THE UNIVERSITY OF MANITOBA

FACTORS AFFECTING THE NUMBERS OF APHIDS ON GRAIN CROPS IN MANITOBA WITH OBSERVATIONS ON APHID PREDATORS AND PARASITES

by

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ABSTRACT

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Various biotic and abiotic factors prevented aphids on grain crops from reaching their potential on fields under observation in Manitoba in 1968 and 1969. These included wind, rain, predators, parasites and fungus disease. In some cases wind or rain or a combination of wind and rain with other factors caused population decline before plants ripened.

Laboratory studies on the effectiveness of the common lady beetle species found preying on aphids on grain crops in Manitoba revealed that *Hippodamia tredecimpunctata tibialis* and *H. convergens* were effective aphid predators. They had a high voracity and fecundity and they developed on all the five main aphid species studied. In field collections, the former made up 52% in 1968 and 62.4% in 1969 of all lady beetle species found, and the latter constituted 43.8% and 14.6%.

Surveys of aphid predators and parasites in the field

revealed that Coccinellids were the most abundant aphid predators followed by Syrphids and Chrysopids. The most commonly found primary parasites of aphids on grain crops were *Aphelinus mali*, *Aphidius avenaphis* and *Lysiphlebus testaceipes*. The effectiveness of primary parasites was reduced by the hyperparasites *Asaphes fletcheri*, *Pachyneuron siphonophorae*, *Charips* sp., *Lygocerus* sp., and *Alloxysta* sp.

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CHAPTER I

INTRODUCTION

"Aphids or plant lice are among the smallest most defenseless, and most preyed upon of all insects; yet because of their immense vitality and extraordinary fecundity, due to shortness of their life cycle and ability to reproduce parthenogenetically they cover the earth with an enormous assemblage of species and tons of individuals affecting nearly every kind of green plant." (Metcalf *et al*, 1962).

Aphids feed on the sap of plants attacking either leaves, twigs, fruits, or roots causing damage to plants as well as transmitting diseases from one plant to another. They would be a great deal more destructive to vegetation were it not for their numerous parasites, predators and pathogens. Detrimental effects of chemical applications to control insect pests have made it necessary to develop the integrated control concept to combat insect pests.

Integrated control is a program of pest regulation which makes the most efficient use of weather, natural predators, parasites, or pathogens and integrates them with artificial control methods if economic injury levels are threatened.

The Problem

The purpose of the study was threefold: (1) to determine to what extent abiotic factors prevented aphid populations from causing injury to wheat, oats and barley at Winnipeg, Manitoba, in 1968 and 1969; (2) to investigate which predators are most effective in controlling the important aphid species on grain crops, ornamentals and weeds in Manitoba; (3) to determine which species of parasites are found parasitizing aphid populations on grain crops, ornamentals and weeds in Manitoba.

Importance of the Study

Although knowledge of the continuity of the population dynamics of aphids and their complex of parasites, predators, and pathogens from area to area and year to year would be ideal, Smith (1966a) stated that, "knowledge of the short term population dynamics of one population cycle restricted to a single portion of an agricultural field is critical to the development of integrated control procedures to combat insect pests."

Proper utilization of the integrated control concept requires some conceptual models which can predict when aphid populations will reach economic thresholds. Conceptual models require a knowledge of the type of numerical changes occurring and the factors which determine these changes in numbers (Clarke et al, 1967).

It is important to have a knowledge of all the potential parasites and predators of aphids on grain crops, as well as their sources of alternate prey and host aphids, on other plants (Imperti, 1966d). A study of aphid parasites and predators in Winnipeg on grain crops, ornamentals, and weeds was attempted in 1968 and 1969.

Since the main predators of aphids on grain crops were a few species of coccinellids, a laboratory study was conducted to determine the relative effectiveness of the coccinellids in the laboratory, and how abundance of predators was related to numbers of aphids, and type of grain crop.

Organization of Thesis

The literature is reviewed in Chapter II. It covers: aphid population dynamics; relationships between aphids and their parasites in the field; relationships between aphids and their predators in the field, and aphid pathogens.

Chapter III explains the materials and methods used. Chapter IV includes the data and discussion on the population trends exhibited by aphids of economic importance on wheat, oats and barley in Manitoba. Chapter V includes data and discussion on the laboratory studies to determine the effectiveness (voracity, fecundity, and development rate) of the most important predators of grain aphids in Manitoba.

