# Effects of soil type and moisture on emergence of tuber flea beetles, *Epitrix Tuberis* (Coleoptera: Chrysomelidae) from potato fields

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## ABSTRACT

The numbers of adult tuber flea beetles, *Epitrix tuberis* Gentner, emerging from different soil types in the lower Fraser Valley of British Columbia were compared in 1987 and 1988. Overwintered beetles (P1) were released at known densities onto caged Russet Burbank potato plants grown in soils with different inorganic, organic, and moisture characteristics. The time from the introduction of P1 beetles in June to the mean initial emergence of first generation (F1) beetles ranged from 38 to 47.2 days during the two years of study. The female:male sex ratio of 2210 F1 beetles was 1:0.94, with a slight but significant bias in females early in the emergence period. Although significantly more F1 beetles emerged from some highly organic soils than from some mineral soils in both years, inorganic, organic and moisture factors of the test sites did not correlate consistently with the emergence of F1 beetles in time or numbers. F1 emergence from mineral soils was never significantly greater than that from highly organic soils. This work indicates that the economic injury level derived from studies of P1 beetles in highly organic soils could be applied to other soil types with minimal risk to potato crops.

## INTRODUCTION

The tuber flea beetle, *Epitrix tuberis* Gentner, is a serious pest of potatoes grown commercially and domestically in the lower Fraser Valley of British Columbia. Adults overwinter in soil in and around potato fields (Vernon and Thomson 1991) and emerge from mid-May to early June. Although they are polyphagous, overwintered tuber flea beetles prefer to feed and oviposit on potato plants (Finlayson 1950), and in particular on late season varieties such as Russet Burbank. Oviposition by overwintered beetles (P1) occurs from late May to early July. The resulting first larval generation (F1) feeds on the seed pieces and developing roots of young potato plants, but generally causes little or no economic damage at this stage (Giles 1987). The ensuing F1 summer adults produce the second larval generation (F2) from mid-July through August when tubers are maturing. Feeding by F2 larvae results in tuber deformations, in surface channels and in sub-surface tunnelling that can seriously lower crop marketability.

To avoid damage from flea beetles, growers often apply sprays on a 7-10 day schedule, beginning at crop emergence. This can amount to as many as 10 sprays per season. To improve timing and thereby reduce the number of sprays, visual and sweep-net monitoring programs for adults of the P1 and F1 generations were developed (Vernon et al. 1990; Cusson et al. 1990) and are available to producers through commercially operated integrated pest management (IPM) programs. A major objective of these IPM programs is to improve control of the P1 adult generation so that spraying against the later F1 adults is not needed. By not having to spray F1 adults, mechanical plant damage and soil compaction caused by spray machinery is reduced, and the build-up of natural parasites and predators of aphids is augmented during the critical period of aphid outbreak in July and August.

Giles (1987) proposed that maintaining P1 beetles below 0.05 beetles per row- metre of potatoes would prevent economic damage to tubers from occurring without the need for F1 beetle sprays. This action threshold has been in use in potato IPM programs since 1988, and it has gen-

erally been found that P1 adults can be maintained below the action threshold with one or no sprays. Using sweep-net monitoring of F1 beetles as a backup, and a mean action threshold of one F1 beetle per sample of 10 sweeps (Anon. 1991), economic tuber damage has not occurred in any of the 700 fields monitored since 1988 (R.S. Vernon, unpublished data).

Giles' (1987) P1 action threshold was derived from research conducted near Cloverdale, a vegetable growing area of the lower Fraser Valley with soil high in organic matter and moisture. Population growth of the closely related potato flea beetle, *E. cucumeris* (Harris), was found to be greatly affected by differences in soil type and soil moisture (Daniels 1933; Hoerner and Gillette 1928). Their observations suggest that the P1 action threshold developed for *E. tuberis* may also vary depending on soil moisture, temperature and soil type. The question is important, since most potatoes in B.C. are grown in mineral soils low in organic matter and water-holding capacity, and monitoring programs that employ Giles' P1 action threshold are rapidly expanding into these areas.

