STUDIES ON PEST AND BENEFICIAL INSECTS OF WHEAT FROM 1970 THROUGH 1972 AT THE COLLEGE OF AGRICULTURE AND VETERINARY SCIENCE, NATIONAL UNIVERSITY OF ASUNCION, SAN LORENZO, PARAGUAY

by

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INTRODUCTION

Paraguay is one of two land-locked nations in South America, located in the approximate center of the continent, and bordered on the southeast, south and west by Argentina; the northwest and north by Bolivia; and the northeast and east by Brazil (Appendix A, Map A-1). It is the ninth largest Latin American republic, slightly smaller than California. It is divided into the Chaco, and the eastern regions. The Chaco comprises 60% of the area and is part of the Gran Chaco of Argentina, Bolivia, and Paraguay. Marshes, lagoons, forests and grasslands are prevalent; it appears to be best suited for hunting and livestock. The eastern region has generally fertile soil, undergoes extensive cultivation and has a denser population.

Because wheat has been the largest food import item it was felt that gains in foreign exchanges could be made, and dependence upon foreign suppliers decreased, if more wheat were produced. Although climatological and soil conditions favor crop cultivation year-round, traditional agricultural practices have limited crops to the spring-summer growing season, while the fall-winter cycle was relatively inactive. By Presidential Decree Number 14.880 dated November 22, 1965, the Wheat Commission was created to implement the National Wheat Plan, initiated by Resolution Number 9 of the National Council for Economic Coordination dated October 29, 1965 (Ministry of Agriculture, Paraguay 1966). The United States Agency for International Development (USAID) has been extensively involved since then with the Government of Paraguay (GOP) in financial support of this program between USAID, the GOP, and the Paraguayan National Development Bank.

Self-sufficiency in wheat production was proclaimed as the chief goal. In 1973 this would represent approximately 136.6 thousand metric tons (50,191,600 bushels) of wheat for Paraguay's 2.3 million inhabitants. Whether or not self-sufficiency is completely attained, the program's effect on agricultural development should be beneficial. While wheat was selected as the primary commodity, it is hoped that extensive efforts on the utilization of modern inputs would encourage improved practices with other crops. Availability of better seeds, more fertilizers, proper insecticides, herbicides, and machinery would stimulate greater overall productivity and in time, improve storage, transportation, and marketing (White 1972). The National Wheat Program has made striking advances. In 1966 only 7,200 hectares were harvested but by 1971, 46,053 hectares were under cultivation, and total production rose from 7.92 to 45.53 thousand metric tons, a net increase of 6.39 fold in hectares harvested and a 5.74 fold increase in production. National averages of yield per hectare have fluctuated widely from a low in 1969 of 941 Kg/Ha. (13.99 Bu/A) to a high of 1,200 Kg/Ha. (17.84 Bu/A) in 1968.

Approximately 600 varieties and lines of wheat from the International Wheat Collection have been tested yearly from 1958 to 1966 in the National Agronomic Institute (IAN). By 1965 five varieties commonly referred to as 1, 6, 8, 9, and 11, had been selected for their good production potential and all but varieties 6 and 11 were still under production during 1972 to at least some degree (Ministry of Agriculture, Paraguay 1966; Alarcone 1972). During 1972, 2,600 lines were tested by IAN, and 500 to 600 by the Experimental Station at Capitan Miranda, indicating a resurging effort to obtain better adapted varieties (Alarcone 1972).

Located 13 kilometers southeast of Asuncion is the College of Agriculture and Veterinary Science (Facultad de Agronomia y Veterinaria, FAV) founded in 1956 as part of the National University of Asuncion (Appendix A, Map A-2). Upon the writer's arrival in September 1969 as a Peace Corps Volunteer assigned to the FAV to develop its first entomology laboratory, the College had approximately 440 students and 99 professors (Mosqueira 1969). The USAID/GOP contract includes a New Mexico State University group, working directly with the FAV in such projects as improving research and teaching facilities, electrical services, and general curriculum. The successful establishment of the Entomology Laboratory can in part by attributed to the financial backing from the USAID/GOP/NMSU/FAV contract. Cooperation between these groups in forming a firm foundation for advanced agricultural education and research is essential to promote future economic growth. One area of research through which the College is directly contributing is in the production of wheat. For this reason and because of the need for entomological investigations, a general plan was developed to determine the importance of insects in Paraguayan wheat production: (1) to determine what insects were present; (2) to test sampling procedures applicable to Paraguayan agricultural practices; (3) to obtain preliminary data that would indicate future population trends, so that factors influencing these, i.e., planting dates, could be adjusted accordingly; (4) to analyze the pest population dynamics in terms of natural mortality factors, such as weather and natural enemies; (5) to obtain preliminary data on the economics of controlling pest species; and (6) to test effectiveness of control methods to determine those most suitable for incorporation into a pest management program, for example insecticides, planting dates, natural enemies.

During three years data were collected. In 1970 it dealt primarily with insect identification, population growth curves, and pest control with an insecticide. In 1971 research was directed to specific analysis of pest control by one or two applications of an insecticide, in addition to studying population growth. The 1972 experiments measured population growth in relation to planting dates, analysis of sampling techniques, and determination of the biotype of the greenbug *Schizaphis graminum*.

REVIEW OF LITERATURE

Wheat accounted for about five million of the seven million dollars of imported foodstuffs from 1962 to 1966, and annual wheat production averaged only 7,320 metric tons during this period (USAID/Rockefeller visit data 1969). In 1968, Arnold presented production data from 1956 to 1967 which included similar data to those prepared for Rockefeller's visit. Somewhat contrasting data are presented elsewhere but the basic quantities indicate the same trend of relatively low productivity (Ministry of Agriculture, Paraguay 1968; Ministry of Agriculture, Paraguay 1970a; Pincus 1968; USDComm. 1968). White (1972) indicated that production in 1968 more than doubled that of previous levels. In 1970, while production increased to 47.7 thousand metric tons, the legal importation of wheat from Argentina and the United States supplied an additional 76.4 thousand metric tons (Henning 1973; Ministry of Agriculture, Paraguay 1971a). Based on these 1970 figures, it is evident that Paraguay needed 124.1 thousand metric tons of wheat to feed its population; this figure does not account for wheat entering the country illegally by an unknown but perhaps substantial quantity. This allows an average of approximately 51.28 kilograms of wheat per inhabitant per year. Applying this average to projected Paraguayan population figures by the years 1980 and 2000 (Ceuppens 1971), 174.95 and 300.98 thousand metric tons of wheat will be needed by these dates, respectively. Observing the present world wheat situation with low stockpiles and uncertain future production, Paraguay should be encouraged to produce its maximum economic potential.

Average annual yields from 1966 to 1971, 993.1 Kg/Ha (14.68 Bu/A), are extremely low. Innumerable problems such as inclemency of weather, improper planting dates, poor germination, unsuitable land and fertilization, weeds, plant diseases, and insects have plagued Paraguay's wheat production. Many of these problems were readily apparent while others were discovered through research and experiences of others. Research in the FAV by R. Samudio and R. Bianchi (1971) with three dosages of 2,4-D herbicide, indicated increases up to 1,109 Kg/Ha over check plots, with normal wheat development unaffected by the application at any of the three plant stages tested. Notable control of wild radish, *Raphanus* spp., the second most important weed affecting wheat, was obtained. The primary weed problem, "Pirí," (*Cypreus* spp.) is not controllable with 2,4-D. Alarcone (1972) indicated the severity of the weed problem particularly in the northern wheat producing areas. Spraying of 2,4-D amine has been detrimental to Coccinellidae larvae (Adams 1960). Plant diseases of various types are important, depending on location. Of the five varieties released by IAN in 1965, numbers 8, 9, and 11 are susceptible to rusts and are not widely cultivated. Septorium spp. is frequently a severe problem in the southern and Misiones regions, while Helminthosporium spp. is more frequently a problem in the FAV, IAN, and northern production areas (Alarcone 1972; Stauffer 1972). Climate, especially water availability, and lack of a sufficiently long cool period, are problems in some areas in certain years (Alarcone 1972). MacPherson and Arnold (1969) believe that prospects for Paraguay to become self-sufficient and an exporter of wheat appear remote because of geographical location and ecological factors. Although prospects for exportation seem unlikely, attaining wheat self-sufficiency will depend largely on research to select new, well adapted varieties; improved utilization of pesticides, especially herbicides; accurate determination of a more limited and acceptable range in planting dates; and reformed utilization of the machinery necessary in modern agriculture.

Very little information has been published on the various pest and beneficial species of insects in Paraguay. To this writer's knowledge the only extensive article in the North American literature on insects from Paraguay was that of J. Nickel in 1958 entitled "Agricultural Insects of the Paraguayan Chaco." Of the insect described, only two are among the fifteen identified during the course of these studies. In addition the presence of nabids, chrysopids, and a species of Coleomegilla spp. are mentioned. Since Nickel's research was conducted in the Chaco, the insect situation may be quite different from that normally occurring in other regions of Paraguay. An undated listing of economic insects prepared by L. Tarsia, who worked with the Paraguayan Extension Service (STICA) sometime shortly before 1967 includes only *Aphis* (*Rhopalosiphum*) *maidis*. Aranda and Granovsky (1971) presented a partial list of agricultural pests in Paraguay and mentioned *Schizaphis graminum* and *Macrosiphum* spp. The Paraguayan Ministry of Agriculture reported *S. graminum* as attacking wheat, oats, barley and rye (Ministry of Agriculture, Paraguay 1971b). In neighboring countries several of these insects have been studied quite extensively (Fagundes 1971 and 1972a; Guido 1945; Martins 1970; Mineiro Kober 1971; and Olazarri 1970).

Of the Aphididae reported from Argentina, Bolivia, Brazil, and Uruguay, the most commonly cited species occurring in small grains were *Rhopalosiphum maidis* and *Schizaphis graminum*. The earliest citing of *S. graminum* was in the Province of La Pampa, Argentina in 1914 (Blanchard 1940; Guido 1945; Hayward 1942; and Piscucci 1967), in Brazil by Costa Lima in 1927, and Uruguay in 1937 (Guido 1945). Guido indicated that although *S. graminum* was not found and identified in Uruguay until 1937, it was probably introduced prior to that date but its effect on crops had been slight. The review of the history of *S. graminum* in South America presented by Guido is excellent. He also observed that shortly after 1937 this aphid was found on sorghum in the Argentine Chaco and on wheat in the Province of Cordoba, Argentina. This suggests that *S. graminum* was also present in Paraguay by the early 1940s. Very few references were obtained from Bolivia, therefore the presence of *S. graminum* cannot be discounted, although the 1955 list of Bolivian insects by Munro does not include either it or *R. maidis*. Rizzo (1970) reported *R. maidis* and *S. graminum* in Argentina on various cereals such as barley, oats, rye, and wheat while Blanchard reported these aphids in 1940. Hayward (1941 and 1942) mentioned S. graminum and several other aphids of Macrosiphum spp. on cereals in 1937 as occurring in Argentina. Costa and Eastop (1972) reported collecting R. maidis and S. graminum in water traps in Brazil. The only references to Macrosiphum avenae occurring in these countries were by Fagundes (1972b) and Mineiro Kober (1971), both in Brazil. The latter states that this aphid was present in numbers to 150 per spike and caused up to 20% yield reduction in experiment plots. Mineiro Kober (1971) stated that S. graminum severely attacks wheat from plant emergence until floration and was most common from June to August during 1967 to 1971. In 1942, losses by S. graminum were reported between 60% and 70% on one million hectares of wheat in Argentina (Piscucci 1967). Guido (1945) reported losses ranging from 15% to 100% in oats during 1944, and a $20 million loss for all of Uruguay by S. graminum. In Chile, Zuñiga S. (1969) reported M. avenae in wheat, R. maidis in corn and sorghum and S. graminum in cereals.

Information on other insects from these areas of Latin America is also somewhat lacking. In wheat, various Syrphidae were reported in Uruguay (Guido 1945) and Brazil (Mineiro Kober 1971). Ratkovich (1950) also encountered various syrphids feeding on Aphididae but did not indicate specific aphids or crops. Nabis spp. is mentioned in a few articles from Latin America sources (Candia 1971; Covarrubias 1969; Mendoza 1972; Ojeda Peña 1971; and Zazueta N. 1964). Ojeda Peña (1971) studied the habits and biology of Nabis capsiformis Germar and demonstrated the important role it plays as a predator of lepidopterous larvae. Mention of Nabis spp. in wheat is made by Covarrubias (1969) in Mexico. Development of Chrysopa lanata was published in Argentina by Bruch (1917), which was the earliest reported occurrence of Chrysopa in this region of Latin America. Navis (1929, 1932) reported C. lanata from Cordoba, Argentina and other Chrysopa spp. were reported (1930, 1931) to occur in the Tucuman and Misiones regions. Ratkovich (1950) reported three species of Chrysopa spp. occurring in the Tucuman area of Argentina. In Uruguay, Guido (1945) indicated the presence of Chrysopa spp. in wheat sampled with a sweepnet but did not indicate numbers per sweep. Chrysopa spp. collected in Mexico were reported from wheat by Covarrubias (1969) and by Vazquez (1971), and from cotton by Zazueta (1964). In various crops throughout Chile, Zuñiga (1969) reported Chrysopa spp. feeding on a wide variety of Aphididae. Mendoza (1972) in Peru reported the effect of various pesticides applied to rice on beneficial insects, including Chrysopa spp.

