# Crop Development and Yield of Transplanted and Direct-Seeded Broccoli (*Brassica oleracea* var *italica* Pl.) Subjected to Flea Beetle (Coleoptera: Chrysomelidae) Feeding

by

Juliana Soroka

A thesis
presented to the University of Manitoba
in partial fulfillment of the
requirements for the degree of
Master of Science
in
Department of Plant Science

Winnipeg, Manitoba

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## ABSTRACT

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Title: Crop Development and Yield of Transplanted and Direct-Seeded Broccoli (Brassica oleracea var. italica Pl.) Subjected to Flea Beetle (Coleoptera: Chrysomelidae) Feeding.

Major Professor: Dr. M. K. Pritchard.

A two year field study involved recording of flea beetle (Coleoptera: Chrysomelidae) populations and determining the effect of their feeding on growth, yield, and quality of transplanted and direct-seeded broccoli (Brassica oleracea var. italica Pl.). Six plantings in 1982 and five in 1983 were carried out at two week intervals beginning in mid-May; each planting contained 2, 3, and 4 week old transplants and direct-seeded plants with and without carbofuran (Furadan) granules in furrow. Flea beetle populations were determined by water traps baited with mustard oil and by vacuum sampling.

In 1983 the overwintering population of flea beetles emerged later than in 1982, with population peaks occurring in mid-June, versus the mid-May peak in 1982. Despite the larger numbers of flea beetles present in 1983, broccoli losses were less in 1983 than in 1982. Damage, in terms of both direct mortality and delayed yield, was most severe in the first planted plots in both years.

Young transplants and newly-emerged seeded plants were the most seriously damaged by flea beetles, while broccoli beyond the 6 to 8 leaf stage suffered negligible damage, even under heavy feeding pressure. The extremely populous summer generation of flea beetles emerging in August - September, 1983, reduced marketable yields of heads by feeding on bud florets.

Of all treatments, direct-seeded plants without carbofuran suffered the most mortality and defoliation, and had the longest and most variable period of days to harvest and, generally, the lowest quality of head. The oldest transplants were the most tolerant to flea beetle attack of the three transplant sizes. Carbofuran provided good protection of the seedling plants. Over both years, direct-seeded broccoli yielded 37% of the marketable harvest of direct-seeded plus carbofuran broccoli.

Percent leaf area eaten was a better indicator of flea beetle damage to plants and subsequent yield than were flea beetle numbers determined by either water trap or vacuum sampling.

Results of a competition study in the greenhouse indicated that, after approximately 48 days of growth, plants surrounded by broccoli 5 and 12 days older were significantly smaller in height and weight than similar aged plants not surrounded by older plants. Plants surrounding such delayed seedlings were not significantly larger than equal aged plants in a uniform stand.

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Chapter I

# INTRODUCTION

Cruciferous vegetables comprise about 30% of the Manitoba vegetable industry in terms of area planted and cash receipts (Manitoba Agriculture, 1982). The growing trend towards direct-seeding rather than transplanting of most cruciferous vegetables (Hemphill, 1982) increases the potential for crop losses due to damage by flea beetle feeding. Feeding on crucifers such as rapeseed is most severe on newly emerged seedlings planted early in the season (Lamb, 1984); well established transplants, on the other hand, may be minimally affected.

While most of the western Canadian investigations on flea beetles which feed on crucifers have been concerned with beetle damage to rapeseed and mustard crops, cruciferous vegetables, including cabbage, cauliflower, broccoli, radish, and rutabagas, are also subject to flea beetle attack. However, little work has been carried out on flea beetle feeding patterns on cruciferous vegetables and on the crops' response to this feeding.

As monocultures increase in area, so do the densities of their insect pests (Root, 1973). The area seeded to rapeseed on the Canadian prairies has increased from about 30,000 ha in 1960 to over 2 million ha in 1980 (Lamb and Turnock, 1982). Concomitant to this area increase has been the increase in damage to rapeseed crops by crucifer-feeding flea beetles.

Effects of flea beetle feeding on vegetables may be somewhat different than on rapeseed. Loss of plant stand early in the season is critical for vegetable crops, for not only is yield decreased because of the gap, but uniformity of stand and maturity may also decrease. Pest damage late in the season may cause cosmetic damage rendering a vegetable crop unmarketable.

To determine the effect of flea beetle attack on a cruciferous vegetable, a two year field study was undertaken involving the recording of flea beetle populations and determining the effect of their feeding on yield and quality of transplanted and direct-seeded broccoli. Multiple plantings of direct-seeded treatments with and without an insecticide along with plantings of different sized transplants were carried out. Feeding damage was assessed by measuring plant survival and percent leaf area eaten of youngest mature leaves of randomly selected plants. Broccoli head dimensions, quality, and days to maturity were recorded.

## Chapter II

## LITERATURE REVIEW

### 2.1 BROCCOLI CULTURE

Two methods commonly used to establish a broccoli (*Brassica oleracea* var *italica* Planck) crop are transplanting and direct-seeding. While broccoli is usually transplanted as a four or five week old seedling in the home garden, commercial plantings may be entirely transplanted, transplanted for early harvest and direct-seeded for fall yield, or entirely direct-seeded. The decision to direct-seed or transplant is dependent upon market expectations, availability of suitable transplants, facilities to grow transplants, labour, and other management considerations.

The biggest advantage of transplanting is early harvesting, with transplanted plants maturing approximately three weeks earlier than direct-seeded crops (Waters and Albrecht, 1982). The grower can control stand density and uniformity of plant size much more than in direct-seeding. The problems of decreased seedling emergence due to soil crusting and weed and insect pests affecting seedling establishment are avoided with transplant use (Hemphill, 1982).

The major advantage of direct-seeding is the elimination of transplant and labour costs. Seeding can be completed faster and earlier in the season, with less dependency on outside labour in the planting schedule (Johnson and Wilcox, 1972). Direct seeding results in less incidence of disease development in the seedlings than occurs in transplants, and there is more flexibility in choice of cultivar and plant population. As direct-seeding techniques and equipment have improved, traditional problems such as weed competition, overseeding to compensate for sub-optimum plant emergence, and the necessity for thinning have been greatly alleviated (Johnson and Wilcox, 1972). Hectarages of transplanted broccoli have decreased in recent years with accompanying increases in areas direct-seeded to final stand densities (precision seeding) (Hemphill, 1982). In Manitoba all of the commercial production of broccoli is precision-seeded (Connery, personal communication).

In direct-seeded crops reduced emergence is directly related to soil crusting caused by such factors as excessive mechanical handling of the soil, compaction of wet soil at seeding, or heavy precipitation after seeding (Hegarty, 1976). While several anticrusting materials have been used experimentally (Johnson and Wilcox, 1972; Kretschmer _et al_., 1981), cole crop (_B_. _oleracea_) anticrusting has been especially successful with horticultural vermiculite applied over the seed to fill the furrow (Hemphill, 1982).

Direct-seeding has facilitated establishment of much higher plant populations per hectare than traditional densities when transplants are used. While the major determining factor in choice of plant spacings for a commmercial crop is the head size required for sale (Thompson and Taylor, 1976; Chung, 1982), close spacings of 11 to 22 plants/$m^2$ (Manitoba Agriculture, 1983) allow maximum yields while maintaining marketable heads. In contrast, the customarily recommended wider spacings of 3 to 6 plants/m² (Ontario Min. of Agriculture, 1983) yield larger but fewer heads. These closer spacings increase yield per area, provide greater uniformity of the size of central heads and of maturity rates as compared to wider spacings (Thompson and Kelly, 1957), and cause an elongation of the central stalk and a decrease in individual head size. These features facilitate once-over mechanical harvest and reduce the number of hand harvests required, thereby lowering labour costs for the crop (Thompson and Taylor, 1976).

Commercial growers undertake successive weekly or biweekly plantings from about two weeks before the last spring frost to the end of June (Ontario Min. of Agriculture, 1983), which results in a Canadian marketing season from early July to late November (Agriculture Canada, 1975). In Manitoba growers direct-seed from the beginning of May until the second week of July (Connery, personal communication).

Among the several stress-related disorders to which broccoli is susceptible is premature heading or buttoning, which is the development of heads early in plant growth, preventing the head from reaching a marketable size (Waters and Albrecht, 1982). Buttoning may be caused by use of large transplants (Baggett and Mack, 1970), chilling injury to the seedlings, unbalanced or low soil fertility, drought stress, severe root pruning, and poor control of insects and diseases (Bantoc, 1976). Blindness, loss of the terminal meristem so that a marketable head is not produced, is caused by low temperatures, insect damage, or rough handling of transplants (Waters and Albrecht, 1982).

In Manitoba insect infestation of cole crops usually follows a definite temporal sequence. Flea beetles (Chrysomelidae) are the first pest complex to attack cruciferous vegetable crops in the spring, often destroying or severely defoliating seedlings as they emerge from the soil. Roots of surviving plants may become infested with cabbage root maggot (*Delia radicum* (L.)) larvae, usually in mid-June. The cabbage aphid (*Brevicoryne brassicae* (L.)) is most damaging to young plants, while several species of cutworms (Noctuidae), which usually attack in June or July, can sever plants at ground level. Caterpillar species, including imported cabbageworm (*Pieris rapae* L.), cabbage looper (*Trichoplusia ni* (Hubner)), and diamondback moth (*Plutella xylostella* (L.)), feed on broccoli leaves in the summer and early fall. Finally, a summer generation of flea beetles emerges in August-September and feeds on leaves and heads until the weather becomes cool (Manitoba Agriculture, 1979; Manitoba Agriculture, 1983b).

Applications of foliar sprays of insecticides such as endosulfan or carbaryl, repeated as necessary, are recommended for flea beetle control in cole crops (Manitoba Agriculture, 1983). Because of very heavy flea beetle populations, growers in some years have sprayed seedlings twice daily to combat the beetles (Connery, personal communication). In an assessment of the effectiveness of various insecticides and insecticide combinations for flea beetle control in rapeseed crops, Boyle and Freshwater (1982) found that carbofuran (Furadan) as an in-furrow 5% granular application provided the most effective control of seven insectide treatments analyzed. Lamb and Turnock (1982) had similar results, particularly at high crop stress levels.

Carbofuran granular is a systemic carbamate insecticide which is absorbed by plant roots to provide protection for up to three weeks after seedling emergence (Westdal et al., 1979). In part because of the longevity of carbofuran residues in plants, the only vegetable crop for which it is registered in Manitoba is rutabagas for the control of root maggot.

Loss of plant stand due to insects, disease, or poor emergence results in increased variability in maturity dates and uneven size of mature heads, since plants growing near gaps in a row grow larger and faster than plants which are evenly spaced (James et al., 1973). Uneven plant densities due to plant loss result in increased quality defects, including hollow stem (hollowing of the head, branches, and stem) and bractiness (leaves within the head), two disorders associated with low plant populations (Thompson and Taylor, 1976; Waters and Albrecht, 1982).

The time from planting to harvest depends upon the cultivar of broccoli grown, for there are early, mid, and late season types, the time of seeding, and the growing conditions (Splittstoesser, 1979). In Manitoba vegetable trials from 1978 to 1982, days to first harvest varied from 51 to 72 days for various transplanted cultivars, and 70 to 80 days to first harvest for direct-seeded crops (Luther and Pritchard 1978, 1979, 1980, 1981, 1982). In 1983, days to first harvest for the cultivar 'Premium Crop' when direct-seeded were 84, 81, 84 and 84 days for trials at Morden, Manitoba, Brooks, Alberta, Simcoe, Ontario, and Charlottetown, Nova Scotia, respectively (Chubey, personal communication).

The crop is mature when heads are full, firm, and compact, (7 to 15 cm in diameter for fresh market, 2.5 to 10 cm for processing) with full but unopened flower buds (Alberta Agriculture, 1981; Thompson and Taylor, 1976; Cutcliffe, 1975). Hot weather tends to promote a loose, spreading head, early development of florets, and a rapid passage through maturity, as well as increased bractiness (Bantoc, 1976). Open-flowered heads are unmarketable.

There are no grade regulations for broccoli but characteristics commonly used for cultivar evaluation are a good indicator of head quality. These include days to maturity, head weight, head and stalk diameter, and ratings, usually on a scale of 1 to 9, of head colour, density, and uniformity of shape, head size and uniformity, stalk thickness, and an overall quality rating (Luther and Pritchard, 1978, 1981; Waters et al., 1980).

Broccoli is harvested with 20 to 25 cm of stalk left with the head. Commercially a once-over mechanical harvest or two to four hand-harvesting operations should include most of the marketable heads (Cutcliffe, 1975; Chung, 1982).

## 2.2 ECONOMIC SIGNIFICANCE OF FLEA BEETLE DAMAGE

The economic effects of flea beetle damage in cruciferous vegetables has not been reported. However, Osgood (1975) postulated that flea beetles may become one of the limiting factors in rapeseed production in Manitoba. In 1979, 74% of Manitoba rapeseed growers used insecticides to control flea beetle populations (Boyle and

Freshwater, 1982), spending a total of about $12 million to combat the problem in that year (Lamb and Turnock, 1982). In spite of this expenditure, the latter authors found that average rapeseed yield losses of about 10% occur annually due to flea beetle feeding, while quality reduction due to delayed and uneven maturity has not been quantified. The problem may worsen, since insecticide application can reduce yield losses but does little to suppress flea beetle populations (Lamb and Turnock, 1982). As well, there are indications that flea beetle numbers are increasing (Burgess, 1977).

## 2.3 FLEA BEETLE BIOLOGY

### 2.3.1 Distribution

Flea beetles (Coleoptera: Chrysomelidae) are a group of small, leaf-feeding beetles which have greatly enlarged hind femora and which jump when disturbed (Burgess, 1977). The flea beetle subfamily Alticinae, the largest Chrysomelid subfamily, has 6000 species worldwide, 400 of which occur north of Mexico (Smith, 1973), many of which are economic pests.

There are at least 8 species of crucifer-feeding flea beetles on the Canadian prairies (Burgess, 1977, 1981). Of these, 3 species are consistently found feeding on rapeseed crops (*Brassica napus* L. and *B. campestris* L.). On rapeseed crops in the Red River Valley of southern Manitoba, Wylie (1979) reported that *Phyllotreta cruciferae* (Goeze), the crucifer-feeding flea beetle, comprised 80 to 90% of the population, *Phyllotreta striolata* (F.), the striped flea beetle, comprised less than 10%, with *Psylliodes punctulata* Melsh., the hop flea beetle, comprising most of the remainder. He found *Phyllotreta* bipustulata (F.) in low numbers at 2 Manitoba sites and Phyllotreta robusta Lec. at one location.

While the 3 less abundant species are native to North America, P. cruciferae and P. striolata are not. P. striolata was introduced to this continent prior to 1801 (Chittenden, 1923) and is now found across Canada, in many parts of which it is a common pest on garden crucifers (Burgess, 1977). P. cruciferae was introduced on the west coast in the 1920's and possibly on the east coast shortly thereafter (Milliron, 1953). It rapidly spread across the continent and by the late 1930's it had become a serious pest of cultivated crucifers on the prairies (Burgess, 1977). Mitchener in 1937 reported practically total destruction of turnip and cabbage seedlings at a Winnipeg site by P. lewisii (Crotch), which is thought to be a misidentification of P. cruciferae (Westdal and Romanow, 1972). P. cruciferae soon became the predominant flea beetle species on prairie crucifers.

### 2.3.2 Life Cycle

The life cycle of P. cruciferae is typical of the life cycles of flea beetles feeding on prairie rapeseed crops. Adults overwinter in leaf litter or occasionally in soil in fencerows, windbreaks, and headlands around fields and, less commonly, in cultivated areas (Kinoshita et al., 1979). Emergence begins with the first extended period of warm weather and peaks about mid-May (Burgess, 1977). Adults feed on cruciferous weeds and volunteer rapeseed, moving onto rapeseed and other cruciferous crops as they emerge. Eggs are laid in moist soil near the roots of host plants from the end of May to early

July, after which the adults die (Burgess, 1977). Larvae feed on host plant roots and pupate in the soil. The summer generation of adults emerges from late July to September, feeding on whatever crucifers are present and seeking hibernation sites as the weather cools in late September and early October.

P. striolata emerges from 1 to 4 weeks earlier in the spring than P. cruciferae (Westdal and Romanow, 1972); summer adults of P. striolata also emerge earlier, and seek hibernation sites earlier as well (Wylie, 1979). Ps. punctulata adults emerge around the beginning of April, about 10 days earlier than P. striolata.

The species are univoltine, having one generation per year on rapeseed on the prairies, with population peaks coinciding with early spring and late summer adult emergence (Westdal and Romanow, 1972; Burgess, 1977; Wylie, 1979). However, Westdal and Romanow (1972) reported that development from egg to adult could be completed in 7 weeks and in favorable environmental conditions the possibility of the occurrence of two summer generations may exist. Kinoshita and co-workers (1979) reported two summer generations occurring on garden crucifers in southern Ontario in 1975, while finding only one summer generation on turnips in the cooler summer of 1974. These researchers found that the number of generations per year varied with temperature.

Biological control of flea beetles is limited in nature; the insects have few pathogens, predators, or parasites and at present these exist in very low numbers (Osgood, 1975; Burgess, 1977b). Flea beetles are well adapted to climatic regions where rapeseed and other crucifers are grown; their winter mortality is low (Burgess, 1981b).

### 2.3.3 Host Preference

*Ps. punctulata* is the most polyphagous of the three common species, feeding on a wide variety of plants including crucifers and hops (*Humulus lupulus* L.). On the prairies, feeding occurs on rhubarb, *Rheum rhaponticum* L., weeds in the Polygonaceae, Chenopodiaceae, Boraginaceae, and Compositae families (Burgess, 1977), and on garden beets, *Beta vulgaris* L. (Westdal and Romanow, 1972).

The two *Phyllotreta* species have host ranges restricted to plants of the Cruciferae, Capparidaceae, and Tropaolaceae (Feeny *et al.*, 1970). Dobson (1956) suggested that smaller species such as cabbage, *Brassica oleracea* var. *capitata* L., and cauliflower, *B. oleracea* var. *botrytis* L., were more heavily attacked than larger species such as turnip, *B. rapa* L. and mustard, *B. hirta* L. On the other hand, Vargas and Kershaw (1979) reported that flea beetles showed preference towards summer turnip, mustard, and radish, *Raphanus sativus* L. and fed only minimally on *B. oleracea* cultivars, while Feeny *et al.* (1970) found similar flea beetle densities on mustard and broccoli. It is probable that host selection is based on chemical, physical, and environmental characteristics of the host plants (Feeny *et al.*, 1970; Putnam, 1977; Nielson, 1978a, 1978b; Kinoshita *et al.*, 1979; Lamb, 1980).

### 2.3.4 Crop Damage

Plants are most vulnerable to injury as seedlings, particularly at their emergence when overwintering adult beetles are prevalent and when only cotyledons are present (Westdal et al., 1979). Beetles may kill plants directly by severing the hypocotyl or by eating the meristem at emergence. Feeding may also result in small round holes on cotyledons, leaves, or stems, giving the plant a "shot-hole" appearance (Burgess, 1977). Heavy attack, especially when accompanied by hot dry weather which increases plant dessication, may destroy a crop (Lamb and Turnock, 1982).

In rapeseed crops Osgood (1975b) found that, under most climatic conditions, a certain amount of plant stand thinning due to insect damage or other problems did not significantly affect yield because of the compensatory ability of the crop. Rapeseed yields are similar over a wide range of plant densities. This is in contrast to a row crop situation such as with broccoli production, where a missing plant not only decreases overall yield through its loss, but yield reductions may also occur if surrounding plants grow larger heads which may be unmarketable as they take advantage of decreased competition. Since crop stand is very important to final yield in most vegetable crops, poor stand establishment usually necessitates reseeding.

Apart from seedling mortality, foliar feeding by insects may cause yield losses due to reduced plant vigour, delayed and uneven maturity, and reduced harvest quality (Westdal et al., 1979; Lamb and Turnock, 1982). Osgood (1975b) found that flea beetles reduced yield by 38% at densities of 3 beetles per plant when permitted to feed for only 4 days on newly emerged rapeseed seedlings. Osgood (cited in Westdal et al., 1979) further reported that with continued flea beetle injury on older seedlings, 10% damage to rapeseed plants in the 3 to 7 leaf stage resulted in a yield loss of 224-280 kg/ha (4 to 5 bu/acre), whereas 20 to 30% damage resulted in yield losses of 448-784 kg/ha (8 to 14 bu/acre). At present, control methods for flea beetles on rapeseed are recommended when 25% or more of seedling leaf area has been destroyed by feeding (Manitoba Agriculture, 1982c).

While Kinoshita et al. (1979) stated that larvae of some flea beetle species may reduce plant stand by feeding on roots, Burgess (1977) noticed no major effects on rapeseed plant vigour or growth due to larval root feeding. Larval feeding on rapeseed has generally been considered as negligible, even though no research data are available to substantiate this assumption (Osgood, 1975b). Kinoshita et al. (1978) reported that flea beetle larvae can destroy or reduce marketability of root crops such as radish and rutabaga, but offered no evidence for such damage.

As crucifers mature, the effect of foliage feeding on them lessens. Foster (1983) reported that damage to Brassicas was rarely significant once plants became well established. Bardner and Taylor (1970) found that radish dry matter was negatively and linearly correlated with the number of feeding holes/$cm^2$ of leaf area. The authors reported that as plant biomass increased towards harvest, the injurious effect of each feeding hole diminished. Gerber (1975) suggested that fields with large plants would require a larger pest density to cause economic damage than fields with small seedlings. Wyman and Oatman (1977) found that "extensive" feeding damage by lepidopterous larvae on broccoli between thinning and preheading stages had no effect on yield. Although Straka (1979) found that economic damage greater than

3% occurred when 14 to 16% of the leaf area of an early cauliflower cultivar was removed during vegetative growth, when Cranshaw artificially defoliated broccoli transplants 20, 31, and 45 days after transplanting by removing 25, 50, and 100% of the leaves, only complete defoliation consistently affected head weights because of the great ability of the plants to compensate for leaf loss (Cranshaw, personal communication).

While Foster (1983) reported that severe attacks by summer adult flea beetles may not have any effect on ultimate yield of forage and root Brassicas, Lamb (1980) found such adults may strip the epidermis of rapeseed pods, resulting in premature drying and shattering as well as increased susceptability to fungal attack. Chalfant and co-workers (1979) found that cabbage was sensitive to defoliation during head development, while Cranshaw (1982) suggested that broccoli required chemical protection during head development to prevent damage to and contamination of the marketed product by lepidopterous larvae.

Climatic conditions play an important role in flea beetle activity and damage impact. Osgood (1975b) reported that flight was common at temperatures above 20°C in calm winds, and that beetles could rapidly invade rapeseed fields. Burgess (1977) found that flea beetles fed most actively when the weather was sunny, warm, and dry. Cool, damp weather reduced feeding intensity and aided plant growth so that plants were better able to withstand attack. Kinoshita _et al_. (1979) found that flea beetle activity was reduced in wet and windy weather, during which adults would burrow into soil cracks and crevices. Reed and Byers (1981) found that in the laboratory watering of flats containing flea beetles on forage kale plants was detrimental to flea beetle survival. Burgess (1977) reported that flea beetles preferred to attack rapeseed plants whose foliage was exposed to bright sunlight, such as seedlings, isolated volunteer plants, or crops planted in widely spaced rows. Conversely, shade seemed to inhibit attack.

Weather affects both flea beetle behavior and development. Kinoshita et al. (1978) found that in the laboratory beetle life cycle development was fastest at 30°C, the highest temperature tested. A warm summer, therefore, will increase egg-laying and the speed of beetle development (Foster, 1983), so that not only is there a risk of prolonged crop damage by summer adults, but if this large overwintering population is subjected to a mild winter and a warm, dry spring, severe crop losses in the next year are likely. Foster (1983) found that severity of damage and economic loss would be reduced by a long cold spring or by high rainfall in May and June.

Chapter III

# MATERIALS AND METHODS

## 3.1 FIELD STUDIES

### 3.1.1 Study of the Effect of Flea Beetle Feeding on Broccoli of Different Ages

#### 3.1.1.1 Plot Establishment and Design

A two year field study was undertaken at the Agriculture Canada Special Crops Substation, Portage la Prairie, Manitoba. The soil type is Neuhorst clay loam and Tables 1 to 3 provide climatological information for the area (Environment Canada, 1982).

In both 1982 and 1983 the test site was broadcast fertilized with 110 kg/ha ammonium nitrate phosphate, 23-23-0. The herbicide trifluralin (Treflan) applied in the spring at a rate of 2 L/ha was incorporated using standard field procedures and the plots were packed to form as smooth and firm a seedbed as possible.

Five treatments were planted at each of six planting dates in 1982 and 5 planting dates in 1983. The treatments were:

Treatment A - 4 week old transplants

Treatment B - 3 week old transplants

Treatment C - 2 week old transplants

Treatment S - direct seeded

Treatment S+F - direct seeded plus carbofuran (Furadan) granules.

TABLE 1

Mean monthly temperatures and precipitation at Portage la Prairie for the years 1951-1980 inclusive.

| | Mean Monthly Temperature (°C) | Mean Monthly Precipitation (mm) | |
|---|---|---|---|
| January | -18.3 | 26.2 | |
| February | -14.6 | 21.4 | |
| March | - 7.4 | 27.3 | |
| April | 3.2 | 42.6 | |
| May | 11.2 | 62.3 | |
| June | 17.0 | 75.7 | |
| July | 19.7 | 76.3 | |
| August | 18.4 | 81.0 | |
| September | 12.4 | 50.0 | |
| October | 6.5 | 30.8 | |
| November | - 4.1 | 29.4 | |
| December | -13.1 | 21.9 | April-Oct |
| | $\bar{x}$ = 2.6 | Sum = 544.9 | 418.7 |

TABLE 2

Mean monthly temperatures and total precipitation at Portage la Prairie, 1982 and 1983.

| | 1982 | | 1983 | |
|---|---|---|---|---|
| | Mean Monthly Temperature (°C) | Total Monthly Precipitation (mm) | Mean Monthly Temperature (°C) | Total Monthly Precipitation (mm) |
| April | 2.6 | 12.4 | 2.9 | 6.9 |
| May | 12.7 | 43.1 | 8.3 | 48.3 |
| June | 13.9 | 66.0 | 16.9 | 64.1 |
| July | 19.8 | 183.3 | 22.2 | 37.3 |
| August | 17.0 | 47.0 | 22.7 | 41.4 |
| September | 12.4 | 66.2 | 12.8 | 53.4 |
| October | 6.3 | 69.7 | 5.9 | 19.9 |
| | | Sum = 487.7 | | Sum = 271.3 |

TABLE 3

Frost data for Portage la Prairie, 1922 to 1963 inclusive.

| | |
|---|---|
| Mean date of last frost in spring (0°C) | May 17 |
| Mean date of last killing frost in spring (-2°C) | May 11 |
| Mean date of first frost in fall (0°C) | Sept 23 |
| Mean date of first killing frost in fall (-2°C) | Oct 2 |
| Average duration of frost free period (>0°C) | 128 days |
| Average duration of killing frost free period (>-2°C) | 151 days |
| Annual growing degree days (base temp. 5°C) | 2800-3000 |

In all plantings except the first one of 1983, transplanting and seeding were done on the same day. Because the temperature on May 11, the first scheduled planting date in 1983, was very cold with snow flurries predicted, only the two seeded treatments were planted. The transplants, which had been stored in the dark at 4°C on May 10, were transplanted May 16.