This study was initiated to assess the effect of soil type and irrigation on E. tuberis populations from the P1 adult to the F1 adult generations. The importance of these findings for implementing and improving monitoring programs for *E. tuberis* in other potato growing areas of British Columbia is discussed.

## MATERIALS AND METHODS

**Emergence Cages:** Pyramidal emergence cages, modified from Giles (1987), were constructed from 1.3 cm thick plywood, with a 46 x 105 cm open base tapering to a 5 x 5 cm flat top, and 35 cm in height. A 0.7 cm diam hole was drilled in the center of the cage top, and a clear plastic tygon tube (0.7 cm diameter by 4 cm long) pushed 1 cm into the plywood. Small clear plastic vials with a hole drilled in the cap were inserted cap down over the tubing to collect emerging beetles orienting upwards against gravity and towards the light. To ensure that light was entering the cages only from the hole at the top, all joints were sealed with fibreglass from the inside, and painted black.

Two experiments were done to determine the efficiency of the cages in collecting known numbers of beetles. Six cages were placed over bare ground, and the bases covered with soil. Twenty *E. tuberis* adults were collected and dropped through the top of each cage on 3 and 22 August, 1988. Beetles trapped in the vials atop each cage were counted for 2 days following each release.

**Emergence Studies:** Experiments were conducted in 1987 and 1988 to examine the effects of the inorganic, organic, and moisture characteristics of soil on the population growth of *E. tuberis* in commercial potato fields. Population increase was measured by caging known numbers of P1 adults for fixed intervals on plants in different soil types, and quantifying the subsequent emergence of F1 beetles over time using the emergence cages described. This approach gave an estimate of comparative habitat suitability for *E. tuberis* populations.

**1987:** The plantings of potato were established at three different sites in the lower Fraser Valley: at Abbotsford in an orthic humo ferric podzol; at Cloverdale in a highly organic peaty gleysol; and at Delta in a rego gleysol. The methods used to characterize the inorganic and organic fractions of each soil are described by McKeague (1976), and the physical characteristics of each soil are listed in Table 1. At each location, the soil was rotovated to a depth of 30 cm before planting. Whole tubers (cv. Russet Burbank) of uniform size were planted in pairs at a depth of 15 cm, with 30 cm between the pair of plants. A minimum of 1 m separated adjacent pairs. Seeding was done on 20, 21 and 25 May at the three sites, respectively, and all the plants were hilled once before emergence. Shortly after emergence, each pair of plants was enclosed in a wood-framed screen (.04 cm mesh) cage (80 x 69 x 63 cm) to prevent outside infestation by wild *E. tuberis*. Since wild *E. tuberis* typically infest potato fields along the outermost rows (Cusson et al. 1990), plots in both the 1987 and 1988 studies were located well inside commercial fields of potatoes to further reduce the threat of natural infestation.

The caged plants were infested with *E. tuberis* collected from a holding plot near the Abbotsford site. The holding plot consisted of a 0.04 ha planting of potatoes (cv. Russet Burbank) that was infested between 1 and 15 June with more than 10,000 beetles collected from backyard

gardens in Abbotsford. For release into each cage, a given number of mating pairs of beetles were aspirated from plants, placed into individual 10 cm lengths of tygon tubing and transported in coolers on the same day, to the three sites. Five mating pairs were released into each cage at each site on 19 June, and a further two mating pairs were added on 22 June. The cages were removed on 29 June, and the surviving beetles on each plant pair collected with aspirators over a period of 2 days. By 30 June, 78%, 70%, and 61% of the beetles at Abbotsford, Cloverdale and Delta, respectively, had been recaptured. Visual inspections of the exposed plants conducted each week between 2 and 24 July confirmed that reinfestation from outside the plots did not occur.

