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RELATIONSHIPS BETWEEN TARNISHED PLANT BUG AND ALFALFA PLANT BUG (HEMIPTERA: MIRIDAE) ON ALFALFA IN MICHIGAN

By

Jose I. Romero S.

A THESIS

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ABSTRACT

RELATIONSHIPS BETWEEN TARNISHED PLANT BUG AND ALFALFA PLANT BUG (HEMIPTERA: MIRIDAE) ON ALFALFA IN MICHIGAN

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The present studies were carried out both at laboratory and field conditions, and were directed at determining interspecific competition between the mirids tarnished plant bug, Lygus lineolaris (Palisot de Beauvois), and the alfalfa plant bug, Adelphocoris lineolatus (Goeze).

The developmental period of the tarnished plant bug was followed for five successive generations in the laboratory using pods of green beans as the host. Intraspecific competition in the tarnished plant bug was observed to be accentuated by lack of food, its cannibalistic habit, and interference by accidental contact between them. The alfalfa plant bug could be reared only during the parental generation in the laboratory. The preliminary observations on the alfalfa plant bug in the laboratory indicates that there is a diapause in the egg stage of this species, but more investigation is needed on this subject. Interspecific competition between the tarnished plant bug and alfalfa plant bug is shown by the longer developmental period, shorter longevity, and higher variability of developmental time of the tarnished plant bug when reared together with the alfalfa plant bug than when the tarnished plant bug was reared by itself.

A weekly survey by net sweep sampling was made in five different alfalfa fields and observations were made on the various aspects of biology, habits, behavior, natural enemies, and host plant relationships of both species of mirids. Natural enemies, other than those previously reported, were found, but their presence had no significant effect on the population densities of the mirids. These natural enemies were the spotted lady-bird beetle, Coleomegilla maculata DeGeer, the common toad, Bufo americanus Holbrook, and a fungus identified as a Hyphomicete. The sex ratio was found to be approximately 1:1 in the tarnished plant bug while the females outnumbered the males of the alfalfa plant bug. The tarnished plant bug has a broader range of hosts than the alfalfa plant bug.

These two mirids are found in the same alfalfa producing areas of the United States and occupy similar ecological niches in the alfalfa fields. The records of distribution and abundance of the two species during the years 1940 to 1959 as well as in the present study show that the tarnished plant bug population is dominant over the numbers of the alfalfa plant bug. This equilibrium is probably maintained by different parameters for the two species: the natural enemies, periodic cutting of the alfalfa and intraspecific competition probably being of major importance to the tarnished plant bug; the high female to male sex ratio and the resistant chorion of the egg (Knight 1941) that permits overwintering as eggs are probably the dominant factors influencing the alfalfa plant bug.

A complicating factor is that the alfalfa plant bug is an introduced species that may not have fully adapted to its new environment. The two species are closely related and do occupy similar niches in the alfalfa fields. They are, however, differentially affected by these different parameters and no direct evidence of interspecific competition between them was measured in the field.

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INTRODUCTION

Alfalfa (Medicago sativa L.) has a wide range of insects that cause important problems in its production. Various species of mirids have been considered pests in the alfalfa producing areas of the United States. Three species of Lygus have been present in the Western United States: Lygus hesperus Knight, Lygus elisus Van Duzee, and Lygus lineolaris (Palisot de Beauvois). Lygus lineolaris occurs in almost all alfalfa areas of the United States, according to the records to date, and it is the common eastern species (Stitt 1940). Other mirids usually found in numbers in alfalfa fields in Michigan include the alfalfa plant bug, Adelphocoris lineolatus (Goeze), Trigonotylus ruficornis (Geoffroy), and Plagiognatus pollitus (Uhler). Losses in alfalfa production caused by these Lygus species are well known, although the plant damage is often not spectacular, and is thus less readily noticed than that of many other insects. This research was designed to investigate the population interactions between two mirids commonly found in Michigan: the tarnished plant bug and the alfalfa plant bug.

As stated by Odum (1966), theoretically, populations of two or more species may interact in eight different ways: 1) neutralism, in which neither population is affected by association with the other; 2) competition, in which each population adversely affects the other in the struggle for food, living space, or other common needs; 3) mutualism or symbiosis, in which growth and survival

of both populations are benefited and neither can survive under natural conditions without the other; 4) protocooperation, in which both populations benefit from the association but relations are not obligatory; 5) commensalism, in which one population is benefited but the other is not affected; 6) amensalism, in which one population is inhibited and the other not affected; 7) parasitism and 8) predation, in which one population adversely affects the other by direct attack but is dependent on the other.

All of these population interactions are likely to occur in the average community. Furthermore, the competitive interaction may involve common food, space, natural enemies, severe climatic conditions, diseases and many other types of mutual interactions. Competition, at least under hypothetical conditions, can result in equilibrium adjustments by two species, or it may result in one species population replacing another or forcing it to occupy another space or to use another food (Odum 1966). Attempts to clarify these aspects in the mirid complex on alfalfa are part of the purpose of this work.

OBJECTIVES

The purpose of this study is to determine the interspecific relationships between the tarnished plant bug and the alfalfa plant bug on alfalfa for hay production in Michigan, as a contribution to understanding competition and faunal relationships within cultivated fields.

REVIEW OF LITERATURE

There has been a good deal of writing and discussion for many years as to the relative importance of the relationships between animals of different species, particularly, as to the interspecific competition in insect populations. Many textbooks and investigators give the description, definition and meaning of types of interaction that can occur between two species, of competition in its broad sense, and of interspecific competition (Pearce 1939, Allee et al. 1949, Odum 1967, Birch 1957). Milne (1961) proposes the following single definition for use in ecology, genetics and evolution, to cover both intraspecific and interspecific relationship: "Competition is the endeavor of two or more animals to gain the same particular thing, or to gain the measure each wants from the supply of a thing when that supply is not sufficient for both or all". Nicholson (1933) states that in competition between searching animals, whether these animals are controlled by competition for food, or for suitable places in which to live, or by competition of their natural enemies, there is for each species a particular

density, referred to as the "steady density" at which balance exists and he adds: "Competition always tends to cause animals to reach, and to maintain, their steady densities. Factors, such as climate and most kinds of animal behavior, may have an important influence on the values at which competition maintains these densities".

DeBach (1966) describes insect populations and all organisms as rare, common or abundant, according to the typical average density that they exhibit in their habitable zones. He attributes the absence of a species from a habitat, to physical, or biological factors, and between these, to interspecific interactions. In this respect, he refers to competitive displacement between ecological homologues where one species brings about the extinction or displacement of another ecologically homologous species or prevents such species from invading and colonizing all or part of its habitat.

DeBach (op cit.) prefers the term "competitive displacement principle" to other designations of the phenomenon, such as Gause's law, Grinnel's axiom, the Volterra-Gause principle, the competition exclusion principle, or the Lotka-Volterra principle. The same author discusses with examples the importance of the competitive displacement principle or its converse, the coexistence principle, as having application in many fields such as evolution, ecology, and particuarly in biological control, eradication and other control programs of applied entomology.

On interspecific competition little has been studied in the field, but on the contrary, many laboratory experiments have been performed on competition between different species, mainly

granivorous insects and Drosophila (Park 1954, Solomon 1957). A complete analysis of certain complex situations in which there are present in the environment animals of different kinds and other sorts of organisms is given by Andrewartha and Birch (1954). According to them, species with identical requirements and identical or similar ecology, as applied to insects in nature, can not persist together. The study of interspecific competition has been influenced by mathematical theory which is usually attributed to Lotka (1925, 1932) and Volterra (1926, 1931). Essentially they state that "when a population of animals, all of the same kind, is increasing in a place where food and space are finite and constant, it will obey two simple laws: a) the relative rate of increase decreases from a maximum to zero as the density of the population increases from very few to saturation; b) the relationship between rate of increase and density is assumed to be linear throughout this range". Crombi (1947) has said that all organisms tend toward unlimited increase, but they meet resistance from their biological and physical environment: a) the organism itself (environmental conditions to which it is adapted and characteristics such as its life history, its method of reproduction); b) the physical and abiotic environment (such as climate and soil); and c) the effects of organism upon organism, which can occur directly or indirectly. The biological environment is usually referred to as "density dependent" or "biotic factors". The physical environment is referred to as "independent of population density" or "abiotic factors" (Thompson 1939). The biological factors are also called

"individualized" or "facultative" and the physical factors, "general" or "catastrophic" (Andrewartha and Birch 1954).

Among insects, interspecific competition studies have received some attention. DeBach and Sundby (1963) have reported the competitive displacement between three closely related species of the genus Aphytis (Hymenoptera: Aphelinidae) which are minute ectoparasites attacking the California red scale, Aonidiella aurantii (Haskell), in Southern California. This study showed that an absolute food shortage is not necessary for competitive displacement to occur. Likewise, experimental studies showed that one species always eliminated the other.

Flanders (1966) discusses the cases of species replacement among parasitic Hymenoptera and states that it is most commonly observed in them because of their dominance in biological control. His conclusions are that reciprocal and non-reciprocal balance among this parasitic groups are correlated with the two types of species replacement as determined by extrinsic and intrinsic competition. He refers to reciprocal balance in host-parasite interactions, when there is a host regulative effect by the parasite; and non-reciprocal balance, when there is no host regulative effect by the parasite. In regard to intrinsic competition, the same author (op cit.) explains that it consists of interference between individuals of the interacting populations,manifested by such factors as cannibalism, mutualism, starvation, suffocation and production of toxic or repellent excretions and secretions. On extrinsic competition he refers to interaction of populations as groups and manifested mainly by host-habitat finding, host-finding and host-acceptance.

In the same way Istock (1967) observed a transient competitive displacement of Dineutes nigrior by D. horni in a northern Michigan pond and the uniform rate of displacement during one larval generation was estimated. He concluded that competitive displacement and competitive coexistence are the results of high and low rates of displacement, the first leading to species sorting in the communities, whereas the second may contribute to community stability and, if prolonged, to diversifying evolution.

On the other hand, Ross (1957) in Illinois, showed that several species of sycamore leafhoppers, comprising a complex of the genus Erythroneura, may occupy the same ecological niche at the same time. During the period of his study interspecific competition did not occur and his observations indicate that in the entire genus Erythroneura, if interspecific competition occurs, it is sporadic and local.

Evidence for interspecific competition in natural populations of the Monarch and Queen Butterflies, Danaus plexippus and D. gilippus berenice in South Central Florida was suggested by 1) the fact that there is a periodic change between extensive sympatry and nearly complete allopatry as the annual migration cycle of the Monarch occurs; 2) the fact that the reduction in numbers of the Monarch coincided with the build-up of the Queen population and that during the heavy spring breeding of the Monarch, the Queen females avoided the most common species of Asclepias food plant but later readily oviposited on it after most of the Monarch had left (Brower 1962).

Competition among three parasites of the spotted alfalfa aphid, Therioaphis maculata (Buckton) was found in the laboratory studies due to such factors as the ability to find host rapidly, to oviposit rapidly and frequently, and to parasitize young aphids before they become attractive to other parasite species (Force and Messenger 1965).

The phenomenon of interspecific competition among insect parasites has been analyzed by Smith (1929), who concluded that in such competition two types can be distinguished; one type refers to the competition between parasitic larvae within the body of the host (intrinsic competition); the other type refers to environmental relationships of the adult parasites outside the host (extrinsic competition), such as fighting among adults or differential survival to physical factors.

With mirid populations, only Richards (1963) has made a study of this type. After trying to determine some factors controlling five species of mirid insects living in Scotch broom in England, he concluded that the complexity of the relations of these species with one another is such as to discourage one from attempting to construct any simple mathematical model. In relation to Lygus populations, investigations were made on the fluctuations of populations of Lygus hesperus Knight, in alfalfa in Arizona (Butler and Wardecker 1970). They emphasized the effects of lygus bugs on a particular crop, the intercrop migration and the seasonal trend of the population. Lindquist and Sorensen (1970) show that the

tarnished plant bug increase on aphid-susceptible varieties of alfalfa was 123.2% compared with 17.6% on aphid-resistant varieties. They observed tarnished plant bugs feeding on pea aphids, Acyrthosiphon pisum (Harris), and on spotted alfalfa aphids, Therioaphis maculata (Buckton).

It can be seen by reviewing the more recent literature, that studies on competitive interactions are of importance in applied entomology. The present studies having this in mind, were aimed toward examining the possibilities of any interspecific competition between the tarnished plant and the alfalfa plant bug that may have applications in future studies of management of these pests in Michigan.

METHODS

The present work was carried out both in the field and under laboratory conditions. Field studies were made on alfalfa fields, 'Vernal' variety, at Michigan State University, East Lansing. Five unsprayed alfalfa fields were chosen and a weekly survey of all mirid species was done in them. In each of these fields, five different places were chosen as a good representative sample, four in the corner areas and one in the central area of each field. The insects were collected by sweeping 20 times with a standard 15 inch diameter net on each area of the field. All insects were placed in glass jars with 70% alcohol and the sorting and counting process was done in the laboratory. The sorting for the mirid complex was made using the method developed by Dr. Ruppel (unpublished) at Michigan State University, and included the adult and immature stages of all of the mirids found by sweeping. With Ruppel's procedure, the samples collected in each glass jar were poured in a plastic funnel, 11 inches wide, containing 70% alcohol and a sieve with 1/4 inch mesh at the top, thus the debris was held in the sieve or floated on the surface of the alcohol and the insects sank to the bottom where they were taken out by means of a rubber tube and a clip for counting and preserving them.

The daily activity of the mirids in alfalfa fields was recorded by sampling on three different days at 5:00 and 11:00 a.m., and 7:00 and 11:00 p.m.; collecting, sorting and counting the insects as the field studies mentioned before were done. The following

observations were also made on field conditions: hosts other than alfalfa, habits of feeding, movement and oviposition, natural enemies, and date and frequency of cutting of the host plant.

The laboratory studies were undertaken by collecting adult tarnished plant bugs and alfalfa plant bugs and rearing them in incubators in the laboratory and the rearing chambers at the Pesticide Research Center. As the alfalfa plant is not satisfactory for rearing lygus bugs in the laboratory (Beards and Leigh 1960, Butler 1968), green pods of the common bean (Phaseolus vulgaris L.) were used as a food source and for oviposition. Some of the bean pods were bought in the market and others were grown in the greenhouses. This rearing procedure followed that outlined by Ridgway and Gyrisco (1960), with some modifications. The pods were held in small plastic containers and placed in the incubator at 78-80°F, with a light provided by a flourescent lamp for 16 hours a day, and 65 ± 5% R.H. The rearing included both the tarnished plant bug, and the most abundant other mirid, the alfalfa plant bug. Both species were reared together in the same cage, and each species separated for observations of interspecific relationships, especially any competitive interaction.