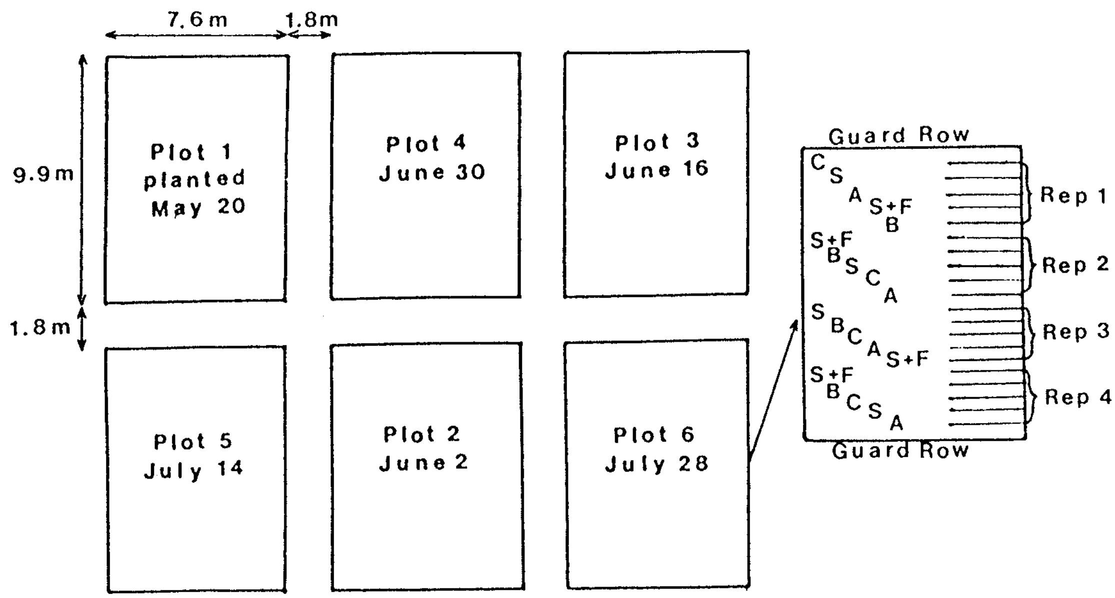
The plots were laid out in a randomized complete block design, with four replicates of each treatment in each plot in both years. Figure 1 illustrates the field layout and planting dates for both years.

Plant spacings were similar in both years, with transplants spaced 15 cm apart in each row and all rows spaced 45 cm apart. Direct seeded treatments were seeded at a rate of 2.2 kg seed/ha (0.76 g/7.6 m row) and thinned to 15 cm spacings between plants. A guard row of transplants 30 cm apart ran parallel to the treatments at either end of each plot. Pathways of 1.5 to 1.8 m separated each plot.

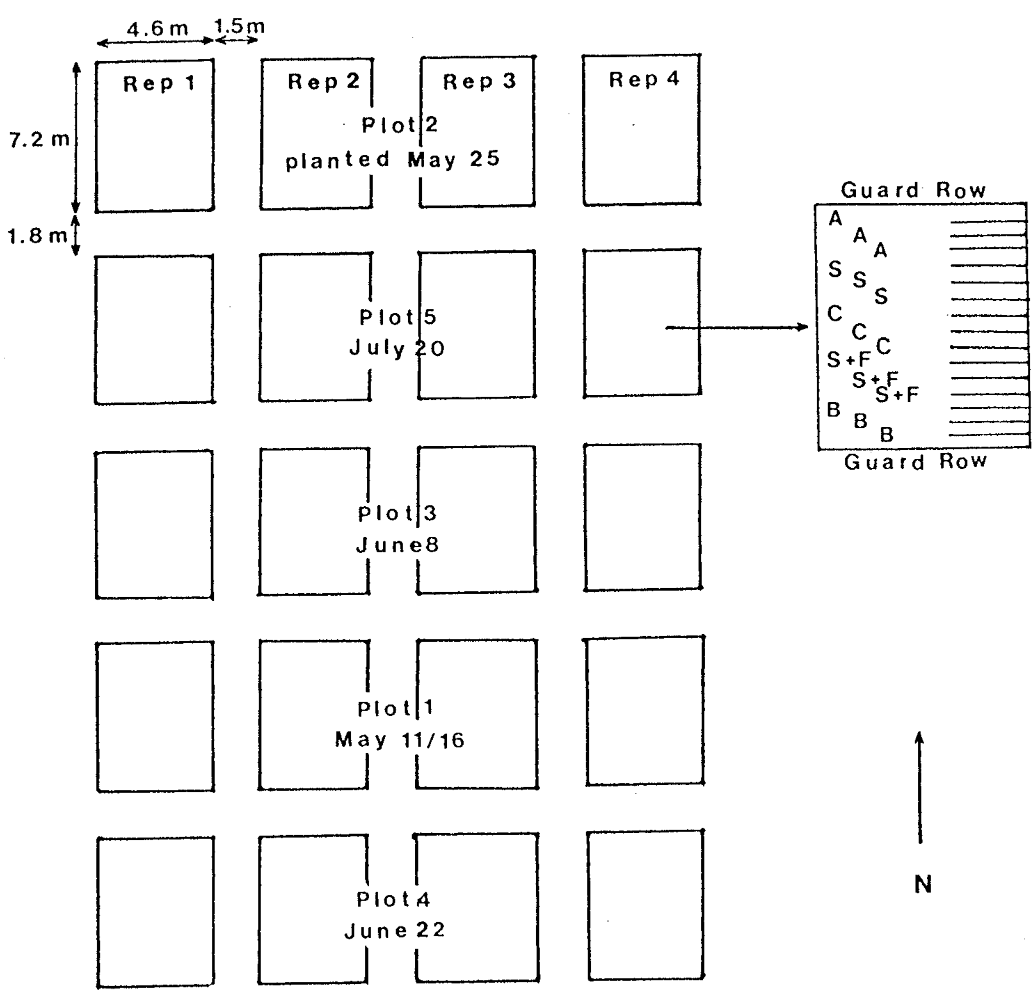
In 1982 each treatment occurred as one row per replicate, while each row was 7.6 m long, so that there were 50 transplants per row. In 1983, to overcome possible inter-row competition within replicates,

Figure 1: Field layout and planting dates of plots planted to determine the effects of flea-beetle feeding on transplanted and direct-seeded broccoli.

1982


7.6 m
1.8m
9.9 m
1.8 m
Plot 1 planted May 20
Plot 4 June 30
Plot 3 June 16
Plot 5 July 14
Plot 2 June 2
Plot 6 July 28
Guard Row
C S A S+F B
S+F B S C A
S B C A S+F
S+F B C S A
Guard Row
Rep 1
Rep 2
Rep 3
Rep 4

1983


4.6 m
1.5m
7.2 m
1.8 m
Rep 1
Rep 2
Rep 3
Rep 4
Plot 2 planted May 25
Plot 5 July 20
Plot 3 June 8
Plot 1 May 11/16
Plot 4 June 22
Guard Row
A A A
S S S
C C C
S+F S+F S+F
B B B
Guard Row
N

each treatment was planted in rows of three, with harvest data recorded from the center row only, although all three rows were harvested when mature. As well, in 1983 row lengths were reduced to 4.6 m, so that 30 transplants were placed in each row.

In 1983 the field site was approximately 20 m south-west of the 1982 site. In both years the study site was surrounded by vegetable cultivar trials, including cabbage, cauliflower, broccoli, Brussels sprouts, turnips, carrots, chicory, and potatoes as well as buckwheat in 1982.

3.1.1.2 Transplant Preparation

The broccoli seed used in both years was the hybrid mid-season cultivar 'Premium Crop', obtained from the Harris Seed Co., Rochester, New York in 1981. Seeds were treated with hot water and the fungicides thiram and benomyl by the company. They were not size-graded, but only large, plump seeds were used for growing transplants.

Transplants were seeded in 50 x 30 x 9 cm wooden flats in a pasteurized 1:1:1 soil:peat:sand mixture. They were watered as needed and grown in an opaque plastic greenhouse held at about 20°C with no artificial lighting. All seeds germinated in 3 to 7 days with germination rates of 90% or greater. Plants of Treatment A were initially seeded at approximately 60 seeds per row, 6 rows per flat, and transplanted 7 to 8 days later at a rate of 54 plants per flat. Treatments B and C were seeded at a rate of 54 seeds per flat.

Flats were fertilized with a 20-20-20 soluble fertilizer at a rate of 3.3 g/L, 600 ml per flat weekly, so that Treatment A was fertilized 3 times, Treatment B twice, and Treatment C once before transplanting. Flats were placed outside in cold frames to harden off the transplants; Treatment A transplants were outside 10 to 14 days, Treatment B 7 to 10 days, and Treatment C plants 3 to 7 days before planting. Cold frames were covered when there was a risk of frost.

Bare-rooted plants were removed from the flats the day before field planting and stored overnight in plastic bags in the dark at 4°C. Transplant sizes were:

Treatment A - 3 to 4 leaf stage, average height excluding roots 17 to 19 cm

Treatment B - 1 to 3 leaf stage, average height 12 to 15 cm

Treatment C - cotyledon to 2 leaf stage, average height 6 to 8 cm.

3.1.1.3 Transplanting and Seeding

Plants were hand-planted and watered in with tap water. All plots were irrigated immediately after transplanting with the exception of Plot 5, the July 20, 1983 planting, when, in spite of the 33°C temperatures, the plot was not irrigated until the day after transplanting due to a malfunctioning irrigation pump. Plots were irrigated as necessary, receiving an equivalent of about 2.5 cm of water a week. The source of irrigation water was the Assiniboine River in 1982 and local wells drilled in the field in 1983.

Direct-seeded treatments were seeded with a single-row, hand driven V belt seeder (Mechanical Welding Ltd., Winnipeg, Manitoba). Seeding depth was approximately 1 cm. In the seeded plus Furadan treatment Furadan 5G granules were mixed with the seed on the V belt at a rate of 5 kg/ha (1.74 g/7.6 m row equivalent), the rate recommended for flea beetle control in rapeseed. To overcome crusting problems encountered in 1982, rows of both direct-seeded treatments were covered with horticultural vermiculite at a rate of 1 L/5 m row in 1983.

Weeds were not a major problem in 1982. The most prominent weed in the plots was purslane (Portulaca oleracea L.), which did not appear until late June and which was kept under control by hand-hoeing. In 1983 purslane populations were much greater than in 1982 and at times managed to reach a considerable biomass before being hoed. Purslane plants were preferentially removed from newly planted plots and plots with small broccoli plants; the weed was ignored in plots with very large broccoli plants where it may have been established but did not compete well.

### 3.1.1.4 Beetle Sampling

For sampling flea beetles a 3 L yellow plastic honey pail (Bee Maid Co., Winnipeg, Manitoba) was randomly placed between treatment rows in each replicate so that there were four pails per plot. To each pail was added approximately 300 ml of tap water, a small amount of detergent (Sparkleen or Sunlight dishwashing liquid), and approximately 0.6 to 1.0 ml allyl isothiocyanate 94% (Aldrich Chemical Co., Milwaukee, Wisconsin). Beetles were removed from pails and fresh water and chemical added every 2 to 7 days, usually every 3 to 4 days. Waste water was drained onto the soil about 3 m north of the north edge of Plots 1, 4, and 3 in 1982 and a similar distance east of the east edge of Plots 1, 3, and 5 in 1983. In 1982 buckets for Plots 1, 2, and 3 were placed in the field May 20, while Plots 4, 5, and 6 buckets were set out on June 29. In 1983 buckets were set out a few days before each plot was planted, so that buckets were set out May 8, May 24, June 3, June 21, and July 18 in Plots 1 to 5, respectively.

In 1982 flea beetles were also sampled by means of a D-Vac vacuum insect net sampler (D-Vac Co., Riverside, California), which sampled insects from a host plant. The vacuum hose aperture was 0.0285 $m^2$. Five plants from each treatment were randomly sampled. Beetles from each sample of Treatments A, B, and C were counted separately; when S and S+F plants were very small, 5 plants were vacuumed in one sample.

In 1982 100 beetles from one water trap sample in each plot or as many flea beetles as were in one bucket up to a total of 100 beetles were identified to species level in the laboratory.

### 3.1.1.5 Control of Insect Pests

To eliminate insect pests other than flea beetles and to prevent beetle feeding on S+F plants after the Furadan had ceased being effective, several insecticides were applied to the plots.

Cutworms, present in about equal numbers in both years, were baited with carbaryl (20% Sevin granules), a few grains of which were applied to the base of young plants. The non-volatile non-systemic synthetic pyrethroid deltamethrin (Decis 2.5 E.C.) was used as a root drench to combat root maggots. In 1983 Lepidoptera larvae were killed by spraying the plants with Dipel (Bacillus thuringiensis), using a tractor and field sprayer on one occasion and a single nozzle backpack sprayer on another. Foliage of S+F treatments was sprayed with Decis 2.5 E.C., using a single nozzle backpack sprayer which gave about a 20 mm spray band. Table 4 lists insecticide treatments and application dates. Other pests, including rabbits in 1982 and a persistent groundhog in 1983, were eventually removed from the plots.

### 3.1.1.6 Damage Assessment, Harvest Procedure and Head Variables

To assess flea beetle damage, plant stand counts were taken throughout each season, so that percent mortality of transplanted plants was determined. Per cent mortality of direct-seeded rows could not be directly determined since emergence rates were not known.

Foliar feeding was measured as a visual estimation of the percent leaf area eaten of the youngest mature or fully expanded leaf on a plant, with 10 (Treatments A, B, C) or 5 (Treatments S, S+F) plants sampled per treatment row. To check this estimation, the area of numerous eaten leaves was measured photometrically using a Li-Cor leaf area meter (Li-Cor Ltd., Lincoln, Nebraska). Leaves of similar outline were cut out of paper and also measured and the difference between the two measurements, the percent leaf area eaten, was compared to the original estimation. Both methods gave results which were statistically similar but the mean percent leaf area eaten derived by estimation was approximately 4% lower than mean defoliation derived by photometric measurement.

TABLE 4

Insecticide treatments for control of non-target pests.

| Date 1982 | Pest | Insecticide | Rate | Plot |
|---|---|---|---|---|
| June 11 | cutworms | 20% Sevin granular | few grains/ plant | 1 & 2 all plants |
| June 25 | flea beetles | Decis 2.5 E.C. | 300 ml/ha (1.5 ml/4L) | 1, 2, 3 S+F |
| | cutworms | 20% Sevin granular | few grains/ plant | 1, 2, 3 all plants |
| June 29 | root maggots | Decis 2.5 E.C. | 1 ml/L drench* | 1, 2, 3 all plants |
| July 12 | root maggots | Decis 2.5 E.C. | 1.75-2 ml/L drench | 1, 2, 3 all plants |
| July 19 | cutworms | 20% Sevin granular | few grains/ plant | 4, 5 all plants |
| July 26 | flea beetles | Decis 2.5 E.C. | 300 ml/ha | 5, S+F |
| July 30 | flea beetles | Decis 2.5 E.C. | 300 ml/ha | 5, 6, S+F |
| Aug 19 | flea beetles | Decis 2.5 E.C. | 300 ml/ha | 5, 6, S+F |
| 1983 | | | | |
| June 6 | flea beetles | Decis 2.5 E.C. | 300 ml/ha | 2, S+F - center rows only |
| June 10 | flea beetles | Decis 2.5 E.C. | 300 ml/ha | 1, 2, S+F all rows |
| June 14 | flea beetles | Decis 2.5 E.C. | 300 ml/ha | 1, 2, 3 S+F - all rows |
| | cutworms | 20% Sevin granular | few grains/ plant | 2 - all rows 1 - center rows |
| June 17 | cutworms | 20% Sevin granular | few grains/ plant | 1 - companion rows 3 - center rows |
| June 21 | cutworms | 20% Sevin granular | few grains/ plant | 3 - companion rows |
| July 5 | root maggots | Decis 2.5 E.C. | 1-2 ml/L drench | 2 - all plants 1, 3 - center rows |
| July 15 | root maggots | Decis 2.5 E.C. | 1 ml/L drench | 3 - all plants 1, 4 - center rows |
| July 15 | root maggots | Decis 2.5 E.C. | 1 ml/L drench | 2 - center rows |
| [Aug 15 | groundhog | strychnine | 1-2 ml/head | 3 - Rep 1 heads] |
| Aug 24 | Lepidoptera larvae | Dipel B.t. | 640 g/ha | 5 - all plants |
| Aug 30 | Lepidoptera larvae | Dipel B.t. | 640 g/ha | 4 - all plants |

* approximately 300 ml per plant.

When assessing percent leaf area eaten the leaf stage of the plant was also recorded. When plants had considerable foliage which could not be easily counted, at about the 8 leaf stage, further assessments of leaf stage were discontinued.

Plants were hand-harvested when their heads were firm and the beads or florets were large but unopened. Twenty to 25 cm of stalk were retained with each head, with all but one or two small wrapper leaves removed. Plants were harvested as they matured, with harvests occurring every 3 to 4 days, up to every 7 days late in the season, from July to October in both years. All mature heads including guard row and companion plants were harvested.

After harvesting, each head was trimmed to 20 cm in length, heads were weighed and head and stalk diameters were measured. Bead uniformity and colour, head shape and looseness, stalk thickness, and an overall quality assessment were rated on a scale from 1 to 10. Days from field planting to harvest of plants from each treatment were recorded.

### 3.1.2 Insecticide Application for Protection of Broccoli Seedlings

In 1983 a small spray experiment was carried out to determine flea beetle damage under various spray regimes. Rows of transplants and seeded broccoli 1.5 m in length were planted with or thinned to 15 cm spacings between plants, and with 45 cm between rows. Rows were direct-seeded May 11 at 2.2 kg seed/ha, with the 15 cm spacings resulting in a maximum of 10 plants per row, while 10 transplants per row were planted May 16. Seedlings were in the late cotyledon to early first leaf stage when transplanted.

Treatments were:

A - No Spray

B - Spray 1 Week

C - Spray 2 Weeks

D - Spray 3 Weeks

Each of the 3 replicates consisted of 2 rows of each treatment randomly arranged, as illustrated in Figure 2. Guard rows of transplants spaced 30 cm apart were planted at either end of each transplanted and seeded replicate. Plants were seeded and transplanted using the same methods as described in the previous experiments.

Decis 2.5 E.C. at a rate of 300 ml/ha was sprayed on the rows twice a week with a single nozzle back-pack sprayer and a narrow spray band of 18 to 20 cm. Table 5 outlines the spray schedule. All replicates of the transplant Spray 1 Week Treatment were inadvertently sprayed on May 30, when the last spraying was supposed to be on May 24.

Insect problems similar to those described in the previous experiment were treated in the same way. On June 14 a few grains of Sevin 20% granular were applied to the base of each plant as cutworm bait, while Decis 2.5 E.C. at a rate of 6 ml/L was applied as a root drench to combat root maggots on June 27, July 5 and July 15.

Twice a week five plants in each row or as many plants as survived up to a maximum of five were randomly selected to estimate percent leaf area eaten and leaf stage of the youngest mature leaf. Plots

Figure 2: Field layout of plots seeded May 11 and transplanted May 16, 1983 to determine the duration of insecticide application for protection of broccoli seedlings.

Treatment A not sprayed
B sprayed 1 week
C sprayed 2 weeks
D sprayed 3 weeks

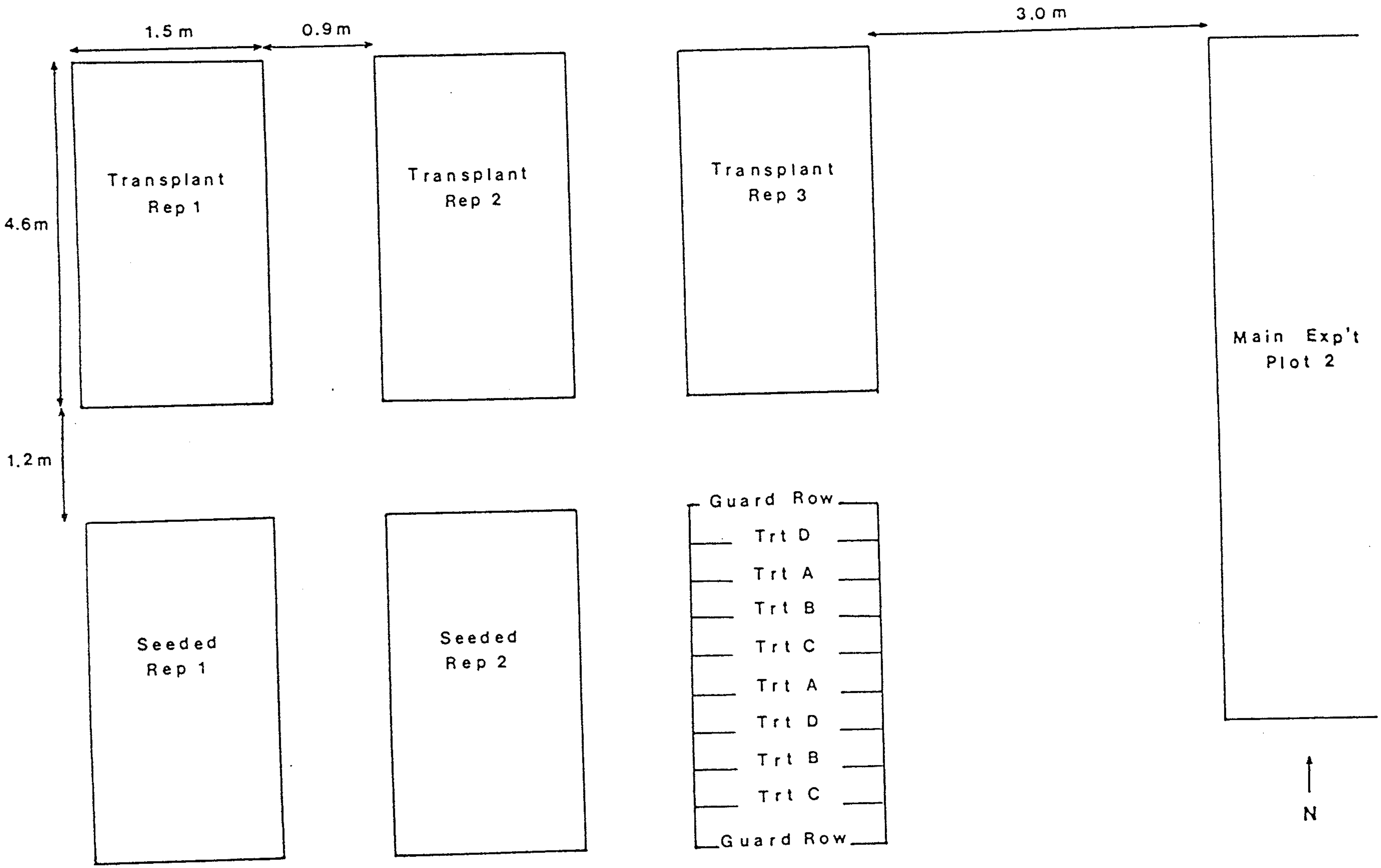

1.5 m
0.9 m
3.0 m
4.6 m
1.2 m
Transplant Rep 1
Transplant Rep 2
Transplant Rep 3
Main Exp't Plot 2
Seeded Rep 1
Seeded Rep 2
Guard Row
Trt D
Trt A
Trt B
Trt C
Trt A
Trt D
Trt B
Trt C
Guard Row
N

TABLE 5

Spray experiment spray schedule

| Treatment | Spray Date: Transplanted Plots | Spray Date: Seeded Plots |
|---|---|---|
| 0 | no spraying | no spraying |
| 1 | May 16, 20, 24, 30[1] | May 16, 20, 24, 27, 30 |
| 2 | May 16, 20, 24, 27, 30 | May 16, 20, 24, 27, 30, June 3, 6 |
| 3 | May 16, 20, 24, 27, 30, June 3, 6 | May 16, 20, 24, 27, 30, June 3, 6, 10, 14 |

[1] sprayed in error.

were irrigated, heads were harvested, and harvest data recorded with methods similar to those used in the main experiment.

## 3.2 LABORATORY STUDIES

In the main field experiment in 1982 it was noticed that some direct-seeded plants in rows grown next to rows of the largest transplants appeared to grow more slowly than direct-seeded plants in rows adjacent to other direct-seeded rows. To determine what effects, if any, competition between seedlings of different ages or stages of development had on each other, a greenhouse study was initiated in February and repeated in May, 1983. The heights and leaf stages of seedlings with similar aged seedlings on either side of them in a row were compared with heights and leaf stages of comparable-aged seedlings grown between two plants five or twelve days older.

