PEA APHID, *ACYRTHOSIPHON PISUM* (HARRIS), POPULATIONS ON CULTIVARS OF FIELD PEAS IN MANITOBA AND THEIR EFFECTS ON PEA YIELD

BY

JULIANA JUDY SOROKA

A thesis

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ABSTRACT

Pea Aphid, Acyrthosiphon pisum (Harris), Populations on Cultivars of Field Peas in Manitoba and Their Effects on Pea Yield

by

Juliana Judy Soroka

Major Advisor: Dr. Patricia A. Mackay

The research for this project was undertaken from 1984 to 1987. Natural infestations of pea aphids, Acyrthosiphon pisum (Harris), were measured throughout the summer on five (1984) or six (1985, 1986) cultivars of field peas in small field plots near Glenlea, Manitoba. Starting from equal numbers of pea aphids per cage, in 1986 pea aphid populations were also monitored in 1 m^3 field cages which contained plants of one of these six field pea cultivars. Throughout the summers of 1985 and 1986 pea aphids were also sampled in a total of nine Century, four Trapper and two Triumph commercial pea fields in several regions across the province.

In all of these tests, pea aphid population growth patterns were similar among cultivars. Aphid numbers rose from low levels during the vegetative to blooming stages of plant growth in mid-July, peaked in late July or early August as pods developed and matured, and declined rapidly by mid- to late August as pea plants senesced. However, numbers

of pea aphids at the time of population peak differed consistently and significantly with the cultivar upon which they grew. Peak numbers of pea aphids were larger on Triumph or Trapper plants than they were on Century or Tipu plants. In commercial fields, populations of pea aphids rose more rapidly on Trapper than they did on Century or Triumph plants.

In field plots seed weight was the yield component most sensitive to aphid feeding. Triumph had significantly lower seed yields in infested than in control subplots in two out of three years. Seed weight was significantly reduced in infested subplots of Tara peas in one year. Because aphid numbers were low and generally occurred later than at flowering or pod initiation in Century peas, no yield losses due to pea aphids occurred in this cultivar in any of the tests. However, linear regression of seed weight over aphid density indicated that, of the cultivars tested, Century is most susceptible to increasing aphid numbers. Trapper seed weight was least related to aphid density despite the relatively high numbers of pea aphids occurring on this cultivar.

In laboratory studies pea aphids had the greatest intrinsic rates of natural increase, r_m, on the cultivar Trapper and the smallest on the cultivars Tipu and Century. Ten days after infestation, the most antixenosis resistance was expressed by the cultivar Tipu, and the least by Triumph. After 20 days, Triumph still was most preferred by the aphid. Trapper appeared somewhat tolerant of the effects of pea aphid feeding.

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CHAPTER 1

INTRODUCTION

1.1 The Problem

With declining Canadian Wheat Board payments to producers over the last several years, prairie farmers have increased production of crops not marketed by the Board (Anonymous, 1984a). One such crop is field peas, Pisum sativum L., which has quadrupled in area of production in Manitoba in the last 10 years (Anonymous, 1985a, 1987a).

The main insect pest of field peas in Manitoba is the pea aphid, Acyrthosiphon pisum (Harris) (Anonymous, 1986). In Manitoba, economic thresholds have been established for this pest (Maiteki and Lamb, 1985a), but these were determined only for the commonly grown cultivar Century. Several new field pea cultivars have recently been released that outyield Century (Ali-Khan, 1973, 1978, 1980, 1982). Increased pea aphid densities have been reported on one of these newer cultivars (Maiteki et al., 1986), and there is speculation that aphid control is more likely to be required on cultivars sustaining high aphid populations (Lamb and Maiteki, 1985). However, no research has been conducted comparing pea aphid densities and their impact on various pea cultivars in Manitoba.

1.2 Objectives of the Study

The objectives of this research project were:

1. To determine if different field pea cultivars consistently support different densities of pea aphids in Manitoba pea fields.