The results of studies on the important aphid-parasite and aphid-predator relationships on agricultural crops, ornamentals, and weeds in Manitoba are given in Chapter VI. Chapter VII contains the summary and conclusions.

CHAPTER II

REVIEW OF LITERATURE

Robinson and Hsu (1963) reported 11 species of aphids in Manitoba on grain crops: *Schizaphis graminum* (Rondani) (greenbug); *Macrosiphum avenae* (Fabricius) (English grain aphid); *Rhopalosiphum padi* (Linnaeus) (bird cherry oat aphid); *Rhopalosiphum maidis* (Fitch) (corn leaf aphid); *Metopolophium dirhodum* (Walker) (rose grass aphid); *Rhopalosiphum fitchii* (Sanderson) (apple grain aphid); *Sipha kurdjumovi* (Mordvilko) (quackgrass aphid); *Hyalopterus pruni* (Geoffroy) (mealy plum aphid); *Hysteroneura setariae* (Thomas)(rusty plum aphid); *Brachycolus tritici* Gillette (western wheat aphid); and *Forda olivacea* Rohwer (a root aphid on Graminae).

Oswald and Houston (1951) mentioned the first five of the above species as being associated with transmission of virus to grain crops in the United States. These five species were the important aphids found on wheat, oats, and barley at Winnipeg, Manitoba, in 1968 and 1969.

Medler (1962) stated that *S. graminum*, *M. avenae*, and *R. maidis* overwinter in the southern United States (Oklahoma, Kansas, Texas, Missouri) and migrate northward in the spring. Populations build up in the northern United States (and, it is assumed, Manitoba) from the migrants which settle and reproduce. Species such as R. padi migrate from overwintering areas in the south, and also overwinter locally (Medler, 1962). M. dirhodum overwinters locally on Rosa species, and it has not been reported as migrating from the south.

Johnson (1969) stated that: "Little is published about duration of single flights, the duration of the flying period of individual greenbugs, and the quantitative aspects of discharge at sources, and delivery at terminus. Nor are the conditions known that lead to prolonged flight as distinct from a succession of short flights involving a succession of generations which extend further and further northwards as the season advances". Taylor (1965) described the possible mechanics involved in aphid migrations in the central United States. He thought that S. graminum could endure prolonged flight if it fell from cold upper air into warm lower air such as a low level jet stream.

Hosts of the English grain aphid, M. avenae, included the exposed leaves and heads of oats, wheat and barley, and various grasses (Bruehl, 1961; Forbes, 1962; Adams and Drew, 1964a, 1964b; Wood, 1965; Apablaza, 1967). Apablaza (1967) found that the English grain aphid was the most destructive aphid on older plants, in the laboratory. Robinson and Hsu (1963) stated that some insecticides were applied in Manitoba in 1962 to prevent the English grain aphid from damaging wheat. The greenbug, S. graminum, was reported on 62 species of Graminae by Patch (1938). Peairs (1941), Bruehl (1961), Metcalf *et al* (1962) and Little (1963) reported that it was the most destructive aphid attacking grains in the United States. Apablaza (1967) found it to be the most harmful to young seedlings in the laboratory. He also found it reproduced equally well on wheat, oats and barley. Robinson and Hsu (1963) stated that chemical application to reduce high greenbug populations was required in Manitoba in 1962.

Normal amounts of rain fell in July and August, but the monthly meteorological summary for Winnipeg, June, 1962, shows that precipitation occurred on only six days and was 1.08 inches below the normal of 3.19 inches. No large amounts of precipitation occurred on any particular day. June 1962 also had the lowest mean monthly windspeed on record to that date, with no gale force winds. Aphid colonies probably developed rapidly in the early summer and persisted throughout the season.

The corn leaf aphid, *R. maidis*, prefers to feed on the whorls of barley (Bruehl, 1961; Adams and Drew, 1964b; Wells and MacDonald, 1961; Robinson and Hsu, 1963) while wheat and oats are less attractive (Wildermuth and Walter, 1932; Adams and Drew, 1964b; Apablaza, 1967). Apablaza (1967) found that the corn leaf aphid was the least harmful of the three species which he tested in the laboratory. Robinson and Hsu (1963) stated that many thousands of acres of barley were destroyed in western Canada in 1955 by the corn leaf aphid. *R. padi* is found on barley (Adams and Drew, 1964b; Green, 1966; Harper and Blakely, 1968), wheat (Adams and Drew, 1964b; Wood, 1965; Kieckhefer and Gustin, 1967) and oats (Forbes, 1962; Adams and Drew, 1964a).