An asbestos-sided greenhouse bench of dimensions 3.2 x 1.2 x 0.15 m was lined with plastic and filled with a pasteurized 1:1:1 soil:sand:peat moss mixture to a depth of 10 cm. Four rows of the broccoli cultivar 'Premium Crop' were seeded in the bed according to the design in Figure 3. Plants were seeded 3 per site 12.5 cm apart in the row, with rows 30 cm from each other and 15 cm from the sides of the bench. Seedlings were thinned so that only the strongest was left at each site. Planting dates were:

Planting 0 - planted Feb 25, May 19

Planting M - planted Mar 2, May 24

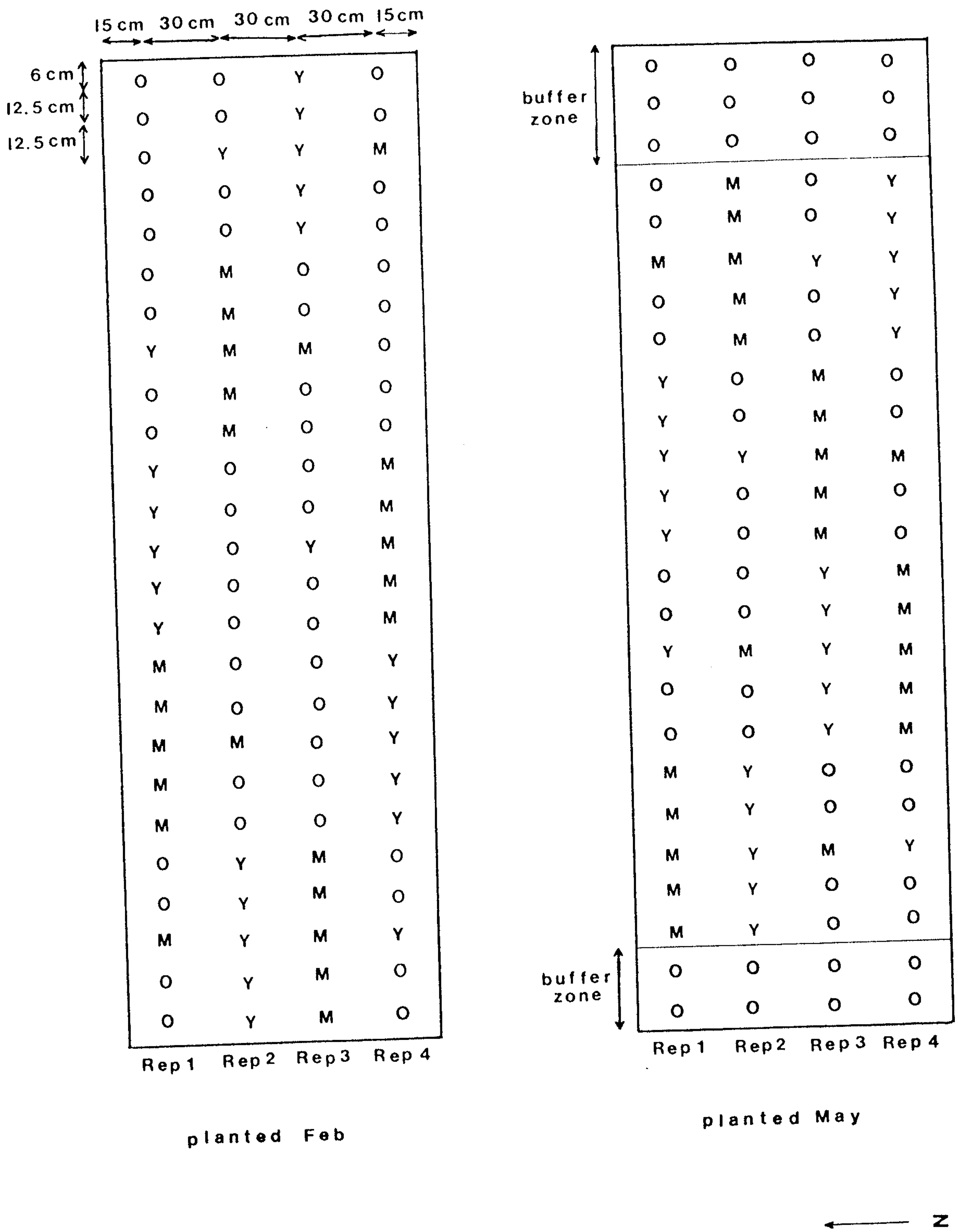
Planting Y - planted Mar 9, May 31

The three center plants in a group of 5, that is 0<u>000</u>0, M<u>MMM</u>M or Y<u>YYY</u>Y were considered to be the control for each planting date; the center plants in the sequences 00<u>M</u>00 and 00<u>Y</u>00 were compared to the controls for effects of competition from the older, larger plants on either side of them. In the February - March trial, each 0-0, M-M, Y-Y, and the two competition sequences 00M00 and 00Y00 appeared once in each row. Because of marked border effects at either end of the bench in the earlier seeding, in the May seeding a buffer zone of three 0 plants at the east and two 0 plants at the west end of each row was seeded. Only M-M, Y-Y, 00M00, and 00Y00 sequences were randomly repeated in each replicate.

The greenhouse was glass-sided and supplemented with 16 hours of artificial light daily. The temperature was set at 20°C for both trials with relative humidity maintained at approximately 60%.

Figure 3: Planting design for greenhouse competition experiment.

O - 'old' plants
M - 'medium' plants, 5 days younger than old ones
Y - 'young' plants, 12 days younger than old ones


15 cm
30 cm
30 cm
30 cm
15cm
6 cm
12.5 cm
12.5 cm
Rep 1
Rep 2
Rep 3
Rep 4
planted Feb
buffer zone
buffer zone
Rep 1
Rep 2
Rep 3
Rep 4
planted May
N

The bed was fertilized weekly with 13 L of 20-20-20 at a rate of 3.3 g/L water. The plants from each planting date, none of which were in the sequence OMO or OYO, were randomly selected each week and their above ground heights and leaf stages measured. All plants were harvested 47 days after the experiment was initiated, and 49 days after it was repeated in May, before plant growth was considered to be affected by the small volume of soil. Stems were severed at soil level, and fresh weight, height, and leaf stage of all plants were measured. Plants were then dried at 80°C for 24 hours and their dry weights recorded.

## 3.3 DATA ANALYSIS

Standard analyses of variance and covariance, linear regression, and correlation were conducted using the Statistical Analysis System on the Amdahl 470/V7 computer. Tests of homogeneity of variance were undertaken on a Hewlett Packard Model 10 programmable calculator. Statistical significance rankings were determined using Duncan's Multiple Range Test at the 0.05 and 0.01 probability levels. When special statistical analyses were used they were noted in the Results section.

Chapter IV

# RESULTS

## 4.1 BROCCOLI COMPETITION - GREENHOUSE STUDY

In the experiment conducted to determine the interplant competition characteristics of broccoli, "old" (0) plants surrounded "medium" broccoli 5 days younger (OMO, the bar indicating the plant measured), and "young" plants, 12 days younger (OYO). These plants were compared to plants surrounded by plants of similar ages (OOO, MMM, and YYY). In the earlier of the two trials, which was conducted in February - March, plants from both MMM and YYY treatments were larger in all variables measured than OMO and OYO plants, respectively. However, partly because of the strong edge effects, with east and west sides of the greenhouse bench exerting variability on replicates, only one parameter, dry weight of the YYY plants, was significantly greater than the dry weights of OYO plants (Table 6).

There were no significant differences in height, weight or leaf stages of the mean of two oldest plants surrounding an old (OOO), medium (OMO), or young (OYO) plant in the first experiment (Table 6).

Plant heights and leaf stages were generally greater in the second trial, conducted in May, than those of plants seeded earlier. However, MMM, OMO, YYY, and OYO fresh and dry weights were smaller in the second trial than in the first, while OMO and OYO weights were slightly larger. This increase in height and decrease in weight was

TABLE 6

Harvest results of broccoli competition study

a) First Trial

| Treat-ment | n | Plant Ht (mm) | S.E.M.[1] | Fresh Wt (g) | S.E.M. | Dry Wt (g) | S.E.M. | Leaf Stage[2] | S.E.M. |
|---|---|---|---|---|---|---|---|---|---|
| MMM[3] | 4 | 395.0[4] | 9.2 | 42.8 | 7.4 | 4.2 | 0.7 | 7.5 | 0.3 |
| OMO | 4 | 366.5 | 13.6 | 26.3 | 3.3 | 2.5 | 0.2 | 7.0 | 0 |
| YYY | 4 | 306.0 | 24.5 | 15.6 | 5.1 | 2.0* | 0.3 | 5.8 | 0.2 |
| OYO | 4 | 278.8 | 14.5 | 7.7 | 0.8 | 0.8* | 0.05 | 4.8 | 0.2 |
| OOO | 8 | 452.7 | 21.2 | 69.0 | 10.4 | 6.7 | 1.0 | 8.9 | 0.3 |
| OMO | 8 | 428.4 | 32.8 | 57.2 | 14.8 | 5.6 | 1.4 | 8.5 | 0.3 |
| OYO | 8 | 420.9 | 24.8 | 55.7 | 12.6 | 5.6 | 1.3 | 8.6 | 0.4 |

b) Second Trial

| Treat-ment | n | Plant Ht (mm) | S.E.M. | Fresh Wt (g) | S.E.M. | Dry Wt (g) | S.E.M. | Leaf Stage | S.E.M. |
|---|---|---|---|---|---|---|---|---|---|
| MMM | 4 | 397.5** | 9.4 | 34.1* | 2.5 | 3.9** | 0.2 | 8.0 | 0 |
| OMO | 4 | 321.8** | 19.0 | 16.0* | 3.2 | 1.8** | 0.3 | 7.5 | 0.3 |
| YYY | 4 | 328.5* | 7.4 | 12.6** | 0.3 | 1.4** | 0.1 | 6.0** | 0 |
| OYO | 4 | 253.8* | 13.9 | 4.6** | 0.6 | 0.4** | 0.0 | 4.5** | 0.3 |
| OOO | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| OMO | 8 | 442.9 | 23.3 | 57.4 | 6.8 | 6.7 | 0.7 | 9.6 | 0.4 |
| OYO | 8 | 460.4 | 13.2 | 65.2 | 7.0 | 7.2 | 0.8 | 10.2 | 0.2 |

[1] S.E.M. = Standard error of the mean.

[2] Mean number of leaves.

[3] M: plants 5 days younger, and Y: plants 12 days younger than O plants; plant being measured is underlined.

[4] Within columns values within each grouping differ statistically if followed by * ($P<0.05$) or ** ($P<0.01$).

probably due to increased solar radiation received in May, with a concomitant increase in the heat buildup in the greenhouse. Broccoli, a cool season crop, grows spindly and matures quickly at high temperatures, with smaller plants being more affected than larger ones.

In May, with the buffer zone of O plants neutralizing edge effects, Treatment OMO was significantly smaller than Treatment MMM in fresh weight ($P<0.05$), height, and dry weight ($P<0.01$) (Table 6). Only leaf stage was not significantly different, although it, too, was less in plants with older plants on either side. When comparing YYY plants with OYO plants, fresh and dry weights as well as leaf stage of Treatment OYO plants were significantly smaller than in Treatment YYY ($P<0.01$), as was plant height ($P<0.05$).

Although all four growth parameters were larger in O plants grown next to a 12 day younger plant Y as compared to O plants grown next to a 5 day younger plant M, differences were not statistically different. Both OMO and OYO Treatments had larger plants in May than in February.

From the greenhouse study it would appear that larger plants growing next to smaller ones are not as positively affected as smaller plants are negatively affected when growing next to larger ones. Thus growth parameters of OOO plants were not statistically different than those for OMO and OYO plants in the early trial. And while OYO plants were larger than OMO plants in May, these differences were not as great as the differences between OYO/YYY and OMO/MMM plants.

## 4.2 DURATION OF INSECTICIDE APPLICATION FOR PROTECTION OF BROCCOLI SEEDLINGS

### 4.2.1 Foliage Feeding

A twice-weekly Decis spray regime, conducted for 1, 2, or 3 weeks on transplanted and seeded broccoli, resulted in defoliation curves illustrated in Figure 4. Non-sprayed transplants had much more foliage eaten by flea beetles throughout the period sampled than transplants in the three spray treatments, all of which had rather low levels of feeding (Figure 4a). The feeding peak in the No Spray Treatment occurred eleven days after transplanting, when plants were in the 1 leaf stage. Although the last sprays of Spray 1, 2, and 3 Week Treatments occurred 14, 14, and 21 days after transplanting, respectively, the peak feeding for all 3 treatments occurred 32 days after transplanting, at approximately the 6 leaf stage. This indicates a possible reluctance of the flea beetles to feed on sprayed plants even though Decis has no residual effects.

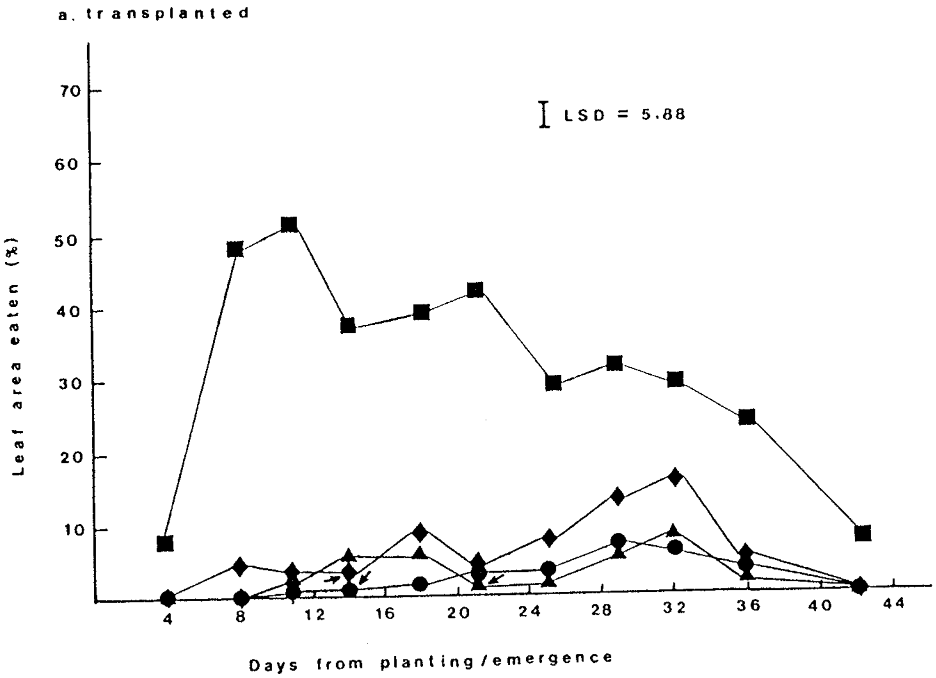
Because the transplant Spray 1 Week Treatment was accidentally sprayed 6 days after its last scheduled spraying, the results of this treatment must be viewed with caution. Although the Spray 1 Week and Spray 2 Week Treatment spraying ended the same day, the treatments are not identical since both were sprayed 8 and 14 days after transplanting but the Spray 2 Week Treatment was also sprayed 11 days after transplanting. Therefore, one would expect feeding on the Spray 1 Week Treatment to be higher earlier in the season had the accidental spraying not occurred.

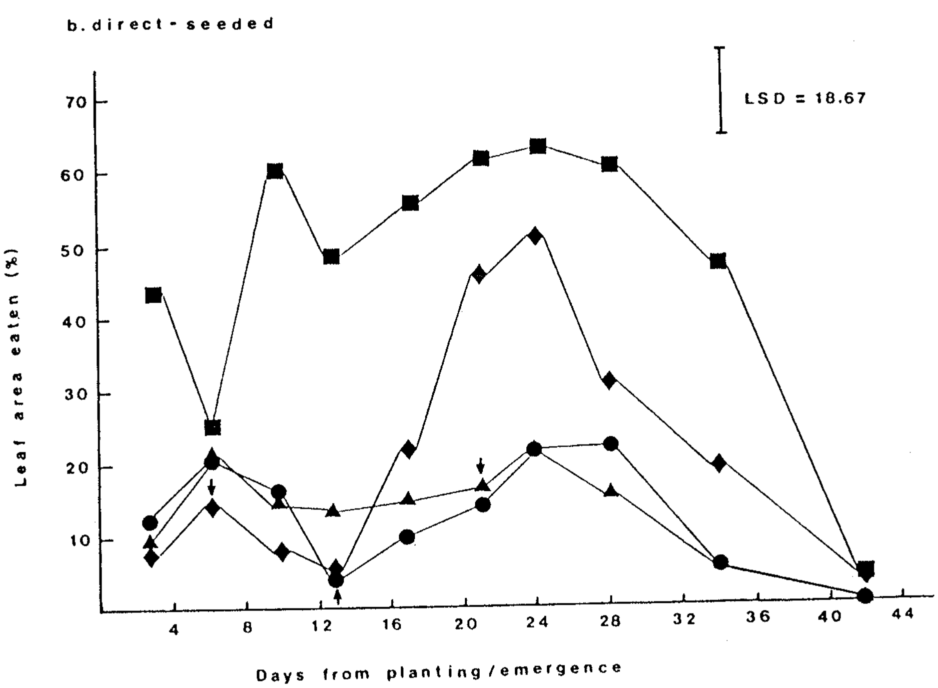
Figure 4: Per cent leaf area eaten by flea beetles of transplanted and direct seeded broccoli.

- ■ Treatment A not sprayed
- ◆ B sprayed 1 week[1]
- ▲ C sprayed 2 weeks
- ● D sprayed 3 weeks
- ↓ end of spraying

Vertical bars represent LSD=0.05 between treatments at a given sampling date; n=30 unless flea beetle feeding reduced broccoli populations below this level, in which case the entire number of surviving plants was sampled.

[1] except for Transplant Trt B - erroneously sprayed 6 days after last intended spraying.


a. transplanted
LSD = 5.88
Leaf area eaten (%)
70
60
50
40
30
20
10
4
8
12
16
20
24
28
32
36
40
44
Days from planting/emergence


b. direct-seeded
LSD = 18.67
Leaf area eaten (%)
70
60
50
40
30
20
10
4
8
12
16
20
24
28
32
36
40
44
Days from planting/emergence

An analysis of variance indicated that sampling date had an effect on amount of leaf area eaten; as well, there was a significant date * treatment interaction. The analysis of variance also showed that the mean leaf area eaten of the No Spray Treatment over a 42 day period after transplanting varied highly significantly from the means of the spray treatments, which did not vary significantly from each other (Table 7). However, Figure 4a illustrates that the Spray 1 Week Treatment had higher feeding levels than the Spray 2 Week and Spray 3 Week regimes 24 days after transplanting, and this difference may have been greater had the Spray 1 Week Treatment not been inadvertently sprayed.

TABLE 7

Mean foliage damage for various spray treatments.

| Treatment | % Leaf Area Eaten Transplanted | Seeded |
|---|---|---|
| No Spray | 31.0[1] a | 48.6 a |
| Spray 1 Week | 5.2 b | 21.5 b |
| Spray 2 Weeks | 3.0 b | 12.1 c |
| Spray 3 Weeks | 2.5 b | 13.1 c |

[1] Within columns, means followed by the same letter do not differ significantly ($P<0.01$).

In all transplant treatments feeding after about 40 days (6 to >8 leaves) became negligible as plant biomass became so large that feeding did not affect it and as beetles moved onto younger plants.

A higher percent of the foliage was consumed in the seeded plot than in the transplant plot (Figures 4b and 5). The seeded No Spray Treatment had the highest level of feeding of all 8 transplant and

Figure 5: Flea beetle feeding damage on broccoli seedlings protected from feeding for various periods. Photographs taken 41 days from seeding, 36 days from transplanting.

Treatment A not sprayed
B sprayed 1 week[1]
C sprayed 2 weeks
D sprayed 3 weeks

[1] Except for Transplant Trt B - erroneously sprayed 6 days after last intended spraying.

NOTICE/AVIS

PAGE(S) 45 IS/ARE EST/SONT colour photos

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VEUILLEZ ECRIRE A L'AUTEUR POUR LES RENSEIGNEMENTS OU VEUILLEZ CONSULTER L'EXEMPLAIRE DONT POSSEDE LE DEPARTEMENT DES ARCHIVES ET DES COLLECTIONS SPECIALES, BIBLIOTHEQUE ELIZABETH DAFOE, UNIVERSITE DU MANITOBA, WINNIPEG, MANITOBA, CANADA, R3T 2N2.


a) transplanted plot


b) seeded plot

seeded treatments, with a mean of 48.6% leaf area eaten throughout the period sampled (Table 7). High feeding levels in the No Spray Treatment occurred at 10 days after initial emergence, about the same time as the transplant No Spray Treatment, but, unlike the latter, feeding levels remained very high for about 3 weeks in the seeded No Spray Treatment.

The seeded Spray 1 Week Treatment also suffered high feeding damage, at some dates exceeding defoliation of transplant unsprayed plants. The Spray 1 Week feeding peak occurred at 24 days after emergence (2-3 leaf stage), slightly earlier than in the transplant Spray 1 Week plot.

Two and 3 Week spray treatments had defoliation patterns similar to each other, with initial feeding peaks 6 days after emergence and second peaks occurring 28 and 24 days after emergence, or 14 and 3 days after their last spraying, respectively (Figure 4b). Overall defoliation rates of these two treatments were greater than for the corresponding transplant treatments, but maximum defoliation reached only slightly over 20%. As in the transplant plot, percent leaf area eaten for all treatments in the seeded plot declined to very low levels at about 42 days from initial emergence.

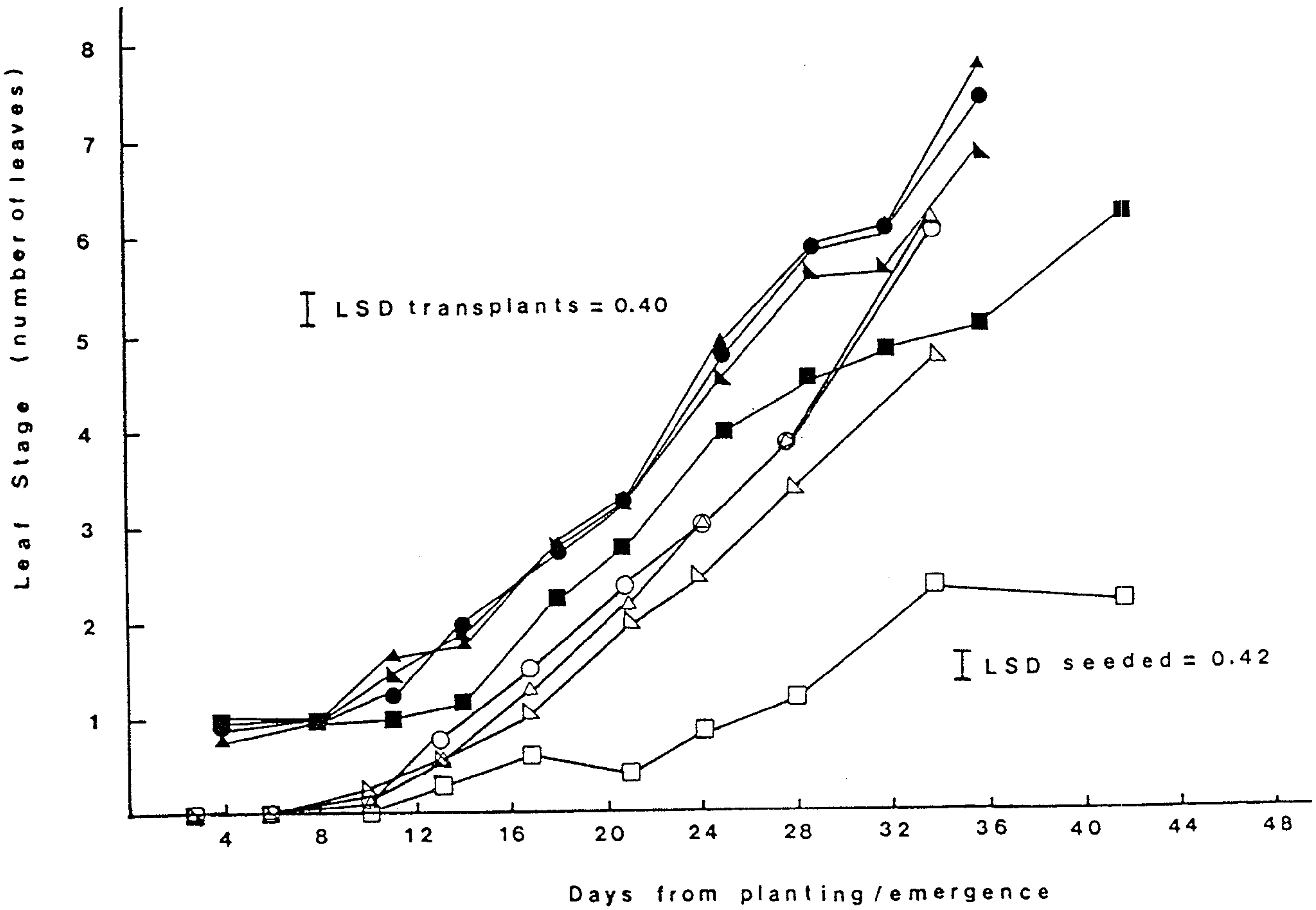
An analysis of variance of the seeded plot data indicated that mean leaf area eaten in the No Spray Treatment was significantly different from the means of the three spray treatments, while the mean of the 2 and 3 Week Treatments were significantly lower than the mean foliage eaten in the Spray 1 Week Treatment (Table 7).

### 4.2.2 Leaf Growth

Figure 6 illustrates the pattern of leaf growth of all 8 transplanted and seeded treatments. The growth rate for the transplant No Spray Treatment was significantly slower than for the other 3 transplant treatments. An analysis of variance indicated that the growth patterns of plants in the 2 and 3 Week Spray Treatments were similar throughout the measured period. As the season progressed growth of the Spray 1 Week Treatment plants lagged behind growth of plants in the Spray 2 and 3 Week Treatments significantly. As expected, the anova also indicated that days from planting significantly affected leaf stage.

As well as having the highest feeding levels of all 8 treatments, the seeded No Spray Treatment had the slowest growth rate, with significantly fewer leaves than the other seeded treatments throughout the sampling period (Figure 6). The Spray 1 Week Treatment, while having a similar number of leaves as the Spray 2 Week and Spray 3 Week Treatments initially, lagged behind in growth as the season progressed, with the gap similar to but larger than the gap between the transplant Spray 1 Week Treatment and the Spray 2 and 3 Week Treatments.

Seeded plants had a longer initial lag phase in growth than transplants, with a sharper increase in growth towards the end of the



Leaf Stage (number of leaves)
LSD transplants = 0.40
LSD seeded = 0.42
Days from planting/emergence

sampling period. At about 36 days from emergence the seeded 2 and 3 Week Spray Treatments reached similar leaf stages as the 3 transplant spray treatments, having overcome the 2 week growth advantage of the transplants.

### 4.2.3 Harvest Data

A univariate normal analysis indicated that data representing mean days to harvest in the seeded plot as well as weight and diameters of heads and stalks in both transplanted and seeded plots were normal, and therefore were analyzed by means of standard analysis of variance and Duncan's Multiple Range Test. No statistical operations were performed on head quality ratings.

Bartlett's test for homogeneity of variances indicated that variances of days to maturity in the transplanted plot were not homogeneous. Since log and square root transformations did not render the variances homogeneous, data were therefore ranked by replicates and analyzed by a Friedman's nonparametric analysis of variance.