Beginning on 2 July at all sites, the uncovered paired plants were allocated watering regimes: 1) no watering (control plots); 2) 10 L water once every 2 weeks; 3) 10 L water once per week and; 4) 10 L water twice per week. At Abbotsford and Cloverdale, five and four replicates, respectively, of all watering regimes were used. At Delta, four replicates each of watering regimes 1, 2 and 3 were used. Watering was stopped on 23 July. The watering regimes (treatments) were arranged in randomized complete blocks at each site.

To prevent run-off of water, soil dykes were made (46 by 105 cm) around each pair of plants. Water was applied evenly inside the dykes with a watering can on Mondays (watering regimes 2, 3 and 4) and Thursdays (watering regime 4). Soil moisture samples (cores 2 cm diameter by 15 cm deep) were taken from between each pair of plants every Wednesday from 2-22 July. Each soil sample was weighed, dried in an oven, and the percent moisture content by weight determined.

On 24 July, the plants in each treatment were cut off just below soil level and the dyked area cleared of plant debris. Emergence cages were placed over the area where the plants had been removed, and the bases of the cages sealed with soil. The cages were examined for emerged beetles daily from 25 July until emergence had declined to one beetle per cage per day. At the Cloverdale and Delta sites, beetles emerging daily from each irrigation treatment were retained and their sex determined in the laboratory.

**1988:** The effect of soil type and moisture on tuber flea beetle emergence was further studied at 9 locations in the lower Fraser Valley. The characteristics of the soils at each location are listed in Table 2. On 9 June, all plots were prepared and planted as described for the 1987 study. On 22 June, ten mating pairs of beetles were collected from a new holding plot at Abbotsford and released into each of 5 or 6 cages at each site (Table 2). The cages were removed on 1 July, and the surviving beetles on each plant collected by aspiration during the next 2 days. An average of 65% of the beetles released had been collected from the plants (range = 57-81%) by 2 July. Visual inspections of the exposed plants were conducted each week between 2 and 28 July, which confirmed that reinfestation from outside the plots did not occur. On 28 July, emergence cages were installed, and the cages were examined for emerged beetles daily from 29 July until emergence at each site had declined to one beetle per cage per day.Seven of the 9 locations were chosen to provide a wide range of values of percent organic matter in the soil. At each location, mean daily air temperatures from the time of P1 release to the end of the F1 emergence were recorded using electronic hygrothermographs (Datapods, Model DP220, Omnidata International, Inc., Logan Utah) placed at ground level in Stevenson screens.

Two of the nine study locations were used to assess the effects of continuous irrigation on *E. tuberis* emergence (Table 2). Two adjacent rows of potatoes, 10 m long, were planted 4 m apart on 9 June. Potatoes in each row were planted in six pairs, with 30 cm between each paired plant, and 1.5 m between consecutive pairs. Each pair of plants was caged, and 10 mating pairs of beetles introduced to each cage. After beetle removal on 1 July, a perforated soaking hose was installed 2 cm below the surface, 30 cm along the north and south sides of plants in the northernmost potato row. Water was delivered continuously for the next 20 days so that the ground was visibly moist but not flooded. Soil samples were taken every 3-4 days from between each potato pair at all 9 locations in the study from 2-22 July, and their moisture content determined.

