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I am submitting herewith a thesis written by Sheila Mae Moore entitled "Evaluation of Systemic Insecticide-Nematicides for the Control of Aphids and for the Effect on Selected Non-target Organisms on Tomato in East Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Biology.

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EVALUATION OF SYSTEMIC INSECTICIDE-NEMATICIDES FOR THE CONTROL OF APHIDS AND FOR THE EFFECT ON SELECTED NON-TARGET ORGANISMS ON TOMATO IN EAST TENNESSEE

A Thesis

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Degree

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ABSTRACT

In East Tennessee, twelve insecticide-nematicides were evaluated at high rates in 1976 and reduced rates in 1977 in regard to: control of Myzus persicae (Sulz.) and Macrosiphum euphorbiae (Thomas) on tomato; the effect on densities of the non-target organisms Aphidius matricariae Hal., Ceratomegilla maculata DeG., Coccinella novemnotata Hbst., and Jalysus spinosus Say; and the effect upon fruit yield and quality.

Seasonal totals for treatments compared to a check indicated that only Dasanit treatments provided efficient aphid control without reduction of numbers of beneficial insects for both the 1976 and 1977 seasons. Efficient aphid control with reduced beneficial density occurred on Di-Syston, Mocap (1x), (2x), Dasanit + Di-Syston (except for high percent parasitism) and Mocap Plus (1x) (except for high numbers of J. spinosus) as compared with check population levels in 1976. Low pest and non-target insect numbers occurred on Ambush (except for high percent parasitism), Dasanit + Di-Syston, Mocap Plus (1x), and Nemacure (except for high numbers of J. spinosus) treatments compared to the check in 1977.

Furadan and Di-Syston treatments allowed high pest and high predator-parasite population levels compared to

the check in 1977. Ambush was the only treatment which allowed high pest numbers, but which was detrimental to non-target organisms compared to check populations in 1976. This high pest-low natural enemy response was not observed for any treatment in 1977.

Although differences between the treated and untreated plants for aphid infestation were significant in 1976 and 1977 ($P = 0.05$), lack of significant differences among the predator treatments may have been due in part to interplot movement of the predators. Multiple correlation and regression analysis indicated lowest aphid numbers occurred for periods of highest temperatures. Heavy rainfall was correlated with reduced beneficial insect numbers and activity. Late season aphid resurgence was observed for both species on untreated and treated tomato plant, and was attributed to prior reduction of beneficial insect numbers, decreased residual activity, and/or senescent leaflets.

Yields were significantly different ($P = 0.05$) in 1976 with highest yields obtained from Dasanit + Di-Syston treated plants and high yields obtained from Ambush and Vydate treated plants. Lowest yields occurred for Mocap (2x) treatments. Yields were greater on all treatments than check in 1977, but were not significantly different.

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CHAPTER I

INTRODUCTION

Four thousand known aphid species threaten agricultural crops with transmission of plant pathogens and plant injury in temperate and tropical regions throughout the world (Mackauer and Way, 1976). Aphid reproductive potential is immense due to parthenogenesis, viviparity, and fast development. Effective control has diminished with the expansion of agriculture into extensive monocultures and the use of pesticide treatments. These cropping systems provide better conditions for aphid development than are available in a natural environment (Bosch, 1972; Osburn and Spencer, 1938; Smith and Hagen, 1959).

Tomato production provided a revenue of 19 million dollars to Tennessee growers in 1977 (Moore and Lambdin, unpublished data, 1977). Thirty-eight of Tennessee's 95 counties utilized 2300 acres for commercial production in 1977 (Anonymous, 1977a), providing a yield of 280,000 cwt. compared to a national average of 21,492,000 cwt. (Anonymous, 1977b) (Figure 1).

In a survey of Tennessee extension agents, the green peach aphid (Myzus persicae (Sulzer)) and potato aphid (Macrosiphum euphorbiae (Thomas)) were cited second only to the tomato fruitworm as the most important pest to

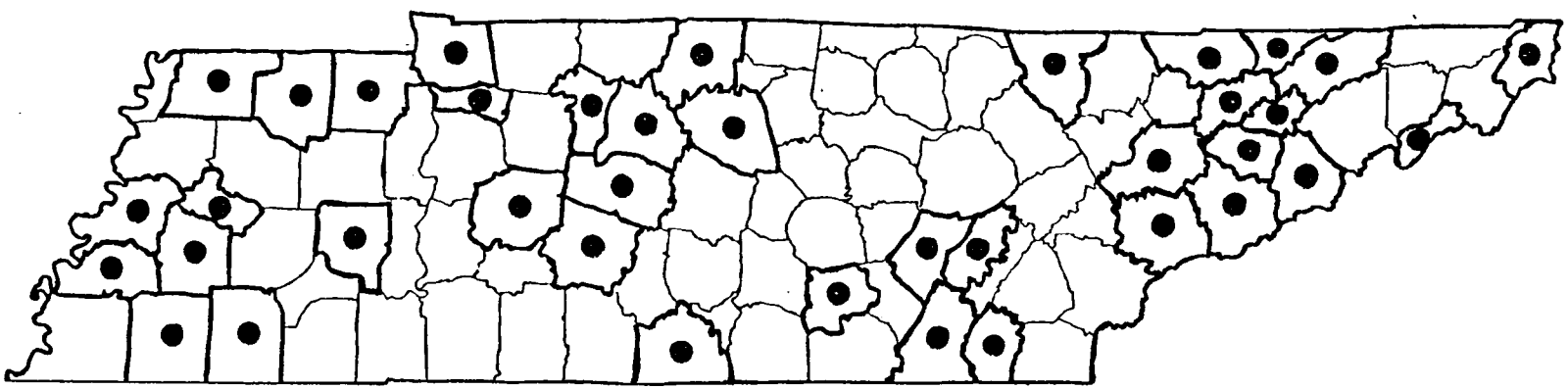


Figure 1. Distribution of commercial tomato producers in Tn 1977. Dots indicate counties where tomatoes are commercially produced.

commercial producers in Tennessee, and were the aphid pests evaluated in this investigation (Figures 2 and 3). Systemic control measures are not employed by Tennessee's commercial producers, although they offer the added advantage of lessened contact with predator and parasite populations.

Evaluation of systemic compounds for control of these tomato pests was conducted since their effect on non-target insect populations had not previously been determined. Efficacy of twelve systemic insecticide-nematicides was evaluated for aphid control on tomato (Lycopersicum esculentum cv. Walters) in East Tennessee. Also, treatment effect was determined on yield and on population densities of non-target organisms. Entomophagous insects were further evaluated for aphid control by means of host-predator-parasite density models on untreated plants (Bombosch, 1963; Emden, 1963, 1965, 1966a; Hassel, 1966; Tamaki, 1974; Tamaki et al., 1974). Ecological and biological information obtained can be further utilized in the development of future integrated pest management programs, in addition to more accurately defining the role of systemics in aphid control.



Figure 2. A green peach aphid, Myzus persicae (Sulzer).



Figure 3. A potato aphid, Macrosiphum euphorbiae (Thomas).

CHAPTER II

LITERATURE REVIEW

Aphid colonies on leaves and stems of the tomato plant inflict damage by: extraction of sap from leaves and shoots; producing a toxic effect from salivary secretions injected during feeding that may result in stunted growth and/or deformation of leaves and fruit (Palmer, 1952); and transmission of viruses (Bradley and Ganong, 1955; Essau et al., 1961) such as those causing mosaics and leaf-roll (Metcalf et al., 1962).

Kennedy et al. (1962) reported M. persicae to be a vector of over 100 diseases of plants in more than 50 families. Because of their role in viral transmission, the critical population level was cited by Sylvester and Cox (1961) as one aphid per plant. Although the tendency of aphids to colonize individual plants leads to an over-dispersed (contagious) distribution, the critical population levels are reached before 100% of the plants are infested.

Both green peach and potato aphids are migratory. These species overwinter as eggs laid the previous autumn by sexual females. Overwintering host plants for M. persicae are peach, plum, apricot, and cherry trees, while M. euphorbiae prefers rose bushes.

Eggs of both species give rise in the spring to apterous, parthenogenetic, viviparous females (fundatrices). These females produce a similar generation (fundatrigeniae) among which a few winged females may occur. The latter are concerned with migration and dispersal of the species (Johnson, 1954). These spring migrants may fly to numerous hosts in addition to tomato, and initiate production of 'alienicolae' on the secondary host. From the 'alienicolae' are produced a generation of winged females and males in late summer. These winged aphids (sexuparae) give birth to wingless nymphs, often back on the perennial plant from which the species began the cycle in the spring. The 'sexuales' appear only once in the life cycle and consist of sexually reproducing males and females. After successful mating, the females lay fertilized eggs (Baker, 1920; Metcal et al., 1962; Richards and Davies, 1977).

Major damage to plants inflicted by the 'alienicolae' form on tomato throughout the summer (Kennedy and Stroyan, 1959). They produce an average of 65 young per female. The intrinsic rates of population increase was found to be optimum at 25° C for potato aphids (Barlow, 1962). The capacity for increase was shown to be greater for M. persicae, especially at temperatures between 15° and 25° C, because of a more rapid development for this

species. Upper and lower temperature threshold for population increase of both species was estimated as 25° C to 30° C and below 5° C, respectively.

Fluctuations in aphid population density are not only influenced by climatic factors, but by host plant condition, action of natural enemies, presence or absence of biotic factors that promote their reproduction, cultural measures, and the application of chemicals. Emden et al. (1969) attributed the stability of field populations to be influenced by intraspecific interactions. Alatae produced in response to 'over-crowding' are poorly fecund and most fail to colonize suitable new food plants.

The green peach aphid and potato aphid, although polyphagous, are severely restricted by the physiological condition of available food plants (Emden and Williams, 1974). For example, senescent leaflets have been found more favorable to aphid reproduction due to the higher concentration of nitrogen (Dethier, 1966; Emden, 1964, 1966 b,c; Kennedy, 1958).

Carnegie (1965) determined that the intensification of pesticide treatments does not eradicate aphids, but contributes to development of resistant populations which exhibited more vitality than the original strains. Routine pesticide treatments have adversely influenced parasite and predator populations (Bartlett, 1963; Bosch,

1972; Zeleny, 1966) by the reduction or elimination of hosts in extensive monoculture systems.

Costs for aphid control on deciduous fruits and nuts, forage crops, and vegetables in the United States amount to millions of dollars each year (Stern. 1965). One possibility for least damage to parasite and predator populations is the use of systemic compounds. Although many chewing insects are not affected by systemic insecticides, Howe (1963) revealed systemic treatments particularly useful against aphids, mealybugs, and some spider mites and leaf-mining larvae. Howe emphasized the limitation of systemics to be the result of their oil-water partition which hinders the movement of the insecticide into the water phase. Numerous incidences of selective and effective systemic control for aphid pests have been determined (Baraonowski, 1960; Helgesen and Tauber, 1974; Lindquist and Baverle, 1972; and Tedders, 1970).

Unfortunately, negative aspects of systemic carbamates and/or organophosphorus compounds for aphid control are becoming increasingly evident (Eto, 1974). Facultatively phytophagous predators have been severely affected by certain systemics (Ahmed et al., 1954; Newsom et al., 1976). Also, Cate et al. (1972) reported that soil applications of Ambush as a side dress of 2 lbs. per acre resulted in sufficient translocation to the extrafloral nectar to kill 100% of adults of the parasite

Campoletis perdistinctus Viereck if fed nectar collected three days after treatment and 13% if fed collected 22 days after treatment.

Insecticide resistance in aphids was first reported by Boyce (1928) who induced it in Aphis gossypii Glov. by artificial selection with hydrocyanic acid. Anthon (1955) first cited evidence for green peach aphid resistance to organophosphorus compounds under field conditions. Subsequently, resistance in field populations of M. persicae and M. euphorbiae has been widely noted (Baranyovits and Ghosh, 1969, FAO, 1967, 1969, 1970; Georghiou, 1963; Gould, 1966; Hurkova, 1970; Shirck, 1960; Wyatt, 1967). The occurrence of resistant strains of aphids demonstrated the need for biological control where effectiveness of pesticides has decreased to a negligible value (Bonnemaison, 1966; Hodek, 1966a; Smith and Hagen, 1959).

More recently, Needham and Sawiki (1971) reported resistance of the green peach aphid to organophosphates as an increasing problem, both in the greenhouses and fields of the United Kingdom of Great Britain. As with their study, Sudderuddin (1973) worked out the resistance levels of M. persicae. Devonshire et al. (1975) reported continued aphid resistance to Di-Syston and dimethoate in greenhouses, but showed that these same insecticides were able to control resistant strains in the field. Needham and Devonshire (1973, 1975, 1976) investigated control of

M. persicae on sugar beets by organophosphorus compounds and revealed five- to ten-fold resistance to demeton-S-methyl and dimethoate.

Griffiths et al. (1975) noted that organophosphorus insecticides tend to vary in relative effectiveness in different soil conditions. This may be attributable to varying degrees of absorption and movement in soils of different characteristics and moisture contents, so that the conditions that favor one insecticide may decrease the effectiveness of another. Bromilou and Tucker (1974) suggested that organophosphates be more closely and more uniformly spaced in soil to achieve maximum control. This would increase the effectiveness of such strongly absorbed, less mobile nematicides as the organophosphates and the compound Furadan. Less uniform soil mixture was reported necessary for the more mobile oxime carbamate Vydate.

Little information is available concerning the effects of systemic insecticides on the morphology and physiology of tomato plants. Plant growth has been shown to be inhibited by some insecticides (Arthur and Arant, 1954) and plant yields have been increased by others (Wrissell and Driscoll, 1964). Wheeler and Bass (1971) and Shehane and Bass (1974) determined Furadan and Di-Syston to have no affect upon germination, number of mature pods, or yield of soybeans. Hull (1974) and

Cooke (1975) reported that with the use of the systemic nematicides Vydate and Ambush, sugar beet yield was increased. Both Hull and Cooke related this increase of productivity to an early aphid reduction and a subsequently lower incidence of virus yellows.

Jacques and Patterson (1962) determined that the injudicious use of fungicides against plant pathogens adversely affect entomogenous fungi (Verticillium lecanii, Entomophthora sps.). Fungicides were later shown to protect aphids from infection by entomophagous fungi (Hall, 1975; Nanne and Radcliffe, 1971). There occurred an increase in the aphid population and a reduction of the incidence of diseased aphids in the fungicidal treatments.

Integrated control programs seek to manage aphid populations by maximizing environmental resistance and by supplementing this by use of selective pesticide applications if economic tolerance levels are threatened to be exceeded. An in-depth knowledge of the bionomics and ecology of aphidophagous insects is therefore important for most efficient aphid control, and has become the object of much recent research (Hodek, 1966b).

Examination of essential and alternative prey of aphidophagous coccinellids has allowed prediction of populations in a given field containing different prey-pests, and has shown the two coccinellid species Ceratomegilla maculata (DeGeer) and Coccinella novemnotata Herbst to

be economically important in aphid control. Adult C. maculata (Figure 4) and C. novemnotata (Figure 5) do not lay eggs when only an alternative prey is present. In these situations, the predators would serve as only a temporary controlling factor.

Food for these polyphagous predators includes pest-species of Homoptera (Psylloidea, Aleurodidea, Cicadoidea), mites, small nematocerous Diptera and young instars of Lepidoptera and Coleoptera (Balduf, 1932; Fulmek, 1957; Schilder and Schilder, 1928).

In his study on the phytophagous feeding habits of ladybugs, Hagen (1962) observed C. maculata to feed on nectar, pollen and green leaves. Pollen is particularly important in the diet of the spotted ladybug, C. maculata. In a study by B. C. Smith (1966) C. maculata was actually shown to prefer corn pollen to aphids.

It was determined from experiments by Hodek (1966b, 1967) that not all accepted food was necessarily the essential food enabling development of larvae and ripening of ovaries for C. maculata and C. novemnotata. Much research has demonstrated both of these coccinellids to be efficient aphid predators and pest control agents (Banks, 1955; Iperti, 1965; Solomon, 1949; Szumkowski, 1955; Thompson, 1928). B. C. Smith (1966) and Hagen (1962) have shown that by addition of alternative foods to the crops, these ladybugs could be attracted and



Figure 4. Ceratomegilla maculata (DeGeer) on tomato leaf.



Figure 5. Coccinella novemnotata Herbst on tomato leaf.

maintained during periods when aphid prey were scarce. Balduf (1932) and Hodek (1966a) both concluded that all species of aphids are equally acceptable as prey by aphidophagous Coccinellidae, but that the number of aphids killed by coccinellid predators increases significantly when temperatures fluctuate (Hodek, 1967; Gawande, 1966). Food intake of C. maculata was highest the first eight days after emergence of the adult. Developmental time of the first and second generation of individuals feeding on aphids was 23.3 ± 1.0 and 27.9 ± 2.5 days, respectively.

Shands et al. (1972 a,b) concluded that predators and entomogenous fungi were chiefly responsible for initiating 14 and 17 decreases, respectively, of the potato aphid population. Aphid control by predators was often much below the commercially-acceptable level because the population decreases were late in the fall.

The main factor of efficiency for aphidophagous coccinellids is their voracity, depending on the species, developmental stage, the climatic conditions and species of aphid. Iperti's study (1966) of five coccinellids, including C. novemnotata, determined a high fecundity with high gregariousness of larvae originating from one large egg batch to result in a high predatory efficiency of the species. Using these criteria, adult C. novemnotata was evaluated to have a medium predator efficiency with a possible adult aphid consumption of 100

aphids a day (MacFarland, 1963; Meir, 1966; Putnam, 1964; Smith, 1965).

The spined stilt bug, Jalysus spinosus Say (Figure 6), was initially noted as an occasional pest of tomato (Anonymous, 1944; Faust and Harrison, 1968; Phipps, 1924; Somes, 1914, 1916). Readio (1923) and Abott (1933) redescribed J. spinosus (Say) and illustrated all stages. Phipps (1924) cited the stilt bug as feeding little on leaves and stems, preferring instead buds of tomato plants.

The predatory role of the stilt bug went unnoticed until Gilmore (1938) described the predation of the stilt bug on the eggs of the hornworm Manduca sexta (L.). Later Kulash (1949) reported J. spinosus to be a predator of aphids. Rabb et al. (1955) and Lawson (1958, 1959) studied the predation of the stilt bug in tobacco fields. A comprehensive study by Elsey (1971, 1972, 1973, 1974) on stilt bug predation indicates that greater predation occurred on artificially infested tobacco hornworm eggs than eggs from natural infestations. Predation of tobacco budworms, tobacco hornworms, and aphids was noted on tobacco (Ganyard et al., 1972; Ellis et al., 1972, 1973; Elsey and Stinner, 1971). As an aphid predator and plant feeder, the spined stilt bug could provide both benefit and injury in an integrated control program for aphids on tomato.



Figure 6. Jalysus spinosus (Say) on tomato leaf.

The effectiveness of predators was reviewed recently by Hagen and Bosch (1968). Hodek, Hagen, and Emden (1972) discussed methods used to measure predator impact on prey populations. Bombosch (1963) developed a predictive model balancing predator voracity against a geometric increase in aphid numbers. The components of this model included the potential rate of increase of the aphid population without predation, the initial aphid population, the aphid population density on a subsequent day, and the number of aphids consumed by the predators present. The predator-aphid relationship was an interaction of the three components: 1) voracity, a function of appetite, activity and abundance of predators; 2) synchronization, the time relationship of the attack by aphidophagous insects with the aphid population and life span of the individual aphid and 3) aphid reproductive rate (Tamaki et al., 1974). This model was first related to field conditions by Emden (1963, 1965).

Parasitism by species of the hymenopterous families Aphidiidae and Aphelinidae was cited by Mackauer and Way (1976) as the most commonly observed cause of aphid mortality in the field. Over 300 species of Aphidiidae were listed by Mackauer and Stary (1967). Stary (1970, 1976) published extensive accounts of the biology of this group. Hagen and Bosch (1968) investigated the impact of parasites on their aphid hosts, including relevant aspects of their biology.

Percentages parasitism in natural aphid populations have been observed as high as 80-90% (Frazer and Bosch, 1973). Parasitism rates are usually much lower. Shands et al. (1965) reported that a maximum of 63% of green peach aphid on potatoes were parasitized in northeastern Maine during a 12-year period. Because parasitized aphids tend to migrate away from their host plants (Behrendt, 1968) and are missed by the usual sampling techniques, the degree of parasitism is often greater than the percentages obtained from mummy counts.