The experimental design can be specified as follows:

Treatment	Replications	Code	Population Category
1	6	E	Mixed species, TPB and APB, 5 pairs (5 males and 5 females) of each species.
2	6	C	Single species, TPB, 5 pairs (5 males and 5 females)
3	6	C	Single species, APB, 5 pairs (5 males and 5 females)

Observations were made of both adult and immature stages of natural enemies that they may have had by dissecting and examining them for parasites. Records were made of the stage attacked, the numbers and the species of some parasites and predators found in the field.

BIOLOGY OF THE TARNISHED PLANT BUG AND THE ALFALFA PLANT BUG

TARNISHED PLANT BUG

Hosts.- The literature about the tarnished plant bug shows extensive records of serious injury to many cultivated plants in this country (Crosby and Leonard 1914, Porter 1926, Stitt 1945, Scholl and Medler 1947, Taksdal 1963, Niemczyk and Guyer 1963, Broersma and Luckman 1970). It shows the wide host range which includes more than 120 plant species varying from economically important

plants such as apple, pear, apricot, peach, strawberry, grape, potato, beans, beets, corn, wheat, and alfalfa, to wild and less economically important ones such as horsenettle (Solanum carolinense L.), barnyard grass (Echinochloa crusgalli L.), daisy fleabane (Erigeron ramosus Walt.), and many others. In the present studies an attempt was made to identify other weeds where the bugs were observed feeding. A list of these weeds follows:

Lady's thumb (Polygonum persicaria L.)

Lambs quarter (Chenopodium album L.)

Rabbit foot clover (Trifolium arvense L.)

Rag weed (Ambrosia elatior L.)

Rough pig weed (Amaranthus retroflexus L.)

Spotted knapweed (Centaurea maculosa Lam.)

Mouse-ear chickweed (Cerostium vulgatum L.)

Dandelion (Taraxacum officinale Weber)

Old-witch grass (Panicum capillare L.)

Common mullen (Verbascum thapsus L.)

Bull thistle (Cirsium vulgare L.)

Yellow nut grass (Cyperus exculentus L.)

Sow thistle (Sonchus arvensis L.)

Quackgrass (Agropyron repeus L.)

Foxtail grass (Setaria spp.)

It is difficult to classify the most and least preferred host weeds because of the migratory habit of the tarnished plant bug. When disturbed they move slowly around the stem or flower where they are or move from one flower raceme to another on the same

or a different plant. When the destruction or removal of insect food is made, as in alfalfa cutting, subsequent migration of these mirids to adjacent food plants may result. Conversely, it was observed that when a weed field is cleaned up, the collection made in the adjacent alfalfa field was higher than normal.

Feeding habits.- Apparently the tarnished plant bug prefers to feed on buds, flowers, tip leaves and other tender plant tissues. However, groups of 2 to 8 bugs were frequently found feeding together in a characteristic radial way on the stem immediately below the petioles of some leaves of spotted knapweed (Centaurea maculosa Lam.) in alfalfa fields.

Below the petiole, they remain immobile for a long time, being observed for about one hour on different days; one by one they were moving short distances, taking different directions and setting down on alfalfa or other plants. Some small galls probably produced by these insects were observed on the stem below the petiole where the bugs were feeding. Also, their excrement was found to produce a kind of damage like a burned spot of a cigarette, the size of a pin head.

Overwintering.- It has been stated that the tarnished plant bugs overwinter in the adult stage. They hibernate under fallen leaves and trash of alfalfa, clover, and orchards and alongside hedges, under stones, loose bark of dead trees and crevices and other protected places in the ground. Some bugs do

not go into hibernation until the advent of the actual cold weather. I have swept them from alfalfa fields as late as November 17th at the Michigan State University farms. On the other hand, Zia-ud-Din (1950) observed that the cold winter of Michigan causes a heavy mortality of the overwintering adults.

Spring appearance.- Adults of tarnished plant bug which were able to pass the winter in this stage were swept from alfalfa fields at the Michigan State University farms on May third, 1971. They were feeding on the tender shoots and leaves of alfalfa. The literature reports that the insect at this time does not breed to any extent on opening buds of apple, pear, quince or plum that they attack, but in such plants like clover, alfalfa, or grassy fields and low weeds (Crosby and Leonard 1914).

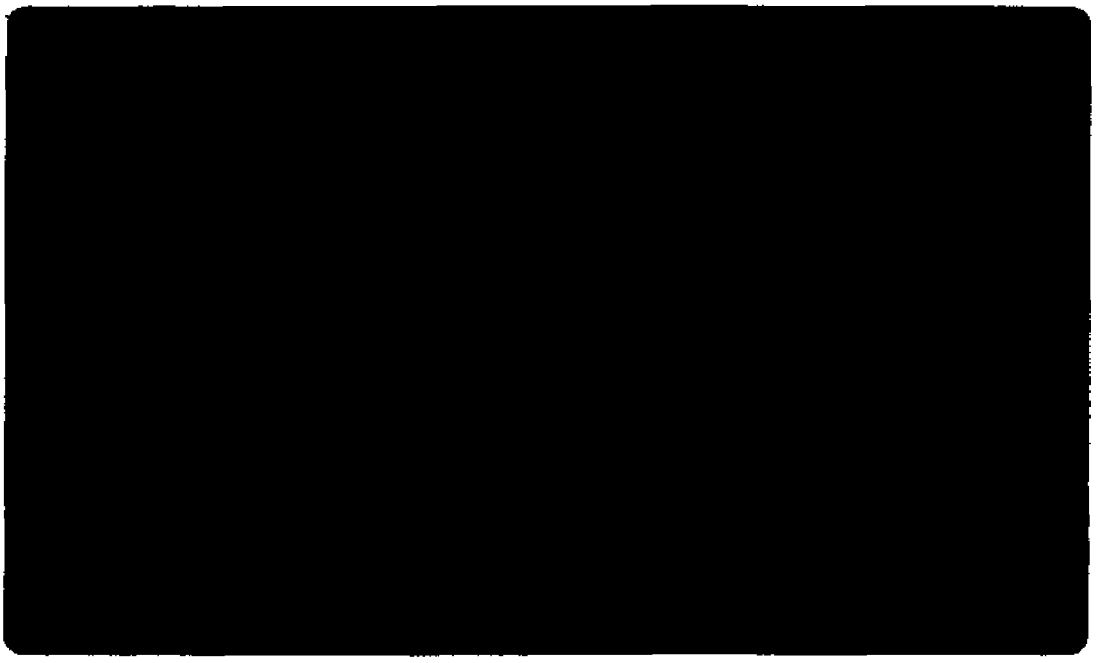
Oviposition.- According to Crosby and Leonard (1914), the tarnished plant bug lays eggs in the midribs of leaves and leaf petiole of those plants it usually feeds on. Eggs are also inserted, scattered and in irregular rows or groups, into tender tips, blossom buds, stems, and leaves of the plants, and in some cases, the eggs are deposited in the flower heads of various species of composite plants such as daisies, asters, horsenettle and others. Crosby and Leonard (op cit.) observed that the eggs stage was about 10 days. In the present study by rearing this insect at laboratory conditions, the egg stage was about 6.68 days, the minimimum being 5 days and the maximum 13 days, at 78-80°F, and 65 ± 5%

R.H. (Table 1). The number of eggs laid by a female was observed in the laboratory to be about 24, with a minimum of 5 eggs and a maximum of 60, with common bean pods as oviposition sites, but the numbers of eggs laid varied with the individual from day to day. The eggs are laid one by one and inserted into the plant tissue almost completely (Fig. 1). In some cases the beans were invaded by fungus but the eggs still hatched (Fig. 2). From the number of eggs laid, a mean of 23.14% reached the adult stage (first generation), 9.55% of the second generation, and 7.67%, 6.75%, and 9.48% of the third, fourth, and fifth generations, respectively (Table 2).

Nymphal stages.- The mean developmental period of the five instars of the tarnished plant bug was 16.9 days; these results being almost the same as those obtained by Hughes (1943) in St. Paul, Minnesota. The variation factor in this nymphal development apparently was due to the amount of food available and the population density inside the rearing cages. The nymphal development has been described in detail by different authors. After the third nymphal instar the development of wing pads may be observed. In the fourth instar the wing pads are clearly evident while in the fifth instar the wing pads usually extend back to the middle of the abdomen (Fig. 3). Apparently, in the nymphal stage the bugs migrate very little.

Figure 1. Tarnished plant bug ovipositing in the peeled area of a bean pod at laboratory conditions.

Figure 2. Common bean pod attacked by a fungus infection, however, the eggs were still viable.



Adults.- As a rule the males are somewhat darker and smaller than the females. During this study mating was never observed. However, the females did start laying eggs about 9.35 days after they reached the adult stage.

Adults and nymphs are very active during the summer. According to field samples there was no significant difference in the activities of this bug at different times of day and even with different weather conditions such as sunny and cloudy, windy or calm days. They reach maximum densities about early summer, and because of the cutting of the fields their numbers go down, but increase again to the same peak at the end of the season, decreasing again with the coming fall.

Migration.- There is evidence of the migratory habit of the tarnished plant bug especially as caused by cutting or removal of food (Scholl and Medler 1947). The most important factor for migration would probably be the wide host range (polyphagous habit) of this insect. If the alfalfa field is cut, they may migrate to clover fields, cereal plantings or grassy or weedy fields where they can also breed and build up populations. During the present study,a few cases were observed where the cutting of weedy fields adjacent to the sampling area brought about a considerable increase in the size of the sample.

Natural enemies.- Studies to determine the status of the tarnished plant bug parasites and predators were previously

Table 1. Rate of development in days of the tarnished plant bug at laboratory conditions (78-80°F) in five different replications reared from 29 March to 1 December 1971. East Lansing, Michigan. 1971.

Group Number	Statistics	Hatching	Second Instar	Fifth Instar	Adults	Eggs	Total Duration	Adult Longevity
	Total*	166	105	193	110	237	809	970
1	Mean	6.64	4.20	7.72	4.4	9.48	32.36	38.80
	Std.Dev.	1.04	.91	1.21	1.0	2.35	2.56	8.89
	Total	161	101	187	114	224	786	964
2	Mean	6.44	4.04	7.48	4.56	8.96	31.44	38.56
	Std.Dev.	1.23	1.06	1.39	1.73	1.81	2.72	9.45
	Total	137	81	157	97	197	669	845
3	Mean	6.85	4.05	7.85	4.85	9.85	33.45	42.25
	Std.Dev.	1.34	.99	1.23	1.59	2.68	3.78	15.65
	Total	138	84	161	88	179	648	743
4	Mean	6.90	4.29	8.05	4.4	8.95	32.40	37.15
	Std.Dev.	1.02	1.24	1.60	1.6	1.96	2.28	8.82
	Total	131	82	145	82	210	652	804
5	Mean	6.55	4.10	7.25	4.1	10.50	32.60	40.20
	Std.Dev.	.83	.97	1.25	1.48	2.95	3.25	8.26

* The counts were based on 25 reared individuals on each replication.

Table 2. Summary of population numbers in five generations of tarnished plant bug eggs, nymphs, and adults, reared at laboratory conditions (78-80°F, and 65 ± 5% RH) with five replications, from March 29 through December 1, 1971. East Lansing, Michigan.

Generation	Replic. 1	%	Replic. 2	%	Replic. 3	%	Replic. 4	%	Replic. 5	%
Parents	10		10		10		10		10	
Eggs	298		110		117		149		86	
Adults F_1	70	23.49	32	29.09	14	11.97	45	30.20	18	20.93
Eggs	2018		1081		900		912		1063	
Nymph 2nd l.	253		263		175		310		343	
Nymph 5th l.	144		97		141		135		180	
Adults F_2	101	5.00	75	6.94	135	15.00	81	8.88	127	11.95
Eggs	1854		2033		2069		2638		3701	
Nymph 2nd l.	238		278		149		336		285	
Nymph 5th l.	180		200		125		245		196	
Adults F_3	160	8.63	157	7.72	112	5.41	223	8.45	250	8.14
Eggs	3460		3224		2509		2794		2723	
Nymph 2nd l.	333		228		275		308		382	
Nymph 5th l.	273		180		205		256		266	
Adults F_4	212	6.13	155	4.81	176	7.01	213	7.62	223	8.19
Eggs	2869		4798		2862		2682		3561	
Nymph 2nd l.	638		433		245		400		530	
Nymph 5th l.	518		300		209		272		423	
Adults F_5	435	15.16	233	4.86	187	6.53	260	9.69	399	11.20

summarized and recorded (Clancy and Pierce 1966). Several parasites were found in the families Mymaridae, Braconidae, Ichneumonidae and Tachinidae, in Canada and the United States. Among the predators, mostly polyphagous species of Hemiptera, Coleoptera and Neuroptera were recorded (Clancy and Pierce 1966). The more common species were Geocoris spp. and Nabis spp.

Painter (1929) reported parasitization of about 11% of the tarnished plant adults collected in swampy areas by the nematode Hexamermis spp.

By observation in the field during the years 1970 and 1971, the larva of the spotted lady-bird beetle, Coleomegilla maculata DeGeer, was found at different times feeding on fourth and fifth instar nymphs of the tarnished plant bug. Furthermore, a few toads, Bufo americanus Holbrook, were found and collected when sampling the alfalfa fields in 1970. In the dissection of four, two of them had seven tarnished plant bug adults in their gut. A small toad about 1 $\frac{1}{2}$ inches long had five tarnished plant bugs in its gut, one of them almost entirely whole; the others were identified by their heads. Organisms other than mirids were not counted in these two toads. The more abundant organisms found in the other toads were ants, millipedes, lygaeids, weevils (larvae and adults), elaterids (larvae and adults), noctuids (larvae) and coccinellids (larvae and adults) (Table 3).

In 1970, a recently killed tarnished plant bug was found infected with a fungous disease. This specimen was sent to the University of California at Berkeley for identification, and Dr. Gerard M. Thomas identified the fungus as an Hyphomycete. This fungus may have caused

Table 3. Organisms found in the gut of four toads, Bufo americanus, picked up from alfalfa fields, East Lansing, Michigan. 1970.