2. To determine if there are any differences in cultivar reaction to pea aphid feeding.

3. To determine the bases or mechanisms of differential reactions or resistance of the cultivars.

1.3 Benefits of the Research

The occurrence of different pea aphid densities on different cultivars suggests that aphid resistance factors may be present in some pea cultivars. Host plant resistance represents one of the most cost effective means of pest control (Horber, 1972), and examination of the bases for variable aphid densities could disclose sources of resistance suitable for incorporation into the genomes of new cultivars. Many examples of garden peas with varying degrees of resistance to pea aphid have been found (Searls, 1932; Maltais, 1949; Cartier, 1963; Bintcliffe and Wratten, 1980; Bieri et al., 1983). At present pea aphid control in Manitoba is based entirely on pesticide application (Anonymous, 1986). Utilization of aphid resistant pea cultivars could result in substantial savings in production costs for prairie farmers.

1.4 Thesis Organization

This thesis is a report of the research carried out in growers' fields throughout south central Manitoba, in small field plots at the University of Manitoba's Glenlea Research Station, and in a controlled environment chamber at the University of Manitoba, Winnipeg, from May 1984 to June 1987.

Chapter 2 is a general review of the literature relevant to the research. Chapter 3 is a detailed presentation of the research project organized into four sections, each describing one aspect of the research and written in the style of manuscripts suitable for submission to scientific journals. Chapter 4 is an overall discussion of the research undertaken, and Chapter 5 summarizes the work and the conclusions drawn from it.

CHAPTER 2

LITERATURE REVIEW

2.1 Field Pea Production in Manitoba

2.1.1 Use and Importance of Field Peas

Field peas, P. sativum, are an annual pulse or edible grain legume crop. The main use of field peas in Canada is in split pea and puree soup manufacture. On the prairies, dried peas are also used to balance low-protein animal feeds (Anonymous, 1984b). To a much lesser extent, protein isolate, pea fibre and purified pea starch are also made from field peas (Nickel, 1986).

Recently, a large export market has been developed for Canadian field peas, and approximately three quarters of the Canadian crop is now exported as whole or split peas (Ali-Khan and Zimmer, 1989). Canadian field peas for human consumption are exported worldwide, reaching markets in India, Britain, Cuba, Columbia and Venezuela, among others. In 1986 the European Economic Community purchased significant quantities of Manitoba field peas for animal feed (F. Baudette, Roy Legumex Inc., St. Jean, MB, personal communication). In some years, depending on markets, premiums may be paid to producers of large-seeded peas (K. Lyons, Newfield Seeds, Nipawin, SK, personal communication).

Field pea production in Canada is centered in the three prairie provinces, with Manitoba producing about 65% of the total Canadian harvest (Anonymous, 1984a). The area sown to peas in Manitoba increased steadily from 15,400 ha in 1976, with a cash value of $4.7 million (Anonymous, 1985a), to 64,800 ha in 1986, with a cash value of $22.1

million (Anonymous, 1987a). In 1985 the crop ranked eighth in total crop value to Manitoba farmers (Anonymous, 1985a).

2.1.2 Field Pea Agronomy

Field peas are a cool season crop similar to wheat in days to maturity; therefore, the crop can be grown in most agricultural parts of the province (Anonymous, 1977). The principal production areas are located along and adjacent to the Red River Valley, but expansion of pea production to the north-west and Interlake regions of Manitoba has occurred (J. Rogalsky, Manitoba Dept. of Agriculture, Winnipeg, MB, personal communication).

Young pea seedlings are comparatively frost hardy (Anonymous, 1977) because they can regenerate from axillary buds below the soil surface. Thus early planting is advised (Anonymous, 1985b). Planting after May 25 is not recommended, because high temperatures, especially if they occur before full bloom, may decrease the number of pods, seed size, and yield (Fletcher et al., 1965; Nonnecke et al., 1971).

Seed inoculation with specific Rhizobium nodule-forming bacteria is advised (Anonymous, 1985b). Nitrogen fertilization is not recommended, for it may interfere with nitrogen-fixing Rhizobium ssp. (Salisbury and Ross, 1978), but field peas respond well to phosphorus (Gubbels et al., 1982), potassium, and sulphur fertilization (Anonymous, 1985b) where deficiencies occur.