Tamaki et al. (1970) suggested that effects on aphid fecundity caused by parasitism and parasite activities are more important than aphid mortality. Pea aphid fecundity was reduced when aphids were exposed to searching and ovipositing parasite activities. Also, parasitized aphids showed a significant reduction in fecundity and longevity as compared to normal individuals. The degree of reduction varied with host age at the beginning of parasitism (Arthur, 1944; Fox et al., 1967; Hafez, 1961).

Aphidius matricariae Haliday has been cited as the most common and probably most effective parasite of the green peach aphid and other Nectarosiphon species (Mackauer and Stary, 1967). Its host range includes a large number of other Aphididae with an affinity for the Brachycandus-Myzus-Rhopalosiphum genera, although the

green peach aphid seems to be the preferred host (Schlinger and Mackauer, 1963). This species is native to Europe and was introduced accidentally to North and South America, Southern Rhodesia and Australia.

Accounts on various aspects of the biology were published by Wheeler (1923), Vevai (1942), Schlinger and Mackauer (1963), Shands et al. (1965). Development rate depends largely on temperature and humidity, but averages 2-3 weeks in the summer (Wheeler, 1923). Highest number of eggs obtained during the lifetime of a single female was 309 (Vevai, 1942). The parasite is strongly heliotropic and its longevity is increased in diffused light. The parasite disperses readily under field conditions of 21.1° C, relative humidity 70% and wind velocity under 5 miles per hour.

Available data on percentage parasitism in the field are rare. Dunn (1949) raised 57 specimens of A. matricariae out of 100 parasitized green peach aphids collected on potatoes in Northumberland, England. In extensive surveys 15.0% parasitism by A. matricariae and A. picipes Nees was recorded on potatoes and 2.5% on cruciferous crops in the Netherlands (Hafez, 1961), and 18.5% on cruciferous crops in Germany (Sedlag, 1958). In Southern Rhodesia the percentage of M. persicae killed by the parasite varied locally between 0.8 and 28.0% on tobacco. Hyperparasites are rare (Bunzli and Buttiker, 1959).

Huffaker, Messenger, and DeBach (1971) described effective enemies as those which possess a high reproductive capacity, have a short generation time, are dispersive, and are well synchronized with and specific to their hosts. These attributes, as well as adaptability and genetic fitness, denote good colonizing ability (Mackauer, 1972). Hymenopterous parasites of aphids meet most of these requirements.

McLeod (1937, 1940) was the first to report on the successful control of several aphid species, including green peach aphid, in greenhouses. Richardson and Westdal (1965), Wyatt (1970) noted similar examples, and Scopes (1970) described a technique for maintaining green peach aphid on chrysanthemums.

Various authors (Hussey, 1965; McLeod, 1937; Smith, 1931) reported that A. matricariae effectively controls the green peach aphid in greenhouses at daily temperatures of 18.3° C or more. Contact insecticides are highly toxic to the parasite (Way, 1949), whereas systemic aphidicides are only moderately toxic or harmless to predators and parasite insects (Shorey and Hale, 1963). The discovery of a strain of A. matricariai which appears resistant to insecticides (Wyatt, 1967) may provide additional opportunities for integrated control of the green peach aphid. However, there is at present no sound basis for expecting that a polyphagous pest on field crops, such as M. persicae, can be controlled by parasites. Published

reports of parasite impact on green peach and potato aphid state that natural enemies, with the exception of certain predators, do not significantly influence the aphid's population dynamics (Bonnemaison, 1971; Leclant and Remaudiere, 1970; Shands et al., 1965; Shiga, 1967, 1968; Tamaki, 1973; Vevai, 1942).

CHAPTER III

MATERIALS AND METHODS

Six-week (17.8 cm.) old tomato seedlings (cv. Walter) were transplanted on 4 June, 1976, 29 April 1977, at the University of Tennessee Plant Science Farm, Knoxville, Tennessee. Soil was treated 28 May, 1976, and 22 April, 1977, with granular insecticide-nematicides. Rates of active ingredient per hectare were Ambush (0.9 kgs., 3.09 kgs.); Dasanit (23.3 kgs., 3.09 kgs.); Dasanit + Di-Syston (24.5 kgs., 3.09 kgs.); Di-Syston (7.4 kgs., 3.09 kgs.); Furadan (3.09 kgs.); Mocap (2.7 kgs., 5.4 kgs.); Mocap Plus (2.7 kgs., 3.09 kgs., 6.18 kgs.); Nemacure (4.64 kgs.); Vydate (3.09 kgs.). Treatments used for both seasons were Ambush, Dasanit, Dasanit + Di-Syston, Mocap Plus, and Vydate.

In 1976, chemicals were applied at above recommended rates except for Mocap which was also applied at twice the rate (2x). In 1977, treatments were applied at the rate of 0.09 grams AI per meter. Chemicals were applied in a 30.5 cm. band with a shaker bottle, and incorporated into the top 20-30 cm. of soil. Standard recommended rate (0.69 kg./0.38 liter) for Manzate-D was applied to all plants twice weekly from May 20 through July 15, 1977, for early blight control.

The treatment plots were arranged in a randomized complete block design replicated five times with five plants per replicate. A total of 200 plants was used in 1976; 250 plants was used in 1977. Plants were spaced 0.31 m. apart; each replicate was 1.52m x 2.74m. The Florida weave method was used in tying plants to wooden stakes. Field plots for both seasons were adjacent to a plot of field corn and a second plot of varied vegetables (snapbeans, melon, squash, and broccoli).

Absolute counts per plant were made weekly of: Coccinella novemnotata Herbst, Ceratomegilla maculata (DeGeer) (spotted ladybug), Epitrix cucumeris (Harris) (potato flea beetle), Epitrix hirtipennis (Melsheimer) (tobacco flea beetle), Jalysus spinosus (Say) (spined stilt bug), Macrosiphum euphorbiae Thomas (potato aphid), Myzus persicae Sulzer (green peach aphid), and Systena blanda Melsheimer (pale striped flea beetle). Aphids parasitized by Aphidius matricariae Haliday were distinguished in the field by the pearly-white mummified condition and were monitored weekly as an absolute number per plant. Mummified aphids were selected from treated and check plants, brought into the laboratory, and the parasite was allowed to develop and emerge under laboratory conditions for species identification.

Tomatoes were harvested and weighed twice weekly at maturity. Fruit was evaluated for tomato fruitworm (Heliothis zea (Boddie)) and leafhopper damage. Fruitworm damage was typified by circular punctures in the epidermis and rated as follows: 1= no damage; 2= 1-2 holes; 3= 3-4 holes; 4= 5-6 holes; 5= 7+ holes. Leafhopper damage index was: 1= no damage; 2= 1-5 scars; 3= 6-10 scars; 4= 11-15 scars; 5= 16 or more pinpoint or crescent-shaped cuticular scars.

Insect counts were transformed to log x for interpretation of parasite-host densities (Hassel, 1966). Predation effect on aphid density was evaluated by the Bombosch Model (1963). Inspect counts and fruit yields were analyzed by analysis of variance and Duncan's Multiple Range Test. Environmental data, treatment effects, and insect population densities were analyzed using the Statistical Analysis System 1976 for correlation (Pearson product-moment) and multiple regression (Stepwise Procedure with the Maximum R^2 Improvement).

CHAPTER IV

RESULTS AND DISCUSSION

I. SEASONAL ABUNDANCE OF PESTS AND NON-TARGET ORGANISMS

In the Type 3 Model for aphid dynamics (Sluss and Hagen, 1966) predator-parasite numbers increased during period of favorable climatic conditions and low aphid density occurred as a result of aphidophagous activity. The highest mean of 306 unparasitized and 192.4 parasitized green peach aphids per plant were observed the second week of June. Pest-enemy numbers on untreated plants in 1976 typified this Model (Figure 7). Subsequent aphid numbers were much reduced and continued at low levels until a moderate resurgence occurred in late July. During the period of reduced aphid numbers, adult C. novemnotata and stilt bug numbers were high and increased consistently with peak densities reached late in July. Conversely, the spotted ladybug declined in numbers per plant from late June through mid-July. This fluctuation in density indicated a probable migration of adult C. maculata to an adjacent field corn plot where corn pollen, a preferred food (Ewert and Chiang, 1967), was available for nourishment when aphid densities were low. Thus, data

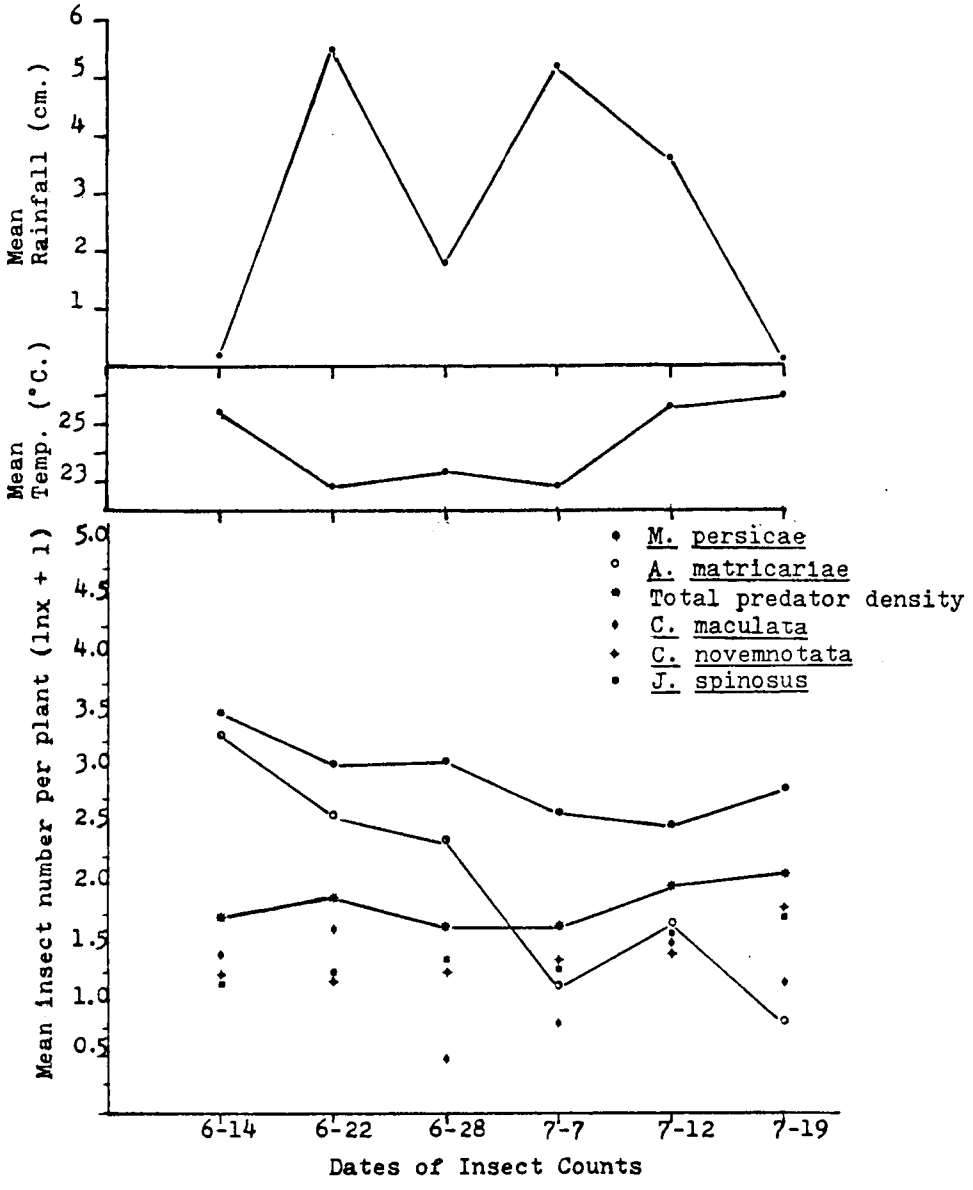


Figure 7. Seasonal abundance of pest and non-target organisms on untreated plants, 1976.

from untreated tomato plants in 1976 suggests predation to be an important control factor for apterous green peach aphids on tomato. Percent parasitism by A. matricariae (Figure 8) decreased throughout the season for aphids on check and indicated the predominant role of predators, particularly C. novemnotata and J. spinosus, in aphid control during the 1977 season.

Ambush and Vydate did not alter peak periods of green peach aphid and parasitized aphid numbers compared to check in 1976 (Figure 9). Also, peak predator numbers were comparable to those of the check. Highest numbers of parasitized aphids and predators occurred on Ambush rather than on Vydate treatments, and contributed to a greater late season aphid resurgence than on Vydate-treated plants.

Green peach aphid population levels decreased from June 14 through the first of July in Dasanit, Di-Syston, and Dasanit + Di-Syston treated plots; lowest numbers were observed on Di-Syston-treated plants June 22 to July 7, 1976 (Figure 10). Parasitized aphids were observed at lower levels than the number of unparasitized aphids June 14, and continued to decline throughout the remainder of the count period on Dasanit and Dasanit + Di-Syston-treated plants. The increase in parasitized aphid numbers observed June 28 for Di-Syston-treated plants suggested a decreased toxicity affect on the parasite and/or a

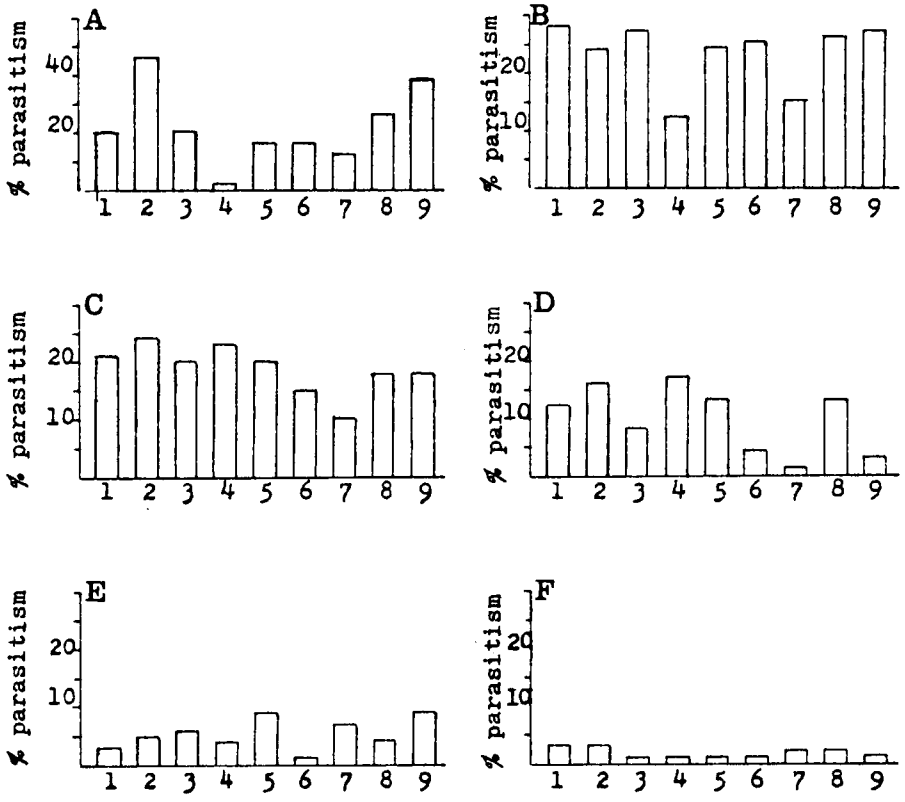


Figure 8. Percent parasitism observed for Ambush (1), Dasanit (2), Dasanit+Di-Syston (3), Di-Syston (4), Mocap (1x) (4), Mocap (2x) (5), Mocap Plus (6), Vydate (7), and check (8) treatments, 1976. Count dates follow: A - June 14; B - June 22; C - June 28; D - July 7; E - July 12; F - July 19.

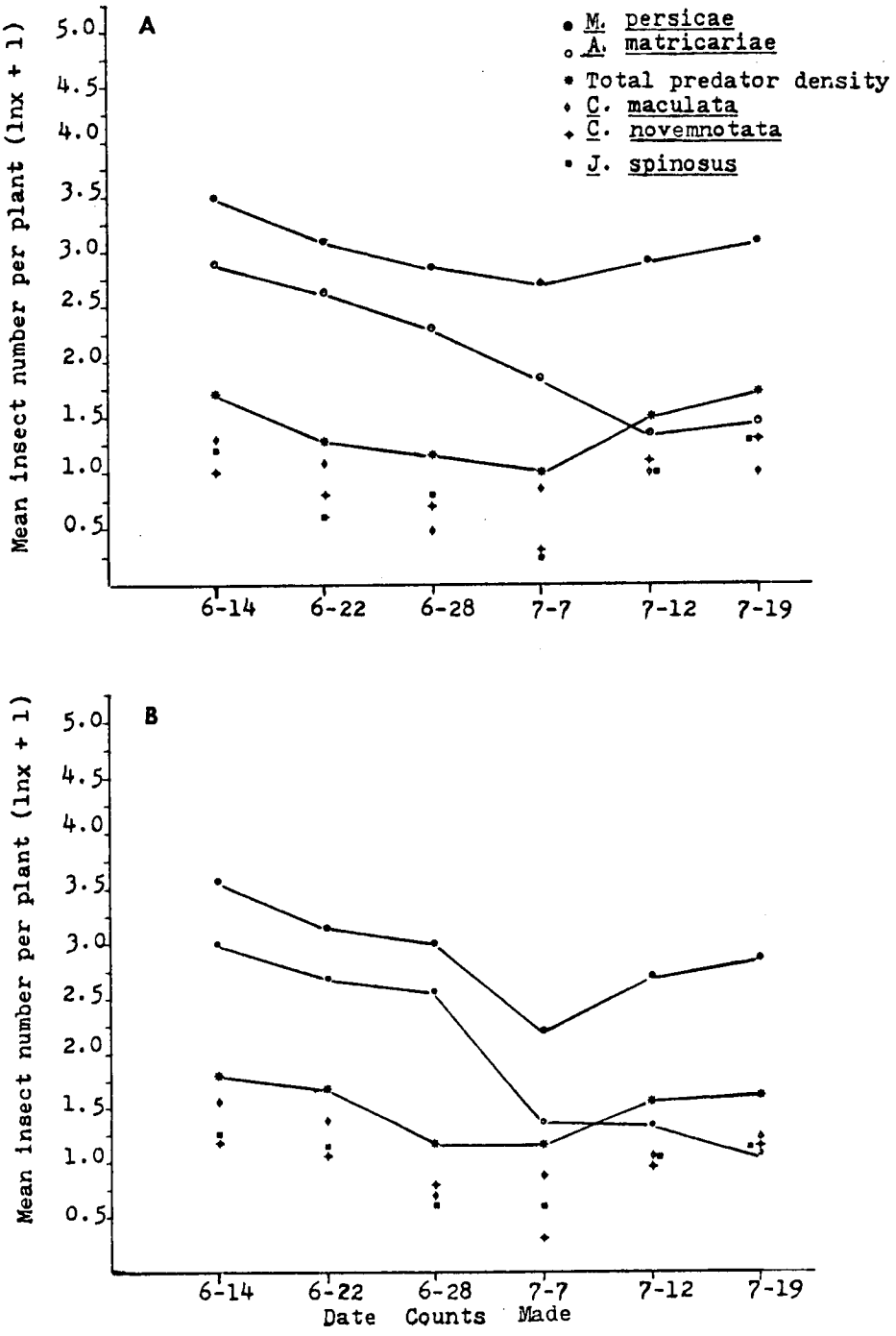


Figure 9. Seasonal abundance of pest and non-target organisms on Ambush (A) and Vydate (B)-treated tomato plants, 1976.