Organisms	Toad Number			
	1	2[a]	3	4
Ants-adults	12	0	0	0
Millipedes	8	0	0	0
Lygaeids-adults	6	0	0	0
Elaterids-adults	5	2	0	0
Weevils-adults	4	0	0	0
Weevils-larvae	7	0	0	0
Centipedes	4	0	0	0
Staphylinids-adults	4	2	0	0
Flies	1	0	0	0
Coccinellids	0	3	0	0
Noctuids-larvae	0	5	0	0
Corizids-adults	0	2	0	0
Tarnished plant bugs	0	0	5	2
Unidentified-larvae	2	0	0	0
Nabids-adults	0	2	0	0

[a] All kinds of body parts of insects and millipedes were found in this toad and were difficult to identify.

a number of other unexplained adult deaths found in the field and was perhaps not always detected in the early stages of infection or may have developed later in the season after sampling had ceased.

ALFALFA PLANT BUG

By reviewing the pertinent literature and by means of the present studies on the biology of the alfalfa plant bug, the following features may be observed.

Hosts.- The alfalfa plant bug has been reported to feed especially on alfalfa and clovers and, in some cases, on potatoes, buckwheat, golden rod, and beans. When disturbed in alfalfa fields, this bug moves a greater distance than the tarnished plant bug, but generally no more than twenty feet.

Feeding habits.- The alfalfa plant bug was always found alone on leaves, stems, or buds, feeding or resting in an upwards or downwards position. They are more readily disturbed than the tarnished plant bug, and even the gravid females, which were heavier than the other bugs, were able to fly short distances when disturbed.

Overwintering.- The alfalfa plant bug overwinters in the egg stage in Michigan, especially in the stubble of alfalfa. The eggs in these stems hatch in early May. Temperature probably has a bearing on the length of the hatching time (Hughes 1943),

although Knight (1941) states that these mirid eggs have a relatively impermeable chorion which permits them to remain viable for several months, even embedded in material which is almost completely desiccated. In the present work, several alfalfa stems with alfalfa plant bug eggs embedded in them were brought to the laboratory in mid-October, 1971. These eggs were carefully taken out and placed in small plastic containers with humid filter paper in the bottom. These cages were kept in incubators at 78-80°F, and 65 ± 5% RH, and 16 hours of light provided by a flourescent lamp. The filter paper was moistened every day and observations were conducted as to the dates of nymphal emergence. The first nymphs appeared at 17 days; others spent 55 days and other emerged at 72 and 81 days after the eggs were placed in the incubators. Other unhatched eggs were observed to be still alive after this time.

The difference in time for these eggs to hatch is probably due to the fact that the alfalfa plant bug diapauses in the egg stage. As this could happen, the egg development would not be resumed until water in the plastic container is available, but only after the period of diapause development in the egg itself has been completed. There is the possibility that these eggs were laid at different times of the season, so those which were laid earlier probably completed their period of diapause and hatched earlier than the others that were laid later on. Obviously, much more research would be needed to state any conclusions on the alfalfa plant bug egg diapause.

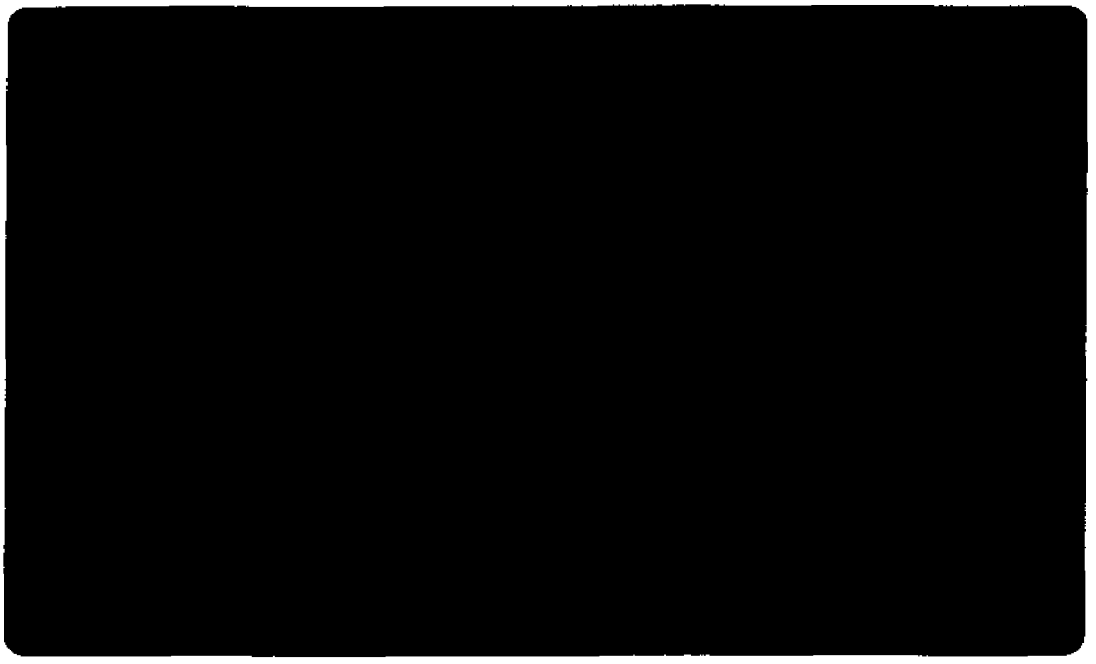
Spring appearance.- The first nymphs of alfalfa plant bugs were collected on the Michigan State University, East Lansing farms on June 4, 1970 and June 5, 1971, when they were feeding on the new tender alfalfa stems. This species exhibits a restricted host range (oligophagous), by feeding especially on alfalfa, sweet clover and a few additional plants including potatoes, buckwheat, golden rod and beans (Hughes 1943).

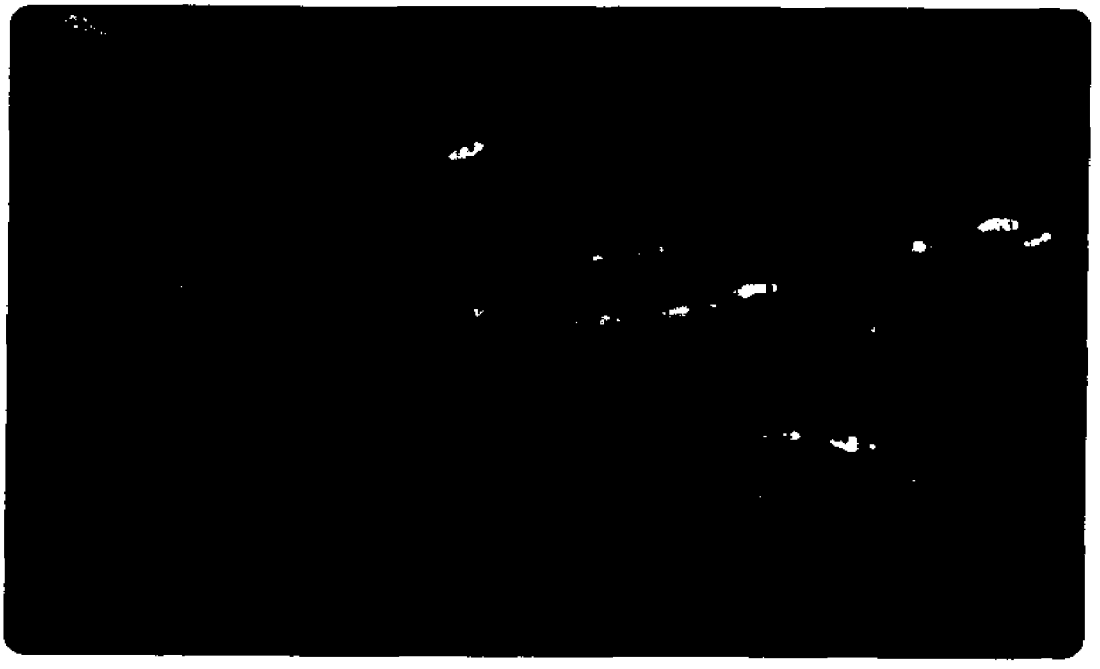
Oviposition.- The alfalfa plant bug is probably more specific than the tarnished plant bug in its oviposition habits. The alfalfa plant bug confines most egg laying to alfalfa stems. By observations in the field and when adults were confined in cages containing alfalfa plants in the laboratory, the insects seemed to choose the tender succulent growth, possibly because the stems were easy to puncture with their ovipositors. The eggs are laid closely together in groups or rows, being a little bigger than those of the tarnished plant bug (Figure 4). In both of them, when rearing was done under laboratory conditions, the egg caps protruded slightly above the epidermis of the bean pod.

Nymphal stages.- The mean developmental period of the five instars of the alfalfa plant bug has been states as 18.47, and 28.30 days after mean temperatures of 79.28 and 62.74°F, respectively, the temperature being the most important factor in the length of time required for successive instars to emberge (Hughes op.cit). The higher the mean temperature, the shorter the nymphal period.

Figure 3. Tarnished plant bug emerging from the fifth nymphal instar.

Figure 4. Alfalfa plant bug eggs laid in a common bean pod at laboratory conditions.





Adults.- The first alfalfa plant bugs collected by sweeping in the field were taken at the Michigan State University farms on June 2nd, 1970. The adults are active in alfalfa fields and fly readily when disturbed, usually only to adjacent plants, but they are not considered strong fliers, so spread is probably due to gradual migration and occasionally, they may be transported long distances in hay in the egg stage.

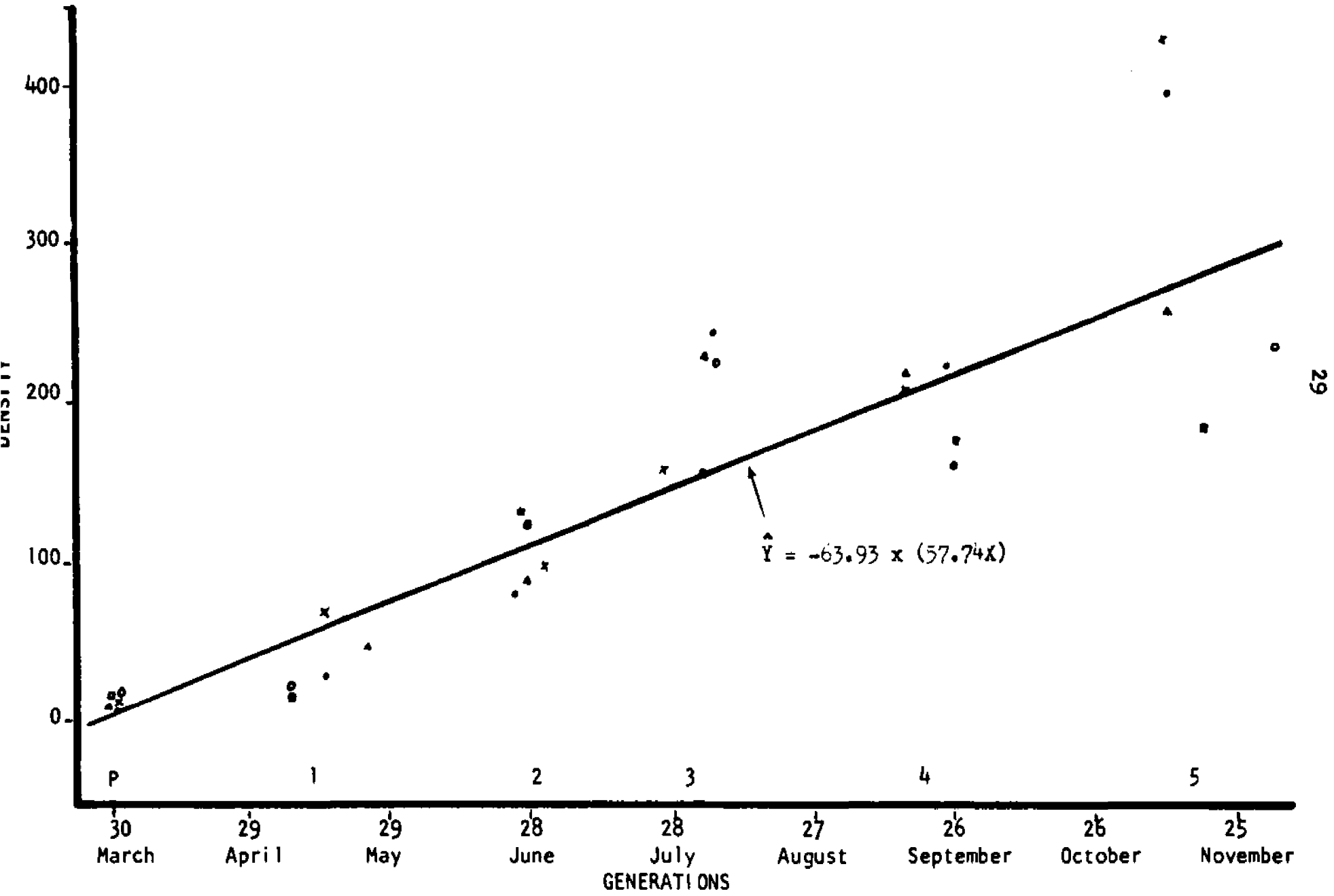
Natural enemies.- During the present study period, no natural enemies were observed for the alfalfa plant bug, and none of them have been reported by the literature. This does not mean that it does not have them.

LABORATORY REARING

The rearing process for the tarnished plant bug was carried out with relative success in the laboratory under a controlled temperature of 78-80°F, with a relative humidity of 65 ± 5%, and with light provided by a flourescent lamp for 16 hours a day. Initially, the process was performed with some difficulties, as many specimens died without reproduction at all or at least without laying eggs. However, gradually the techniques of rearing them in the incubators were improved, so data could be recorded.

Five successive generations were reared with five groups of tarnished plant bugs, starting with five pairs as parental generations. The adults for the five generations are presented graphically in Figure 5, and the complete data are presented in Tables 1 and 2. Counts of different stages of the tarnished plant bugs were taken at 2 day intervals during the year of 1971. Mortality of tarnished plant bugs during the rearing process was high, as can be seen in Table 2, especially in the immature stages, and some specimens were injured by handling. Those injured and some dead individuals were usually attacked by normal adults and nymphs, a cannibalistic habit that was observed throughout the whole laboratory rearing of the tarnished plant bug. In contrast, the alfalfa plant bug did not show any cannibalism at all. This kind of intraspecific competition might affect the status of these two mirid species in their competitive interference with each other. It was observed that in some cases, some specimens that first reached the adult stage fed on the other nymphal stages, especially on those after the second instar. It

Figure 5. Regression line of number of tarnished plant bug reared under laboratory conditions, on generation.


