SOME RELATIONSHIPS BETWEEN THREE SPECIES OF APHIDS AND THREE CEREAL GRAINS

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ABSTRACT

by

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Effects resulting from the feeding of the greenbug, *Schizaphis graminum* (Rondani), the corn leaf aphid, *Rhopalosiphum maidis* (Fitch), and the English grain aphid, *Macrosiphum avenae* (Fabricius) on Parkland barley, *Hordeum vulgare* L., Selkirk wheat, *Triticum aestivum* L., and Rodney oats, *Avena sativa* L., were studied at different stages of plant growth in growth cabinets.

The greenbug proved to be the most harmful to young seedlings of all three cereals, because it killed them more quickly. The English grain aphid was about as destructive as the greenbug to older plants and also caused larger reductions in yield. The corn leaf aphid was the least destructive aphid on Parkland barley; it did not successfully establish on wheat and oats.

Seventeen varieties of barley, that had shown some evidence of resistance to aphids, were tested in the field against the greenbug and the corn leaf aphid. Poor weather conditions ruined many of the replicates and thus only parts of the data were of use.

Experiments were done in a growth room to evaluate the possible influence of change of hosts, including Swan barley, Parkland barley, Selkirk

wheat and Rodney oats on the reproduction of the three aphid species mentioned above. The greenbug and the corn leaf aphid showed a lower fecundity when reared, during nymphal life, on wheat and oats, regardless of the hosts on which later reproduction took place. The number of progeny produced by the greenbug was reduced when it reproduced on wheat. The corn leaf aphid had a lower fecundity when transferred to oats and wheat. No conclusion was reached concerning the reproduction of the English grain aphid, possibly due to a behavioural factor.

The same aphid species were also allowed to choose freely among hosts of Swan barley, Parkland barley, Selkirk wheat and Rodney oats in the growth room. The greenbug and the English grain aphid showed no special preference for any of the hosts, nor did their two morphs, winged and wingless summer viviparae, differentially settle down on them. The corn leaf aphid showed a preference for barley, and this preference was essentially the same for winged and wingless females.

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CHAPTER I

INTRODUCTION

"The struggle between man and insects began long before the dawn of civilization, has continued without cessation to the present time, and will continue, no doubt, as long as the human race endures." (Forbes, 1915).

Metcalf et al. (1962) stated: ". . . man's advancing civilization has in many ways made him more vulnerable to insect attack. Modern agriculture with its vast contiguous plantings of standardized crops offers optimum conditions for the development and spread of enormous populations of destructive insects . . . The accumulation and storage of millions of bushels of farm surplus grain has enabled the stored-product insects to multiply on an unprecedented scale. Mountains, deserts, and oceans -- geographic barriers which have restricted the dispersal of insects since time began -- have lost much of their effectiveness because of modern air transportation."

Thus, the so-called "balance of nature" has been disturbed by man, whose production of food and fiber has resulted from necessarily ecologically simplified crop systems. The multiplication of insect pests has been a consequence.

The aphids or plant lice (Homoptera: Aphididae) are one of the major insect enemies of man because they cause wilting, distortion, stunting, discoloration, defoliation, damage by honeydew excretion, the formation of galls and pseudogalls, as well as transmitting diseases to valuable plants.

The problem

The purpose of this study was to examine and elucidate the relationships among three species of aphids, the greenbug, Schizaphis graminum (Rondani), the corn leaf aphid, Rhopalosiphum maidis (Fitch), and the English grain aphid, Macrosiphum avenae (Fabricius), and varieties of barley, Hordeum vulgare L., wheat, Triticum aestivum L., and oats, Avena sativa L.

At the International Great Plains Conference of Entomologists (1964) mention was made of the lack of information on losses caused by aphids to field crops and especially the problem of the extension entomologist who is asked to advise the farmer as to whether or not he should spray his crops for aphid control. These problems were the basis for setting up experiments to evaluate the effects of the above mentioned aphids on Parkland barley, Selkirk wheat and Rodney oats, at different stages of plant growth. The length of time required by the aphids to kill seedlings and the effect of the aphids on yield, were also used to evaluate the degree of resistance, mainly tolerance (the ability of the plant to withstand insect attack) exhibited by the plants.

An attempt was made to test seventeen varieties of barley in the field for resistance against S. graminum and R. maidis. These varieties had already shown some antibiosis (the adverse effects on the biology of the insect resulting from feeding on a resistant host plant) in previous tests (Belvett, 1965). Swan barley was used as a check, because it is the variety used in the growth room on which aphids are reared.

One question of technique is very important, namely "to what extent the previous host of an aphid affects its biology?" To answer this question a set of experiments was carried out in which the rate of reproduction of the greenbug, the corn leaf aphid and the English grain aphid was measured after they had first been cultured on and then transferred to each of Swan barley, Parkland barley, Selkirk wheat and Rodney oats. The number of progeny produced per adult aphid during a given period of time is commonly used as a reliable measurement of insect resistance (antibiosis) in plants.

In order to complement the previous investigations an experiment was designed to allow the aphids to choose their hosts from among the four above mentioned cereal grains. This has been called "preference" or "non-preference" (Painter, 1951).

Importance of the study

Undoubtedly insect control is one of the most important aims of Entomology. It has ordinarily been divided into two main branches: natural and applied or artificial control. Natural factors acting as checks on insect populations are climate, physical barriers, insect predators and parasites, and insect diseases, over which man has no control. Applied or artificial control includes the use of chemical compounds, mechanical and physical means, cultural measures, biological control, and legal measures.

At present, chemical control is the most efficient measure used by man to lessen insect damage and to combat insect outbreaks, especially since World War II. However, its use has also resulted in some detrimental effects: hazards to mammals including human beings, appearance of insecticide resistance in insect pests, adverse effects on populations of beneficial insects (insect pollinators, insect predators and parasites), and general disturbance to wild life. The integrated control concept has brought a new outlook on how best to control pests by combining and integrating chemical, biological, and natural methods.

According to Beck (1965) "suppression of pest populations through the use of resistant plants has long been considered to be the ideal control method." Even if complete elimination of the insect pest is not attained but enough is done to keep it under the economic threshold, insect resistance in crop plants should be considered excellent, having in mind that insect control is not aimed at primarily killing insects, but at increasing the quantity and improving the quality of fiber and food.

Despite having achieved some progress through the use of insect-resistant plants, the basis of resistance has proven to be very complex and not exactly known. Workers such as Beck (1965) estimate that "the rate of progress realized will be closely correlated with the rate of accumulation of fundamental biological and biochemical knowledge concerning the complex interactions between insects and their host plants."

The aims of the present study have been:

(1) to supply information on damage done by the greenbug, the corn leaf aphid and the English grain aphid to barley, wheat and oats, thus helping the extension entomologist and the farmer,

(2) to verify in the field the resistance shown by plants under artificial conditions,

(3) to find out what influence if any the previous hosts have on the aphids under study, and

(4) to learn more about host selection (preference or non-preference) by these cereal aphids.

Organization of the thesis

Literature concerned with aphids is reviewed in Chapter II. It covers: the economic importance of each aphid, especially emphasizing their role as vectors of plant virus diseases, and the fundamentals of aphid resistance in crop plants, including host selection, antagonistic effects of the plants on the biology of aphids, kind of damage caused by aphids, and the relative success of using aphid resistant varieties.

Chapter III explains the materials and methods used. Chapter IV includes the data and discussion of tests made to evaluate the effects of the three aphid species on Parkland barley, Selkirk wheat and Rodney oats infested at various stages of plant growth.

Chapter V deals with attempts in field tests to select barley varieties resistant to the greenbug and the corn leaf aphid. Results of the effect of change of hosts on the reproduction of *S. graminum*, *R. maidis* and *M. avenae* are shown and discussed in Chapter VI.

Tests on preferences among four hosts by all three aphids are presented in Chapter VII. Chapter VIII contains the summary and conclusions.

CHAPTER II

REVIEW OF THE LITERATURE

The three species of aphids, the greenbug, Schizaphis graminum (Rondani), the corn leaf aphid, Rhopalosiphum maidis (Fitch), and the English grain aphid, Macrosiphum avenae (Fabricius), have been considered pests of small grains for many years. Sanderson (1913) included the greenbug and the English grain aphid among the insect pests of small grains, and the corn leaf aphid among those of corn. Peairs (1941) mentioned all three aphids as insects injurious to grasses and grains.

Economic importance of the aphids

The greenbug, also previously called the spring grain aphid, was first recorded by Rondani in 1852. Patch (1938) reported sixty-two species of Gramineae as hosts of this aphid. Metcalf et al. (1962) indicated that many grasses, and all the small grains, serve as hosts. Kelley (1917) pointed out that a cool wet summer and early fall, a mild winter, early spring warmer than usual, and late spring cooler than usual preceded destructive greenbug outbreaks. That sequence would provide exceptionally good conditions for this aphid and at the same time minimize the control exerted by predators and parasites (Glenn, 1909; Hunter, 1909; Webster and Phillips, 1912; Davis, 1914; Wadley, 1931). In the United States there have been fifteen serious outbreaks since this aphid was first reported in 1882 (Dahms et al., 1955). In certain years of severe infestations losses have been estimated at more than fifty million bushels of grain in the Central and Southwestern States (Wood, 1961b). Peairs (1941) pointed out that the greenbug is the most destructive of the aphids attacking small grains in the United

States. Little (1963) mentioned this aphid as one of the most destructive pests of wheat and other small grains in the southwest of the same country. Metcalf et al. (1962) mentioned that in some years the damage has amounted to 25 per cent of the wheat crop and estimated that the greenbug possibly causes a loss annually of from 1 to 3 per cent of the wheat crop of the entire world. Bruehl (1961) stated: "It owes much of its destructiveness to its ability to develop under cool conditions when the hosts are small, to its unusual fecundity, to its reluctance to disperse, and to a toxic constituent of its salivary secretions." Chatters and Schlehuber (1951) studied the mechanics of feeding of this aphid on Hordeum, Avena and Triticum, observing that an increase in number of greenbugs on a host plant caused a damage tending to increase geometrically due to competition for available vascular tissue, that the injection of saliva appeared to be the primary cause of tissue injury, and that the effect varied from lysis in Hordeum, to cell-wall modification in Avena, to a combination of lysis and cell-wall modification in Triticum. Maxwell and Painter (1961, 1962a, 1962b, 1962c) reported on some of the auxins extracted by the greenbug while feeding. Dahms and Wood (1957) found that even small infestations of S. graminum on small grains caused a measurable reduction in yield. Whitehead and Fenton (1950), by means of aerial photos of greenbug-infested grain fields in Oklahoma showed many chlorotic, heavily infested areas. Ortman and Painter (1960) measured the damage caused by this aphid to four wheat varieties quantitatively and found that the root systems and above-ground plant parts were almost equally damaged. Kantack and Dahms (1957) indicated that the injury symptoms caused by the greenbug to Pawnee wheat, Tenkow barley and Wintok oats appeared much earlier than if they were infested with apple grain aphid, *Rhopalosiphum fitchii* (Sanderson), that plants infested with greenbugs became more susceptible to frost damage than uninfested plants, and that this aphid caused a marked delay in formation of tillers. Wadley (1929) found that this aphid decolorised chlorophyll and that *M. avenae* and *R. fitchii* could exist in large numbers on a given host without causing much visible damage, but that an equal number of greenbugs would kill the plant. The decline of young host plants supporting a heavy population of greenbugs can be so rapid that wingless morphs and nymphs die in the field before they are able to walk the distance to new host plants (Kelley, 1917).

The corn leaf aphid, *Rhopalosiphum maidis*, was described by Fitch in 1856. The biology of the corn leaf aphid was studied by Wildermuth and Walter (1932) who obtained males in the laboratory. Eastop (1955) and Cartier (1957) have also reported the production of males. However, reproduction in nature appears to be entirely parthenogenetic. Metcalf *et al.* (1962) among its hosts included sorghums, corn, barley, sugar cane, Sudan grass, and many other wild and cultivated grasses. It prefers to feed in the whorls of its host plants, and, according to Bruehl (1961), barley is its preferred host among cool season cereals. Robinson and Hsu (1963) found that it preferred *Hordeum vulgare* and *Echinochloa crusgalli*. Adams and Drew (1964b) also found that *Hordeum* was its most acceptable host, and on *Triticum* it did not reproduce and had a shorter life-span. Wildermuth and Walter (1932) reported it to be less frequent on oats and wheat. Adams and Drew (1964a, 1965) observed its occurrence in small sporadic numbers in oat fields in New Brunswick. Wells and McDonald (1961) indicated that heavy infestations of *R. maidis* severely injured barley at early stages of plant growth. Robinson and Hsu (1963) were not able to rear this aphid on plants of Zea mays less than thirty days old but older plants often became heavily infested. They also noted that thousands of acres of late-seeded barley were destroyed by this aphid in 1955 in Western Canada. Bruehl (1961) reported its preference for the tassels of corn and the inflorescences of sorghum when they begin to emerge from the whorl. Neiswander and Triplehorn (1961) suggested that large numbers of aphids may cause the tassel of corn to fail to open or produce pollen. Everly (1960) found that there was a correlation between losses in corn yield (as high as 40 per cent in many fields of Indiana in 1959) and the percentage of plants infested with corn leaf aphid. Howitt and Painter (1956) observed that this aphid may sometimes be a serious pest of sorghum where it begins to feed in the whorl and may injure the crop by hindering the exsertion of the head from the boot. McColloch (1921) and Ali (1950) found that heads of sorghums supporting large numbers of aphids produced a small quantity of seed of low vitality. Losses as high as 33 per cent in weight and 50 per cent in volume were cited by McColloch (1921). Its sticky excretion of honeydew on the grain heads encourages the growth of molds which lower the quality of seeds, reduces shedding of pollen, and attracts the corn earworm moths (Cartier and Painter, 1956). It also causes a reddish discoloration, often followed by rotting and decay of the stalks (McColloch, 1921; Hayes, 1922: Ali, 1950). Branson and Simpson (1966) reported that overcrowding of the corn leaf aphid on sorghum plants caused a reduction of fecundity and that a higher percentage of alate forms developed on nitrogen deficient plants. Bruehl (1961) mentioned that the aphid normally migrates in summer from sorghum to corn or barley.