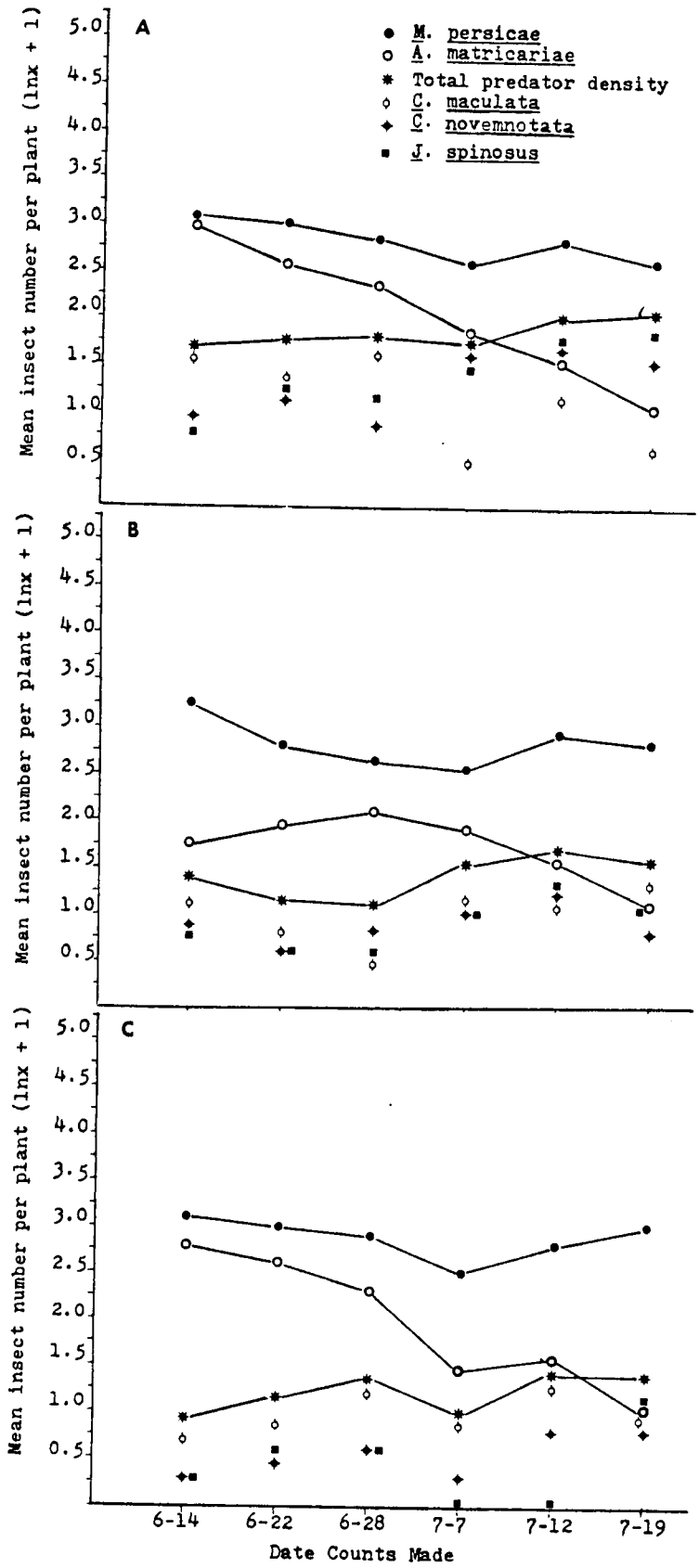


Figure 10. Seasonal abundance of pest and non-target organisms on Dasanit (A), Di-Syston (B), and Dasanit+Di-Syston (C)-treated plants, 1976.

numerical response to aphid numbers. Both predator and parasite numbers were reduced the first week of July on Dasanit + Di-Syston treatments, and provided favorable conditions for a late-season aphid resurgence the end of July. Fewer stilt bugs and C. novemnotata than C. maculata occurred throughout the season on Di-Syston and Dasanit + Di-Syston treatments. C. maculata was the predominant predator on Dasanit-treated plants only through the end of June. Concurrent with an abrupt aphid decline the first week of July, C. maculata numbers declined and did not recover during the remainder of the season. Di-Syston appeared to be more selective against both the green peach aphid and natural enemies through the first week of July. Late season resurgence for aphids and predators, particularly C. maculata, on Di-Syston-treated plants was probably due to ineffective residual activity.

Green peach aphid numbers were reduced below check population levels on plants treated with Mocap (1x), (2x), and Mocap Plus by late June, but surpassed the number of aphids on check in July, 1976 (Figure 11). Lowest parasitized aphid numbers occurred on Mocap Plus compared to the check, Mocap (1x), Mocap (2x)-treated plants, and on Mocap (2x) compared to the check and Mocap (1x)-treated plants. Mocap Plus predator numbers were also greatly

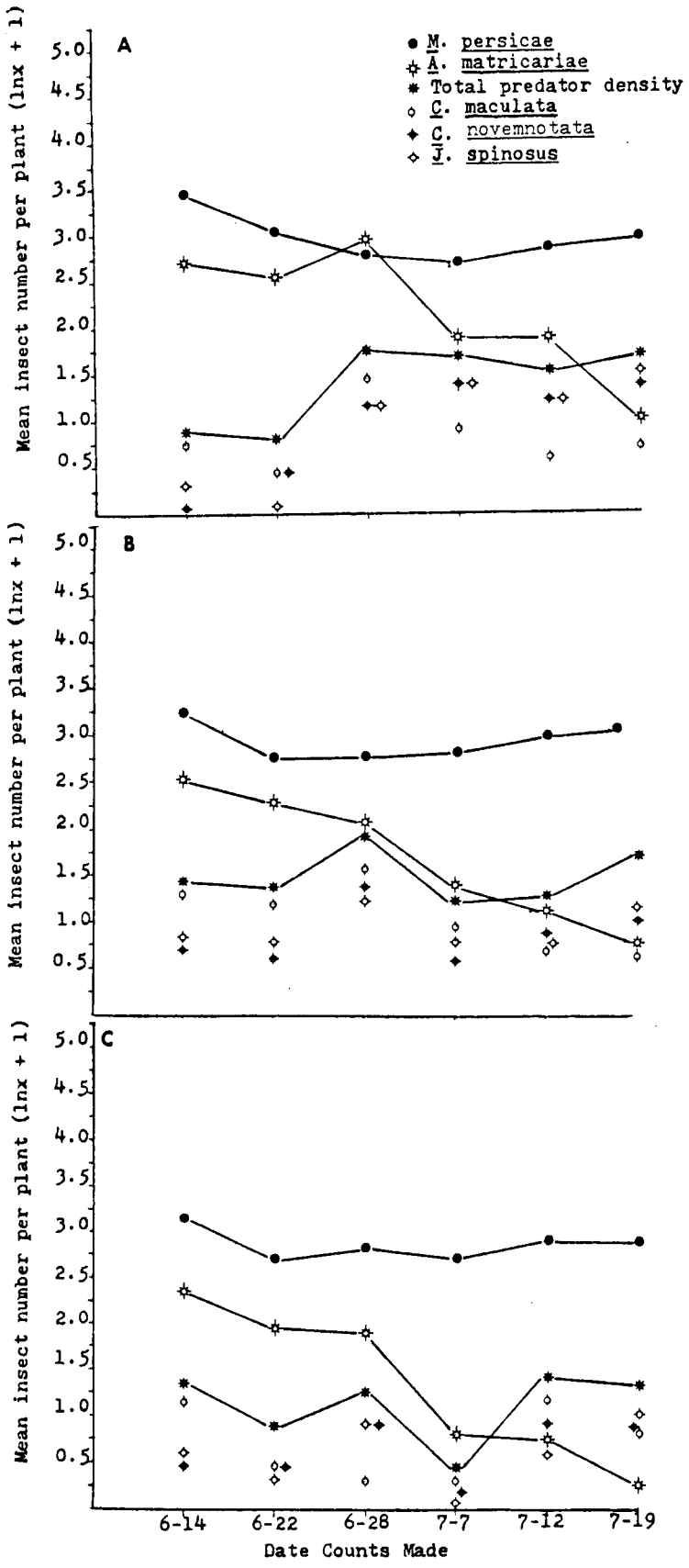


Figure 11. Seasonal abundance of pest and non-target organisms on Mocap (1x) (A), Mocap (2x) (B), and Mocap Plus (C)-treated tomato plants, 1976.

reduced as compared to densities observed for check, Mocap (1x), Mocap (2x) treatments until mid-July, when a moderate resurgence was observed. Less efficient late-season aphid control was obtained for Mocap and Mocap Plus treatments due to lack of establishment of predators and parasites in June and to decreased residual activity in July.

The mean aphid-predator-parasite population levels on untreated plants in 1977 concurred with the Type 3 Model for aphid dynamics (Sluss and Hagen, 1966) (Figure 12). This indicated late season pest numbers to be reduced due to aphidophagous insects, particularly since the first population peak declined gradually (indicative of natural enemy control activity) rather than abruptly (indicative of climatic or disease control). High temperatures unfavorable for aphid reproduction were present in July, and population levels for both species were reduced at that time. Heavy rainfall occurred only the fourth week of the count period and was not accompanied by pest or beneficial population decrease. Following a May to June increase, M. persicae and M. euphorbiae numbers declined. These low population levels held until the first of August. Slight resurgence of both species was probably due to senescent tomato leaflets (Dethier, 1966; Emden, 1964, 1966 b, c; Kennedy, 1958) and reduced

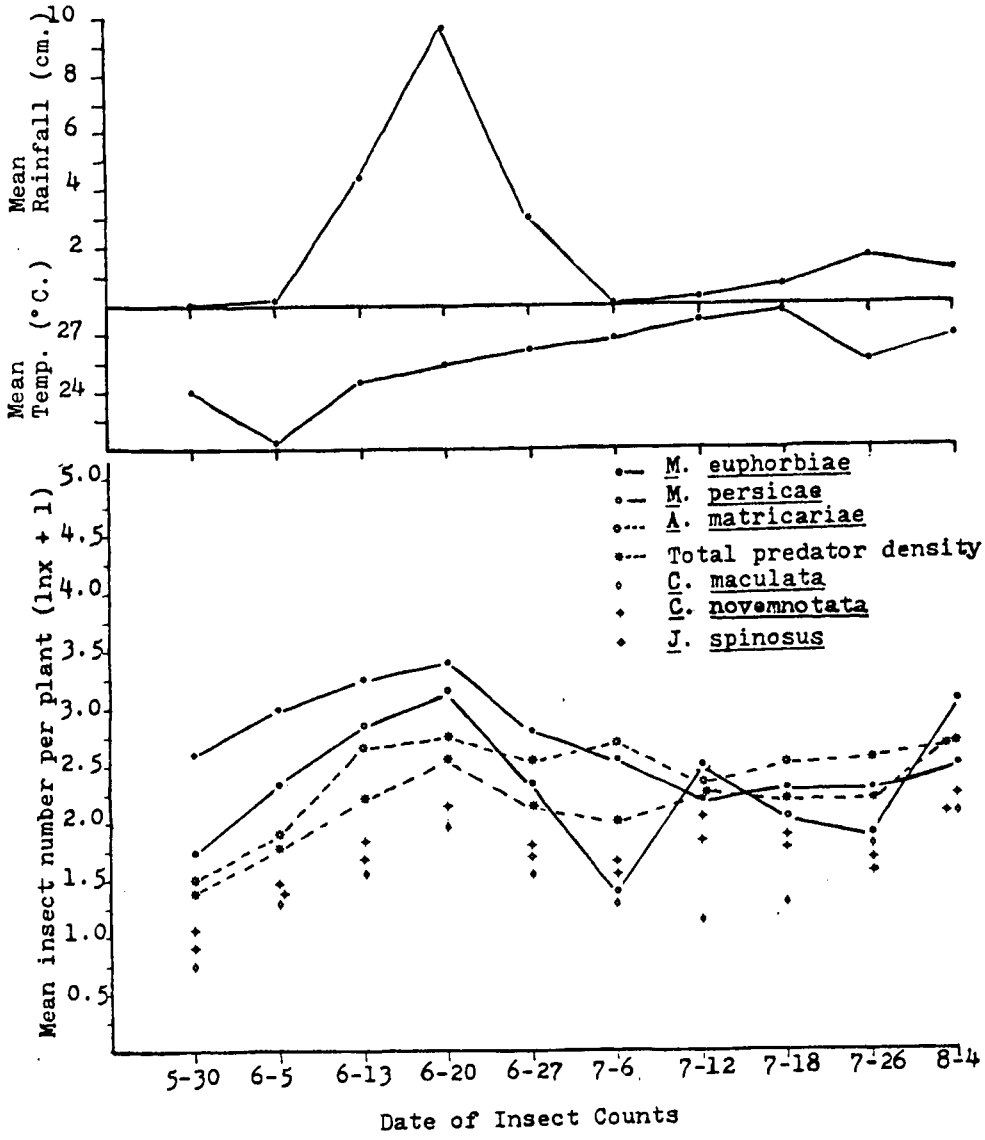


Figure 12. Seasonal abundance of pests and non-target organisms on untreated tomato plants, 1977.

predator numbers in mid-July. Low percent parasitism (Figure 13) occurred June 5, July 12, and August 4 for most treatments and also contributed to the late-season aphid increase.

Compared to check, fewer green peach aphids, potato aphids, and parasitized aphids were observed on Ambush, Furadan, and Vydate in 1977 (Figure 14). Lowest pest-enemy numbers occurred on Ambush-treated plants in late May, but recovered to allow concurrent peak populations with Furadan and Vydate in late June and early August. Adult predators were observed to peak early in the season (June 5), but declined along with host numbers through mid-July. Maximum recovery of predator numbers was observed August 4. Because this predator increase was preceded by an increase in green peach aphids and potato aphids, a direct density-dependent relationship and numerical response to prey density were indicated (Galecka, 1966; Holling, 1961; B. D. Smith, 1966). An increase in aphid numbers on Furadan-treated plants occurred in early July and was probably due to the decreased parasitism rate that occurred in late June. A greater fluctuation in aphid numbers for the season occurred on Furadan treatments, and indicated this treatment to be the least efficient carbamate evaluated for aphid pest control.

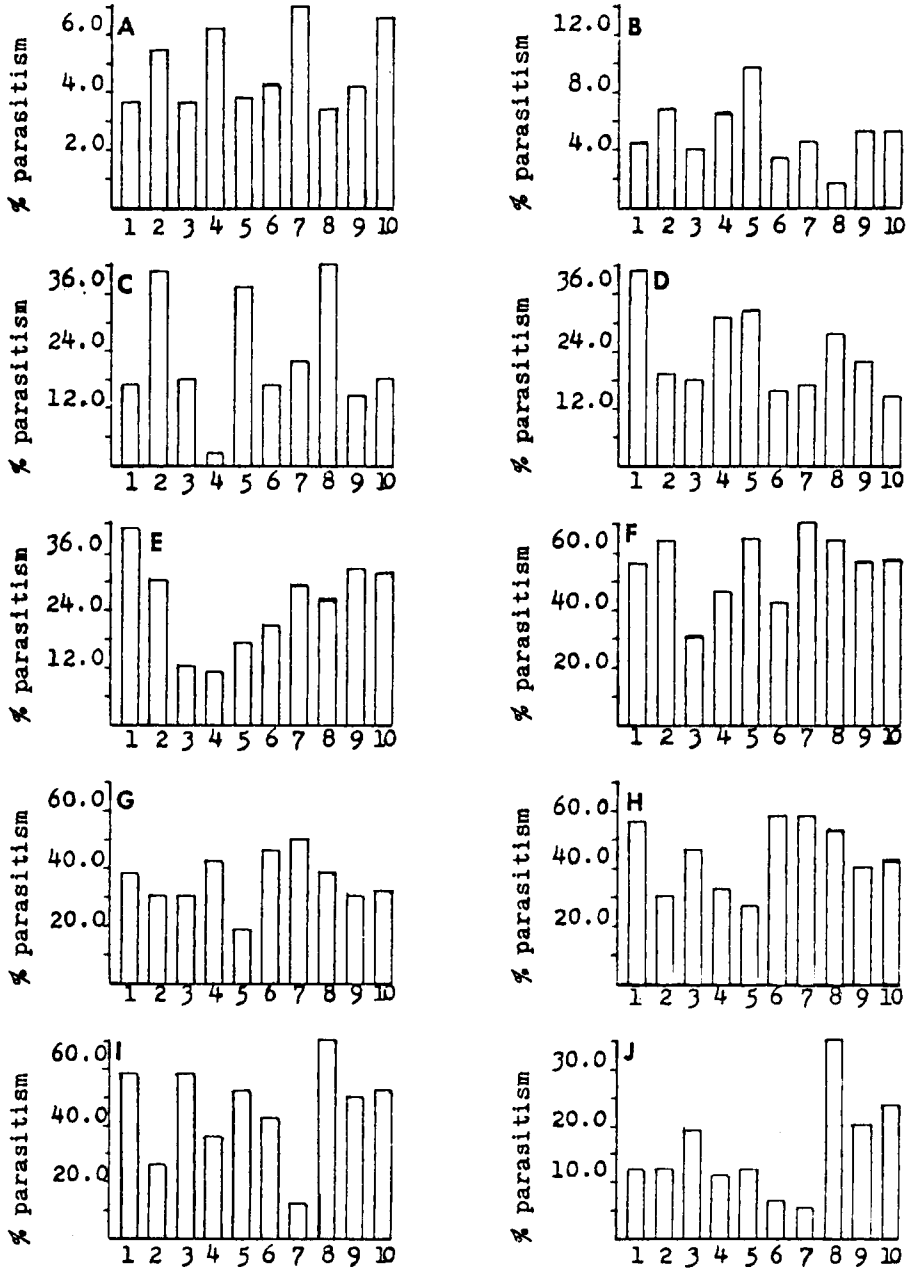


Figure 13. Percent parasitism observed for Ambush (1), Dasanit (2), Di-Syston (3), Dasanit+Di-Syston (4), Furadan (5), Mocap Plus (1x) (6), Mocap Plus (2x) (7), Nemacure (8), Vydate (9), and check (10) treatments during the ten week count period (A-J) May 30 to August 11, 1977.

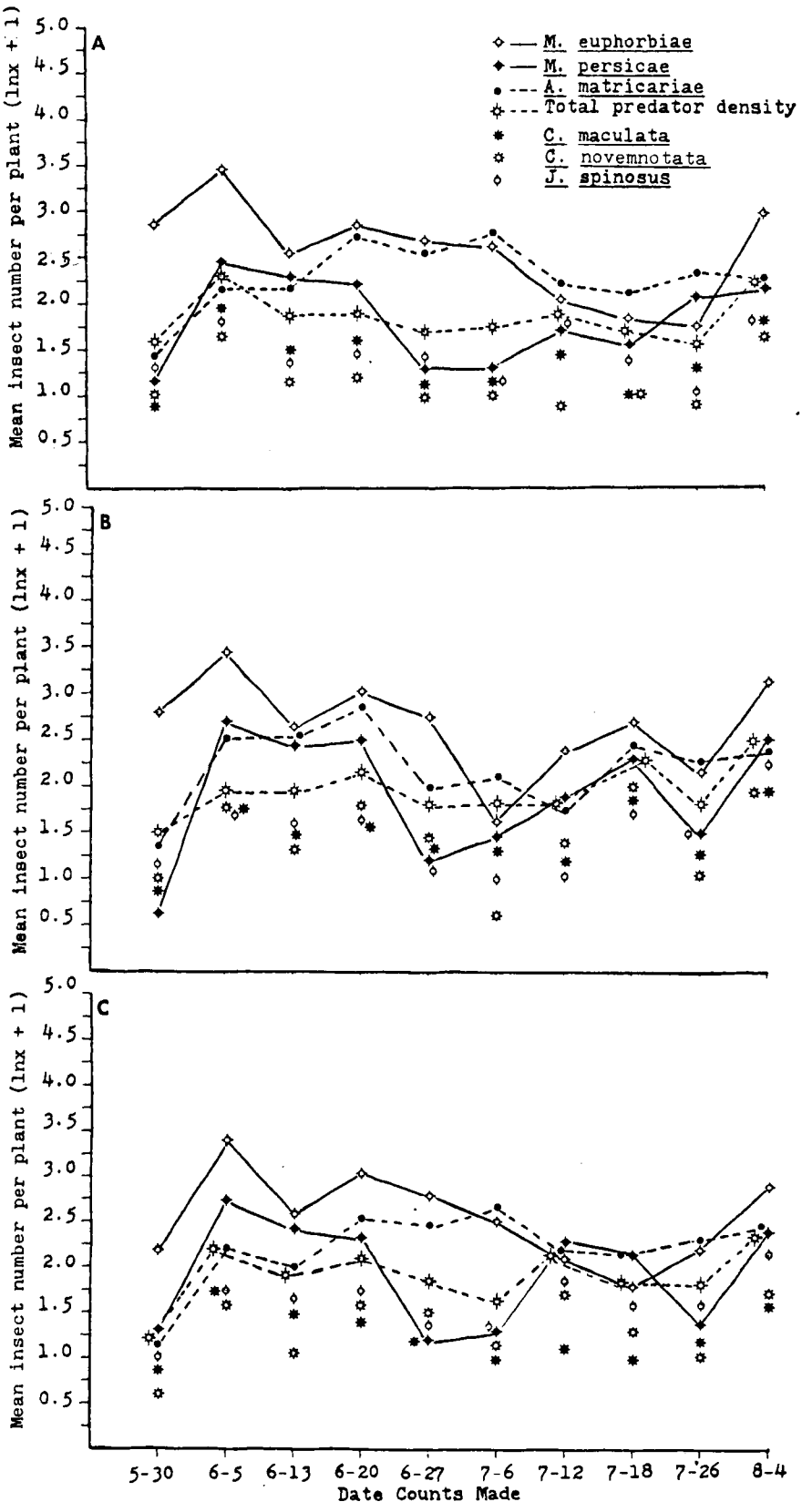


Figure 14. Seasonal abundance of pests and non-target organisms on Ambush (A), Furadan (B), and Vydate (C) treated tomato plants, 1977.