### Statistical Analysis

**Temporal Emergence Patterns:** The number of days between the initial release of P1 bee-

**Table 1**

1987 Studies. Emergence of F1 adult tuber flea beetles from soils with different inorganic and organic characteristics and watering regimes in 3 potato growing areas of the lower Fraser Valley of British Columbia.

| Study site and watering regime | Soil characteristics (% by weight) | | | | | Mean days to F1 adult emergence | | F1 adult emergence | |
|---|---|---|---|---|---|---|---|---|---|
| | Inorganic fraction | | | Organic | | Initial | 50% | Mean/plot/ovip. day[1] | Sex ratio |
| | Sand | Silt | Clay | matter | $H_20$ | (± S.E.) | (± S.E.) | (± S.E.) | Fem:Male |
| ABBOTSFORD (n = 5) | | | | | | | | | |
| No watering | 38.3 | 55.1 | 6.6 | 3.9 | 17.4 | 43.2 ± 1.0 | 49.8 ± 0.9 | 1.03 ± 0.27 | – |
| 10 L water 1x/2 weeks | ” | ” | ” | ” | 17.6 | 45.4 ± 1.0 | 50.6 ± 0.8 | 0.75 ± 0.11 | – |
| 10 L water 1X/1 week | ” | ” | ” | ” | 19.9 | 43.8 ± 0.9 | 49.8 ± 0.4 | 1.03 ± 0.14 | – |
| 10 L water 2x/1 week | ” | ” | ” | ” | 19.5 | 47.2 ± 1.1 | 51.4 ± 0.7 | 0.83 ± 0.09 | – |
| CLOVERDALE (n = 4) | | | | | | | | | |
| No Watering | 26.5 | 46.9 | 26.7 | 58.0 | 50.4 | 42.5 ± 0.5 | 49.5 ± 0.6 | 3.79 ± 0.39 | 1:0.80 |
| 10 L water 1x/2 weeks | ” | ” | ” | ” | 51.1 | 42.2 ± 1.1 | 49.0 ± 0.4 | 2.38 ± 0.24 | 1:1.06 |
| 10 L water 1X/1 week | ” | ” | ” | ” | 50.4 | 42.5 ± 1.0 | 50.3 ± 0.3 | 3.53 ± 0.29 | |
| 1:0.83 | | | | | | | | | |
| 10 L water 2x/1 week | ” | ” | ” | ” | 53.2 | 41.7 ± 0.9 | 49.3 ± 0.9 | 3.81 ± 0.72 | 1:1.14 |
| DELTA (n = 4) | | | | | | | | | |
| No Watering | 4.2 | 76.5 | 19.4 | 3.4 | 16.5 | 38.3 ± 1.0 | 45.2 ± 0.9 | 2.28 ± 0.76 | 1:0.90 |
| 10 L water 1x/2 weeks | ” | ” | ” | ” | 17.2 | 41.0 ± 0.7 | 45.8 ± 1.0 | 1.21 ± 0.23 | 1:1.22 |
| 10 L water 1X/1 week | ” | ” | ” | ” | 18.0 | 40.0 ± 1.0 | 46.0 ± 0.6 | 1.41 ± 0.41 | 1:1.04 |

1. The number of female oviposition days is the number of P1 females released /plot times the number of days between P1 release and recapture. This amounted to a standard 64 oviposition days/plot for each of the three study sites.

tles and the mean initial and 50% emergence of F1 beetles was determined for each study site and for every watering regime. Mean days to initial and 50% emergence, both within and between study sites for each year, were compared by ANOVA, and Duncan's (1955) multiple range test. Mean daily air temperature in 1988 from the time of P1 release to the mean initial and 50% emergence of the F1 adult generation, respectively, were regressed on time to initial F1 emergence at each study site to investigate the effect of temperature on the rate of development of *E. tuberis*.

**Sex Ratio at Emergence:** Beetles emerging from each watering treatment at the Cloverdale and Delta sites in 1987 were grouped into 4 emergence periods. The first 3 periods were 5 days long and the last was 12 days. The effects of site, treatment and emergence period on the sex ratio of the emerging beetles were tested by analysis of Chi-square using the SAS procedure CATMOD (Grizzle et al. 1969). In this analysis, emergence period was treated as a continuous variable.