Coccinellidae are reported from Latin America in most papers dealing with aphids. There are frequent references to the extremely common and widely distributed Cycloneda sanguinea from Mexico to Argentina (Bosq 1943; Candia 1971; Carrasco 1962; DeSantis 1967; Hayward 1941; Mendoza 1972; Mineiro Kober 1971; Munro 1955; Ratkovich 1950; Vazquez 1971; and Zazueta 1964). Frequent citings of Eripris connexa are also made in Argentina, Chile, and Uruguay (Bosq 1943; Delfin 1900; DeSantis 1967; Guido 1945; Hayward 1941; IIA, Chile 1970; and Zuñiga 1969). The parasitoid Aphidius platensis has been reared from one or more of S. graminum, M. avenae, and R. maidis in distinct locales (DeSantis 1967; Guido 1945;

Hayward 1941; IIA, Chile 1970; Mesa Carrion 1947; Millan 1956; Mineiro Kober 1971; Nuñez 1940; Ong 1962; Piscucci 1967; Ratkovich 1950; and Zuñiga 1969). An additional aphid parasitoid Diaeretiella spp. has been reported from Argentina, Provinces of Rio Negro, Buenos Aires, Cordoba, and San Juan in S. graminum by DeSantis (1967), and in Chile on unspecified wheat aphids (IIA, Chile 1970). Other aphid parasitoids are mentioned by DeSantis (1967) and Guido (1945), but the aforementioned two are the principal genera involved. Millan (1956) presented a detailed account on the metamorphosis and ecology of A. platensis in Argentina. Nineteen aphid hosts for A. platensis were cited by Millan (1956) from Argentina, Brazil, Chile, and Uruguay, along with nine of its hyperparasitoids. A parasitoid of aphidophagous Syrphidae, Diplazon laetatorius (Hymenoptera: Ichneumonidae) was reported from Uruguay (Guido 1945), Argentina (DeSantis 1967), Bolivia (Munro 1955), and Peru (Korytkowski 1967). It is widely distributed throughout the world but is itself attacked by other parasitoids (DeSantis 1967). Twenty-one species of Syrphidae are reportedly parasitized by D. laetatorius, with levels of parasitism reaching 40% to 50% (Korytkowski 1967).

Entomophogous fungi have been reported on aphids in Chile, Paraguay, and Uruguay by IIA, Chile (1970), Ministry of Agriculture, Paraguay (1971b), and Guido (1945), respectively. Entomophthora aphidis used in Chile to control aphids in alfalfa irrigated in mid-afternoon, produced over 95% control. But the application of Metasystox and malathion reduced the germination of the fungus. Best fungi development was obtained when temperatures were between 21°C to 24°C (69.8°F to 75.2°F) but was restricted by temperatures below 10°C and above 28°C (50°F and 82.4°F), whereas the relative humidity during the evening of 90% aided growth but that below 60% restricted growth (IIA, Chile 1970). Guido (1945) in Uruguay isolated the fungus Empusa aphidis Hoffman from S. graminum in wheat. The fungi Empusa spp. are difficult to cultivate on artificial media, or at most sporulate very poorly, and the best multiplication of this fungus could probably be obtained using naturally infested aphids (Guido 1945).

Aphids are recognized as the chief pest in wheat throughout Latin America, with S. graminum the most frequently mentioned. In certain areas Macrosiphum avenae has been recently reported as extremely important in reducing wheat yields (Covarrubias 1969; Fagundes 1972b; Mineiro Kober 1971; and The Rockefeller Foundation 1957, 1958, 1959). Fagundes (1971, 1972a), Martins F. (1970), and Mineiro Kober (1971) reported Acyrthosiphum dirhodum (Walker) a severe pest in the Rio Grande do Sul region of Brazil. This aphid was also reported as a principal pest in Chile by Caballero (1972), IIA, Chile (1970), and Zuñiga S. (1969). Other aphids reportedly collected in wheat include Rhopalosiphum maidis, R. rufiabdominalis, and R. padi (Costa & Eastop 1972; Fagundes 1972b; Mineiro Kober 1971; Munro 1955; Rizzo 1970; and Zuñiga S. 1969).

Yield reduction produced by M. avenae and S. graminum are quite variable. Guido (1945) in Uruguay reported losses from 15% to 100% in wheat by S. graminum, and complete loss of 248,848.8 hectares of 350,752.0 hectares, 70.9%. Recently in Uruguay an attack produced 80% losses (Olazarri 1970). Argentina's loss to S. graminum during 1942 affected 60% to 70% of the 1,000,000 hectares in cereals and forage grains throughout the Provinces of Buenos Aires, Cordoba, San Luis, and La Pampa (Piscucci 1967). Utilizing granulated insecticides applied for control of S. graminum in Brazil, maximum yield increases of 617.5 Kg/Ha were obtained by Martins F. (1970), whereas in Mexico, maximum increases were only 153.7 Kg/Ha with the application of foliar sprays (Vazquez 1971). Similarly, 100 Kg/Ha increases were obtained by Covarrubias (1969) in Mexico by controlling M. avenae with foliar sprays. Research from 1956 to 1959 by the Rockefeller Foundation in Mexico on control of M. avenae resulted in various yield increases. In 1956 to 1957 average populations of 50 aphids per spike in the late milk stage reduced yields by about 5%. When aphids averaged 17 per spike in the late blossom stage of untreated wheat, reductions of 16% occurred, about 500 kilograms in wheat expected to yield 3 tons. Seed yields per spike in grams for treated and non-treated areas varied according to the number of aphids present. With 30 aphids per spike yield was reduced by 25.9% and 0 to 10 aphids reduced yield by 11.27% (Rockefeller Foundation 1957). From 1957 to 1958 losses in Mexico by individual farmers reached 25% to 33% of potential yield. During the previous four years, yield losses to M. avenae were reportedly greater than combined losses from all other insects and plant diseases. Prior to introduction of improved agricultural practices, M. avenae was present but not of economic importance. Succulent plants of dense growth produced an ideal micro-climate for aphids in grain fields, especially in years of favorable climatic conditions (Rockefeller Foundation 1958). During 1958-1959, 100 to 200 aphids per spike in the milk stage were more than sufficient to reduce yields by over a ton per hectare (13.48 Bu/A). With 30 to 50 aphids per spike at flowering a 22% reduction in yield resulted (Rockefeller Foundation 1959). In Brazil, Fagundes (1971b) cited two basic types of damage produced by M. avenae: if infestation occurs before seed formation, the spike will produce fewer grains; secondly, if infestation occurs after seed formation, grains will be small and shriveled. Mineiro Kober (1971) in Brazil cited work from Mexico reporting 100 kilograms per hectare losses by just 10 M. avenae per spike and cited Fagundes showing 20% yield reduction in untreated vs. treated plants.

Kolbe (1969) demonstrated, in Germany, that when infestation density exceeded 30 aphids per spike, a heavy yield loss and a significant reduction of the 1000 grain weight occurred and that a heavy infestation during flowering was an important influence, particularly on the number of seeds formed per spike and hence a reduction of yield per spike. In Manitoba, Apablaza (1967) demonstrated that, if one adult apterous M. avenae was placed on Selkirk wheat when heading commenced, only one spike was produced and 1000 iernels weighed 2.6 grams, compared to 1.2 spikes and 25.0 grams for the check. If one aphid was added 10 or 20 days after heading commenced, the 1000 kernel weights were 6.4 and 12.5 grams, respectively. This coincides with findings by Rautapää (1965) in Finland, who indicated that under certain conditions, aphids in spikes at flowering time may cause greater yield losses than if the same number were present during the ripening period. In contrast, Forbes (1962) in British Colombia, did not discover significances in yield reduction on oats by M. avenae, even though 47 aphids were present per tiller. Harper (1973), in Alberta, demonstrated that M. avenae reduced weight of kernels by 8%. He suggested 1000 seed weights were a more precise measure of late season aphid damage, since a decrease in seed weight appeared to be the main factor that caused yield decreases. Only a single study of this type on wheat by a U. S. author was encountered. Wood (1965) in Oklahoma observed that yield was not significantly reduced by M. avenae when 200 aphids per linear foot (calculated to be approximately 4 to 5 aphids per tiller) were observed feeding on foliage of Triumph wheat during the pre-boot stage.

Known pests of wheat such as Cecidomyiidae, Cephidae, Chloropidae, Eurytomidae and Lygaeidae generally have not been recognized as economic problems. Periodic outbreaks of various Noctuidae have been given occasional recognition. Some were personally witnessed in Paraguay, and some have been documented in other countries (Caballero 1972; Casella 1971).

In Latin America the cyclic nature of aphid populations in wheat usually demonstrates a rise and peak during March to October, depending on the area. Piscucci (1967) reported that S. graminum had 15 generations per year in Argentina and that temperatures below 20^{o}C favored its development, because natural parasitoids were less active while aphid propagation continued. Adults reportedly produced 80 young, and 5 to 15 days were required for subsequent development to adults. In Uruguay, Olazarri (1970) reported S. graminum at its peak from March to May, although attacks occurred in mid-February. He also reported a longer life cycle of between 20 to 25 days, although Guido (1945) indicated only 6.5 to 17.5 days (January to February and August, respectively) were required depending when the aphids appeared. Mineiro Kober (1971) reported S. graminum as most prevalent from June to July during 1967 to 1971 in Rio Grande do Sul, Brazil. In Mexico, Covarrubias (1969) found S. graminum was most prevalent from mid-February to the end of March, 1968 to 1969, while M. avenae was most common at the end of March, 1968. In the United States, Rogers et al. (1972) indicated that S. graminum outbreaks in Oklahoma usually occurred following a year of above-normal precipitation in the spring and summer; above normal winter, spring, and fall temperatures; and below normal summer temperatures.

Head counts, plant counts, and sweepnet collections have been utilized for sampling of aphids in Latin America. The Rockefeller Foundation and Covarrubias (1969) in Mexico employed head counts in many studies, especially those with M. avenae, and Fagundes (1972b) and Mineiro Kober (1971) employed it in Brazil. Aphids per plant are reported in various articles (Fagundes 1972b; IIA, Chile 1970; Vazquez 1971). The sweepnet has been employed in Uruguay, Peru, and Mexico on diverse crops by Covarrubias (1969), Guido (1945), Mendoza (1972), and Vazquez (1971). Chile includes sweepnet collections, head and stem counts, and sometimes numbers per plant (Apablaza H. 1972; Carrillo L. 1972). Utilization of aphids per linear foot was not encountered.

Natural control in Latin America has involved the introduction of the parasitoid Aphidius platensis (Guido 1945; and Mesa C. 1947); or non-intervention, that is letting natural enemies and climatological factors run their course. In wheat, there are few published studies of this type from South America.

Mendoza (1972) reported a reduction in beneficial species with all nine chemicals applied to rice. In Mexico, a single application of ten insecticides gave control ranging from 81.8 to 99.4% of wheat aphids and a 60.7 to 89.0% reduction of natural enemies. Neither Mendoza nor Vazquez employed Ekatin(R) among the insecticides tested.

MATERIALS AND METHODS

Investigations were conducted in wheat from 1970 through 1972 in experimental plots at the College of Agriculture and Veterinary Science, San Lorenzo, Paraguay. Insect populations in relation to planting dates were studied during the three years with greatest emphasis in 1972; insecticidal and yield studies were conducted only during 1970 and 1971. A foliar systemic phosphate insecticide-acaracide Ekatin(R) (thiometon) was selected because of its specific action against aphids and commercial availability. Technical data for this insecticide are given in Appendix A (Sandoz 1966; Farm Chemicals Magazine 1970; Thomson 1973). All yield, population, and climatological data were analyzed by the Kansas State University computer with the ARDVARK, BAST, and NV+NTR programs, in addition to utilization of Snedecor's text (1972).

1970 Experiments

Insect Identification and Population Studies. Insect identifications and population growth curves were studied for wheat of variety number 6, a Frontana//Kenya 58/Nextatch 150 cross (Ministry of Agriculture 1970b) planted April 12th at 100 kilograms per hectare. Four sets of sweepnet collections of 20 sweeps each were made with a 15-inch California Standard Sweepnet. Live and preserved counts of immature and adult Aphididae, *Dolichomiris*, Nabidae, *Chrysopa*, Coccinellidae, Syrphidae, and Aphidiidae were periodically made from 4 locations in the field. Counts were initiated 25 days after planting and continued at approximately 7-day intervals until 111 days after planting. Insects were sent to the former Insect Identification and Parasite Introduction Research Branch, ERD, ARS, USDA for identification.