A decline in potato aphid numbers occurred on Di-Syston, Dasanit + Di-Syston, and Di-Syston-treated plants June 13, 1977 (Figure 15). Although green peach aphids were also observed to decrease abruptly June 13 on Dasanit and Dasanit + Di-Syston-treated plants, population levels for Di-Syston were observed at high levels throughout June. Peak green peach aphid numbers observed June 20 and July 26 for Di-Syston treatments were concurrent with highest aphid numbers observed for the check. Periods of peak potato aphid and green peach aphid abundance were also longer in duration for Di-Syston treatments and occurred from June 26 to July 6 and June 13 to June 20, respectively. Adult J. spinosus and C. novemnotata numbers on Dasanit, Dasanit + Di-Syston, and Di-Syston were synchronized with populations of both aphid species. Lowest C. novemnotata density was observed on Dasanit + Di-Syston during the first three weeks of the count period. J. spinosus was the dominant predator throughout the count period, and had a 21-day developmental period as indicated by the population peaks on all treatments June 20, July 12, and August 4, 1977. As for check, C. maculata numbers were most abundant on Dasanit, Di-Syston, and Dasanit + Di-Syston treatments during periods of peak aphid increase. Reduction of M. persicae rather than M. euphorbiae and increased parasitized aphid numbers in late May, mid-June

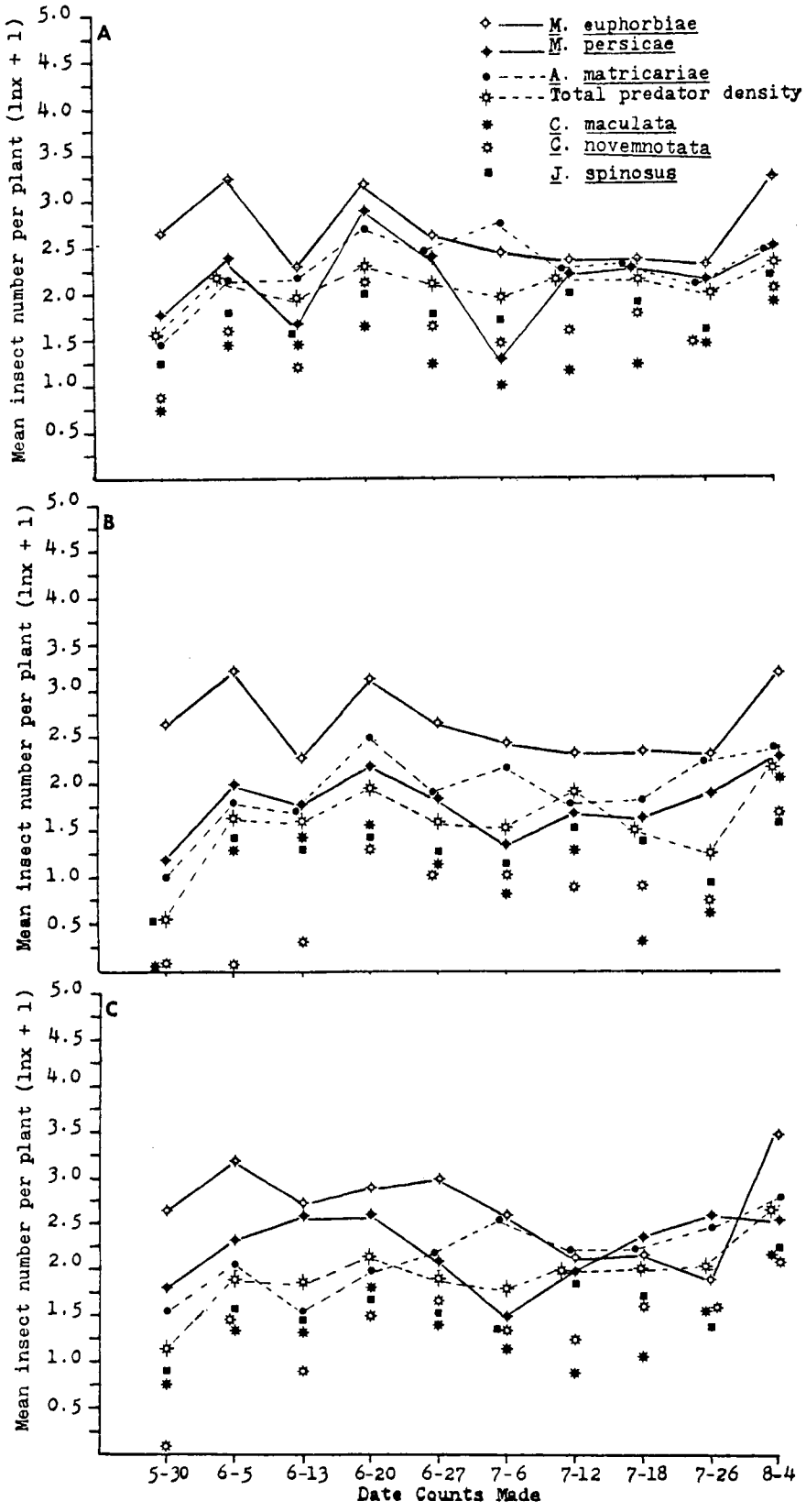


Figure 15. Seasonal abundance of pests and non-target organisms on Dasanit (A), Dasanit + Di-Syston (B), and Di-Syston (C) - treated tomato plants, 1977.

and early July indicated a parasite host preference for the green peach aphid over the potato aphid. Lowest numbers of parasitized aphids occurred on Dasanit + Di-Syston.

Pest numbers fluctuated during June on Mocap Plus (1x), Mocap Plus (2x), and Nemacure-treated plants, with lowest population levels observed June 13 (Figure 16). The rapid resurgence of aphid numbers that followed June 20 indicated that residual activity for these treatments was not effective against aphid increase during the first month of the count period. Aphid numbers through mid-July were reduced, whereas parasite and total predator numbers were greater than levels observed in June. Thus, mid-season aphid control on plants treated with Mocap Plus (1x), Mocap Plus (2x), and Nemacure was probably attributable to natural control agents. Lowest stilt bug and C. novemnotata numbers were observed on Mocap Plus (1x), Mocap Plus (2x) compared to Nemacure-treated plants June 20 to July 6. Highest predator numbers occurred on Nemacure treatments. Highest parasite numbers occurred on Mocap Plus (2x) and Nemacure-treated plants. Both predator and parasite numbers were high on Mocap (1x) and Nemacure compared to check following the first aphid reduction in mid-June, and served to lessen late-season aphid resurgence for these treatments.

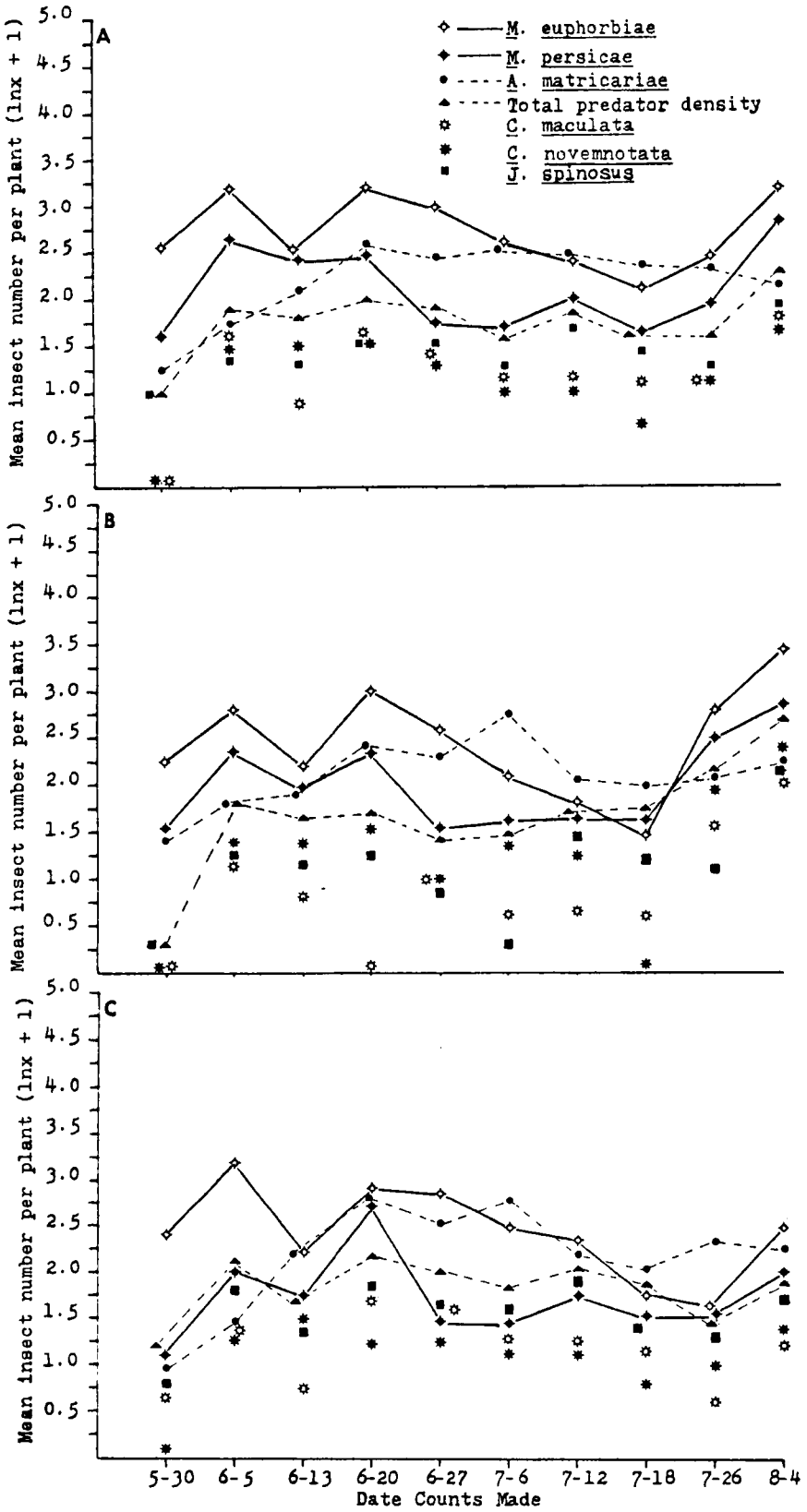


Figure 16. Seasonal abundance of pests and non-target organisms on Mocap Plus (1x) (A), Mocap Plus (2x) (B), and Nemacure-treated tomato plants, 1977.

The Sluss and Hagen Type 3 Model for aphid dynamics was applicable for all treatments evaluated in the 1977 season. Because aphids were never completely eliminated from either untreated or treated plants, coccinellid predators remained in the field plot and responded to changes in aphid density. Fluctuations in aphid numbers on untreated plants were indicative of predator-parasite control activity. Variations observed on treated plants were due to prevention of aphid conditioning, loss of chemical residual activity and, in some instances, a reduction of predator-parasite numbers and aphid control.

II. TREATMENT EFFECT ON PESTS AND NATURAL ENEMIES

Variation of aphid-predator-parasite densities due to treatment effect was analyzed by Duncan's multiple range test for both 1976 and 1977 data. All treatments except Ambush, Mocap 1x, and Vydate were superior to the check on June 14, 1977, for green peach aphid control (Table 1). After one week, only Mocap Plus, Mocap (2x), and Di-Syston differed from check. All treatments were superior to check on June 28, with lowest green peach aphid numbers observed on Di-Syston-treated plants. Ambush and Mocap treatments maintained high aphid numbers July 7 through July 19, with highest levels observed for Mocap (2x)-treated plants during this period. Lowest

Table 1. Efficacy of systemic insecticide-nematicides for control of green peach aphid, Myzus persicae (Sulzer), on tomato, Knoxville, TN 1976.

Treatment	kg. AI/ha	$\bar{X}$ number of aphids per plant at designated date[ab] 6-14	6-22	6-28	7-7	7-12	7-19	Total $\bar{X}$
Ambush	0.9	338.0 e	119.0 c	72.0 bc	53.0 bc	87.0 de	122.2 d	791.2
Dasanit	23.3	119.0 a	115.0 c	71.0 bc	38.0 b	69.0 bcd	43.2 a	455.2
Dasanit + Di-Syston	24.5	247.0 c	107.0 c	82.0 cd	32.0 ab	61.0 bc	95.4 cd	624.4
Di-Syston	7.4	174.0 b	66.0 b	43.0 a	36.0 b	87.0 de	59.4 ab	465.4
Mocap Plus	2.7	151.0 ab	49.0 a	62.0 b	51.0 bc	81.0 cd	80.0 bc	474.0
Mocap 1x	2.7	292.0 d	110.0 c	63.0 b	50.0 bc	75.0 cd	95.6 cd	685.6
Mocap 2x	5.4	176.0 b	57.0 ab	60.0 b	67.0 c	106.0 e	122.4 d	588.4
Vydate	3.1	377.0 f	142.4 d	97.0 d	16.0 a	51.4 ab	70.2 abc	754.0
Control	---	306.0 de	112.0 c	117.0 e	42.0 b	39.0 a	72.8 bc	688.8

[a]Average of five replicates.

[b]Means in a column not followed by same letter are significantly different (P=0.05) (Duncan's Multiple Range Test).

pest density occurred on check and Vydate July 7 to July 12, and on Di-Syston, Vydate, and check treatments on the final count date. Seasonal reduction of the green peach aphid was most efficient by the organophosphates Dasanit, Di-Syston, and Mocap Plus. Least efficient aphid control by Ambush and Vydate treatments, but aphid resurgence was later observed (July 19) for Ambush compared to check and Vydate treatments. All compounds were significantly superior to the check for green peach aphid control in late June. Aphid resurgence occurred early in July and was also greater on all compounds compared to the check except Vydate.

M. euphorbiae was monitored along with M. persicae during the 1977 field test (Table 2). The most significantly high population level for the potato aphid was observed on Ambush, Vydate, Furadan, Mocap (1x) and check treatments in early June, 1977. Reduced numbers for both aphid species occurred on all treatments during the mid-season period of June 13 to June 18. Notable differentiation of treatment effect occurred in mid-July for M. euphorbiae and in early July for M. persicae. M. euphorbiae numbers were significantly reduced on Furadan and Mocap Plus (2x)-treated plants July 6 and July 12, respectively. Potato aphid densities July 18 were significantly reduced compared to check on Ambush, Dasanit + Di-Syston, Di-Syston, and Mocap Plus (2x), and

Table 2. Efficacy of systemic insecticide-nematicides for control of green peach aphid, Myzus persicae (Sulzer), and potato aphid, Macrosiphum euphorbiae (Thomas), on tomato, Knoxville, TN 1977.

Treatment	kg. AI/ha	$\bar{X}$ number of aphids/plant at designated date[ab] 5-30	6-5	6-13	6-20	6-27	7-6	7-12	7-18	7-26	8-4	Total $\bar{X}$
						M. euphorbiae						
Ambush	3.1	71.0 e	297.2 e	35.0 a	69.2 a	46.0 a	43.4 c	11.2 ab	7.4 a	5.2 a	92.6 abc	678.2
Dasanit	3.1	42.6 bc	182.3 bc	19.6 a	152.0 a	46.2 a	30.4 bc	22.2 bc	22.4 a	21.6 ab	178.8 c	718.1
Dasanit + Di-Syston	3.1	25.0 a	153.7 ab	18.8 a	133.8 a	60.4 a	34.0 c	9.2 ab	4.0 a	6.8 a	97.4 abc	543.1
Di-Syston	3.1	47.0 cd	161.6 ab	43.0 a	76.0 a	106.8 b	43.2 c	11.2 ab	15.4 a	9.2 ab	326.2 d	839.6
Furadan	3.1	58.0 d	277.4 de	41.8 a	112.2 a	57.2 a	4.4 a	25.6 c	56.0 b	14.0 ab	141.6 bc	788.2
Mocap Plus 1x	3.1	36.0 abc	165.2 b	33.8 a	172.6 a	108.0 b	43.8 c	26.4 c	12.4 a	27.6 b	144.2 bc	770.0
Mocap Plus 2x	6.2	32.0 ab	133.2 ab	30.0 a	126.6 a	49.0 a	13.2 ab	6.4 a	3.0 a	68.8 c	277.8 d	740.0
Nemacure	4.6	26.0 a	172.2 bc	15.6 a	76.2 a	63.0 a	34.0 c	22.0 bc	5.6 a	3.8 a	30.6 a	449.0
Vydate	3.1	27.0 a	228.4 cd	38.6 a	107.2 a	65.0 a	32.6 c	12.8 abc	6.4 a	16.2 ab	79.0 ab	613.2
Control	---	38.6 abc	103.2 a	168.2 b	234.0 a	60.8 a	36.8 c	16.0 abc	21.0 a	20.4 ab	118.0 abc	817.0
						M. persicae						
Ambush	3.1	1.4 ab	28.0 c	19.2 b	16.2 a	2.2 ab	2.0 a	5.2 a	3.4 a	10.6 ab	13.8 a	102.0
Dasanit	3.1	6.0 c	25.2 bc	5.4 a	77.2 ab	25.0 d	2.0 a	21.6 b	20.4 b	13.2 b	30.4 ab	264.0
Dasanit + Di-Syston	3.1	1.6 ab	11.0 a	6.0 a	15.4 a	6.4 b	2.2 a	5.2 a	4.6 a	6.8 ab	19.8 a	78.4
Di-Syston	3.1	6.6 c	18.2 ab	43.0 c	41.4 a	14.0 c	3.2 a	9.8 a	20.4 b	43.6 d	37.2 ab	200.4
Furadan	3.1	0.4 a	50.4 de	27.2 b	31.2 a	1.4 a	4.0 a	7.4 a	20.4 b	3.2 a	36.2 ab	181.8
Mocap Plus 1x	3.1	4.4 abc	46.6 d	28.8 b	30.6 a	5.8 ab	5.0 a	9.4 a	4.4 a	8.2 ab	59.0 bc	202.2
Mocap Plus 2x	6.2	3.4 abc	22.4 bc	17.0 ab	23.4 a	3.6 ab	4.0 a	4.6 a	4.2 a	32.0 c	73.2 c	187.8
Nemacure	4.6	1.2 a	11.2 a	5.4 a	60.0 a	3.0 ab	3.0 a	5.6 a	4.2 a	3.8 a	10.4 a	107.8
Vydate	3.1	4.0 abc	56.0 e	24.4 b	23.8 a	1.6 a	2.0 a	20.6 b	14.2 b	2.6 a	27.2 ab	176.4
Control	---	5.4 bc	21.8 bc	66.0 d	131.0 b	23.0 d	2.6 a	33.4 c	21.0 b	14.2 b	55.6 bc	374.0

[a]Means are the average of 5 replicates.

[b]Means in columns followed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test).

significantly higher on Furadan-treated plants. Superior green peach aphid control was obtained on Vydate-treated plants from June 27 to July 6; low population levels were also observed at that time on Ambush, Mocap Plus (1x), Mocap Plus (2x), and Nemacure-treated plants. Least efficient green peach aphid control occurred on Dasanit and check treatments June 27 to July 6.

A late-season pest increase occurred July 26 to August 4, 1977. Highest potato aphid populations were observed on Mocap Plus (2x) July 26, and on Di-Syston and Mocap Plus (2x) the following week. Highest green peach aphid numbers were observed on Mocap Plus (2x) for both observation dates. Least potato aphid resurgence occurred on Dasanit + Di-Syston and Nemacure-treated plants July 26, but increased only on Nemacure-treated plants the subsequent week. Least green peach aphid resurgence was observed on Furadan, Nemacure, and Vydate treatments July 26, and on Dasanit + Di-Syston and Nemacure treatments August 4.