The rose grass aphid, *M. dirhodum*, is found on orchard grass, oats and various grasses (Forbes, 1962; Green, 1966; Robinson and Bradley, 1968). It does not occur in the heads but prefers the exposed blades (Forbes, 1962; Green, 1966). The following chart shows the status of five species of aphids on three cereal crops in Manitoba, based on observations by Professor A. G. Robinson of the University of Manitoba, over the past 20 years.

STATUS OF FIVE SPECIES OF APHIDS
ON THREE CEREAL CROPS IN MANITOBA

	Wheat	Oats	Barley
Greenbug	xxx(1950) xx	xx	xx
English grain aphid	xx	xx	xx
Corn leaf aphid	x	x	xxx xx(1955)
Rose grass aphid	x	x	xx
Birdcherry oat aphid	xx	xx	xx

x Occasional or unsatisfactory development of aphid on plant
xx Normal development of aphid on plant
xxx Economic injury level and year in which it occurred.

Aphid Population Dynamics

Population dynamics is the study of the interrelated processes that govern change of numbers or age distribution of a species over a period of time. Clarke et al (1967) stated that the understanding of the population dynamics of a species required "knowledge of the kinds of numerical changes that occur in a population, analysis of the factors causing these changes, and the construction of a conceptual model that interrelates changes of abundance with their causes." Construction of conceptual models has been hampered by complexities of population sampling (Hafez, 1961; Van Emden et al, 1969), unknown numerical relationships between populations occurring on a sequence of host plants (Van Emden et al, 1969), polymorphism (Van Emden et al, 1969), long distance migrations (Hafez, 1961; Van Emden et al, 1969), overlapping generations (Hafez, 1961), confusion between aphids sucked dry by predators and exuviae of immature stages (Van Emden, 1969).

Population changes involve interspecific factors, as well as intraspecific factors due to the aphids themselves. Interspecific factors include fungus (Shands and Simpson, 1959; Hafez, 1961; Hughes, 1963; De Fluiter, 1966; and Van Emden et al, 1969), predators (Pimentel, 1961; Hafez, 1961; Forbes, 1962; De Fluiter, 1966; Hughes, 1963; Sluss, 1967; Way, 1967; and many other authors), parasites (Shands and Simpson, 1959; Hafez, 1961; Pimentel, 1961; Hughes, 1963;

De Fluiter, 1966; Van Emden *et al*, 1969 and many other authors), temperature affecting reproduction, development and survival (Hafez, 1961; Sun, 1965; Hagen and Sluss, 1966; Sluss, 1967; Harper and Blakely, 1968), temperature affecting flight (Freeman, 1945; Taylor, 1965), precipitation destroying aphids mechanically (Way and Banks, 1967), precipitation associated with fungus epizootic (Hafez, 1961), precipitation preventing flight (Hafez, 1961; Taylor, 1965), wind preventing aphid flight (Taylor, 1965), leaf conditioning (Sluss and Hagen, 1966; Sluss, 1967), ripening and maturing of host plants (Ito, 1960; Forbes, 1962; Green, 1966), and chemical and cultural control (De Fluiter, 1966). Intraspecific factors causing population changes include decrease in reproduction rate due to low plant metabolism (Mittler, 1958; Hughes, 1963; Way and Banks, 1967), emigration following maturation of fall migrants (Shands and Simpson, 1959), emigration due to drying of plants (Ito, 1960; Forbes, 1962; Hughes, 1963; Wyatt, 1965; Way and Banks, 1967; Van Emden *et al*, 1969), crawling away of third and fourth instar nymphs, and flying away of alate aphids (Apablaza, 1967; Way and Banks, 1967), redistribution on all plants in the field followed by emigration of alates from the field (Ito, 1960; Wyatt, 1965), and decreased survival when population reaches a certain density (Way, 1967; Way and Banks, 1968). This could be due to the above factors alone or by modification of their action by weather, host plant, and aphid populations.