400
300
200
100
0
29
$\hat{Y}$ = -63.93 x (57.74X)
P
1
2
3
4
5
30 March
29 April
29 May
28 June
28 July
27 August
26 September
26 October
25 November
GENERATIONS

seemed that this condition was one of the highest mortality factors, after lack of food, for the last three nymphal instars. Only the counts of the adults are presented because it is believed that this stage is more reliable in demonstrating population peaks in a particular generation from the reproductive standpoint.

It was observed during the present studies that the different stages of the tarnished plant bug are quite variable in the length of time required for their development. The first and fifth instars were the longer stages in this study. These data agree, for the most part, with that presented by Hughes (1943) on the time required for nymphal development. The hatching period in the five different replications showed a mean ranging from 6.44 to 6.90 days. The first instar had a mean period of 4.04 to 4.20 days, and the fifth instar a mean of 4.1 to 4.85 days (Table 1). The five replications of insects showed a mean preoviposition period ranging from 8.95 to 10.50 days, and the adult longevity a mean of 37.15 to 42.25 days.

The alfalfa plant bug was only reared during the parental generation. They were feeding and ovipositing in the bean pods, but the eggs did not hatch and the bean pods got dry. Therefore, only the tarnished plant bug was reared up to the fifth generation, when it was stopped arbitrarily.

The number of eggs laid in bean pods by the parental generations of tarnished and alfalfa plant bugs, when caged together and separately is presented in Table 4.

Table 4. Comparison of the number of eggs laid in common beans by the parental generations of the tarnished and alfalfa plant bugs, reared mixed and singly in groups of five pairs, at 78-80°F and 65 ± 5% RH, East Lansing, Michigan. 1971.

Replic. Number	Date	Number of eggs laid			
		Mixed		Singly	
		TPB	APB	TPB	APB
1	7/29/71 to 8/14/71	142	119[a]	777	230
2	7/29/71 to 8/20/71	181	210	1919	236
3	7/29/71 to 8/12/71	98	189	1019	178
4	7/29/71 to 8/12/71	171	17	1340	284
5	7/29/71 to 8/12/71	54	122	911	248
6	7/29/71 to 8/12/71	48	74	b	317
	Means	115.67	120.17	1193.2	248.83

[a] The alfalfa plant bug eggs died and the process could not be followed for more than one generation.

[b] Data not registered.

The tarnished plant bug eggs, when the insects were reared alone, significantly outnumbered either the alfalfa plant bug alone, or the tarnished plant bug mixed with the alfalfa plant bug. It was observed that the tarnished plant bug females were even laying eggs several weeks after the males had died, in such a way that oviposition was accomplished without contact between sexes, probably because the females mate once and ovigenesis continues after oviposition has begun.

Oviposition in the tarnished plant bug was favored by peeling a small strip of the bean pods longitudinally or cutting an end. In this way oviposition was concentrated in those areas of the bean and eggs were easily counted. Most of the alfalfa plant bug eggs were observed laid close to the junction of the petiole of the bean, even though they laid some eggs on the peeled area of the beans. On several occasions, the beans were attacked by fungus where peeling or cutting was made. However, most of the nymphs hatched. The alfalfa plant bug eggs, when the insects were reared alone significantly outnumbered the tarnished plant bug eggs and alfalfa plant bug eggs when the insects were reared together during the parental generation (Table 4). In six replications of each species during the present work, the alfalfa plant bug eggs slightly outnumbered the tarnished plant bug, when reared together. But, as these alfalfa plant bug eggs did not hatch, the observations could not be followed for subsequent generations.

FIELD STUDIES

The samples of the mirid complex taken in alfalfa fields at Michigan State University, East Lansing, from May 19 to November 17 of 1970, and from May 3 to November 3 of 1971, are presented in detail in Tables 5 and 6, and showed graphically in Figures 6-13. Of foremost importance in this study are the tarnished plant bug and the alfalfa plant bug. These two pests occur throughout much of the Eastern United States.

Tarnished plant bug.- The first mirid bugs of the complex to show up were the tarnished plant bugs, probably because of their habit of overwintering in the adult stage. With the sample taken on May 3, 1971 the population density was 2 in five fields and a total of 500 sweeps. The population densities gradually increased up to the time of the first cutting in early June, when some of them possibly died or migrated to the closest fields, and some of them remained on the ground and fed on the young stems and buds after cutting. Some others may appear after the overwintering stage under leaves, straw, crevices and vegetable material left in the field; so when sweeping after cutting, some adult bugs are collected.

The adult population peak after the first cutting was reached in early July in 1970, and in mid-July, 1971, when the alfalfa fields in both years were flowering the most (Figures 6 and 7). By this time the second cutting was done and the population densities went down to about one fourth the previous peak. After this cutting, the

Table 5. Comparison of the population densities of three plant bugs as collected by sweeping in five fields at the Michigan State University farm, East Lansing, Michigan. 1970.

Date		Accumulated Days	Tarnished Plant Bug		Alfalfa Plant Bug		*Trigonotylus ruficornis*
			Adults	Nymphs	Adults	Nymphs	Adults[b]
May	19	139	59	0	0	0	0
	29	149	84	0	0	0	0
June	5	156	103	70	2	22	2
	12	163[a]	14	95	4	1	4
	19	170	83	23	23	7	1
	23	174	43	1	4	9	0
July	1	182	140	1	27	24	0
	11	192	605	29	37	69	46
	15	196	434	90	36	118	77
	21	202[a]	319	121	16	145	139
	31	212	108	124	90	245	121
August	4	216	195	326	127	510	164
	10	222	282	486	162	753	118
	17	229	448	166	163	729	30
	24	236[a]	427	117	184	575	193
September	2	245	368	183	146	396	207
	8	251	351	472	214	446	245
	16	259	827	905	216	231	135
	21	264	581	399	177	118	56
	28	271	616	231	125	97	16
October	5	278	417	164	81	52	4
	12	283	719	117	105	41	29
	21	292	300	42	44	21	5
	27	298	188	11	15	0	2
November	3	305	185	8	20	0	0
	11	313	151	4	8	0	0
	17	319	10	0	1	0	0

[a] Cutting

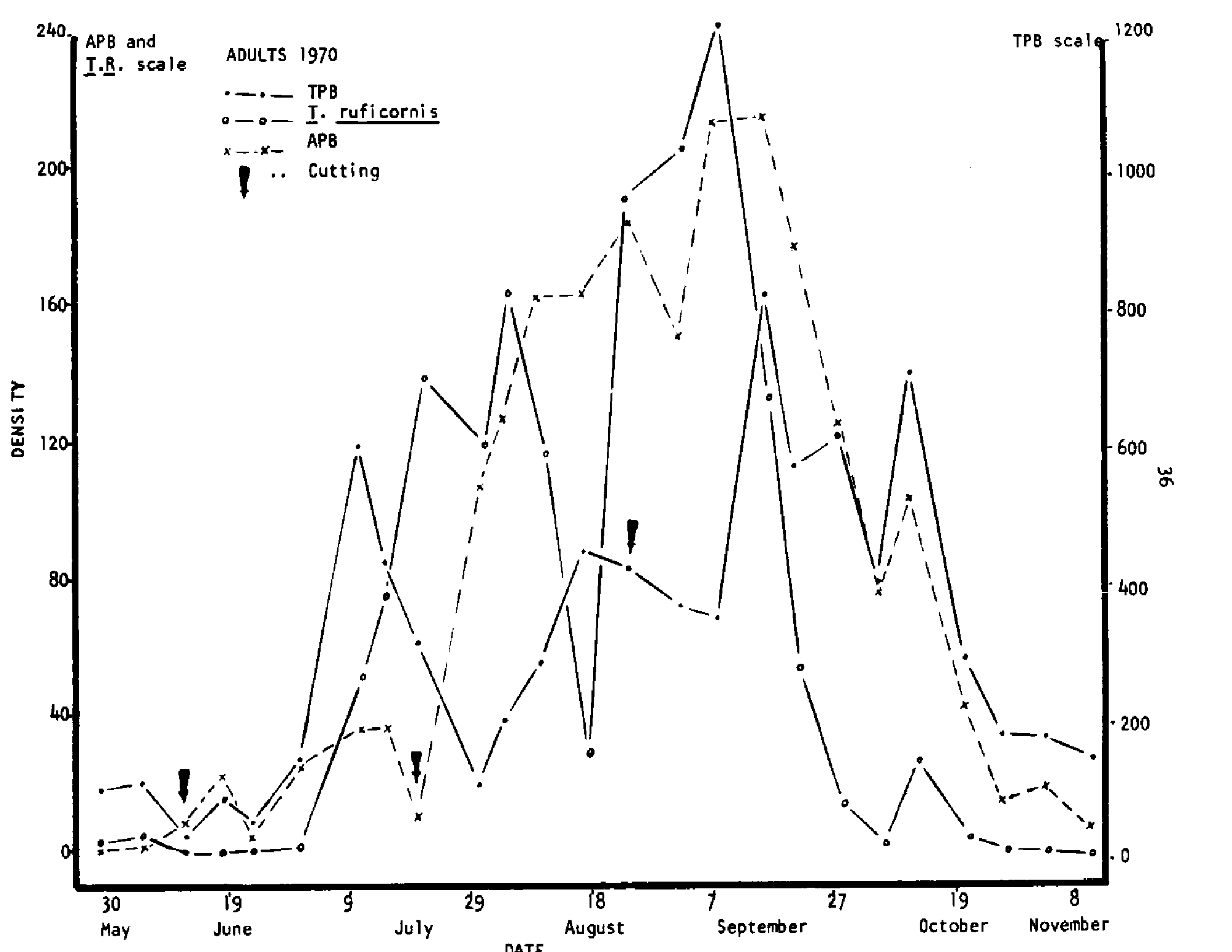
[b] Nymphs for this species were not counted.

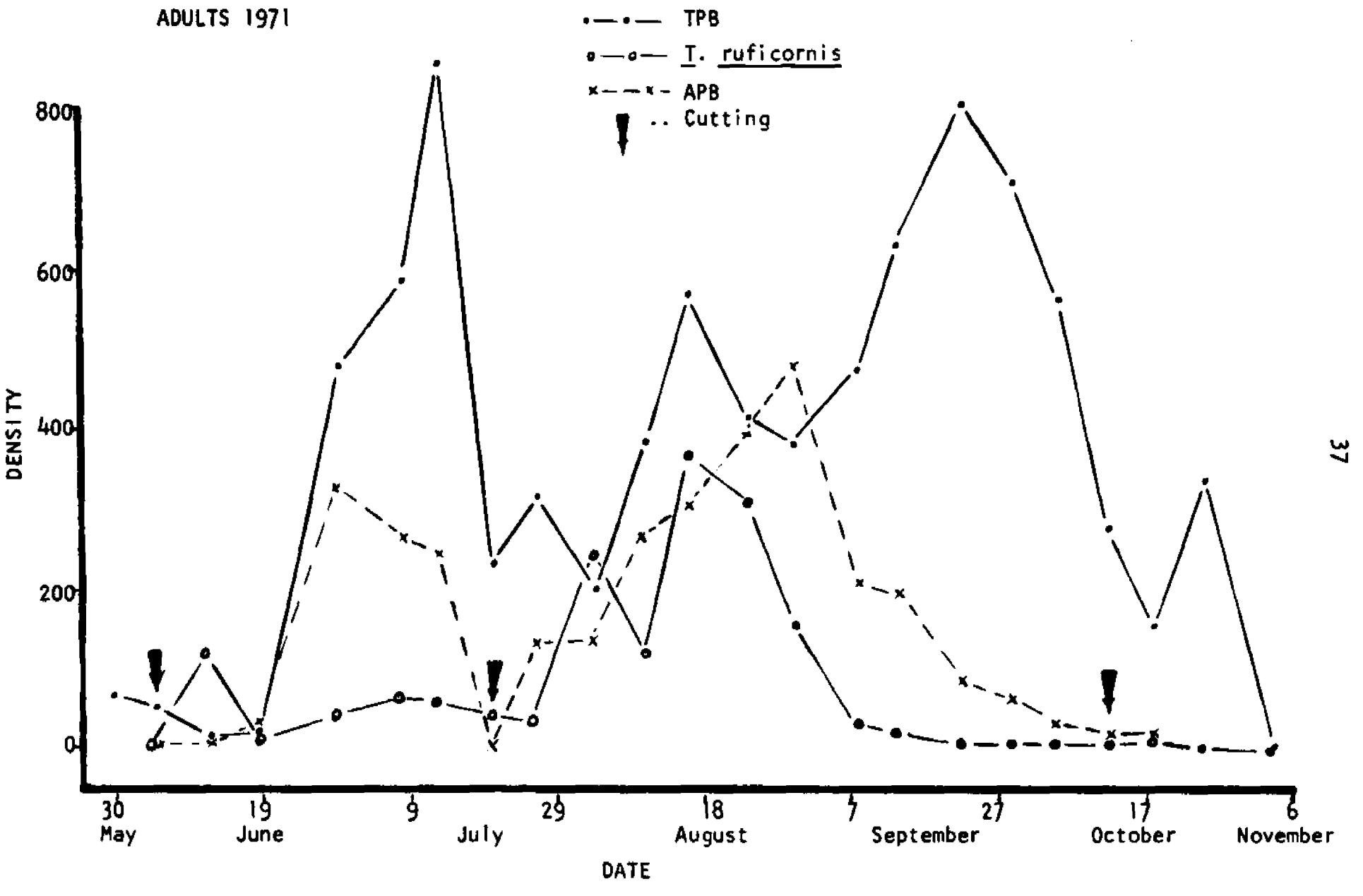
Table 6. Comparison of the population densities of three plant bugs as collected by sweeping in five fields at the Michigan State University farm, East Lansing, Michigan. 1971

Date		Accumulated Days	Tarnished Plant Bug		Alfalfa Plant Bug		*Trigonotylus ruficornis*	
			Adults	Nymphs	Adults	Nymphs	Adults	Nymphs
May	3	123	2	0	0	0	0	0
	12	132	4	0	0	0	0	0
	18	138	27	0	0	0	0	0
	29	149	67	0	0	1	0	0
June	4	155[a]	51	0	0	13	0	33
	11	162	13	69	6	214	116	371
	18	169	17	35	22	100	10	7
	29	180	482	8	355	67	42	2
July	8	189	590	32	277	164	65	3
	13	194	853	182	269	211	59	5
	20	201[a]	256	137	11	180	40	4
	26	207	312	309	133	370	39	7
August	3	215	201	377	138	554	245	61
	10	222	386	429	271	541	157	34
	16	228	568	372	307	491	370	25
	24	236	414	255	395	131	315	22
	30	242	382	361	474	81	152	14
September	8	251	478	1103	205	32	39	19
	13	256	625	1191	196	45	22	3
	22	265	800	490	81	25	8	0
	29	272	706	208	62	15	9	0
October	5	278	561	59	24	2	6	0
	12	285[a]	276	13	7	0	2	1
	18	291	151	5	2	0	8	0
	25	298	332	3	2	0	2	0
November	3	307	8	0	0	0	0	0

[a] Dates of cutting. The dry season probably caused the delay in the last cutting. This happened in only one field.