The English grain aphid, Macrosiphum avenae, was described by Fabricius in 1794. Metcalf et al. (1962) stated: "This insect feeds on all the small grains and many of the wild and cultivated grasses." Bruehl (1961) observed its tendency to feed on the juices involved in kernel formation when the plants produce the inflorescence. Forbes (1962) found the aphids scattered over the blades of oats until heading, at which time they clustered on the inflorescence. Orlob (1961) and Robinson and Hsu (1963) found it to be more prevalent on cereals than on grasses. Forbes (1962) reported that it was the most abundant cereal aphid on oats in British Columbia. Adams and Drew (1964a, 1965) observed that M. avenae infested oats in New Brunswick for approximately seven to eight weeks, from the time the plants were three inches high until the panicles emerged. Wood (1965) found that the attack of two hundred English grain aphids per linear foot on Triumph wheat during the preboot stage of growth did not cause enough damage to make control measures necessary, when plant diseases were not involved.

Aphids as vectors of plant diseases

The damage caused by aphids attacking cereals varies between species, between hosts, and in different years (Wadley, 1929; Oswald and Houston, 1951; MacNay, 1955; Lowe, 1961; Forbes, 1962; Markkula and Myllymaki, 1963; Robinson and Hsu, 1963). Their ability to transmit cereal viruses increases their economic importance (Slykuis et al., 1959; Hille Ris Lambers, 1960; Orlob and Arny, 1960; Mueller, 1961).

Kennedy et al. (1962) published a conspectus of aphids as vectors of plant viruses including the viruses transmitted by S. graminum, R. maidis and M. avenae.

S. graminum transmits Barley Yellow Dwarf Virus (BYDV) (Oswald and

Houston, 1952b, 1953; Summers and Bowman, 1953; Walters, 1954; Takeshita, 1956; Jedlinski and Brown, 1959; Orlob and Arny, 1959; Rochow, 1959), Millet Red-leaf Virus (Yu et al., 1957), Sugarcane Mosaic Virus (Ingram and Summers, 1936, 1938) and Wheat Mosaic (Western) Virus (Atkinson, 1949).

R. maidis is a vector of BYDV (Oswald and Houston, 1951, 1952a; Takeshita, 1956; Hebert et al., 1959; Orlob and Arny, 1959; Rochow, 1959; Slykhuis et al., 1959; Butler et al., 1960; Watson and Mulligan, 1960), Abaca Mosaic Virus (Celino and Ocfemia, 1941), Canna Mosaic Virus (Brierley and Smith, 1948), Cucumber Mosaic Virus (Wellman, 1934; Dickson et al., 1949), Maize Leaf Fleck Virus (Yu et al., 1957), Onion Yellow Dwarf Virus (Tate, 1940) and Sugarcane Mosaic Virus (Brandes, 1920, 1923; Kunkel, 1922; Stahl, 1927; Ingram and Summers, 1938; Tate and Vandenberg, 1939; Summers et al., 1948; Vasudeva, 1954).

M. avenae is a vector of BYDV (Moore, 1952; Oswald and Houston, 1952a, 1953; Summers and Bowman, 1953; Walters, 1954; Oswald and Thung, 1955; Takeshita, 1956; Toko and Bruehl, 1956; Hebert et al., 1959; Orlob and Arny, 1959; Rochow, 1959; Slykhuis et al., 1959; Butler et al., 1960; Watson and Mulligan, 1960), Bean Yellow Mosaic Virus (Swenson, 1958) and Radish Yellows Virus (Duffus, 1960).

The Barley Yellow Dwarf Virus, which has many hosts among the Gramineae, is obligately vector-transmitted since other means of transmission have failed, and, according to Bruehl (1961), it must be transmitted by aphid vectors, of which there are at least nine species. The existence of greenbug in those areas of the United States which suffered severe losses from BYDV in 1959 (Caldwell et al., 1959; Hebert et al., 1959; Jedlinski and Brown, 1959; Sill et al., 1959; Thomas and Munson, 1959; Orlob and

Arny, 1960) constitutes strong evidence that it serves as a major vector. Bruehl (1961) considered the greenbug not to be a serious problem in most seasons, because of its tendency to be less "vagabond" than other aphid vectors. The corn leaf aphid has not appeared as an important vector of BYDV in spring-seeded barley probably due to its adaptation to warmer weather, but this factor may become important for early-seeded fall barley, as suggested by Bruehl (1961). Summers and Bowman (1953) observed the tendency, shown by the English grain aphid, to spread widely as opposed to that exhibited by the greenbug which multiplies extensively in one place before the conditions of the host, competition, and crowding force it to migrate. This tendency, of the English grain aphid to disperse uniformly, probably increases the efficiency of a given population to disseminate viruses. Carter (1939) stated that toxicogenic insects are seldom efficient vectors, but Bruehl (1961) noted that it was still not known whether the presence of the toxic substance injected by the greenbug while feeding lessens the effectiveness of this aphid as a vector of BYDV. However, Thomas and Munson (1959) reported a heavy loss of barley in Missouri due to BYDV disseminated by the greenbug. Rochow (1959), by comparing some of the cereal aphids, concluded that *S. graminum* was the least efficient vector of BYDV. More recently the same author (Rochow, 1960a, 1960b) reported that different collections of greenbugs differed in their capability to transmit given strains of the same virus.

Plant resistance to aphids

Observations on the resistance of plants to insect attack date back to the earliest days of Economic Entomology, e.g., Havens (1792) and Lindley (1831). Perhaps the classical example of plant resistance is that of

American vines to the grape phylloxera, Phylloxera vitifoliae Fitch. Painter (1951) compiled and published the information available up to that date. Since 1951 many workers have further studied the subject of resistant plant varieties, the complex insect-plant relationships, and the influence of environmental factors on both insect and plant host. Snelling (1941) defined insect resistance in crop plants as ". . . including those characteristics which enable a plant to avoid, tolerate or recover from the attacks of insects under conditions that would cause greater injury to other plants of the same species."

This definition is only slightly different to that given by Painter (1951): "the relative amount of heritable qualities possessed by the plant which influence the ultimate degree of damage done by the insect," who also indicated different levels of plant resistance; other phenomena ordinarily included under the term pseudoresistance; the three bases of resistance, namely, preference or non-preference, antibiosis and tolerance, which may be acting alone, or two of them, or all three together. Preference or non-preference (Painter,1951), has been used to denote the group of plant characters and insect responses that lead to or away from the use of a particular plant or variety for oviposition, for food, for shelter, or for combination of the three. The term antibiosis, proposed by Painter (1941), has been referred to "those adverse effects on the insect life history which result when the insect uses a resistant host-plant variety or species for food." And tolerance of a plant (Painter, 1951) "is the ability to grow and reproduce itself or to repair injury to a marked degree in spite of supporting a population approximately equal to that damaging a susceptible host."

The converse mechanisms in a susceptible plant, as indicated by

Auclair (1957), would be preference, probiosis and intolerance. There are many factors influencing resistance. Mumford (1931) classified the reported causes of resistance as "epiphylaxis" and "endophylaxis." Painter (1951) grouped them into plant factors, environmental factors, and insect-plant interaction factors; many of them being interrelated.

Painter (1958) pointed out that there are more known cases of breeding resistant crop plants to aphids than to other insects. Metcalf et al., (1962) stated: "There is scarcely a kind of plant, cultivated or wild, but what supports from one to several species of aphids." The search for virus resistant plants began in recent years, e.g., Schaller et al., (1963) with at least as many problems as the search for insect resistant plants. Wilcoxson and Peterson (1960) stated "Breeding red clover for resistance to aphids may be a more successful approach than trying to breed for resistance to virus diseases."

Several authors have reported on host selection and adaptation of aphids (Kennedy, 1950, 1953, 1958; Wertheim, 1954; Lipke and Fraenkel, 1956; Bodenheimer and Swirski, 1957; Muller, 1958; Kennedy and Stroyan, 1959; Orlob, 1961b; and others). Aphids have been reported to prefer young or senescent leaves to mature ones (Kennedy, 1950; Hull, 1964; and others), to be more attracted to certain colours (Searls, 1935; Cody, 1941; Moericke, 1950, 1955a, 1955b, 1955c, 1957; Kennedy and Booth, 1954; Eastop, 1955; Heathcote, 1957; Coon and Rinick, 1962; Cartier, 1963; O'Longhlin, 1963; Cartier and Auclair, 1964; Muller, 1964; and others), to be influenced by intensities of light (Kennedy and Booth, 1961), to be influenced by plant height in alighting (Shands et al., 1956; Cartier, 1963) and to prefer virus-diseased plants to healthy ones (Arenz, 1951; Kennedy, 1951; Baker, 1960).

Some antibiotic effects reported for aphids have been: lower fecundity (Jones et al., 1950; Cartier and Painter, 1956; Howitt and Painter, 1956; Auclair, 1957; Cartier, 1959; Wilcoxson and Peterson, 1960; Carnahan et al., 1963; Hsu, 1963; Hsu and Robinson, 1963; Belvett, 1965), increased mortality (Cartier and Painter, 1956; and many other authors), reduction of body size (Cartier and Painter, 1956; Auclair et al., 1957; Maltais and Auclair, 1957; Auclair and Cartier, 1958, 1960; Cartier, 1963; and other authors), abnormal length of stadium or life (Harrington, 1941; Jones et al., 1950; Wilcoxson and Peterson, 1960; Carnahan et al., 1963; and other authors), restlessness (Jones et al., 1950; Wilcoxson and Peterson, 1960; Cartier, 1963), reduction of food reserves (Painter, 1958), reduction of excretion (Auclair, 1957), reduction of wing production (Cartier and Painter, 1956). And among the factors that have been reported to affect antibiosis on aphids are: feeding mechanism (Painter, 1951, 1958; Kindler and Howe, 1961; Beck, 1965; Robinson, 1965; and many other authors), temperature (Jones et al., 1950; Isaak et al., 1963; Robinson, 1965; and other authors), humidity (Isaak et al., 1963), light (Robinson, 1965), plant age (Kindler and Howe, 1961; and many other authors), chemical content of the plant (Guthrie et al., 1962; Thurston and Webster, 1962; Bottger et al., 1964), aphid biotypes (Harrington, 1943, 1945; Dahms, 1948; Painter, 1951; Cartier and Painter, 1956; Pathak and Painter, 1958a, 1958b, 1959; Maxwell and Painter, 1962d; Painter and Pathak, 1962; and other authors), aphid morphological forms (Evans and Gyrisco, 1956).

The more commonly observed effects from aphids on their host plants have been wilting, distortion, stunting, discoloration, defoliation, problems of honeydew excretion, formation of galls, formation of pseudogalls and transmission of plant diseases (Cottier, 1953). The kind of injury and the ability to repair it, which is tolerance in part, depend upon the age and size of plants (Painter, 1951; Howe and Pesho, 1960, Manglitz and Gorz, 1961; and other authors), plant varieties involved (Painter, 1958; Shaposhnikov, 1961; and other authors), aphid morphs and biotypes present (Pathak and Painter, 1958a, 1958b; Maxwell and Painter, 1961; Shaposhnikov, 1961; and other authors), size of aphid populations (Painter, 1951; Manglitz and Gorz, 1961; and other authors), and the amount and kind of auxins extracted (Went, 1940; Maxwell and Painter, 1961).