Table 8 summarizes various parameters of the seedling protection experiment while Table 9 lists harvest data for marketable heads (heads whose quality rating is greater than 6). Because beetles often killed seedlings as they emerged from the ground, the number of plants per seeded row could not be determined. The situation was aggravated

TABLE 8

Seedling protection experiment harvest data.

a) Transplant Plot

| Treatment | Plants Harvested # | Plants Harvested % of Planted | Plants Harvested % of Best Trt | Marketable # | Marketable % of Planted | Heads Left in Field # | Heads Left in Field % of Planted | Plants Killed By Beetles # | Plants Killed By Beetles % of Planted | Plants Killed By Other # | Plants Killed By Other % of Planted |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No Spray | 33 | 55 | 83 | 31 | 52 | 7 | 12 | 15 | 25 | 6 | 10 |
| Spray 1 Week | 40 | 67 | 100 | 38 | 63 | 1 | 2 | 1 | 2 | 18 | 30 |
| Spray 2 Weeks | 39 | 65 | 98 | 34 | 57 | 1 | 2 | 0 | 0 | 20 | 33 |
| Spray 3 Weeks | 40 | 67 | 100 | 36 | 60 | 1 | 2 | 0 | 0 | 19 | 31 |

b) Seeded Plot

| Treatment | Plants Harvested # | Plants Harvested % of Best Trt | # Market-able | # Heads Left in Field | # Plants Killed By Beetles | # Plants Killed By Other |
|---|---|---|---|---|---|---|
| No Spray | 4 | 13 | 4 | 8 | 19 | 13 |
| Spray 1 Week | 30 | 100 | 29 | 10 | 8 | 12 |
| Spray 2 Weeks | 17 | 55 | 14 | 1 | 5 | 27 |
| Spray 3 Weeks | 17 | 55 | 15 | 3 | 9 | 25 |

TABLE 9

Seedling protection experiment harvest data for marketable heads.

a) Transplant Plot

| Treatment | n | Days to Harvest | S.E.M.[1] | Head Weight (g) | S.E.M. | Head Diam (cm) | S.E.M. | Stalk Diam (cm) | S.E.M. | Rating[2] (1-10) | S.E.M. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A - No Spray | 31 | 95.0[3]b | 3.2 | 212.89 a | 10.98 | 10.92 a | 0.37 | 3.53 a | 0.09 | 8.3 | 0.17 |
| B - Spray 1 Week | 38 | 76.8 a | 2.3 | 168.68 b | 7.96 | 10.00 b | 0.28 | 3.15 b | 0.08 | 8.6 | 0.17 |
| C - Spray 2 Weeks | 34 | 70.8 a | 1.0 | 140.39 b | 7.82 | 9.79 b | 0.28 | 2.88 b | 0.10 | 8.8 | 0.17 |
| D - Spray 3 Weeks | 36 | 72.3 a | 1.1 | 155.19 b | 7.89 | 9.99 b | 0.30 | 3.00 b | 0.08 | 8.5 | 0.18 |

b) Seeded Plot

| Treatment | n | Days to Harvest | S.E.M. | Head Weight (g) | S.E.M. | Head Diam (cm) | S.E.M. | Stalk Diam (cm) | S.E.M. | Rating (1-10) | S.E.M. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A - No Spray | 4 | 123.2 a | 3.5 | 164.95 n.s. | 27.04 | 9.68 b | 1.08 | 3.05 n.s. | 0.29 | 7.2 | 0.25 |
| B - Spray 1 Week | 29 | 108.7 ab | 3.1 | 212.62 n.s. | 13.76 | 0.54 ab | 0.36 | 3.56 n.s. | 0.14 | 8.4 | 0.18 |
| C - Spray 2 Weeks | 14 | 94.7 b | 3.1 | 247.49 n.s. | 14.57 | 2.10 a | 0.40 | 3.84 n.s. | 0.16 | 8.6 | 0.25 |
| D - Spray 3 Weeks | 15 | 105.6 ab | 5.2 | 224.79 n.s. | 18.69 | 1.27 ab | 0.58 | 3.75 n.s. | 0.16 | 8.0 | 0.17 |

[1] S.E.M. = Standard error of the mean.
[2] Rating scale: 10 = most desirable, 1 = least desirable.
[3] Within columns, means followed by the same letter do not differ significantly ($P<0.05$); n.s. - not significant.

by the fact that, because of the very cold weather at seeding, germination was delayed and two (and in some cases three) germination flushes occurred, the first about 13 days after seeding, the second 26 to 30 days after seeding. Although rows were covered with vermiculite at seeding, emergence rates for all four seeded treatments were less than optimum. The highest plant density per treatment at one time was 88% of the optimum of 10 plants/1.5 m row, even considering a seeding rate 3 times that of desired final stand. However, factors impeding seedling emergence applied equally to all four treatments, so that differences between plant populations illustrated in Table 10 were real. In Table 10 the number of plants/9 m represents the sum of plants in 3 replicates of 2 x 1.5 m rows per treatment.

TABLE 10

Plant populations in seeded plot treatments.

Total # of Plants/9 m Row

| Days from Emergence | Treatment | | | |
|---|---|---|---|---|
| | No Spray | Spray 1 Week | Spray 2 Weeks | Spray 3 Weeks |
| 3 | 10 | 42 | 45 | 28 |
| 6 | 13 | 53 | 44 | 40 |
| 10 | 9 | 46 | 46 | 32 |
| 13 | 9 | 53 | 49 | 36 |
| 17 | 14 | 54 | 49 | 41 |
| 21 | 10 | 52 | 48 | 39 |
| 24 | 10 | 46 | 46 | 39 |
| 28 | 7 | 50 | 43 | 35 |
| 34 | 9 | 50 | 41 | 33 |
| 42 | 12 | 48 | 44 | 39 |
| 49 | 12 | 41 | 23 | 20 |

The results of the spray experiment were confounded by the heavy attack by cabbage root maggots on both the transplant and seeded plots. Thus the "Plants Killed By Other" column in Table 8 is almost entirely due to root maggot damage. The No Spray Treatments in both the transplant and seeded plots had the highest number of plants which died because of flea beetle attack; these were killed shortly after emergence. Thus in Table 10 the number of plants in the seeded No Spray Treatment is much less than in any of the three spray treatments three days after emergence. (Note that the Spray 3 Week Treatment had lower and more delayed germination than the 2 other spray regimes). Maggots, however, concentrated their feeding on plants which were not affected by flea beetles, that is, plants in the Spray 1, 2 and 3 Week Treatments in both transplant and seeded plots.

The effect of maggot damage became noticeable 5 to 6 weeks after planting/emergence. This period corresponded to head formation in the transplant plot spray treatments. Plants which were not killed by maggots outright were weakened so that head sizes and weights in the 3 spray treatments were decreased over those expected (Table 9). Plants in the transplant and seeded No Spray Treatments, heavily attacked by flea beetles, were either killed immediately or slowly recovered from this attack throughout the season, escaping major maggot damage. The broccoli heads in the transplant No Spray Treatment, therefore, were much heavier with large diameter than those in the Spray 1, 2 and 3 Week Treatments. Conversely, the period necessary to reach maturity for the No Spray Treatment was much longer than for the spray treatments, which had not suffered as great initial flea beetle feeding damage as the No Spray Treatment (see Figure 4a).

In the seeded plot, the maggot attack corresponded to the 1 (No Spray) to 5 (Spray 3 Week) leaf stage of the broccoli plants, earlier in the season than for the transplants. Here the main effect of maggot damage was to kill plants, not to decrease head size. Fewer harvestable plants had evidence of maggot attack than in the transplant plot. Thus plants which were damaged but not killed by maggots managed to overcome maggot injury; therefore, while mean weight differences between treatments were not significant (Table 9) because of variability, head weight and head and stalk diameter were considerably larger in the three spray treatments than in the No Spray Treatment. As in the transplant plot, the time to maturity was longest in the No Spray Treatment. The 2 Week Spray Treatment had the shortest days to maturity period in both plots, as well as the highest quality rating, although this parameter was not significantly different from other treatments in the transplant plot.

## 4.3 EFFECTS OF FLEA BEETLE FEEDING ON DIRECT-SEEDED AND TRANSPLANTED BROCCOLI OF DIFFERENT AGES

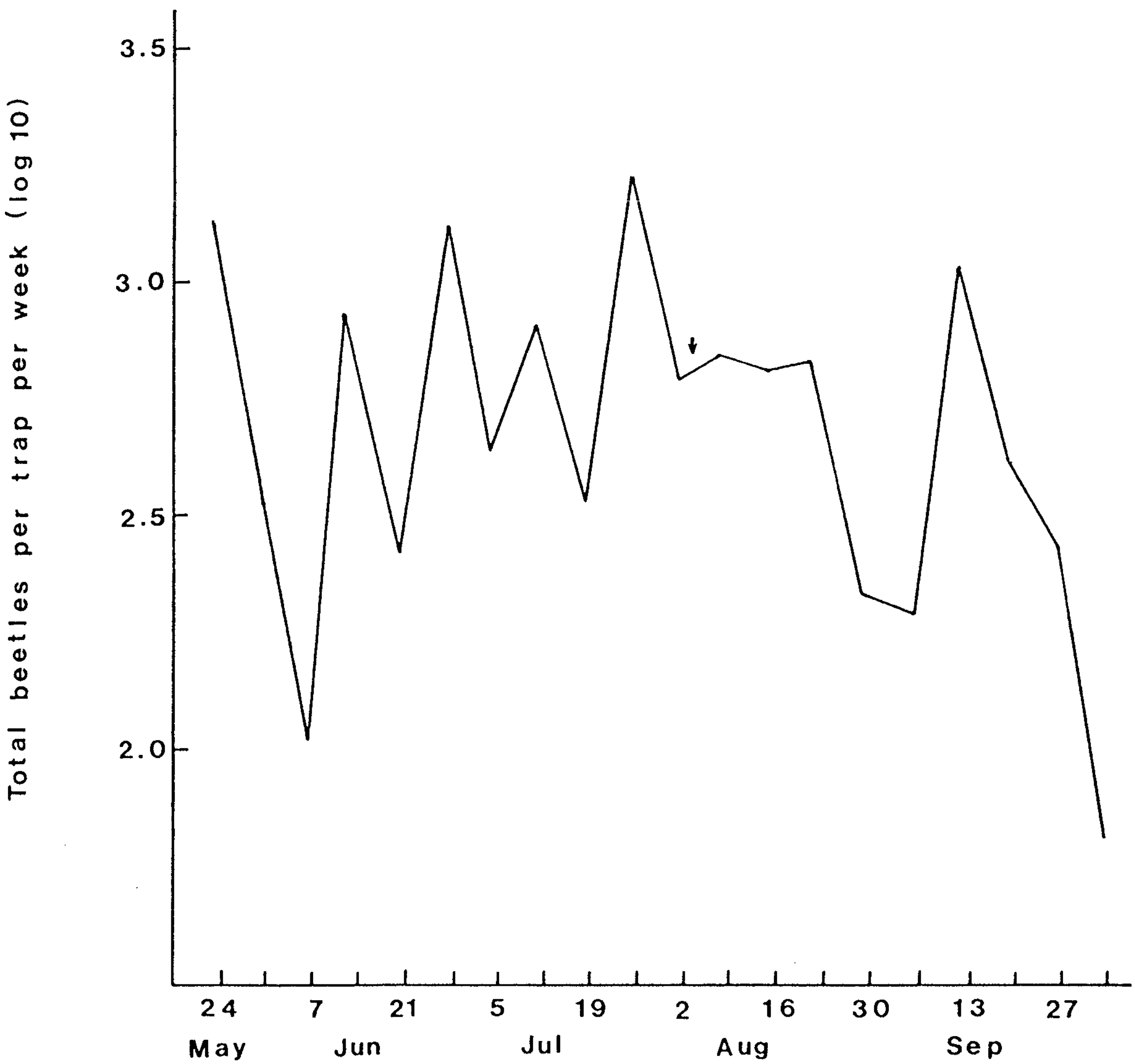
### 4.3.1 Beetle Populations

#### 4.3.1.1 Water Trap Sampling

When beetle populations were estimated by placing water traps in the plots, a tremendous variation in population occurred within each season and between seasons (Figures 7 and 8), and often between water traps in the same plot. The coefficient of variation of flea beetles per bucket per sampling period was greater than 100% at some times. Weekly numbers of beetles per trap showed a negative correlation with weekly precipitation levels and a positive correlation with weekly

Figure 7: Flea beetle populations determined by water trap sampling 1982.

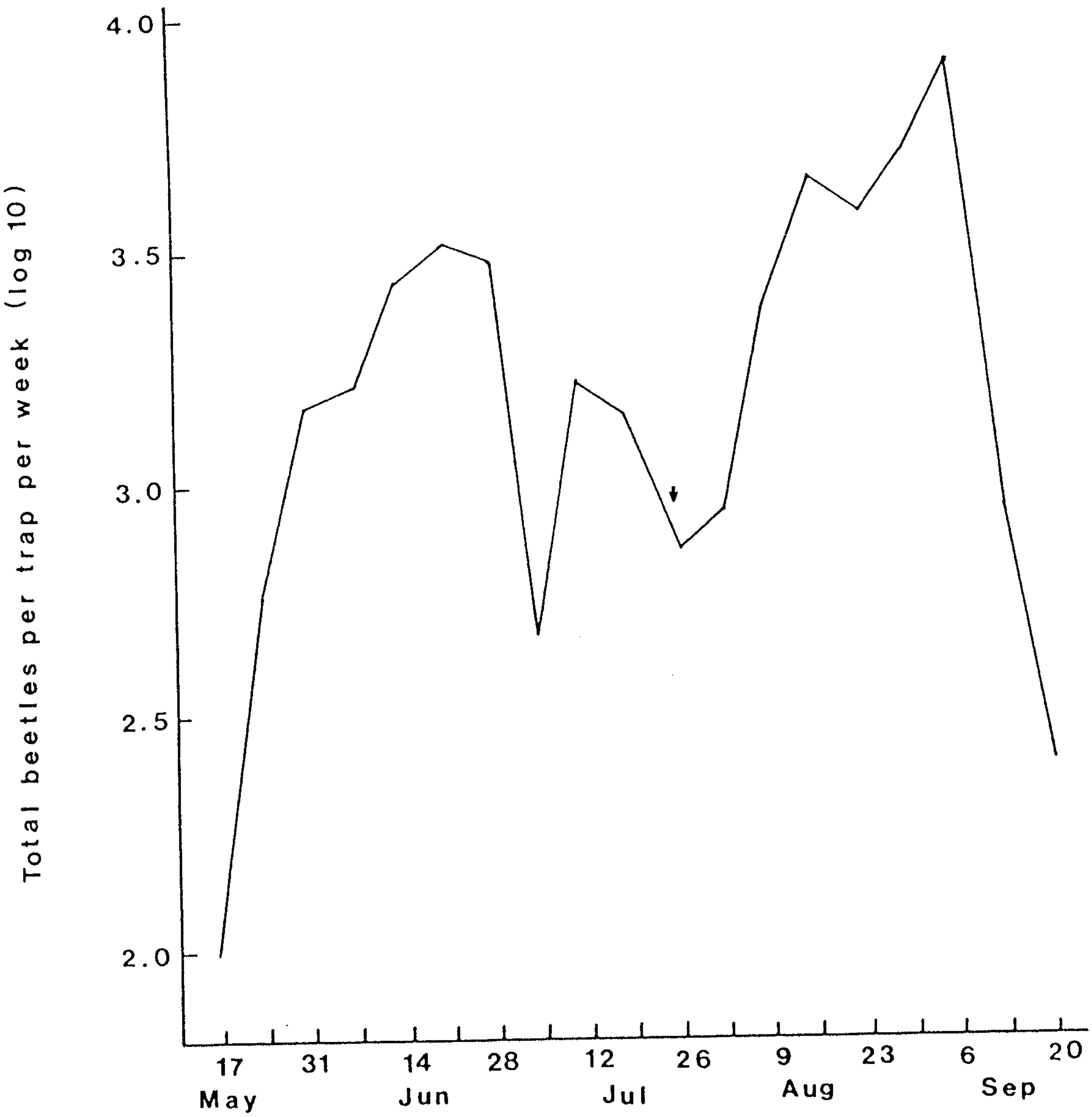
↓ first observation of summer generation adults.



Total beetles per trap per week (log 10)
3.5
3.0
2.5
2.0
24
May
7
Jun
21
5
Jul
19
2
Aug
16
30
13
Sep
27

Figure 8: Flea beetle populations determined by water trap sampling 1983.

↓ first generation of summer generation adults.



Total beetles per trap per week (log 10)
4.0
3.5
3.0
2.5
2.0
17
May
31
14
Jun
28
12
Jul
26
9
Aug
23
6
Sep
20

mean temperatures, but these relationships were not statistically significant over the entire season. However, many of the sharp decreases in beetle numbers in Figure 7 and the July 5 decrease in Figure 8 corresponded with periods of high precipitation.

The mean number of flea beetles per water trap per week over all planting dates in 1983 was more than three times greater than the over all mean in 1982, a statistically significant difference ($P<0.01$) (Table 11). However, in 1983 flea beetle numbers gradually increased to a first generation peak about June 21 (Figure 8); in contrast, beetle numbers were very high on May 24, the first sampling date in 1982, and the population peak may have occurred before sampling was initiated. The 1982 population data did not show a well defined over-wintering population peak.

The graphs for both 1982 and 1983 illustrate summer generation peaks. Despite the very cold spring of 1983, the warm summer that followed hastened beetle development so that the first summer generation beetles to emerge were observed on July 26, 8 days earlier than those observed in 1982. As well, the 1983 summer generation population peaked on September 7, 6 days earlier than the corresponding date in 1982.

Within each season, the average numbers of flea beetles per trap did not vary significantly between plots (Table 11). However, there was an apparent trend for beetles to move onto younger plants as the season progressed. Figures 9 and 10 illustrate that, generally, towards autumn more beetles were caught in buckets in plots planted

TABLE 11

Seasonal mean of flea beetle numbers collected per week in water traps located in plots planted at various dates.

| 1982 Plot No. | Planting Date | Mean Weekly No. of Beetles/Trap | S.E.M.[1] | 1983 Plot No. | Planting Date | Mean Weekly No. of Beetles/Trap | S.E.M. |
|---|---|---|---|---|---|---|---|
| 1 | May 20 | 591.2 | 136.1 | 1 | May 11/16 | 2165.6 | 440.6 |
| 2 | June 2 | 526.3 | 108.0 | 2 | May 25 | 1995.8 | 386.4 |
| 3 | June 16 | 458.1 | 92.2 | 3 | June 8 | 1943.7 | 454.8 |
| 4 | June 30 | 761.8 | 168.6 | 4 | June 23 | 2136.2 | 356.6 |
| 5 | July 15 | 970.0 | 250.1 | 5 | July 20 | 3183.9 | 1035.4 |
| 6 | July 28 | 473.5 | 70.4 | | | | |
| Mean of all plots | | 611.0**[2] | 60.1 | Mean of all plots | | 2210.9** | 231.8 |

[1] S.E.M. = Standard error of the mean.
[2] Mean of all plots - ** - statistically significant ($P<0.01$).

later in the season (Plots 4, 5, and 6, planted June 30, July 15, and July 28, 1982, respectively, and Plots 4 and 5, planted June 23 and July 20, 1983, respectively) than in earlier planted plots. This apparent increase in the number of beetles collected in water traps in Plots 4 and 5 in 1982 and in Plot 5 in 1983 over plots planted earlier (Table 11) may have been a feature of the sampling method. Baited traps may have provided a greater attraction to flea beetles than small plants in a plot while the traps collected few flea beetles as plants became larger and more attractive to them. Thus beetle numbers

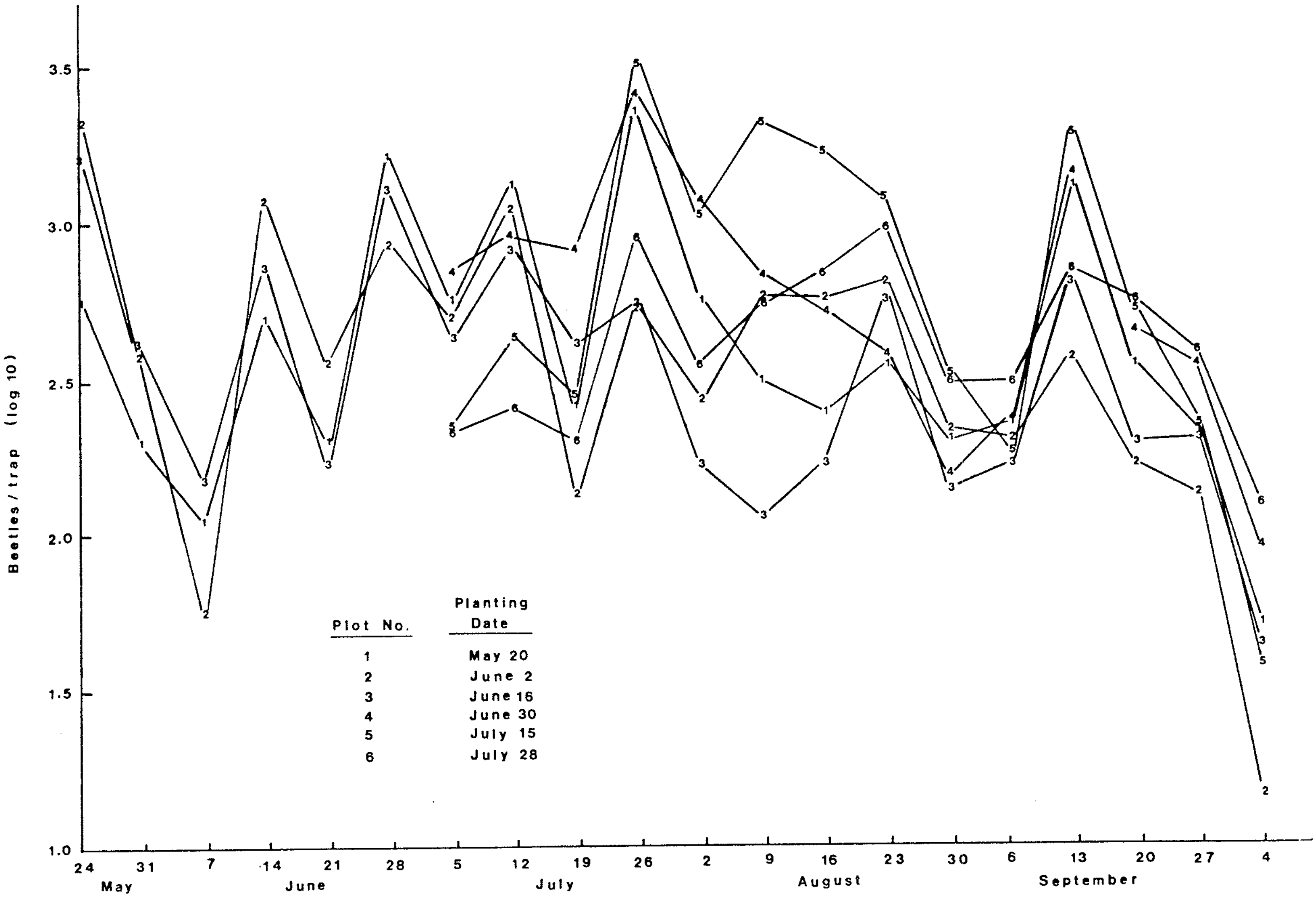
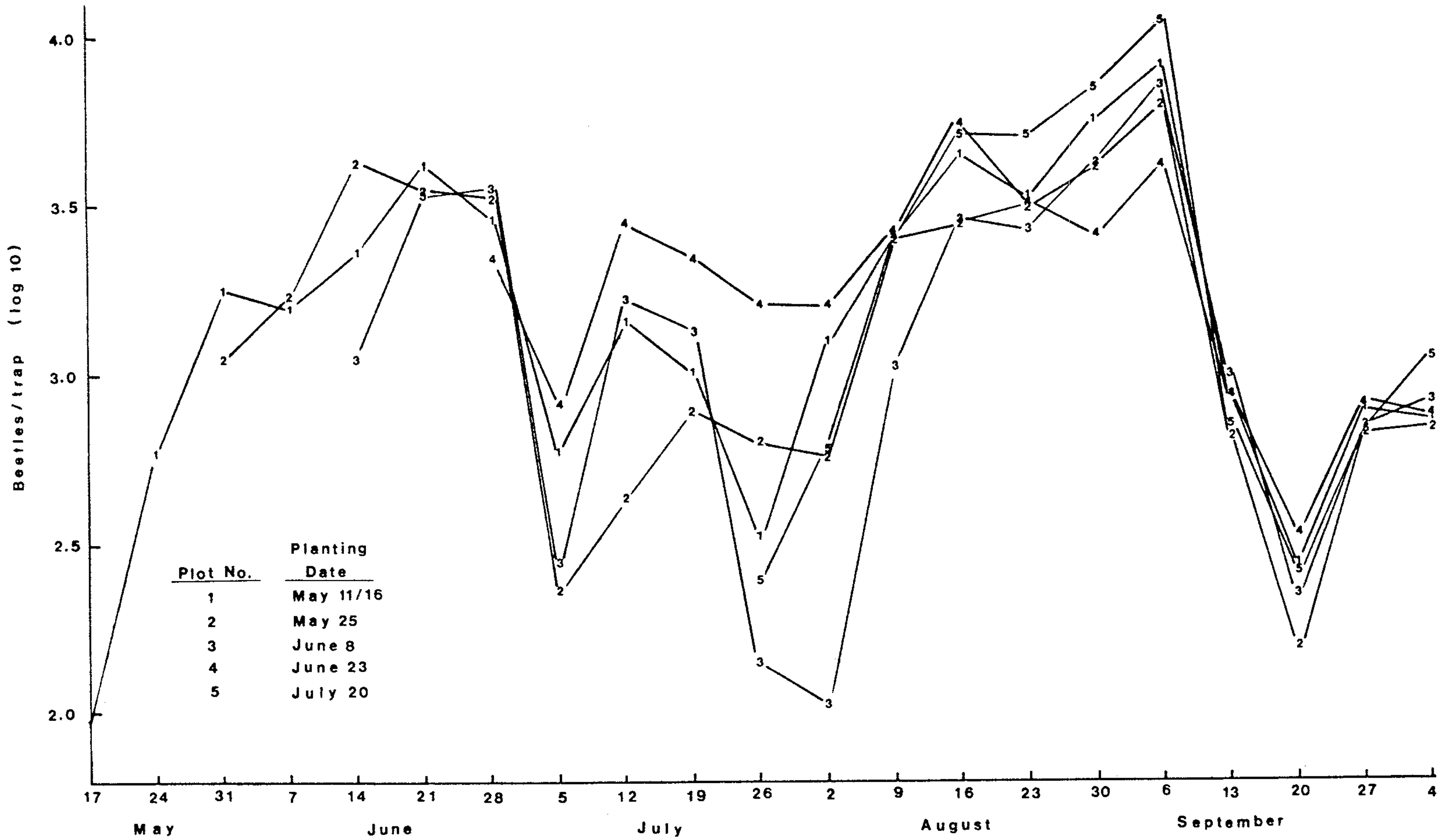

Beetles / trap (log 10)
3.5
3.0
2.5
2.0
1.5
1.0
24
31
May
7
14
21
28
June
5
12
19
26
July
2
9
16
23
30
August
6
13
20
27
4
September
Plot No.
Planting Date
1 May 20
2 June 2
3 June 16
4 June 30
5 July 15
6 July 28

Figure 10: Weekly mean number of flea beetles per water trap in plots with various planting dates, 1983.

| Plot | Planting Date |
|---|---|
| 1 | May 11/16 |
| 2 | May 25 |
| 3 | June 8 |
| 4 | June 23 |
| 5 | July 20 |


Beetles / trap (log 10)
4.0
3.5
3.0
2.5
2.0
17
24
31
7
14
21
28
5
12
19
26
2
9
16
23
30
6
13
20
27
4
May
June
July
August
September
Plot No.
Planting Date
1
May 11/16
2
May 25
3
June 8
4
June 23
5
July 20

may have been similar in plots planted early and late in the season while water trap results indicated otherwise.

When identifying samples of 100 flea beetles per water trap per plot throughout the 1982 season, it was found that all plots had similar species composition on any particular day sampled. Phyllotreta cruciferae percentages were lowest early in the season and at the beginning of the emergence of the summer generation compared to percentages of other species. On June 1, 86% of the flea beetles identified were P. cruciferae, with the remaining 14% being P. striolata ; similarly, a sample consisting of 78% P. cruciferae and 22% P. striolata was obtained on August 10. At all other times in the season P. cruciferae comprised 90 to 100%, usually 95 to 99%, of the population. Of the remainder, Psylliodes punctulata comprised up to 5% but usually 1 to 2% of the population, with P. striolata making up most of the rest. On several occasions one to three Epitrix sp. flea beetles were present in the samples, and in two samples a Chaetocnema sp. was identified.

