ECONOMIC INJURY LEVELS AND FEEDING STUDIES FOR THE POTATO FLEA BEETLE, *Epitrix cucumeris* (Harris), IN MANITOBA

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Stephen F. Pernal

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

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Dedicated to my parents,

Nan Barton

and

Andrew Bolesław Pernal

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University of Manitoba, 1992

Economic Injury Levels and Feeding Studies

for *Epitrix cucumeris* (Harris) in Manitoba

Major Professor: N. J. Holliday

ABSTRACT

In 1989 and 1990, cv. Russet Burbank potato plants were grown in cages in field plots, and densities of potato flea beetles, *Epitrix cucumeris* (Harris), and Colorado potato beetles, *Leptinotarsa decemlineata* (Say), were introduced in different multiples of naturally occurring field densities. Colorado potato beetles were introduced only in the early part of the growing season, but potato flea beetles were introduced for the duration of the season. Numbers of feeding punctures per leaflet were counted in the lower, middle, upper and upper non-terminal strata of plants. The yield of tubers was weighed, graded and examined for common scab, *Streptomyces scabies* (Thaxter).

Without early season injury by Colorado potato beetle, plants had no yield loss up to 290 flea beetles per plant; above this density, yield was inversely proportional to flea beetle density. The level of economic damage for these plants ranged between 0.43-1.87%, equivalent to a peak density of 300-335 flea beetles per plant. For plants which had sustained early season Colorado potato beetle injury, yield loss was linear and inversely proportional to flea beetle density over the entire response. For these plants, the level of economic damage ranged between 0.40-1.88%, equivalent to a peak density of only 4-19 potato flea beetles per plant.

Behavioral models were used to describe the spatial and temporal switching pattern of flea beetle feeding. Beetles changed their preferred site of feeding from lower parts of the plant to upper regions as the growing season progressed. High densities of flea beetles had an inhibitory effect on the amount of defoliation caused per individual, and this may alter the pattern of feeding preference by causing beetles to disperse more evenly throughout the plant. A population model was also derived which established a relationship between feeding punctures per leaflet and average potato flea beetle weeks. This relationship enables the estimation of flea beetle numbers per plant, but is very sensitive to the accuracy of feeding puncture counts.

Very few tubers exhibited signs of common scab disease, but there was a positive correlation between number of feeding punctures and numbers of immature potato flea beetles. The absence of scab disease suggests that its incidence is less affected by flea beetle densities, than by abiotic factors such as soil moisture, and varietal differences in susceptibility.

A preliminary examination of feeding by *Melanoplus bivittatus* (Say) and *Melanoplus sanguinipes* (Fabricius) on potato plants showed no significant yield response to occur at varying densities of these species.

CHAPTER I

INTRODUCTION

The potato plant, *Solanum tuberosum* L., is one of about 2,000 species in the family Solanaceae. There are 160 wild and 20 cultivated species of tuber-bearing Solanaceae, all of New World origin (Burton 1989). Such plants as tomato, tobacco, eggplant, pepper, bittersweet, horse nettle, ground cherry and petunia are also placed in this family. The closest wild relative of *S. tuberosum* is *Solanum andigenum* Juz. & Buk., which is indigenous to the Andes Mountains (Thornton and Sieczka 1980). There are over 170 different cultivars of *S. tuberosum* available in North America. The most widely grown, Russet Burbank, is a late maturing variety which requires a 140-150 day growing season. Average yield for Russet Burbank is 18-27 t/ha in Manitoba (B. Geisal, pers. comm.), but may exceed 65 t/ha in the Canadian Maritimes (Campbell et al. 1984). Plants of this cultivar have long leaflets, white blossoms and vigorous growth. The large cylindrical tubers are characterized by having shallow eyes, white flesh and russetted skin. The variety is resistant to common scab, but is susceptible to Fusarium wilt, Verticillium wilt, leafroll and virus Y (Campbell et al. 1984). Russet Burbank plants require uniform soil moisture and nitrogen, otherwise knobby tubers result.

The economic importance of potatoes to Canada is great. Agriculture Canada (1990) statistics indicate that gross revenue paid to potato producers was over 400 million dollars in 1990. Manitoba is a leading potato grower, having over 19,000 ha of land sown in 1990; this area of potatoes was exceeded only in New Brunswick and Prince Edward Island.

Manitoba stands fifth in total production, with 352,000 t of potatoes being grown in 1990, equivalent to 12% of all Canadian production.