Insect Experiment, Two Applications. The effect of two applications of the insecticide Ekatin$^{(R)}$ on insect populations in wheat of variety 11, a K 338 AA/Ns 3880 - 191 - N D 53 cross (Ministry of Agriculture 1970b), planted May 27th was tested. Five treatments, replicated four times at random in experimental plots, were used. Individual plots measured 8 by 16 meters. Planned treatment dates were determined by the number of days after planting (NODAP): Check (A), no insecticide; 45 and 75 days after planting (B); 60 and 90 days after planting (C); 75 and 105 days after planting (D); 90 and 120 days after planting (E). Actual applications were made, however, at 47, 62, 78, 92, and 111 days after planting, with the 120-day treatment being omitted. Fifteen liters of a 1:1000 (Ekatin$^{(R)}$:water) mixture were used, representing approximately 30 percent of the recommended dosage per hectare (293 cc/Ha, 73.25 actual, instead of the recommended 1,000 to 2,000 cc/Ha, 250 to 500 actual). Sweepnet collections of 10 sweeps each with a 15-inch diameter net were made from all 20 plots and live counts of immature and adult forms of Aphididae, *Dolichomiris*, *Chrysopa*, Coccinellidae, and Aphidiidae were made. Counts were initiated 38 days after planting and continued at approximately seven-day intervals until 131 days. Two counts were made before the first application at 47 days, and two between each successive application, except for three counts before and after the final application at 111 days. Yield samples were obtained from each plot by harvesting linear and square meter samples. Three random samples were taken by each method from each of the 20 plots. The chaff was separated in the laboratory from the spikes by cutting each spike immediately below the basal node. Spikes were counted and gross weight in grams taken and recorded. Spikes from the linear meter samples were measured in centimeters from the basal node to the tip of the apical floret. Seed was not separated from chaff because a threshing machine was not available. Therefore, a calculated yield was made based on corresponding chaff to seed weight ratios obtained from 1971 experiments.

1971 Experiments

Insecticide Experiment, Two Applications. Wheat of variety 6 was planted June 21 and June 30, 1971. In the earlier planted wheat, an experiment identical in design to the second experiment of 1970 was established. Actual application dates were 47, 61, 77, 91, and 108 days after planting. Sweepnet collections of 10 sweeps each with the 15-inch net were made from all 20 plots and live and preserved counts of immature and adult forms of Aphididae, *Dolichomiris*, Nabidae, *Chrysopa*, Coccinellidae, Syrphidae, and Aphidiidae were made. Counts were initiated 28 days after planting and continued at approximately 7-day intervals until

119 days after planting. Three counts were made before the first application at 47 days, two between the first to second, three between the second to third, and two between each of the successive and after the final applications. Yield samples and measurements were obtained from each of the 20 plots by methods identical to those described for the second experiment of 1970. Because of seed separation problems encountered the previous year, in 1971 wooden threshing boxes approximately 12" x 17" x 3" and 12" x 12" x 3" with an inside base of textured rubber floor matting were constructed. Pressure blocks whose lower surfaces were covered with rubber floor matting were constructed to fit inside the boxes. To separate seed from chaff, a few spikes were added to the larger box and its pressure block placed on top. Then by moving the block back and forth inside the box, friction separated the seed from the chaff. The contents of the box were then passed through a metal sieve with 14 openings per 7.63 cms (4.66 openings/inch), and the chaff recycled to the smaller threshing box separater to assure extraction of all seed. The extracted seed, with some chaff, was then packaged for future cleaning. Final cleaning was made using a small diameter metal kitchen sieve and a blower. Small quantities of the seed-chaff mixture were added to the sieve and held at a distance of approximately one meter over the blower. In this manner the chaff was separated from the seeds, which were then packaged for weighing of net seed yields. Counts and weights of four replicated groups of 100 seeds were made for calculations of 1000 seed test weights. Yields were based on the square meter and linear meter samples as follows:

Type of Measurement	Sample Type: Square meter	Sample Type: Linear meter
Number of spikes	yes	yes
Weight of all whole spikes	yes	yes
Average whole spike weight	yes	yes
Seed weight/unit area	yes	yes
Average seed weight/spike	yes	yes
Average length/spike	no	yes
Yield in Kilograms/Hectare	yes	yes
Yield in Kilograms/Acre	yes	yes
1000 seed test weight	no	yes

Insecticide Experiment, One Application. The second experiment of 1971, utilizing wheat planted June 30, was established with five treatments replicated four times at random in experimental plots. Individual plots measured 8 by 16 meters. Treatments were based on the number of days after planting (NODAP), but only one application of Ekatin(R) was made per treatment. The five planned treatments were: Check (A), no insecticide; 45 days after planting (B); 60 days after planting (C); 75 days after planting (D); and 90 days after planting (E). Actual applications were made 45, 61, 76, and 90 days after planting. Fifteen liters of a 1:1000 (Ekatin(R):water) mixture were used for all applications in the four plots of a given treatment on each date, representing approximately 30 percent of the recommended dosage per hectare (293 cc/Ha, 73.25 actual, instead of the recommended 1,000 to 2,000 cc/Ha, 250 to 500 actual). Sweepnet collections of 10 sweeps each with a 15-inch diameter net were made and live and preserved counts of immature and adult forms of Aphididae, Dolichomiris, Nabidae, Chrysopa, Coccinellidae, Syrphidae, and Aphidiidae were periodically made from all 20 plots. Counts were initiated 45 days after planting and continued at approximately 7-day intervals until 118 days after planting. One count was made before the first application at 45 days, two between both the first to second and second to third, one between the third to fourth and two before and after the fifth application. Linear meter yield samples and measurements were obtained from each of the 20 plots by methods identical to those described for the 1970 and 1971 experiments. Seed separation was made by the same tedious process described for the earlier planted wheat of 1971. Calculation of 1000 seed test weights were made from counts and weights of four replicates of 100 seeds each. Yield data were determined based on linear meter samples as described in the first experiment of 1971.

1972 Experiments

Populations and Planting Dates. Experiments in 1972 were designed to test the relationships between planting dates and insect populations and to determine the biotype of the greenbug, *Schizaphis graminum*, in Paraguay. Wheat of variety 214/60, a KT 54/Norin 10 - B 12 - 1c - II - 7028. 10 Y. 1h.1R.2M cross, planted at five dates over a 70-day period was studied to analyze the effect planting dates may have on the distinct insect populations. The five areas were planted on April 20, and 22, May 4, and 26, and June 30, 1972. Four sweepnet collections with a 15-inch diameter sweepnet of 10 sweeps each were taken in each area at approximately weekly intervals. Counts were initiated about 30 days after seeding of each field. Live and preserved counts of immature and adult forms of Aphididae, *Dolichomiris*, Nabidae, *Chrysopa*, Coccinellidae, Syrphidae, and Aphidiidae were made on each collection date.

Linear Foot Comparison Samples. Comparison between sweepnet counts and the linear foot method (30 cms) were made of the seven insect groups in areas planted April 20, 22, and May 26. Four samples were selected in each area at random by counting ten rows of wheat, 150 to 170 cms, to the left of the path taken for the sweepnet samples. In this manner the ten sweep sample was first taken and preserved, then from the center of the area just sampled ten rows to the left were counted at which point a one foot (30 cms) sample was taken. Plants were either thoroughly examined in the field or cut and packaged in plastic bags for examination in the laboratory. Counts utilizing this technique were taken at approximately 7 to 14 day intervals.

100 Spike-Aphididae Counts. The third experiment in 1972 was designed to sample the number of insects, especially the English grain aphid, *Macrosiphum avenae*, on 100 spikes 110 days after planting. Samples were taken in eight of the eleven fields of distinct planting dates. Counts in three fields and yield samples from the eleven fields were not obtained because of a family emergency in the United States which necessitated the researcher's presence. Utilizing the standard head count method, five samples of 20 spikes each were cut and packaged in plastic bags for counting of all live and dead aphids as well as other insects in the laboratory. Forty paces separated each of the 5 sampling locations in each field.

Biotype Determination of the Greenbug. To determine the biotype of 1972 field collected greenbugs, *S. graminum*, cultures were established on wheat of variety 6 in five-inch earthen pots and tested on "Piper sudangrass" grown in six-inch earthen pots. Normally two Piper sudangrass plants, enclosed and separated by glass lamp chimneys, were studied in each pot, one serving as the test plant and the other the check. Aphids were manipulated by camel's-hair brush transfer and leaf transfer techniques. Piper sudangrass plants were infested with from 5 to 35 wingless, reproductively active females and/or immature young. After one week all aphids were counted.

Climatological Data

Daily observations of atmospheric conditions were obtained from the meteorological station in the FAV from January 1, 1970 to October 31, 1972, and monthly averages are presented in Appendix C. The station was located approximately one to one and a half kilometers (3/4 to 1 mile) from all experimental sites and was operated by Juan M. Fernandez of the Division of Meteorology, Ministry of Defense. Maximum, minimum, and median temperatures (^{o}C), relative humidity (%), precipitation (mm), insolation (number of hours/day of sun), and solar radiation/one minute of exposure and total solar radiation/day (gram calories/cm^2) were recorded from 1970 to 1972. These observations were made in order to examine the influences weather phenomena had on various insect groups and to publish a limited yet much needed analysis of some atmospheric conditions in Paraguay. On the basis of maximum and minimum temperatures ^{o}C, the following formula was devised, based on the formula presented by Arnold (1960), to calculate Degree Days, D.D., ^{o}F:

$$\text{Degree Days } ^{o}F = \frac{(\text{Max. T. } ^{o}C + \text{Min. T. } ^{o}C)(1.8) + 64}{2} - (50)(1 \text{ D.D.})$$

In this manner Degree Days were determined for the periods of field experiments from 1970 through 1972, utilizing 50^{o}F as a base temperature.

Preliminary Cost Analysis

Cost analyses of new management strategies involving changes in agricultural techniques are essential in order to determine whether these innovations should be recommended and to what extent. An analysis of the input-output relationships based on known cost, wheat prices in Paraguay, and cost of implementing insect control techniques was also made. These recommendations are based on experiments from 1970 through 1972, with 1973 prices and projection of results on wheat production in Paraguay.

RESULTS AND DISCUSSION

Insect Identifications

Few publications in systematics deal with the insect fauna of Paraguay and therefore an extensive number of insect determinations to species needed to be made. A number of species observed during these studies are additions to the known insect fauna of Paraguay or additions to distribution records. *Aphis* (*Rhopalosiphum*) *maidis*, and *Coleomegilla* spp. had already been reported in Paraguay (Nickel 1958; Tarsia 1967). *Macrosiphum* and *S. graminum* were reported by B. Aranda and Granovsky (1971), and *S. graminum* by the Paraguayan Ministry of Agriculture in 1971. By October 1972 fifteen insect species had been determined, as follows:

Insect determined as	Determined by
HOMOPTERA: Aphididae	
Macrosiphum avenae (F.)	L. M. Russell
**Rhopalosiphum fitchii* (Sand.)	T. A. Granovsky
R. maidis (Fitch)	"
Schizaphis graminum (Rond.)	"
HEMIPTERA: Miridae	
**Dolichomiris linearis* Reuter	J. L. Herring
Nabidae	
Nabis capsiformis Germar	R. C. Froeschner
NEUROPTERA: Chrysopidae	
Chrysopa near *lanata* Bks.	O. S. Flint
COLEOPTERA: Coccinellidae	
**Coleomegilla quadrifasciata* (Schon.)	R. D. Gordon
Cycloneda sanguines (L.)	"
Eriopis connexa (Germar)	"
DIPTERA: Syrphidae	
**Mesograpta* near *flavocuneus* (Hull)	L. V. Knutson
M. lachrymosa (Bigot)	"
HYMENOPTERA: Aphidiidae	
Aphidius spp.	P. M. Marsh
Diaeretiella spp.	"
Ichneumonidae	
Diplazon laetatorius (F.)	R. W. Carlson

* Apparently new citings for this region of South America.

Several of these species are known to occur in neighboring countries. The Aphidiidae are still subject to complete determination and may closely coincide with species found in Argentina, Brazil, Chile, and Uruguay.

Although the experiments were conducted in the Central Department, results should be applicable to other wheat producing areas. These insects were observed by the author in the Central, Cordillera, Itapua, and Misiones Departments in 1971 and 1972. Similar experiments could be conducted throughout these regions to determine their prevalence and seasonal occurrence, especially at the Agricultural School in San Juan Bautista, and the Experimental Stations at Caacupe (IAN) and at Capitan Miranda.

Effect of Insecticide Experiments on Populations and Yields

Fluctuations in aphid populations and the effect one and two Ekatin(R) applications had on populations are presented in Figures 1, 2, and 3. In 1970, distinct bimodal curves were present in all treatments for wheat planted May 27, 1970 (Figure 1), with the first peak comprised mainly of *S. graminum* (greenbug) and the larger second of *M. avenae* (English grain aphid). Peaks corresponded to plant growth stages with the first (greenbug) peak occurring during early vegetative growth and the second (English grain) peak during early boot through seed formation. A similar bimodal curve occurred in wheat planted June 21, 1971 (Figure 2) with the first peak small in comparison to the larger second peak. Aphid populations in wheat planted late, June 30, 1971 (Figure 3) reached only a single peak.