Various authors have used different means to measure aphid resistance in crop plants: numbers of aphids or colonies per freely-chosen host plant (Dahms *et al.*, 1955; Cartier and Painter, 1956; Howitt and Painter, 1956; Wilcoxson and Peterson, 1960; Orlob, 1961b; Cartier, 1963; Kishaba and Manglitz, 1965), progeny counts (Dahms *et al.*, 1955; Cartier and Painter, 1956; Howitt and Painter, 1956; Hsu and Robinson, 1962, 1963; Hsu, 1963; Isaak *et al.*, 1963; Belvett, 1965), aphid survival (Cartier and Painter, 1956; Isaak *et al.*, 1963), weight of aphids (Cartier and Painter, 1956; Cartier, 1963), length of stadium and/or life of aphids (Jones *et al.*, 1950; and others), assessment of damage caused to the host plant (Dahms *et al.*, 1955; Painter and Peters, 1956; Chada, 1959; Hormchong and Wood, 1963), length of time required by aphids to kill the plants (Dahms *et al.*, 1955; Ortman *et al.*, 1960; Wood, 1961b; Hormchong and Wood, 1963), and amount of plant growth following aphid infestations (Dahms *et al.*, 1955).

Dahms *et al.* (1955) screened many varieties and hybrids of small grains for resistance to the greenbug. Wood (1961) screened wheat lines and Chada *et al.* (1961) screened the world collection of barley for greenbug resistance. Harvey and Wilson (1962) reported differences in injury caused by the greenbug to a resistant line of wheat and a susceptible variety. Daniels and Porter (1956) found that wheat grown in soil following alfalfa resulted in more tolerance inasmuch as it supported greater populations, than wheat grown in soil taken from wheat land. Haseman (1946) had indicated that the greenbug had a high nitrogen requirement and would not reproduce as well on small grains grown on land deficient in nitrogen and iron. However, Arant and Jones (1951) reported that greenbug populations varied inversely with the amount of nitrogen applied to oats. Blickenstaff *et al.* (1954) reported that populations of *S. graminum* decreased on oats and rye as the nitrogen was increased.

Hormchong and Wood (1963) screened barley varieties for resistance to the corn leaf aphid by measuring the amount of injury caused to the plants. Hirano and Ito (1964) reported that there was no difference in mortality and fecundity of *R. maidis* on barley plants of various maturities, but on young wheat plants it had a higher mortality and a lower fecundity than on old plants. Adams and Drew (1964b) reported that this aphid did not survive on wheat under greenhouse conditions.

Markkula and Laurema (1964) reported that the reproduction of *M. avenae* remained unchanged while feeding on oats infected with barley yellow dwarf virus and increased concentrations of free amino acids in the plant. Adams and Drew (1964b) pointed out that the English grain aphid seemed to be more adaptable to *Hordeum*, *Avena*, *Triticum* and *Poa* than *R. maidis* and *Rhopalosiphum padi* (L.) because of little variation in its reproduction on all four hosts. Adams and Drew (1965) noted that *R. padi*, *M. avenae* and *R. maidis* were not found on oats in fields of New Brunswick after the panicle stage had been reached.

Although the mechanism of insect resistance in crop plants is still not exactly known, it has been possible to use resistant varieties sometimes as a principal control method, e.g., the use of resistant grape vines against the grape phylloxera (Bioletti *et al.*, 1921; Painter, 1951). More commonly, resistant plant varieties have been used as an adjunct to other control measures. Emden and Wearing (1965) discussed the large scale use of highly resistant plants and suggested that resistant strains of insects may arise, similar to that condition which has happened in the case of indiscriminate use of chemicals. These authors considered that the existence of biotypes in aphids may increase breakdown of plant resistance. They suggested that a more efficient method of control might be found by combining: "a low level of plant resistance with, for example, the action of natural enemies." Another use of plant resistance is as a safeguard against the release of susceptible varieties (Painter, 1951).

Many authors have discussed the inheritance of resistance of plants to insects (Painter, 1951; Painter and Peters, 1956; Daniels and Porter, 1958; Curtis *et al.*, 1960; Chada *et al.*, 1961; Porter and Daniels, (1963; and others).

Thus far, several authors have reported aphid resistant varieties (Gernert, 1917; DeLong and Jones, 1926; Le Pelley, 1927; Searles, 1935; Dunnam and Clark, 1938; Hubert and Schwartze, 1938; Dahms and Painter, 1940; Snelling *et al.*, 1940; Ivanoff, 1944; Anonymous, 1955; Dahms *et al.*, 1955; Harvey *et al.*, 1960; Lehman *et al.*, 1963). Corn varieties have been reported resistant against the corn leaf aphid (Snelling *et al.*, 1940), and barley varieties against the greenbug (Anonymous, 1955; Dahms *et al.*,1955).

CHAPTER III

MATERIALS AND METHODS

The three species of aphids, Schizaphis graminum (Rondani), Rhopalosiphum maidis (Fitch) and Macrosiphum avenae (Fabricius), were obtained from previous stock cultures of the Department of Entomology, The University of Manitoba. Subsequent cultures were maintained in a basement growth room on Swan barley plants, which were renewed every week. The cultures were kept under fine-screen cages to prevent infestations by winged aphids and to exclude predators and parasites. Each culture of the aphids may be considered to belong to a line or clone with the same genetical background because they descended from a single apterous summer vivipara, thus avoiding possible differences from biotypes. Problems with other morphs were eliminated by using only summer viviparae.

Seeds of Swan barley, Parkland barley, Selkirk wheat and Rodney oats were supplied by the Department of Plant Science, The University of Manitoba. The aphids were reared and maintained on Swan barley because it had been used successfully in earlier experiments (Hsu, 1963; Belvett, 1965; Sun, 1965).

Temperatures in the growth room fluctuated from 20°C in winter to 32°C in summer, and relative humidity remained about 55 per cent. Precise controls could be maintained in the growth cabinets located in the plant growth room.

A few preliminary tests were conducted to determine the exact time of emergence of seedlings and the time required for them to reach a height of one to two inches, by sowing five seeds in each of five five-inch clay pots. Because the aphids were to be cultured on benches in the growth room, experiments were carried out to find out if there was any difference in the prereproductive period of the aphids reared in the growth room compared to that reported by Belvett (1965) in growth cabinets.

Effects of aphids on cereal grains at various stages of plant growth

Each species of aphid was tested on each of Parkland barley, Selkirk wheat and Rodney oats, as indicated in Table I.

Three seeds were sown in each of eighty to ninety five-inch clay pots for each experiment. The pots were placed in a growth cabinet and used as required. The total time for each experiment varied from 110 to 115 days. After emergence the strongest plant in each pot was selected and the rest eliminated.

The first infestation with aphids was made when the plants reached one to two inches high, which was five days after seeding for Parkland barley, six for Selkirk wheat and seven for Rodney oats. A single newly moulted adult wingless vivipara which was ready to start reproducing was transferred to each of seven to ten seedlings which were kept under a cage. Ten days later a new infestation was similarly made, and this was done in succession at ten day intervals until the plants reached an age approximately sixty to seventy days after seeding.

The newly moulted adult aphids were obtained by isolating the nymphs produced by apterous adults in twenty-four hours and then allowing them to reach maturity. The greenbugs selected were six to seven days old,

TABLE I

SUMMARY OF TIME SCHEDULES OF TESTS ON EFFECTS OF APHIDS ON CEREAL GRAINS AT VARIOUS STAGES OF PLANT GROWTH

Experiment number	Species of aphid	Plant host	Age of plants at infestation time (days after seeding)
1	*Schizaphis graminum* (Rond.)	Parkland barley	5-15-25-35-45-55-65
2	" " "	Selkirk wheat	6-16-26-36-46-56-66
3	" " "	Rodney oats	7-17-27-37-47-57-67
4	*Rhopalosiphum maidis* (Fitch)	Parkland barley	5-15-25-35-45-55-65
5	" " "	Selkirk wheat	6-16-26-36-46-56-66
6	" " "	Rodney oats	7-17-27-37-47-57-67
7	*Macrosiphum avenae* (Fab.)	Parkland barley	5-15-25-35-45-55-65
8	" " "	Selkirk wheat	6-16-26-36-46-56-66
9	" " "	Rodney oats	7-17-27-37-47-57-67

and the corn leaf aphids and English grain aphids were seven to eight days old. Adults that had already produced one to four nymphs were preferred for the experiments, for better uniformity.

The aphids were checked on the following day and replaced if absent. Plants that did not have a colony of aphids in subsequent days were eliminated from the experiment.

The progress of the infestations was observed and the death of seedlings recorded. A plant was considered dead when it appeared completely dried out and the aphids had abandoned it. Dead plants that had not produced heads were removed immediately. If heads had formed, the plants were kept until harvested along with those that still supported some aphids.

When the uninfested plants (checks) reached maturity, all the heads were cut off and allowed to dry for two or three weeks at room temperature. Then the grain was separated, counted and weighed on an electric balance with a precision of 0.1 gram.

All these experiments were conducted in cabinets at a temperature of $22^{\circ}C \pm 1.5^{\circ}C$ and relative humidity of $65\% \pm 10\%$. The photoperiod was set at sixteen hours of light and eight hours of darkness. The soil consisted of four parts of Red River loam and one part of sand. Fertilizer 11-48-0 was used in all experiments except experiment number 1. All transfers of aphids used in this thesis were made by means of an aspirator (Robinson, 1961).

The plants received two hundred cubic centimeters of water every third or fourth day. Emergence of seedlings was four or five days after seeding. The three-leaf stage was attained twelve to sixteen days after seeding. Tillering usually started when plants were older than twenty days after seeding. Heads appeared when plants were fifty to sixty-five days after seeding and maturity was reached one hundred to one hundred and ten days after seeding. There was little difference in growth among varieties.

Field tests on resistance (antibiosis) of barley varieties against the greenbug and the corn leaf aphid

Seventeen varieties of barley and a check were used. They were C.I. 4474, C.I. 4220-2, Poda C.I. 652, Brachytic C.I. 6572, Rojo C.I. 5401, Gopal C.I. 1091, C.I. 4273-1, C.I. 4388, C.I. 3906-1, Pasha C.I. 984, Kipper C.I. 1291, Hordeum vulgare B 227, Sublaxum C.I. 2231, (Vantage X Jet) Br. 5209-7, Galore C.I. 7150, B. 193, C.I. 4148-1, and Swan (check). Excluding the check, all these varieties had shown some resistance in previous tests (Belvett, 1965). They were planted in the field in rows eighteen inches apart in June, 1965. Twenty plants of each variety were chosen at least eighteen inches apart in the row, for artificial infestation by newly moulted adult wingless female aphids of both *Schizaphis graminum* (Rondani) and *Rhopalosiphum maidis* (Fitch).

The aphids were cultured in a growth room as described above.

Ten plants of each variety were infested, each with one greenbug, and ten plants each with one corn leaf aphid. Individual organdy cages supported by wires were placed over each plant as described by Hsu (1963).

It was planned to infest the plants when they were two to four inches high, and antibiosis was to be measured by counting the progeny produced by each female aphid in five days. However, due to incessant rain, and muddy plots, the plants were over twelve inches high before there was an opportunity to place the aphids on them, and further rain delayed the counting until eight days after the infestation was made.

Effect on fecundity of aphids reared on one host plant and transferred to other plants

"Effects of preconditioning" is a term commonly used to denote possible influences on the biology of an insect resulting from change of hosts. *S. graminum*, *R. maidis* and *M. avenae* were first cultured on, and then transferred to, each of Swan barley, Parkland barley, Rodney oats and Selkirk wheat, in order to study any differences in rate of reproduction resulting from change of hosts.

The aphids used were newly moulted wingless summer female adults. They were obtained by placing many adults on each host plant, allowing them to reproduce for one day, then removing them and leaving the nymphs to reach maturity. Thus the aphids used in tests were within twenty-four hours or less of being the same age. Next, thirteen to twenty plants of the second host were infested with one aphid each, and covered with a fine-mesh organdy cage supported by wires. The progeny were counted six days later. If adults were not present at the time of the count, the data were not used.

The experiments were made either in the growth room or in the cabinets as indicated in Chapter VI. Plants on which the aphids were reared, were seeded and grown in small flats; those used as hosts on which the aphids reproduced, were grown and selected as described in page 20.

Host preference of aphids

Since previous experiments dealt with the greenbug, the corn leaf aphid and the English grain aphid on Swan barley, Parkland barley, Selkirk wheat and Rodney oats, it was decided to ascertain what host preferences they might have if allowed a free choice of hosts, rather than being caged on a specific host.

From a source consisting of forty to fifty Swan barley seedlings heavily infested with winged and wingless adult summer viviparae, as well as nymphs, the aphids were allowed to freely choose their hosts from among the four plant varieties mentioned above, arranged as follows:

I	II		III	IV
P. b.	S. w.		R. o.	S. b.
R. o.	S. b.	Source	P. b.	S. w.
S. b.	R. o.		S. w.	P. b.
S. w.	P. b.		S. b.	R. o.

S. b. : Swan barley

P. b. : Parkland barley

S. w. : Selkirk wheat

R. o. : Rodney oats

These tests were made on a bench covered with a large cage in the growth room at a temperature of $23^{o}C. \pm 2.5^{o}C.$, and a photoperiod of 16 hours of light and 8 hours of darkness.

