program to combine resistance with desirable agronomic characters.

However, the 46 varieties which demonstrated antibiosis, and the 25 varieties which showed tolerance, should also be considered as possible parents in a breeding program. It has been demonstrated that once barley plants reach the heading stage, they are no longer suitable as hosts for the aphids. Antibiosis expressed as reduced fecundity allows more plants to survive to the heading stage, because fewer aphids are present to harm the plant. Painter (1958 b), in

TABLE XX

PER CENT OF 468 VARIETIES OF THE CANADIAN GENETIC STOCK OF BARLEY SHOWING RESISTANCE TO *Rhopalosiphum padi* (L.)

Test	Both antibiosis and tolerance	Antibiosis only	Tolerance only	No resistance
Greenhouse	10.04% (47)	7.48% (35)	9.62% (45)	72.86% (341)
Field[1]	9.19% (43)	9.83% (46)	5.34% (25)	2.78% (13)

[1] Only those varieties which showed antibiosis or tolerance in greenhouse tests were selected for field tests.

discussing the resistance of barley and wheat varieties to the feeding damage of the greenbug, *Toxoptera graminum* (Rond.), stated that a difference in reproductive rate of half an aphid per day may make the difference between a small or mediocre yield and complete crop destruction, and that an antibiosis difference between resistant and susceptible varieties, even when small, reinforces the value of tolerance.

The possible reasons for the apparent correlation between vector resistance and virus resistance (exemplified by the varieties Rojo and C.I.3906-1) should be further investigated. It may be that the fewer the aphids, the less the virus transmission, but this is not necessarily so, because a very few migrant winged aphids may infect many plants because of their habits of feeding perhaps on several plants before finally settling to produce a colony of young.

In the tests reported in this thesis, aphids were not allowed to demonstrate preference or nonpreference for varieties. Experiments allowing winged or wingless aphids a free choice among varieties are easier to conduct, but less reliable, than caging aphids in tests for antibiosis or tolerance. However, it would be worthwhile to test the more promising varieties shown in Table XX for preference or non-preference.

And finally, a plant breeding program should be initiated using the resistant varieties demonstrated during this research, to try and produce barley varieties resistant to aphids and barley yellow dwarf virus, and to study the possible genetic or biochemical mechanisms of resistance to this aphid in barley varieties.

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APPENDIX

LIST OF 264 VARIETIES OF BARLEY
TESTED IN THE FIELD, 1959-1960

Abacus, C.I.1088	(2), (LC), (LNC)
Abyssinian, C.I.2192	(1), (SC), (SNC)
Accession, No. 814, B40	(1), (SC), (SNC)
Accession, No. 817 B44	(1), (SC), (SNC)
Afghan II, C.I.6366	(1), (MC), (SNC)
Algerian, C.I.1179, B33	(4), (LC), (LNC)
Alpha, C.I.959, C.A.N.801	(1), (SC), (SNC)
Archer, C.I.1031, C.A.N.88	(2), (MC), (MNC)
Archer Gold Thorpe, C.A.N.1003	(1), (LC), (LNC)
Arequipa, C.I.2329	(1), (LC), (SNC)
Argyle, C.I.202	(2), (MC), (SNC)
Arlington Awnless, C.I.702, C.A.N.882	(2), (LC), (SNC)
Atlas, C.I.4118, C.A.N.702	(3), (LC), (LNC)
Austral, C.I.6483	(1), (SC), (SNC)
Austrian Hannast, 66, C.A.N.46	(6), (LC), (LNC)
Baker, C.I.975, C.A.N.87	(4), (MC), (SNC)
Barboff	(4), (SC), (SNC)
Bark C.I.2793, C.A.N.703	(1), (LC), (LNC)
Barley Miscellaneous Carre	(2), (SC), (SNC)
Barley Miscellaneous Cebada Capa	(2), (SC), (SNC)
Barley Miscellaneous Mianwali, C.I.3400	(3), (MC), (SNC)
Barley Miscellaneous, C.I.5324	(1), (SC), (SNC)
Barley Miscellaneous Gem	(1), (SC), (SNC)
Barley Miscellaneous Feebar	(3), (SC), (SNC)
Barley Miscellaneous, H-106-1	(1), (SC), (SNC)
Barley Miscellaneous Jet	(2), (SC), (SNC)
Barley (1951) Miscellaneous Nepal	(1), (SC), (SNC)
Barley Miscellaneous Peruvian, Sel.19	(3), (SC), (SNC)
Barley Miscellaneous S.C.235	(1), (SC), (SNC)
Barley Miscellaneous Valke	(2), (SC), (MNC)
Barley Miscellaneous Vantage	(3), (LC), (LNC)
Barley Miscellaneous Velvon-11	(2), (SC), (SNC)
Barley Miscellaneous, 36-AB-6127	(1), (LC), (SNC)
Barley Miscellaneous 4220-1	(2), (SC), (SNC)
Barley Miscellaneous 4974	(1), (SC), (SNC)
Barley Miscellaneous 4979	(1), (SC), (NNC)
Baru, C.I.709, C.A.N.870	(2), (LC), (SNC)
Batna, C.I.3391	(1), (SC), (SNC)
Bavaria, C.I.6395	(4), (SC), (SNC)
Bay Brewing, C.I.257, C.A.N.707	(2), (LC), (LNC)
Beecher, C.I.6566, C.A.N.1153	(1), (SC), (MNC)
Beldi, C.I.190	(3), (LC), (MNC)
Beldi Giant, C.I.2777, C.A.N.1024	(2), (LC), (LNC)