#### 4.3.1.2 D-Vac Vacuum Sampling

Because water traps were randomly placed in plots, they gave no indication of the number of beetles associated with transplant or direct-seeded plants of a particular size. The D-Vac vacuum sampling method used in 1982 gave a direct measurement of the number of beetles on plants of a specific treatment.

Plants were sampled from the time they emerged or were transplanted until they reached a size where the D-Vac nozzle could no longer encompass the plant without breaking or excluding leaves; plants by this time had more than 8 mature leaves.

Figures 11a to 11e illustrate the seasonal variability of beetle numbers on plants of different treatments within a plot and variability between plots. Part of this population variability can be explained by variation in sampling conditions. Although the majority of weekly D-Vac samplings were conducted between 1200 and 1500 hours, on July 1 sampling took place at 0900 hours, before beetles reached peak activity levels. This accounted for the very low beetle numbers on plants in Plots 1, 2, and 3 on that date (Figures 11a to 11c). Similarly, a sudden rain which occurred while sampling Plot 4 on July 23 accounted for the great decrease in beetle numbers on that date (Figure 11d). Likewise very high wind gusts occurred while sampling part of Plot 5 and all of Plot 4 on August 12.

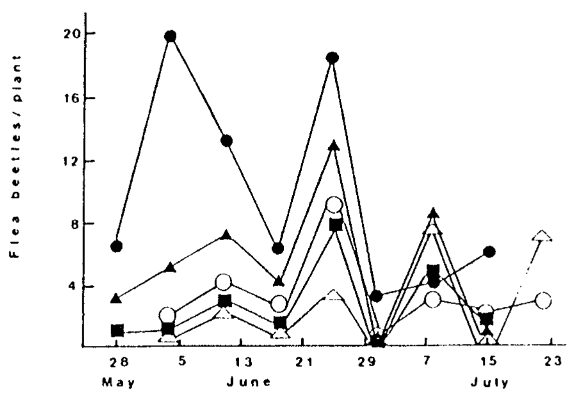
Beetle flight activity was observed to be greater when a shadow was cast upon the plants, so that while every precaution was made to sample from the north end of plot to the south end, with the person doing the vacuuming positioned facing south to minimize shadow formation, beetle numbers appeared to be more variable on days with bright sunshine than on cloudy days.

In all six plots beetles tended to congregate on older plants (Treatments A, B, and C, or 4, 3, and 2 week old transplants) early in the season, then shift onto the seeded treatments as the season progressed. Throughout the period sampled, although the seeded plus

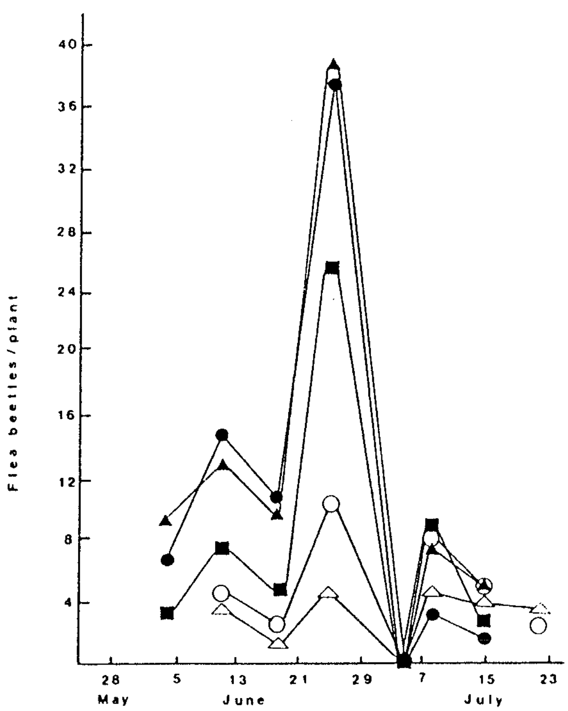
Figure 11: Flea beetle numbers per plant collected by D-Vac sampling, for plots with various planting dates, 1982.

| | | | |
|---|---|---|---|
| ● | Treatment | A | 4 week old transplants |
| ▲ | | B | 3 week old transplants |
| ■ | | C | 2 week old transplants |
| △ | | S | direct-seeded plants |
| ○ | | S+F | direct-seeded plants plus Furadan |

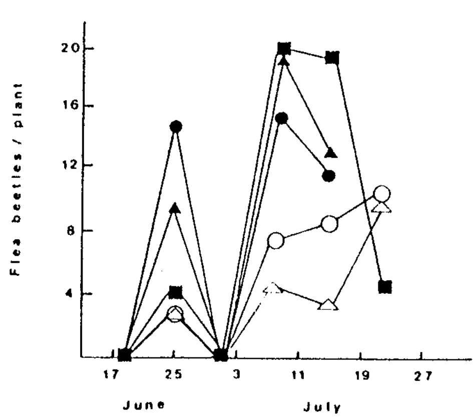
a Plot 1 planted May 20



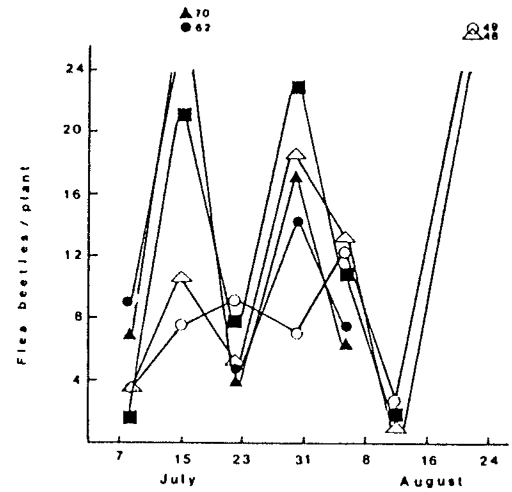

b. Plot 2 planted June 2



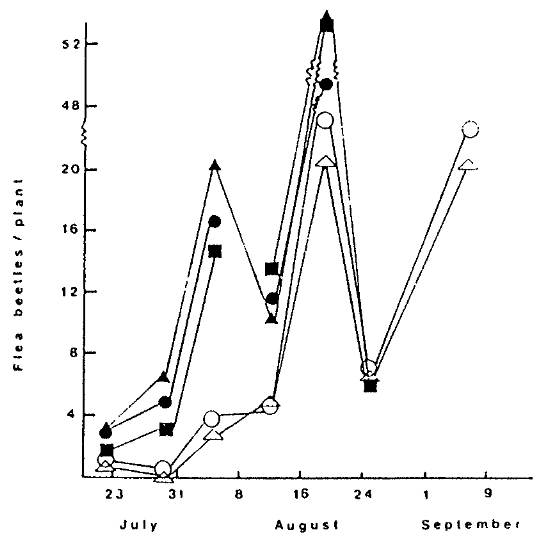

c. Plot 3 planted June 16



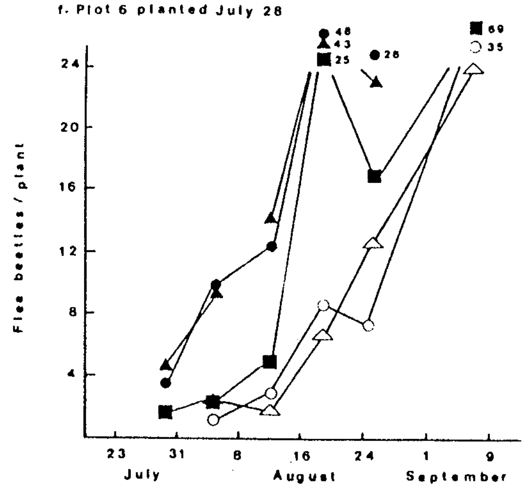

d. Plot 4 planted June 30




e. Plot 5 planted July 14




f. Plot 6 planted July 28



Furadan (S+F) treatment had slightly higher flea beetle numbers than the seeded (S) treatment in all plots except Plot 4, planted July 15, this difference was not significant.

Numbers of beetles per plant were higher on the plants of the June 30, July 15, and July 28 plantings than in the three earlier plantings (Figures 11d, 11e, and 11f), similar to trends found with water trap sampling. The highest mean number of beetles per plant, 70, occurred on September 7, 1982, on Treatment C (which had been transplanted 2 weeks from seeding) in Plot 6 (Figure 11f), although all five treatments in Plot 5 had very high numbers on August 19.

4.3.1.3 Water Trap Sampling vs D-Vac Sampling

A correlation analysis was conducted on flea beetle population data obtained from water trap and D-Vac samples to determine if there was a consistent relationship between the two sampling methods. The average number of flea beetles per D-Vac'd plant in a particular plot was compared to the average number of beetles sampled by means of water traps per plot on the day of vacuum sampling. As well, data from all plots were combined and the two methods compared. Appendix A presents the data.

No overall consistent relationship could be determined between the two sampling methods, nor was there any consistency when flea beetle numbers were transformed to logarithms or square roots. As Table 12 shows, the only significant relationship ($P<0.01$) between D-Vac and water trap beetle numbers occurred in the earliest planting data, Plot 1. In Plots 2 to 6 the correlation coefficient is negative, indicating a decrease in the numbers of one sampling method with an increase in numbers of the other, but the probability factor P indicates the relationships tended towards randomness.

TABLE 12

Correlation of flea beetle populations derived from D-Vac and water bucket sampling.

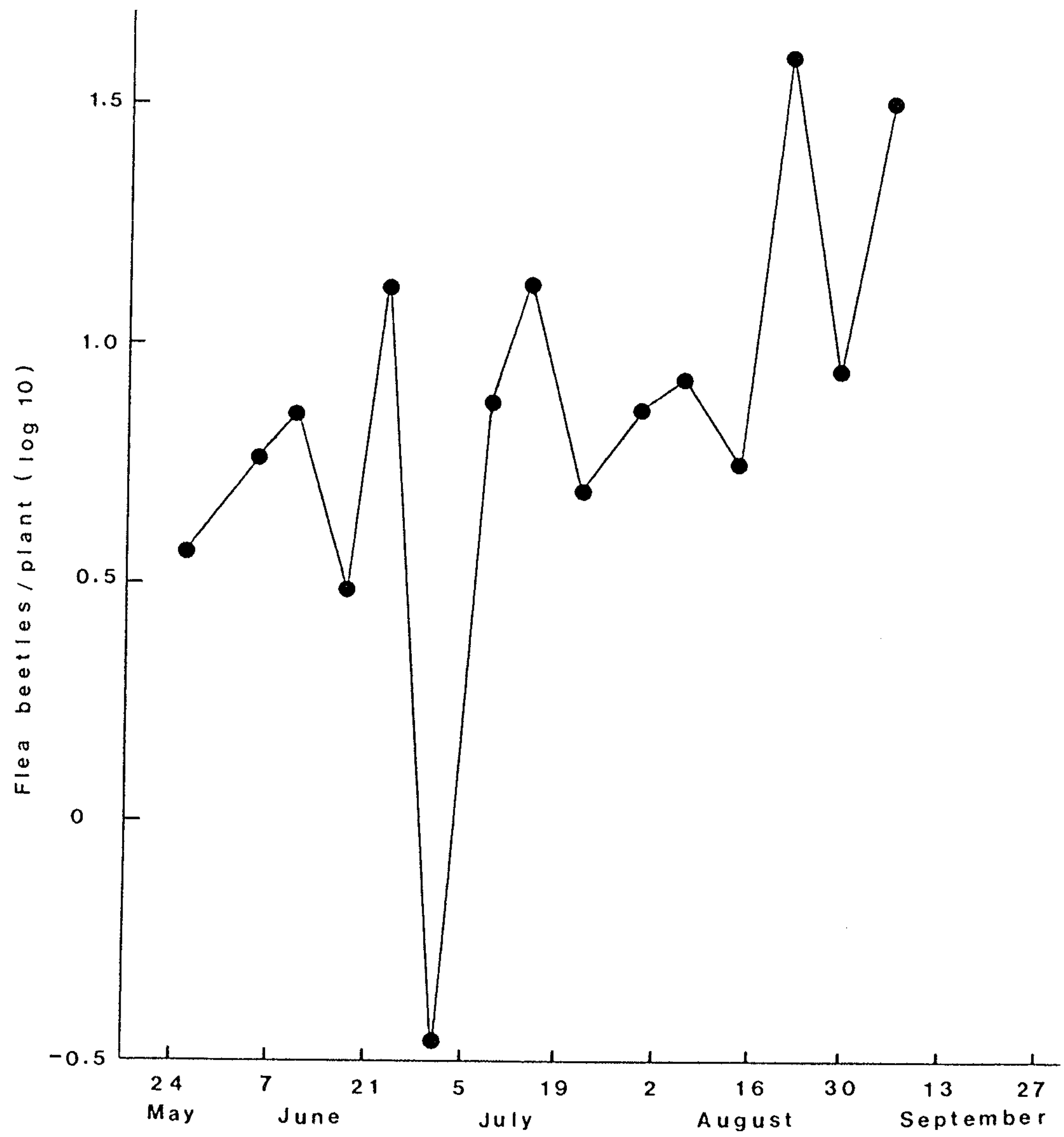
| Plot No. | Planting Date | Correlation Coefficient, r | Probability Correlation is Significant, P |
|---|---|---|---|
| 1 | May 20 | 0.8364 | 0.0097**[1] |
| 2 | June 2 | 0.1447 | 0.7570 |
| 3 | June 16 | -0.0126 | 0.9840 |
| 4 | June 30 | -0.3018 | 0.5106 |
| 5 | July 15 | -0.2398 | 0.6046 |
| 6 | July 28 | -0.0178 | 0.9734 |
| Overall | | -0.0039 | 0.9810 |

[1] Statistically significant ($P<0.01$).

Flea beetle populations estimated by both methods were compared to the ranked percentage leaf area eaten of broccoli plants per plot. In a majority of plots the linear regression of percent leaf area eaten over the logarithm of beetle numbers caught in water traps in both years was not significant, indicating a random association (Appendix B). Similarly, in a majority of plots in 1982 the percent leaf area eaten was randomly related to the logarithms of beetle numbers per D-Vac'd plot.

A comparison of Figure 7, the log of beetle numbers per water trap per week, with Figure 12, the log of beetle numbers per D-Vac'd plant per week throughout the 1982 season, indicates that from May 10 to

Figure 12: Flea beetle population per plant of all plots, sampled by D-Vac vacuuming, 1982.



Flea beetles / plant ( log 10 )
1.5
1.0
0.5
0
-0.5
24
May
7
June
21
5
July
19
2
August
16
30
13
September
27

August 15 beetle population patterns, when logarithmically expressed, were somewhat similar in the two sampling methods (discounting the undersampling which occurred when D-Vac'ing on July 1). Beetle numbers obtained from water trap sampling were about two logarithm units or 100 times higher than numbers of beetles vacuumed from individual plants during this period. However, the D-Vac sampling method resulted in much lower beetle numbers at the beginning of the sampling period and many more beetles than the water trap method late in the season.

D-Vac vacuuming of newly emerged plants may have had a detrimental effect on their subsequent development. Although the vacuum nozzle was held over each plant for only 2 to 3 seconds, the suction pressure was enough to slightly tatter leaves and to remove soil from around very small seedlings. Many such plants could be identified from their non-vacuumed companions. This difference in appearance faded as the plants grew, but the possibility of growth retardation of seeded plants as compared to transplanted plants because of the D-Vac process cannot be discounted.

On the other hand, plants adjacent to water traps were often much more severely defoliated than plants in rows farther away from the buckets because of beetle congregation and feeding near the traps. Also, as plants grew larger their leaves tended to cover the water traps; beetle numbers in such shaded traps decreased when compared to traps set in more open areas. Because of this, in both years as plants matured water traps were "randomly" situated in each plot so that they were not hidden by broccoli leaves. As the older transplant treatments matured, this resulted in traps often being placed near two week transplant, seeded and seeded plus Furadan treatment rows. However, when harvest began buckets could be placed near open spaces where heads had been harvested.

### 4.3.2 Broccoli Defoliation and Leaf Growth

#### 4.3.2.1 Statistical Analysis

A univariate test for normality of both percent leaf area eaten and leaf stage indicated that the majority of treatments in a majority of plots had normally distributed data for both variables. However, a Bartlett's test indicated that leaf area eaten variances were not homogeneous. Square root, logarithm, arcsine, cosine, sine hyperbola, and Probit transformations did not greatly improve this ratio. Analyses of variance were therefore conducted on ranked data, and while plot and treatment means presented here are means for actual measurements, their statistical significance groupings were determined from ranked data. In most cases there was little or no difference between statistical significance of non-ranked and ranked data; in cases where there were differences, significance levels of both non-ranked and ranked data are presented.

#### 4.3.2.2 Leaf Area Eaten

Typical flea beetle feeding damage on a young broccoli plant is illustrated in Figure 13, while Figures 14a-f and 15a-e illustrate the patterns of flea beetle feeding on individual treatments in each plot. Generally, the sequence of feeding from most to least defoliation was

Figure 13: Flea beetle feeding damage on a four-leaved broccoli plant.

NOTICE/AVIS

PAGE(~~S~~) 77 IS/~~ARE~~ EST/~~SONT~~ colour photo

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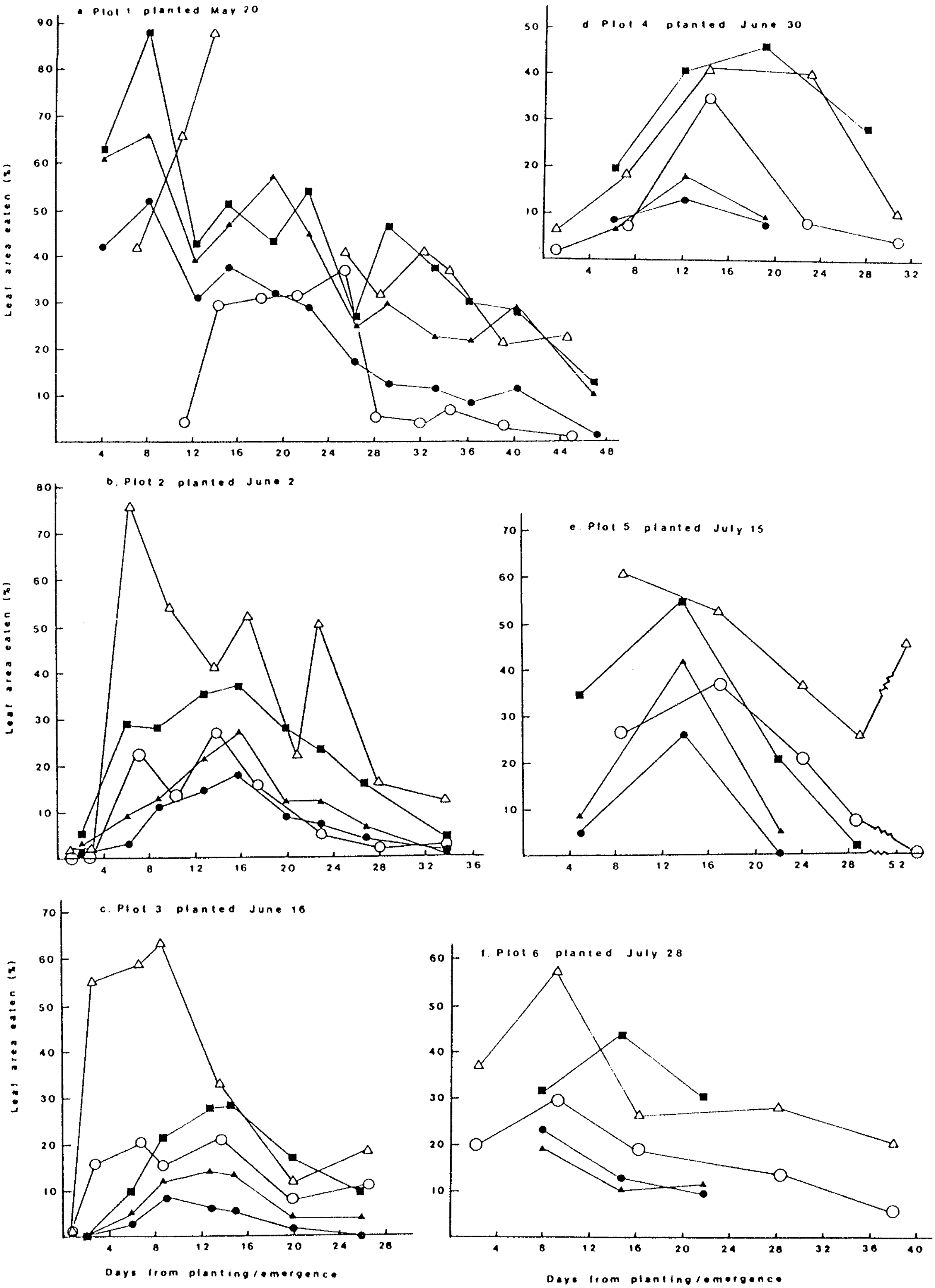
Figure 14: Defoliation of broccoli plants by flea beetles in plots of various planting dates in 1982.

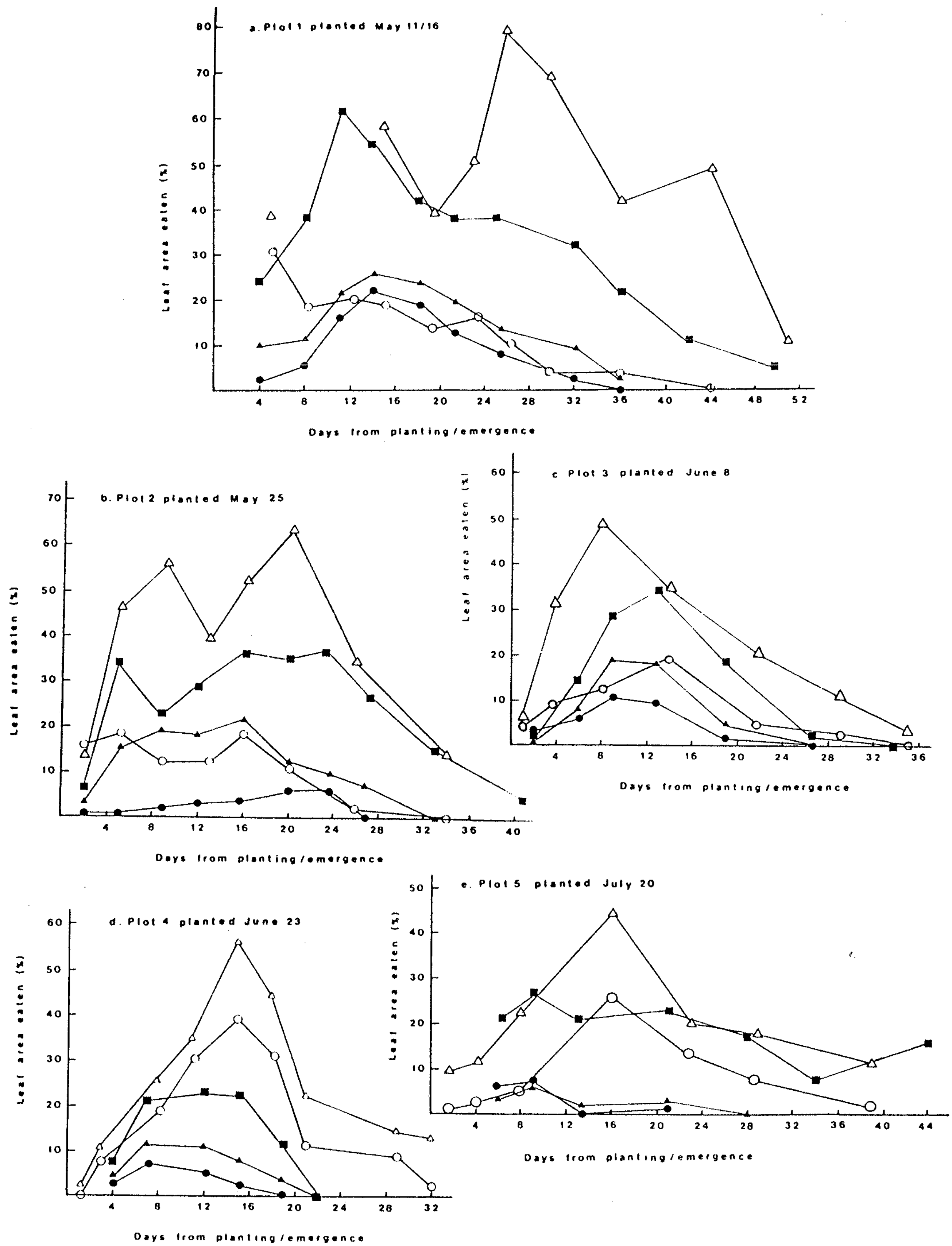
| | | | |
|---|---|---|---|
| ● | Treatment | A | 4 week old transplants |
| ▲ | | B | 3 week old transplants |
| ■ | | C | 2 week old transplants |
| △ | | S | direct seeded plants |
| ○ | | S+F | direct seeded plants plus Furadan |



a Plot 1 planted May 20
d Plot 4 planted June 30
b. Plot 2 planted June 2
e. Plot 5 planted July 15
c. Plot 3 planted June 16
f. Plot 6 planted July 28
Leaf area eaten (%)
Days from planting/emergence

Figure 15: Defoliation of broccoli plants by flea beetles in plots of various planting dates in 1983.

| | | | |
|---|---|---|---|
| ● | Treatment | A | 4 week old transplants |
| ▲ | | B | 3 week old transplants |
| ■ | | C | 2 week old transplants |
| △ | | S | direct-seeded plants |
| ○ | | S+F | direct-seeded plants plus Furadan |


a. Plot 1 planted May 11/16
Leaf area eaten (%)
Days from planting/emergence
b. Plot 2 planted May 25
Leaf area eaten (%)
Days from planting/emergence
c Plot 3 planted June 8
Leaf area eaten (%)
Days from planting/emergence
d. Plot 4 planted June 23
Leaf area eaten (%)
Days from planting/emergence
e. Plot 5 planted July 20
Leaf area eaten (%)
Days from planting/emergence

similar in both years, with Treatment S, seeded alone, being the most heavily grazed, then Treatment C, two week old transplants, Treatment B, three week old transplants, and Treatment A, four week old transplants, which were usually the least fed upon. The S+F (seeded plus Furadan) treatment suffered variable defoliation, from feeding less than that on Treatment A (Figure 14a), to defoliation almost as heavy as that suffered by plants in Treatment S (Figure 15d). However, Treatment S+F usually suffered damage between levels suffered by Treatment A and by Treatments B or C (Figures 14b, 14c, 14f, 15a, 15b, 15c). Treatment C in most plots suffered feeding damage similar to but slightly less than Treatment S, with the exception of Plot 4 in 1982, in which feeding on Treatment C plants was generally heavier than on Treatment S plants.

Defoliation and mortality of Treatment S plants in the first plots of both years (Figures 14a and 15a) was so severe that leaf area eaten measurements had to be discontinued for a time because of a lack of seedlings with leaves. Sampling resumed when damaged seedlings grew new leaves and/or a new flush of seedlings germinated in the rows.