Upon first arrival of aphids into the field and until the end of infestation the host plant influences all phases of the population dynamics (Kennedy and Stroyan, 1959; Auclair, 1963; Apablaza, 1967; Van Emden _et al_, 1969). De Fluiter (1966) stated that populations of aphids depend on host plant nutrition, attraction and suitability. It has been found by many authors that the period of increase of aphids occurs during tillering of cereal plants and reaches a peak at or before boot stage. After this, populations begin to decline as the plant matures (Forbes, 1962; Adams and Drew, 1964a, Green, 1966). Drying of plants finally forces all aphids to leave the plant.

Smith (1966) divided short term population dynamics into initiation, increase, crash and survival during unfavourable periods. Van Emden _et al_ (1969) divided the population ecology of _Myzus persicae_ (Sulzer) into initial aphid attack, development of infestation and decline of infestation.

Smith (1966) defined initiation as "the period of establishment of the aphid population in the area together with its predators, parasites, pathogens, and competitors. In unstable environments this may require a new colonization of an area by part of the complex. In permanent situations the population is the result of differential attrition during the previous unfavourable period."

Adams and Drew (1964a) in New Brunswick showed that initial numbers of *M. avenae* and *R. maidis* from 1959 and 1963 were not found until the middle of June when the oat crops were six inches high. Forbes (1962) found that populations of *M. avenae* and *M. dirhodum* first appeared on oats in British Columbia in the mid to late tillering stage. Green (1966) concluded that *M. avenae* and *M. dirhodum* population buildup on barley in Oregon were influenced by planting date. Smith (1966) stated that synchronization, sources of aphids and distance travelled by immigrants, and weather are the main factors to be considered in development of initial populations. Shands and Simpson (1959) found that numbers of aphids on potatoes at this point vary considerably because of weather. They found initial populations were influenced by time of spring migration, emergence of plants and size of initial infestation. Movement occurs from plant to plant in the field until all plants in the field support one or more aphids, after which populations build up on individual plants (Shands and Simpson, 1959; Ito, 1960; Wyatt, 1965). Hughes (1963) found initial populations had high reproductive rates, suffered no starvation, and showed little emigration, parasitism, or fungus disease.

Smith (1966) defined increase as "the period when conditions are most favourable to the aphids and without the intervention of outside factors the aphid numbers would increase almost geometrically." In the laboratory it was shown by Apablaza (1967) that one aphid could destroy a plant in 20 to 60 days, depending on aphid species, cereal species, and stage of growth of the plant when the aphid was placed on it. Development of peak populations is usually related to host plant condition and type, soluble nitrogen and carbohydrate content, osmotic pressure of sap, and pH levels (Van Emden et al, 1969). Assessment of the actual part the host plant plays in aphid population dynamics is limited by the complex interaction of plant physiological factors (Van Emden et al, 1969). The important factors to be considered during the period of increase are the balance between voracity of aphidophagous species and reproduction rate of the aphids (Imperti, 1966a; Van Emden, 1966), weather (Hodek, 1966b), type of plant and its maturation (Bombosch, 1966; Van Emden et al, 1969), original pattern of infestation (Way, 1966), leaf conditioning (Sluss and Hagen, 1966; Way, 1966), rate and pattern of growth of host plant (Way, 1966), and selectivity and maximum consumption of aphids by predators (Yakhontov, 1966). Adams and Drew (1964a) found that peak numbers of M. avenae on oats were 674, 7, and 39 per 100 plants in 1959, 1962, and 1963 respectively, before panicles emerged from the sheaths. Wells and McDonald (1961) found some damage due to peak numbers of R. maidis on early stages of barley. Green (1966) found a peak population of M. avenae in mid July in Oregon. Large populations of M. dirhodum occurred in later stages of barley development and fluctuated between peak levels for a month. Shands and Simpson (1959) observed "explosive" population buildup on individual plants after all plants in the field were infested with at least one aphid each.

Smith (1966) defined crash or decline of aphid infestation as "the checking of the rapid rise of aphid population so that numbers are depressed to low levels or exterminated locally." The combination of these factors varies from place to place, and year to year (Shands and Simpson, 1959; Sluss and Hagen, 1966). Adams and Drew (1964a) found that M. avenae and R. maidis left the plant by emigration, as soon as the oat panicles emerged from the sheaths. They did not reproduce before emigrating. Forbes (1962) found increasing numbers of emigrating alates of M. avenae and M. dirhodum as the oats ripened. All aphids left when the plants matured. Factors associated with population decline were coccinellid, syrphid, and chrysopid predators, and parasites. A peak population of 47×10^6 aphids per acre was calculated during one season, but it did not reach an economic injury level. This was due to aphid densities not being maintained for a long period because of predators, parasites, and drying of host plant soon after peak. Two weeks after the peak population occurred the oats dried, and aphids were forced to leave the plants.