Plants were either sown directly into the soil on the bench, followed by thinning in order to select the best plants or transplanted from previously germinated seeds at a temperature of $25^{o}C. \pm 1^{o}C.$ The latter gave more uniformity, and they were two to three inches high when each experiment began. There were equal numbers of plants for each host, spaced 1.0 to 1.5 inches apart. The distance between replicates was three inches, and from replicates II-III to the source of six inches. A count of aphids settled on each plant was made four or five days later.

CHAPTER IV

EFFECTS OF APHIDS ON CEREAL GRAINS AT VARIOUS STAGES OF PLANT GROWTH

As shown in Table I, nine experiments were planned to test S. graminum, R. maidis and M. avenae on each of Parkland barley, Selkirk wheat and Rodney oats under the artificial conditions of the growth cabinets. The corn leaf aphid did not establish successfully on Selkirk wheat or Rodney oats, thus reducing the number of experiments from nine to seven. Adams and Drew (1964b) had previously reported its preferences for barley and its inability to reproduce on wheat. Robinson and Hsu (1963) also observed its preferences for barley. Wildermuth and Walter (1932) reported that this aphid occurred less frequently on oats and wheat; and Adams and Drew (1964a, 1965) its occurrence in small sporadic numbers in oat fields. Most of the newly moulted adults of R. maidis walked off the plants of Selkirk wheat or Rodney oats soon after being placed on them. A few of them stayed long enough to produce some nymphs, but the small populations thus formed decreased in numbers after a few days.

Results of the remaining seven experiments are presented in Tables II - VIII. The length of time required for the aphids to kill the plants is indicated in the fourth column of each table. These data were analysed by the "Student's" t test for unpaired data, thus comparing differences between means (Johnson, 1950). The last three columns of each table give information on damage caused by the aphids to older plants. Most of these older plants produced heads before being killed by the aphids. The average number of heads per plant was calculated by dividing the total number of heads produced by the number of plants tested in each group, thus indicating the effect of the aphids on plant head formation and indirectly also showing reduction of tillering. The quantity of kernels produced per infested plant and the quality of them are compared against those of kernels produced by the uninfested (check) plants in the second last and last columns respectively. The average weight of kernels produced per plant was calculated by dividing the total weight of seeds by the number of plants tested in each group. The weight of 1,000 kernels is a common measurement used by plant scientists such as Smith and Fitzsimmons (1965), and is obtained as follows: the weight of kernels produced by each group of plants is divided by the total number of kernels and multiplied by one thousand.

<u>Effects of greenbug populations on Parkland barley plants of different ages</u>

This test was carried out from February 10, 1965 to May 31, 1965. The greenbug became readily established on plants of all different ages tested. Soon after the original infestations were made chlorotic spots caused by the injection of its toxic saliva while feeding, became conspicuous. As the aphid populations increased, these spots enlarged and finally the leaves and stems became completely dried out, and the aphids walked off the plants. The greenbug preferentially congregated on new shoots and leaves produced by the older plants when the latter began tillering. The aphids were also observed feeding on the heads. The older leaves, except for the lowest ones, and the main stems lived the longest before the plant died.

TABLE II

EFFECTS OF GREENBUG POPULATIONS ON PARKLAND BARLEY PLANTS OF DIFFERENT AGES

Age of plant when infested with one aptera vivipara (days after seeding)	No. of plants tested	No. of plants killed	No. of days required to kill plants		Av. no. of heads per plant	Av. wt. of kernels produced per plant (g.)	Wt. of 1,000 kernels (g.)
			Range	Mean			
5	9	9	14-19	16.4 a*			
15	10	10	16-22	19.3 b			
25	9	9	24-26	24.9 c			
35	9	9	24-33	29.2 d	0.4	0.04	7.4
45	10	10	31-39	35.4 e	0.9	0.11	17.5
55**	10	10	31-43	39.1 f	1.8	1.83	32.2
65	9	3	30-		1.7	2.46	41.4
Check***	10				2.2	2.66	38.6

* Each mean was given a letter. Means followed by the same letter are not significantly different at 5%

** Plants began heading

*** Plants were harvested 103 days after seeding

Young seedlings, after being infested, continued to grow less normally as the aphid populations increased. They appeared to stop growing at a certain point when the attack was very intense, and eventually died. This sequence was not so conspicuous when the plants were heading or later at the time of infestation, when desiccation was more gradual.

Results of this test are presented in Table II. All seedlings infested up to 55 days after seeding were killed, the younger ones being killed in a shorter time. Though there was some overlapping in the number of days required by the greenbug to cause their death, as indicated by the range, each group of plants was significantly different to the rest.

The older the plants at time of infestation the more heads they produced, though little difference was shown when plants were infested from an age of 55 days after seeding and older. The same holds true when the last two columns are examined: the greenbug did not affect to a very large degree either the weight of kernels produced per plant or the weight of 1,000 kernels of those plants infested when heading began, and later ages.

Twenty-one days before harvest the check plants were removed from the cabinet and placed on benches in the growth room in order to avoid accidental infestations by other aphids. This could have had some influence on the weight of kernels since the conditions of the growth room were slightly drier and warmer than those of the cabinet.

Effects of greenbug populations on Selkirk wheat plants of different ages

Results of this test are presented in Table III. It was carried out from June 4, 1965 to September 22, 1965. The greenbug did not establish itself as readily on the Selkirk wheat seedlings as it did on those of Parkland barley. Some wingless adult viviparae abandoned their hosts and were therefore replaced the day after the original infestations had been made.

As described for the preceding experiment, chlorotic spots followed by desiccation, death of younger leaves first, and progress of the aphid populations, were observed.

All the seedlings which were infested were killed. As shown in Table III, plants infested at ages of 6 and 16 days after seeding were killed in a significantly shorter time. Little difference in length of time to be killed was shown by plants of ages of 26, 36 and 46 days after seeding. Plants of an age of 56 days after seeding resisted longest. The oldest group of plants was desiccated in a shorter number of days probably due to senescence and eventual natural death of older leaves after ear emergence (Watson, 1956; Thorne, 1966).

There was an increasing number of heads produced per plant when infested at an older age. Though plants of age of 36 days after seeding were the first to produce heads, none of them had seeds. Kernels were produced when plants began heading or later, at time of infestation. It is shown that the yield per plant and the weight of kernels also increased when plants were infested at a more advanced age, being maximum for the check plants which also produced the largest numbers of heads.

TABLE III

EFFECTS OF GREENBUG POPULATIONS ON SELKIRK WHEAT PLANTS OF DIFFERENT AGES

Age of plant when infested with one aptera vivipara (days after seeding)	No. of plants tested	No. of plants killed	No. of days required to kill plants		Av. no. of heads per plant	Av. wt. of kernels produced per plant (g.)	Wt. of 1,000 kernels (g.)
			Range	Mean			
6	9	9	20-23	21.1 a*			
16	10	10	24-29	26.6 b			
26	7	7	27-30	28.4 c			
36	7	7	25-35	29.3 cd	1.0		
46**	7	7	26-34	28.1 cde	2.0	0.16	10.1
56	7	7	32-34	32.7 f	2.7	0.71	16.9
66	7	7	23-25	23.7 g	3.1	0.83	15.5
Check***	7				3.6	1.84	32.9

* Each mean was given a letter. Means followed by the same letter are not significantly different at 5%

** Plants began heading

*** Plants were harvested 103 days after seeding

Effects of greenbug populations on Rodney oats plants of different ages

This experiment lasted from June 4, 1965 to September 22, 1965. Results are presented in Table IV. *S. graminum* established as successfully on Rodney oats seedlings as on those of Parkland barley. This is better than on those of Selkirk wheat.

The development of the aphid populations and the symptoms shown by the plants infested were similar to those mentioned for the two previous experiments: appearance of chlorotic spots, desiccation, preferential congregation of greenbugs feeding on younger leaves and new shoots, and feeding on the panicles when they were formed.

The group of plants of age of 37 days after seeding, shortly after being infested were also accidentally attacked by a few other stray greenbugs whose populations grew so fast as to make their elimination impossible. This test was repeated at a later date but unfortunately the conditions were not similar and the plants grew somewhat differently; hence the original data were kept but not statistically compared with the others. However, it was possible to estimate that the aphids would require an average number of days to kill the plants of about 50.

Seedlings up to an age of 57 days after seeding were all killed. The younger plants required a shorter time for the greenbug to cause their death, except those of an age of 57 days after seeding. The latter showed again that senescence of plant parts (Thorne, 1966) would contribute to a quicker death of older plants by this aphid.

TABLE IV

EFFECTS OF GREENBUG POPULATIONS ON RODNEY OATS PLANTS OF DIFFERENT AGES

Age of plant when infested with one aptera vivipara (days after seeding)	No. of plants tested	No. of plants killed	No. of days required to kill plants		Av. no. of heads per plant	Av. wt. of kernels produced per plant (g.)	Wt. of 1,000 kernels (g.)
			Range	Mean			
7	10	10	19-25	22.2 a*			
17	9	9	31-42	37.1 b			
27	7	7	44-49	47.3 c	1.0	0.37	13.9
37**	7	7	35-38	36.7	1.0	0.33	12.6
47	7	7	45-57	53.3 e	1.6	1.83	30.8
57***	7	7	39-42	40.3 f	1.6	1.66	28.5
67	7	5	32-		2.0	2.23	33.0
Check****	7				2.4	2.49	35.4

* Each mean was given a letter. Means followed by the same letter are not significantly different at 5%

** Plants accidentally infested with other aphids

*** Plants began heading

**** Plants were harvested 104 days after seeding

The three last columns show increasing numbers of heads produced per plant, increasing yield of kernels, and increasing weight of 1,000 kernels with increasing age of plants at time of infestations from 27 days after seeding and older.

Effects of corn leaf aphid populations on Parkland barley plants of different ages

As was previously mentioned, *R. maidis* successfully established only on Parkland barley, under the conditions of the growth cabinets. Populations of this aphid increased considerably before the plants appeared to be affected. Seedlings which were infested continued to grow for many days before being seriously damaged. Then, gradual desiccation was the only symptom shown. A co-effect observed was that the heads and most of the plants were partly coated with honeydew which this aphid excretes. Some fungi also grew on the top soil probably as a result of this excretion.

R. maidis preferentially fed and reproduced on the whorls of the plants. Winged forms were observed when the populations increased.

This experiment lasted from September 20, 1965 to January 16, 1966. Results are shown in Table V. Plants infested up to an age of 35 days after seeding were completely killed. There was no significant difference in the length of time required for *R. maidis* to cause their death.

The numbers of heads produced by the plants increased when they were infested from an age of 35 days after seeding and older. The yield and the weight of 1,000 kernels were affected little by the feeding of aphids when plants infested were of an age of 45 days after seeding and older.

TABLE V

EFFECTS OF CORN LEAF APHID POPULATIONS ON PARKLAND BARLEY PLANTS OF DIFFERENT AGES

Age of plant when infested with one aptera vivipara (days after seeding)	No. of plants tested	No. of plants killed	No. of days required to kill plants		Av. no. of heads per plant	Av. wt. of kernels produced per plant (g.)	Wt. of 1,000 kernels (g.)
			Range	Mean			
5	7	7	41-66	52.6 a*			
15	9	9	38-59	47.4 ab			
25	7	7	39-50	46.0 abc			
35	9	9	33-54	47.4 abcd	0.7		
45	9	4	50-		1.2	1.06	38.9
55**	9	0			1.3	1.12	37.6
65	9	1	45-		1.8	1.41	36.3
Check***	9				2.4	1.34	39.5

* Each mean was given a letter. Means followed by the same letter are not significantly different at 5%

** Plants began heading

*** Plants were harvested 106 days after seeding

Effects of English grain aphid populations on Parkland barley plants of different ages

This experiment was carried out from January 18, 1966 to May 6, 1966. Data are presented in Table VI. *M. avenae* became readily established on Parkland barley plants of all the different ages tested. Seedlings experienced only gradual desiccation as the aphid populations increased. Winged morphs of this aphid were observed sooner after infestations and in larger numbers flying at the top of the cages than in the case of *S. graminum* and *R. maidis*.

Before the plants began heading *M. avenae* fed scattered all over the plants, but as soon as ears emerged the aphids clustered preferentially to feed on them.

All seedlings infested were killed. There was little difference in length of time required by *M. avenae* to cause the death of seedlings infested at 15, 25, 35, 45 and 55 days after seeding. The youngest group of plants was killed quicker and also the oldest group, possibly influenced by senescence of plant leaves. Plants were able to produce some kernels only when they began heading or later at time of infestations. The aphids reduced both the yield and the quality of grain produced, as shown in the last two columns in Table VI.