Most treatments of the first planting dates in both years, but especially that of 1982, had the most severe levels of feeding and the most variable feeding patterns of all plots, as well as the longest period of feeding. This variability in feeding may have been due, in part, to fluctuating cold temperatures early in the season which would restrict beetle above-ground feeding. The feeding period was also prolonged on plots planted late in the season (Figures 14e, 14f, and 15e), as early plots were harvested and as summer generation flea beetles prepared for winter diapause.

Table 13 lists the mean percent leaf area eaten on plants of each treatment in each plot. Except for Plot 4, 1983, Treatments S and C consistently had the most heavily grazed plants in all plots throughout both seasons. The mean feeding levels of the other three treatments varied, but in a majority of plots Treatment S+F had a seasonal defoliation mean between that of Treatment A and Treatment B.

When considering the percent leaf area eaten among plots it was found that in 1982 the order of defoliation means was different between ranked and non-ranked data (Table 13). Plot 1 suffered the most feeding in both ranked and non-ranked analyses, but the order of defoliation severity among the rest of the plots was different when data were ranked from when they were not. An analysis of covariance on ranked data indicated that sampling date significantly affected percent leaf area eaten, so that when sampling date was taken into account Plots 1 to 3 in 1982 had ranked mean defoliation levels different from each other and from Plots 4 to 6. Likewise, in 1983 Plots 1 and 2 had feeding levels significantly different from each other and from Plots 3, 4 and 5 (Table 13). The three plots planted last in both years had overall defoliation levels which did not significantly differ from each other.

Defoliation differences among treatments over all plots are outlined in the last column of Table 13. Analysis of covariance on ranked data determined that all treatment means were significantly different in 1983 and all except S and C means were significantly different in 1982. With the exception of Treatments B and S+F, the order of mean defoliation severity was similar in both years.

TABLE 13

Mean percent leaf area eaten by flea beetles on broccoli plants.

a) 1982

Mean Per Cent Leaf Area Eaten

| Treatment | Plot 1 Planted May 20 | Plot 2 Planted June 2 | Plot 3 Planted June 16 | Plot 4 Planted June 30 | Plot 5 Planted July 15 | Plot 6 Planted July 28 | Over All Plots |
|---|---|---|---|---|---|---|---|
| A | 23.6 b[1] | 7.6 cd | 3.2 d | 9.8 bc | 10.6 c | 15.0 b | 13.0 c |
| B | 37.4 a | 11.5 bc | 6.9 d | 11.0 bc | 18.5 bc | 13.9 b | 19.7 b |
| C | 43.0 a | 22.9 a | 16.0 ab | 31.2 a | 28.3 b | 27.3 ab | 29.4 a |
| S | 43.8 a | 30.1 ab | 33.9 a | 19.0 b | 44.2 a | 34.7 a | 33.5 a |
| S+F | 14.2 c | 8.8 d | 12.6 bc | 9.9 c | 18.5 bc | 20.0 b | 13.1 c |
| Over all treatments: | | | | | | | |
| Data not ranked | 32.0 a[2] | 16.4 c | 14.5 c | 16.4 c | 25.2 b | 23.4 b | |
| Data ranked | 26.2 a[2] | 24.2 b | 17.9 c | 11.3 d | 10.3 d | 9.8 d | |

b) 1983

Mean Per Cent Leaf Area Eaten

| Treatment | Plot 1 Planted May 11/16 | Plot 2 Planted May 25 | Plot 3 Planted June 8 | Plot 4 Planted June 23 | Plot 5 Planted July 20 | Over All Plots |
|---|---|---|---|---|---|---|
| A | 8.9 c[1] | 2.6 d | 5.0 c | 3.2 c | 4.1 b | 5.2 e |
| B | 13.9 b | 12.3 bc | 8.4 bc | 6.5 c | 3.6 b | 9.9 d |
| C | 30.3 a | 22.7 b | 14.1 ab | 13.8 b | 19.9 a | 21.9 b |
| S | 38.7 a | 40.8 a | 22.4 a | 24.4 a | 20.0 a | 29.4 a |
| S+F | 12.5 bc | 11.7 c | 7.7 bc | 16.6 ab | 8.8 b | 11.8 c |
| Over all treatments: | | | | | | |
| Data ranked | 20.4 a[2] | 18.2 b | 11.8 c | 14.5 c | 12.4 c | |

[1] Analysis conducted on ranked data; within columns, means followed by the same letter do not differ significantly ($P<0.05$).

[2] Within rows, means followed by the same letter do not differ significantly ($P<0.05$).

The 'Over All Treatments' rows and the 'Over All Plots' column in Table 13 indicate that over the entire season feeding levels on both a per plot and per treatment basis were higher in 1982 than in 1983. This was in spite of the fact that many more beetles were collected in water traps in 1983 than in 1982.

Plant stand counts for Plots 1 to 4 in 1983 are listed in Table 14. The number of transplants planted per treatment was 120, with the 4 seeded plus Furadan rows per plot thinned to 30 plants each whenever seedlings emerged in excess of that number. Treatment S never had to be thinned, despite over-seeding. The table lists the number of plants which survived several types of mortality including flea beetles early in plot sampling and cutworms later in sampling, but before root maggot attack which accounts for most of the difference in numbers between treatments in the last sampling date for each plot and the numbers harvested. Many seeded plants in Plot 4 did not reach maturity. Numbers of seeded plants in Plot 1 increased occasionally from sampling to sampling because of several emergence flushes. At other times numbers of various treatments increased because a plant which was apparently dead one day had a green, functioning meristem the next.

The greatest mortality levels caused by flea beetles on transplants occurred within the first 10 days of transplanting, usually within the first 3 or 4 days. Table 14 also shows that the biggest difference between survival of Treatment S and S+F plants occurred at or before the first sampling date after seeding, or just after emergence. This difference was evident in plots in both years.

TABLE 14

Number of broccoli plants surviving or appearing to survive after planting or emergence in 1983.

a) Plot 1 planted May 11/16

| Date | Treatment[1] A | B | C | S | S+F |
|---|---|---|---|---|---|
| May 20 | 120 | 112 | 113 | | |
| May 24 | 119 | 108 | 69 | 16 | 75 |
| May 27 | 113 | 104 | 65 | 8 | 105 |
| May 30 | 111 | 104 | 53 | 6 | 76 |
| June 1 | 111 | 104 | 60 | 0 | 97 |
| June 6 | 111 | 104 | 47 | 3 | 90 |
| June 10 | 110 | 106 | 74 | 5 | 90 |
| June 14 | 110 | 104 | 77 | 9 | 91 |
| June 17 | 107 | 101 | 72 | 6 | 92 |
| June 21 | | | | 18 | 90 |
| July 5 | | | | 18 | 88 |
| No. Harvested: | 74 | 92 | 58 | 9 | 76 |

b) Plot 2 planted May 25

| Date | Treatment A | B | C | S | S+F |
|---|---|---|---|---|---|
| May 27 | 120 | 120 | 120 | | |
| May 30 | 120 | 117 | 112 | | |
| June 3 | 120 | 117 | 89 | 79 | 117 |
| June 6 | 120 | 117 | 91 | 62 | 118 |
| June 10 | 120 | 108 | 95 | 62 | 118 |
| June 14 | 118 | 102 | 97 | 62 | 120 |
| June 17 | 117 | 102 | 98 | 65 | 120 |
| June 21 | | | | 66 | 118 |
| No. Harvested: | 114 | 96 | 89 | 50 | 113 |

c) Plot 3 planted June 8

| Date | Treatment A | B | C | S | S+F |
|---|---|---|---|---|---|
| June 10 | 120 | 119 | 120 | | |
| June 14 | 118 | 118 | 117 | 86 | 106 |
| June 17 | 118 | 118 | 117 | 84 | 111 |
| June 21 | 117 | 118 | 117 | 84 | 112 |
| June 27 | 117 | 118 | 117 | 69 | 89 |
| July 5 | 111 | 104 | 47 | 80 | 90 |
| July 12 | | | | 78 | 80 |
| No. Harvested: | 100 | 99 | 96 | 55 | 75 |

d) Plot 4 planted June 23

| Date | Treatment A | B | C | S | S+F |
|---|---|---|---|---|---|
| June 27 | 120 | 120 | 120 | 38 | 54 |
| June 30 | 120 | 120 | 120 | 95 | 96 |
| July 5 | 120 | 119 | 120 | 84 | 96 |
| July 8 | 120 | 119 | 120 | 88 | 102 |
| July 12 | 120 | 116 | 114 | 83 | 100 |
| July 15 | 118 | 102 | 97 | 67 | 98 |
| July 26 | | | | 78 | 93 |
| No. Harvested: | 111 | 98 | 83 | 19 | 43 |

[1] Treatments A, B, and C - 4, 3, and 2 week old transplants; S - seeded alone; S+F - seeded plus Furadan.

#### 4.3.2.3 Leaf Stage

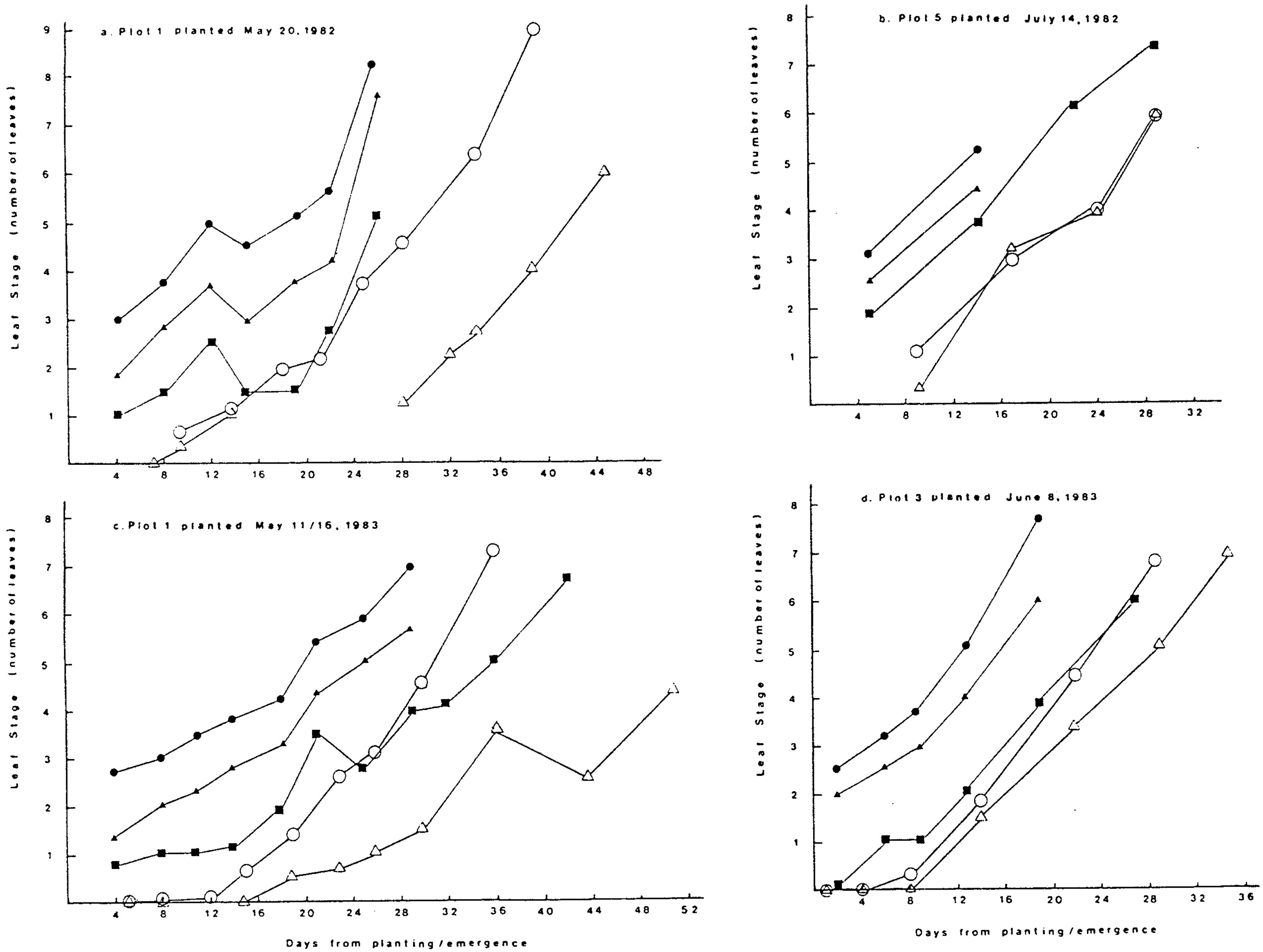
In 1982 leaf stage, the number of mature leaves which plants of a particular treatment possessed at a particular time, was not recorded for as long a period as in 1983, when plants were observed to the 8 leaf stage. This was especially true for transplant treatments.

Graphs of leaf stage of individual transplant treatments versus days from planting were not directly comparable to curves of seeded plant leaf stage versus days from emergence because of the various ages and sizes of the transplants when set in the field. However, the initial growth advantage of the transplants over seeded plants was offset in part by transplant shock and in part by their growth in the field slightly earlier in the season and presumably under slightly colder temperatures than growth of their direct-seeded counterparts. Thus field growth patterns of all five treatments were found to be similar in Plots 3 to 5 in both years as exemplified by Figure 16b and d, in spite of varying levels of flea beetle feeding among plots and treatments. Leaf stage data for the other plots in both years are listed in Appendices C and D.

In the earliest planted plots of both years and the last plot planted in 1982, plants of Treatment S (seeded) grew considerably more slowly than those of any other treatment, while Treatment S+F (seeded plus Furadan) plants reached sizes larger than Treatment C (2 week old) transplants which were two or more weeks older (Figure 16a and b). In all plots the initially larger-sized transplants of Treatment A (4 week old transplants) reached a particular leaf size earlier than the 3 or 2 week old transplants.

Figure 16: Growth patterns of broccoli plants planted early and late in each season.

| | | | |
|---|---|---|---|
| ● | Treatment | A | 4 week old plants |
| ▲ | | B | 3 week old plants |
| ■ | | C | 2 week old plants |
| △ | | S | direct-seeded plants |
| ○ | | S+F | direct-seeded plants plus Furadan |



a. Plot 1 planted May 20, 1982
b. Plot 5 planted July 14, 1982
c. Plot 1 planted May 11/16, 1983
d. Plot 3 planted June 8, 1983
Leaf Stage (number of leaves)
Days from planting/emergence

In 1983 Treatments A, B, C, and S suffered the most feeding damage of the season in the first planted plot. Correspondingly, a comparison of the slopes of growth curves of individual treatments indicated that in 1983 Treatments A, B, and C grew the most slowly in the first planted plot, while Treatment S grew the most slowly in the first planted plot of both years (Table 15). However, while Treatment S grew more slowly in the first planted plot in 1982, the heaviest feeding damage to which it was subjected occurred in Plot 2 of that year. Likewise, in 1982 plants in Treatment A grew more slowly in Plot 2 than in any other planting, even though the mean percent leaf area eaten in Treatment A in that plot was the second lowest of any plot in that year. Similarly, plants in Treatment B grew slower in Plot 2 in 1982 than in any other plot, while flea beetle feeding on Treatment B in Plot 2 was relatively low when compared to feeding in Plot 1 of that year.

A regression of leaf stage over percent leaf area eaten (data ranked) on a per treatment per plot basis indicated that in 1983 most treatments developed less foliage with more feeding by flea beetles; in contrast, in 1982 only the two seeded treatments had consistently fewer leaves with more leaf area eaten and in a majority of plots this relationship was not significant (Table 16). However, when all treatments were combined in a plot there was, as expected, a negative relationship between ranked data of percent leaf area eaten and leaf stage in all plots, a relationship which was significant in most plots (Table 17). Thus, the amount of flea beetle feeding to which plants of various treatments in a plot were subjected was primarily responsible for the reduced leaf growth shown in these treatments.

TABLE 15

Slopes of growth curves of broccoli of various treatments subjected to flea beetle feeding.

a) 1982

Slope of Leaf Stage *vs* Time Growth Curve

| Treatment | Plot 1 Planted May 20 | Plot 2 Planted June 2 | Plot 3 Planted June 16 | Plot 4 Planted June 30 | Plot 5 Planted July 15 | Plot 6 Planted July 28 |
|---|---|---|---|---|---|---|
| A | 0.2007 | 0.1562 | 0.2166 | 0.2125 | 0.2444 | 0.4892[1] |
| B | 0.2014 | 0.1765 | 0.1855 | 0.2417 | 0.2111 | --[2] |
| C | 0.1340 | 0.1192 | 0.2264 | 0.1542 | 0.2398 | 0.1313 |
| S | 0.1375 | 0.1740 | 0.1941 | 0.2089 | 0.2012 | 0.1881 |
| S+F | 0.3018 | 0.2218 | 0.2348 | 0.2271 | 0.2193 | 0.2678 |

[1] only 2 data points sampled.
[2] insufficient data.

b) 1983

Slope of Leaf Stage *vs* Time Growth Curve

| Treatment | Plot 1 Planted May 11/16 | Plot 2 Planted May 25 | Plot 3 Planted June 8 | Plot 4 Planted June 23 | Plot 5 Planted July 20 |
|---|---|---|---|---|---|
| A | 0.1963 | 0.2149 | 0.3147 | 0.2817 | 0.3625 |
| B | 0.2068 | 0.2124 | 0.2472 | 0.2781 | 0.2452 |
| C | 0.1544 | 0.1854 | 0.2457 | 0.2701 | 0.1722 |
| S | 0.0851 | 0.1357 | 0.2146 | 0.1779 | 0.2175 |
| S+F | 0.2404 | 0.2681 | 0.2705 | 0.2395 | 0.2588 |

TABLE 16

Linear regression of leaf stage over percent leaf area eaten (data ranked) of broccoli plants damaged by flea beetle feeding.

a) 1982

| Plot | Planting Date | Regression Coefficient<br>Treatment A | Treatment B | Treatment C | Treatment S | Treatment S+F |
|---|---|---|---|---|---|---|
| 1 | May 20 | -0.122**[1] | -0.067* | -0.025n.s. | -0.160** | -0.122** |
| 2 | June 2 | 0.060** | 0.069** | 0.035** | -0.008n.s. | -0.050n.s. |
| 3 | June 16 | 0.120* | 0.085** | 0.053n.s. | -0.027n.s. | -0.007n.s. |
| 4 | June 30 | 0.123n.s. | 0.159** | 0.156* | -0.220** | -0.291** |
| 5 | July 15 | 0.244* | 0.162* | -0.348** | -0.364** | -0.181n.s. |
| 6 | July 28 | -0.389n.s. | 0.150n.s. | -0.190* | -0.054n.s. | -0.117n.s. |

b) 1983

| Plot | Planting Date | Regression Coefficient<br>Treatment A | Treatment B | Treatment C | Treatment S | Treatment S+F |
|---|---|---|---|---|---|---|
| 1 | May 11/16 | -0.061n.s. | -0.083* | -0.105** | -0.021n.s. | -0.193** |
| 2 | May 25 | 0.186** | -0.100** | -0.101** | -0.067* | -0.190** |
| 3 | June 8 | -0.078n.s. | 0.027n.s. | -0.058n.s. | -0.195** | -0.157* |
| 4 | June 23 | -0.070n.s. | -0.094n.s. | -0.140** | 0.000n.s. | -0.066n.s. |
| 5 | July 20 | -0.108* | -0.156* | -0.219** | 0.022n.s. | -0.066n.s. |

[1] Significance of regression of leaf stage with percent leaf area eaten: n.s. - not significant; * - significant at $P<0.05$; ** - significant at $P<0.01$.

TABLE 17

Regression equations of leaf stage over percent leaf area eaten for broccoli plants attacked by flea beetles when all treatments were combined.

| Plot | Planting Date | Regression Equation | P>\|T\|[1] |
|---|---|---|---|
| a) 1982 | | | |
| 1 | May 20 | LS = -0.0779 LAE[2] + 5.857 | ** |
| 2 | June 2 | LS = -0.0190 LAE + 2.739 | n.s. |
| 3 | June 16 | LS = -0.0242 LAE + 2.870 | n.s. |
| 4 | June 30 | LS = -0.0256 LAE + 5.240 | ** |
| 5 | July 15 | LS = -0.1460 LAE + 5.476 | ** |
| 6 | July 28 | LS = -0.1764 LAE + 5.292 | ** |
| b) 1983 | | | |
| 1 | May 11/16 | LS = -0.098 LAE + 6.163 | ** |
| 2 | May 25 | LS = -0.112 LAE + 5.783 | ** |
| 3 | June 8 | LS = -0.110 LAE + 4.991 | ** |
| 4 | June 23 | LS = -0.104 LAE + 5.203 | ** |
| 5 | July 20 | LS = -0.062 LAE + 5.223 | n.s. |

[1] Probability that regression of leaf stage over per cent leaf area eaten is significant; n.s. - not significant; ** - significant at P<0.01.
[2] Per cent leaf area eaten data ranked.

When considering leaf growth of all treatments on a per plot basis over the summer, growth was slowest in the earliest planted plots in both years and generally increased as the season progressed (Table 18). Within each year leaf stage vs time regression lines for both plots and treatments had significantly different slopes ($P<0.01$).

TABLE 18

Combined slope of leaf stage vs time of all treatments per plot of broccoli plants attacked by flea beetles.

| | 1982 | | 1983 | |
|---|---|---|---|---|
| Plot | Planting Date | Slope | Planting Date | Slope |
| 1 | May 20 | 0.0750 | May 11/16 | 0.1056 |
| 2 | June 2 | 0.1115 | May 25 | 0.1480 |
| 3 | June 16 | 0.1207 | June 8 | 0.1643 |
| 4 | June 30 | 0.1300 | June 23 | 0.1347 |
| 5 | July 15 | 0.1136 | July 20 | 0.1618 |
| 6 | July 28 | 0.1452 | | |

An analysis of covariance indicated that the time of planting significantly affected leaf growth. When considering leaf growth of treatments over all plots, plants of the three transplant treatments grew at similar rates to each other in the field, while Treatment S plants grew the slowest and Treatment S+F plants grew the fastest (Table 19).

TABLE 19

Combined slope of leaf stage vs time of all plots per treatment of broccoli attacked by flea beetles.

| Treatment | 1982 Slope | 1983 Slope |
|---|---|---|
| A - 4 week old transplants | 0.1937 | 0.1691 |
| B - 3 week old transplants | 0.1700 | 0.1792 |
| C - 2 week old transplants | 0.1770 | 0.1711 |
| S - direct-seeded plants | 0.1380 | 0.1147 |
| S+F - direct-seeded plus Furadan | 0.2224 | 0.2041 |

### 4.3.3 Harvest Results

The harvest period began in mid-July in both years and extended to the first killing frost, on October 20, 1982, and October 18, 1983.

In commercial production of broccoli in Manitoba, the last direct seeding, which is carried out the end of June or beginning of July, may or may not reach harvest maturity. This lack of sufficient time to maturity is the reason that no direct-seeded plants seeded July 15 and 28, 1982, and July 20, 1983 were harvested (Tables 20 and 21). As well, the June 30, 1982 planting had very few seeded plus Furadan (Treatment S+F) heads harvested and no seeded alone (Treatment S) heads, even though the number of plants left in the field indicated good germination. The 4 week old transplants (Treatment A) produced considerable numbers of harvestable heads when transplanted until the middle of July.

Treatment A generally had the highest percentage of plants harvested of the three transplant treatments (Tables 20 and 21). In

TABLE 20

Fate of broccoli plants from various treatments planted in 1982.

| Planting Date | Plot & Trt No.[1] | Plants Harvested No. | Plants Harvested % of Total[2] | Plants Harvested % of SF | % Plants Marketable[3] | Left in Field No. | Left in Field % of Total | % Plants Killed by Flea Beetles |
|---|---|---|---|---|---|---|---|---|
| May 20 | 1A | 139 | 76.4 | 96.5 | 84.2 | 5 | 2.7 | 20.9 |
| | 1B | 116 | 62.0 | 80.6 | 97.4 | 24 | 12.8 | 25.1 |
| | 1C | 87 | 44.4 | 60.4 | 95.4 | 28 | 14.3 | 41.3 |
| | 1S | 21 | | 14.6 | 100.0 | 25 | | |
| | 1S+F | 144 | | 100.0 | 95.1 | 15 | | |
| June 2 | 2A | 198 | 100.0 | 153.5 | 90.0 | 0 | 0 | 0 |
| | 2B | 176 | 99.4 | 136.4 | 88.1 | 1 | 0.6 | 0 |
| | 2C | 134 | 76.1 | 103.8 | 81.3 | 14 | 8.0 | 15.9 |
| | 2S | 66 | | 51.2 | 92.4 | 58 | | |
| | 2S+F | 129 | | 100.0 | 91.5 | 23 | | |
| June 16 | 3A | 197 | 100.0 | 218.9 | 86.3 | 0 | 0 | 0 |
| | 3B | 191 | 100.0 | 212.2 | 83.8 | 0 | 0 | 0 |
| | 3C | 155 | 87.1 | 172.2 | 87.1 | 16 | 9.0 | 3.9 |
| | 3S | 25 | | 27.8 | 88.0 | 97 | | |
| | 3S+F | 90 | | 100.0 | 81.0 | 40 | | |
| June 30 | 4A | 185 | 97.9 | 2642.9 | 91.4 | 4 | 2.1 | 0 |
| | 4B | 177 | 92.2 | 2528.6 | 91.0 | 15 | 7.8 | 0 |
| | 4C | 118 | 73.3 | 1671.4 | 96.6 | 43 | 26.7 | 0 |
| | 4S | 0 | | 0 | | 184 | | |
| | 4S+F | 7 | | 100.0 | 85.7 | 148 | | |
| July 15 | 5A | 148 | 77.5 | | 99.3 | 43 | 22.5 | 0 |
| | 5B | 105 | 60.3 | | 99.0 | 69 | 39.7 | 0 |
| | 5C | 30 | 20.4 | | 96.7 | 116 | 78.9 | 0.7 |
| | 5S | 0 | | | | 51 | | |
| | 5S+F | 0 | | | | 59 | | |
| July 28 | 6A | 1 | 0.5 | | 100.0 | 195 | 98.0 | 1.5 |
| | 6B | 0 | | | | 195 | 99.0 | 1.0 |
| | 6C | 0 | | | | 136 | 95.1 | 4.9 |
| | 6S | 0 | | | | 70 | | |
| | 6S+F | 0 | | | | 87 | | |

[1] A, B, C = 4, 3, and 2 week old seedlings, respectively; S - seeded alone; S+F - seeded plus Furadan.
[2] Excluding plants killed by other pests or by accident.
[3] As a percent of number harvested.