The potato flea beetle, *Epitrix cucumeris* (Harris) is an important pest of potatoes. Unlike the tuber flea beetle, *Epitrix tuberis* Gentner (Gentner 1944), injury to tubers by the subterranean larvae of *E. cucumeris* is rare. Adult potato flea beetles injure plants by chewing small round holes in leaflets. The timing of such defoliation is important because, if it occurs during the tuber bulking phase of plant growth, yield may be considerably compromised (Cranshaw and Radcliffe 1980; Shields and Wyman 1984). In Prince Edward Island, significant yield losses due to this pest have been documented in several different potato cultivars (Thompson 1984, 1985, 1987). In Manitoba, insecticides are applied when high densities of the insect are present in late summer (Senanayake 1987), but little is known about what levels are actually economically injurious to the crop.

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say) originated in Mexico, where it fed on native host plants such as buffalobur, *Solanum rostratum* Dunal (Neck 1983). *Solanum tuberosum* was included in its host range about 150 years ago, and late in the 19th century it was first reported to be a pest of potatoes (Edgerton 1861, cited by Casagrande 1987). The pest rapidly became the most destructive insect pest of potatoes in North America (Hare 1990). During World War I Colorado potato beetle was inadvertently introduced into western Europe, where it is now well established, except in the British Isles. It continues to extend its geographic range southward and eastward throughout

Europe and Asia (Hurst 1975).

Populations of larval and adult Colorado potato beetles, if uncontrolled, can easily completely defoliate field crops of potatoes in Manitoba (Senanayake 1987). If plants are attacked during specific stages in the growth cycle, yield may be totally lost (Hare 1980). Colorado potato beetle was one of the first targets of large-scale insecticide use in field crops (Hare 1990). The insect is still adapting to new geographic areas (Hsiao 1978), and resistance to a wide range of insecticides has developed in some populations (Forgash 1981). As a consequence of effective insecticidal control earlier this century, research on ecological relationships between this pest and environmental factors, host plants and natural enemies was reduced (Hare 1990). Recently, much emphasis has been placed on the need to implement integrated pest management strategies to control Colorado potato beetle, as the pesticide race appears to be a losing battle.

The causal organism of common scab disease of potatoes is *Streptomyces scabies* (Thaxter) Waksman & Henrici (syn. *Actinomyces scabies* (Thaxter) Gussow). This is a widespread soilborne disease that can infect fleshy roots and underground stems of several crops and weeds (Rich 1983). Common scab produces no above ground symptoms on potato crops, and has little or no effect on yield, but has a tremendous effect on the marketability of the crop. Common scab occurs in Africa, Asia, Australia, Europe and North and South America (Rich 1983).

Tubers infected with common scab have brown, roughened, irregularly shaped areas that may be raised or sunken and can cover the entire surface of the tuber. The type and severity of symptoms exhibited in this disease are influenced by the strain of the organism and the variety of potato affected (Hooker 1981). Most scab damage on potato tubers can be removed during processing, but market value of table stock is severely diminished.

Very little published information is available concerning *E. cucumeris*. Although this insect is a potential source of yield reduction in commercial potato production, very little work has been done to determine what levels of this insect are economically injurious, or how it interacts with other potato pests. The objectives of this study were:

1. To estimate an economic injury level for *E. cucumeris* on cv. Russet Burbank potatoes and examine how such an injury level is affected by early season defoliation by *L. decemlineata*.

2. To examine the spatial and temporal patterns of accumulation of feeding punctures by potato flea beetle on cv. Russet Burbank potatoes, and determine if feeding punctures can be used as an index of actual population numbers of this insect.

3. To determine whether the density of potato flea beetles per plant has an effect on the incidence or severity of common scab on cv. Russet Burbank tubers.

A fourth objective was addressed during the summer of 1990, which was not part of the main objectives of this thesis. During that time, a surplus of caged potato plants and the presence of large numbers of grasshoppers prompted a study to be undertaken with little preplanning. The objective of this study was to determine whether the grasshoppers *Melanoplus bivittatus* (Say) and *Melanoplus sanguinipes* (Fabricius) feed on potato plants, and if so, whether any relationship exists between pest density and yield.

This thesis is written in a paper style. Chapter II is a review of pertinent literature. The methods of research, results and discussion are presented in Chapter III as three papers and a scientific note, written in a form suitable for publication. Part 1 of Chapter III will be combined with data from Senanayake (1987) for preparation of a manuscript to be submitted to the Journal of Economic Entomology. Part 2 of Chapter III will be submitted to the same journal. Chapter IV contains an overall discussion of the research in this thesis.