Insecticide Experiments 1970. In 1970 insecticide treatments did not reduce aphid populations noticeably during the early season, possibly because of the low dosage used, but a reduction of 58% to 82% occurred in the English grain aphid populations as a result of the late season application (Figure 1). Yields in plots where populations of English grain aphids were reduced, produced up to 160.8 Kg/Ha (2.39 Bu/A) more than in untreated plots. Although yield differences were not significant at the 5% level (Table 1), aphid populations over 90 English grain aphids per 10 sweeps (approximately 228 per linear foot, 17.47 per plant) during the boot and seed formation stages did reduce yields.

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EXPLANATION OF FIGURE 1

Average number of total aphids/10 sweeps collected 38 to 131 days after planting of wheat on May 27, 1970.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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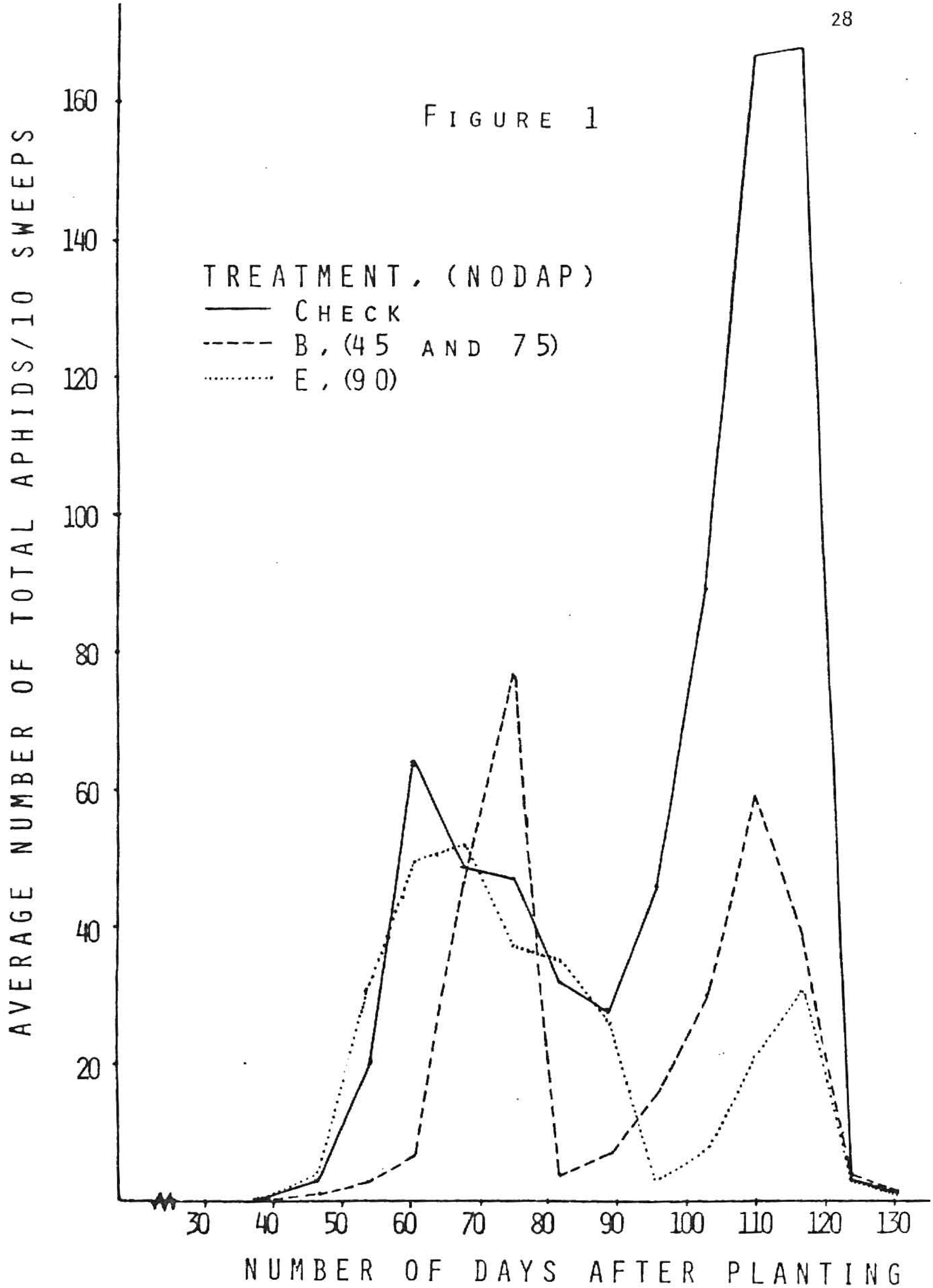
FIGURE 1
TREATMENT, (NODAP)
CHECK
B, (45 AND 75)
E, (90)
AVERAGE NUMBER OF TOTAL APHIDS/10 SWEEPS
160
140
120
100
80
60
40
20
30
40
50
60
70
80
90
100
110
120
130
NUMBER OF DAYS AFTER PLANTING

EXPLANATION OF FIGURE 2

Average number of total aphids/10 sweeps collected 28 to 119 days after planting of wheat on June 21, 1971.

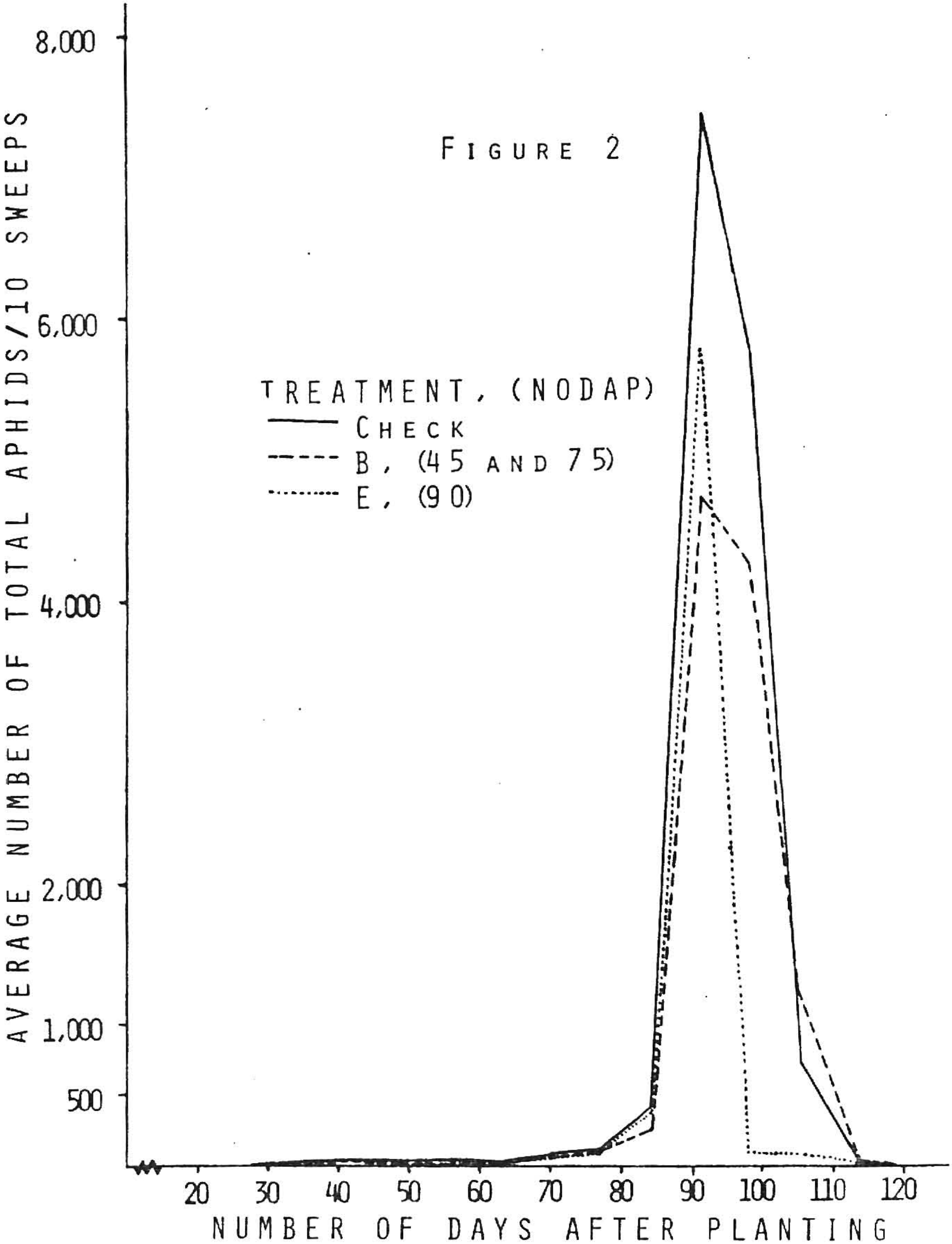
FIGURE 2
TREATMENT, (NODAP)
CHECK
B, (45 AND 75)
E, (90)
AVERAGE NUMBER OF TOTAL APHIDS/10 SWEEPS
8,000
6,000
4,000
2,000
1,000
500
20
30
40
50
60
70
80
90
100
110
120
NUMBER OF DAYS AFTER PLANTING

EXPLANATION OF FIGURE 3

Average number of total aphids/10 sweeps collected 45 to 118 days after planting of wheat on June 30, 1971.

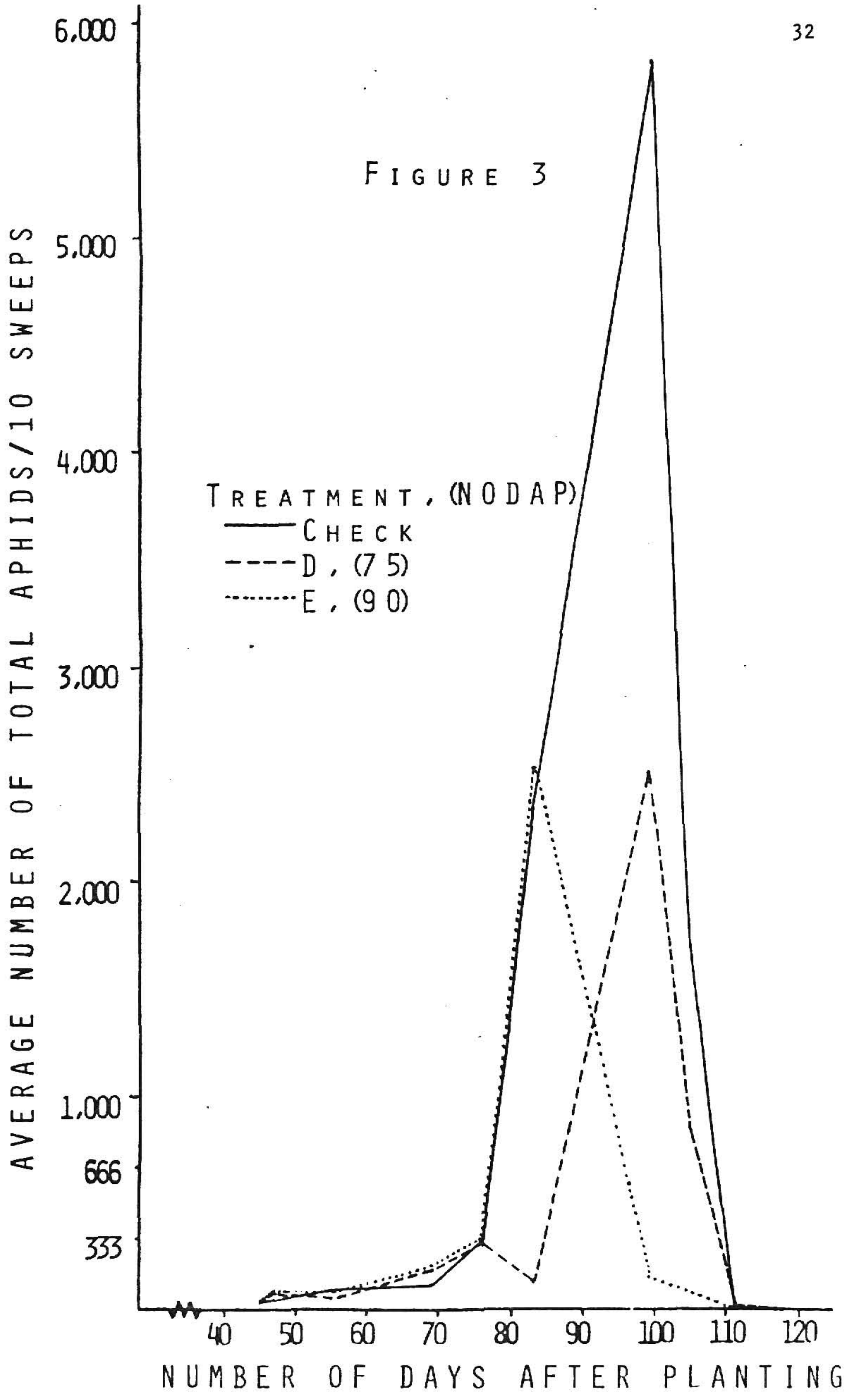
FIGURE 3
6,000
5,000
4,000
3,000
2,000
1,000
666
333
AVERAGE NUMBER OF TOTAL APHIDS/10 SWEEPS
TREATMENT, (NODAP)
CHECK
D, (75)
E, (90)
40
50
60
70
80
90
100
110
120
NUMBER OF DAYS AFTER PLANTING

Table 1. Average yields for wheat harvested on October 13, 1970 for linear meter samples and on October 18, 1970 for square meter samples. Weights are in grams and lengths in centimeters unless otherwise noted.