Effects of English grain aphid populations on Selkirk wheat plants of different ages

M. avenae established as readily on Selkirk wheat plants of all ages tested as it did on those of Parkland barley. The following observa-

TABLE VI

EFFECTS OF ENGLISH GRAIN APHID POPULATIONS ON PARKLAND BARLEY PLANTS OF DIFFERENT AGES

Age of plant when infested with one aptera vivipara (days after seeding)	No. of plants tested	No. of plants killed	No. of days required to kill plants		Av. no. of heads per plant	Av. wt. of kernels produced per plant (g.)	Wt. of 1,000 kernels (g.)
			Range	Mean			
5	9	9	18-26	20.9 a*			
15	9	9	28-47	39.2 b			
25	9	9	32-44	37.3 bc			
35	9	9	34-51	41.8 bcd			
45	9	9	37-48	41.1 b de	0.5		
55**	9	9	30-42	34.8 bc f	1.0	0.24	14.7
65	9	9	20-35	25.8 g	1.0	0.39	22.2
Check***	9				1.2	0.63	38.6

* Each mean was given a letter. Means followed by the same letter are not significantly different at 5%

** Plants began heading

*** Plants were harvested 108 days after seeding

tions were made: gradual desiccation of infested seedlings, aphids widely scattered all over the plants first and then feeding preferentially on the ears following heading, appearance of many winged forms flying at the top of the cages as the populations increased.

This experiment lasted from January 17, 1966 to May 6, 1966. Data are presented in Table VII. All plants infested were killed. Plants of an age of 16 and 26 days after seeding survived the longest with no significant difference in numbers of days required to kill them. There was also little difference among those infested at an age of 6, 36, 46 and 56 days after seeding. The group of plants infested when oldest died quicker, as in other previous experiments.

The number of heads produced per plant was affected little when plants began heading or later at the time of infestation. However, there was a considerable reduction in yield and size of kernels.

Effects of English grain aphid populations on Rodney oats plants of different ages

M. avenae established successfully on Rodney oats plants of all ages tested, scattering all over the plants at first and then gathering to feed on the panicles when they emerged. However, Rodney oats plants looked stronger and larger than those of Parkland barley and Selkirk wheat, and winged forms were observed to appear later and less abundantly than on Parkland barley and Selkirk wheat seedlings.

The experiment lasted from May 10, 1966 to September 20, 1966. Data are shown in Table VIII. The aphids did not kill the younger plants

TABLE VII

EFFECTS OF ENGLISH GRAIN APHID POPULATIONS ON SELKIRK WHEAT PLANTS OF DIFFERENT AGES

Age of plant when infested with one aptera vivipara (days after seeding)	No. of plants tested	No. of plants killed	No. of days required to kill plants		Av. no. of heads per plant	Av. wt. of kernels produced per plant (g.)	Wt. of 1,000 kernels (g.)
			Range	Mean			
6	9	9	23-39	30.2 a*			
16	9	9	35-52	43.2 b			
26	9	9	31-48	42.4 bc			
36	9	9	29-32	30.9 a d			
46**	9	9	29-34	30.8 a de	1.0	0.02	2.6
56	9	9	22-33	28.3 a ef	1.0	0.08	6.4
66	9	9	18-27	22.1 g	1.1	0.23	12.5
Check***	9				1.2	0.43	25.0

* Each mean was given a letter. Means followed by the same letter are not significantly different at 5%

** Plants began heading

*** Plants were harvested 109 days after seeding

TABLE VIII

EFFECTS OF ENGLISH GRAIN APHID POPULATIONS ON RODNEY OATS PLANTS OF DIFFERENT AGES

Age of plant when infested with one aptera vivipara (days after seeding)	No. of plants tested	No. of plants killed	No. of days required to kill plants		Av. no. of heads per plant	Av. wt. of kernels produced per plant (g.)	Wt. of 1,000 kernels (g.)
			Range	Mean			
7	9	-					
17	9	-					
27	9	-					
37	9	1	58-		0.4		
47	9	5	53-		1.0	0.32	12.0
57*	9	9	54-66	60.0	1.0	0.81	21.4
67	9	7	39-		1.0	2.10	27.8
Check**	9				2.2	2.81	33.5

* Plants began heading
** Plants were harvested 125 days after seeding

which were infested, but their feeding delayed the growth of plants so much that the first group of plants which produced panicles was that infested at an age of 37 days after seeding. Younger seedlings had not reached maturity by the time that the uninfested check plants had. Only plants of an age of 57 days after seeding at time of infestation were all killed. There were more plants killed when they were infested at an advanced age; this suggests that senescence of plants with reduced physiological activities (Thorne, 1966) results in more rapid death.

M. avenae reduced similarly the number of heads produced per plants infested at ages of 47 days after seeding and later, compared with the check. The average weight of kernels per plant and weight of 1,000 kernels increased progressively with the age of the plants, starting with 47 days after seeding; however in all three cases they were lower than that of the check.

Comparative effects of aphids

Results already shown in previous tables have been rearranged in order to compare the effects of S. graminum, R. maidis and M. avenae on the different hosts. The average number of days required for these aphids to kill the plants and the weight of 1,000 kernels were the measurements selected because of their accuracy and common use in plant research, respectively.

Table IX shows the comparative effects of the three species of aphids on Parkland barley. S. graminum killed seedlings more rapidly than the other two species when plants were aged from 5 to 45 days after seeding at time of infestation. Next was M. avenae. R. maidis required the

TABLE IX

COMPARATIVE EFFECTS OF THE GREENBUG, THE CORN LEAF APHID AND THE ENGLISH GRAIN APHID ON PARKLAND BARLEY

Age of plant when infested with one aptera vivipara (days after seeding)	Aphid	No. of plants tested	Av. no. of days required to kill plants	Wt. of 1,000 kernels (g.)
5	S. graminum	9	16.4 a*	
	R. maidis	7	52.6 b	
	M. avenae	9	20.9 c	
15	S. graminum	10	19.3 a	
	R. maidis	9	47.4 b	
	M. avenae	9	39.2 c	
25	S. graminum	9	24.9 a	
	R. maidis	7	46.0 b	
	M. avenae	9	37.3 c	
35	S. graminum	9	29.2 a	7.4
	R. maidis	9	47.4 b	-
	M. avenae	9	41.8 b	-
45	S. graminum	10	35.4 a	17.5
	R. maidis	9	-	38.9
	M. avenae	9	41.1 c	-
55	S. graminum	10	39.1 a	32.2
	R. maidis	9	-	37.6
	M. avenae	9	34.8 c	14.7
65	S. graminum	9	-	41.4
	R. maidis	9	-	36.3
	M. avenae	9	25.8	22.2
Check	S. graminum	10	-	38.6
	R. maidis	9	-	39.5
	M. avenae	9	-	38.6

* Means followed by the same letter in each separate plant age group are not significantly different at 5%

longest time to kill plants. However, M. avenae killed the two oldest groups of plants more quickly, followed by S. graminum. The English grain aphid also caused the greatest reductions of weight of kernels, followed by the greenbug.

Hence, S. graminum was the most destructive for young seedlings and M. avenae was the most harmful to older plants. R. maidis appeared to be the least harmful of the three species for plants of Parkland barley.

Effects of S. graminum and M. avenae on Selkirk wheat plants are shown in Table X. The greenbug killed the youngest groups of plants more quickly. For older plants both aphids killed the plants in approximately the same time. Considering the difference in weight of the kernels produced by the uninfested (check) plants, there was little difference between the reduction in weight exerted by both aphids. Perhaps M. avenae was slightly more harmful.

Table XI compares the effects of S. graminum and M. avenae on Rodney oats plants. It clearly shows that S. graminum was more destructive, since it killed all seedlings infested up to 57 days after seeding. M. avenae did not cause death of seedlings, except in one age group. However, M. avenae had a greater effect in reducing the weight of 1,000 kernels.

Comparative effects on plants

The rearranged results, presented in Tables XII and XIII, show the different effects on the plants caused by the greenbug and the English grain aphid, based on length of time required by the aphids to kill the different seedlings, and the weight of 1,000 kernels.

TABLE X

COMPARATIVE EFFECTS OF THE GREENBUG AND THE ENGLISH GRAIN APHID ON SELKIRK WHEAT

Age of plant when infested with one aptera vivipara (days after seeding)	Aphid	No. of plants tested	Av. no. of days required to kill plants	Wt. of 1,000 kernels (g.)
6	S. graminum	9	21.1 a*	
	M. avenae	9	30.2 b	
16	S. graminum	10	26.6 a	
	M. avenae	9	43.2 b	
26	S. graminum	7	28.4 a	
	M. avenae	9	42.4 b	
36	S. graminum	7	29.3 a	
	M. avenae	9	30.9 a	
46	S. graminum	7	28.1 a	10.1
	M. avenae	9	30.8 b	2.6
56	S. graminum	7	32.7 a	16.9
	M. avenae	9	28.3 b	6.4
66	S. graminum	7	23.7 a	15.5
	M. avenae	9	22.1 a	12.5
Check	S. graminum	7	-	32.9
	M. avenae	9	-	25.0

* Averages followed by the same letter in each separate plant age group are not significantly different at 5%

TABLE XI

COMPARATIVE EFFECTS OF THE GREENBUG AND THE ENGLISH GRAIN APHID ON RODNEY OATS

Age of plant when infested with one aptera vivipara (days after seeding)	Aphid	No. of plants tested	Av. no. of days required to kill plants	Wt. of 1,000 kernels (g.)
7	S. graminum	10	22.2	
	M. avenae	9	-	
17	S. graminum	9	37.1	
	M. avenae	9	-	
27	S. graminum	7	47.3	13.9
	M. avenae	9	-	-
37	S. graminum	7*	36.7	12.6
	M. avenae	9	-	-
47	S. graminum	7	53.3	30.8
	M. avenae	9	-	12.0
57	S. graminum	7	40.3	28.5
	M. avenae	9	60.0	21.4
67	S. graminum	7	-	33.0
	M. avenae	9	-	27.8
Check	S. graminum	7	-	35.4
	M. avenae	9	-	33.5

*Plants accidentally infested with other aphids

Table XII shows that Rodney oats plants survived the longest under the attack of greenbug populations. The three youngest groups of Parkland barley plants infested were killed sooner than those of Selkirk wheat, but conversely, the three oldest groups of Selkirk wheat were killed faster. Reduction of the weight of 1,000 kernels was greatest on Selkirk wheat followed by Parkland barley and Rodney oats, respectively.

Similarly, Table XIII shows that Rodney oat plants survived the longest the attack of English grain aphid populations. The three youngest groups of infested seedlings of Parkland barley were killed faster than the respective groups of Selkirk wheat, but the older groups showed that the opposite was true. *M. avenae* greatly reduced the size of kernels of Selkirk wheat, Parkland barley and Rodney oats, in that order.

As far as the corn leaf aphid is concerned, it only caused damage to Parkland barley seedlings infested, because suitable experimental populations did not establish on wheat or oats.

Further discussion

It is well known that the feeding damage caused by aphids to cereal crops is most conspicuous in the spring when plants are in their first stages of growth. Of the aphids studied in this work the greenbug proved to be most harmful to young seedlings, confirming those qualifications of "destructive" (Little, 1963), "serious pest" (Pfadt, 1962), and others given to it. The withdrawal of plant sap, the injection of toxic saliva and the rapid increase in numbers (Belvett, 1965) played an important role in killing young cereal plants.

TABLE XII

COMPARATIVE EFFECTS OF THE GREENBUG ON PARKLAND BARLEY, SELKIRK WHEAT AND RODNEY OATS

Plant host	Age of plant when infested with one aptera vivipara (days after seeding)	No. of plants tested	Av. no. of days required to kill plants	Wt. of 1,000 kernels (g.)
Parkland barley	5	9	16.4 a*	
Selkirk wheat	6	9	21.1 b	
Rodney oats	7	10	22.2 b	
Parkland barley	15	10	19.3 a	
Selkirk wheat	16	10	26.6 b	
Rodney oats	17	9	37.1 c	
Parkland barley	25	9	24.9 a	-
Selkirk wheat	26	7	28.4 b	-
Rodney oats	27	7	47.3 c	13.9
Parkland barley	35	9	29.2 a	7.4
Selkirk wheat	36	7	29.3 a	-
Rodney oats	37	7	36.7 c	12.6
Parkland barley	45	10	35.4 a	17.5
Selkirk wheat	46	7	28.1 b	10.1
Rodney oats	47	7	53.3 c	30.8
Parkland barley	55	10	39.1 a	32.2
Selkirk wheat	56	7	32.7 b	16.9
Rodney oats	57	7	40.3 a	28.5
Parkland barley	65	9	-	41.4
Selkirk wheat	66	7	23.7	15.5
Rodney oats	67	7	-	33.0
Parkland barley	check	10	-	38.6
Selkirk wheat	check	7	-	32.9
Rodney oats	check	7	-	35.4

*Averages followed by the same letter in each separate plant age group are not significantly different at 5%

TABLE XIII

COMPARATIVE EFFECTS OF THE ENGLISH GRAIN APHID ON

PARKLAND BARLEY, SELKIRK WHEAT AND RODNEY OATS

Plant host	Age of plant when infested with one aptera vivipara (days after seeding)	No. of plants tested	Av. no. of days required to kill plants	Wt. of 1,000 kernels (g.)
Parkland barley	5	9	20.9 a*	
Selkirk wheat	6	9	30.2 b	
Rodney oats	7	9	-	
Parkland barley	15	9	39.2 a	
Selkirk wheat	16	9	43.2 a	
Rodney oats	17	9	-	
Parkland barley	25	9	37.3 a	
Selkirk wheat	26	9	42.4 b	
Rodney oats	27	9	-	
Parkland barley	35	9	41.8 a	
Selkirk wheat	36	9	30.9 b	
Rodney oats	37	9	-	
Parkland barley	45	9	41.1 a	-
Selkirk wheat	46	9	30.8 b	2.6
Rodney oats	47	9	-	12.0
Parkland barley	55	9	34.8 a	14.7
Selkirk wheat	56	9	28.3 b	6.4
Rodney oats	57	9	60.0 c	21.4
Parkland barley	65	9	25.8 a	22.2
Selkirk wheat	66	9	22.1 a	12.5
Rodney oats	67	9	-	27.8
Parkland barley	check	9	-	38.6
Selkirk wheat	check	9	-	25.0
Rodney oats	check	9	-	33.5

*Averages followed by the same letter in each separate plant age group are not significantly different at 5%

However, the English grain aphid was the most harmful to older cereal plants. It was about as destructive as the greenbug but caused a larger reduction in yield. This is probably a result of its preferential feeding on the ears as soon as they are formed. This may be explained physiologically from a consideration of a statement by Thorne (1966): "Most of the carbohydrate in the grain of barley, and probably also in that of other cereals, is formed from CO_2 assimilated after the ears emerge. . . . The CO_2 absorbed after ear emergence by the part of the shoot above the flag-leaf node, including the ear, accounted for most of the grain dry weight of barley and wheat (Thorne, 1963, 1965)."