Black Barbless, C.A.N.11	(1), (SC), (SNC)
Blackhull C.A.N.813	(2), (LC), (LNC)
Blackhull C.I.878	(3), (LC), (LNC)
Black Hulless C.I.666, C.A.N.761	(1), (LC), (LNC)
Black Hulless (Bonneville), C.I.1097 C.A.N.761	(1), (SC), (SNC)
Blue Hulless, C.I.4848, C.A.N.760	(6), (LC), (LNC)
Bolivia, C.I.1257, C.A.N.12	(1), (LC), (MNC)
Byng, C.I.6089, C.A.N.1096	(6), (LC), (MNC)
California Brewing, C.I.4870, C.A.N.706	(1), (SC), (SNC)
California Feed, C.I.799, C.A.N.26	(6), (MC), (SNC)
California Mariout, C.I.1455, C.A.N.729	(1), (SC), (SNC)
Callas, C.I.2440	(1), (SC), (NNC)
Canadian Thorpe, C.I.740, C.A.N.816	(1), (SC), (SNC)
Cape, C.I.557, C.A.N.708	(2), (LC), (SNC)
Carre 26, C.I.3386	(2), (LC), (SNC)
Charlottetown 80, C.I.2732, C.A.N.1100	(2), (LC), (SNC)
Chevalier, C.I.278, C.A.N.83	(6), (LC), (MNC)
Chevron C.I.1111, C.A.N.1121	(2), (SC), (SNC)
Chile	(1), (SC), (SNC)
Chilean, C.I.1433	(1), (SC), (SNC)
Chilean Brewing, C.I.657, C.A.N.709	(1), (SC), (SNC)
C.I.510, C.A.N.72	(1), (LC), (SNC)
C.I.1347, C.A.N.437	(1), (LC), (SNC)
C.I.1613	(2), (LC), (LNC)
C.I.1961	(1), (SC), (SNC)
C.I.2223	(3), (SC), (SNC)
C.I.2237	(2), (SC), (SNC)
C.I.2329, C.A.N.537	(1), (SC), (SNC)
C.I.2492	(1), (SC), (SNC)
C.I.2538	(1), (LC), (SNC)
C.I.2542	(1), (LC), (SNC)
C.I.3737	(1), (SC), (SNC)
C.I.4156-2	(1), (SC), (SNC)
C.I.4160-1	(1), (MC), (SNC)
C.I.4219	(1), (NC), (SNC)
C.I.4223-2	(2), (MC), (SNC)
C.I.4356	(1), (SC), (SNC)
C.I.4975	(1), (SC), (SNC)
C.I.5326	(1), (SC), (SNC)
C.I.5366	(1), (SC), (NNC)
C.I.5644	(1), (SC), (SNC)
C.I.5862	(1), (SC), (SNC)
C.I.5863	(1), (SC), (SNC)
C.I.6306	(1), (MC), (SNC)