Yield analysis based on	Insecticide Treatments[a]				
	A	B	C	D	E
Square Meter Samples, m^2					
Avg. no. of spikes/m^2	202.50	222.67	206.17	193.42	211.25
Avg. total spike wt/m^2	211.17	134.75	215.75	190.33	215.75
Avg. whole spike wt	1.034	1.048	1.047	0.984	1.023
Avg. seed wt/spike[b]	0.714	0.724	0.732	0.665	0.669
Seed wt/m^2 [b]	146.33	162.41	150.91	128.50	147.41
Avg. bu/acre[b, c]	21.759	24.150	22.440	19.107	21.919
Linear Meter Samples, lm					
Avg. no. spikes/lm	42.42	43.08	45.17	44.42	47.08
Avg. total spike wt/lm	39.83	45.92	43.58	42.83	47.25
Avg. whole spike wt	0.938	1.065	0.964	0.964	1.003
Avg. seed wt/lm[b]	24.083	32.166	28.500	27.416	30.166
Avg. seed wt/spike[b]	0.564	0.714	0.624	0.618	0.637
Avg. length/spike	6.030	6.699	6.406	6.142	6.558

[a] No statistically significant differences at the 5% level.
Ekatin(R) applied as follows: A = Check, no insecticide; B = at 47 and 78 days after planting; C = at 62 and 92 days after planting; D = at 78 and 111 days after planting; E = at 92 days after planting.

[b] Calculated weight from gross weights, number of spikes, and corresponding seed:chaff ratio for 1971 data. Due to a lack of threshing equipment, seed was not separated from chaff during 1970.

[c] One bushel equals 60 lbs, or 27.2157 kilograms; and 2.47 acres equal one hectare.

Insecticide Experiments on Wheat Planted June 21, 1971. During 1971 aphid populations reached extremely high levels in all treatments (Figures 2 and 3) but the bimodal effect was apparent only with the earlier planted wheat. In the June 21, 1971 planted wheat, yields per hectare were not significantly different, although differences up to 117.5 Kg/Ha (1.74 Bu/A) were obtained. Significant differences were obtained for whole spike weights (5% level), average seed weight per spike (1% level), and 1000 seed test weights (5% level) (Table 2). The 1000 seed test weights were very light, ranging from only 23.631 gms in untreated plots to 26.943 gms in plots of treatment E. Average weight of seed per spike ranged from 0.569 gms to 0.675 gms for check and E treatment, suggesting the effect insect control would have on a field with greater density of spikes. Yields in treatments B and E were the highest and their aphid populations were considerably less than those in untreated plots. In check plots a maximum of 7,441 aphids per 10 sweeps (approximately 18,825/linear foot) were collected (Figure 2). Control effectiveness varied, resulting from reinfestation of the treated areas and from the small quantity of spray utilized for these plots. The differences in yield obtained indicate that populations of approximately 100 English grain aphids per plant significantly affected average whole spike weight and 1000 seed weight (5% level) and average seed weight per spike (1% level).

Insecticide Experiments on Wheat Planted June 30, 1971. Treatments reduced aphid populations noticeably (Figure 3) but yields per hectare were not statistically different. Only single applications of Ekatin(R) were made and resulted in maximum increases of nearly 150 Kg/Ha (2.22 Bu/A). Average whole spike weight, average seed weight per spike, and

Table 2. Average yield for wheat planted June 21, 1971, and harvested October 21 and 22, 1971 for linear meter samples and on October 25, 1971 for square meter samples. Weights are in grams and lengths in centimeters unless otherwise noted.

Yield analysis based on	Insecticide Treatments[a]				
	A	B	C	D	E
Square Meter Samples, m^2					
Avg. no. of spikes/m^2	132.249	139.499	132.083	133.666	137.249
Avg. total spike wt/m^2	122.083	134.666	123.666	125.499	133.749
Avg. whole spike wt	0.882	0.964*	0.936	0.937	0.974*
Avg. seed wt/spike	0.561	0.640**	0.622**	0.622**	0.652**
Seed wt/m^2	77.749	89.499	82.083	82.666	89.416
Avg. bu/acre[b]	11.561	13.308	12.206	12.292	13.296
Linear Meter Samples, lm					
Avg. no. spikes/lm	30.416	34.749	32.499	32.666	33.916
Avg. total wt spikes/lm	28.583	33.583	31.166	31.833	35.083
Avg. whole spike wt	0.937	0.964	0.968	0.981	1.035
Avg. seed wt/lm	17.333	22.583	20.333	20.499	22.833
Avg. seed wt/spike	0.569	0.648	0.632	0.633	0.675
Avg. length/spike	8.729	8.563	8.553	8.800	8.960
1000 seed test wt	23.631	25.006	26.006*	25.259	26.943*

* Significant at the 5% level.

** Significant at the 1% level.

a Ekatin(R) applied as follows: A = Check, no insecticide; B = at 47 and 77 days after planting; C = at 61 and 91 days after planting; D = at 77 and 108 days after planting; E = at 91 days after planting.

b One bushel equals 60 lbs, or 27.2157 kilograms; and 2.47 acres equal one hectare.

1000 seed test weight differences were significant at the 1% level for treatments D and E (Table 3). The average seed weight per spike ranged from 0.498 gms for check plots to 0.628 gms for plots of treatment D. Again this suggests the influence more spikes per hectare would have on total production per hectare. Treatments D and E yielded 58.8 and 149.5 Kg/Ha more, respectively, than check plots. Aphids reached 102 and 690 per plant in D and E plots before control was realized (Figure 3). The D treatments initially reduced the aphids but rapid reinfestation occurred and the population peaked 23 days later at 2,503 aphids per 10 sweeps, 3,322 aphids fewer per 10 sweeps than occurred in check plots, a reduction of 57.0%. Population reduction for the E treatment was from 2,526 aphids per 10 sweeps to 163 per 10 sweeps, a 93.5% reduction, and 97.2% fewer per 10 sweeps than simultaneously occurred in check plots (Figure 3).

Insecticide Experiments-Yields, Basic Considerations. In these 3 experiments utilizing approximately 30% the recommended dosage of Ekatin$^{(R)}$, none were statistically different compared to check plots. Average whole spike weight, average seed weight per spike, and 1000 seed test weights were statistically different for some treatments. Normally 1000 seed test weights are over 25.0 gms, depending on variety, thus indicating that in all check plots during 1971 the seeds were considerably underweight. In addition to insects, weeds and plant diseases may have caused these low weights. Average seed weights per spike were also significantly different and may be an indication of potential yield increases. Tables 1, 2, and 3 indicate low spike densities in all plots analyzed, with a slight trend for more spikes in treated plots. If the

Table 3. Average yields for wheat planted June 30, 1971 and harvested on October 22, 1971 for linear meter samples. Weights are in grams and lengths in centimeters unless otherwise noted.

Yield analysis based on	Insecticide Treatments[a]				
	A	B	C	D	E
Linear Meter Samples, lm					
Avg. no. spikes/lm	27.666	27.374	25.458	23.624	26.999
Avg. total wt spikes/lm	22.416	22.416	21.208	22.708	25.374
Avg. whole spike wt	0.809	0.819	0.841	0.960**	0.937**
Avg. seed wt/lm	13.875	13.708	13.041	14.875	15.416
Avg. seed wt/spike	0.498	0.500	0.517	0.628**	0.605**
Avg. length/spike	9.165	9.198	8.841	8.965	9.098
Avg. kilos yd/hectare	816.165	806.361	767.146	874.988	965.673
Avg. bushels yd/acre[b]	12.136	11.990	11.407	13.010	14.359
1000 seed test wt	22.806	22.924	22.974	26.558**	26.454**

** Significant at the 1% level.

[a] Ekatin(R) applied as follows: A = Check, no insecticide; B = at 45 days after planting; C = 61 days after planting; D = 76 days after planting; E = 90 days after planting.

[b] One bushel equals 60 lbs, or 27.2157 kilograms; and 2.47 acres equal one hectare.

number and weight of spikes produced per hectare could be increased through more viable seed, seeding rate, improved varieties, weed control, disease prevention and improved pest management, then very significant advances in yields could be achieved.

The low dosage of 30% the recommended quantity of Ekatin(R) probably was responsible for the rather poor insect control. Short residual duration occurred, an average lasting 7 to 14 days, although a 25-day residual was evident during 1970 in two treatments under lower population pressures. Stronger doses of Ekatin(R) may have ensured better yields but further experiments are needed to analyze this and the effects increased dosages may have on natural enemies of the aphids.

Two important periods in the aphid population control-wheat growth stages are evident: that around 45 days and 90 days after planting. These periods are associated with foliage development, flowering, seed setting, and seed formation. However, it should be noted that plants less than 45 days old are very susceptible to damage by aphids.

Influence of Ekatin(R) on Natural Enemies. The effects of low dosages of Ekatin(R) on aphid natural enemies are presented in Tables 4, 5, 6, and 7. The first three tables present listings of all the insects studied and the effects of the Ekatin(R) applications, while Table 7 presents a summary of the total number of times each insect was significantly affected. These results are based on analysis of variance at the 10%, 5% and 1% levels for weekly population counts from all the treated and non-treated plots. Of the seven basic groups studied, Nabidae and Syrphidae appeared not to be adversely influenced by the Ekatin(R), and

Table 4. Effects of Ekatin(R) applications on various insects in most recently sprayed plots vs. check plots, in wheat planted May 27, 1970.

Insect	July			August					September				Oct.		
	13 i	20	27 i	3	10 i	17	24 i	31	7	14 i	21	30	5	Total[b]	Percent[c]
APHIDIDAE															
Alate	ns	ns	ns	*	*	***	ns	ns	***	ns	ns	ns	ns	4	30.77
Apterous	ns	ns	**	*	ns	***	***	***	***	*	ns	ns	ns	7	53.84
DOLICHOMIRIS															
Nymphs	a	a	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	1	9.09
Adults	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0	0.0
CHRYSOPA															
Larvae	a	a	a	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0	0.0
Adults	ns	ns	a	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0	0.0
COCCINELLIDAE															
Larvae	a	a	a	ns	ns	a	a	a	a	ns	*	ns	ns	1	16.66
Adults	a	a	a	a	a	a	a	ns	ns	ns	ns	ns	ns	0	0.0
APHIDIIDAE															
Total	ns	ns	ns	ns	ns	**	**	**	ns	ns	ns	ns	a	3	25.00
APHIDIDAE															
Total	ns	ns	**	*	ns	***	***	***	***	*	ns	ns	ns	7	53.84
DOLICHOMIRIS															
Total	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0	0.0
CHRYSOPA															
Total	ns	ns	a	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0	0.0
COCCINELLIDAE															
Total	a	a	a	ns	ns	a	a	ns	ns	ns	**	ns	ns	1	12.50

Table 4 (concluded).

Insect	July 13 [i]	20	27 [i]	August 3	10 [i]	17	24 [i]	31	September 7	14 [i]	21	30	Oct. 5	Total[b]	Percent[c]
ALL PEST SPECIES	ns	ns	**	*	ns	***	***	***	***	*	ns	ns	ns	7	53.84
ALL BENEFICIAL SPECIES	ns	ns	ns	*	ns	**	ns	**	ns	ns	***	ns	ns	4	30.77
TOTAL WHICH ARE SIGNIFICANT	0	0	3	5	1	7	4	5	4	3	3	0	0	35	

[a] No insects of this group present on this collection date.

[b] Total times significantly affected.

[c] Percentage based on only those times when insect occurred in the population.

[i] Insecticide applied between these dates.

* Significant at 10% level.

** Significant at 5% level.

*** Significant at 1% level.

ns Not significant at 10%, 5% or 1% levels.

Table 5. Effects of Ekatin[(R)] applications on various insects in most recently sprayed plots vs. check plots, in wheat planted June 21, 1971.