CHAPTER II

LITERATURE REVIEW

The Potato Plant

Morphology

A thorough description of the morphology and vasculature of the potato plant is given by Artschwager (1918) and McCauley and Evert (1988). The morphology of the basal leaves of the main potato shoot is variable, ranging from simple to pinnate compound in arrangement. The upper leaves are generally more uniform; they are odd pinnate with three major pairs of lateral leaflets and a number of folioles. The primary vascular system of this dicotyledonous plant consists of three large and three small bundles. The three large bundles are highly interconnected through a repeated series of branchings and arch-producing mergers. Each of the small bundles in the stem is a median leaf trace which extends three internodes before diverging into a leaf. Potato leaflet margins are lined toward the abaxial side by short, simple tooth-like trichomes. In addition to marginal trichomes, two other types of trichomes are found on leaves: glandular hairs with knob-like secretary swellings at the tips of short, uniserate stalks; and simple uniserate, multicellular hairs of varying lengths. Trichomes occur on both sides of leaflets, although many more are on the abaxial side. Adaxial trichomes are found mainly on the ribs, whereas abaxial trichomes occur on the ribs and scattered across the leaf surface.

Ivins and Milthorpe (1963) and Thornton and Sieczka (1980) provide a complete description of tuber structure. Potato tubers are simply enlarged portions of underground stems called stolons or rhizomes. The stolons closely resemble the above ground stems in having leaf scales located alternately on their surface. Tubers originate from stolon tips or along the stolon itself, and have characteristics of normal stems including dormant true buds (eyes) and leaf scars (eyebrows). Lenticels are conspicuous on most tubers and are similar to stem pores which allow air penetration deep into the stem interior. The single layer of cells on the surface of a potato tuber is called the epidermis. The red and blue pigment of some potato skins, anthocyanin, is often located in the periderm, which consists of several layers of corky cells immediately below the epidermis. The skin of a mature tuber is comprised of the hardened, corky periderm after the epidermis has been sloughed off. In a few varieties, the anthocyanin is located in the outer layers of the cortex, the region inside the periderm that extends inwardly to the vascular ring. The fleshy portion of the tuber is called the medullary area and is divided into outer and inner regions. The outer medulla is relatively dense, while the inner medulla is watery and translucent. The inner medulla extends towards each eye, so forming a continuous tissue network among all eyes of the tuber.

Buds are located on the exterior of a potato tuber, and are arranged in a spiral fashion. They are concentrated at the seed end, which is the portion of the tuber furthest away from the stem. Apical dominance is a characteristic in which the eyes of the seed end are the first to sprout. When whole tubers are planted, the effect of apical dominance is important as only one to three large, productive stems per hill usually emerge. The effect of apical dominance is lessened when tubers are cut into seed pieces, but differences between stem-end and seed-end sprouts still exist.

Propagation and Growth

Ewing (1981) discusses several factors concerning potato plant propagation. Reproduction in the potato plant is clonal in nature. The plant is notoriously heterozygous not only because of its asexual reproduction, but also because it is tetraploid. As a consequence of asexual propagation, bacterial, fungal, and viral diseases and the potato cyst nematode are readily spread from generation to generation through the tubers. Disease transmission by seed tubers still remains a problem in potato production. The North American practice of cutting seed tubers can lead to the dissemination of disease from infected to healthy tubers. Furthermore, cut tuber pieces are more susceptible to infection by soil-borne pathogens.

The initiation of tubers at stolon tips usually occurs when plants are 15-24 cm high or 5-7 weeks after planting (Thornton and Sieczka 1980). Tuber initiation is controlled by a tuberization stimulus (Gregory 1956), which is assumed to be a chemical substance. Formation of the stimulus is favoured by photoperiods shorter than a genetically determined critical photoperiod and by cool temperatures (Epstein 1971). In contrast to a commonly accepted notion, tuberization is independent of flowering. As Ewing (1981) states, the chemical nature of the stimulus is unknown, but it is suspected that the ratio of cytokinin(s) to gibberellin(s) affects the stimulus. However, other researchers feel that the stimulus is not cytokinin-like (Jameson et al. 1985). Upon receiving the tuberization stimulus the main shoot ceases development, leaves enlarge and form wide angles with the stem, internodes become short, stems thicken and aboveground axillary branching is suppressed. Below the soil, the stimulus restricts root growth and causes tubers to form on very short stolons. Very high ratios of tuber to total plant weight result in association with high levels of tuberization stimulus (Ewing 1981).