Lowest parasitism rates for the 1976 season occurred on Di-Syston, Mocap Plus, and Mocap treatments (Table 3). Treatments on which maximum aphid numbers occurred (Ambush, Vydate, check) also maintained the highest parasitism rates. Wide differentiation of treatment effect on parasite density during June reflected the increased differentiation of aphid density between treatments; both were probably due to the chemical compound's

Table 3. Effect of systemic insecticide-nematicides on parasitism of the green peach aphid by Aphidius matricariae Haliday on tomato, Knoxville, TN 1976.

Treatment	kg. AI/ha	$\bar{X}$ number of parasitized aphids/plant[ab] 6-14	6-22	6-28	7-7	7-12	7-19	Total $\bar{X}$
Ambush	0.9	81.0 d	45.2 c	20.0 bcde	7.0 b	2.2 ab	3.0 b	158.4
Dasanit	23.3	101.6 e	36.8 c	22.4 de	7.4 b	3.4 abc	1.2 a	172.8
Dasanit + Di-Syston	60.0	64.0 c	39.2 c	20.4 bcde	2.8 a	3.6 abc	1.0 a	131.0
Di-Syston	7.4	5.8 a	9.2 a	12.8 abc	7.4 b	3.2 abc	0.8 a	39.2
Mocap Plus	2.7	23.2 b	9.0 a	7.8 a	0.6 a	5.6 cd	1.8 ab	48.0
Mocap 1x	2.7	53.8 b	34.0 bc	15.6 bcd	7.4 b	7.2 d	1.0 a	119.0
Mocap 2x	5.4	33.6 b	18.8 ab	11.8 ab	2.6 a	1.4 a	0.6 a	68.8
Vydate	3.1	126.4 f	50.4 c	21.4 cde	2.4 a	2.4 ab	1.2 a	204.2
Control	---	192.4 g	42.8 c	25.6 e	1.4 a	4.2 bc	0.6 a	267.0

[a]Average of five replicates.

[b]Means in a column not followed by same letter are significantly different (P=0.05) (Duncan's Multiple Range Test).

early season residual activity. Parasitism rates were significantly lower on all treatments compared with control on June 14. The number of parasitized aphids observed on July 7 for Ambush, Dasanit, Di-Syston, and Mocap (1x) treatments were significantly greater than levels observed for check. The number of parasitized aphids decreased during July. Highest population levels were observed on Ambush and Mocap Plus compared with all other treatments on July 19, 1976.

Although seasonal population numbers of parasitized aphids observed in 1977 were higher, the decreased fluctuation was probably due to the reduction of treatment rates utilized (Table 4). Seasonal parasitism rates were lowest on Dasanit + Di-Syston and Mocap Plus (2x) treatments in 1977. Higher numbers were observed on Furadan, Di-Syston, and Ambush treatments. In 1976, peak numbers of parasitized aphids were directly associated with seasonal population peaks for M. persicae which occurred in late June, mid-July, and early August. Parasitism rates in 1977 were lower on all chemical treatments than check July 6 to August 11, following a slow increase on untreated plants throughout the month of June. The number of parasitized aphids observed on Ambush June 27 was comparable to check population levels. Numbers comparable to check the following week were observed on Ambush, Dasanit, Mocap Plus (2x), and Nemacure. The number of parasitized aphids

Table 4. Effect of systemic insecticide-nematicides on parasitism Aphidius matricariae (Haliday) of aphid on tomato, Knoxville, TN 1977.

Treatment	kg. AI/ha	$\bar{X}$ number of parasitized aphids/plant at designated date[ab] 5-30	6-5	6-13	6-20	6-27	7-6	7-12	7-18	7-26	8-4	Total $\bar{X}$
Ambush	3.1	2.8 a	14.8 b	15.6 a	58.4 a	33.6 d	56.8 de	15.4 ab	13.8 ab	21.2 ab	16.6 ab	249.0
Dasanit	3.1	2.8 a	14.8 b	17.0 a	53.4 a	29.2 cd	57.4 de	18.6 abc	18.2 abc	12.8 a	28.0 b	252.2
Dasanit + Di-Syston	3.1	1.0 a	6.6 ab	5.4 a	33.6 a	8.8 a	16.0 a	6.4 a	7.2 a	19.4 ab	26.4 ab	130.8
Di-Syston	3.1	3.6 a	11.6 ab	3.2 a	50.6 a	14.2 ab	40.6 bc	15.4 ab	16.8 ab	31.6 cd	46.6 c	234.2
Furadan	3.1	2.2 a	35.0 c	39.2 b	67.0 a	9.2 a	12.8 a	6.6 a	28.2 cd	18.2 ab	29.4 b	247.8
Mocap Plus 1x	3.1	1.8 a	5.8 ab	12.6 a	34.4 a	29.4 cd	35.0 b	29.8 c	22.0 bcd	26.2 bc	13.2 a	210.2
Mocap Plus 2x	6.2	2.8 a	6.2 ab	12.6 a	27.6 a	21.4 bc	55.2 de	11.2 ab	10.0 a	13.6 a	18.4 ab	179.0
Nemacure	4.6	1.0 a	3.0 a	15.8 a	51.2 a	22.0 bc	64.4 e	16.8 ab	10.8 a	22.6 abc	21.6 ab	229.2
Vydate	3.1	1.4 a	16.0 bc	10.2 a	36.8 a	31.0 cd	44.2 bcd	14.0 ab	14.4 ab	19.0 ab	27.0 ab	214.0
Control	---	3.2 a	7.4 ab	50.8 b	59.6 a	37.2 d	52.0 cde	23.2 bc	30.2 d	36.8 d	51.8 c	352.2

[a]Means are the average of 5 replicates.

[b]Numbers in columns followed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test).

per plant began to decline in mid-July, and did not recover (as did host density) in late July or August compared with check.

Peak numbers of spotted ladybugs were observed on treatments and check June 22 and July 12, 1976. C. novemnotata and stilt bug peak densities were observed July 19, 1977, after a gradual increase in number during the previous five weeks (Table 5). All treatments except Vydate and Dasanit reduced C. maculata numbers the first count date, June 14, compared to the check. Lowest C. maculata density was comparable to check population levels the following week for Dasanit treatments and was more numerous for all treatments except Ambush, Di-Syston, and Mocap Plus compared with the check on June 28. Only Di-Syston treatments differed significantly from check on July 7. No significant difference between treatments occurred for spotted ladybug numbers the following week. Population levels for all chemical treatments on July 19 were lower than check.

Initial infestations of C. novemnotata were most abundant on check with high numbers observed for Ambush and Dasanit-treated plants; lowest numbers occurred on Mocap-treated plants. C. novemnotata numbers on Dasanit and Vydate treatments were equal to check the following week (June 22). Fluctuation of parasitized aphid density occurred the remainder of the count period, with highest

Table 5. Effect of systemic insecticide-nematicides on abundance of adult predators of Ceratomegilla maculata, Coccinella novemnotata, and Jalysus spinosus on tomato, Knoxville, TN 1976.

Predators	Survey Date	Ambush 0.9 kg.	Dasanit 23.3 kg.	Dasanit + DiSyston 24.5 kg.	DiSyston 7.4 kg.	Mocap Plus 2.7 kg.	Mocap 2.7 kg.	Mocap 5.4 kg.	Vydate 3.1 kg.	Control ---
		$\bar{X}$ number of adult predators/plant for designated treatment at indicated date[ab]								
	June 14									
C. maculata		2.1 bc	3.6 d	0.5 a	1.2 ab	1.4 abc	0.6 a	1.9 bc	3.7 d	2.4 c
C. novemnotata		1.1 de	0.9 cd	0.2 ab	0.7 bcd	0.3 ab	0.0 a	0.5 abc	1.5 ef	1.7 f
J. spinosus		1.6 c	0.6 abc	0.2 a	0.6 abc	0.4 ab	0.2 ab	0.6 abc	1.6 c	1.4 bc
	June 22									
C. maculata		1.1 bc	2.3 d	0.7 ab	0.6 ab	0.3 a	0.3 a	1.6 c	2.4 d	4.3 e
C. novemnotata		0.6 a	1.4 b	0.3 a	0.4 a	0.3 a	0.3 a	0.4 a	1.2 b	1.5 b
J. spinosus		0.4 abc	1.8 d	0.4 abc	0.4 abc	0.2 ab	0.0 a	0.6 abcd	1.4 bcd	1.6 cd
	June 28									
C. maculata		0.3 a	3.7 de	1.5 c	0.3 a	0.2 a	2.8 d	4.0 e	0.5 ab	0.3 a
C. novemnotata		0.5 a	0.8 ab	0.4 a	0.6 a	0.8 ab	1.4 bc	2.0 c	0.6 a	1.8 c
J. spinosus		0.6 a	1.4 ab	0.4 a	0.4 a	0.8 ab	1.4 ab	1.8 ab	0.4 a	2.4 b
	July 7									
C. maculata		0.7 a	0.3 a	0.9 ab	1.4 b	0.2 a	0.8 ab	0.9 ab	0.8 ab	0.6 a
C. novemnotata		0.2 a	3.5 c	0.2 a	1.0 a	0.1 a	2.4 b	0.4 a	0.2 a	2.2 b
J. spinosus		0.2 a	3.0 d	0.0 a	1.0 abc	0.0 a	2.2 cd	0.6 ab	0.4 a	2.0 bcd
	July 12									
C. maculata		1.0 a	1.4 a	1.8 a	1.2 a	1.5 a	0.4 a	0.5 a	1.2 a	3.5 b
C. novemnotata		1.2 ab	4.2 d	0.6 ab	1.5 ab	0.6 a	1.6 b	0.8 ab	1.2 ab	3.2 c
J. spinosus		1.0 a	4.6 b	0.0 a	1.6 a	0.4 a	1.6 a	0.6 a	1.2 a	3.4 b
	July 19									
C. maculata		1.0 bcd	0.4 a	1.0 bc	1.8 e	0.6 ab	0.5 ab	0.5 ab	1.6 de	1.5 cde
C. novemnotata		2.0 ab	3.6 b	0.6 a	0.6 a	0.8 a	2.4 ab	1.2 a	1.4 a	6.1 c
J. spinosus		2.0 a	6.8 b	1.0 a	1.2 a	1.0 a	2.6 a	1.4 a	1.4 a	5.6 b
					$\bar{X}$ seasons total/plant					
C. maculata		6.2	11.6	6.4	6.4	4.2	5.4	9.3	10.2	12.6
C. novemnotata		5.6	14.5	2.4	4.8	2.9	8.2	5.4	6.0	16.5
J. spinosus		5.8	18.2	2.0	5.2	2.8	8.0	5.6	6.4	16.4

[a]Means are the average of 5 replicates.

[b]Mean separation in horizontal rows by Duncan's Multiple Range Test (P=0.05).

population levels most frequently observed on Dasanit and Mocap-treated plants. Treatment effect for stilt bugs followed a similar trend. Initial populations were highest on Ambush and Vydate treatments. Number of J. spinosus slightly exceed those on check on June 22 for Dasanit treatments. Highest populations most frequently occurred on Dasanit and Mocap treatments during the remainder of the 1976 season; however, the numbers were not significantly superior to check. The reduced predator numbers on all chemical treatments during 1976 was probably due to a detrimental toxicity affect and in response to reduced host density.

As in 1976, highest stilt bug densities in 1977 occurred on Dasanit and check treatments (Table 6). Although fewer stilt bug nymphs were observed than adults during the 1977 season, differentiation between treatments were proportionately the same as observed in the 1976 field test. High seasonal totals of adults and nymphs occurred on Furadan, Vydate, and Di-Syston-treated plants, and lowest seasonal totals occurred on Dasanit + Di-Syston and Mocap Plus (2x)-treated plants. Adults were most numerous on all treatments June 5, June 20, July 12, and August 4, whereas nymph population peaks occurred June 20, July 12, and August 4. Early-season treatment effect (June 5) on adult stilt bugs was most detrimental on Mocap Plus-treated plants.

Table 6. Effect of systemic insecticide-nematicides on Jalysus spinosus Say numbers on tomato, Knoxville, TN 1977.

Treatment	kg. AI/ha	$\bar{X}$ stiltbug number/plant at designated date[ab] 5-30	6-5	6-13	6-20	6-27	7-6	7-12	7-18	7-26	8-4	$\bar{X}$ Total for Season
						Adults						
Ambush	3.1	1.2 a	4.6 c	2.0 a	2.4 a	1.2 ab	1.8 ab	4.4 abc	0.4 ab	0.6 ab	3.0 a	21.6
Dasanit	3.1	1.2 a	5.2 c	3.6 ab	7.4 bc	4.6 bc	3.4 b	5.6 c	3.6 d	2.4 b	10.4 c	47.4
Dasanit + Di-Syston	3.1	0.4 a	2.0 abc	1.4 a	2.2 a	1.4 ab	0.8 a	3.4 abc	0.2 a	0.4 a	2.4 a	14.6
Di-Syston	3.1	0.8 a	3.0 abc	2.4 ab	3.2 a	2.6 abc	2.0 ab	4.6 abc	1.2 abc	1.6 ab	9.0 bc	30.4
Furadan	3.1	1.0 a	5.0 c	3.2 ab	3.8 a	1.2 ab	0.4 a	1.6 a	2.2 bcd	1.6 ab	8.8 bc	28.8
Mocap Plus 1x	3.1	0.6 a	1.2 ab	1.0 a	2.0 a	2.2 ab	1.4 ab	3.0 abc	0.4 ab	1.0 ab	5.0 ab	17.8
Mocap Plus 2x	6.2	0.0 a	1.0 a	1.0 a	1.6 a	0.6 a	0.2 a	1.8 ab	0.2 a	0.6 ab	7.0 abc	14.0
Nemacure	4.6	0.4 a	4.4 bc	1.6 a	4.0 a	3.0 abc	1.8 ab	4.8 abc	2.0 abcd	0.8 ab	2.8 a	25.6
Vydate	3.1	0.6 a	4.0 abc	3.4 ab	4.6 ab	2.0 ab	1.2 a	4.0 abc	1.4 abc	1.8 ab	7.0 abc	30.0
Control	---	0.8 a	2.2 abc	5.2 b	9.4 c	5.8 c	2.2 ab	5.2 bc	2.8 cd	4.2 c	9.6 bc	47.4
						Nymphs						
Ambush	3.1	0.4 a	1.8 a	0.8 a	1.8 a	1.2 a	0.2 ab	1.6 ab	2.0 a	0.6 a	2.8 ab	13.2
Dasanit	3.1	0.6 a	1.6 a	1.2 ab	3.6 b	0.8 a	1.6 cd	4.8 ab	4.4 a	1.8 a	9.0 d	29.4
Dasanit + Di-Syston	3.1	0.0 a	0.6 a	0.6 a	0.6 a	0.4 a	0.6 abcd	1.4 a	3.0 a	0.4 a	2.8 ab	10.4
Di-Syston	3.1	0.0 a	1.0 a	0.8 a	1.6 a	1.0 a	0.4 abc	3.0 ab	3.8 a	1.2 a	7.8 cd	20.6
Furadan	3.1	0.4 a	1.6 a	1.2 ab	0.8 a	0.0 a	0.6 abcd	2.4 ab	3.2 a	1.4 a	8.8 d	20.4
Mocap Plus 1x	3.1	0.4 a	1.2 a	1.2 ab	1.4 a	0.8 a	0.6 abcd	2.2 ab	2.2 a	0.8 a	3.8 abc	14.6
Mocap Plus 2x	6.2	0.2 a	1.4 a	0.4 a	0.2 a	0.2 a	0.0 a	1.0 a	1.4 a	0.6 a	5.4 abcd	10.8
Nemacure	4.6	0.4 a	1.8 a	0.6 a	1.6 a	1.2 a	1.8 d	3.8 ab	3.0 a	1.6 a	1.6 a	17.4
Vydate	3.1	0.6 a	1.6 a	1.4 ab	1.2 a	0.8 a	1.0 abcd	3.6 ab	2.6 a	2.2 a	6.4 bcd	21.4
Control	---	0.4 a	0.8 a	2.0 b	1.2 a	0.2 a	1.4 bcd	5.8 b	3.8 a	1.8 a	8.2 d	25.6

[a]Means are the average of 5 replicates.

[b]Means in columns followed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test).

C. maculata and C. novemnotata varied in abundance according to treatment in 1977 (Table 7). Seasonal totals for C. maculata were greater than C. novemnotata on Ambush, Dasanit + Di-Syston, Di-Syston, and Mocap Plus (2x)-treated plants. Conversely, greater seasonal totals for C. novemnotata than the spotted ladybug occurred on Dasanit and check treatments. Seasonal totals comparable to check were only observed for C. maculata on Mocap Plus-treated plants. Population peaks for both coccinellid species occurred June 20 and August 4, 1977.

Initial C. maculata and C. novemnotata densities were higher on Ambush and Furadan treatments compared to check in 1977. Numbers the following week were higher on Vydate treatments, in addition to Ambush and Furadan, compared to check. C. maculata population levels for all treatments were significantly less than check June 13 and June 20, whereas C. novemnotata density was comparable to check on June 20. Both coccinellids were significantly higher on Furadan-treated plants than all other treatments and check July 6 and July 18. C. maculata density on Mocap Plus (2x) treatments was highest the last two count dates of the 1977 season (July 26, August 4).

Furadan and Ambush most effectively controlled the potato flea beetle (Table 8). Seasonal population numbers for Nemacure treatments were comparable with check plants. High population levels were also observed on

Table 7. Effect of systemic insecticides-nematicides on population density of adult Ceratomegilla maculata and Coccinella novemnotata on tomato, Knoxville, TN 1977.

Predator	$\bar{X}$ number of ladybugs for designated treatment and rate kg. AI/ha[ab]									
	Ambush 3.1	Dasanit 3.1	Dasanit + Di-Syston 3.1	Di-Syston 3.1	Furadan 3.1	Mocap + 3.1	Mocap + 6.2	Nemacure 4.6	Vydate 3.1	Control ---
					May 30					
C. maculata	0.8 b	0.6 ab	0.0 a	0.6 ab	0.8 b	0.0 a	0.0 a	0.0 a	0.0 a	0.6 ab
C. novemnotata	1.2 b	0.8 ab	0.0 a	0.0 a	1.0 b	0.0 a	0.0 a	0.6 ab	0.4 ab	0.8 ab
					June 5					
C. maculata	7.6 c	3.0 ab	2.0 a	2.6 ab	5.2 bc	2.8 ab	2.6 ab	3.2 ab	5.6 bc	2.0 a
C. novemnotata	6.0 de	4.2 bcd	0.0 a	3.0 bc	8.2 e	3.0 bc	1.4 ab	4.0 bcd	4.8 cd	2.6 abc
					June 13					
C. maculata	3.2 a	3.0 a	2.4 a	2.8 a	3.2 a	3.2 a	2.6 a	2.4 a	3.2 a	4.2 b
C. novemnotata	1.4 a	1.6 a	0.2 a	0.8 a	2.0 a	0.8 a	2.6 a	0.6 a	1.2 a	5.4 b
					June 20					
C. maculata	4.0 a	4.4 a	3.8 a	6.2 ab	3.8 a	3.4 a	3.6 a	3.0 a	2.6 a	9.6 b
C. novemnotata	1.6 ab	14.4 e	2.4 abc	3.2 bc	6.6 d	4.0 bcd	0.0 a	5.4 cd	4.2 bcd	15.2 e
					June 27					
C. maculata	1.6 ab	1.8 ab	1.2 ab	3.0 ab	2.0 ab	2.2 ab	1.0 a	2.2 ab	1.6 ab	3.4 b
C. novemnotata	1.2 ab	5.4 d	1.2 ab	4.4 cd	3.0 abcd	2.6 abc	1.0 a	3.8 bcd	3.0 abcd	5.6 d
					July 6					
C. maculata	1.8 ab	1.0 a	0.6 a	1.4 ab	3.4 b	1.0 a	2.4 ab	1.4 ab	0.8 a	2.2 ab
C. novemnotata	1.4 ab	2.8 bc	1.2 ab	2.4 b	0.4 a	1.4 ab	0.4 a	2.0 ab	1.8 ab	4.4 c
					July 12					
C. maculata	2.8 a	1.4 a	2.2 a	0.8 a	1.6 a	1.0 a	1.8 a	1.4 a	1.2 a	1.4 a
C. novemnotata	0.8 a	4.4 bc	0.8 a	1.8 ab	2.6 ab	1.4 a	0.4 a	1.8 ab	5.4 c	7.0 c
					July 18					
C. maculata	1.0 ab	1.6 ab	0.2 ab	1.2 ab	7.0 c	0.4 ab	0.0 a	0.6 ab	0.8 ab	2.2 b
C. novemnotata	1.0 a	6.2 cd	0.8 a	4.4 bc	9.6 e	1.2 a	0.4 a	1.4 a	2.2 ab	8.4 de
					July 26					
C. maculata	2.2 ab	3.0 ab	0.4 a	3.6 b	1.8 ab	1.2 ab	10.0 c	1.0 ab	1.6 ab	8.0 c
C. novemnotata	0.8 ab	3.0 bcde	0.6 ab	3.6 de	1.2 abc	1.4 abcd	3.4 cde	0.4 a	1.2 abc	4.4 e
					August 4					
C. maculata	6.0 ab	8.4 b	13.0 c	14.6 c	9.0 b	5.2 ab	23.4 d	2.6 a	4.0 a	13.4 c
C. novemnotata	4.0 ab	12.4 e	4.4 ab	12.2 e	9.0 cde	6.4 bcd	10.0 de	1.8 a	4.8 abc	13.2 e
					Total $\bar{X}$ number/plant for the season					
C. maculata	31.0	28.2	25.8	36.8	37.8	20.4	47.4	17.8	21.4	47.0
C. novemnotata	19.4	55.2	11.6	35.8	43.6	22.2	17.6	21.8	29.0	67.0

[a]Means are the average of 5 replicates.