TABLE 21

Fate of broccoli plants from various treatments planted in 1983.

| Planting Date | Plot & Trt No.[1] | Plants Harvested No. | Plants Harvested % of Total[2] | Plants Harvested % of SF | % Plants Marketable[3] | Left in Field No. | Left in Field % of Total | % Plants Killed by Flea Beetles |
|---|---|---|---|---|---|---|---|---|
| May 11 | 1A | 74 | 94.9 | 97.4 | 74.3 | 0 | 0 | 5.1 |
| May 11 | 1B | 92 | 86.0 | 121.0 | 90.2 | 0 | 0 | 14.0 |
| May 11 | 1C | 58 | 49.2 | 76.3 | 89.7 | 17 | 14.4 | 36.4 |
| May 16 | 1S | 9 | | 11.8 | 100.0 | 7 | | |
| May 16 | 1S+F | 76 | | 100.0 | 90.8 | 14 | | |
| May 25 | 2A | 114 | 100.0 | 100.1 | 81.6 | 0 | 0 | 0 |
| | 2B | 96 | 93.2 | 85.0 | 83.3 | 3 | 2.8 | 3.9 |
| | 2C | 89 | 75.4 | 78.8 | 84.2 | 8 | 6.8 | 17.8 |
| | 2S | 50 | | 44.2 | 86.0 | 22 | | |
| | 2S+F | 113 | | 100.0 | 80.5 | 7 | | |
| June 8 | 3A | 100 | 95.2 | 133.3 | 78.0 | 2 | 1.9 | 3.0 |
| | 3B | 99 | 98.0 | 132.0 | 83.8 | 2 | 2.0 | 0 |
| | 3C | 96 | 92.3 | 128.0 | 89.6 | 5 | 4.8 | 2.9 |
| | 3S | 55 | | 73.3 | 89.1 | 16 | | |
| | 3S+F | 75 | | 100.0 | 92.0 | 7 | | |
| June 23 | 4A | 111 | 91.7 | 258.1 | 77.5 | 10 | 8.3 | 0 |
| | 4B | 98 | 86.7 | 227.9 | 73.5 | 15 | 13.3 | 0 |
| | 4C | 83 | 84.7 | 193.0 | 72.4 | 14 | 14.3 | 1.2 |
| | 4S | 19 | | 44.2 | 73.7 | 62 | | |
| | 4S+F | 43 | | 100.0 | 100.0 | 47 | | |
| July 20 | 5A | 55 | 49.5 | | 100.0 | 56 | 50.5 | 0 |
| | 5B | 45 | 43.3 | | 94.3 | 59 | 56.7 | 0 |
| | 5C | 0 | | | | 73 | 100.0 | 0 |
| | 5S | 0 | | | | 107 | | |
| | 5S+F | 0 | | | | 95 | | |

[1] A, B, C = 4, 3, and 2 week old seedlings, respectively; S - seeded alone; S+F - seeded plus Furadan.
[2] Excluding plants killed by other pests or by accident.
[3] As a percent of number harvested.

1983 harvest yields were generally very good for A and B Treatments (4 and 3 week old transplants, respectively) in all plots until the last planting date. The harvest yield of Treatment C (2 week old transplants) was low in the first two plantings of 1983, reaching commercially acceptable levels only in Plots 3 and 4 (planted June 8 and June 23, respectively).

The percentage of Treatments A and B plants harvested in the first plot of 1982 was much smaller than in 1983, with the percentage of Treatment C plants harvested in Plot 1 in 1982 was slightly lower than the comparable figure in 1983. As in 1983, the percentage of plants harvested from Treatments A and B in 1982 plots was very high after the first planting until decreased season length imposed harvest limitations on broccoli of plots planted July 15 and 28.

In the transplant treatments the highest broccoli mortality caused by flea beetle feeding was in the first plots planted in both years (Table 20 and 21). In 1982 Treatment C plants continued to suffer mortality in Plots 2 and 3, planted June 2 and June 16, while Treatments A and B did not again suffer mortality caused by flea beetles until the last planted plot, July 28. The broccoli mortality due to flea beetle feeding in the earliest planted plot was much less in 1983 than in 1982, especially in the 4 and 3 week old transplants. In 1983 various levels of mortality were experienced by the transplant treatments in plots planted throughout the spring, although at much lower levels than suffered by transplants in the earliest planting. In 1983 there was no transplant mortality caused by flea beetles in the last plot, planted July 20.

Of the three transplant treatments, Treatment C (2 week old transplants) had the highest number of unharvested plants in most plots in both years (Tables 20 and 21). In 1983 the number of 4 and 3 week old transplants (Treatments A and B) left in the field rose from none in the first plot to a high of 50.5 and 56.7%, respectively, in Plot 5. In the first plot 14% of Treatment C plants were left in the field. Only Plot 5, planted last, had more Treatment C plants unharvested than this high value in Plot 1.

In 1982 the numbers of plants left in the field in all three transplant treatments were highest in Plots 1, 5, and 6 (planted May 20, July 15, and July 28, respectively). The high number of unharvested heads in the last two plantings was due to the shortness of the growing season. Since plants of the first plots of both years had the longest periods of harvest, from July to October, the number left in the fields in these plots had a much longer period of time to reach maturity than plants in late-seeded plots. There were higher percentages of plants left in the field in 1982 than in 1983.

There was little difference in the percent marketable heads (those scoring 7 or higher in an overall quality assessment of harvested heads) among treatments and among plots within years (Tables 20 and 21). On a total plot basis there was a lower percentage of marketable heads produced in 1983 than in 1982, with many more heads in 1983 being of smaller dimensions and irregular outline than in 1982. Many more broccoli heads in all plots in 1983 exhibited bractiness or leaves within the heads than in 1982. As well, there was considerably more flea beetle feeding on broccoli heads as they neared maturity in 1983 than in 1982, resulting in yellowing or browning of heads which lowered the cosmetic appearance of the heads and decreased their quality and marketability (Figure 17).

In 1983 about 3% of the plants surviving to harvest were not true to type, exhibiting cauliflower and cabbage-like characteristics. This was a much higher number than was produced in 1982. The growth of two small main stalks instead of one large one was also more prevalent in 1983.

In 1982 a group of broccoli heads were harvested which had similar irregular physical features. These heads were smaller than heads of surrounding plants, their floret heads were often arranged in a flower-like pattern with several large full beads encircling many immature ones. They possessed very long, thin and tough stems. Plants with such heads matured after the main flush of heads in a row had been harvested and occurred in small numbers in all treatments of all plots. In 1983 such heads were not as noticeable as in 1982, mainly because in 1983 heads, in general, were smaller and had longer thinner, stems than in 1982.

Since flea beetles often fed on and killed seeded plants shortly after or even before emergence, the total number of plants which emerged from direct-seeded plots was unknown. Hence, the number of direct-seeded plants harvested or left in the field could not be expressed as a percentage of the total number planted, nor could the number of direct-seeded plants killed by flea beetles be determined since most seedlings were killed before they could be counted.

Figure 17: Flea beetles feeding on a maturing broccoli head.

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When the number of seeded plants (Treatment S) harvested was expressed as a percentage of the seeded plus Furadan (Treatment S+F) number harvested, the figures ranged from 0 to 51.2% in 1982 plots to the slightly higher range of 11.8 to 73.3% in 1983 plots (Tables 20 and 21). Ratios of the number of Treatment S plants harvested to the number of Treatment S+F plants harvested were similar in the first planted plots of both years. The lowest number of Treatment S plants as compared to Treatment S+F plants in any plots was harvested in Plot 1 of 1983 and, excluding Plot 4 planted June 30, 1982, where no S plants were harvested but the number of S+F plants was also very low, Plot 1 of 1982. The S:S+F ratios were similar between the second planting dates of 1982 and 1983, but the mid-June planting of 1982 had a lower percentage of Treatment S plants harvested as compared to Treatment S+F plants harvested than the June plantings in 1983. In all plots combined in 1982, yield of marketable heads of broccoli seeded alone was 31.1% of the yield of marketable heads of broccoli which was seeded with Furadan and sprayed with Decis under high flea beetle feeding pressure. In 1983 Treatment S yielded 42.3% of the Treatment S+F marketable heads harvested.

As well as very low numbers of heads harvested, in the first three plots in 1982 there were about twice as many Treatment S plants left in the field as compared to Treatment S+F plants. There were more Treatment S plants left in the field than Treatment S+F plants in four of the five plots in 1983, but the numbers were less than in 1982, in part due to shorter row length.

In both years 4 week old Treatment A plants consistently had the shortest time to maturity of any treatment, with the majority of plants in 9 of 11 plots reaching maturity in less than 81 days from field planting (Tables 22 and 23). Plants in Treatment B (3 week old transplants) had similar but slightly slower rates of maturation in 8 of 10 plots. The majority of Treatment C (2 week old) transplants in 4 of 9 plots reached maturity in less than 81 days, with Treatment C plants in 3 other plots reaching maturity in less than 91 days. In 5 of 8 plots the majority of seeded plus Furadan (Treatment S+F) plants reached maturity in 90 days or less, 2 of these plots achieving S+F maturity maxima of less than 81 days. In 5 of 7 plots the majority of Treatment S (seeded alone) plants did not reach maturity until 100 days or more from seeding.

Broccoli in the first plots planted in both years had the longest days to maturity requirement of any plots planted before the last week in June, with the exception of Treatment S+F plants in 1982, which had similar rates of maturity in three of the four plots in which they were harvested. The first plot planted in 1982, in particular, had plants of all treatments except Treatment S+F harvested over a long period of time.

These trends in variable harvest were reflected in mean days to harvest of each treatment (Tables 24 and 25). Data of this variable were not normally distributed so that ranked analysis was used; however, significance levels and groupings of treatments were similar using ranked and non-ranked data.

TABLE 22

Harvest schedule of broccoli plants in 1982.

| Planting Date | Plot/ Trt No.[1] | Per Cent Plants Harvested in <80 Days | 81-90 Days | 91-100 Days | >100 Days |
|---|---|---|---|---|---|
| May 20 | 1A | 60.7[2] | 15.4 | 10.3 | 13.7 |
| | 1B | 17.7 | 12.4 | 24.8 | 45.1 |
| | 1C | 2.4 | 24.1 | 28.9 | 44.6 |
| | 1S | 0 | 0 | 9.5 | 90.5 |
| | 1S+F | 16.8 | 37.2 | 25.5 | 20.4 |
| June 2 | 2A | 95.5 | 2.3 | 1.1 | 1.1 |
| | 2B | 94.8 | 1.2 | 1.9 | 1.9 |
| | 2C | 71.6 | 11.0 | 8.3 | 9.2 |
| | 2S | 0 | 9.8 | 13.1 | 77.0 |
| | 2S+F | 12.7 | 40.7 | 24.6 | 22.0 |
| June 16 | 3A | 97.1 | 2.9 | 0 | 0 |
| | 3B | 98.8 | 0.6 | 0.6 | 0 |
| | 3C | 55.6 | 37.8 | 5.2 | 1.5 |
| | 3S | 0 | 4.5 | 22.7 | 72.7 |
| | 3S+F | 4.1 | 57.5 | 21.9 | 16.4 |
| June 30 | 4A | 94.7 | 4.7 | 0.6 | 0 |
| | 4B | 88.2 | 8.7 | 1.2 | 1.9 |
| | 4C | 0 | 47.4 | 20.2 | 32.5 |
| | 4S+F | 0 | 0 | 0 | 100.0 |
| July 15 | 5A | 37.4 | 62.6 | 0 | 0 |
| | 5B | 40.4 | 59.6 | 0 | 0 |
| | 5C | 0 | 0 | 0 | 100.0 |

[1] A, B, C - 4, 3 and 2 week old seedlings, respectively; S - seeded alone; S+F - seeded plus Furadan.

[2] Harvest period in which a majority of plants per treatment were harvested is underlined.

TABLE 23

Harvest schedule of broccoli plants in 1983.

| Planting Date | Plot/ Trt No.[1] | Per Cent Plants Harvested in <80 Days | 81-90 Days | 91-100 Days | >100 Days |
|---|---|---|---|---|---|
| May 16 | 1A | 98.2[2] | 1.8 | 0 | 0 |
| May 16 | 1B | 85.5 | 9.6 | 3.6 | 1.2 |
| May 16 | 1C | 3.8 | 50.0 | 17.3 | 28.8 |
| May 11 | 1S | 0 | 0 | 0 | 100.0 |
| May 11 | 1S+F | 0 | 35.8 | 47.8 | 16.4 |
| May 25 | 2A | 100.0 | 0 | 0 | 0 |
| | 2B | 92.5 | 5.0 | 2.5 | 0 |
| | 2C | 46.7 | 38.7 | 6.7 | 8.0 |
| | 2S | 0 | 0 | 65.1 | 34.9 |
| | 2S+F | 62.6 | 34.1 | 2.2 | 1.1 |
| June 8 | 3A | 100.0 | 0 | 0 | 0 |
| | 3B | 100.0 | 0 | 0 | 0 |
| | 3C | 93.0 | 1.2 | 2.3 | 3.5 |
| | 3S | 40.8 | 34.7 | 10.2 | 14.3 |
| | 3S+F | 79.7 | 8.7 | 4.3 | 7.2 |
| June 23 | 4A | 67.4 | 22.1 | 5.8 | 4.7 |
| | 4B | 59.7 | 29.2 | 6.9 | 4.2 |
| | 4C | 22.5 | 46.5 | 23.9 | 7.0 |
| | 4S | 0 | 7.1 | 28.6 | 64.3 |
| | 4S+F | 2.3 | 9.3 | 58.1 | 30.2 |
| July 20 | 5A | 56.4 | 30.9 | 12.7 | 0 |
| | 5B | 45.2 | 35.7 | 19.4 | 0 |

[1] A, B, C - 4, 3 and 2 week old seedlings, respectively; S - seeded alone; S+F - seeded plus Furadan.

[2] Harvest period in which a majority of plants per treatment were harvested is underlined.

TABLE 24

Mean harvest data of marketable broccoli heads harvested in 1982.

| Planting Date | Plot/ Trt No[1] | Days to Harvest[2] | Head Weight (g) | Quality Rating[3] (7-10) |
|---|---|---|---|---|
| May 20 | 1A | 80.4 a[2] | 208.8 n.s. | 8.85 |
| | 1B | 100.7 c | 213.6 | 8.70 |
| | 1C | 103.6 c | 239.0 | 8.75 |
| | 1S | 122.5 d | 237.2 | 8.33 |
| | 1S+F | 93.2 b | 219.4 | 8.78 |
| June 2 | 2A | 61.3 a | 154.0 c | 8.37 |
| | 2B | 62.7 a | 177.7 b | 8.61 |
| | 2C | 77.0 b | 160.7 c | 8.60 |
| | 2S | 109.4 d | 191.7 ab | 8.64 |
| | 2S+F | 91.5 c | 199.3 a | 8.46 |
| June 16 | 3A | 64.4 a | 219.2 a | 8.39 |
| | 3B | 66.9 b | 227.7 a | 8.16 |
| | 3C | 79.6 c | 178.9 b | 8.74 |
| | 3S | 109.6 e | 175.4 b | 8.18 |
| | 3S+F | 94.1 d | 164.2 b | 8.40 |
| June 30 | 4A | 70.1 a | 235.6 a | 8.69 |
| | 4B | 72.6 a | 212.7 ab | 8.47 |
| | 4C | 92.7 b | 188.6 b | 8.54 |
| | 4S+F | 106.0 c | 126.4 c | 7.67 |
| July 15 | 5A | 86.8 a | 215.0 n.s. | 8.58 |
| | 5B | 86.9 a | 204.8 | 8.53 |
| | 5C | 94.4 b | 227.2 | 8.55 |

[1] A, B, C - 4, 3, and 2 week old transplants, respectively; S - seeded alone; S+F - seeded plus Furadan.

[2] Values presented are means of actual measurements, while statistical rankings were determined from ranked data. Within columns, means followed by the same letter do not differ significantly ($p>0.01$); n.s. - not significant.

[3] Marketable heads were those whose quality rating was greater than 6.

TABLE 25

Mean harvest data of marketable broccoli heads harvested in 1983.

| Planting Date | Plot/ Trt No[1] | Days to Harvest[2] | Head Weight (g) | Quality Rating[3] (7-10) |
|---|---|---|---|---|
| May 16 | 1A | 62.3 a[2] | 130.9 b | 8.42 |
| May 16 | 1B | 72.3 b | 140.4 b | 8.60 |
| May 16 | 1C | 94.6 c | 203.5 a | 8.60 |
| May 11 | 1S | 120.0 d | 216.2 a | 8.00 |
| May 11 | 1S+F | 92.0 c | 161.0 b | 8.39 |
| May 25 | 2A | 60.7 a | 122.0 c | 8.76 |
| | 2B | 73.1 b | 165.3 b | 8.51 |
| | 2C | 85.5 d | 193.1 a | 8.40 |
| | 2S | 103.8 e | 167.5 b | 7.70 |
| | 2S+F | 80.7 c | 177.0 ab | 8.28 |
| June 8 | 3A | 63.3 a | 175.7 n.s. | 8.32 |
| | 3B | 63.4 a | 179.6 | 8.25 |
| | 3C | 72.8 b | 160.4 | 9.05 |
| | 3S | 87.0 d | 179.7 | 8.40 |
| | 3S+F | 77.5 c | 185.3 | 9.13 |
| June 23 | 4A | 73.4 a | 140.5 ab | 7.91 |
| | 4B | 76.4 a | 139.0 ab | 7.85 |
| | 4C | 85.7 b | 129.8 b | 7.77 |
| | 4S | 104.2 c | 151.8 ab | 7.79 |
| | 4S+F | 100.8 c | 160.9 a | 8.70 |
| July 20 | 5A | 80.4 n.s. | 171.0 n.s. | 9.27 |
| | 5B | 82.4 | 172.7 | 9.26 |

[1] A, B, C - 4, 3, and 2 week old transplants, respectively; S - seeded alone; S+F - seeded plus Furadan.

[2] Values presented are means of actual measurements, while statistical rankings were determined from ranked data. Within columns, means followed by the same letter do not differ significantly ($p>0.01$); n.s. - not significant.

[3] Marketable heads were those whose quality rating was greater than 6.

As expected, Treatment A plants required the fewest days to reach harvest size in all plots. However, Treatment B means were similar to those of Treatment A in several plots, indicating that in these plots Treatment B overcame the one week head start in growth which Treatment A plants possessed. Mean days to harvest of all treatments increased in plots planted late in the season as compared to those planted earlier.

A comparison of head weights showed that in the first planted plots in both years Treatments C and S had the largest broccoli heads, although these differences were not significant in Plot 1, 1982 (Tables 24 and 25). There was no pattern of larger or smaller head weights within and among plots other than Plot 1 in either year. Average weight of broccoli heads in all plots was considerably larger in 1982 than in 1983.

Quality ratings, likewise, did not show any consistent patterns within or among plots in either year, and were rather uniform throughout plots in each year. Treatment S had a quality rating which was lowest or very close to being the lowest of all treatments in 5 of 7 plots in both years.

Heavy heads tended to be of large diameter, but this relationship was not consistent over all treatments in all plots (Appendices E and F). No correlation between head and stalk diameter could be ascertained. In 1983 Treatment S heads were usually of slightly smaller diameter than heads of other treatments within plots, but this difference was often not significant. In 1982 there was no clear pattern of head diameter among plots. In 1983 head diameters were generally smaller than in 1982.

Stalk diameters also varied unpredictably among treatments and plots (Appendices E and F), but in general were similar in all treatments in both years.

# Chapter V

# DISCUSSION

## 5.1 BROCCOLI COMPETITION - GREENHOUSE STUDY

The greenhouse competition study was undertaken to quantify growth differences in different aged broccoli plants. While broccoli growing beside plants 5 and 12 days older were decidedly smaller, especially in weight, than their counterparts in an equal aged stand in this experiment, the oldest plants when surrounding younger ones were not significantly larger than when they were grown in groups of similarly aged plants.

The study simulated effects of uneven stand establishment. In a uniformly planted field any plants which were delayed in growth by slow emergence or by injury due to insects or other factors while surrounding plants were not would likely be out- competed by these plants. Subsequent harvest yield of plants delayed at or shortly after emergence would be reduced. The competition study indicated that plants surrounding a weak seedling would tend to grow larger and faster than equal aged seedlings in a uniform stand, but this increase in size may not be sufficient to render the heads of larger plants unmarketable on the basis of weight alone. However, in broccoli stands even, close spacings promote uniformly sized, tight heads; plants maturing earlier and growing larger than slower neighbours could be overmature at first harvest or be downgraded because of loose, ricey heads.

Due to area constraints, plant spacings in this experiment were not directly comparable to the field experiments. However, the competition results should be kept in mind when considering the growth of seeded plants growing next to 4 week old transplants in 1982.

## 5.2 INSECTICIDE APPLICATION FOR SEEDLING PROTECTION

Because the study to determine the frequency of insecticide application required to protect seedlings from flea beetles was conducted in one year only and because plants suffered considerable root maggot damage, the results are not definitive. However, several interesting trends were discovered.

In all treatments in both transplanted and seeded plots, very little flea beetle feeding occurred on plants which were in the field more than 40 days, a period which, according to nearby water trap samples, corresponded with the peak activity of the overwintering flea beetle population. This was in part due to the large biomass of the plants at this stage, all of which, with the exception of No Spray seeded plants, had 6 or more leaves. The number of feeding holes which on a very small plant covered considerable area of a leaf had negligible effects on larger leaves. As well, the plot of the experiment to determine flea beetle effects on various sized plants which was located next to plants in the insecticide duration study was planted 2 weeks later than the spray experiments plots. As these seedlings emerged, flea beetles tended to shift on to them and generally vacated the spray experiment plots.

When transplanted as two week old seedlings, broccoli treatments sprayed for 1, 2, or 3 weeks all had commercially acceptable harvest yields, both in number and quality of heads (excluding plants killed by other pests). Suppressing flea beetle feeding on 2 week old seedlings for one week after transplanting was sufficient to control flea beetles whose overwintering generation population peak occurred several weeks after planting.

When one considers that most commercial transplants are 4 to 5 weeks old with 4 or 5 true leaves at the time of field planting, it is possible that in a season in which peak flea beetle feeding occurred some time after field planting, chemical protection necessary for such large transplants may be minimal.

However, all of Manitoba commercial broccoli is seeded, not transplanted. While differences in harvest and head parameters in the seeded plots were caused , in part, by differences in feeding severity and duration over the growing season, the time period at or shortly after emergence was the most critical in terms of the plants' ability to survive flea beetle attack. Differences in mortality between treatments caused by flea beetle feeding were greatest in the first sampling date, 3 days after emergence. If plants survived this initial defoliation, most of them eventually formed some sort of head, albeit the quality and maturity rate of which varied with different levels of subsequent feeding.

Plants which had been protected from feeding for 2 weeks had similar leaf growth patterns as plants which had been sprayed 3 weeks, but had fewer numbers of heads left in the field or killed by flea beetles. This anomoly was likely due to the poor emergence and root maggot damage in the Spray 3 Week plot. Spray 2 Week plants had the largest heads and shortest days to harvest period of all direct-seeded plots and much higher and earlier yields than plants sprayed for 1 week or not sprayed at all. Kostromitin (1978) found that in turnip and radish seedlings, the period of susceptibility to flea beetle feeding attack was from seedling emergence to the formation of the second pair of true leaves. After this period the author found that further feeding had little effect on plants unless the leaf area eaten of these vegetables was greater than 20%. In our study, the three spray treatments had plants with one or more true leaves 2 weeks after emergence, while No Spray plants had cotyledons to one leaf. Only No Spray and Spray 1 Week Treatments suffered substantially more than 20% leaf feeding throughout the rest of the sampling period.

In the chemical protection plots, plants which survived flea beetle feeding most vigorously were the most heavily attacked by root maggots.

## 5.3 FLEA BEETLE FEEDING EFFECTS ON DIFFERENT AGED PLANTS

### 5.3.1 Beetle Populations

The species composition and proportions of flea beetles identified from water trap samples in 1982 were similar to those found by Wylie (1979) in southern Manitoba rapeseed fields.

The occurrence of overwintering generation emergence in both years was related to spring weather conditions. In April, 1982, temperatures were slightly above normal while precipitation was 30% of normal; similar warm, dry temperatures in May encouraged early emergence and high levels of flea beetle feeding on the limited amount of vegetation available.

April of 1983 was cool and dry, while in the month of May four record low temperatures were tied or broken, and winds were high for most of the month. These cool, windy conditions resulted in delayed flea beetle emergence, with peak numbers of flea beetles sampled occurring in the third week of June. By this time various cruciferous species were established in the test plot area and feeding was not as intense on the first planted plots as in 1982.

As well as influencing emergence and development rates, weather also affected flea beetle behavior. The windy, cool spring of 1983 depressed feeding levels as flea beetles were often inactive.

The relatively mild winter of 1982 probably contributed to high survival rates of overwintering flea beetles. The overwintering generation peak of 1983 was larger than the summer generation peak of 1982, and must have included flea beetles migrating from other areas. The large flea beetle densities sampled in the summer and fall of 1983 indicated the potential for a very large overwintering population, with a threat of inflicting very heavy damage in 1984, especially since the winter of 1983-84 was relatively mild.

Both water trap and vacuum sampling had advantages and disadvantages. Water traps sampled an unknown area over a considerable period of time, so that they were less precise than D-Vac sampling in estimating a population at a particular point in time and space (Wylie, 1981). Also, while traps were changed every 3 to 4 days, varying weather conditions resulted in different levels of volatilization of the isothiocyanate bait, so that water traps had varying levels of attraction to flea beetles over time. However, water traps were easier to use and less detrimental to plants than D-Vac sampling; they also collected large numbers of adults and gave a better indication of the flea beetle population in the area.

Nevertheless, both sampling methods resulted in a crude approximation of population densities. Flea beetles can invade an area very quickly and, if plants are very small, can inflict considerable damage in a very short time. Determining economic damage thresholds on the basis of actual beetle numbers is not feasible because an accurate assessment of the population is difficult and the relationship between flea beetle numbers and resultant yield losses in a crop is often not clear. Measuring the amount of seedling surface area destroyed by flea beetles and relating this to potential yield loss is an easier and more accurate method of monitoring potential crop loss, since it relies only on the amount of physical damage to plants (Osgood, 1975b).

This study found that population estimates determined by water trap sampling were not well correlated with estimates determined by D-Vac vacuuming of individual plants, nor was either sampling method well correlated with the amount of broccoli leaf area eaten per plot. In other studies various sampling techniques have been used, including sticky trap sampling, net sweeping, and water traps with baited wicks. The varying population densities which these sampling methods estimate make comparison of such studies difficult. While a direct comparison of rapeseed foliage damage to that of other crucifers such as broccoli can not be made because of differing leaf and growth characteristics, an assessment of plant damage such as percent leaf area eaten or number of shotholes per leaf area more accurately reflect potential yield losses than numbers of flea beetles alone.

When a plot was newly planted, more beetles were vacuumed from transplanted than from seeded plants, with the most flea beetles sampled from 4 week old transplants. However, as the season progressed beetles shifted onto younger, direct-seeded plants. Initial preference, therefore, was likely due to the fact that newly emerged seedlings had much smaller leaf areas than transplants and could not support large numbers of feeding flea beetles, especially when stems or petioles or even entire seedlings were consumed. More flea beetles were vacuumed from seeded plus Furadan (S+F) plants than from seeded plants, yet the latter sustained more feeding damage. Presumably the Furadan discouraged feeding (but not necessarily biting) without affecting the number of beetles landing on S+F plants, while the heavily damaged seeded plants had less surface area on which to land.