Undoubtedly the corn leaf aphid was the least harmful aphid, especially on wheat and oats. On barley, after plants had headed out, weights of 1,000 kernels were similar to those of the check.

Rodney oats was the most tolerant of the cereals tested. This may be related to its larger and stronger seedlings. Young Parkland barley seedlings proved to be the most susceptible to aphid attack, and Selkirk wheat experienced the greatest reductions in yield.

All these results must be interpreted in reference to the artificial conditions of the growth cabinets. The temperature of $22^{\circ} \pm 1.5^{\circ}C$ remained constant throughout the time the experiments lasted. It was more suitable for aphid reproduction than for the growth of plants. This may also be true when the photoperiod is fixed at 16 hours of light per day. Influences of both temperature and light on the growth of cereals are discussed in detail by Friend (1966). However, the check (uninfested) plants were grown under the same conditions; they remained alive and reached maturity thus showing that conditions for plant growth were not entirely unsuitable and that formation of heads and weight of kernels could be used for reliable comparisons.

In addition to the artificial growth conditions for the plants, a few factors must be considered if the results of these experiments are to be compared with actual field conditions. Under natural conditions the aphid populations would be genetically mixed (with possibly greater variability), rather than clones descended from one parthenogenetic mother. In the field, aphid populations are subject to attack from predators and parasites, and their numbers are often decreased by these control factors. Under natural conditions, plant viruses may be transmitted by aphid vectors, thus hastening the death of plants. In the experiments outlined above, a single aphid was placed on each plant, whereas in the field several winged migrants may settle on a single plant. However, weighing all the factors involved, the stress placed on the plants in the growth cabinets was probably greater than that normally occurring under field conditions.

CHAPTER V

FIELD TESTS ON ANTIBIOSIS OF BARLEY VARIETIES AGAINST THE GREENBUG AND THE CORN LEAF APHID

As mentioned previously, Belvett (1965) found some evidence for resistance in seventeen barley varieties to four species of grain aphids, in laboratory tests. Those varieties, plus a check, were tested during June and July, 1965, in the field. Unfortunately, due to excessive rainfall, and muddy plots, the schedule could not be adhered to, and the plants were excessively high (over twelve inches) at time of infestation. Therefore counts could not be made at the end of five days.

Due to the growth of the plants, and the loosening of the cages by wind and rain, some of the organdy cages were lifted up, allowing lady beetles to enter and destroy aphids on the barley plants. These various factors resulted in the discarding of counts from several of the plants under test. Table XIV shows the number of progeny counted eight days after initial infestation by one aphid.

Because the plants were no longer in the seedling stage at time of infestation, and because so many replicates had to be discarded, the data in Table XIV must be interpreted with these in mind. None of the varieties showed outstanding resistance to either of the two species of aphids, and most of them differed little in numbers of progeny produced, compared with the check. There is some evidence that the greenbug established more successfully, and produced more progeny, than did the corn leaf aphid.

TABLE XIV

ANTIBIOSIS OF EIGHTEEN BARLEY VARIETIES IN THE FIELD TO GREENBUG AND CORN LEAF APHID, MEASURED AS NUMBER OF PROGENY PRODUCED IN EIGHT DAYS

Barley variety	Greenbug			Corn leaf aphid		
	No. of adults	Progeny produced		No. of adults	Progeny produced	
		Range	Mean		Range	Mean
C.I. 4474	6	3-25	13.5	7	8-25	18.4
C.I. 4220-2	6	10-30	16.8	3	6-18	10.3
Poda C.I. 652	8	6-31	17.0	8	8-24	17.4
Brachytic C.I. 6572	3	6-26	18.3	3	16-23	18.7
Rojo C.I. 5401	6	14-32	19.8	1	---	19.0
Gopal C.I. 1091	1	---	20.0	3	19-26	21.7
C.I. 4273-1	6	14-30	20.5	6	8-21	16.0
C.I. 4388	7	11-32	20.9	9	5-22	16.2
C.I.3906-1	4	6-35	21.5	3	14-20	16.3
Pasha C.I. 984	8	8-36	22.7	---	---	---
Kipper C.I. 1291	5	9-31	23.0	1	---	9.0
Hordeum vulgare B 227	3	22-25	23.3	9	7-24	16.2
Sublaxum C. I. 2231	4	18-33	23.7	---	---	---
(Vantage X Jet) Br.5209-7	8	19-33	25.7	3	21-29	24.3
Galore C.I. 7150	3	19-32	26.3	4	16-30	20.2
B. 193	5	20-36	28.0	2	8-10	9.0
C.I. 4148-1	2	29-33	33.0	---	---	---
Swan (Check)	6	12-35	23.0	5	9-15	12.4

Once the experiments on antibiosis were finished and the organdy cages removed, the progress of the colonies was observed. The English grain aphid was added to the aphid population by placing ten wingless adults on ten uninfested plants, one aphid per plant.

It was noted that greenbugs preferred the lower leaves and that they became gradually fewer in numbers as the plants grew older. The corn leaf aphid remained for the longest time, partly escaping the action of predators by living in the whorls of the plants. The English grain aphid did not build up a considerable population and was observed on the plants for a short time only, before it disappeared.

A few rose grass aphids Acyrthosiphon dirhodum (Walker) established themselves on the plants and infestations of winged greenbugs and corn leaf aphids were also observed.

However, none of the barley plants was killed or badly injured. Hence, it may be concluded that predators must exert an important natural control on populations of aphids.

Among the predators were four species of lady beetles (Coccinellidae), Hippodamia convergens Guerin, Coccinella transversoguttata Faldermann, Hippodamia tridecimpunctata tibialis (Say) and Adalia bipunctata (L.) present in large numbers in the plots. Some adult and larval syrphid flies (Syrphidae) and lacewings (Chrysopidae) were also observed.

CHAPTER VI

EFFECT ON FECUNDITY OF APHIDS OF REARING THEM ON ONE HOST PLANT AND TRANSFERRING THEM TO OTHER PLANTS

S. graminum, *R. maidis* and *M. avenae* were cultured during their nymphal lives on, and then transferred as adults to, each of Swan barley, Parkland barley, Selkirk wheat and Rodney oats, and their reproduction measured.

Tables XV, XIX and XXIII show the results of these tests. Average numbers of progeny produced per aphid were compared by "Student's" t test for unpaired data (Johnson, 1950). The other tables show the same data rearranged and pooled as required for further statistical analysis.

It was originally planned to infest twenty seedlings of each host, but in some cases this number was reduced by shortage of adequate aphids or seedlings, or by accidental damage caused to the roots of the plants from wires supporting the cages. Moreover, not all of the aphids which were placed on the second host stayed until the count of progeny was made; this further reduced the size of the samples. A few of the aphids might have been accidentally injured while transferring them. However, it is more likely that the reduction in numbers of aphids successfully established, especially when it was more marked, shows a certain unacceptability effect of the new host by the aphid.

Effect on fecundity of the greenbug

Table XV shows the results of tests which were conducted in the growth room during the Winter 1965/1966 and Spring 1966, at a temperature of 23°C.± 2.5°C.

Greenbug nymphs were more restless on wheat and adults reared to maturity were smaller in size, than on oats or barley.

Data shown in Table XV were statistically studied by analysis of variance (Table XVI). It is evident that fecundity of S. graminum was affected by the first host, on which it was reared during its nymphal life. It was influenced more by the second host, to which the adults were transferred and on which it actually reproduced.

In order to find out which were the first and second hosts affecting the fecundity of S. graminum, the average numbers of progeny produced per aphid were compared by the "Student's" t test in Tables XVII-XVIII.

Table XVII includes the data obtained when each cereal plant was used as first host. In the third column the greenbug appears to have a lower fecundity when reared on Selkirk wheat and Rodney oats, regardless of the hosts where actual reproduction took place. This is further supported by the greater reduction of aphids successfully established when Selkirk wheat and Rodney oats were the hosts the aphids were reared on, as shown in the first two columns.

Table XVIII shows the data obtained for each cereal plant when used as second host. It is evident that the greenbug fecundity was significantly reduced when reproducing on Selkirk wheat (also shown in Table XV), regardless of the host on which it was reared during its nymphal life.

There was no significant difference on the other three cereal plants. This evidence is further supported by the greater reduction of aphids successfully established on Selkirk wheat, compared to those established on the other three cereal plants.

Effect on fecundity of the corn leaf aphid

Results of tests are shown in Table XIX. They were made from September to December, 1966, in the growth cabinets where temperature was maintained at 21°C with a photoperiod set at 16 hours of light and 8 hours of darkness.

This aphid was reared on Selkirk wheat and Rodney oats with great difficulty. Adults were restless and the nymphs produced on both hosts were minute in size. Besides, the prereproductive period was prolonged for one day on Rodney oats and five to seven days on Selkirk wheat.

Statistical analysis of data shown in Table XIX is presented in Table XX. It is evident that both first and second hosts influenced the reproductive rate of *R. maidis*.

Table XXI shows that the number of progeny produced by the corn leaf aphid was significantly reduced when reared on Selkirk wheat and Rodney oats, being reduced most when reared on Rodney oats, regardless of the hosts on which the aphids later reproduced. This is further supported by the greatest reduction in numbers of aphids successfully established when reared on Rodney oats, as shown in the first two columns of Table XXI.

Similarly, the number of progeny produced by the aphids was greatly reduced on Selkirk wheat and Rodney oats, as indicated in

Table XXII (also shown in Table XIX). Again this reduction was most obvious on Rodney oats. The number of aphids successfully established was also reduced to the greatest extent on both Selkirk wheat and Rodney oats.

Effect on fecundity of the English grain aphid

Tests on fecundity of the English grain aphid were carried out in the growth cabinets under the same conditions and almost at the same time as those of the corn leaf aphid. Results are shown in Table XXIII.

M. avenae nymphs did not present any difficulty while being reared as they stayed readily on all four host plants. However, it was more difficult to remove them as adults from the first hosts, to which they appeared to be firmly attached by means of their beaks while feeding. Also, when placed on the second hosts they did not immediately settle down to feed and reproduce, possibly due to the previous disturbance caused to them.

An analysis of variance is shown in Table XXIV. It appears that the first hosts influenced reproduction of *M. avenae*, but not so the second hosts.

Table XXV indicates that reproduction was not significantly different when the aphid was reared on Swan barley and Selkirk wheat; it was significantly reduced when reared on Parkland barley, and it was increased on Rodney oats. Establishment was least successful on Swan barley.

Table XXVI shows that the aphid reproduced equally well on all four hosts, and establishment was least successful on Selkirk wheat.

If differences in numbers of progeny produced per aphid in

Table XXIII are also considered, results appear somewhat contradictory.

At this point there are two factors which may have influenced the fecundity of the English grain aphid. First, experiments with each first host and transfers to its four second hosts were made at one time, but this was not true for all different first hosts; this may explain the apparent reduction of number of progeny produced when the aphid was reared on Parkland barley (Table XXV), which in turn might have been influenced by unknown factors. Secondly, the behaviour of the English grain aphid when transferred to the second hosts, because it did not immediately settle down; hence reproduction may have started at different times. This behavioural factor might have affected similarly all of these experiments in the same way. The method might not be the most appropriate for this particular aphid; if counts were made eight or nine days later the effect of the second factor might be reduced.