[b]Mean separation in rows (horizontal by Duncan's Multiple Range Test (P=0.05).

Table 8. Efficacy of systemic insecticide-nematicides for control of potato flea beetles, Epitrix cucumeris (Harris), on tomato, Knoxville, TN 1977.

Treatment	kg. AI/ha	X number of adult flea beetles/plant at designated date[ab]										Total $\bar{X}$
		5/30	6/5	6/13	6/20	6/27	7/6	7/12	7/18	7/26	8/4	
Ambush	3.1	2.0 ab	1.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	2.0 ab	2.0 a	25.2 a	32.2
Dasanit	3.1	1.0 a	2.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	25.0 d	2.0 a	30.0 a	60.0
Dasanit + Di-Syston	3.1	4.0 b	3.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	3.0 ab	5.0 a	30.0 a	45.0
Di-Syston	3.1	4.0 b	3.0 a	0.0 a	0.0 a	0.0 a	0.0 a	2.0 ab	8.0 abc	2.0 a	24.8 a	43.8
Furadan	3.1	1.0 a	1.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	1.0 a	1.0 a	23.2 a	27.2
Mocap Plus	3.1	3.0 ab	2.0 a	0.0 a	0.0 a	0.0 a	0.0 a	5.0 bc	23.0 d	3.0 a	25.2 a	61.2
Mocap Plus	6.2	1.0 a	1.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	4.0 ab	12.0 a	30.0 a	48.0
Nemacure	4.2	1.0 a	1.0 a	0.0 a	0.0 a	0.0 a	0.0 a	2.0 ab	10.0 bc	26.0 b	30.0 a	70.0
Vydate	3.1	3.0 ab	2.0 a	0.0 a	0.0 a	0.0 a	0.0 a	4.0 bc	15.0 c	7.0 a	28.4 a	59.4
Control	---	8.0 c	12.0 b	0.0 a	0.0 a	0.0 a	0.0 a	7.0 c	10.0 bc	12.0 a	25.4 a	74.4

[a]Means are the average of 5 replicates.

[b]Means in a column not followed by the same letter are significantly different (P=0.05)(Duncan's Multiple Range Test).

Dasanit, Mocap Plus (1x) and Vydate treatments. Potato flea beetle numbers were significantly reduced for all chemical treatments compared with check May 30 and June 5, 1977. No potato flea beetles were observed on check or treated plants June 13 to July 12. Highest densities occurred on Dasanit and Mocap Plus (1x)-treated plants July 18, and Nemacure treatments July 26. Final and most abundant population levels (August 4) were not significantly different.

Mocap Plus (2x) most effectively controlled the tobacco flea beetle during the 1977 season (Table 9). Low numbers were also observed for Ambush and Furadan treatments. Seasonal totals observed for Dasanit, Vydate, and Mocap Plus (1x) treatments exceeded total check population levels. Like the potato flea beetle, few if any E. hirtipennis were present June 12 to June 20. All treatments were significantly different from check June 5 except Mocap Plus (1x), Dasanit, and Nemacure. Only Nemacure and Vydate treatments differed significantly from control the last two weeks of June. Population numbers increased July 6 to July 12. Highest increase in tobacco flea beetles occurred in early August for all treatments (except Mocap Plus (1x)) and check.

Very low population levels of the pale striped flea beetle were present on tomato during the 1977 season (Table 10). No flea beetles were observed on Ambush,

Table 9. Efficacy of systemic insecticide-nematicides for control of tobacco flea beetles, Epitrix hirtipennis (Melsheimer), on tomato, Knoxville, TN 1977.

Treatment	kg. AI/ha	$\bar{X}$ number of adult flea beetles/plant at designated date[ab]										Total $\bar{X}$
		5/30	6/5	6/12	6/20	6/27	7/6	7/12	7/18	7/26	8/4	
Ambush	3.1	0.0 a	4.0 ab	0.0 a	21.0 c	0.0 a	0.2 a	12.0 bc	10.0 a	7.0 a	82.0 b	136.2
Dasanit	3.1	0.0 a	12.0 cd	0.0 a	0.0 a	0.0 a	20.0 b	10.0 b	32.0 b	78.0 d	100.0 b	234.0
Dasanit + Di-Syston	3.1	0.0 a	4.0 ab	0.0 a	0.0 a	1.0 a	1.8 a	21.0 cd	7.0 a	60.0 c	100.0 b	194.8
Di-Syston	3.1	0.0 a	6.0 abc	0.0 a	5.0 b	0.0 a	0.0 a	16.0 bcd	34.0 b	14.0 a	102.0 b	177.0
Furadan	3.1	0.0 a	5.0 ab	0.0 a	0.0 a	0.0 a	1.0 a	0.0 a	48.0 cd	8.0 a	80.0 b	142.0
Mocap Plus 1x	3.1	17.0 c	13.0 d	0.0 a	0.0 a	1.2 a	3.2 a	14.0 bc	56.0 d	76.0 d	42.0 a	222.4
Mocap Plus 2x	6.2	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	12.0 bc	8.0 a	8.0 a	100.0 b	128.0
Nemacure	4.2	0.0 a	9.0 bcd	0.0 a	0.0 a	8.0 b	1.6 a	34.0 e	8.0 a	25.0 b	100.0 b	185.6
Vydate	3.1	0.0 a	5.0 ab	0.0 a	4.0 b	13.0 c	0.0 a	13.0 bc	40.0 bc	60.0 c	98.4 b	233.4
Control	---	4.0 b	16.0 d	0.0 a	0.0 a	5.0 b	0.0 a	24.0 d	5.0 a	60.0 c	85.6 b	199.6

[a]Means are the average of 5 replicates

[b]Means in a column not followed by the same letter are significantly different (P=0.05) (Duncan's Multiple Range Test).

Table 10. Efficacy of systemic insecticide-nematicides for control of pale-striped flea beetles, Systena blanda Meisheimer, on tomato, Knoxville, TN 1977.

Treatment	kg. AI/ha	$\bar{X}$ number of adult flea beetles/plant at designated date[ab] 5/30	6/5	6/13	6/20	6/27	7/6	7/12	7/18	7/26	8/4	Total $\bar{X}$
Ambush	3.1	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0
Dasanit	3.1	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	1.0 ab	0.0 a	1.0
Dasanit + Di-Syston	3.1	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	1.0 ab	0.0 a	1.0
Di-Syston	3.1	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0
Furadan	3.1	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0
Mocap Plus 1x	3.1	1.0 b	9.2 c	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.2 a	0.0 a	0.0 a	10.4
Mocap Plus 2x	6.2	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	2.0 b	2.0
Nemacure	4.2	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.2 a	0.0 a	0.0 a	0.0 a	0.2
Vydate	3.1	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.2 a	1.0 ab	0.0 a	1.2
Control	---	0.0 a	5.0 b	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	2.0 b	0.0 a	7.0

[a]Means are the average of 5 replicates.

[b]Means in a column not followed by the same letter are significantly different (P=0.05) (Duncan's Multiple Range Test).

Di-Syston, or Furadan-treated plants. Low seasonal numbers also occurred on Dasanit, Dasanit + Di-Syston, Nemacure, and Vydate treatments. Highest seasonal numbers were observed on Mocap Plus (1x).

Seasonal totals of treatments compared to check population levels indicated low pest and high beneficial insect numbers for both the 1976 and 1977 season occurred on Dasanit treatments with the exception of reduced C. maculata numbers in 1977. High pest and low beneficial insect numbers occurred on Ambush and Vydate in 1976 and were the least efficient treatments evaluated. A high pest-low beneficial response was not observed in 1977 probably due to the reduction of chemical rates for that season. Low pests and beneficial insect numbers occurred on Dasanit + Di-Syston, Di-Syston, Mocap (1x), Mocap (2x) and Mocap Plus (1x) treatments in 1976. In 1977, low pests and beneficial numbers occurred on Ambush, Dasanit + Di-Syston, Mocap Plus (1x), Mocap Plus (2x), Nemacure, and Vydate treatments. This response was probably due to an effective and long lasting toxicity effect against the pest species. Di-Syston and Furadan were the least efficient treatments evaluated in 1977 since both pests and beneficial numbers were higher than check (with the exception of high M. persicae and A. matricariae numbers on Di-Syston) during that season.

III. COMPONENTS OF PREDATOR EFFICIENCY FOR CHECK

The effectiveness of aphidophagous insects for aphid control on untreated plants was evaluated in 1976 and 1977 field tests for potential aphid increase, potential predator voracity, and predator-pest synchronization. Field data for each season was illustrated by the Bombosch model (1963), which balances predator voracity against a geometric aphid increase. Mean aphid reproductive rate was considered the daily multiplication factor (q) (Way and Banks, 1962), and voracity (k) was determined from the daily aphid feeding rate per predator (Iperti, 1966; B. C. Smith, 1966). Graphs were evaluated using Emden's criteria for biological significance (1963, 1965). A combined density for M. persicae and M. euphorbiae was utilized in calculations for the 1977 season.

The initial population levels for M. persicae and its predators were high and well synchronized during the 1976 season (Figure 17). The second week, June 14 to June 22, was marked by a 36% decrease in aphid numbers. Predator density and percent potential predation increased at that time. Although the aphid population remained constant at this reduced level from June 22 to June 28, predator numbers and percent predation were reduced 60.8%. Heavy rainfall and cooler temperatures during this period contributed to decreased predator activity and searching

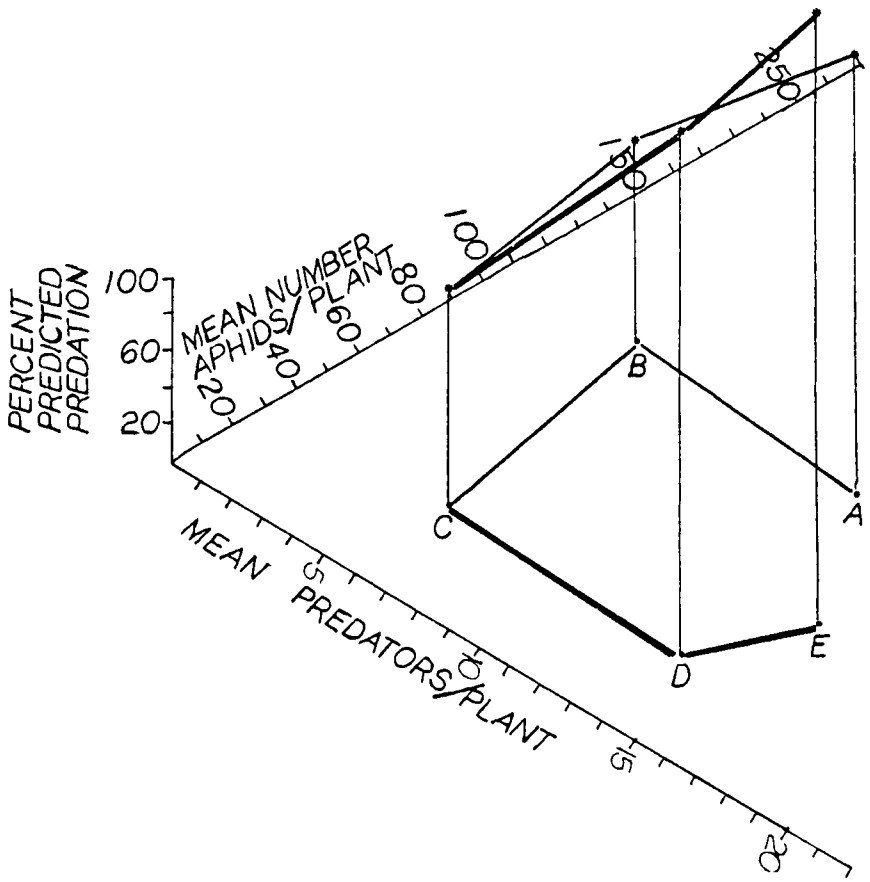


Figure 17. The efficiency of predator action in a field population of M. persicae, Knoxville, TN 1976. Count periods were June 14 - June 22 (A), June 22 - June 28 (B), June 28 - July 7 (C), July 7 - July 12 (D), and July 12 - July 19 (E).

efficiency (Hodek, 1967). Reduced predator numbers could also have occurred as a density-dependent response to decreased aphid numbers.

A second decrease of 35% aphid density was observed during week four (June 28 to July 7); predator numbers and percent predation remained unchanged. Such a seasonal decrease in aphid numbers associated with a stable predator density was previously noted by Bonnemaison (1966) in his study of aphid control in temperate regions. Bonnemaison (1971) proposed that C. novemnotata was effective for aphid control in temperate regions since coccinellid adults emerged when aphid numbers were increasing (i.e. late June and July). An increase in predator density and low aphid density the following week, July 7 to July 12, was also supportive of Bonnemaison's assessment of coccinellid synchronization with aphids on field crops. Heavy rainfall provided an additional factor aside from predator activity for aphid control June 28 to July 12. M. persicae and predator numbers increased 47% and 24% respectively the final week of the 1976 count period (July 12 to July 19).

A significant increase in potential predation occurred along with increased aphid numbers the second week of the 1977 count period, and indicated that effective predator response was due, in part, to timely synchronization with aphid occurrence (Figure 18). Predator-prey

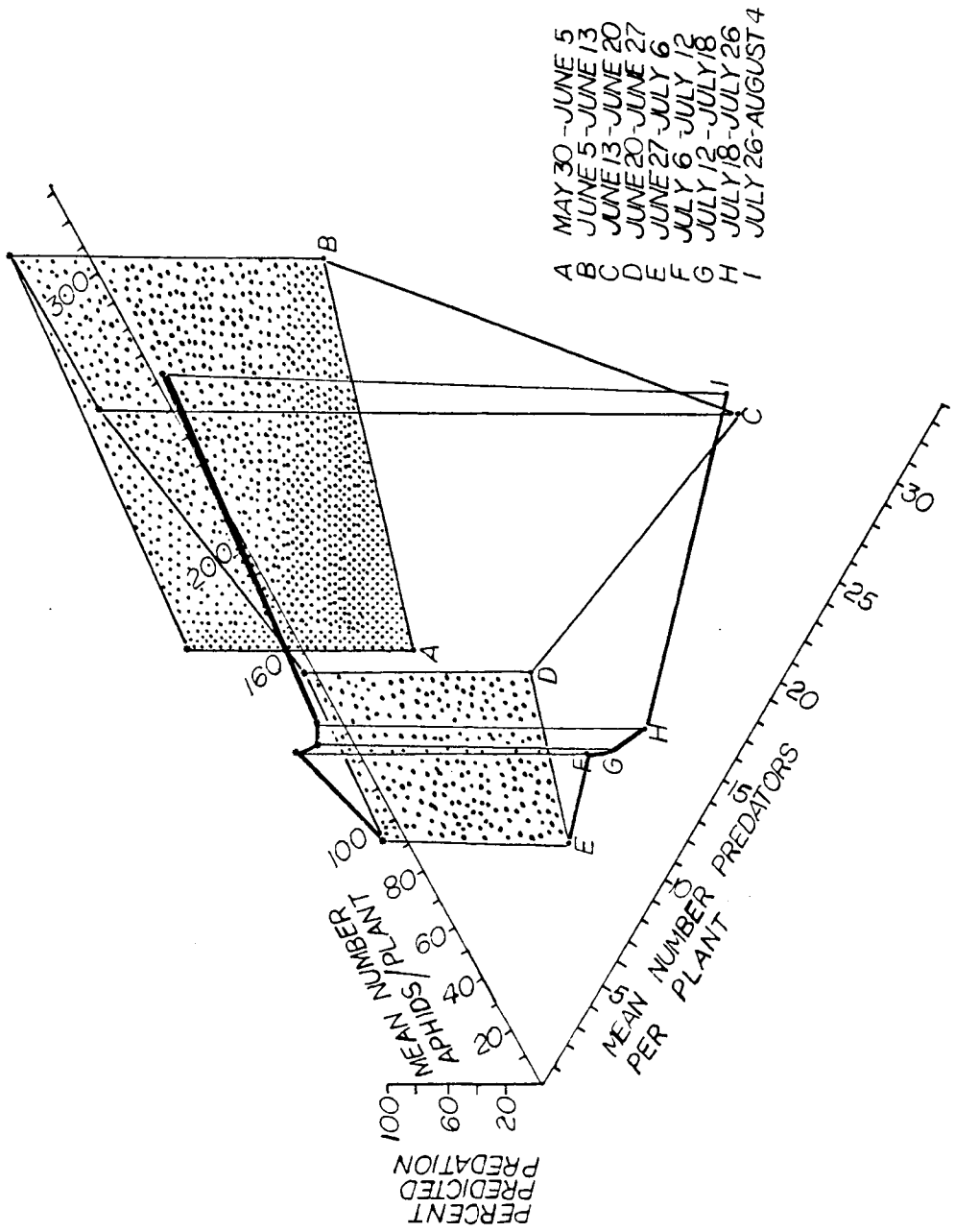


Figure 18. The efficiency of predator action in a field population of M. persicae and M. euphorbiae, Knoxville, TN 1977.

density continued to increase and reached a maximum level by the fourth count date, June 20. This represented an eight-fold increase of aphids and a fifteen-fold increase for predators over initial population densities. A significant reduction of 23% and 43% for aphid and predator densities occurred the following count date, June 27. Percent potential predation also declined. Heavy rainfall (9.7 cm.) appeared to be an important factor in the abatement of pest density at that time.

Along with increased predation, a slight increase in predator-aphid densities (35% and 8%) was observed on July 12, 1977. Continued increase in predator numbers and potential predation occurred July 18, and aphid density decreased 15%. This observation indicated aphidophagous insects to be important in late season aphid control when nutritionally favorable senescent leaves promote pest resurgence. Moreover, lack of rainfall and warm temperatures during this period promoted maximum coccinellid efficiency in aphid consumption and searching ability.

A five-fold increase in aphid density occurred the last week of the observation period, July 26 to August 4. This pest increase occurred despite a two-fold increase in predator numbers and increased percentage potential predation. Predator increase confirmed a density-dependent relationship with the aphid pests; however,

late-season control was insufficient due to the lack of increased predation the previous week. Thus, Emden's (1966a) assessment of predator limitation was corroborated. The potential voracity of predators was limited by their long generation time in comparison with their prey, and by the fact that increased numbers of predators produced an additive reduction in numbers of aphids unlike the geometric increase characteristic of aphid reproduction.