C.I.6915	(1), (SC), (NNC)
Clifford, C.I.1910, C.A.N.825	(1), (SC), (SNC)
Club Mariout, C.I.261, C.A.N.729	(1), (SC), (NNC)
Coast, C.I.276	(2), (LC), (MNC)
Coast, C.I.690	(3), (MC), (SNC)
Colsess, C.I.2792, C.A.N.772	(1), (SC), (SNC)
Cruzat, C.I.6482	(2), (SC), (SNC)
Danish Island, C.A.N.1002	(1), (SC), (NNC)
Danubian, C.I.6525, C.A.N.1020	(1), (SC), (NNC)
Dorsett, C.I.4821	(1), (SC), (SNC)
Duckbill C.I.1916, C.A.N.826	(6), (LC), (LNC)
Egypt 4, C.I.6481	(1), (SC), (SNC)
Egyptian Sudan, C.I.6489	(1), (SC), (SNC)
Featherston, C.I.1120, C.A.N.715	(1), (SC), (SNC)
Foreign 127, C.A.N.48	(6), (LC), (LNC)
Foreign 828, C.A.N.62	(2), (SC), (SNC)
Frankonia, C.I.680, C.A.N.1017	(4), (LC), (MNC)
French Chevalier, C.I.175, C.A.N.822	(2), (MC), (NNC)
Galore	(1), (SC), (SNC)
Gartons C.I.645, C.A.N.1134	(1), (SC), (NNC)
Gatami, C.I.575, C.A.N.717	(1), (SC), (SNC)
Gatami, C.I.2276	(1), (SC), (SNC)
German Brewing, C.A.N.1008	(4), (LC), (SNC)
Glabron, C.I.4577, C.A.N.718	(1), (LC), (LNC)
Glacier	(2), (SC), (SNC)
Gold, C.I.1145, C.A.N.829	(2), (SC), (SNC)
Golden Drop, C.I.2135, C.A.N.49	(1), (LC), (SNC)
Golden Pheasant, C.I.2488, C.A.N.830	(1), (MC), (SNC)
Gordon, C.I.4842, C.A.N.833	(1), (SC), (SNC)
Halikon, C.A.N.52	(4), (SC), (SNC)
Halikon, C.I.6004, C.A.N.834	(6), (LC), (LNC)
Hanna, C.I.30	(6), (LC), (SNC)
Hanna, C.I.203	(6), (LC), (LNC)
Hanna, C.I.906	(6), (LC), (LNC)
Hanna, C.I.1122	(6), (LC), (LNC)
Hannchen, C.I.531, C.A.N.837	(2), (SC), (SNC)
Heil's Hanna, C.I.682, C.A.N.61	(6), (SC), (MNC)
Hero, C.I.1286, C.A.N.719	(6), (LC), (LNC)
Hero, C.I.4602, C.A.N.719	(1), (SC), (NNC)
Heys Special, C.I.6487	(1), (SC), (SNC)
Himalaya, C.I.620, C.A.N.763	(1), (LC), (SNC)
Hooded Spring C.I.716	(1), (SC), (SNC)
Hordeum hexastichum euryleps, Winter Habit	(1), (MC), (MNC)
H. hexastichum pyramidatum, Winter Habit	(2), (LC), (MNC)
H. intermedium cornutum, C.I.2215 C.A.N.897	(1), (MC), (MNC)

APPENDIX (continued)

H. intermedium mortoni, C.I.2210, C.A.N.894	(2), (SC), (SNC)
H. intermedium nudimortoni, C.I.2214, C.A.N.896	(1), (SC), (MNC)
H. intermedium nudihantoni, C.I.2213, C.A.N.895	(1), (SC), (MNC)
H. tetrastichum coerulescens	(2), (LC), (MNC)
H. tetrastichum pallidum	(1), (LC), (LNC)
H. vulgare aethiops, C.I.2208, C.A.N.892	(2), (LC), (LNC)
H. vulgare atrum, C.I.2204, C.A.N.888	(1), (SC), (SNC)
H. vulgare horsfordianum, C.I.2203, C.A.N.887	(1), (SC), (SNC)
H. vulgare trifurcatum, C.I.2207, C.A.N.891	(6), (LC), (LNC)
H. deficiens decorticatum, C.I.2230 C.A.N.881	(1), (SC), (MNC)
H. deficiens deficiens, C.I.2225, C.A.N.880	(4), (SC), (SNC)
H. deficiens steudelli, C.I.2226, C.A.N.789	(2), (SC), (SNC)
H. deficiens triceros, C.I.2227, C.A.N.790	(6), (SC), (MNC)
H. deficiens tridan, C.I.2228, C.A.N.791	(6), (LC), (LNC)
H. distichon angustispicatum, C.I.2219, C.A.N.900	(5), (SC), (MNC)
H. distichon nigrinudum, C.I.2222, C.A.N.787	(6), (LC), (LNC)
H. distichon nigrum, C.A.N.21	(6), (LC), (LNC)
H. distichon nudum, C.A.N.22	(4), (SC), (MNC)
H. distichon nutans, C.A.N.23	(2), (LC), (LNC)
H. distichon nutans A, C.A.N.24	(6), (LC), (MNC)
H. distichon nutans B, C.A.N.25	(1), (SC), (SNC)
H. distichon rimpani, C.I.2220, C.A.N.786	(6), (LC), (LNC)
Horn, C.I.926, C.A.N.1078	(6), (LC), (LNC)
Horsford, C.I.507, C.A.N.	(3), (SC), (LNC)
Horsford, C.I.877	(1), (SC), (NNC)
Horsford, C.I.1775, C.A.N.	(1), (MC), (SNC)
Icelandic, C.A.N.90	(1), (SC), (SNC)
Italy, C.I.914, C.A.N.54	(1), (MC), (SNC)
Juliaca, C.I.1114, C.A.N.43	(1), (LC), (SNC)
Kindred, C.I.6969, C.A.N.1155	(2), (SC), (SNC)
Korsbyg, C.I.918	(2), (SC), (SNC)
Kuba Summer, C.I.6480	(2), (SC), (SNC)
Kwan, C.I.1016	(1), (SC), (SNC)
L. 1951 Barley Miscellaneous Plush	(6), (LC), (LNC)
Lechtaler, C.I.6488	(2), (SC), (SNC)