Though there is no practical evidence in Tables XXIII-XXVI, it appears that none of these four host plants especially affects the rate of reproduction of M. avenae (as indirectly shown in Table XXVI), and, if any at all, Rodney oats may increase it (also indirectly shown in Table XXV). This would appear to be supported by the observed larger size of adults obtained on Rodney oats than on Swan barley, Selkirk wheat and Parkland barley.

TABLE XV

PROGENY PRODUCED BY WINGLESS ADULT GREENBUG REARED ON ONE HOST PLANT AND TRANSFERRED TO OTHER HOST PLANTS

First host	Second host	No. of aphids transferred	No. of aphids successfully established	No. of progeny produced per aphid in 6 days Range	Mean
Swan barley	Swan barley (check)	20	20	19-36	27.9
	Parkland barley	18	14	23-32	26.5
	Selkirk wheat	20	10	5-33	20.3*
	Rodney oats	18	17	21-37	27.1
Parkland barley	Swan barley	20	18	19-37	25.5
	Parkland barley (check)	14	13	19-36	27.4
	Selkirk wheat	19	14	5-36	19.2**
	Rodney oats	13	11	12-37	30.3
Selkirk wheat	Swan barley	15	5	15-27	23.8
	Parkland barley	20	14	18-32	25.1
	Selkirk wheat (check)	20	10	12-27	20.7
	Rodney oats	20	19	15-33	24.1
Rodney oats	Swan barley	20	14	13-30	22.6
	Parkland barley	20	16	19-30	24.1
	Selkirk wheat	20	9	16-28	20.9**
	Rodney oats (check)	20	15	21-31	25.3

* Means significantly different at 5% to corresponding check
** Means significantly different at 1% to corresponding check

TABLE XVI

STATISTICAL ANALYSIS OF PROGENY PRODUCED BY APTEROUS ADULT GREENBUG REARED ON ONE HOST PLANT AND TRANSFERRED TO OTHER PLANTS

First host	Second host		Aphids successfully established	Sum of progeny produced in 6 days
Swan barley	Swan barley		20	558
	Parkland barley		14	371
	Selkirk wheat		10	203
	Rodney oats		17	461
		Total =	61	1593
Parkland barley	Swan barley		18	459
	Parkland barley		13	356
	Selkirk wheat		14	269
	Rodney oats		11	333
		Total =	56	1417
Selkirk wheat	Swan barley		5	119
	Parkland barley		14	352
	Selkirk wheat		10	207
	Rodney oats		19	457
		Total =	48	1135
Rodney oats	Swan barley		14	316
	Parkland barley		16	387
	Selkirk wheat		9	188
	Rodney oats		15	379
		Total =	54	1270
	Swan barley		57	1452
	Parkland barley		57	1466
	Selkirk wheat		43	867
	Rodney oats		62	1630
		Total =	219	5415

Grand total = 5,415

Correction factor = $5,415^2$: 219 = 133,891

Total sum of squares = 141,155 - 133,891 = 7,264

First host sum of squares = 134,163 - 133,891 = 272

Second host sum of squares = 135,026 - 133,891 = 1,135

Source of Variation	S.S.	d.f.	Variance	F	5%	1%
Total	7,264	218				
First host	272	3	90.7	3.29*	2.65	3.88
Second host	1,135	3	378.3	13.71**	2.65	3.88
Residual	5,857	212	27.6			

* Significant at 5% level
** Significant at 1% level

TABLE XVII

EFFECT ON NUMBERS OF PROGENY PRODUCED BY APTEROUS ADULT GREENBUGS REARED DURING NYMPHAL LIFE ON FOUR DIFFERENT HOST PLANTS

Host	No. of adult aphids transferred to other hosts	No. of aphids successfully established	Av. no. of progeny produced per aphid in 6 days
Swan barley	76	61	26.1 a*
Parkland barley	66	56	25.3 ab
Selkirk wheat	75	48	23.6 b
Rodney oats	80	54	23.5 b

* Means followed by the same letter are not significantly different at 5%

TABLE XVIII

EFFECT ON NUMBERS OF PROGENY PRODUCED BY APTEROUS ADULT GREENBUGS ON FOUR HOST PLANTS REGARDLESS OF THE HOSTS ON WHICH THEY WERE PREVIOUSLY REARED

Host	No. of aphids transferred	No. of aphids successfully established	Av. no. of progeny produced per aphid in 6 days
Swan barley	75	57	25.5 a*
Parkland barley	72	57	25.7 a
Selkirk wheat	79	43	20.2 b
Rodney oats	71	62	26.3 a

* Means followed by the same letter are not significantly different at 5%

TABLE XIX

PROGENY PRODUCED BY WINGLESS ADULT CORN LEAF APHID REARED ON ONE HOST PLANT AND TRANSFERRED TO OTHER HOST PLANTS

First host	Second host	No. of aphids transferred	No. of aphids successfully established	No. of progeny produced per aphid in 6 days: Range	Mean
Swan barley	Swan barley (check)	20	19	14-35	24.5
	Parkland barley	20	15	17-32	24.9
	Selkirk wheat	20	8	3-15	7.5**
	Rodney oats	20	4	3-8	5.2**
Parkland barley	Swan barley	20	18	14-30	22.6
	Parkland barley (check)	20	20	13-30	20.5
	Selkirk wheat	20	9	5-24	11.8**
	Rodney oats	20	7	4-9	7.0**
Selkirk wheat	Swan barley	20	17	9-25	18.1**
	Parkland barley	18	13	5-26	14.4**
	Selkirk wheat (check)	20	14	1-14	7.2
	Rodney oats	20	10	1-13	6.4
Rodney oats	Swan barley	15	3	6-10	8.1
	Parkland barley	15	3	7-16	12.0
	Selkirk wheat	15	9	2-15	7.7
	Rodney oats (check)	15	3	3-7	5.3

** Means significantly different at 1% to corresponding check

TABLE XX

STATISTICAL ANALYSIS OF PROGENY PRODUCED BY APTEROUS ADULT CORN LEAF APHID REARED ON ONE HOST PLANT AND TRANSFERRED TO OTHER PLANTS

First host	Second host		Aphids successfully established	Sum of progeny produced in 6 days
Swan barley	Swan barley		19	465
	Parkland barley		15	374
	Selkirk wheat		8	60
	Rodney oats		4	21
		Total =	46	920
Parkland barley	Swan barley		18	406
	Parkland barley		20	410
	Selkirk wheat		9	106
	Rodney oats		7	49
		Total =	54	971
Selkirk wheat	Swan barley		17	307
	Parkland barley		13	187
	Selkirk wheat		14	101
	Rodney oats		10	64
		Total =	54	659
Rodney oats	Swan barley		3	26
	Parkland barley		3	36
	Selkirk wheat		9	69
	Rodney oats		3	16
		Total =	18	147
	Swan barley		57	1204
	Parkland barley		51	1007
	Selkirk wheat		40	336
	Rodney oats		24	150
		Total =	172	2697

Grand total = 2,697

Correction factor = 2697^2 : 172 = 42,290

Total sum of squares = 54,055 - 42,290 = 11,765

First host sum of squares = 45,102 - 42,290 = 2,812

Second host sum of squares = 49,074 - 42,290 = 6,784

Source of Variation	S.S.	d.f.	Variance	F	5%	1%
Total	11,765	171				
First host	2,812	3	937.3	71.28**	2.67	3.91
Second host	6,784	3	2,261.3	171.96**	2.67	3.91
Residual	2,169	165				

* Significant at 1% level

TABLE XXI

EFFECT ON NUMBERS OF PROGENY PRODUCED BY APTEROUS ADULT CORN LEAF APHIDS REARED DURING NYMPHAL LIFE ON FOUR DIFFERENT HOST PLANTS

Host	No. of adult aphids transferred to other hosts	No. of aphids successfully established	Av. no. of progeny produced per aphid in 6 days
Swan barley	80	46	20.0 a*
Parkland barley	80	54	18.0 a
Selkirk wheat	78	54	12.2 b
Rodney oats	60	18	8.2 c

* Means followed by the same letter are not significantly different at 1%

TABLE XXII

EFFECT ON NUMBERS OF PROGENY PRODUCED BY APTEROUS ADULT CORN LEAF APHIDS ON FOUR HOST PLANTS REGARDLESS OF THE HOSTS ON WHICH THEY WERE PREVIOUSLY REARED

Host	No. of aphids transferred	No. of aphids successfully established	Av. no. of progeny produced per aphid in 6 days
Swan barley	75	57	21.1 a*
Parkland barley	73	51	19.7 a
Selkirk wheat	75	40	8.4 b
Rodney oats	75	24	6.2 c

* Means followed by the same letter are not significantly different at 5%

TABLE XXIII

PROGENY PRODUCED BY WINGLESS ADULT ENGLISH GRAIN APHID REARED ON ONE HOST PLANT AND TRANSFERRED TO OTHER HOST PLANTS

First host	Second host	No. of aphids transferred	No. of aphids successfully established	No. of progeny produced per aphid in 6 days Range	Mean
Swan barley	Swan barley (check)	20	12	15-21	18.2
	Parkland barley	19	13	12-23	17.8
	Selkirk wheat	20	9	15-27	21.3*
	Rodney oats	19	11	8-19	14.6**
Parkland barley	Swan barley	20	17	7-19	12.9
	Parkland barley (check)	20	20	11-17	13.8
	Selkirk wheat	20	12	11-19	14.5
	Rodney oats	20	18	12-18	15.4*
Selkirk wheat	Swan barley	19	19	12-24	18.4
	Parkland barley	20	19	14-28	20.0**
	Selkirk wheat (check)	20	16	10-22	16.1
	Rodney oats	20	19	12-21	16.5
Rodney oats	Swan barley	20	18	8-25	19.8
	Parkland barley	19	17	14-25	20.1
	Selkirk wheat	20	15	14-27	19.7
	Rodney oats (check)	20	18	15-31	22.6

* Means significantly different at 5% to corresponding check
** Means significantly different at 1% to corresponding check

TABLE XXIV

STATISTICAL ANALYSIS OF PROGENY PRODUCED BY APTEROUS ADULT ENGLISH GRAIN APHID REARED ON ONE HOST PLANT AND TRANSFERRED TO OTHER PLANTS

First host	Second host		Aphids successfully established	Sum of progeny produced in 6 days
Swan barley	Swan barley		12	218
	Parkland barley		13	232
	Selkirk wheat		9	192
	Rodney oats		11	161
		Total =	45	803
Parkland barley	Swan barley		17	220
	Parkland barley		20	277
	Selkirk wheat		12	174
	Rodney oats		18	278
		Total =	67	949
Selkirk wheat	Swan barley		19	350
	Parkland barley		19	380
	Selkirk wheat		16	257
	Rodney oats		19	314
		Total =	73	1301
Rodney oats	Swan barley		18	357
	Parkland barley		17	342
	Selkirk wheat		15	296
	Rodney oats		18	407
		Total =	68	1402
	Swan barley		66	1145
	Parkland barley		69	1231
	Selkirk wheat		52	919
	Rodney oats		66	1160
		Total =	253	4455

Grand total = 4,455
Correction factor = $4,455^2$: 253 = 78,447
Total sum of squares = 82,923 - 78,447 = 4,476
First host sum of squares = 79,863 - 78,447 = 1,416
Second host sum of squares = 78,456 - 78,447 = 9

Source of Variation	S.S.	d.f.	Variance	F	5%	1%
Total	4,476	252				
First host	1,416	3	472.0	38.06**	2.64	3.87
Second host	9	3	3.0	0.24	2.64	3.87
Residual	3,051	246	12.4			

** Significant at 1% level

TABLE XXV

EFFECT ON NUMBERS OF PROGENY PRODUCED BY APTEROUS ADULT ENGLISH GRAIN APHIDS REARED DURING NYMPHAL LIFE ON FOUR DIFFERENT HOST PLANTS

Host	No. of adult aphids transferred to other hosts	No. of aphids successfully established	Av. no. of progeny produced per aphid in 6 days
Swan barley	78	45	17.8 a*
Parkland barley	80	67	14.2 b
Selkirk wheat	79	73	17.8 a
Rodney oats	79	68	20.6 c

* Means followed by the same letter are not significantly different at 1%

TABLE XXVI

EFFECT ON NUMBERS OF PROGENY PRODUCED BY APTEROUS ADULT ENGLISH GRAIN APHIDS ON FOUR HOST PLANTS REGARDLESS OF THE HOSTS ON WHICH THEY WERE PREVIOUSLY REARED

Host	No. of aphids transferred	No. of aphids successfully established	Av. no. of progeny produced per aphid in 6 days
Swan barley	79	66	17.3
Parkland barley	78	69	17.8
Selkirk wheat	80	52	17.7
Rodney oats	79	66	17.6

The numbers of progeny produced per aphid are not significantly different

CHAPTER VII

HOST PREFERENCE OF CEREAL APHIDS

S. graminum, *R. maidis* and *M. avenae* were allowed to choose host plants from among Swan barley, Parkland barley, Selkirk wheat and Rodney oats seedlings arranged in such a manner that each aphid could easily reach any variety by walking or flying (see Chapter III). Plants were also close enough to each other to permit the aphids to leave the first host and to move to another if the first one was not suitable.