Figure 6. Population densities of the tarnished plant bug, the alfalfa plant bug, and Trigonotylus ruficornis during the 1970 season.


APB and T.R. scale
ADULTS 1970
TPB
T. ruficornis
APB
.. Cutting
TPB scale
DENSITY
240
200
160
120
80
40
0
1200
1000
800
600
400
200
0
30 May
19 June
9 July
29
18 August
7 September
27
19 October
8 November
DATE
36


ADULTS 1971
TPB
T. ruficornis
APB
Cutting
800
600
400
200
0
DENSITY
30 May
19 June
9 July
29
18 August
7 September
27
17 October
6 November
DATE

tarnished plant bug population increased as the alfalfa grew up, reaching the highest density in mid-September for 1970 and a week later in 1971. The tarnished plant bug populations went down after this time more rapidly than they had built up. Many factors probably took part in this event, such as the decreasing temperature that lead them to the overwintering stage; a third alfalfa cutting in some cases, and also, the effect of some biological agents, such as Nabis spp. and Geocoris spp. (which were observed in the field), possibly played an important role (Clancy and Pearce 1966), although no evidence of this was clearly noted in the present study.

Alfalfa plant bug.- The alfalfa plant bug populations appeared in lower densities and later than those of the tarnished plant bug (Tables 5 and 6). In 1970, the first adult bugs were swept about 15 days after the initial collection of tarnished plant bugs, and in 1971, they were collected more than one month later (Figures 6 and 7). These facts give more strength to the generally accepted concensus of the overwintering of the alfalfa plant bug in the egg stage, in contrast with the tarnished plant bug which overwinters in the adult stage.

Apparently the first cutting does not affect the initial increase of the alfalfa plant bug population, because at this time they are starting to hatch out from the overwintering egg stage in the old alfalfa stubble. Their population densities were increasing although relatively at low levels, reaching the highest peak about mid-September, and decreasing after that as rapidly as the tarnished plant bug in 1970.

The curve for 1971 (Figure 7) shows the effect of cutting, especially if the sample is taken the same week the cut is made. However, a week later, the numbers are about ten times more, reaching the highest density in late August, and decreasing later on to zero in mid-October.

Trigonotylus ruficornis.- This species slightly outnumbered the adult populations of the alfalfa plant bug during 1970, but were significantly inferior in numbers during 1971. The population reached two peaks during 1970; one in early August and another, the highest one, in early September. During 1971, the population only showed a small peak in about mid-August, being the last in the mirid complex that showed up and the first to disappear.

Nymphal stages.- The nymphal populations are also shown in Tables 5 and 6, and presented graphically in Figures 8 - 13. In 1970, this stage showed up early in the season for both the tarnished and alfalfa plant bugs. In 1971 alfalfa plant bug nymphs appeared first and in higher numbers than the tarnished plant bug. This may be explained by the overwintering of the former in egg stage and the latter in adult stage. The first alfalfa cutting did not seem to affect either one of the populations, possibly because of their low densities, and both in 1970 and 1971 the nymphal alfalfa plant bug densities were higher than those of the tarnished plant bug at the same time. The nymphal alfalfa plant bug peaks were reached first but their densities at this point were about half those reached

Figure 8. Nymphal population densities of the tarnished plant bug and the alfalfa plant bug during the 1970 season.

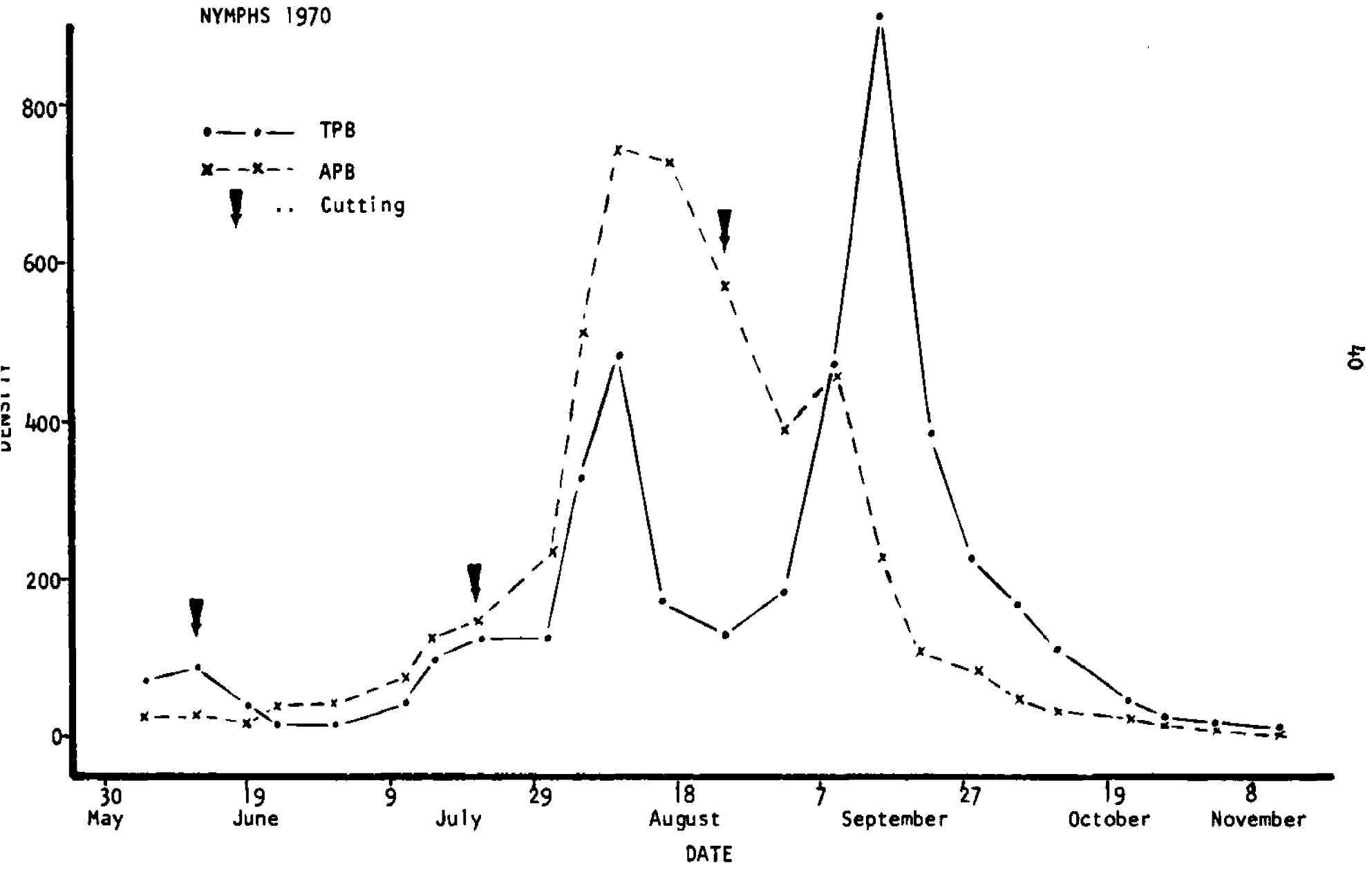
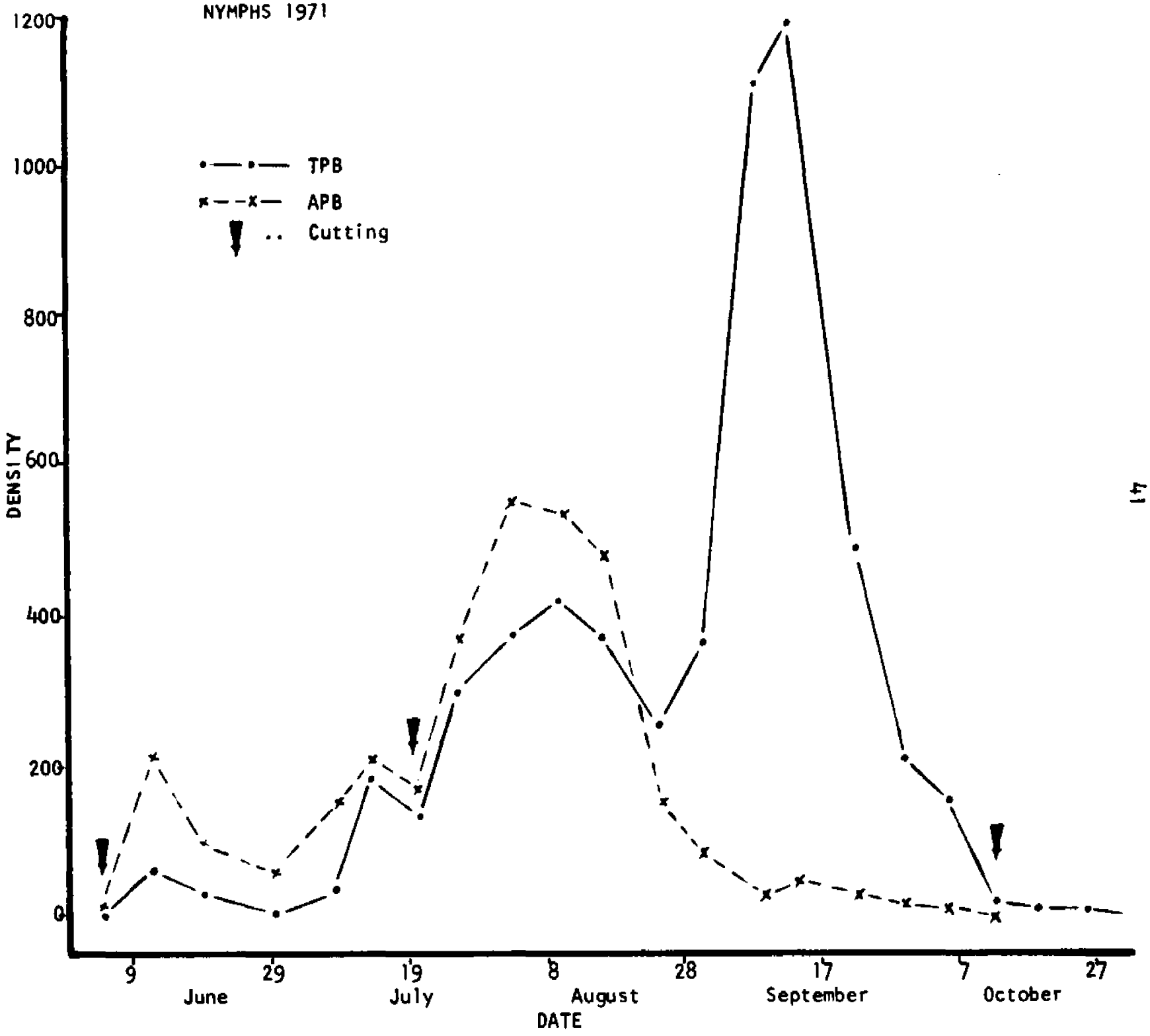

NYMPHS 1970
TPB
APB
Cutting
800
600
400
200
0
30 May
19 June
9 July
29
18 August
7 September
27
19 October
8 November
DATE

Figure 9. Nymphal population densities of the tarnished plant bug and the alfalfa plant bug during the 1971 season.

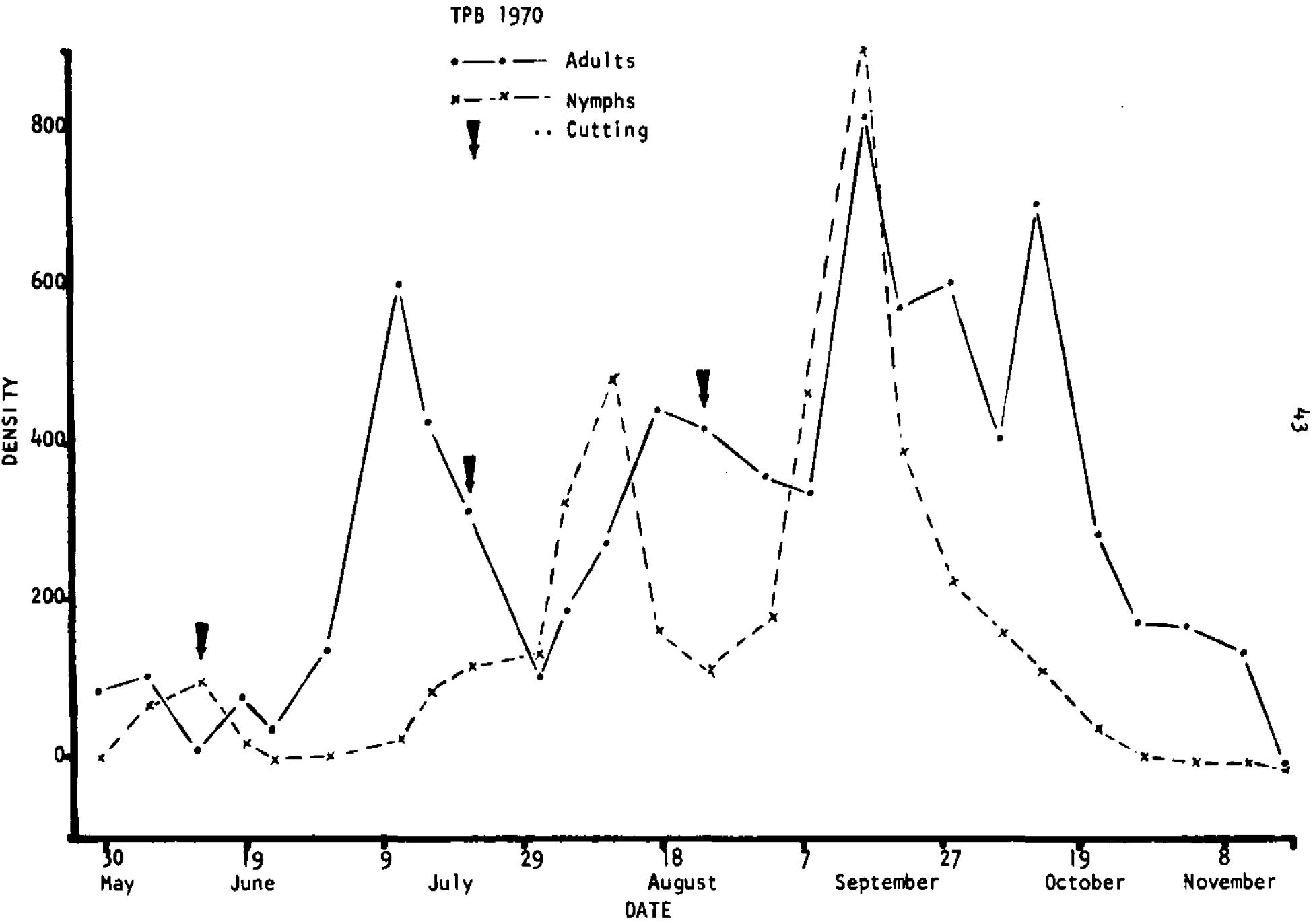

NYMPHS 1971
1200
1000
800
600
400
200
0
DENSITY
TPB
APB
.. Cutting
9
29
19
8
28
17
7
27
June
July
August
September
October
DATE