Aphid Parasite Relationships

The ichneumonoid families Aphidiidae and Aphelinidae contain the most important aphid parasites. Hagen and Van Den Bosch (1968) divided hymenopterous parasites into two groups, primary parasites and hyperparasites. Hagen and Van Den Bosch (1968) divided the hyperparasites into 3 superfamilies; Chalcidoidea, Proctotrupoidea, and Cynipoidea. Parasites also occur on the main aphid predators, and one family of aphid parasites, Cecidomyiidae belongs in the order Diptera.

If the first or second instar of an aphid is parasitized it dies before maturing. If later instars are parasitized some nymphs are produced before the death of the adult, but fecundity is reduced.

Detection of the aphid host may occur by antennal contact (Wheeler, 1923; Spencer, 1926; Vevai, 1942; Way _et al_, 1954; Schlinger and Hall, 1959; Sekhar, 1960) or odour from aphids or their honeydew (Schlinger and Hall, 1961). All aphid stages are attacked, but intermediate stages are preferred (Hagen and Van Den Bosch, 1968). Griffiths (1960) stated that the oviposition behaviour depends on the parasites' age, nutrition, temperature, light, humidity, presence of suitable odour, and hosts of the right shape and activity. Webster (1909) described the act of oviposition, and stated that the preferred oviposition site is the area between the aphids' cornicles.

Schlinger and Hall (1960) found three larval stages for the parasite _Praon palitans_ Muesebeck. The aphid appears normal up to the third day after oviposition by the adult parasite. On the fourth day the larva becomes active and begins to consume the entire contents of the aphid. The aphid becomes inactive and grips the leaf. Before the aphid dies the parasite larva chews a slit in the ventral surface of the aphid, spins a cocoon, and pupates. The silk from the cocoon adheres to the plant substrate through the slit and fastens the aphid to its host plant. The parasitized aphid is now called a "mummy" (Spencer, 1926). After pupation the adult parasite chews its way out of the aphid with its mandibles if the humidity is favourable (Schlinger and Hall, 1960). Adults feed on honeydew (Hagen and Van Den Bosch, 1968).

Spencer (1926), Schlinger (1960), and Stary (1962, 1966) thought that parasites of dioecious (two host plants) aphids diapause primarily on the primary host plants so that synchronization of aphid, plant host, and parasite is more efficient.

Hille Ris Lambers (1950) stated that the evolution of aphids and their host plants is so closely associated that plant hosts of aphids could be utilized in aphid classification. Similarly aphids and their parasites are so closely associated that Mackauer (1965) stated that "parallel evolution" has occurred between aphids and their parasites. Stary (1964) believes that habitat is the most important feature in the host specificity of aphidiid and aphelinid parasites. He listed many of the habitat associations of many aphids and their aphidiid parasites (Stary, 1964, 1966). Sekhar (1960) discovered that host plant and aphid species may influence aphid acceptance by the parasite. Doutt (1959) described the chain of events which determined host specificity. These were finding host habitat, finding the aphid host in its habitat, accepting host, and host suitability. Salt (1938) defined a suitable host as one in which the parasitoid can produce fertile offspring. Flanders (1953) suggested that conditions inside the aphid's body determine which aphid is a suitable host for the parasite, resulting in adequate or inadequate parasitism. He defined an inadequate aphid host-parasite relationship as "occasional, physiologically incomplete or ecologically incomplete." Salt (1938) listed the known causes of host unsuitability. Griffiths (1960) found that encapsulation of aphidiid eggs occurred in some aphid species. Schlinger and Hall (1960) and Sekhar (1960) observed many cases of parasites failing to emerge from parasitized aphids.

Various aphid parasites have been found associated with aphids on grain crops: *Lysiphlebus testaciepes* parasitizing *S. graminum* in Kansas (Hunter, 1909), *Aphelinus asychis* parasitizing *S. graminum* in Canada (Richardson and Westdal, 1965). Hagen and Van Den Bosch (1968) stated that *Aphelinus* sp. parasitized aphids in low vegetation which belong to the genera *Acyrthosiphon*, *Aphis*, *Lipaphis*,