As broccoli plants grew larger and more mature, their thick waxy cuticle or other physical or chemical factors may have made them less palatable than younger plants. Kinoshita _et al_. (1979) speculated that flea beetle host plant preference was moderated by cultivars of crucifers available and the stage of plant development, while Gerber (1975) suggested that greener rapeseed plants were more attractive to the red turnip beetle than plants reaching maturity.

### 5.3.2 Broccoli Defoliation and Leaf Growth

Defoliation of broccoli plants by flea beetles was most severe in the plots planted first in both years. The severity of this feeding damage was caused in good measure by a localization of food plants; that is, suitable foliage for emerging flea beetles was restricted mainly to plants of these early planted plots. As the seasons progressed and diversity of vegetation developed, the effects of flea beetle feeding on individual plants lessened as more plants were fed upon.

Feeding levels were lower over all plots and treatments in 1983 than in 1982 despite the lower number of flea beetles in 1982. This was due in part to the gradual increase in the population of overwintering beetles in the spring of 1983, so that at the time of peak beetle activity considerable vegetational biomass had accumulated, and in part because of the experimental design, with 3 rows of each treatment per replicate instead of just one as in 1982. Thus the increase from 50 to 90 plants per replicate tended to dilute flea beetle feeding severity.

However, with the emergence of the large summer generation of 1983, flea beetle feeding on maturing heads was more severe and resulted in decreased quality and marketability of many more heads in 1983 than in 1982.

Plants of the seeded plus Furadan (S+F) treatment had consistently less feeding than those of the seeded treatment (Figure 18), which is not surprising considering both Furadan and, under heavy feeding pressure, Decis were used to prevent feeding on S+F plants. Despite these disincentives some feeding occurred on S+F plants in all plots in both years. Under heavy feeding pressure it is likely that flea beetle feeding will cause some defoliation on chemically protected plants through sheer numbers. In this study it is important to note the spraying S+F plots with Decis and drenching all plots with Decis to control root maggots may have affected the number of summer generation flea beetle larvae surviving. Feeding on S+F and possibly all plants late in the season may have been more severe had not Decis been applied.

Excluding the first planted plots, feeding on late planted plots, especially in Treatments C (2 week old transplants), S+F, and S of such plots, was often more severe and extended over a greater period than in plots seeded earlier in the spring. This feeding trend was similar to trends in beetle populations previously mentioned, and was likely due to preference for young plants. The significance of such a preference is greater in fields in which crops are planted sequentially, such as broccoli, than in those planted at one time, such as rapeseed. While in rapeseed crops the most crucial period for monitoring flea beetles consists of 2 or 3 weeks when the crop is emerging, commercial cruciferous vegetable growers must monitor their crops throughout the period of sequential planting. This period

Figure 18: Growth of direct-seeded (Trt S) and seeded plus Furadan (Trt S+F) plants in Plot 1, seeded May 11, 1983. Photographs taken 41 days from seeding.

NOTICE/AVIS

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a) direct-seeded

b) seeded plus Furadan

a) direct-seeded

b) seeded plus Furadan

extends from approximately the beginning of May until 2 or 3 weeks beyond the end of June.

Likewise, the monitoring period for summer generation flea beetles which may decrease marketability by feeding on broccoli heads extends from the formation of the first heads until forces flea beetles seek winter hibernation sites, usually around mid-September. In both years of this study feeding on late planted plots extended well into September. Although it was not noted in this experiment, flea beetles will also migrate onto standing cruciferous vegetable plots after rapeseed in the area has been harvested (Askew, personal communication).

Leaf growth of the various treatments reflected the amount of feeding damage to which they were subjected, with seeded plants suffering the most feeding and growing the most slowly. Similarly, Westdal et al. (1979) found a marked delay in the leaf development of untreated rapeseed plants 14 days after seeding. However, this variable was not a reliable indicator of plant damage to a given treatment since over all plots, 2 week old transplants grew at rates similar to 3 and 4 week old transplants, while suffering much more defoliation. However, Lamb (1984) found that rapeseed plants were shorter in plots without insecticide application than in plots in which insecticides had been applied. It is possible that leaf growth was suppressed by feeding levels beyond a certain severity, while below this threshold leaves of plants of all treatments, regardless of amount eaten, grew at similar rates.

Leaf stage is not a good indicator of potential yield, since many plants were observed to have numbers of leaves equal to those of surrounding plants, yet were one quarter their height and never formed heads.

Plants in 1982 grew more slowly than plants in 1983 on a per plot basis, a reflection of the warm summer and less flea beetle feeding in 1983. However, on a per treatment basis, the similar but slower growth rates in 1983 treatments as opposed to 1982 treatments were not explainable and may have been due to the brevity of the sampling period in 1982.

### 5.3.3 Harvest Results

Transplant treatments had greater numbers of plants harvested than seeded treatments, with a two year total of 947, 907, and 725 marketable heads of Treatments A, B, and C (4, 3, and 2 week old transplants) respectively, as compared to 219 for seeded alone (Trt S) and 606 for seeded plus Furadan (Trt S+F). This is a reflection, in part, of emergence problems to which seeded treatments were subjected, especially in 1982, when an anticrustant was not used. This was also due to the longer maturation period required of seeded plants, with many plants of the late seeded plots being left in the field.

In the first planted plot in 1982 and the second planted plot in 1983 Treatment S+F outyielded all 3 transplant treatments; in the first plot in 1983 only Treatment B had greater yields than Treatment S+F. This would indicate that, when plants were subjected to heavy feeding damage as in the first planted plots, chemical control was a better method of attaining high yields than was the use of transplants.

More plants of all treatments were left in the field in 1982 than in 1983, a reflection of the generally higher feeding levels in 1982 and of the warm 1983 summer which tended to reduce the number of days required for heads to reach maturity.

There were many more marketable heads in 1982 than in 1983, partly because of the detrimental effects of the heat in 1983 and of extensive flea beetle feeding on heads nearing maturity in the latter year. In many of the plots Treatment S had the highest percentage of marketable heads, likely because so many seeded plants were initially killed by flea beetles that the ones that remained grew fairly well. However, over both years combined, marketability as a percentage of the number of heads harvested was very similar in all 5 treatments with values of 86.2, 88.1, and 88.7% for Treatments A, B, and C, respectively, while Treatment S had 89.4% and Treatment S+F had 89.5% of their harvested heads marketable.

Marketable heads of Treatment S generally had a lower quality rating than those of other treatments. Ratings for marketable heads of the other treatments were rather similar over plots in both years, indicating that varying levels of flea beetle feeding below those suffered by Treatment S plants did not have direct effects on head quality.

In 1982, in 15 of 24 replicates seeded plants were grown next to four week old transplants. The mean weight of Treatment S plants in the first planting was greater than that of any other treatment, and in the rest of the plots the mean weights of heads in all treatments were variable. Therefore it would appear that inter-row competition was not a major factor in development of head size in that year. Such competition may have affected days to harvest values, but these values were similar (albeit slightly longer over most plots) to days to harvest values in 1983, when no inter-row competition occurred. Therefore, such competition exerted little effect on final harvest results.

The first plots planted in both years had the longest days to harvest of plots planted before mid-June, reflecting the stress caused by severe feeding. In 1982 Treatment S+F had similar rates of maturity in all four plots in which it was harvested. This was a reflection of the feeding damage which it incurred, for Treatment S+F had the least range in mean percent leaf area eaten over all plots of any treatment. Plants of all other treatments had very variable defoliation levels over all plots, and varying rates of maturation as well. In 1983 Treatments A, B, and S+F had narrower ranges of mean feeding among plots, with more uniform rates of maturity than Treatment S. However, Treatment C had variable feeding levels but quite a narrow range in days to harvest over all plots.

Uniformity of maturity is as important to a grower as earliness of maturity. A maximum number of heads harvested in the least number of passes over the field will provide the best economic returns to the producer. Of the 5 treatments in this study, 4 week old transplants had the most number of heads maturing in the shortest period of time. Of the seeded treatments, three quarters of the seeded plus Furadan plots had greater than 80% harvest by 100 days, a respectable figure when considering that in variously located cultivar trials in 1983 the average days to first harvest for 'Premium Crop' was 83 days. In the seeded alone treatment, only 1 of 7 plots had greater than 35% harvest by 100 days, which rendered such production of broccoli economically unfeasible.

In all plots combined over both years, broccoli seeded alone resulted in 36.7% of the number of marketable heads of broccoli seeded with Furadan.

Head weight and diameter as well as stalk diameter did not vary uniformly with the treatments or the percent leaf area eaten of the treatments. Defoliation levels were related to percent mortality and maturity rates of the various treatments, while head quality was somewhat affected by the amount of leaf area eaten.

Apart from the first plots in both years, direct mortality to plants of the transplanted treatments was rather low. Some producers may feel that such mortality figures do not warrant the cost of chemicals and labour for flea beetle control. However, it should be pointed out that economic losses may occur from indirect flea beetle feeding damage, including late and uneven maturity as well as possible loss in head weight and quality.

## 5.4 GENERAL

This study involved the growth of one cultivar only, and varying results may occur if two or more cultivars are grown close to one another. Kostromitin (1978) found that in turnips and radish different cultivars of each crop had different susceptibilities to attack. The author also reported less damage on the faster growing radish than on turnip.

This study reflected the damage done by a certain composition of flea beetle populations. In East Central Saskatchewan in 1983, where P. striolata is more prevalent than in southern Manitoba, flea beetles, while inflicting little damage to newly seeded or transplanted garden crucifers, caused almost total destruction at the time of head formation (Schappert, personal communication).

No figures for economic loss on cruciferous vegetables due to flea beetle feeding in Manitoba are available, but it is likely more than the 10% average annual yield loss of rapeseed reported by Lamb and Turnock (1982). These authors found that rapeseed grown in small test fields had up to 4 times the feeding damage of rapeseed grown in large hectarages, since small plots tended to enhance the effects of insect mobility. Most cruciferous vegetables are grown in small plots in Manitoba, and one would expect more severe feeding than in large rapeseed fields.

Broccoli and other vegetables are row crops. Burgess (1977) reported that P. cruciferae especially preferred attacking rapeseed whose foliage was exposed to bright sunlight such as seedlings, isolated plants, or crops in widely spaced rows.

A third reason for speculating that economic losses due to flea beetle feeding on broccoli are greater than those on rapeseed is the fact that rapeseed has a compensatory ability to produce acceptable yield levels over a wide range of plant densities, so that mortality of some plants results in greater numbers of seed pods per plant in others. Plant losses in broccoli or other cole crops not only result in reduced yield due to the direct loss of the plant but possibly reduced yield due to overmaturity of surrounding plants.

Lastly, granular insecticides commonly used in rapeseed production have been found to be more effective in controlling flea beetles than insecticidal sprays which are recommended for cruciferous vegetable production (Boyle and Freshwater, 1982).

# Chapter VI

## CONCLUSIONS

Of the 5 treatments in this study, in both years the seeded alone treatment (S) consistently had the highest percent leaf area eaten, slowest growth rate and longest days to harvest, highest mortality, and least number of heads harvested of any treatment. Plants of the two week old transplant treatment (C) had the next highest levels of defoliation and suffered the most mortality of the 3 transplant treatments. In several plots yields of Treatment C heads were less than that of seeded plus Furadan heads.

For all treatments, the highest seedling mortality due to flea beetle damage occurred at or shortly after emergence or transplanting. Control of flea beetles early in crop establishment is, therefore, of paramount importance if high yields are to be maintained. The heaviest feeding and mortality occurred on the earliest planted plots in both years, although heavy feeding late in the season led to downgrading of marketable heads in 1983.

The severity of damage was dependent upon prevalent climatic conditions. The cool windy spring of 1983 decreased flea beetle feeding levels on seedlings over those of the warmer spring of 1982, while the hot, dry summer of 1983 promoted feeding on mature heads and on late planted plots.

Four week old transplants (Trt A) in all but the first planting in 1982, which suffered the heaviest feeding of any plot, had low levels of mortality due to flea beetles, although the number of marketable heads expressed as a percentage of the number of heads harvested was slightly lower in Treatment A than in any other treatment.

Using no insecticidal control of flea beetles on direct-seeded plants resulted in marketable head yields which were 31.1 and 42.3% of yields of marketable heads of broccoli planted with Furadan and sprayed with Decis in 1982 and 1983, respectively.

Mortality and uneven crop establishment due to flea beetle feeding led to non-uniform plant development, resulting in a long harvest period and uneven uniformity of heads.

Water trap sampling and D-Vac vacuum sampling resulted in flea beetle population estimates which were not correlated with each other, nor with mean percent leaf area eaten of the treatments. The leaf area eaten was a better indicator of subsequent yield than were beetle numbers derived from either sampling method.

Practically, a granular insecticide such as Furadan, which is not registered for cole crops, would be more effective in minimizing flea beetle damage than a spray insecticide because the greatest mortality to a crop occurs shortly after emergence, possibly before spraying can be undertaken.

Cole crop producers should ensure that plants in all direct-seeded plots, especially early planted ones, are chemically protected as they emerge from the soil if flea beetles have been a problem in the past.

If the weather is favorable for flea beetle development and if there are indications of considerable flea beetle populations in an area or if plants exhibit feeding damage, insecticidal protection should be maintained until plants are large and well established.

Unless there is heavy feeding through the summer, once plants are large and have begun head formation spraying should not be necessary until the crop is nearing maturity, when control may again be required to maintain quality and marketability of heads.

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## Appendix A

NUMBER OF FLEA BEETLES PER PLANT AND PER WATER TRAP DETERMINED BY VACUUM AND WATER TRAP SAMPLING, RESPECTIVELY, IN 1982.

| Sampling Date | Plot 1 (Planted May 20) # of Beetles per | | Plot 2 (Planted June 2) # of Beetles per | | Plot 3 (Planted June 16) # of Beetles per | | Plot 4 (Planted June 30) # of Beetles per | | Plot 5 (Planted July 15) # of Beetles per | | Plot 6 (Planted July 28) # of Beetles per | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Plant | Trap | Plant | Trap | Plant | Trap | Plant | Trap | Plant | Trap | Plant | Trap |
| May 28 | 3.78 | 44.0 | | | | | | | | | | |
| June 4 | 5.55 | 17.1 | 6.40 | 4.5 | | | | | | | | |
| June 11 | 5.87 | 65.6 | 8.59 | 170.4 | | | | | | | | |
| June 18 | 3.29 | 21.8 | 5.83 | 28.9 | 0.22 | 4.2 | | | | | | |
| June 25 | 10.48 | 547.9 | 23.33 | 65.5 | 6.71 | 338.4 | | | | | | |
| July 1 | 0.77 | 98.0 | 0.05 | 47.9 | 0.11 | 51.3 | 0 | 57.8 | | | | |
| July 8 | 5.56 | 53.4 | 6.94 | 46.3 | 13.33 | 52.8 | 4.86 | 43.8 | | | | |
| July 15 | 2.40 | 39.1 | 3.74 | 25.4 | 11.29 | 32.4 | 34.43 | 138.3 | | | | |
| July 22 | 5.35 | 282.2 | 3.18 | 87.8 | 8.27 | 103.3 | 6.05 | 351.4 | 1.88 | 492.1 | | |
| July 30 | | | | | | | 16.17 | 236.7 | 2.88 | 155.0 | 3.38 | 33.5 |
| Aug 5 | | | | | | | 10.16 | 179.3 | 10.79 | 435.4 | 5.17 | 152.1 |
| Aug 12 | | | | | | | 1.85 | 113.5 | 8.81 | 25.9 | 7.24 | 60.0 |
| Aug 19 | | | | | | | 48.58 | 71.7 | 45.10 | 248.3 | 26.34 | 179.3 |
| Aug 25 | | | | | | | | | 6.10 | 97.0 | 17.78 | 82.5 |
| Sep 7 | | | | | | | | | 25.88 | 19.8 | 42.77 | 42.0 |

## Appendix B

### REGRESSION EQUATION OF PERCENT LEAF AREA EATEN OVER LOGARITHMS OF FLEA BEETLE NUMBERS DETERMINED FROM WATER TRAP AND D-VAC SAMPLING.

a) Beetle numbers determined from water trap samples

i) 1982

Plot 1 % LAE = -4.001 Beetle no. + 41.22**[1]
Plot 2 % LAE = 1.922 Beetle no. + 16.74*
Plot 3 % LAE = 3.950 Beetle no. + 1.34**
Plot 4 % LAE = 1.867 Beetle no. + 1.65n.s.
Plot 5 % LAE = 0.008 Beetle no. + 8.17 n.s.
Plot 6 % LAE = -1.123 Beetle no. + 14.79 n.s.

ii) 1983

Plot 1 % LAE = 0.786 Beetle no. + 21.52 n.s.
Plot 2 % LAE = 3.384 Beetle no. + 3.84 **
Plot 3 % LAE = 5.022 Beetle no. - 9.28 **
Plot 4 % LAE = -0.404 Beetle no. + 19.97 n.s.
Plot 5 % LAE = 0.527 Beetle no. + 12.60 n.s.

b) Beetle numbers determined from D-Vac samples in 1982

Plot 1 % LAE = -0.412 Beetle no. + 30.60 n.s.
Plot 2 % LAE = -0.999 Beetle no. + 28.97 n.s.
Plot 3 % LAE = 0.553 Beetle no. + 19.13 n.s.
Plot 4 % LAE = 5.106 Beetle no. + 2.03 **
Plot 5 % LAE = -3.599 Beetle no. + 17.48 **
Plot 6 % LAE = -0.936 Beetle no. + 12.08 n.s.

[1] Significance levels of regression equations;
n.s. - not significant; * - significant at P<0.05;
** - significant at P<0.01.

Appendix C

GROWTH PATTERNS OF BROCCOLI PLANTS IN TREATMENTS OF VARIOUS PLOTS PLANTED IN 1982.

Plot 2 - Planted June 2

| Days from Planting | Leaf Stage Trt A | Trt B | Trt C | Days from Emergence | Leaf Stage Trt S | Trt S+F |
|---|---|---|---|---|---|---|
| 2 | 3.0 | 2.0 | 1.0 | 1 | 0[1] | 0 |
| 6 | 3.8 | 3.0 | 1.8 | 3 | 0 | 0 |
| 9 | 3.9 | 3.2 | 1.9 | 7 | 0 | 0 |
| 13 | 4.8 | 4.0 | 2.4 | 10 | 0.2 | 0.4 |
| | | | | 14 | 0.5 | 1.5 |
| | | | | 17 | 1.4 | 2.5 |
| | | | | 21 | 1.6 | 2.9 |
| | | | | 23 | 1.5 | 3.0 |
| | | | | 28 | 4.5 | 6.8 |
| | | | | 34 | 6.3 | 7.0 |

[1] 0 = cotyledon stage.

Plot 3 - Planted June 16

| Days from Planting | Leaf Stage Trt A | Trt B | Trt C | Days from Emergence | Leaf Stage Trt S | Trt S+F |
|---|---|---|---|---|---|---|
| 2 | 3.0 | 2.0 | 1.0 | 1 | 0 | 0 |
| 6 | 3.1 | 2.0 | 1.0 | 3 | 0 | 0 |
| 9 | 4.0 | 2.9 | 1.0 | 7 | 0 | 0 |
| 13 | 4.9 | 3.8 | 1.9 | 9 | 0.2 | 1.0 |
| 15 | 5.7 | 4.2 | 2.2 | 14 | 2.0 | 2.2 |
| 20 | -- | -- | 5.4 | 20 | 3.8 | 3.8 |
| | | | | 27 | 4.5 | 6.0 |

Plot 4 - Planted June 30

| Days from Planting | Leaf Stage Trt A | Trt B | Trt C | Days from Emergence | Leaf Stage Trt S | Trt S+F |
|---|---|---|---|---|---|---|
| 6 | 3.7 | 2.9 | 1.0 | 1 | 0[1] | 0 |
| 12 | 5.0 | 4.4 | 2.0 | 7 | 0.2 | 1.0 |
| | | | | 14 | 2.0 | 2.0 |
| | | | | 23 | 5.5 | -- |
| | | | | 31 | 5.0 | 6.0 |
| | | | | 38 | 7.0 | -- |

Plot 6 - Planted July 28

| Days from Planting | Leaf Stage Trt A | Trt B | Trt C | Days from Emergence | Leaf Stage Trt S | Trt S+F |
|---|---|---|---|---|---|---|
| 8 | 4.0 | 3.5 | 2.0 | 2 | 0 | 0 |
| 15 | 7.4 | -- | 3.6 | 9 | 0.5 | 1.0 |
| 22 | -- | -- | 6.4 | 16 | 1.7 | 3.2 |
| | | | | 28 | 4.8 | 6.8 |

## Appendix D

GROWTH PATTERNS OF BROCCOLI PLANTS IN TREATMENTS OF VARIOUS PLOTS PLANTED IN 1983.

### Plot 2 - Planted May 25

| Days from | Leaf Stage | | | Days from | Leaf Stage | |
|---|---|---|---|---|---|---|
| Planting | Trt A | Trt B | Trt C | Emergence | Trt S | Trt S+F |
| 2 | 3.0 | 1.6 | 0.2 | 2 | 0[1] | 0 |
| 5 | 3.2 | 1.9 | 0.8 | 5 | 0 | 0 |
| 9 | 3.9 | 2.0 | 1.0 | 9 | 0.2 | 0.8 |
| 12 | 4.0 | 2.7 | 1.1 | 13 | 1.0 | 1.6 |
| 16 | 5.5 | 3.7 | 1.8 | 16 | 1.2 | 2.0 |
| 20 | 6.4 | 4.7 | 2.7 | 20 | 1.9 | 3.2 |
| 23 | -- | 5.9 | 3.3 | 26 | 2.0 | 5.4 |
| 27 | -- | 6.3 | 4.6 | 34 | 4.6 | -- |
| 33 | -- | 7.8 | 5.8 | | | |
| 41 | -- | -- | 7.1 | | | |

[1] 0 = coltyledon stage.

### Plot 4 - Planted June 23

| Days from | Leaf Stage | | | Days from | Leaf Stage | |
|---|---|---|---|---|---|---|
| Planting | Trt A | Trt B | Trt C | Emergence | Trt S | Trt S+F |
| 4 | 3.6 | 2.8 | 1.0 | 1 | 0 | 0 |
| 7 | 4.4 | 3.5 | 1.8 | 3 | 0 | 0 |
| 12 | 5.5 | 4.3 | 2.6 | 8 | 0 | 0 |
| 15 | 6.8 | 5.5 | 4.0 | 11 | 0.5 | 0.6 |
| 19 | -- | 7.1 | 5.6 | 15 | 1.2 | 1.6 |
| | | | | 18 | 2.0 | 2.8 |
| | | | | 21 | 3.2 | 4.5 |
| | | | | 29 | 4.7 | 6.4 |
| | | | | 32 | 5.1 | 6.4 |

### Plot 5 - Planted July 20

| Days from | Leaf Stage | | | Days from | Leaf Stage | |
|---|---|---|---|---|---|---|
| Planting | Trt A | Trt B | Trt C | Emergence | Trt S | Trt S+F |
| 6 | 4.6 | 3.6 | 1.4 | 1 | 0[1] | 0 |
| 9 | 5.6 | 4.2 | 2.1 | 4 | 0 | 0 |
| 13 | 7.2 | 5.8 | 3.2 | 8 | 1.0 | 1.2 |
| 21 | -- | 7.2 | 4.4 | 16 | 2.7 | 3.5 |
| 28 | -- | -- | 5.2 | 23 | 4.8 | 5.6 |
| 34 | -- | -- | 7.1 | 29 | 6.1 | 7.5 |
| | | | | 39 | 7.6 | -- |

Appendix E

HEAD SIZE DATA OF MARKETABLE HEADS OF BROCCOLI HARVESTED IN 1982.

| Planting Date | Plot/ Trt No[1] | Head Diam (cm) | Stalk Diam (cm) |
|---|---|---|---|
| May 20 | 1A | 11.1 b[2] | 3.4 n.s. |
| | 1B | 11.3 b | 3.3 |
| | 1C | 12.4 a | 3.3 |
| | 1S | 11.6 b | 3.4 |
| | 1S+F | 11.7 ab | 3.3 |
| June 2 | 2A | 9.9 b | 2.9 b |
| | 2B | 10.5 b | 3.1 a |
| | 2C | 10.2 b | 2.9 b |
| | 2S+F | 11.4 a | 3.2 a |
| | 2S | 11.0 a | 3.2 a |
| June 16 | 3A | 12.2 ab | 3.2 a |
| | 3B | 12.6 a | 3.1 a |
| | 3C | 11.6 b | 2.9 b |
| | 3S | 10.8 c | 3.0 ab |
| | 3S+F | 10.8 c | 2.9 b |
| June 30 | 4A | 12.4 a | 3.3 a |
| | 4B | 11.7 ab | 3.2 a |
| | 4C | 10.6 a | 3.3 a |
| | 4S+F | 8.8 c | 2.7 b |
| July 15 | 5A | 10.9 b | 3.4 n.s. |
| | 5B | 10.5 b | 3.4 |
| | 5C | 10.2 a | 3.6 |

[1] A, B, C - 4, 3, and 2 week old transplants, respectively; S - seeded alone; S+F - seeded plus Furadan.
[2] Within columns, means followed by the same letter do not significantly differ (P<0.01, n.s. - not significant).

Appendix F

HEAD SIZE DATA OF MARKETABLE HEADS OF BROCCOLI HARVESTED IN 1983.

| Planting Date | Plot/ Trt No[1] | Head Diam (cm) | Stalk Diam (cm) |
|---|---|---|---|
| May 16 | 1A | 9.7[2] n.s. | 2.7 n.s. |
| May 16 | 1B | 9.9 | 2.8 |
| May 16 | 1C | 10.6 | 3.4 |
| May 11 | 1S | 9.3 | 3.8 |
| May 11 | 1S+F | 10.5 | 3.1 |
| May 25 | 2A | 9.5 bc | 2.7 c |
| | 2B | 10.0 b | 3.2 b |
| | 2C | 10.9 a | 3.4 a |
| | 2S | 9.0 c | 3.5 a |
| | 2S+F | 10.7 a | 3.1 b |
| June 8 | 3A | 11.0 a | 3.2 b |
| | 3B | 11.1 a | 3.2 b |
| | 3C | 9.7 b | 3.3 b |
| | 3S | 9.4 b | 3.5 a |
| | 3S+F | 10.0 b | 3.5 a |
| June 23 | 4A | 8.9 ab | 3.1 n.s. |
| | 4B | 8.9 b | 3.2 |
| | 4C | 9.3 ab | 3.0 |
| | 4S | 9.3 ab | 3.0 |
| | 4S+F | 9.8 a | 3.1 |
| July 20 | 5A | 9.8 n.s. | 3.3 n.s. |
| | 5B | 9.6 | 3.4 |

[1] A, B, C - 4, 3, and 2 week old transplants, respectively; S - seeded alone; S+F - seeded plus Furadan.

[2] Within columns, means followed by the same letter do not significantly differ (P<0.01, n.s. - not significant).