by the tarnished plant bug nymphs. This happened by mid-August. After this time the nymphal decreasing was evident, as the adult stage of the alfalfa plant bug was still increasing, to the point that by October 27, 1970, alfalfa plant bug nymphs were no longer collected with the sweep net. The last time alfalfa plant bugs were found in 1971 was October 5. The highest peak of nymphal populations in tarnished plant bug was reached by about mid-September in 1970 and also in 1971, after which they decreased and, by November 17, 1970, and November 3, 1971, no nymphal stages were found.

Nymphs-adults relationships.- The relationships between nymphs and adults of the tarnished and alfalfa plant bugs during the years 1970 and 1971 are presented graphically in Figures 10 - 13. During 1970, the nymphal population densities of the tarnished plant bug were relatively low in comparison with the adult populations early in the season, however, after the third alfalfa cutting, the nymphal densities were increasing in such a way that when the nymphs and adults reached their peak, the former was higher than the latter. After this time the nymphs decreased more rapidly than the adults. The last date that nymphs were found in the field was November 11, when 4 were collected. There were 151 adults in 500 sweeps (Figure 10).

During the year 1970, the nymphal population densities of the alfalfa plant bug reached a peak more than twice as high as that reached by the adult populations. The nymphs started to increase first and the decrease was also in the same way, showing only one

Figure 10. Relationships between adult and nymphal population densities of the tarnished plant bug during the 1970 season.


TPB 1970
Adults
Nymphs
Cutting
800
600
400
200
0
DENSITY
30 May
19 June
9 July
29
18 August
7 September
27
19 October
8 November
DATE

peak through the season. The last nymphs collected were on October 21 while the adults were still found on November 17 (Figure 11).

During the sampling made in 1971, the relationships between adult and nymph population densities of the tarnished plant bug were almost identical to that of the previous year. However, there were two peaks of adult density, the early one being a little higher (mid-July) than the later one (mid-September); the nymphs showed only a conspicuous peak about one fourth higher than the highest reached by the adult populations (Figure 12).

On the other hand, the alfalfa plant bug populations (adults and nymphs) were quite different during the same year: the adults showed two peaks (in late June and late August) with densities almost twice as high as the previous year and nymphs with only one conspicuous peak in early August, its density slightly outnumbering the highest adult peak (Fig. 13).

Summarizing, the tarnished plant bug population densities, both in 1970 and 1971, significantly outnumbered those of the alfalfa plant bug (Tables 5 and 6; Figs. 6 and 7), the former making up 80% and 72% of the two mirid populations at the end of each year, respectively. However, the nymphal population of the alfalfa plant bug comprised 54% of the two nymphal populations of the tarnished plant bug in 1970; again, the tarnished plant bug nymphal populations comprised 64% of the total of the two mirid nymphs at the end of 1971 (Tables 5 and 6; Figs. 8 and 9).

Figure 11. Relationships between adult and nymphal population densities of the alfalfa plant bug during the 1970 season.

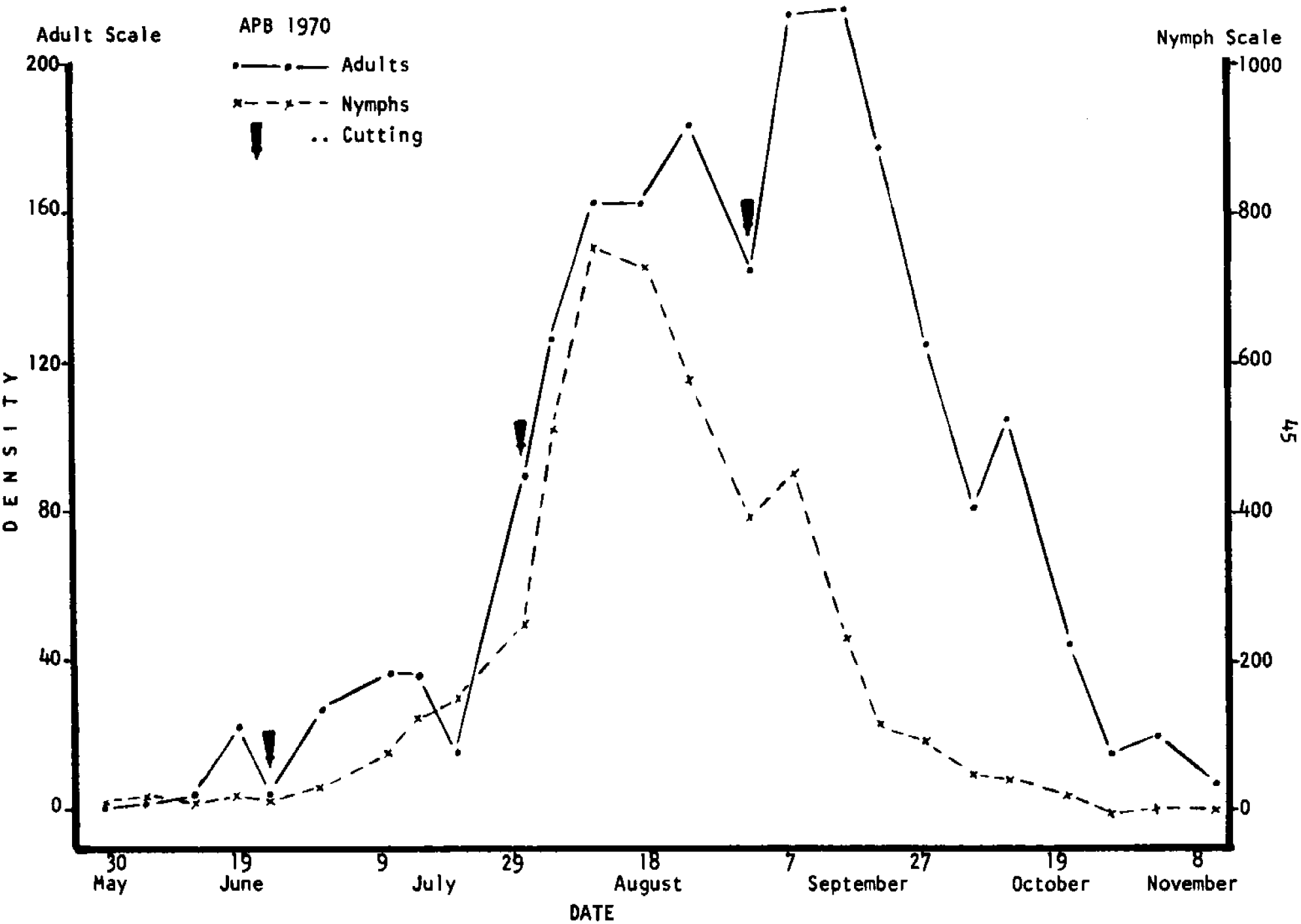

Adult Scale
APB 1970
Adults
Nymphs
.. Cutting
Nymph Scale
200
160
120
80
40
0
1000
800
600
400
200
0
DENSITY
45
30 May
19 June
9 July
29
18 August
7 September
27
19 October
8 November
DATE

Figure 12. Relationships between adult and nymphal population densities of the tarnished plant bug during the 1971 season.

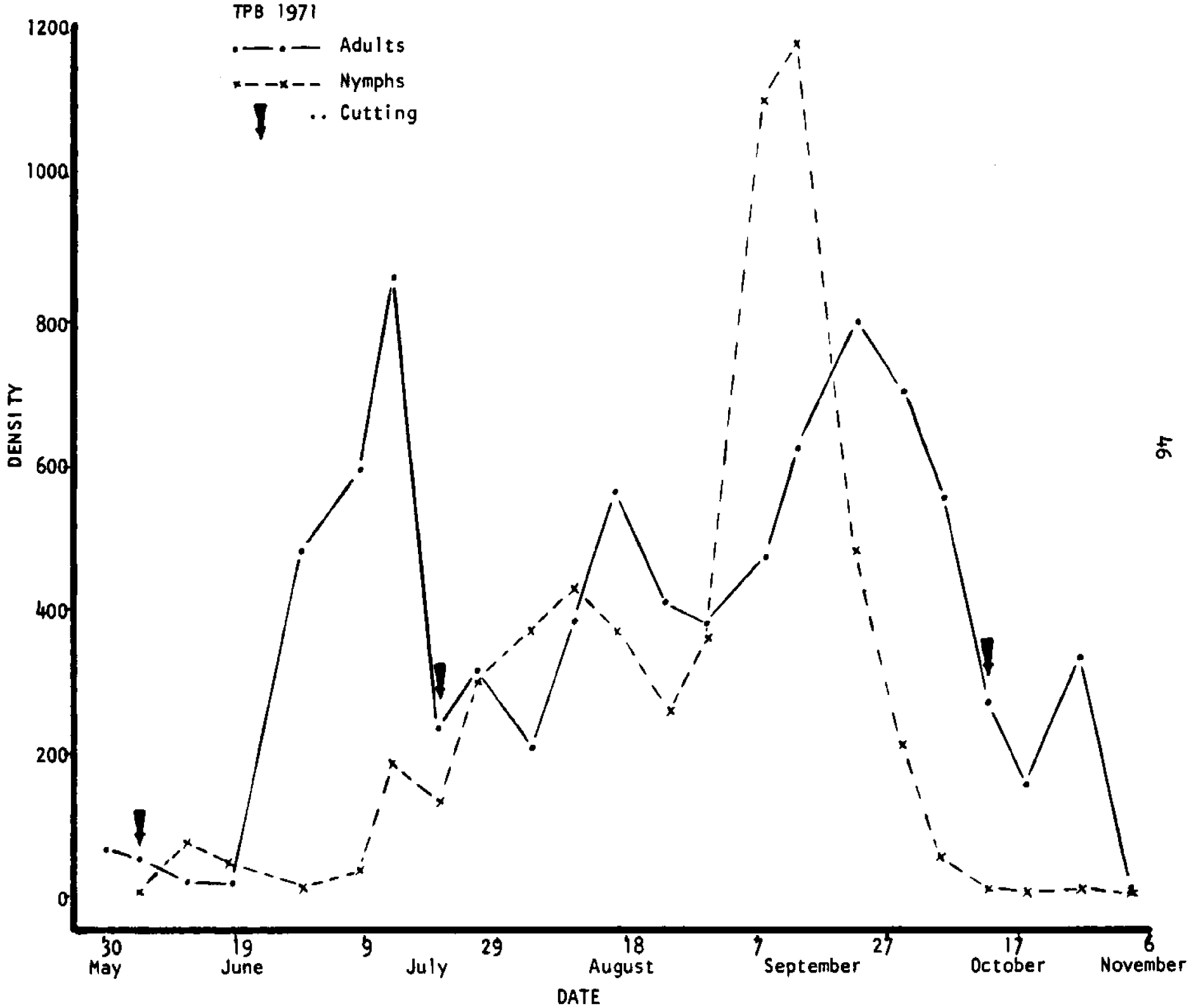

TPB 1971
Adults
Nymphs
.. Cutting
1200
1000
800
600
400
200
0
DENSITY
30 May
19 June
9 July
29
18 August
7 September
27
17 October
6 November
DATE

Figure 13. Relationships between adult and nymphal population densities of the alfalfa plant bug during the 1971 season.