Growth of *S. tuberosum* and the yield of plants are affected by many environmental factors. The greatest single abiotic factor affecting the yield of potato plants is water stress (Burton 1981). For a high quality yield, an adequate water supply is necessary from tuber initiation until near maturity (Epstein and Grant 1973). Yield reduction due to water stress is attributable to reduced leaf area and reduced photosynthesis per unit leaf area (van Loon 1981). Water stress during maximum foliage growth, between emergence and tuber bulking, leads to a decrease in foliage weight and reduces the elongation of stems, leaves and roots (Gandar and Tanner 1976; Hang and Miller 1986).

Potato Flea Beetle

Description and Life History

The eggs of *E. cucumeris* are elliptical and white when first laid, and turn greyish when older. They are deposited in shaded moist soil near a host plant, at depths up to 2.5 cm. Length of eggs may vary from 0.44 to 0.50 mm and width may vary between 0.19 to 0.21 mm (Jewett 1929). The average egg incubation period in Manitoba is 5 days (Cole 1951).

The larval potato flea beetle, as described by Jewett (1929), is less than 1 mm long at hatching and, after four larval instars, reaches 3.5 to

4.5 mm in length. The larvae are thread-like in appearance, have three pairs of short thoracic legs and a pair of pro-legs on the last abdominal segment. The larva is mainly white; the head is light brown, with reddish mouthparts, and the thoracic and anal shields are faintly brown. Larvae have subtriangular mandibles with four blunt teeth, and short subcylindrical antennae (Johannsen 1913). The abdomen has nine segments, and on each segment are approximately 24 setae. Larvae feed on the roots, tubers and below ground portions of stalks of potato plants (Jewett 1929). After feeding has ceased, larvae become shorter and thicker, and then enter a quiescent prepupal stage (Cole 1951). In Manitoba, the average larval period lasts 24 days, which is then followed by a 7 day prepupal period; after this time, larvae construct earthen cells in which to pupate (Cole 1951).

Epitrix cucumeris pupae are white when newly formed, but darken as they mature. The abdomen is bifurcate, with slender incurved forks, and a transverse line of setae on the last segment (Johannsen 1913). Pupae can be found in soil around potato plants at depths of 1.25 to 7.5 cm (Jewett 1929). Potato flea beetles, in Manitoba, have a pupal stage that lasts an average of 10 days (Cole 1951).

Adult potato flea beetles are ovate, and 1.15 - 2 mm long. They are shiny black with antennae and legs of reddish-yellow, except that the enlarged hind femora are black (Jewett 1929). The surface of the elytra is finely and sparsely punctured and is covered in fine setae giving it a pubescent appearance. In Manitoba, overwintered adults begin collecting on potato plants in late May or early June (Senanayake 1987). The adult beetles characteristically jump, but do not fly when disturbed (Cannon 1949); however, potato flea beetle flight has been observed in the laboratory (Cole 1951). The summer generation of adults typically may be found on plants during late July in Manitoba, and continue to feed until the weather becomes cold or the food source diminishes (Senanayake 1987). In the fall after heavy frosts, *E. cucumeris* adults collect under litter or vines in fields and field margins. The insects then enter the soil to overwinter (Anderson and Walker 1936). Development from egg to adult in Manitoba requires approximately 46 days (Cole 1951), and in eastern Canada requires 28-42 days to complete (Hodgson et al. 1977).

Geographical Distribution and Host Plants

The potato flea beetle is found in all Canadian provinces except British Columbia (Hodgson et al. 1977). This species can also be collected as far south as Florida and, at the time of the revision of this genus, extended as far west as North Dakota, South Dakota and Kansas in the United States (Gentner 1944). Prior to this revision, many reports had been published of *E. cucumeris* being found in the western United States. However, it is likely that these were erroneously identified specimens of another species, the tuber flea beetle, *E. tuberis*. In general, the tuber flea beetle is confined to the west of the Rocky Mountains, nonetheless, specimens of *E. tuberis* have been collected in Alberta and Saskatchewan (Kelleher 1983). This suggests that an overlap in the distribution of *E. cucumeris* and *E. tuberis* could also exist in Manitoba, however there are no recorded specimens of *E. tuberis* in Manitoba (Cole 1951), nor have any been found in my identifications of