The objectives of these experiments were primarily to find out if any possible difference in host preferences exists for the various aphid species, and also to find out if any possible difference in preferences exists for the two morphs, winged and wingless summer viviparae, because their means of moving are quite different: flight vs walking. However, the alate morphs could also reach other hosts by walking if their flying muscles became atrophied.

Nymphs were present in large numbers on the source plants and also on the test plants on which the adults were counted. Nymphs were allowed on the source because some of them would reach the adult stage while the experiment was in progress. Nevertheless, they were not considered in the data because some could have reached the hosts by walking from the source, especially the oldest ones at the time of counting. However they could also have been produced by the adults that were established early after the experiments began. Smaller nymphs could have shown a certain degree of establishment as a measure of reproduction on each host, but they could also have either walked by themselves shortly before the final counts, or have been progeny of a mother that left the host to move to some other just before the count.

Data were statistically analysed by the analysis of variance technique shown in Tables XXVII - XXIX. This permitted the finding of any possible different distribution of each aphid species on the hosts and possible different distribution of each morph. At the same time it removed the fact that all four replicates were not equidistant to the source, and that the numbers of winged and wingless adults may have differed greatly.

Host preference of the greenbug

It was mentioned in Chapter IV that the greenbug is especially destructive to young cereal plants. Here that same characteristic showed again, because the final count had been planned for five days after the introduction of the source plants, which already were badly damaged. The aphids moved quickly to the test plants and settled down in very large numbers on those of replicates II and III. On the third day the plants began to appear affected, and thus the final count was made the next day. However at that time it was already too late: the aphids had severely damaged and abandoned the Swan barley, Parkland barley and Rodney oats seedlings in replicates II and III (the closest to the source). Nevertheless, the count was made in replicates I and IV where all the plants were still healthy.

Data and statistical analysis are shown in Table XXVII. The greenbug showed no significant preference for any of the four host plants tested, nor did its two morphs significantly differ in their distribution on them. The distribution on the hosts was different between the replicates.

Host preference of the corn leaf aphid

Although the source plants were not watered during the experiment, they were heavily infested with aphids, and they appeared to be suitable enough for the wingless adults because a considerable number of them would not abandon the plants. On the third day the seedlings were cut and evenly spread on top of the soil of the source; this was done to make the aphids look for other hosts. The count of aphids was made five days after the heavily infested source was introduced.

Data are shown in Table XXVIII. The statistical analysis shows only a significantly different distribution of adult aphids on hosts. This difference was tested by "Student's" t test and is shown in the last column of the table. Significantly fewer numbers of adult aphids settled on oats and wheat, which may be considered as non-preference. There was no difference in preferences between the two morphs.

Host preference of the English grain aphid

This aphid produced many winged morphs as soon as the host plant conditions became less suitable. The latter was forced by withholding water from the heavily infested source plants. The winged aphids readily left the source and infested the host plants. However, the wingless females did not behave similarly and the source plants were cut and spread as mentioned in the preceding experiment.

The statistical analysis for the data shown in Table XXIX shows no special preference of _M. avenae_ for any of the hosts, and no preference differences for the morphs. The only real difference in the experiment is that the numbers of winged adult aphids surpassed the numbers of wingless ones.

TABLE XXVII

DATA AND STATISTICAL ANALYSIS ON NUMBERS OF SUMMER VIVIPARA GREENBUGS ALLOWED TO CHOOSE AMONG FOUR HOST PLANTS

Host	No. of winged adults					No. of wingless adults					Total no. of aphids	Mean
	Replicates					Replicates						
	I	II	III	IV	Total	I	II	III	IV	Total		
Swan barley	12	--	--	33	45	14	--	--	40	54	99	24.7
Parkland barley	35	--	--	9	44	30	--	--	18	48	92	23.0
Selkirk wheat	25	--	--	9	34	19	--	--	17	36	70	17.5
Rodney oats	16	--	--	13	29	21	--	--	23	44	73	18.2
	88	--	--	64	152	84	--	--	98	182	334	

Grand total = 334
Correction factor = 334^2 : 16 = 6,972
Total sum of squares = 8,310 - 6,972 = 1,338
Replicates sum of squares = 6,978 - 6,972 = 6
Hosts sum of squares = 7,123 - 6,972 = 151
Morphs sum of squares = 7,028 - 6,972 = 56
Hosts x Morphs s. s. = 7,205 - 6,792 - 151 - 56 = 26
Hosts x Replicates s. s. = 8,118 - 6,972 - 151 - 6 = 989

Source of Variation	S. S.	d.f.	Variance	F	5%	1%
Total	1,338	15				
Replicates	6	1	6.0	0.22	7.71	21.20
Hosts	151	3	50.3	1.83	6.59	16.69
Morphs	56	1	56.0	2.04	7.71	21.20
Hosts x Morphs	26	3	8.7	0.32	6.59	16.69
Hosts x Replicates	989	3	329.7	11.99*	6.59	16.69
Residual	110	4	27.5			

* Significant at 5% level

TABLE XXVIII

DATA AND STATISTICAL ANALYSIS ON NUMBERS OF SUMMER VIVIPARA CORN LEAF APHIDS ALLOWED TO CHOOSE AMONG FOUR HOST PLANTS

Host	No. of winged adults Replicates I	II	III	IV	Total	No. of wingless adults Replicates I	II	III	IV	Total	Total no. of aphids	Mean
Swan barley	34	29	53	34	150	28	31	38	16	113	263	32.9 a+
Parkland barley	10	99	37	15	161	14	19	19	18	70	231	28.9 ab
Selkirk wheat	17	17	11	8	53	7	9	17	9	42	95	11.9 b
Rodney oats	7	9	7	5	28	3	3	6	2	14	42	5.2 b
	68	154	108	62	392	52	62	80	45	239	631	

Grand total = 631
Correction factor = 631^2 : 32 = 12,443
Total sum of squares = 23,669 - 12,443 = 11,226
Replicates sum of squares = 13,481 - 12,443 = 1,038
Hosts sum of squares = 16,665 - 12,443 = 4,222
Morphs sum of squares = 13,174 - 12,443 = 731
Hosts x Morphs s. s. = 17,910 - 12,443 - 4,222 - 731 = 514
Hosts x Replicates s. s. = 19,868 - 12,443 - 4,222 - 1,038 = 2,165

Source of Variation	S. S.	d.f.	Variance	F	5%	1%
Total	11,226	31				
Replicates	1,038	3	346.2	1.70	3.49	5.95
Hosts	4,222	3	1,407.4	6.61**	3.49	5.95
Morphs	731	1	731.0	3.44	4.75	9.33
Hosts x Morphs	514	3	171.4	0.81	3.49	5.95
Hosts x Replicates	2,165	9	240.6	1.13	2.80	4.39
Residual	2,555	12	212.9			

+ Means followed by the same letter are not significantly different at 5%
** Significant at 1% level

TABLE XXIX

DATA AND STATISTICAL ANALYSIS ON NUMBERS OF SUMMER VIVIPARA ENGLISH GRAIN APHIDS ALLOWED TO CHOOSE AMONG FOUR HOST PLANTS

Host	No. of winged adults Replicates I	II	III	IV	Total	No. of wingless adults Replicates I	II	III	IV	Total	Total no. of aphids	Mean
Swan barley	7	22	8	25	62	12	3	5	5	25	87	10.9
Parkland barley	9	18	24	15	66	6	13	3	3	25	91	11.4
Selkirk wheat	5	25	11	13	54	6	7	3	3	19	73	9.1
Rodney oats	10	9	27	7	53	12	8	3	3	26	79	9.9
	31	74	70	60	235	36	31	14	14	95	330	

Grand total = 330
Correction factor = 330^2 : 32 = 3,403
Total sum of squares = 5,082 - 3,403 = 1,679
Replicates sum of squares = 3,506 - 3,403 = 103
Hosts sum of squares = 3,427 - 3,403 = 24
Morphs sum of squares = 4,016 - 3,403 = 613
Hosts x Morphs s. s. = 4,053 - 3,403 - 24 - 613 = 13
Hosts x Replicates s. s. = 3,832 - 3,403 - 24 - 103 = 302

Source of Variation	S. S.	d.f.	Variance	F	5%	1%
Total	1,679	31				
Replicates	103	3	34.2	0.66	3.49	5.95
Hosts	24	3	8.1	0.16	3.49	5.95
Morphs	613	1	612.5	11.77**	4.75	9.33
Hosts x Morphs	13	3	4.3	0.08	3.49	5.95
Hosts x Replicates	302	9	33.5	0.64	2.80	4.39
Residual	624	12	52.0			

** Significant at 1% level

CHAPTER VIII

SUMMARY AND CONCLUSIONS

This thesis deals with some relationships between the greenbug, *Schizaphis graminum* (Rondani), the corn leaf aphid, *Rhopalosiphum maidis* (Fitch) and the English grain aphid, *Macrosiphum avenae* (Fabricius), and varieties of barley, *Hordeum vulgare* L., wheat, *Triticum aestivum* L. and oats, *Avena sativa* L.

The effects of the three aphid species on Parkland barley, Selkirk wheat and Rodney oats at various stages of plant growth were studied in growth cabinets, and the following were revealed:

(1) *S. graminum* was the most destructive aphid on Parkland barley, because it killed the younger seedlings more quickly. *M. avenae* killed older plants more quickly and caused the greatest reductions in weight of kernels. *R. maidis* appeared to be the least harmful species of the three tested.

(2) *S. graminum* also killed the younger Selkirk wheat seedlings more quickly. For older plants *M. avenae* was as harmful as *S. graminum*, especially if reductions in the weight of kernels shown by both aphids is considered. *R. maidis* did not successfully establish on Selkirk wheat.

(3) On Rodney oats *S. graminum* was the most destructive; *M. avenae* was only capable of causing complete death of one age group of plants, though it did cause greater reduction in weight of kernels. *R. maidis* did not successfully establish on oats.

(4) Rodney oats plants survived longest (most tolerant) the attack of the aphids. The youngest plant groups of Parkland barley were killed more quickly than those of Selkirk wheat, but the reverse was true for the older age groups. The reduction of weight of kernels was greatest for Selkirk wheat, followed by Parkland barley and Rodney oats.

Seventeen varieties of barley that had previously shown some evidence of aphid resistance were tested in the field against the greenbug and the corn leaf aphid. Unfortunately, poor weather conditions ruined many of the replicates and thus only parts of the data were of use.

Experiments were done to evaluate the possible influence of change of hosts, including Swan barley, Parkland barley, Selkirk wheat and Rodney oats, on the reproduction of the aphid species mentioned above. The following observations were made:

(1) S. graminum appeared to have a lower fecundity when reared on Selkirk wheat and Rodney oats, regardless of the hosts on which later reproduction took place. It was also evident that greenbug fecundity was reduced when it reproduced on Selkirk wheat.

(2) The number of progeny produced by R. maidis was reduced when feeding on Rodney oats and Selkirk wheat, both when reared on oats and wheat and when transferred to them. This was most obvious on oats.

(3) It was not possible to draw any conclusions concerning the reproduction of M. avenae, possibly due to a behavioural factor.

Finally, the same aphids were allowed to make a free choice of hosts from among Swan barley, Parkland barley, Selkirk wheat and Rodney oats in the growth room. It was found that:

(1) Adult S. graminum showed no preference for the four hosts tested, nor did its two morphs, winged and wingless summer viviparae, differentially settle down on them.

(2) Adult R. maidis showed a preference for barley and a non-preference for oats and wheat; the winged and wingless females did not differ in their preferences.

(3) Adult M. avenae showed no special preference for any of the hosts. The alate and apterous summer viviparous morphs also showed no special preferences.

Hence, it may be concluded that S. graminum is the most harmful aphid for young cereal crop seedlings, and M. avenae for older plants on which it considerably reduces yields. This evidence is further supported by the fact that both aphids prefer equally well barley, wheat and oats, though the greenbug fecundity is lower on wheat. R. maidis proved to be the least harmful of the aphids tested, which is also supported by its reduced reproduction when confined to oats and wheat. It also shows a certain degree of non-preference for the same hosts. Barley is the host plant that appears more likely to be threatened by the attack of these three aphid species.

When there is a change of hosts aphid reproduction may be influenced as shown in the greenbug and the corn leaf aphid. This may be especially important in experimental techniques involving aphids.

However, all these conclusions must be interpreted in reference to the artificial conditions of the growth room and cabinets, as well as the aphids used. Factors such as temperature, other weather conditions, genetical background of the aphids, predators, parasites, aphid morphs and biotypes, and transmission of plant virus diseases may greatly influence similar experiments.

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