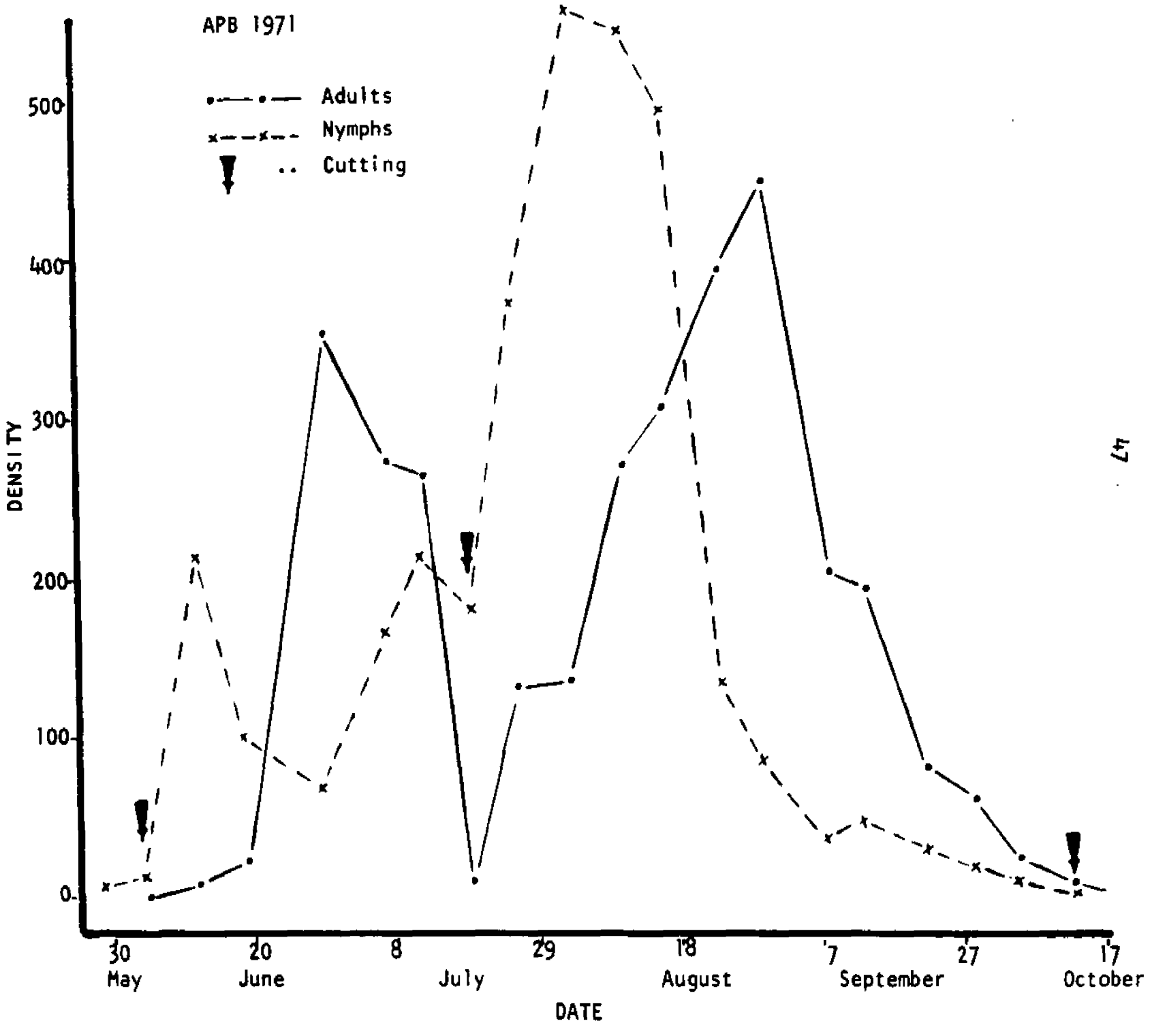

APB 1971
Adults
Nymphs
Cutting
DENSITY
500
400
300
200
100
0
30 May
20 June
8 July
29
18 August
7 September
27
17 October
DATE

Table 7. Total number of males and females of the tarnished and alfalfa plant bugs from weekly sweep sampling in 1970 and 1971. East Lansing, Michigan.

Category and Spp.	Year	Males	Females	Chi Square
June to November Tarnished Plant Bug	1970	3697	4216	34.04**
June to November Alfalfa Plant Bug	1970	969	1058	3.90*
June to November Tarnished Plant Bug	1971	4185	4189	.002
June to November Alfalfa Plant Bug	1971	1469	1726	20.67**

** Difference highly significant

* Difference significant at 5% level.

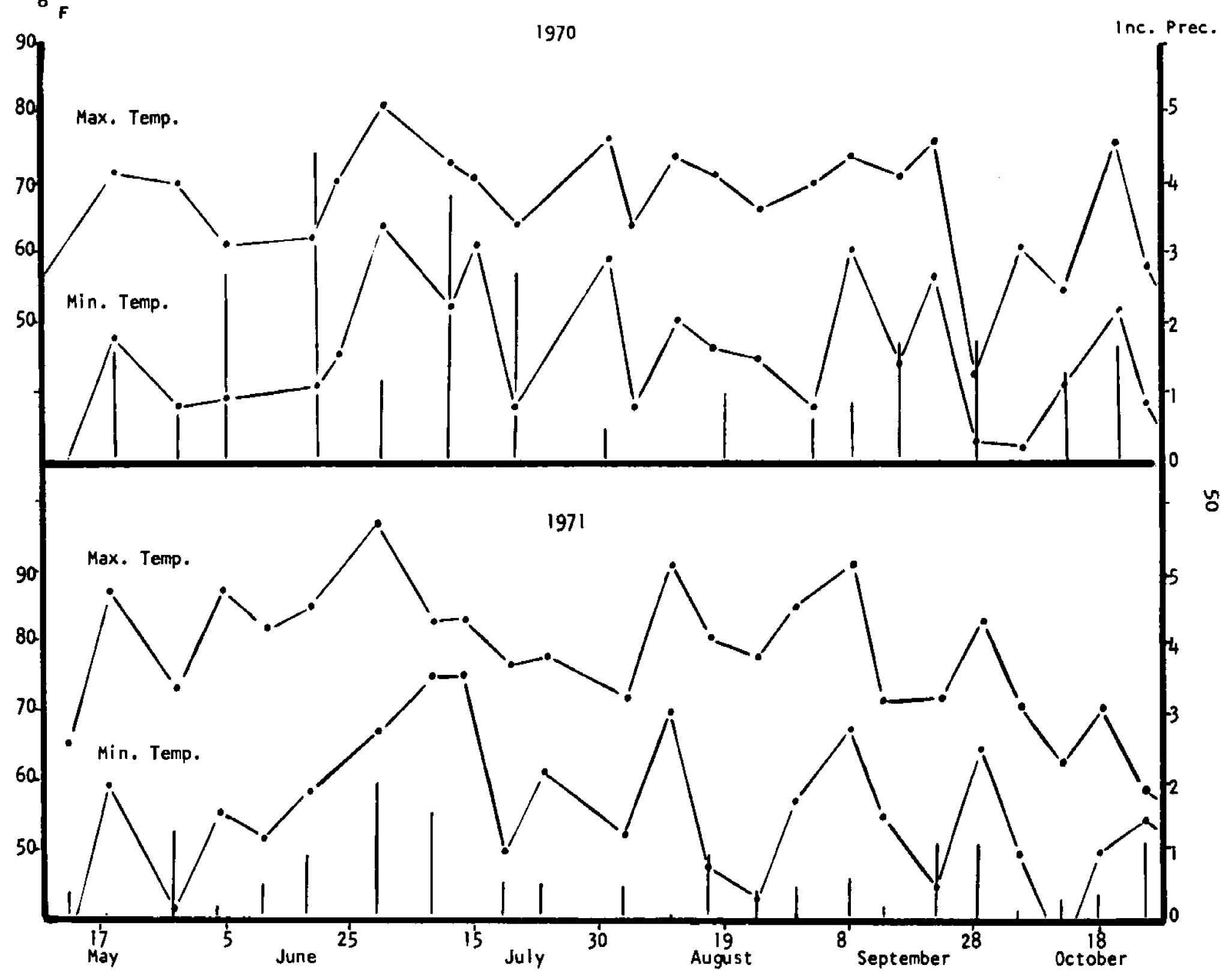
Sex ratio.- Preliminary investigations of the sex ratio in both tarnished and alfalfa plant bugs are recorded in Table 7. The tarnished plant bug females significantly outnumbered the males in the sampling made with a standard sweep net in 1970; whereas, the alfalfa plant bug females slightly outnumbered the males, the Chi square being significant at the 5% level. Insect sex ratio was also determined throughout the 1971 sampling (from June 5th until November 17th) for both species. The Chi square value computed indicated in this instance that the tarnished plant bug sex ratio was almost 1 to 1. The alfalfa plant bug females significantly outnumbered the males. Therefore, these results are not conclusive and more collections are needed to authenticate information about the sex ratio in both mirids.

Environmental Conditions:

Weather.- It is well known that temperature and precipitation play one of the most important roles in insect behavior. Maximum and minimum temperatures, as well as the rainfall during the sampling period of the 1970 and 1971 seasons, are presented in Figure 14. The rainfall is what fell during the time period between each sample.

The temperature was relatively more stable and consistent during the 1970 and 1971 seasons than the rainfall. The rainfall during 1970 was moderate for the East Lansing area while the 1971 season was characterized by a lack of precipitation. How this can be correlated with population densities of tarnished and alfalfa plant bugs can be

Figure 14. Maximum and minimum temperatures (^{o}F) and precipitation (inches), for the East Lansing S. E. Station during the 1970 and 1971 season.


°F
1970
Inc. Prec.
Max. Temp.
Min. Temp.
90
80
70
60
50
5
4
3
2
1
0
1971
Max. Temp.
Min. Temp.
90
80
70
60
50
5
4
3
2
1
0
17
May
5
June
25
15
July
30
19
August
8
September
28
18
October

explained by the direct and indirect effects, since fluctuations in maximum and minimum temperature and precipitation present graphically a complex and irregular mosaic of hit-and-miss variation.

Before early May there is almost no activity of either bug, probably due to the fact that tarnished plant bug adults are still hibernating, so precipitation and cold temperature directly affect tarnished plant bug populations, destroying some adults and possibly nymphs as well. On the other hand, alfalfa plant bug eggs probably do not hatch until minimum temperatures go up to about 50°F (10°C). Furthermore, with the high temperature and precipitation, food supplies are increasing, reaching their peaks when cuttings are made, in the case of alfalfa. Temperature and rainfall not only affect the succulence of alfalfa leaves on which the plant bugs feed, but indirectly, also insect populations. Alfalfa plantations in drought areas supposedly have small insect populations, whereas plantations in humid areas almost invariably have large plant bug populations. From the data collected by sweeping at East Lansing, it may be reported that the dry season in 1971 did not affect the tarnished plant bug populations. In contrast, the alfalfa plant bug had a population density peak in the "dry season" of 1971 of more than twice that reached in 1970. Consequently, the dry season favored the alfalfa plant bug increase.

DISCUSSION

By reviewing the biology of the tarnished and alfalfa plant bug, it can be reported that they represent two groups which appear to occupy similar ecological niches, as far as food is concerned, simultaneously throughout the same areas, but differing morphologically, physiologically and genetically. Here the two mirids are feeding on the same parts of one species of plant in the same alfalfa fields, but obviously they differ from each other, as they represent two different genera. This agrees with DeBach's definition of ecological niche (1966): "Ecological nich refers to the role played by an animal based upon its precise food, spatial, or habitudinal requirements in a particular habitat. What an animal does and what it needs as requisites for survival and reproduction in a given habitat determines its ecological niche."

Even though the alfalfa plant bug is duplicated in the same habitat by the tarnished plant bug in alfalfa areas, the tarnished plant bug differs a little in its food requirements and also has other alternate hosts. The term habitat is used here to denote the physical and biotic environment of a natural population in a locality or area, where individuals of that population normally live and reproduce (Udvardy 1959).

However, the similarity in ecological niches of these two mirids does not make it impossible for competitive interactions to occur among them in natural environments where they attack the same host plant and where they overlap in their distributions. These competi-

tive interactions are a biological phenomena involving intraspecific interactions and other different characteristic factors and mechanisms.

One factor to consider is that in some cases an apparent abundance of food or other resources does not preclude occurrence of competition. In fact, DeBach (op.cit.) states: "The attempt or actual utilization by two or more organisms of common resources or requisites involves competition, even if one does not harm or interfere (in the sense of bother) the other in the process". Therefore competitive interactions among alfalfa plant bug and tarnished plant bug can occur in alfalfa, even when the supplies of food (alfalfa and other plants) are abundant in relation to the immediate needs of both species. This can probably explain the fact that the two mirids have been recorded at about the same population levels once they become established in different regions in the United States. A brief summary of the abundance shown by these two mirids from 1940 to 1959 in different states is presented in Table 8. According to this table, the tarnished plant bug has always significantly outnumbered the alfalfa plant bug for every year and every location. It will perhaps be worthy to mention here that the tarnished plant bug is a native species, while the alfalfa plant bug is an introduced one from the Old World. The establishment of the alfalfa plant bug occurred in the late 1920's in Iowa (Knight 1930), from where the species has spread to the neighboring states and Canada. But its colonization, in relation to the tarnished plant bug, has not been accomplished in numerous populations, apparently because of interspecific interactions.

Table 8. Abundance of L. lineolaris and A. lineolatus in different regions in alfalfa fields in the U.S. and different years, adjusted to a common base of 100 net sweeps.

Place	Species	Year	Number	Reference
S. Paul, Minnesota	L. lineolaris	1940	1308	Hughes, 1943
S. Paul, Minnesota	A. lineolatus	1940	392	Hughes, 1943
S. Paul, Minnesota	L. lineolaris	1942	4808	Hughes, 1943
S. Paul, Minnesota	A. lineolatus	1942	1532	Hughes, 1943
Madison, Wisconsin	L. lineolaris	1945	371	Scholl & Medler, 1947
Madison, Wisconsin	A. lineolatus	1945	133	Scholl & Medler, 1947
Lower Peninsula, Michigan	L. lineolaris	1959	200	Niemczyk & Guyer, 1963
Lower Peninsula, Michigan	A. lineolatus	1959	20	Niemczyk & Guyer, 1963
Aurora, New York	L. lineolaris	1959	1246	Ridgway & Gyrisco, 1960
Aurora, New York	A. lineolatus	1959	----*	Ridgway & Gyrisco, 1960

*Data not found in the literature.

There are, however, different factors that favor the alfalfa plant bug to compete with the closely related species, the tarnished plant bug, without being displaced at all. The overwintering in the egg stage probably provides the main way to spread and possibly to colonize new areas; the morphological characteristics of the egg such as the chorion impermeability being adapted to resist long periods of desiccated environment. Another point is the presence of natural enemies: by the literature review and by observations during the present studies, the tarnished plant bug has been reported with several natural enemies (parasites and predators), while the records to date do not show natural enemies for the alfalfa plant bug.

INTERSPECIFIC COMPETITION IN THE LABORATORY

The results obtained in the laboratory would lead undoubtedly to the conclusion that the tarnished plant bug would displace the alfalfa plant bug. However, as it is well known, laboratory conditions are quite different from those found in natural environments, and because of the lack of enough data on the alfalfa plant bug, these results can not be taken as conclusive. The polyphagous condition of the tarnished plant bug probably favors it in laboratory environments, but this does not mean it has absolute dominance over the alfalfa plant bug. As it is said in another section, the alfalfa plant bug was not reared successfully in the laboratory on common beans. Therefore, by comparing the oviposition of both species when rearing singly and together only during the alfalfa plant bug parental generation, preliminary results can be drawn from their competitive

interactions (Table 4). The number of eggs laid by the alfalfa plant bug slightly outnumbered (on an average of six groups) the tarnished plant bug eggs when reared together. However, when both were reared singly, the number of eggs laid by the tarnished plant bug significantly outnumbered those laid by the alfalfa plant bug. Here, again, different factors may be involved, such as modification of the medium by one species or the other, and active interference with each other. Factors correlated with intraspecific competition such as cannibalism, which is known to occur in tarnished plant bugs, may also come to determine, not the status of the winner, but the depressing effect of one species on the other. No evidence of aggressive action between adults or nymphs in these two mirids was observed during the present studies, and if it occurs it may be accidental when they contact one another.