Field peas are poor competitors with weeds, and prompt weed control is essential for maximum yields (Anonymous, 1977). Aschochyta blight caused by the fungus Mycosphaerella pinodes (Berkeley and Bloxam) Vest. is the most common disease of field peas in western

Canada (Zimmer, 1978; Martens et al., 1984). In some years bacterial blight and root rots may also damage pea plants (Martens et al., 1984). Planting peas once in a five year crop rotation and the use of pedigreed seed that has been treated with an appropriate fungicide are recommended to minimize losses from disease (Anonymous, 1977).

The pea aphid, A. pisum, is the most important insect pest in Manitoba pea fields (Lamb and Maiteki, 1985). Threshold levels of this insect in Manitoba in Century field peas are 2 to 3 aphids per 20 cm plant tip at flowering (Maiteki and Lamb, 1985a). Recommended insecticides for A. pisum control in pea fields are dimethoate at 204 g a.i./ha or malathion at 700 g a.i./ha (Smith et al., 1986).

Peas are harvested when they are mature and hard in the pod (Anonymous, 1977). Delayed harvesting may result in excessive shelling (Ali-Khan and Zimmer, 1989), and seed loss through lodging, germination, or decay in the field (Johnston and Sanderson, 1975), as well as reduced cooking quality (Gubbels et al., 1985). Green peas are susceptible to bleaching and should be harvested early, using a recommended dessicant if necessary (Anonymous, 1984b).

2.1.3 Field Pea Cultivars

Yellow-seeded cultivars are preferred for the soup industry (Anonymous, 1977). Century, Tara, and Tipu are yellow-seeded field pea cultivars recommended in Manitoba for soup production (Anonymous, 1982). Of these, the large-seeded Century, licenced in 1960, is the most popular cultivar grown in Manitoba (Anonymous, 1984b), with an average yield of 2,416 kg/ha in four years of tests in the province (Anonymous, 1986). Tara, licenced in 1978, is a medium-seeded dimpled

cultivar, with powdery mildew resistance and average yields 18% greater than those of Century (Ali-Khan, 1978). Tipu, a large-seeded cultivar licenced in 1985, is a semi-leafless pea possessing normal stipules but with leaflets reduced to tendrils. Similar in yield to Century, Tipu is superior in standing ability, has more uniform drying characteristics than Century (Ali-Khan, 1986), and the canopy has good insecticide penetration properties (Anonymous, 1987b).

Other field pea cultivars grown are Trapper, Lenca, and Triumph. Trapper, licenced in 1970, has small, yellow seeds and is commonly grown for livestock meal; it is the second most commonly grown field pea in Manitoba (Anonymous, 1984b). Lenca is a medium-sized yellow-seeded pea licenced in 1979 for the soup trade. It is not currently recommended for Manitoba production but it is well adapted to eastern Canada, where it outyielded Century by 19% in co-operative tests (Ali-Khan, 1980). Finally, Triumph is a large-seeded green pea also used in the soup industry and the only green coloured cultivar recommended in Manitoba (Anonymous, 1986). Triumph is higher yielding than Century but is more susceptible to weathering and bleaching (Anonymous, 1984b).

Although most of the more recently released field pea cultivars outyield Century, no quantitative studies have been conducted to determine comparative insect infestation levels on these cultivars or to investigate effects of the aphid on different pea cultivars.

2.2 The Pea Aphid

2.2.1 Geographical Distribution, Life Cycle, and Biology

The pea aphid, A. pisum, is cosmopolitan in distribution, occurring in every continent except Antarctica (Eastop, 1966, 1971). Of

Palaearctic origin (Blackman and Eastop, 1985), it is thought to have been introduced to North America from Europe with clover and/or peas in the second half of the nineteenth century (Folsom, 1909), and was first reported in Illinois in 1878 (Davis, 1915). Near the turn of the century the aphid was found near Ottawa, Ontario (Johnson, 1900); this is the first report of its presence in Canada. It is now widely distributed in Canada, ranging from the Atlantic to Pacific coasts in areas with a temperate climate (Mackauer, 1971). It has been collected as far north as Churchill, Manitoba (58°47′N) (Robinson, 1979).