APPENDIX (continued)

Lico, C.I.6279, C.A.N.1152	(2), (SC), (MNC)
L.S.2549	(1), (LC), (MNC)
Luth, C.I.972, C.A.N.972	(1), (SC), (SNC)
Malting, C.I.1129, C.A.N.92	(1), (SC), (NNC)
Manchurian, C.I.739, C.A.N.726	(1), (LC), (SNC)
Manchuria, C.I.2330, C.A.N.724	(1), (MC), (SNC)
Mansfield, C.I.2241, C.A.N.1056	(1), (MC), (SNC)
Marious B113, C.A.N.91	(1), (SC), (SNC)
Mariout B, C.A.N.1130	(2), (SC), (SNC)
Mecknos Morocco, C.I.1379	(2), (MC), (SNC)
Mensury, C.I.4696, C.A.N.730	(1), (LC), (SNC)
Michigan 110	(4), (MC), (SNC)
Michigan Black, C.I.923, C.A.N.28	(2), (MC), (SNC)
Michigan 2 row, C.I.2782, C.A.N.	(1), (MC), (SNC)
Minsturdi, C.I.1556, C.A.N.732	(1), (SC), (SNC)
Modia, C.I.2483	(1), (LC), (SNC)
Montcalm, C.A.N.1135	(2), (SC), (SNC)
Morocco .077, C.A.N.1131	(2), (MC), (SNC)
Morocco, C.I.3902-1	(2), (LC), (SNC)
Morocco, C.I.6311	(6), (MC), (SNC)
Newal, C.I.6088, C.A.N.1089	(1), (SC), (NNC)
Nobarb, C.A.N.1143	(5), (LC), (SNC)
O.A.C.21, C.I.1470, C.A.N.1086	(1), (MC), (SNC)
Oderbrucker, C.I.940, C.A.N.29	(1), (LC), (SNC)
Oderbrucker, C.I.957	(1), (SC), (SNC)
Oderbrucker, C.I.4666, C.A.N.89	(1), (SC), (NNC)
Olli, C.I.6251, C.A.N.739	(1), (SC), (NNC)
Orel, C.A.N.14	(1), (SC), (SNC)
Orel, C.I.351	(1), (SC), (NNC)
Orge, B 100, C.A.N.30	(1), (SC), (SNC)
Orge Frager, B 102	(1), (SC), (SNC)
Orge, 14 B 101, C.A.N.31	(2), (SC), (SNC)
Oregon, C.I.4871, C.A.N.1061	(1), (SC), (NNC)
Pamella Blue, C.I.3609	(2), (MC), (SNC)
Pannier, C.I.1330, C.A.N.1042	(1), (SC), (SNC)
Paso, C.I.5047	(1), (NC), (NNC)
Pearl, C.I.4834, C.A.N.780	(1), (SC), (NNC)
Peatland, C.I.5267, C.A.N.722	(1), (SC), (NNC)
Persicum, C.I.6531	(1), (SC), (SNC)
Peru, C.I.2302, 32	(3), (SC), (SNC)
Peruvian, C.I.935, C.A.N.33	(1), (LC), (SNC)
Peruvian Sel. 1, C.I.5912	(1), (SC), (NNC)
Plumage Archer, C.I.5033, C.A.N.1004	(1), (LC), (SNC)
Polish, C.A.N.56	(1), (MC), (SNC)
Pontiac, C.I.4849, C.A.N.1114	(1), (SC), (MNC)
Princess, C.I.529, C.A.N.57	(1), (LC), (SNC)
Prospect, C.I.6339, C.A.N.1140	(1), (SC), (SNC)
Prussian, C.A.N.58	(2), (LC), (SNC)