The results show that the tarnished plant bug populations build up rather constantly, reaching the fifth generation when reared alone. The rearing was stopped here arbitrarily. Unfortunately, the alfalfa plant bug was not reared successfully during this time for comparison of the biological characteristics when both mirids are caged together, such as their sex ratio, the adult longevity, their average developmental period and the average total progeny per female or actual fecundity, which are helpful to evaluate the results of inter- and intraspecific competition. For the tarnished plant bug, these characteristics are presented in Table 9.

The sex ratio found for the tarnished plant bug was approximately 50 males and 50 females, when common beans were used as host material. The developmental period from oviposition to adult stage (starting to

Table 9. Biological characteristics of the tarnished plant bug reared at 78-80°F, 65 ± 5% RH, and 16 hours of light, East Lansing, Michigan. 1971.

Sex ratio (% females)	50.02
Adult longevity. (days)	39.39
Average developmental period (days)	32.45
Average total progeny per female, or actual fecundity (reaching adult stage)	7.1
Theoretical number of females at third generation	220.00

lay eggs again) was about 32.45 days at 78-80°F, ranging in five groups from 31.44 to 33.45 days. In the same way, the adult longevity was 39.39 days, and the average progeny per female was 7.1; this was indicated by the number of progeny per female which reached the adult stage. Therefore, the theoretical number of females after about 90 days (third generation) would be 220 (Table 9). Starting with 5 pairs of bugs, 5 males and 5 females, the sex ratio being 1:1, and the total progeny per female being 7.1, the number of females for the parental generation would be $(5 \times 7.1)/2 = 17.7$; the theoretical number of females for the next generation would be $(17.7 \times 7.1)/2 = 62$; and the theoretical number of females for the third generation would be $(62 \times 7.1)/2 = 220$. This relationship is shown graphically in Figure 5. In these tests conducted under conditions mentioned before, a high mortality occurs during the immature stages. The cause may have been that there was less food per nymph during the developmental period, but direct evidence was not found.

A few data on the rate of development were recorded from rearing the tarnished and alfalfa plant bugs together under the laboratory conditions previously discussed. They are summarized in Table 10. By comparison of the average developmental period at such conditions, it is observed that in this case, the average developmental period of the tarnished plant bug was significantly longer (40 days) than when the tarnished plant bug was reared alone. The adult longevity of the tarnished plant bug, on the other hand, was significantly reduced (an average of 27.88 days which represents about 30% longevity reduction)

Table 10. The competitive interaction can be seen even in this small test but conclusions can not be drawn from it and more data would be needed.

FIELD INTERACTIONS

As far as it is known, for a long time previous to 1930, of these two mirids, the tarnished plant bug was the only species found in alfalfa fields in the United States. The alfalfa plant bug was perhaps an accidental immigrant from the Old World, which became established by this time. Its abundance from 1940 to 1959 is presented in Table 8, which given an idea of its small densities in the various states where it became colonized. This fact is closely correlated with the general concensus that the closer the relation among species, the stronger the competition is. These preliminary tests on biological and physiological characteristics of the tarnished and alfalfa plant bugs indicate that each of these mirids possesses some advantages over the other one to which it is subject in natural environments. Biological agents (lady-bird beetles, toads, fungus diseases, and others reported in the literature), climate (drought periods and winter temperatures), cutting of the host plant, and intraspecific competition are probably acting as control factors on the tarnished plant bug.

On the other hand, the high female to male sex ratio and over-wintering in the egg stage are probably the major factors causing the alfalfa plant bug to remain at even lower densities than those of the tarnished plant bug.

Table 10. Duration in days of the development of tarnished plant bug when reared mixed with alfalfa plant bug, at 78-80°F, 65 ± 5% RH, and 16 hours of light, from September 18, to December 22, East Lansing, Michigan. 1971.

Replic. No.	Hatching	2nd.Ins.	5th.Ins.	Adults	Preoviposition Period	Total Dev. Period	Longevity of Adults
1	8	6	6	6	8	34	27
2	11	8	9	4	-	35[a]	-
3	7	4	10	3	12	36	24
4	13	4	6	5	-	28[a]	-
5	11	2	14	5	14	46	22
6	11	6	5	6	24	52	38
7	10	4	5	4	11	34	18
8	10	5	9	3	-	27[a]	27
9	9	4	10	3	12	38	35
10	10	4	7	3	-	24[a]	-
11	-	4	11	4	10	29[b]	32
Total	100	51	92	46	91	383[c]	223
Mean	10.0	4.64	8.36	4.18	13.0	40.0	27.88
S.D.	1.7	1.57	2.84	1.17	5.2	7.4	6.7

[a] - Development period without preoviposition time.

[b] - Development period without hatching time.

[c] - Summation of the complete development periods.

CONCLUSIONS

The present studies were carried out under both laboratory and field conditions with the objective of finding if interspecific competition existed between the tarnished plant bug and alfalfa plant bug. The studies in the laboratory were performed using incubators set at 78-80°F, 65 ± 5% RH, and a 16 hour photoperiod provided by a flourescent lamp. The field studies were made at the Michigan State University farms, East Lansing, during the years of 1970 and 1971.

The developmental period of the tarnished plant bug was followed for five successive generations in the laboratory using pods of green beans as the host. Intraspecific competition in the tarnished plant bug was observed to be accentuated by lack of food, its cannibalistic habit, and interference by accidental contact between them. The alfalfa plant bug could be reared only during the parental generation in the laboratory. The preliminary observations on the alfalfa plant bug in the laboratory indicates that there is a diapause in the egg stage of this species, but more investigation is needed on this subject. Interspecific competition between the tarnished plant bug and alfalfa plant bug is shown by the longer developmental period, shorter longevity, and higher variability of developmental time of the tarnished plant bug when reared together with the alfalfa plant bug than when the tarnished plant bug was reared by itself.

A weekly survey by net sweep sampling was made in five different alfalfa fields and observations were made on the various aspects of

biology, habits, behavior, natural enemies, and host plant relationships of both species of mirids. Natural enemies, other than those previously reported were found, but their presence had no significant effect on the population densities of the mirids. These natural enemies were the spotted lady-bird beetle, Coleomegilla maculata DeGeer, the common toad, Bufo americanus Holbrook, and a fungus identified as a Hyphomycete. The sex ratio was found to be approximately 1:1 in the tarnished plant bug while the females outnumbered the males of the alfalfa plant bug. The tarnished plant bug has a broader range of hosts than the alfalfa plant bug.

These two mirids were found in the same alfalfa producing areas of the United States and occupy similar ecological niches in the alfalfa fields. The records of distribution and abundance of the two species during the years 1940 to 1959 as well as in the present study show that the tarnished plant bug population is dominant over the numbers of the alfalfa plant bug. This equilibrium is probably maintained by different parameters for the two species: the natural enemies, periodic cutting of the alfalfa, an intraspecific competition probably being of major importance to the tarnished plant bug; the high female to male sex ratio and the resistant chorion of the egg (Knight 1941) that permits overwintering as eggs are probably the dominant factors influencing the alfalfa plant bug. A complicating factor is that the alfalfa plant bug is an introduced species that may not have fully adapted to its new environment. The two species are closely related and do occupy similar niches in the alfalfa fields. They are, however,

differentially affected by these different parameters and no direct evidence of interspecific competition between them was measured in the field.

REFERENCES CITED

Allee, W. C., A. E. Emerson, O. Park, T. Park, and K. P. Schmidt Principles of animal ecology. Philadelphia. W. B. Saunders Co.

Andrewartha, H. G. and L. C. Birch. 1953. The Lotka-Volterra theory of interspecific competition. Australian J. Zool. 1: 174-7.

_____1954. The distribution and abundance of animals. University of Chicago Press. Chicago, Ill.

Beards, G. W. and T. F. Leigh. 1960. A laboratory rearing method for Lygus hesperus Knight. J. Econ. Entomol. 53: 327-8.

Birch, L. C. 1957. The meanings of competition. Am. Naturalist 91: 5-18.

Broersma, D. B. and W. H. Luckmann. 1970. Effects of tarnished plant bug feeding on soybean. J. Econ. Entomol. 63: 253-6.

Brower, L. P. 1962. Evidence of interspecific competition in butterflies. Ecology 43: 549-52.

Butler, G. D. 1968. Sugar for the survival of Lygus hesperus on alfalfa. J. Econ. Entomol. 61: 854-5.

Butler, G. D. and A. L. Wardecker. 1970. Fluctuations of populations of Lygus hesperus in alfalfa in Arizona. J. Econ. Entomol. 63: 1111-14.

Clancy, D. W. and H. D. Pierce. 1966. Natural enemies of some lygus bugs. J. Econ. Entomol. 59: 853-8.

Crombie, A. C. 1947. Interspecific competition. J. Animal Ecol. 16: 44-73.

Crosby, C. R. and M. D. Leonard. 1914. The tarnished plant bug. N. Y. (Cornell) Agr. Exp. Sta. Bull. 346: 462-526.

Curtis, C. E. and C. E. McCoy. 1964. Some host-plant preferences shown by Lygus lineolaris (Hemiptera: Miridae) in the laboratory. Ann. Entomol. Soc. Am. 57: 511-13.

DeBach, P. 1966. The competitive displacement and coexistence principles. Ann. Rev. Entomol. 11: 183-212.

DeBach, P. and R. A. Sundby. 1963. Competitive displacement between ecological homologues. Hilgardia 34: 105-166.

Doutt, R. L., S. W. Broodryk, C. E. Kennett, C. B. Huffaker and G. L. Finney. 1966. Studies of two parasites of Olive scale, Parlatoria oleae (Colvee). Hilgardia 37: 219-343.

Flanders, S. E. 1966. The circumstances of species replacement among parasitic Hymenoptera. Can. Entomol. 98: 1009-24.

Force, Don C. and P. S. Messenger. 1965. Laboratory studies on competition among three parasites of the spotted alfalfa aphid Therioaphis maculata (Buckton). Ecology 56: 851-59.

Heatwole, M. and D. M. Davis. 1965. Ecology of 3 sympatric species of parasitic insects of the genus Megarhyssa (Hymenoptera: Ichneumonidae). Ecology 46: 140-50.

Hughes, J. H. 1943. The alfalfa plant bug, Adelphocoris lineolatus (Goeze) and other miridae (Hemiptera) in relation to alfalfa seed production in Minnesota. Agr. Exp. Sta. Univ. of Minn. Tech. Bull. 161: 1-80.

Istock, C. A. 1967. Transient competitive displacement in natural populations of whirligig beetles. Ecology 48: 929-37.

Knight, H. H. 1941. The plant bugs, or Miridae of Illinois. Ill. Nat. Hist. Survey Bull. 22: 4.

Lindquist, R. K., R. H. Painter, and E. L. Sorensen. 1967. Screening alfalfa seedlings for resistance to the tarnished plant bug. J. Econ. Entomol. 60: 1442-45.

Milne, A. 1961. Definition of competition among animals. Symposia Soc. Exp. Biol. 15: 40-61.

Nicholson, A. J. 1933. The balance of animal populations. J. Anim. Ecol. 2: 132-78.

Niemczyk, H. D. and G. E. Guyer. 1963. The distribution, abundance and economic importance of insects affecting red and mammoth clover in Michigan. Mich. State Univ. Exp. Sta. Tech. Bull. 293: 1-38.

Odum, E. P. 1966. Fundamentals of ecology. W. B. Saunders Co., Phila.

Painter, R. H. 1929. The tarnished plant bug, Lygus pratensis L.: A progress report. 60th Ann. Rept. Entomol. Soc. Ontario: 102-7.

Park, T. 1954. Experimental studies of interspecies competition. II. Temperature, humidity and competition in two species of Tribolium. Physiol. Zool. 27: 177-238.

Pearce, A. S. 1939. Animal ecology. McGraw Hill Book Co. New York.

Pemberton, C. E. and H. F. Willard. 1918. Interrelations of fruit fly parasites in Hawaii. J. Agr. Res. 12: 285-95.

Porter, B. A. 1926. The tarnished plant bug as a peach fruit pest. J. Econ. Entomol. 19: 43-47.

Richards, O. W. 1963. Some factors controlling insect population living in Scotch broom. Proc. Intern. Congr. Zool. 16th. Washington. 3: 353-56.

Ridgway, R. L. and G. G. Gyrisco. 1960. Studies of the biology of the tarnished plant bug, Lygus lineolaris. J. Econ. Entomol. 53: 1063-5.

Ross, H. H. 1957. Principles of natural coexistence indicated by leafhopper populations. Evolution 11: 113-129.

Scholl, J. M. and Medler. 1947. Trap strips to control insects affecting alfalfa seed production. J. Econ. Entomol. 40: 448-50.

Smith, H. S. 1929. Multiple parasitism; its relation to the biological control of insect pests. Bull. Entomol. Res. 20: 141-49.

Solomon, M. E. 1957. Dynamics of insect populations. Ann. Rev. Entomol. 2: 121-142.

Stitt, L. L. 1940. Three species of the genus Lygus and their relation to alfalfa seed production in Southern Arizona and California. U.S.D.A. Tech. Bull. 741: 1-19.

Taksdal, G. 1963. Ecology of plant resistance to the tarnished plant bug, Lygus lineolaris. Ann. Entomol. Soc. Am. 56: 69-74.

Udvardy, M. D. F. 1959. Notes on the ecological concepts of habitat, biotype and niche. Ecology 40: 725-28.

Van den Bosch, R., E. I. Schlinger, E. J. Dietrick, J. C. Hall and B. Puttler. 1964. Studies of succession, distribution and phenology of imported parasites of Therioaphis trifolii (Monell) in southern California. Ecology 45: 602-621.

Zia-ud-Din. 1950. Studies on the biology and control of Lygus oblineatus (Say). Ph.D. Thesis. Mich. State Univ. (Card No. 2493) 128 p. Mic. Abstr. 11: 500.