In Canada, the pea aphid is holocyclic or sexually reproductive, overwintering as a diploid egg on leaves and stems of alfalfa, clovers, and perennial wild legumes (Harper, 1975). The fundatrix or stem-mother, which emerges from the egg in the spring, parthenogenetically and viviparously produces a generation of daughters on the overwintering host. The daughters in turn parthenogenetically and viviparously produce apterous or alate (wingless or winged) female progeny. Alatae are produced in response to the stimuli of declining host quality (Kenten, 1955; Sutherland, 1969a; Kennedy and Forsbrooke, 1972), and physical contact or crowding (Hille Ris Lambers, 1966; Sutherland, 1969b); their production is also modified by maternal age effects (Mackay and Lamb, 1979) and genetic differences among populations (Lamb and Mackay, 1979). The alate aphids migrate to other hosts, including annual legumes such as field peas, thus ensuring a wide distribution (Cooke, 1963). On the summer hosts, many generations of predominantly apterous females are parthenogenetically and viviparously produced. In the autumn reduced photoperiod and declining temperatures (Kenten, 1955; Lees, 1966; Lamb and Pointing, 1972; Ward

et al., 1984) stimulate parthenogenetic females to produce a single sexual generation composed of oviparae or sexual females and males. These sexualss mate and the oviparae lay eggs on the winter host, thus completing the life cycle (Lees, 1961).

A clone is understood to be the offspring produced through parthenogenesis by a single fundatrix and any subsequent viviparous generations (Mackauer, 1973). Thus the clonal descendents of a single fundatrix show little variability since they are genetically identical (Blackman, 1979), and, if subjected to unchanging environments, tend to remain constant over many generations. Cartier (1957) found in the laboratory that two pea aphid clones maintained stable but different mean adult weights over 44 generations. However, pea aphid fundatrices are the products of fertilized eggs, and there may be considerable genetic heterogeneity among them (Lees, 1966; Neiman, 1971). Field populations are generally composed of descendents of many fundatrices, that is, made up of many clones. The biological responses of single clones are not necessarily the same as those of the population as a whole (Lamb and Mackay, 1983; Subasinghe, 1983).

The six main pea aphid morphs -- fundatrix, apterous or alate vivipara, apterous ovipara, and apterous or alate male -- vary somewhat in appearance, notably in the presence or absence of wings and in body shape and size. The general body form in both winged and wingless morphs is elongate and fusiform. Average body dimensions of alatae are 4.5 by 1.5 mm, while apterae are about 5 mm by 1.6 mm (Folsom, 1909). In general, all morphs are light to dark green in colour. Pea aphid eyes are red and prominent, and antennae are lighter coloured than the body. Joints are darker than the rest of the long conspicuous legs

(Folsom, 1909). Davis (1915) gives a complete description of pea aphid morphs in North America.

In Europe, the pea aphid occurs as a green and a red form (Markkula, 1963). Harper et al. (1978) reported only the green form of A. pisum occurring in North America. However, the red form was collected from alfalfa in the field in Maryland in 1979 and subsequent years (Kugler and Ratcliffe, 1983). The potential of the pea aphid red form as a pest in North America may be greater than that of the green form. This type varies significantly from the green form in such biological attributes as fecundity, total number of alatae produced, searching behaviour (Lowe and Taylor, 1964), response to disturbance (Müller, 1983), and response to alfalfa cultivars (Lowe and Taylor, 1964).