Insect	July		August					September				October				
	19	26	2	[i] 9	16	[i] 24	30	6	[i] 13	20	[i] 27	4	[i] 13	18	Total[b]	Per-cent[c]
APHIDIDAE																
Alate	ns	ns	ns	ns	ns	ns	ns	ns	ns	***	***	***	ns	ns	3	21.43
Apterous	ns	ns	ns	*	**	**	ns	ns	***	***	***	***	ns	ns	7	50.00
DOLICHOMIRIS																
Nymphs	a	a	a	a	a	a	ns	ns	ns	ns	ns	*[d]	ns	a	1	14.28
Adults	a	ns	ns	ns	ns	a	ns	ns	ns	ns	ns	ns	ns	ns	0	0.0
NABIDAE																
Total	a	a	a	a	a	a	a	a	a	ns	ns	ns	a	a	0	0.0
SYRPHIDAE																
Total	a	a	a	a	a	a	a	ns	ns	ns	ns	ns	ns	ns	0	0.0
CHRYSOPA																
Larvae	a	a	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0	0.0
Adults	a	a	a	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0	0.0
COCCINELLIDAE																
Larvae	a	a	a	ns	ns	a	ns	ns	ns	*[d]	***	**	ns	ns	3	30.00
Adults	a	ns	ns	ns	ns	**	ns	ns	ns	ns	**	**[e]	ns	ns	3	23.07
APHIDIIDAE																
Total	a	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	a	a	a	1	10.00
APHIDIDAE																
Total	ns	ns	ns	*	**	***	ns	ns	***	***	***	***	ns	ns	7	50.00
DOLICHOMIRIS																
Total	a	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*[d]	ns	ns	1	7.69
CHRYSOPA																
Total	a	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*[f]	ns	ns	1	7.69

Table 5 (concluded).

Insect	July 19	July 26	August 2 [i]	August 9	August 16 [i]	August 24	August 30	September 6 [i]	September 13	September 20 [i]	September 27	October 4 [i]	October 13	October 18	Total[b]	Per-cent[c]
COCCINELLIDAE Total	a	ns	ns	ns	ns	**	ns	ns	ns	ns	***	**[d]	ns	ns	3	23.07
ALL PEST SPECIES	ns	ns	ns	*	**	**	ns	ns	***	***	***	***	ns	ns	7	50.00
ALL BENEFICIAL SPECIES	a	ns	ns	ns	*	*	ns	ns	ns	ns	***	***	ns	ns	4	30.77
TOTAL WHICH ARE SIGNIFICANT	0	0	0	3	5	6	0	0	3	5	8	11	0	0	41	

[a] No insects of this group present on this collection date.

[b] Total times significantly affected.

[c] Percentage based on only those times when insect occurred in the population.

[d] Significant in plots sprayed once, not significant in plots sprayed twice.

[e] Significant at 10% level in plots sprayed once, and at 5% in those sprayed twice.

[f] Significant at 5% level in plots sprayed once, and at 10% in those sprayed twice.

[i] Insecticide applied between these dates.

[ns] Not significant at 10%, 5% or 1% levels.

[*] Significant at 10% level.

[**] Significant at 5% level.

[***] Significant at 1% level.

Table 6. Effects of Ekatin(R) applications on various insects in most recently sprayed plots vs. check plots, in wheat planted June 30, 1971.

Insect	August 14 i	16	24 i	September 7	14 i	21	October 7	13 i	19	26	Total[b]	Percent[c]
APHIDIDAE												
Alate	ns	ns	ns	ns	ns	***	***	**	ns	ns	3	30.00
Apterous	ns	***	***	***	ns	***	***	**	ns	ns	6	60.00
DOLICHOMIRIS												
Nymphs	ns	ns	a	ns	ns	ns	ns	ns	ns	ns	0	0.0
Adults	a	a	ns	ns	ns	ns	ns	ns	ns	ns	0	0.0
NABIDAE												
Total	a	a	a	a	a	ns	ns	ns	ns	ns	0	0.0
SYRPHIDAE												
Total	a	a	a	ns	ns	ns	ns	ns	ns	ns	0	0.0
CHRYSOPA												
Larvae	ns	ns	a	ns	ns	ns	*	ns	ns	ns	1	11.11
Adults	ns	ns	a	ns	ns	ns	ns	ns	ns	ns	0	0.0
COCCINELLIDAE												
Larvae	a	ns	ns	ns	ns	ns	***	ns	ns	ns	1	11.11
Adults	ns	ns	ns	ns	ns	ns	*	ns	ns	***	2	20.00
APHIDIIDAE												
Total	**	**	***	**	ns	ns	a	a	a	a	4	66.66
APHIDIDAE												
Total	ns	***	***	ns	ns	***	***	**	ns	ns	5	50.00
DOLICHOMIRIS												
Total	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0	0.0
CHRYSOPA												
Total	ns	ns	a	ns	ns	ns	*	ns	ns	ns	1	11.11

Table 6 (concluded).

Insect	August 14	[i] 16	24	[i] September 7	14	[i] 21	October 7	13	[i] 19	26	Total[b]	Percent[c]
COCCINELLIDAE Total	ns	ns	ns	ns	ns	ns	***	*	ns	**	3	30.00
ALL PEST SPECIES	ns	***	***	ns	ns	***	***	**	ns	ns	5	50.00
ALL BENEFICIAL SPECIES	**[d]	**	***	ns	ns	ns	***	ns	ns	***	5	50.00
TOTAL WHICH ARE SIGNIFICANT	2	5	5	2	0	4	10	5	0	3	36	

[a] No insects of this group present on this collection date.

[b] Total times significantly affected.

[c] Percentage based on only those times when insect occurred in the population.

[d] Treatments A and D significant from others at 10% level before any insecticide applications.

[i] Insecticide applied between these dates.

ns Not significant at 10%, 5%, or 1% levels.

* Significant at 10% level.

** Significant at 5% level.

*** Significant at 1% level.

Table 7. Summary of effects of Ekatin(R) applications on various insects in wheat, during 1970 and 1971 studies.

Insect	May 27, 1970		June 21, 1971		June 30, 1971			Total	
	Actual[a]	Percent[b]	Actual[a]	Percent[b]	Actual[a]	Percent[b]	Total[c]	occurrence[d]	Percent[e]
APHIDIDAE									
Alate	4	30.77	3	21.43	3	30.00	10	37	27.02
Apterous	7	53.84	7	50.00	6	60.00	20	37	54.05
DOLICHOMIRIS									
Nymphs	1	9.09	1	14.28	0	0.0	2	27	7.40
Adults	0	0.0	0	0.0	0	0.0	0	33	0.0
NABIDAE									
Total	-[f]	-	0	0.0	0	0.0	0[h]	8[h]	0.0[h]
SYRPHIDAE									
Total	-[g]	-	0	0.0	0	0.0	0[h]	14[h]	0.0[h]
CHRYSOPA									
Larvae	0	0.0	0	0.0	1	11.11	1	31	3.22
Adults	0	0.0	0	0.0	0	0.0	0	32	0.0
COCCINELLIDAE									
Larvae	1	16.66	3	30.00	1	11.11	5	25	20.00
Adults	0	0.0	3	23.07	2	20.00	5	29	17.24
APHIDIIDAE									
Total	3	25.00	1	10.00	4	66.66	8	28	28.57
APHIDIDAE									
Total	7	53.84	7	50.00	5	50.00	19	37	51.35
DOLICHOMIRIS									
Total	0	0.0	1	7.69	0	0.0	1	36	2.77

Table 7 (concluded).

Insect	May 27, 1970		June 21, 1971		June 30, 1971				
	Actual[a]	Percent[b]	Actual[a]	Percent[b]	Actual[a]	Percent[b]	Total[c]	Total occurrence[d]	Percent[e]
CHRYSOPA Total	0	0.0	1	7.69	1	11.11	2	34	5.88
COCCINELLIDAE Total	1	12.50	3	23.07	3	30.00	7	31	22.58
ALL PEST SPECIES	7	53.84	7	50.00	5	50.00	19	37	51.35
ALL BENEFICIAL SPECIES	4	30.75	4	30.77	5	50.00	13	36	36.11
GRAND TOTAL	35[h]		41		36		112[h]	512	21.87

[a] Actual number of times insect affected by insecticide.

[b] Percentage of times insect affected by insecticide in relation to the number of times it occurred in the collections.

[c] Total number of times insect affected during the three experiments.

[d] Total number of times insect occurred in the collections.

[e] Average percentage of times population was affected.

[f] Nabidae not counted during 1970 surveys.

[g] Syrphidae not counted during 1970 surveys.

[h] Nabidae and/or Syrphidae of 1970 are not included in totals or percentages.

larvae of Chrysopidae and nymphs of Dolichomiris sp. were only slightly affected. Coccinellidae were significantly affected, the larvae 20.0% and adults 17.25% of the time, and the Aphidiidae parasitoids 28.57% of the time. The Aphididae were significantly reduced 27.02 and 54.05% for alates and apterous, respectively. Population reduction of the natural enemies could have occurred by direct and/or indirect effects of Ekatin(R); these data do not enable separation of these factors. Zeleny (1966) reported that Ekatin(R) sprayed directly on larvae of Coccinella septempunctata at 1200 mg/sq meter did not adversely affect the insect and similarly had no effect when applied to Chrysopa perla. Aphids systemically poisoned with Ekatin(R), and fed to C. septempunctata larvae and adults, did not induce death of these predators. He did note that both of the hymenopterous parasitoids Praon adjectum Halid. and Lysiphlebus fabarum Marsh were the most sensitive to similar applications. The results obtained by Zeleny are similar to trends observed in Paraguay, indicating that parasitoids were the natural enemy most likely affected by Ekatin(R), while Chrysopa were less affected.

Population Studies 1970 to 1972

Diverse experiments from 1970 to 1972 were analyzed for population dynamics, sampling methods, and biotypes of the greenbug. Utilizing the sweepnet sampling method, population growth curves were established in nine fields; three fields were analyzed using a combined linear foot technique and sweepnet method; and eight fields were studied using the 100 spike analysis for aphids.

Aphid population growths were variable from 1970 to 1972. Factors influencing the extremely high peak during 1971 included various weather phenomena and the number of beneficial insects present by the end of August. Also, some agriculturalists believe that a new influx of aphids and/or species from Argentina or Brazil may have been responsible. It should be stressed that all species were already present during 1970 and new species were not introduced, although an influx of a large population of an already present species may have occurred. Correlation of weekly weather data (Tables 25 to 29) to weekly aphid populations (Tables 8 to 11) from experiments during 1970 and 1971 indicated that the weather phenomena recorded were not significant for the 1970 data, although several phenomena were significant for 1971. The following factors were positively correlated with total aphids during 1971 at the 1% significance level: temperature (^{o}C); total and average degree days, employing a base temperature of 50^{o}F; and total solar radiation. Total solar insolation was positively correlated at the 5% level. Average relative humidity and total precipitation were negatively correlated at the 1% level. Evidently conditions were more favorable during 1971 for larger aphid populations. However, it should be stressed that weather data from only three years is insufficient for firm conclusions about the important influences of climate. The early occurrence of several beneficial species is also important in preventing build-ups. Ideally, the presence of many beneficials early in the season should result in a good degree of natural control, since the enemies can develop and maintain a good ratio against aphids. Beneficial species were correlated with aphids to a stronger degree during 1971 than 1970, probably

Table 8. Average number of seven insect groups[a] occurring per 20 sweeps of a 15-inch sweepnet in untreated wheat planted April 12, 1970.

Date		NODAP[b]	APHIDIDAE		*DOLICHOMIRIS*		NABIDAE[c]	*CHRYSOPA*		COCCINELLIDAE		SYRPHIDAE[d]	APHIDIIDAE[e]
			Alate	Apterous	Nymph	Adult	Total	Larvae	Adult	Larvae	Adult	Total	Total
May	7	25	0	0	0	0	0	0	0	0	0	0	0
	14	32	0	0.25	0	0.50	0	0	0	0	0	0	0
	22	40	0.25	0.25	0	1.50	0	0.25	0.50	0	0	0	0.25
	28	46	0.50	1.25	0	1.50	0	0	0.25	0	0.75	0.25	0.75
June	4	53	0.50	2.25	-[f]	-[f]	0	0.25	0.25	0	0.25	0	0
	11	60	1.00	0.75	1.25	3.75	0	0.25	3.00	0	0	0	0
	19	68	0.25	0.25	0	5.50	0.25	0	5.00	0	0.50	0	0
	26	75	0.75	5.75	1.25	13.50	0.75	0.50	3.75	0	0	0	0.25
July	3	82	0.75	1.75	0	0.25	0.25	0	1.25	0	0	0	0
	10	89	1.75	25.00	6.50	6.75	0.75	0.50	12.25	0	0.25	0	0
	17	96	0	0.75	0	0.75	0	0.25	0.75	0	0	0.75	0
	24	103	1.75	14.00	9.75	3.25	0	0.25	2.75	0	0	0	0
Aug.	1	111	0.75	13.00	2.00	0.25	0	0.50	0.25	0	0	0	0
Total counted			33	261	83[f]	150[f]	8	11	120	0	7	4	5
Avg. no. per sweep/season[g]			0.031	0.246	0.084	0.153	0.007	0.010	0.113	0.0	0.006	0.003	0.004

[a] Seven insect groups are Aphididae, *Dolichomiris*, Nabidae, *Chrysopa*, Coccinellidae, Syrphidae, and Aphidiidae.