**Effect of Soil Type and Moisture on Emergence:** To facilitate comparisons between the two years, the numbers of F1 beetles emerging from soil into cages in each year were standardized by dividing the mean emergence per plot by the number of P1 female oviposition days per plot in each study. P1 female oviposition days were determined by multiplying the number of females released per plot by the number of days between release and recapture. The number of F1 beetles emerging per P1 female per plot per day of oviposition is referred to as the "F1 production". Differences in total F1 production between and within sites for each year were examined by ANOVA after log10 transformation. Differences in emergence were ranked using Duncan's multiple range test. A significance level of $P < 0.05$ was used throughout.

## RESULTS AND DISCUSSION

**Efficiency of Emergence cages:** Numbers of beetles emerging from cages in the 3 Aug. release recapture study (85.8% recapture) were not significantly different from the 22 Aug. study (83.3% recapture), so the results were combined. Of twenty beetles released into each of 12 cages, an average of 16.2 beetles were recaptured on the first day after release (range = 13-20 beetles) and 0.8 beetles on the second day (range = 0-2 beetles). The average recapture per cage was 16.9 beetles (range = 14-20 beetles), or 84.6% of the 240 beetles released. Although a 100% recapture rate by the emergence cages was not a prerequisite for their use in the other emergence studies reported here, these results do show that the emergence cages would probably underestimate the absolute number of beetles emerging from the soil.

**Temporal Emergence Patterns:** Among unwatered plots at the three study sites in 1987, significant differences were observed in the time from P1 beetle release to mean initial emergence ($F = 6.24$; $df = 4,2$; $P = 0.034$), or 50% emergence ($F = 7.12$; $df = 4,2$; $P = 0.026$) of F1 beetles (Table 1). Initial and 50% F1 emergence were at least 4 days earlier in Delta than in Abbotsford or Cloverdale. Differences in initial or 50% emergence among watering regimes at any of the three sites were not statistically significant.

In the 1988 soil type study, significant differences were observed in the time from P1 beetle release to mean initial emergence ($F = 21.54$; $df = 4,6$; $P = 0.0001$), or 50% emergence ($F = 19.9$; $df = 4,6$; $P = 0.0001$) of F1 beetles between sites (Table 2). Mean initial emergence ranged from 38.0 days (site 4) to 45.2 days (site 7). Finlayson (1950) recorded a 42 day period from egg to initial F1 emergence, and a 39 day interval from egg to F2 emergence of *E. tuberis* in the interior of British Columbia.

Temperature affected the length of time from egg to adult of *E. cucumeris* in an insectary (Hill and Tate 1942). This may also explain the differences in the time from egg to adult occurring between sites in our studies. The regression of days to mean initial emergence on mean air temperature during that time (independent variable) for the 7 sites in the soil texture study of 1988, indicated that development time decreased with an increase in mean air temperature ($y = 183.18 - 8.545x$; $r^2 = 0.68$; $P = .02$). A similar trend was observed for mean development time to 50% emergence regressed on mean air temperature ($y = 147.97 - 6.005x$; $r^2 = 0.65$; $P = .03$). The results suggest that a more comprehensive day-degree model based on air temperatures could be developed to help predict the time of emergence of F1 beetles. The regression model for initial

**Table 2**

1988 Studies. Emergence of F1 adult tuber flea beetles from potato fields. The irrigation study examined F1 emergence from non-irrigated plots of potatoes compared to emergence from plots continuously irrigated below ground. The soil type study compared F1 emergence from 7 non-irrigated potato fields with different inorganic, organic and moisture characteristics.