IV. COMPONENTS OF PARASITE EFFICIENCY FOR CHECK

Parasite efficiency for aphid control was evaluated in terms of changes in density of A. matricariae (numerical response) as the host numbers decreased or increased over the same time period. Graphical presentation for intergeneration relationships was established by Varley and Gradwell (1960) and Hassell (1966); an analogous interpretation was used for this study. The logarithm host density was illustrated as the independent variable plotted against the killing power (expressed at the k-value) of the parasite for untreated plants in the 1976 field test (Figure 19). The k-value was derived by subtracting the logarithm of host densities after parasitism from those before parasitism. The elliptical line depicts a delayed density-dependent host mortality which corresponded to results presented by Solomon (1964) on

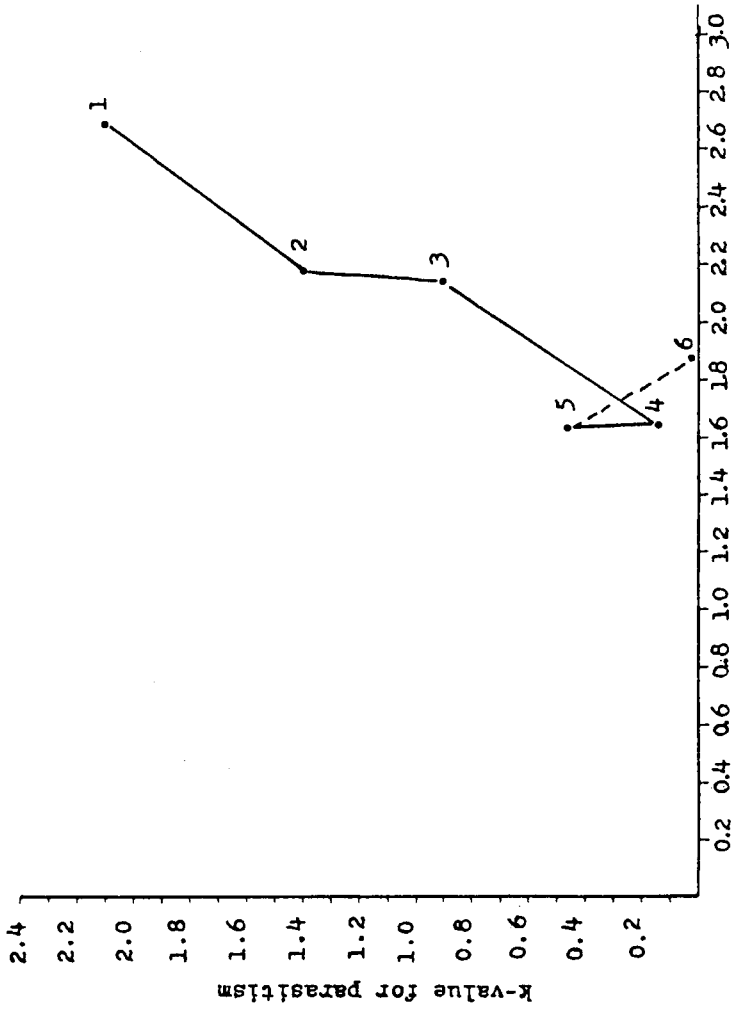


Figure 19. Mean parasitism (expressed as the k-value) per week of the green peach aphid (Myzus persicae Sulz.) compared with logarithm aphid density from June 4 to July 19, 1976, as observed on untreated tomato plants, Knoxville, TN.

parasitism of the black-headed budworm, Acleris variana (Fern.). The regression line for this figure has a positive slope, indicating parasitic behavior to be directly density-dependent. Percent parasitism was higher in regions of high host density.

The superproportional (i. e. directly density-dependent) relationship observed in the 1976 field test represents an aggregative rather than an individual response because A. matricariae selectively parasitizes green peach aphid (Hussey, 1965; McLeod, 1937; Mackauer, 1968, Smith, 1931) and hyperparasitism was shown to be rare by Bunzli and Buttiker (1959).

The logarithm host density was illustrated as the independent variable plotted against the k-value of A. matricariae for untreated plants in the 1977 field test (Figure 20). The spiral was more circuitous for the 1977 season and corroborated host mortality to be delayed density-dependent. An extended observation period of four weeks during the 1977 season allowed more comprehensive examination of host-parasite interaction, and provided the additional data necessary to depict the greater spiral effect. The regression line for behavioral response of the parasite was not superproportional as in 1976.

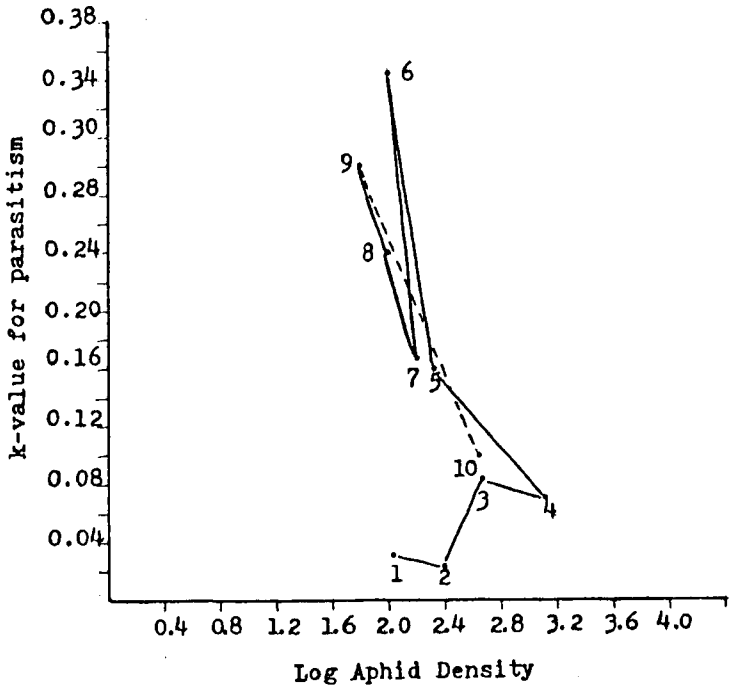


Figure 20. Mean parasitism (expressed as the k-value) per week compared with logarithm aphid density from May 30 to August 11, 1977, as observed on untreated tomato plants, Knoxville, TN.

Lack of definitiveness in the effective mechanism for parasitization was influenced by the occurrence of a second aphid species, M. euphorbiae, throughout the 1977 season. Although A. matricariae maintained a delayed density-dependent host mortality, preference of M. persicae to M. euphorbiae resulted in a slightly subproportional relationship. Therefore, the occurrence of the parasite was high when pest density was low. Because M. persicae occurred at lower population levels than M. euphorbiae, parasitization of the preferred host would necessitate the occurrence of a high parasitism rate with low aphid density.

V. MULTIPLE CORRELATION AND STEPWISE REGRESSION ANALYSIS FOR PEST-PREDATOR-PARASITE ABUNDANCE AND ENVIRONMENTAL INTERACTION

A correlation matrix for the occurrence of insect pests, non-target organisms, treatment effect, and environmental factors was devised for the 1976 season (Table 11). Highest treatment effect was negatively correlated with J. spinosus and C. novemnotata ($P = 0.0001$); less significant treatment effect was negatively correlated with C. maculata ($P = 0.05$). A negative correlation occurred for pest and non-target organisms to rainfall, and a positive correlation occurred for all insects to warmer

Table 11. Correlation matrix of pest-enemy populations, treatment effect, and environmental factors, 1976.[a]

	Pests and nontarget insect species				
	M. persicae	*A. matricariae*	*J. spinosus*	*C. maculata*	*C. novemnotata*
Treatment	+0.1310 0.0300	-0.0762 0.2100	-0.2613 0.0001	-0.1422 0.0200	-0.2947 0.0001
Temperature	+0.4531 0.0001	+0.1894 0.0020	+0.1423 0.0200	+0.1520 0.0100	+0.1569 0.0098
Precipitation	-0.4819 0.0001	-0.2299 0.0001	-0.1525 0.0100	-0.1034 0.0900	-0.1302 0.0300
M. persicae		+0.7306 0.0001	-0.0078 0.8900	+0.2154 0.0001	-0.0577 0.3400
A. matricariae			-0.0134 0.8200	+0.3735 0.0001	-0.0544 0.3700
J. spinosus				+0.1737 0.0040	+0.7032 0.0001
C. maculata					+0.1348 0.0300

[a]Average of five replicates.

temperatures. These values are mutually supportive since temperatures were lower during periods of heavy rainfall. This inverse relationship of temperature to predator numbers agreed with previous studies (Gurney and Hussey, 1970; Hodek, 1967; Iperti, 1965, 1966; Sundby, 1966). Because aphid fecundity increased with warmer temperatures (Barlow, 1962), a second factor was present to promote predator increase.

M. persicae was positively correlated to A. matricariae and C. maculata. All predators were positively correlated to one another. The parasite was positively correlated to both ladybug species, but not to the stilt bug. These correlation values were significant ($P = 0.05$) and suggest: 1) positive parasite-predator correlation to be indicative of a mutual response to pest density; 2) the spotted ladybug and parasite were the natural enemies most consistently associated with green peach aphid on tomato; 3) the green peach aphid to be moderately resistant to chemical control; 4) decreased non-target numbers to result from treatment toxicity and/or decreased aphid density; and 5) increase of beneficials' populations to be suppressed by cooler temperatures and heavy rainfall.

Predation equations for aphid and natural enemy populations associated with environmental and treatment factors were derived for the 1976 season (Table 12).

Table 12. Prediction equations for stepwise regression of pest-predator-prey interaction, 1976.[a]

Dependent variable	Independent variables	Prediction equation	Percent change r^2
M. persicae	x_1=*A. matricariae*	$y= 64.0+1.6x$	53.0%
	x_2=precipitation	$y= 100.7+1.4x-0.3x_2$	64.0%
	x_3=count date	$y= 153.8+1.1x-0.4x_2-11.3x_3$	67.0%
	x_4=temperature	$y= 505.6+1.0x-0.2x_2-13.6x_3+8.6x_4$	69.0%
	x_5=*C. novemnotata*	$y=-537.3+1.1x-0.2x_2-0.2x_3+9.1x_4$	71.0%
J. spinosus	x_1=*C. novemnotata*	$y=-0.0142+1.0860x-0.0270x_2$	87.1%
C. maculata	x_1=*A. matricariae*	$y=5.26+0.06x$	13.9%
	x_2=*J. spinosus*	$y=4.46+0.06x+0.60x_2$	17.1%
C. novemnotata	x_1=*J. spinosus*	$y=2.83+2.60x$	49.4%
	x_2=count date	$y=1.08+2.44x+0.55x_2$	51.2%
A. matricariae	x_1=*M. persicae*	$y=-10.9+0.3x$	53.4%
	x_2=count date	$y= 22.8+0.3x-7.3x_2$	61.9%
	x_3=*C. maculata*	$y= 14.5+0.2x-6.7x_2+1.1x_3$	65.3%

[a]Models were derived from the stepwise regression analysis, maximum r-square improvement, SAS 1976, for mean insect numbers per plant.

A. matricariae was the single factor implementing 53% change r^2 of the aphid population on treated and untreated plants. This relationship was described as $y=64 + 1.6x$ and is represented graphically (Figure 21a). Parasitized aphids increased as aphid population increased. The independent variables fitted to 2-5 degree equations were rainfall, count week, temperature, and spotted ladybug density. These contributed to 71% change in green peach aphid numbers.

Variation of adult stilt bugs (87.1%) was correlated with the occurrence of C. novemnotata as shown in the equation $y= -0.0142 + 1.086x - 0.027x^2$. Adult stilt bugs increased concurrently as the number of C. novemnotata increased (Figure 21b).

The spotted ladybug was closely associated with the occurrence of parasite and stilt bugs, but only 17.1% change r^2 of the spotted ladybug density was correlated with these two natural enemies. The two variable relationship of C. maculata to A. matricariae was described by the equation $y= 5.26 + 0.06x$, where the increase in numbers of parasitized aphids was correlated with increased C. maculata densities (Figure 21c).

Treatment effect for the 1977 field test was shown to be highly significant and negatively correlated with adult and nymph stilt bug densities, and adult C. maculata and C. novemnotata populations (Table 13). Both

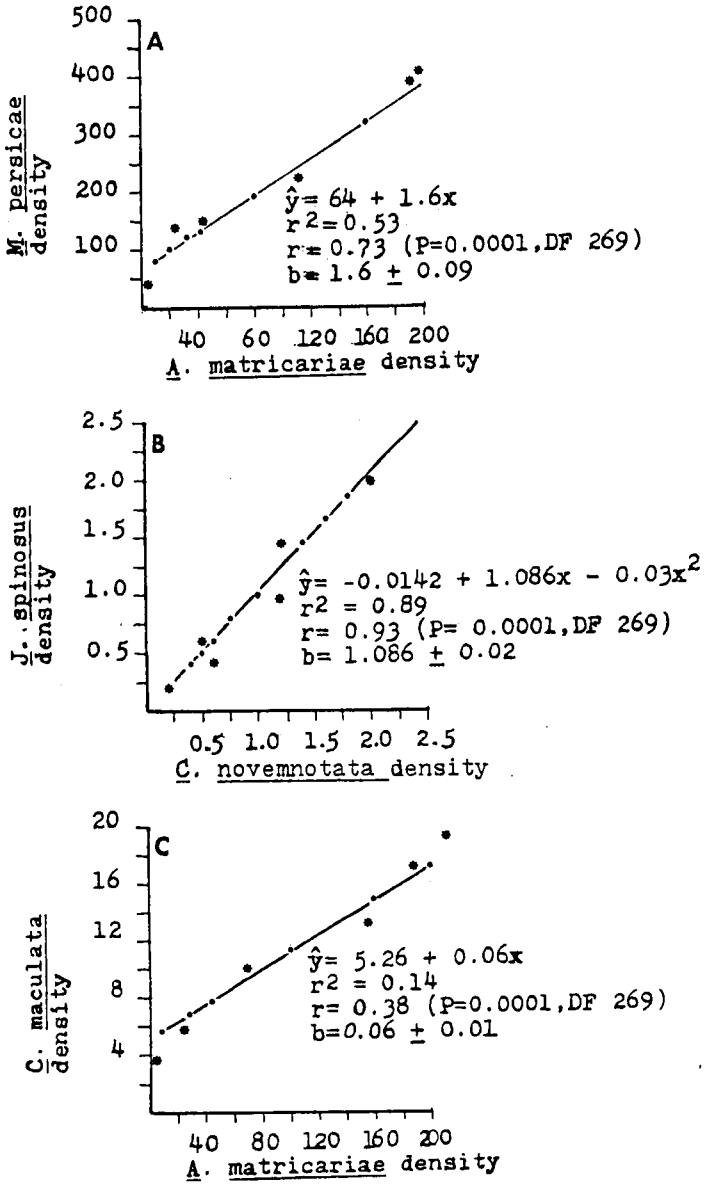


Figure 21. Two variable stepwise regression models for the relationship A. matricariae versus M. persicae (A), C. novemnotata versus J. spinosus (B), and A. matricariae versus C. maculata (C). Mean numbers per plant were observed weekly, June 14 to July 19, 1976.

Table 13. Correlation matrix of insect pests, non-target organisms, treatment effect, and environmental factors, 1977.

	Pests and non-target insect species[a]						
	M. persicae	*M. euphorbiae*	*A. matricariae*	*J. spinosus* adults	*J. spinosus* nymphs	*C. maculata*	*C. novemnotata*
Treatment	-0.0525 0.1459	-0.0689 0.1240	-0.0591 0.1011	-0.1686 0.0001	-0.0931 0.0374	-0.1378 0.0001	-0.2736 0.0001
Temperature	-0.1161 0.0012	-0.1411 0.0016	-0.0883 0.0142	+0.2842 0.0001	+0.4325 0.0001	-0.0205 0.5695	+0.1212 0.0008
Precipitation	+0.0033 0.9264	-0.4054 0.0001	+0.1564 0.0001	+0.1415 0.0001	+0.2821 0.0001	-0.0771 0.0324	-0.0106 0.7698
Weight/tomato	-0.1092 0.0024	+0.1718 0.0001	+0.1037 0.0040	+0.0384 0.2877	-0.1062 0.0175	+0.0791 0.0283	+0.0771 0.0324
M. persicae		-0.2520 0.0001	-0.1999 0.0001	+0.1828 0.0001	+0.3680 0.0001	-0.0639 0.0762	+0.1573 0.0001
M. euphorbiae			+0.4812 0.0001	-0.0402 0.2651	+0.2551 0.0001	+0.3918 0.0001	+0.2345 0.0001
A. matricariae				+0.3735 0.0001	+0.2125 0.0001	+0.4597 0.0001	+0.4830 0.0001
J. spinosus adult					+0.1136 0.0110	+0.2879 0.0001	+0.0799 0.0266
J. spinosus nymph						+0.2024 0.0001	+0.4338 0.0001
C. maculata							+0.4389 0.0001

[a]Average of five replicates.

aphid and beneficial species were significantly correlated with rainfall and temperatures. Unlike the 1976 response whereby the entire host-predator populations were negatively correlated with rainfall, only stilt bug nymphs were negatively correlated with rainfall in 1977. Tomato plants were transplanted two weeks earlier in 1977 than in 1976 and provided more protective foliage for insects during the period of heaviest rainfall (June 20) in 1977. Nymphs were just appearing in the field at that time and were less likely to survive the rain than adult predators monitored. Both aphid species had a highly significant negative correlation to warmer temperatures. The spotted ladybug was the only non-target organism observed that had a negative correlation to warmer temperatures in 1977. Stilt bug adults, nymphs, and parasitized aphids had a highly significant positive correlation to warmer temperatures.

Tomato weights were positively correlated for treated and untreated plants to C. maculata and C. novemnotata density. A highly significant (P= 0.0001) positive correlation occurred for M. euphorbiae with optimum fruit weights. A less significant negative correlation (P= 0.0024) was obtained for tomato weight and M. persicae density. Predator association with optimum quality produce probably reflected a response to greater host numbers on hardier plants rather than a direct

relationship of plant vitality to predator density. Also, predators were positively correlated with each other and with the occurrence of parasitized aphids during the 1977 season.

These correlation values suggest: 1) parasite-predators-prey to be directly density-dependent; 2) the parasite to be most closely synchronized with the green peach aphid; 3) C. maculata and C. novemnotata to be the natural enemies most closely synchronized with the potato aphid; and 4) cooler temperatures to negatively effect aphid (particularly M. euphorbiae) numbers.

Prediction equations were derived pertaining to predator-parasite-prey interactions with environmental factors for the 1977 season (Table 14). The percent change of r^2 increased with a rise in the number of variables incorporated into the prediction equation. One variable equation for M. euphorbiae accounting for 34.3% change r^2 in potato aphid density was $y= 32.77 + 1.97x$ where x= M. persicae per plant. This positive correlation indicated that an increase for potato aphid density occurred concurrently with green peach aphid increase (Figure 22a). M. euphorbiae was more sensitive to temperature than rainfall, and to predators than to the parasite.

Only a maximum of three variables could be incorporated into a prediction equation that accounted for 48.3% of the change in green peach aphid density. Lower green

Table 14. Prediction equations for stepwise regression of pest-predator-prey interactions, 1977.[a]

Dependent variable	Independent variables	Prediction equation	Percent change r^2
M. euphorbiae	x_1=*M. persicae*	$y= 32.8+1.9x$	34.3%
	x_2=temperature	$y=651.8+1.8x-7.9x_2$	44.5%
	x_3=*C. maculata*	$y=666.3+1.4x-8.2x_2+6.5x_3$	51.3%
	x_4=*C. novemnotata*	$y=721.3+1.1x-9.1x_2+4.6x_3+5.1x_4$	54.0%
	x_5=*J. spinosus*,nymph	$y=770.9+1.1x-9.7x_2+4.2x_3+4.4x_4+3.7x_5$	54.8%
	x_6=*A. matricariae*	$y=810.9+1.0x-10.0x_2+4.1x_3+3.8x_4+4.1x_5+0.5x_6$	55.8%
	x_7=precipitation	$y=826.8+1.1x-10.0x_2+4.1x_3+3.8x_4+3.6x_5+6.0x_6-0.1x_7$	56.3%
M. persicae	x_1=*M. euphorbiae*	$y= 6.6+0.2x$	32.0%
	x_2=*C. novemnotata*	$y= 2.3+0.1x+2.5x_2$	43.8%
	x_3=precipitation	$y=-0.5+0.1x+2.3x_2+0.1x_3$	48.3%
J. spinosus adult	x_1=*C. novemnotata*	$y=1.4+0.4x$	31.8%
	x_2=*J. spinosus*,nymph	$y=1.2+0.4x+0.2x_2$	34.8%
	x_3=*C. maculata*	$y=1.0+0.3x+0.2x_2+0.1x_3$	36.8%
	x_4=*M. persicae*	$y=0.9+0.3x+0.2x_2+0.1x_3+0.0x_4$	37.9%
nymph	x_1=*C. novemnotata*	$y=0.9+0.3x$	19.3%
C. maculata	x_1=*C. novemnotata*	$y=1.4+0.6x$	28.4%
	x_2=*M. euphorbiae*	$y=0.9+0.4x+0.01x_2$	33.7%
A. matricariae	x_1=precipitation	$y= 17.8+0.10x$	14.4%
	x_2=*C. novemnotata*	$y= 13.7+0.06x+1.5x_2$	22.1%
	x_3=temperature	$y= -73.6+0.06x+1.4x_2+1.1x_3$	26.1%
	x_4=*M. euphorbiae*	$y=-137.0+0.07x+1.4x_2+1.9x_3+0.07x_4$	27.8%

[a]Models were derived from the stepwise regression analysis, maximum r-square improvement, SAS 1976, for mean insect numbers per plant.