The pea aphid has four nymphal instars (Folsom, 1909; Davis, 1915). Temperature is one of the principal factors affecting the duration of development from birth to adult (Kilian and Nielson, 1971; Hutchison and Hogg, 1984). Temperature thresholds for development of each instar vary with location (Campbell et al., 1974); however, Lamb et al. (1987) found that variation in developmental parameters may be greater among clones within populations than among populations collected from distant locations. Minimum and maximum developmental thresholds are about 2.4°C (Hutchison and Hogg, 1984) and 25° to 30°C (Siddiqui et al., 1973), respectively. There appear to be no deleterious effects on development of A. pisum in temperature ranges from 10° to 26°C (Campbell and Mackauer, 1975; Bieri et al., 1983).

Length of pre-reproductive period varies with degree of temperature fluctuation (Siddiqui et al., 1973), aphid clone (Frazer,

1972), alary morph (Hutchison and Hogg, 1984), and host plant (Mackauer, 1973; Bieri et al., 1983). Times from birth to adult in the laboratory at 19°-20°C vary from 6.2 days for aphids feeding on faba bean (Frazer, 1972), to 7.6 days for those feeding on alfalfa (Campbell and Mackauer, 1975), to 8.3 days for those feeding on peas (Hutchison and Hogg, 1984). Time from birth to reproduction was reported to be 8.4 days (Siddiqui et al., 1973) and 9.0 days (Cartier, 1960) for aphids feeding on pea cultivars. Harrington (1941) reported a 6.6 day period to reach adult status and a 7.4 day period to achieve reproductive ability for the pea aphid on a pea cultivar. In the field, an aphid clone from Kamloops, British Columbia, had a mean pre-reproductive period of 12.3 days feeding on alfalfa (Campbell and Mackauer, 1977). In Wisconsin, time to first reproduction of the pea aphid grown on alfalfa out of doors was 12.5 days for spring apterae and 7.5 days for apterae monitored in the summer (Hutchison and Hogg, 1984).

Fecundity also varies with temperature, with a maximum number of nymphs produced at about 15°C (Siddiqui et al., 1973; Bieri et al., 1983). Fecundity of A. pisum on a pea cultivar near Lennoxville, Quebec, was 66 nymphs at mean August temperatures of 16.5°C and 35 nymphs at mean October temperatures of 12.8°C (Sharma et al., 1974). Fecundity also varies with photoperiod (Sharma et al., 1973), morph (Mackay and Wellington, 1975), aphid clone, and host plant. Markkula and Roukka (1970) reported four pea aphid clones to have 80 to 100 progeny per female on two pea cultivars, and less than 10 per female nymphs each on red clover, while two other clones exhibited the opposite trend in fecundity. These authors also reported average numbers of descendents of one pea aphid clone varying from fewer than

five to about 50 per female on 16 different pea cultivars (Markkula and Roukka, 1971).

Under laboratory conditions reproductive rate increases rapidly to a maximum, which occurs about one third of the way through the reproductive period, and then gradually declines as adults age (Hutchison and Hogg, 1984). The post-reproductive period is extremely variable in length (Campbell and Mackauer, 1977). At a constant temperature of 19.7°C , an A. pisum clone growing on alfalfa had a mean reproductive period of 19.4 days, a post-reproductive period of 9.8 days, and a lifespan of 38.2 days (Campbell and Mackauer, 1977).

The number of generations of pea aphid in the field varies from 14 to 28 in California (Cooke, 1963); 13 generations per year were recorded in Indiana (Davis, 1915), and 6 or 7 generations in the northerly latitudes of Finland (Markkula, 1963). In Wisconsin, A. pisum produces 7 to 8 generations a year on peas in late spring and summer (Harrington, 1941).

Differences in life cycle, growth rates, fecundity and longevity on various host plants have led to the recognition of several biotypes or physiological races of A. pisum (Cartier, 1957, 1959, 1963; Neiman, 1971; Kilian and Nielson, 1971; Frazer, 1972; Mackauer, 1973; Auclair and Srivastava, 1977; Webster and Inayatullah, 1985). Neiman (1971) tested 34 parthenogenetic clones of pea aphid and assigned them to eight biotypes and two feeding complexes on the basis of feeding response. Populations from warmer U.S. regions were found to withstand higher temperatures than populations from cooler regions (Kilian and Nielson, 1971).