[b] NODAP indicates number of days after planting.

[c] Includes nymphs and adults in each day's counts.

[d] Includes larvae and adults in each day's counts.

[e] Includes adults and "mummied" aphids in each day's counts.

[f] One day's counts omitted.

[g] A total of 1060 sweeps were taken May 7 to August 1, 1970.

Table 9. Average number of five insect groups[a] occurring per 10 sweeps with a 15-inch sweepnet in check plots in wheat planted May 27, 1970.

Date		NODAP	APHIDIDAE		DOLICHOMIRIS		CHRYSOPA		COCCINELLIDAE		APHIDIIDAE
			Alate	Apterous	Nymphs	Adults	Larvae	Adults	Larvae	Adults	Total[b]
July	4	38	0	0	0	0.25	0	0	0	0	0
	13	47	0.50	2.25	0	3.00	0	0	0	0	0.25
	20	54	1.00	19.00	0	2.75	0	0.25	0	0	0.75
	27	61	5.00	58.25	0	2.00	0	0	0	0	2.00
Aug.	3	68	3.25	45.00	3.75	3.50	0.25	1.25	0.50	0	1.25
	10	75	2.00	44.75	2.25	2.75	0	1.25	0.25	0	3.25
	17	82	3.00	28.75	2.50	1.75	0.50	0.75	0	0	6.50
	24	89	4.50	22.75	9.00	1.50	1.75	3.75	-[c]	-[c]	3.00
	31	96	3.00	42.25	7.75	2.00	1.50	1.50	0	0	7.75
Sept.	7	103	4.50	84.50	10.00	2.00	0.25	2.50	0	0	5.50
	14	110	3.00	163.75	10.50	1.50	1.75	1.00	0.75	1.00	8.75
	21	117	9.50	158.25	17.25	2.75	2.50	1.00	5.25	2.25	3.00
	30	124	0.75	2.25	9.25	5.00	0.50	0.25	2.00	1.75	0.25
Oct.	5	131	0	0.75	4.75	0.75	0.25	0.25	1.25	1.50	0
Total counted			160	2691	308	126	37	55	40[d]	26[d]	169
Avg. no. per sweep/season[e]			0.285	4.805	0.550	0.225	0.066	0.098	0.076[d]	0.050[d]	0.301

[a] Five insect groups are Aphididae, Dolichomiris, Chrysopa, Coccinellidae, and Aphidiidae.

[b] Includes adults and "mummied" adults in each day's counts.

[c] One day's counts omitted.

[d] Total and average represents only those Coccinellidae collected in 520 sweeps due to the omission of one day's counts.

[e] A total of 560 sweeps were taken July 4 to October 5, 1970.

Table 10. Average number of seven insect groups[a] occurring per 10 sweeps with a 15-inch sweepnet in check plots in wheat planted June 21, 1971.

Date		NODAP	APHIDIDAE		DOLICHOMIRIS		NABIDAE[b]	CHRYSOPA		COCCINELLIDAE		SYRPHIDAE[c]	APHIDIIDAE[d]
			Alate	Apterous	Nymph	Adult	Total	Larvae	Adult	Larvae	Adult	Total	Total
July	19	28	0.25	0	0	0	0	0	0	0	0	0	0
	26	35	0.75	7.75	0	0	0	0	0	0	0	0	1.50
Aug.	2	42	2.75	21.25	0	0.50	0	0	0	0	0.25	0	2.75
	9	49	2.25	26.00	0	0.50	0	1.00	0	2.25	0	0	13.25
	16	56	3.00	34.50	0	0.75	0	0.50	0	1.75	0.25	0	32.25
	24	64	2.25	9.50	0	0	0	0	0.25	0.50	1.50	0	1.00
	30	70	25.00	54.75	0	0.50	0	0	0.50	1.25	1.00	0	3.50
Sept.	6	77	28.00	89.75	0.25	0.25	0	0	1.50	0.25	1.25	0.75	0.75
	13	84	27.50	378.25	0.25	2.25	0	0.50	2.50	0	10.00	0.50	0
	20[e]	91	143.25	7297.75	1.00	1.25	0.25	8.00	2.25	12.50	13.25	0.25	1.75
	27[e]	98	798.25	4949.25	0	0.25	0.25	3.50	6.25	41.25	15.75	2.25	0.25
Oct.	4[e]	105	51.50	680.75	0	0	1.50	0.75	3.75	9.75	5.00	1.00	0
	13	114	0.50	3.50	0.25	0	0	0.50	1.00	0.25	6.75	1.75	0
	18	119	0.25	0	0	0	0	0	0.75	0.25	10.50	2.00	0
Total counted			4,342	54,212	7	26	8	59	75	280	262	34	230
Avg. no. per sweep/season[f]			7.753	96.807	0.012	0.046	0.014	0.105	0.133	0.500	0.467	0.060	0.410

[a] Seven insect groups are Aphididae, Dolichomiris, Nabidae, Chrysopa, Coccinellidae, Syrphidae, and Aphidiidae.
[b] Includes nymphs and adults in each day's counts.
[c] Includes larvae and adults in each day's counts.
[d] Includes adults and "mummied" aphids in each day's counts.
[e] Aphididae data calculated from cubic centimeters of aphids.
[f] A total of 560 sweeps were taken July 19 to October 18, 1971.

Table 11. Average number of seven insects groups[a] occurring per 10 sweeps with a 15-inch sweepnet in check plots in wheat planted June 30, 1971.

Date	NODAP	APHIDIDAE Alate	APHIDIDAE Apterous	DOLICHOMIRIS Nymph	DOLICHOMIRIS Adult	NABIDAE[b] Total	CHRYSOPA Larvae	CHRYSOPA Adult	COCCINELLIDAE Larvae	COCCINELLIDAE Adult	SYRPHIDAE[c] Total	APHIDIIDAE[d] Total
Aug. 14	45	2.75	35.00	0.00	0.25	0.00	0.50	0.25	0.00	0.25	0.00	7.25
16	47	3.25	56.25	0.00	0.00	0.00	0.25	0.00	0.00	1.00	0.00	5.50
24	55	9.25	74.25	0.00	0.25	0.00	0.00	0.00	0.25	0.25	0.00	5.50
Sept. 7	69	59.25	87.25	0.50	1.00	0.00	0.00	0.50	5.00	1.75	0.25	2.50
14	76	80.25	245.50	0.00	0.00	0.00	0.00	1.75	0.50	4.50	0.00	0.75
21	83	62.50[e]	2279.50[e]	0.50	2.25	2.50	3.25	2.00	1.50	14.00	0.25	0.75
Oct. 7[f]	99	806.50[e]	5018.00[e]	0.50	0.25	0.25	1.75	1.00	13.75	8.25	1.00	0.00
13[f]	105	39.00[e]	1658.00[e]	0.00	0.00	1.25	0.75	0.25	2.75	14.25	1.75	0.00
19	111	0.25	2.50	0.25	0.00	0.75	0.00	0.00	0.50	12.25	1.50	0.00
26	118	0.75	0.25	0.25	0.25	0.00	0.00	0.50	0.75	6.75	0.50	0.00
Total counted		4,255	37,826	8	17	19	26	25	100	253	21	85
Avg. no. per sweep/season[g]		11.819	105.072	0.0222	0.0472	0.0527	0.0722	0.0694	0.2777	0.7027	0.0583	0.2361

a Seven insect groups are Aphididae, Dolichomiris, Nabidae, Chrysopa, Coccinellidae, Syrphidae, and Aphidiidae.
b Includes nymphs and adults in each day's counts.
c Includes larvae and adults in each day's counts.
d Includes adults and "mummied" aphids in each day's counts.
e Data calculated from cubic centimeters of aphids.
f Data from only two replicates on these collection dates.
g A total of 360 sweeps were taken August 14 to October 26, 1971.

resulting from the larger aphid populations. Although direct comparisons between years is complicated by a difference in planting dates, by August 16, 1971, the ratio of beneficials to total aphids was better than at the corresponding time in 1970 (fewer aphids were initially present per natural enemy during 1971). By August 24, 1971, the parasitoids were greatly reduced, possibly reacting to recent fluctuations of temperature, relative humidity, total solar insolation and radiation, and a total rainfall of 49.5 mm. In 1970 the parasitoid population fluctuated with the aphid population and was present until the end of September. Variation in weather from August 18 to 24, 1970, also reduced the parasitoids but not by such a striking degree as during 1971. The parasitoids were able to increase their numbers again until mid-September when reduction occurred by the action of a strong rainfall (Tables 9 and 26).

Bimodal aphid populations, discussed under the Insecticide Experiments, were again documented in 1972, but their occurrence seems dependent on planting date. Utilizing wheat planted at five dates over a 70-day period, the effect of planting dates on the insect populations were studied (Figure 4, Tables 12 to 16). The curves of Figure 4 appear to be bimodal but a closer look indicates only single peaks for the April and late June planted fields, while two peaks occurred in fields planted during May. These peaks can be associated with the wheat growth stages as discussed earlier. The occurrence of S. graminum seemed to be somewhat limited to the earlier planted wheat, probably related to climatological conditions. This is not to say it does not occur in later planted wheat, but rather that its relative importance in the population is overridden by M. avenae (see discussion on 100 Spike Samples and Table 23).

EXPLANATION OF FIGURE 4

Average number of total aphids/10 sweeps collected from 5 fields planted over a 70-day period during 1972.

FIGURE 4

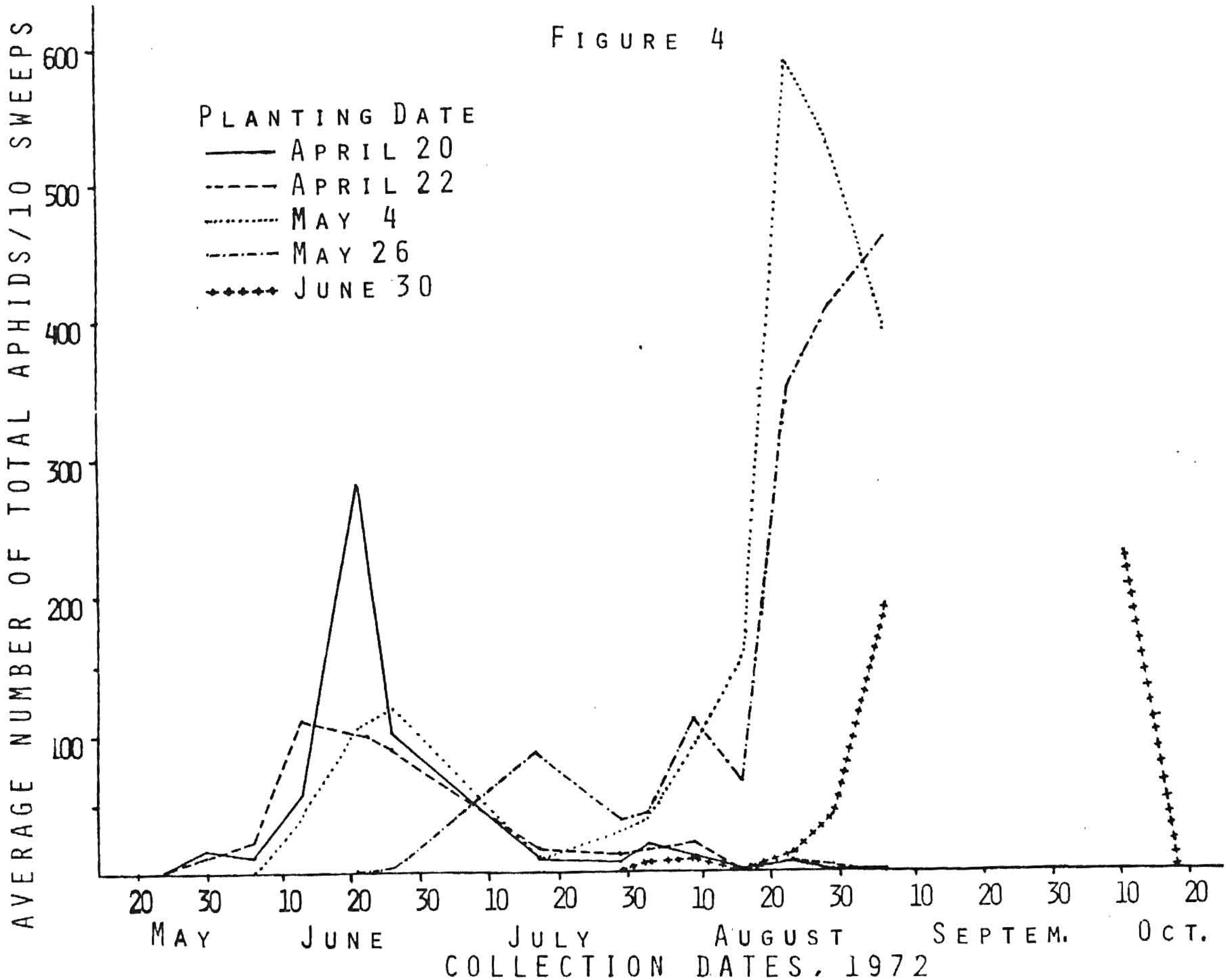
PLANTING DATE
APRIL 20
APRIL 22
MAY 4
MAY 26
JUNE 30
AVERAGE NUMBER OF TOTAL APHIDS/10 SWEEPS
600
500
400
300
200
100
20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20
MAY
JUNE
JULY
AUGUST
SEPTEM.
OCT.
COLLECTION DATES, 1972

Table 12. Average number of seven insect groups[a] occurring per 10 sweeps with a 15-inch sweepnet in untreated wheat planted April 20, 1972.