| Study and site description | Soil characteristics (%) | | | | | Mean days to F1 adult emergence[1] | | F1 adult emergence |
|---|---|---|---|---|---|---|---|---|
| | Inorganic fraction | | | Organic | | Initial | 50% | Mean/plot/ovip. day[2] |
| | Sand | Silt | Clay | matter | $H_2O$ | (± S.E.) | (± S.E) | (± S.E.) |
| 1. IRRIGATION STUDY (n = 6): | | | | | | | | |
| No Irrigation | 32.5 | 61.1 | 6.4 | 2.6 | 20.2 | 42.2±0.3 | 47.5±0.5 | 1.70±0.24 |
| Continuous Irrigation | " | " | " | " | 25.4 | 42.7±0.4 | 47.8±1.7 | 2.60±0.42 |
| 2. SOIL TYPE STUDY (n = 5): | | | | | | | | |
| Site 1 'Abbotsford' | 39.9 | 54.3 | 5.8 | 2.6 | 18.4 | 42.6±0.5c | 50.0±0.3e | 1.40±0.11a |
| Site 2 " | 36.2 | 57.5 | 6.2 | 2.6 | 18.8 | 43.0±0.3c | 49. ±0.6de | 2.28±0.25bc |
| Site 3 'Cloverdale' | 72.6 | 19.2 | 8.2 | 10.1 | 16.9 | 40.2±0.7b | 45.8±0.8ab | 1.83±0.19b |
| Site 4 " | 4.9 | 56.7 | 38.4 | 20.8 | 35.9 | 38.0±0.0a | 44.6±0.7a | 2.60±0.18c |
| Site 5 " | 6.5 | 53.5 | 40.1 | 24.0 | 34.8 | 40.4±b | 46.6±0.2bc | 2.59±0.11c |
| Site 6 " | 29.3 | 49.4 | 21.3 | 35.9 | 40.9 | 42.4±0.7c | 48.0±0.0cd | 2.08±0.18bc |
| Site 7 " | 9.2 | 52.7 | 38.2 | 39.6 | 53.5 | 45.2±0.4d | 50. ±0.5e | 2.27±0.27bc |

1. Means followed by the same letters in columns are not significantly different (Duncan's multiple range test, P = 0.05).
2. The number of female oviposition days was the number of P1 females released /plot times the number of days between P1 release and recapture. Thisamounted to a standard 90 oviposition days/plot for each of the study sites.

emergence, however, is presently limited to the narrow range of mean temperatures encountered during the development period in 1988 (i.e. 16.4-16.9 degrees C). Since temperatures in June and July of 1988 were near the 30 year average for the Fraser Valley, the predictability of the model for mean air temperatures above or below the range of temperatures tested in 1988 would have to be determined with further research. This would be worthwhile, since air temperatures in many B.C. potato fields are already being recorded using Datapods for the prediction of potato late blight, *Phytophthora infestans* (De Bary).

In the absence of a comprehensive day-degree or regression model, existing *E. tuberis* monitoring programs could be immediately improved by ensuring that high risk fields are monitored more intensively for F1 beetles beginning no later than 38 days (the earliest development interval recorded in 1987 and 1988) following the initial detection of P1 beetles. In seasons where mean temperatures are above normal, monitoring should begin earlier than 38 days at the discretion of the consultants. Since F1 females have a pre-oviposition period of 6 days (Finlayson 1950), early detection of above threshold F1 beetles would allow growers to withold sprays up to 5 or 6 days, allowing time for additional emergence to occur to maximize the efficacy of sprays.

**Sex Ratio at Emergence:** The sex of 510, 889, 483 and 328 beetles was determined, respectively, for 4 consecutive emergence periods from the Delta and Cloverdale sites in 1987. The analysis of chi-square indicated that the sex ratio differed significantly ($P = 0.03$) between sites. The female:male sex ratios of F1 beetles emerging from the site in Delta ($n = 801$ beetles) and Cloverdale ($n = 1409$ beetles) were, respectively, 1:1.01 and 1:0.90. The percentage of females emerging (i.e. 53.3, 52.8, 49.9 and 48.2%) over the 4 emergence periods decreased slightly but significantly ($p = 0.04$) with time of emergence. Finlayson (1950), observed a 1:1 sex ratio in P1 beetles emerging from hibernation, but did not determine the sex ratio of F1 beetles emerging over time.