APPENDIX (continued)

Psaknon, B 81, C.A.N.34	(1), (SC), (SNC)
Purple Nepal, C.I.2242	(3), (LC), (SNC)
Quinn, C.I.1024, C.A.N.36	(1), (NC), (SNC)
Recha I, C.I.5051	(2), (SC), (SNC)
Regal, C.I.5030, C.A.N.742	(1), (SC), (SNC)
Rex, C.I.1388, C.A.N.1113	(1), (MC), (MNC)
Sacramento, C.I.4180, C.A.N.744	(1), (SC), (SNC)
Sahara, C.I.3770, C.A.N.3770	(1), (LC), (SNC)
Sanalta, C.I.6087, C.A.N.1088	(2), (LC), (MNC)
Sandred, C.I.937, C.A.N.	(6), (SC), (SNC)
Silver King, C.I.890, C.A.N.1048	(6), (MC), (SNC)
Scotch Standwell C.A.N.1007	(1), (SC), (SNC)
Smooth Awn X Manchuria	(3), (SC), (SNC)
Smooth Awn X Manchuria, 11-21-15	(1), (NC), (SNC)
Smooth Awn X Manchuria, 11-21-18	(1), (LC), (LNC)
Smyrna, C.I.195	(1), (LC), (LNC)
Smyrna, C.I.910	(1), (LC), (MNC)
Spartan, C.I.5027, C.A.N.860	(1), (SC), (SNC)
Star, C.I.1701, C.A.N.748	(2), (SC), (SNC)
Stavropol, C.I.2103, C.A.N.749	(1), (SC), (SNC)
Steigum, C.I.907, C.A.N.862	(1), (SC), (SNC)
Stella, C.I.2678, C.A.N.750	(2), (SC), (SNC)
Stephan, C.A.N.1142	(6), (LC), (LNC)
Success, C.I.4840, C.A.N.783	(2), (SC), (SNC)
Sulu, C.I.1022	(1), (SC), (NNC)
Svalof, C.A.N.59	(6), (MC), (SNC)
Svalof Victory, C.I.5077, C.A.N.868	(6), (LC), (MNC)
Svansota, C.I.1907, C.A.N.865	(2), (LC), (SNC)
Swanbals, C.I.187	(1), (MC), (SNC)
Swan Neck	(2), (SC), (SNC)
Texan, C.I.6499, C.A.N.1173	(3), (SC), (MNC)
Titan, C.A.N.1118	(1), (SC), (SNC)
Tregal, C.A.N.1150	(2), (SC), (SNC)
Vaughn, C.I.1367, C.A.N.759	(2), (SC), (SNC)
Velvet, C.I.4252, C.A.N.	(2), (SC), (SNC)
Velvon, C.I.6109, C.A.N.1151	(2), (SC), (SNC)
Virginia Hooded, C.I.2290, C.A.N.39	(2), (SC), (SNC)
Warrior, C.I.6991, C.A.N.1144	(1), (SC), (SNC)
Wheelers Thrope, C.A.N.60	(2), (SC), (SNC)
White Gatami, C.I.920, C.A.N.40	(2), (SC), (SNC)
White Hulless, C.A.N.785	(1), (SC), (SNC)
White Smyrna, C.I.2084	(2), (SC), (SNC)
Wisconsin #38 C.I.5107, C.A.N.1101	(1), (SC), (MNC)
1951 Barley Miscellaneous Anoidium	(2), (SC), (SNC)
1951 Barley Miscellaneous Beecher	(3), (SC), (MNC)
1951 Barley Miscellaneous Company	(1), (SC), (SNC)
1951 Barley Miscellaneous Goldfoil	(1), (MC), (NNC)
1951 Barley Miscellaneous Trebi	(4), (SC), (MNC)
1951 Barley Miscellaneous Valentine	(5), (SC), (MNC)