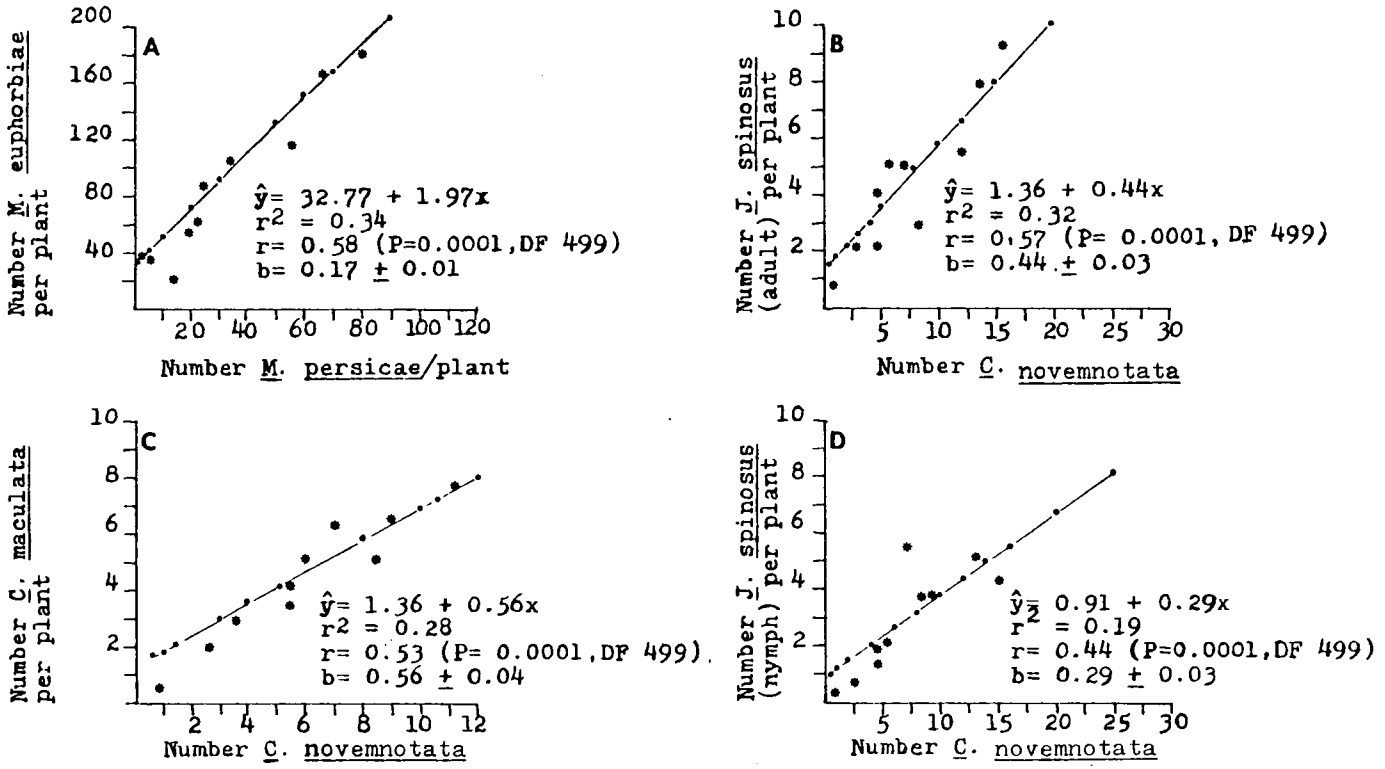


Figure 22. Two variable stepwise regression models for the relationships M. persicae versus M. euphorbiae (A), C. novemnotata versus J. spinosus (adults) (B), C. novemnotata versus C. maculata (C), and C. novemnotata versus J. spinosus (nymphs) (D). Mean numbers per plant were observed weekly, May 30 to August 4, 1977.

peach aphid numbers throughout the 1977 season probably caused this less definitive stepwise regression analysis.

Stilt bug adults were correlated with C. novemnotata for 31.8% change r^2 in numbers per plant. In this predator interaction y= 1.4 + 0.4x. High numbers of adult C. novemnotata were observed concurrent with high adult stilt bug numbers; also, low densities for this predator were matched by low adult stilt bug numbers (Figure 22b). As expected, stilt bug nymphs were the next factor to be incorporated into the two variable model y= 1.2 + 0.4x + $0.2x_2$. Variables for stilt bug adults' prediction equations utilized other predator and parasite densities, rather than pest densities.

J. spinosus nymphs were observed at much lower population levels than adults and only a single variable prediction equation was derived. In this equation, C. novemnotata were positively correlated with the occurrence of stilt bug nymphs. This prediction equation assessed 19.3% change r^2 in nymph stilt bug densities to be y= 0.0 + 0.3x where x= number of C. novemnotata per plant. Hence, both nymph and adult stilt bugs were shown to increase as C. novemnotata increased (Figure 22c).

The spotted ladybug was also positively correlated to the C. novemnotata in the one variable equation y= 1.4 + 0.6x for 28.4% change in r^2 in C. maculata population density. C. maculata was the only predator in the

1977 season to be positively correlated to the potato aphid. A 33.7% change r^2 in C. maculata density was shown in the two variable equation $y= 0.90 + 0.40x_1 + 0.01x_2$ where x= C. novemnotata and x_2 = M. euphorbiae densities. The ladybugs were directly density-dependent (Figure 22d).

A small percent change in parasitized aphid density was assessed in the one variable equation $y= 17.8 + 0.1x$ where x_1= centimeters rainfall per observation week. Rainfall was less than amounts received the corresponding weeks in 1976; therefore, increased rainfall for the 1977 season was favorable to plant growth and less detrimental to the occurrence of pests and enemies. Increased plant growth, a nectar source, and increased aphid numbers would favor the parasitism behavior and development of A. matricariae. Greatest percent change (27.8%) in the number of parasitized aphids per treated and untreated plant was assessed in a four variable equation $y= 137.95 + 0.07x + 1.40x_2 + 1.94x_3 + 0.07x_4$ where x= centimeters rainfall, x_2= C. novemnotata density, x_3= temperature, and x_4= M. euphorbiae density.

Treatment effect and predator-parasite-prey densities were determined for green peach aphids on the basis of combined data for 1976 and 1977 seasons (Table 15). The correlation matrix derived indicated a negative correlation (P= 0.0001) for treatment and stilt bug adults.

Table 15. Correlation matrix of insect pests, non-target organisms, and treatment effect, 1976 and 1977.

	Pests and non-target insect species[a]				
	M. persicae	*A. matricariae*	*J. spinosus* adults	*C. maculata*	*C. novemnotata*
Treatment	+0.0237 0.8308	-0.1053 0.3403	-0.4208 0.0001	-0.1975 0.0720	-0.4533 0.0001
M. persicae		-0.5886 0.0001	-0.1111 0.3142	-0.5722 0.0001	+0.1979 0.0711
A. matricariae			+0.0794 0.4726	+0.3797 0.0001	+0.0102 0.9268
J. spinosus adult				-0.0485 0.6615	+0.5563 0.0001
C. maculata					+0.2992 0.0057

[a]Average of five replicates.

C. maculata (P= 0.07) and C. novemnotata (P= 0.0001) were also negatively correlated with treatment effect. Green peach aphids were positively correlated with parasitized aphid and spotted ladybug densities, and to a lesser degree with the occurrence of C. novemnotata. Stilt bug adults and spotted ladybugs were positively correlated with C. novemnotata. These correlation values suggest: 1) a density-dependent relationship occurred in 1976 and 1977 for A. matricariae, C. novemnotata, and C. maculata with the green peach aphid; 2) a positive correlation occurred for C. novemnotata with both C. maculata and J. spinosus, but stilt bug adults were positively correlated only with the occurrence of C. novemnotata; 3) negative treatment effect was most evident as a variable of predator densities.

The prediction equations derived for M. persicae utilizing 1976 and 1977 indicated the parasite to be one of the most important variables contributing to changes of green peach aphid density (Table 16). In this equation 34.6% of the green peach aphid population can be assessed as a function of parasitized aphid density $y= 250.70 + 1.43_x$ where x= parasitized aphids per plant. An increase of 54.3% r^2 aphid density was shown to result from the following five factors in order of importance: A. matricariae, C. maculata, count date, C. novemnotata, and J. spinosus adult density.

Table 16. Prediction equations for stepwise regression of pest-predator-prey interactions, 1976 and 1977.[a]

Dependent variable	Independent variables	Prediction equation	Percent change r^2
M. persicae	x_1=*A. matricariae*	$y=250.7+1.4x$	34.6%
	x_2=*C. maculata*	$y=53.8+1.1x+6.4x_2$	48.8%
J. spinosus adult	x_1=*C. novemnotata*	$y=11.60+0.20x$	30.9%
	x_2=*M. persicae*	$y=11.80+0.20x-0.01x_2$	42.8%
	x_3=*A. matricariae*	$y=12.90+0.30x-0.01x_2+0.02x_3$	45.0%
	x_4=*C. maculata*	$y=21.20+0.30x-0.01x_2+0.02x_3-0.08x_4$	47.4%
C. maculata	x_1=*M. persicae*	$y=23.4+0.04x$	32.7%
	x_2=*C. novemnotata*	$y=16.5+0.03x+0.17x_2$	36.3%
C. novemnotata	x_1=*J. spinosus*, adult	$y=15.50+1.50x$	30.9%
	x_2=*C. maculata*	$y=-2.14+1.56x+0.37x_2$	41.6%
A. matricariae	x_1=*M. persicae*	$y=109.8+0.2x$	34.6%

[a]Models were derived from the stepwise regression analysis, maximum r-square improvement, SAS 1976, for mean insect numbers per plant.

Combined data for the two seasons showed J. spinosus to be closely associated with C. novemnotata. M. persicae was negatively correlated with stilt bug numbers to account for 42.8% change of the stilt bug population. C. maculata was positively correlated for a 32.7% change r^2 in green peach aphid numbers in the equation y= 23.36 + 0.04x. C. novemnotata was most closely associated with occurrence of stiltbugs

These prediction equations are supportive of the following relationships observed during the 1976 and 1977 season: 1) green peach aphid and parasitized aphid numbers were directly density-dependent for treated and untreated plants; 2) green peach aphids and predators were less closely associated than green peach aphids with A. matricariae in concurrent population peaks; 3) the stilt bug was the predator least affected by green peach aphid density; 4) rainfall, temperature, and treatment effect were less significant than cohort densities in the seasonal variation of prey-predator-parasite densities.

VI. YIELDS AND DAMAGE

Significant variation of yield due to treatment effect ($F = 6.45$, $P = 0.001$) was observed for the 1976 harvest (Table 17). Increased yields were obtained for all chemical treatments, except Mocap (2x), compared to

Table 17. Effect of systemic insecticide-nematicides on tomato yield and quality, 1976 and 1977.[ab]

Treatment	Mean yield (tons)/ha 1976	Mean yield (tons)/ha 1977	Mean wt/tomato (lbs)/treatment 1976	Mean wt/tomato (lbs)/treatment 1977	Fruitworm damage 1976	Fruitworm damage 1977	Leafhopper damage 1976	Leafhopper damage 1977
Ambush	8.10 bc	25.74 a	0.51 a	0.24 a	1.71 a	0.36 a	2.49 a	0.62 a
Dasanit	6.04 abc	22.72 a	0.51 a	0.23 a	1.93 a	0.28 a	2.86 a	0.50 a
Dasanit+Di-Syston	10.62 c	26.60 a	0.44 a	0.27 a	2.08 a	0.66 a	2.46 a	0.61 a
Di-Syston	6.44 abc	22.89 a	0.48 a	0.24 a	2.04 a	0.32 a	2.43 a	0.54 a
Furadan	----	21.54 a	----	0.22 a	----	0.53 a	----	0.61 a
Mocap (1x)	5.13 abc	----	0.43 a	----	1.35 a	----	2.60 a	----
Mocap (2x)	1.83 a	----	0.37 a	----	1.09 a	----	1.51 a	----
Mocap Plus (1x)	5.32 abc	22.30 a	0.41 a	0.24 a	1.28 a	0.48 a	1.92 a	0.52 a
Mocap Plus (2x)	----	26.17 a	----	0.23 a	----	0.37 a	----	0.65 a
Nemacur	----	24.45 a	----	0.23 a	----	0.43 a	----	0.50 a
Vydate	8.48 bc	25.70 a	0.55 a	0.23 a	1.80 a	0.50 a	2.64 a	0.64 a
Control	4.17 ab	23.74 a	0.42 a	0.23 a	2.22 a	0.44 a	2.22 a	0.49 a

[a]Average of five replicates.
[b]Means in columns not followed by the same letter are significantly different (P=0.05) (Duncan's Multiple Range Test).

check in 1976. Highest yields were on Dasanit + Di-Syston treatments and lowest yields on Mocap (2x) treatments. High yields were obtained from Ambush and Vydate-treated plants. No significant difference between Dasanit, Di-Syston, Mocap (1x), and Mocap Plus (2x) treatments occurred and only moderate yields were obtained. Highest yields in 1977 were obtained from plants treated with Dasanit + Di-Syston and Mocap Plus (2x). No significant difference occurred between treatment and check.

Yields for all treatments obtained in 1976 were lower than yields obtained in 1977 because of the increased incidence of plant disease resulting from heavy rainfall (16-18 centimeters) and lack of preventive fungicide treatments in the 1976 season. The predominant plant diseases observed for both seasons were early blight (Alternaria solani), buckeye rot, and fruit cracking. These conditions caused complete destruction of foliage, impaired fruit quality, and exposed fruit to skin damage by the first harvest in 1976. Also, failure of early fruit set favored vigorous vine growth and contributed to yield loss. The incidence of early blight infection was reduced and harvest period extended in the 1977 growing season because of the addition of a biweekly fungicide spray schedule. Highest incidence of diseased plants occurred predominantly in poor drainage areas for both the 1976 and 1977 seasons.

Tomatoes obtained from poor drainage areas were significantly reduced in weight and numbers due to replicate effect in 1976 and 1977. The 1976 mean tomato weight per treatment ranged from 0.37 - 0.55 pounds compared to 0.23 - 0.27 pounds in 1977.

Similar results were reported by Quinn (1973) where weekly fungicide applications during a wet period more than doubled marketable yield compared to untreated crops. Early fruit maturity and increased plant growth have also been associated with physiological changes with plants treated with systemics (Shehane and Bass, 1974; Wheeler and Bass, 1971). Because insecticide rates were greater in 1976 compared to 1977, such an affect on plant growth could have occurred. More indirectly, the decreased tomato weight in 1977 could have reflected an increase in blossom-set or lessened plant vitality incurred from increased pests numbers.

No significant differences between chemical treatments and check occurred for fruitworm or leafhopper damage in either the 1976 or 1977 season. Damage by these insects was greater in 1976, when the occurrence of early blight and buckeye rot throughout the field was much higher than in 1977.

Yield data for 1976 and 1977 indicated that yield differed for treated and untreated plants. Variation per

treatment was further influenced by the rate of applied insecticide-nematicides, utilization of fungicide, and the location of the plant in the field plot.

CHAPTER V

SUMMARY AND CONCLUSIONS

Lowest green peach aphid numbers were observed throughout the 1976 growing season on Dasanit, Di-Syston, and Mocap Plus-treated plants. All chemical treatments maintained lower aphid numbers than check June 22 to June 28. Only Vydate reduced pest populations comparable to check in early through mid-July. Late season aphid counts were lowest on Dasanit and Di-Syston-treated plants.

Parasitism in 1976 was significantly reduced on those treatments which were effective for aphid control. Reduced stilt bug and ladybug numbers occurred on all chemical treatments except Dasanit compared to check. This reduction in predator numbers was probably due to the reduction of aphid numbers on chemical treatments. Multiple correlation analysis determined a negative correlation of stilt bug adults and treatment, thus suggesting that the significant treatment effect on stilt bugs could have occurred due to chemical toxicity since this predator is also a plant feeder.

The potato aphid was more abundant than the green peach aphid throughout the 1977 season. Lowest aphid numbers occurred on Nemacure and Dasanit + Di-Syston-treated plants. High population levels for A. matricariae were

observed on Nemacure-treated plants, and could have served as an additional aphid control measure. Seasonal parasitism rates were lower on all chemical treatments than check. Parasite recovery was directly related to seasonal population peaks of aphid species by the Nicholsonian models developed by Hassel (1966) and Varley et al. (1973), and by the positive correlation of A. matricariae to aphids on both treated and untreated plants.

Seasonal totals for stilt bug adults were equal in 1977 for Dasanit and check treatments. Highest nymph populations were observed on Di-Syston, Furadan, and Vydate treatments and occurred three weeks after adult stilt bug population peaks.

Seasonal population numbers of the spotted ladybug in 1977 exceeded check on Mocap Plus (2x)-treated plants; high numbers were also present on Furadan and Di-Syston treatments. High number of the C. novemnotata were found on Dasanit and Furadan treatments.

Lowest potato flea beetle numbers were observed on Furadan, Ambush, Dasanit + Di-Syston, Di-Syston and Mocap Plus (2x)-treated plants in 1977. Very low population numbers of the pale striped flea beetle were present throughout the season and, with the exception of one count date, no significant difference occurred between chemical treatments and check.

Maximum yield was obtained for Dasanit + Di-Syston treatments, and high yields for Ambush and Vydate treatments compared to check in 1976. No significant difference in yield was determined for the 1977 season. A treatment effect was also not observed on mean tomato weight for treatments in 1976 and 1977.

Seasonal interpretation of predator activity on untreated plants in 1976 and 1977, as provided by the Bombosch model, indicated: 1) predator activity to be synchronized with the occurrence of aphids in mid-June; 2) the predators to be density-dependent upon prey; 3) the number of predators and predation rate was adversely influenced by heavy rainfall; and 4) that predation contributed to aphid control throughout the season and was particularly advantageous for control in mid-June to mid-July.

Investigation of parasite response in the 1976 and 1977 seasons for untreated plants indicated a superproportional intergeneration relationship in 1976 and a subproportional relationship in 1977. Parasitism was subproportional in 1977 because of the occurrence of the potato aphid as a second and dominant aphid pest, whereas only the green peach aphid was observed in 1976. The percentage of aphids parasitized was lower in regions of high host density, which were the areas of potato aphid infestation. These data suggested the preference of A. matricariae for green peach aphid as host. The figure for the 1977 data

was more elliptical than 1976 and indicated a delayed density-dependent response as well as a subproportional response. This is not uncommon when more than one host species is present. (Varley et al., 1973). As in previous investigations (Hassel, 1966), there was an immediate behavioral response by the parasite to prey density, but the reproductive rate was affected only slightly. Thus, A. matricariae appears to be an efficient parasite of green peach aphids and agreed with reported rare occurrence of hyperparasitism for this species and the preference for green peach aphid as host.

The multiple correlation and stepwise regression analyses supported the trends of predator-parasite response to the environment and host density. For both seasons, a negative correlation occurred for pests and non-target organisms to rainfall, and a positive correlation occurred for all insects to warmer temperatures. The spotted ladybug and parasite were positively correlated with green peach aphid density on treated and untreated plants in 1976, whereas a significant positive correlation in 1977 was determined for stilt bugs and C. novemnotata. All predators and the parasite were positively correlated with potato aphid density on treated and untreated plants in 1977. Selective parasitism of the green peach aphid by A. matricariae was indicated in 1977 by a significant negative correlation of the parasite

with green peach aphid and a positive correlation with potato aphid density.

Further investigation of the effectual enemy-aphid ratios could allow application of chemical treatments only when necesssary. Those natural enemies that proved most efficient in aphid control due to synchronization and resistance to treatment effect were C. novemnotata and A. matricariae. Efforts to promote these natural enemies could include nutritional augmentation, development of shelter areas, and mass production and release.

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