**Effect of Soil Type and Moisture on Emergence:** Watering regimes at various intervals in 1987 did not significantly affect beetle emergence at any of the three sites (Table 1). The average water content at each site was raised only slightly (Table 1), even in the most heavily watered treatments. Irrigating the soil continuously following the oviposition period in 1988 did significantly ($F = 162.8$; $df = 3,1$; $P = .001$) increase the soil moisture content (Table 2), but the effect on emergence was not significant ($F = 3.48$; $df = 1,5$; $P = 0.12$). Because watering began after beetles were removed from the plots in both years, the eggs that were layed during the oviposition period would have largely preceded the watering schedule. The egg stage of *E. tuberis* has a mean incubation period of 5.5 days (range 3-14 days, Hill and Tate, 1942). Watering, therefore, would have coincided more with the succeeding larval and pupal stages of *E. tuberis* in this study.

In the unwatered treatments in 1987, significantly more beetles emerged from the Cloverdale site than from the Abbotsford site, but not from the Delta site ($F = 6.01$; $df = 4,2$; $P = 0.037$) (Table 1). In the soil type study of 1988, significant differences ($F = 6.46$; $df = 6,4$; $P = 0.0004$) in emergence also occurred, with sites 4 and 5 having significantly more emergence than sites 1 and 3 (Table 2). Differences in F1 production between the Cloverdale and Abbotsford sites were more pronounced in 1987 (Table 1) than in 1988 (Table 2). F1 production was lower in 1987 than in 1988 in the Abbotsford soils, and higher in 1987 than in 1988 in the Cloverdale soils.

The significant differences observed in F1 production between certain sites in 1987 and 1988, can be attributed to biotic or abiotic effects on *E. tuberis* adult vigour, oviposition, or on the survival of immature stages in the soil. The amount of oviposition by many soil-ovipositing beetles is directly related to the texture and moisture content of the soil (Gaylor and Frankie 1979; Marrone and Stinner 1983a; Brust and House 1990). These variables also affect egg and larval survivorship in some beetle species (Gaylor and Frankie 1979; Marrone and Stinner 1983b). Generally, oviposition and subsequent survival of eggs and larvae are promoted in moist, organic soils. Organic matter and water content were highly correlated in our 1988 study (Pearson correlation coefficient = 0.954, $P < .0002$), but neither of these variables was significantly correlated with the production of F1 *E. tuberis*. Of the inorganic soil components, only clay was

significantly correlated (Pearson correlation coefficient = 0.810, $P < 0.02$) with the emergence of F1 *E. tuberis* in unwatered sites in 1988. Emergence in soils with less than 10% clay varied widely, however, (Table 2) making this relationship of little practical importance. The results from both years do show that F1 production from mineral soils was never significantly higher than from the organic soils. The reason, or reasons for the greater F1 production observed in certain Cloverdale soils, however, could not be determined from this study.

**Soil Type and Action Thresholds**

Giles (1987), working with a peaty gleysol (61.4% organic matter), proposed that maintaining P1 *E. tuberis* at levels below 0.05 P1 beetles per metre of row would keep numbers of F2 larvae below an economic damage level. Until now, this action threshold was valid only for *E. tuberis* monitoring programs conducted in regions of the Cloverdale area with similar, highly organic muck soils. The results reported here indicate that the P1 action threshold developed for the peaty gleysol of Cloverdale could also be used in potato growing areas with different soil types, such as Delta and Abbotsford, without risk to potato crops. This is because the same number of P1 beetles occurring on plants grown in Delta or Abbotsford would ultimately give rise to equal or fewer F1 adults than would the same number of P1 beetles on plants grown in Cloverdale. Since the F1 action threshold of 1 beetle per 10 sweeps is recommended for monitoring programs in any soil type (Anon. 1991), the use of Giles P1 action threshold in a mineral soil should not increase the need for F1 sprays.

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