Date		NODAP	APHIDIDAE		*DOLICHOMIRIS*		NABIDAE[b]	*CHRYSOPA*		COCCINELLIDAE		SYRPHIDAE[c]	APHIDIIDAE[d]
			Alate	Apterous	Nymph	Adult	Total	Larvae	Adult	Larvae	Adult	Total	Total
May	24	33	0	0.25	0	1.50	0	0	0	0.25	0	0	0.25
	30	39	1.50	14.00	0	0.50	0	0.50	0	0	0	0.75	0
June	6	46	0.75	10.50	0	0.50	0	0	0	0.25	0	0.75	0.25
	13	53	6.25	52.25	0	1.25	0	0	0.50	0.75	0.25	1.25	0.75
	21	61	12.50	270.25	0.50	4.00	0	0.50	0.50	0.25	3.00	3.00	8.50
	26	66	4.50	97.75	0	3.25	0.25	0.50	2.75	0.25	0.25	4.25	1.00
July	17	87	1.25	10.25	3.50	5.50	4.00	1.00	2.75	3.50	2.50	2.75	0.50
	29	99	0	7.00	11.25	3.00	5.50	1.75	6.00	0.50	4.50	2.00	1.00
Aug.	2	103	0.25	21.00	6.50	3.75	3.25	3.00	1.25	0.75	1.50	1.25	0.25
	9	110	1.00	10.75	14.00	3.75	5.25	5.00	0.50	0.25	1.25	0.75	0.50
	16	117	0.25	2.25	3.50	2.75	1.25	1.25	0.25	0.25	0.25	0	0
	23	124	0.75	6.50	10.50	4.50	2.25	0.25	0.50	4.25	1.75	0	0
	29	130	0.25	3.00	6.25	2.25	3.25	0.50	0	3.25	1.25	0.50	0
Sept.	6	138	0.50	1.25	2.25	2.75	4.00	0	0.50	0	0	0	0
Total counted			119	2028	233	157	116	57	62	58	66	69	52
Avg. no. per sweep/season[e]			0.2125	3.6214	0.4160	0.2803	0.2071	0.1017	0.1107	0.1035	0.1178	0.1232	0.0928

[a] Seven insect groups are Aphididae, *Dolichomiris*, Nabidae, *Chrysopa*, Coccinellidae, Syrphidae, and Aphidiidae.
[b] Includes nymphs and adults in each day's counts.
[c] Includes larvae, pupae, and adults in each day's counts.
[d] Includes adults and "mummied" aphids in each day's counts.
[e] A total of 560 sweeps were taken May 24 to September 6, 1972.

Table 13. Average number of seven insect groups[a] occurring per 10 sweeps with a 15-inch sweepnet in untreated wheat planted April 22, 1972.

Date		NODAP	APHIDIDAE		*DOLICHOMIRIS*		NABIDAE[b]	*CHRYSOPA*		COCCINELLIDAE		SYRPHIDAE[c]	APHIDIIDAE[d]
			Alate	Apterous	Nymph	Adult	Total	Larvae	Adult	Larvae	Adult	Total	Total
May	24	32	0.50	0.50	0	2.25	0	0	0	0	0	0.25	0
	30	38	1.25	10.25	0	2.00	0	1.50	0	0.25	0	0.25	0
June	6	45	2.25	21.75	0	1.25	0	0.50	0	0	0	0.50	0.50
	13	52	8.00	102.50	0	3.50	0	1.00	1.75	2.75	2.75	2.50	1.25
	22	61	2.25	98.00	0	2.25	0.75	0.50	2.25	2.00	0.25	0.50	2.75
	26	65	4.25	86.00	1.00	3.75	0	0.50	3.50	0	0.75	2.25	2.00
July	17	86	0.75	19.00	3.00	4.75	2.25	1.25	3.50	2.50	1.00	0.25	0.50
	29	98	0.50	14.25	16.00	4.75	6.25	3.00	7.25	1.25	1.50	1.00	2.25
Aug.	2	102	0.50	16.75	17.50	3.00	1.50	5.00	2.25	0.25	0.50	0	0.25
	9	109	0.75	20.50	32.25	5.50	3.25	6.75	3.00	0.25	2.50	0	0.50
	16	116	0	0.25	12.00	1.75	0.75	2.25	0	0.50	0.25	0	0
	23	123	0.25	8.00	28.25	8.75	3.50	3.50	1.50	4.00	0	0	0
	29	129	0.25	5.75	17.50	2.75	2.00	0.50	0	0.50	1.00	0	0
Sept.	6	137	0	0.75	3.25	3.00	1.50	0.25	1.25	0	0	0	0
Total counted			86	1617	523	197	87	106	105	57	42	30	40
Avg. no per sweep/season[e]			0.1535	2.8875	0.9339	0.3517	0.1553	0.1892	0.1875	0.1017	0.0750	0.0535	0.0714

[a] Seven insect groups are Aphididae, *Dolichomiris*, Nabidae, *Chrysopa*, Coccinellidae, Syrphidae, and Aphidiidae.
[b] Includes nymphs and adults in each day's counts.
[c] Includes larvae, pupae, and adults in each day's counts.
[d] Includes adults and "mummied" aphids in each day's counts.
[e] A total of 560 sweeps were taken May 24 to September 6, 1972.

Table 14. Average number of seven insect groups[a] occurring per 10 sweeps with a 15-inch sweepnet in untreated wheat planted May 4, 1972.

Date		NODAP	APHIDIDAE		DOLICHOMIRIS		NABIDAE[b]	CHRYSOPA		COCCINELLIDAE		SYRPHIDAE[c]	APHIDIIDAE[d]
			Alate	Apterous	Nymph	Adult	Total	Larvae	Adult	Larvae	Adult	Total	Total
June	6	33	0	1.50	0	0	0	0.25	0	0	0	0	0
	13	40	5.50	38.25	0.50	3.25	0	1.00	0	0.25	0	1.50	0.50
	21	48	7.25	98.25	0.75	1.75	0	0	0	0	0.50	0.75	10.00
	26	53	8.00	111.25	0	1.00	0	0.50	0.25	0.50	0.25	2.75	4.75
July	17	74	0.25	10.00	0.50	2.00	0.75	0.50	0.50	0.25	0.25	0	3.75
	29	86	1.75	28.75	2.25	3.00	0.25	0	1.50	0	0.25	1.50	5.50
Aug.	2	90	1.75	37.75	5.00	3.75	0	0.75	0.25	0.25	0	1.50	0.75
	9	97	7.00	87.00	24.25	4.25	0.50	0.50	3.25	0	0	1.25	3.25
	16	104	7.00	149.25	5.00	3.50	0.75	2.75	1.00	2.00	1.25	0	1.75
	23	111	20.25	569.25	16.50	8.75	0	3.75	1.00	11.00	1.25	2.50	16.75
	29	117	15.00	524.25	5.00	2.25	0.50	1.00	0.75	13.00	2.25	0.50	2.25
Sept.	6	125	28.50	365.00	7.00	3.50	1.50	1.50	1.00	5.75	8.75	0.75	2.50
Total counted			409	8082	267	148	17	50	38	132	59	52	207
Avg. no. per sweep/season[e]			0.8520	16.8375	0.5562	0.3083	0.0354	0.1041	0.0791	0.2750	0.1229	0.1083	0.4312

[a] Seven insect groups are Aphididae, Dolichomiris, Nabidae, Chrysopa, Coccinellidae, Syrphidae, and Aphidiidae.
[b] Includes nymphs and adults in each day's counts.
[c] Includes larvae, pupae, and adults in each day's counts.
[d] Includes adults and "mummied" aphids in each day's counts.
[e] A total of 480 sweeps were taken June 6 to September 6, 1972.

Table 15. Average number of seven insect groups[a] occurring per 10 sweeps with a 15-inch sweepnet in untreated wheat planted May 26, 1972.

Date	NODAP	APHIDIDAE Alate	APHIDIDAE Apterous	DOLICHOMIRIS Nymph	DOLICHOMIRIS Adult	NABIDAE[b] Total	CHRYSOPA Larvae	CHRYSOPA Adult	COCCINELLIDAE Larvae	COCCINELLIDAE Adult	SYRPHIDAE[c] Total	APHIDIIDAE[d] Total
June 21	26	0.25	0	0	0	0	0	0	0	0	0	0
26	31	0	4.25	0	0.50	0	0	0	0	0	0.25	0
July 17	52	10.50	77.50	0.50	1.25	0	0.25	0.25	0.25	0.50	0.75	3.50
29	64	1.75	37.75	0.25	2.00	0.50	0.25	0.25	0.50	0	0.50	11.50
Aug. 2	68	5.75	38.50	0.25	0.50	0.50	0.75	1.00	0.50	0.50	1.75	7.00
9	75	4.50	106.75	0.75	1.75	0.50	0	0.25	0	0.50	0.50	5.00
16	82	3.25	63.75	0.75	1.00	0.25	0.50	0	0	0.50	0.25	1.00
23	89	10.75	340.00	3.50	5.00	1.50	0.75	2.00	2.50	2.75	0.25	12.50
29	95	9.50	399.00	3.00	4.00	2.00	0.50	1.50	0.75	4.25	1.00	5.25
Sept. 6	103	9.75	450.00	4.00	1.75	2.50	0.75	0.50	2.75	3.00	2.25	5.00
Total counted		224	6070	52	71	31	15	23	29	48	30	203
Avg. no. per sweep/season[e]		0.5600	15.1750	0.1300	0.1775	0.0775	0.0375	0.0575	0.0725	0.1200	0.0750	0.5075

[a] Seven insect groups are Aphididae, Dolichomiris, Nabidae, Chrysopa, Coccinellidae, Syrphidae, and Aphidiidae.
[b] Includes nymphs and adults in each day's counts.
[c] Includes larvae, pupae, and adults in each day's counts.
[d] Includes adults and "mummied" aphids in each day's counts.
[e] A total of 400 sweeps were taken June 21 to September 6, 1972.

Table 16. Average number of seven insect groups[a] occurring per 10 sweeps with a 15-inch sweepnet in untreated wheat planted June 30, 1972.

Date	NODAP	APHIDIDAE		DOLICHOMIRIS		NABIDAE[b]	CHRYSOPA		COCCINELLIDAE		SYRPHIDAE[c]	APHIDIIDAE[d]
		Alate	Apterous	Nymph	Adult	Total	Larvae	Adult	Larvae	Adult	Total	Total
July 29	29	0.75	1.75	0	0	0	0	0	0	0	0	0
Aug. 2	33	0.25	7.00	0	0.25	0	0	0	0.50	0	0	4.25
9	40	0	10.00	0	0.50	0	0.25	0	1.00	0.25	0.25	9.00
16	47	0	3.75	0	0.25	0	0.25	0	0	0.25	0	0
23	54	4.50	9.00	0.25	2.00	0	0	0	0.25	0.25	0.25	2.75
29	60	10.25	31.75	0	2.50	0	0	0	0	0.25	0	0.50
Sept. 6	68	8.50	185.50	0	0.75	0.75	0	0	0	0.25	1.00	0.25
Oct. 11	103	19.25	211.25	21.00	0.50	7.00	0.25	0	24.25	40.00	3.00	0
18	110	0	0.75	1.75	0.75	0.75	0	0	1.00	0.50	0.25	0
Total counted		174	1843	92	30	34	3	0	108	167	19	50
Avg. no. per sweep/season[e]		0.4833	5.1194	0.2555	0.0833	0.0944	0.0083	0	0.3000	0.4638	0.0527	0.13888

[a] Seven insect groups are Aphididae, *Dolichomiris*, Nabidae, *Chrysopa*, Coccinellidae, Syrphidae, and Aphidiidae.

[b] Includes nymphs and adults in each day's counts.

[c] Includes larvae, pupae, and adults in each day's counts.

[d] Includes adults and "mummied" aphids in each day's counts.

[e] A total of 360 sweeps were taken July 29 to October 18, 1972.

Summaries of average numbers of insects collected per sweep in non-treated areas during the three years and corresponding ratios of total pest species to total beneficials indicate early planting of wheat may be less favorable to rapid development of aphid populations. Table 17 presents a summary by planting date and year for the seven groups with their corresponding divisions, i.e., nymphs and adults, for two experiments in 1970, two in 1971 and five in 1972. These data are further summarized in Table 18, and are arranged according to planting dates. The ratio of total pests to total beneficials indicates more beneficials were present per pest when the wheat was planted early. One late planting during 1972 had a favorable ratio (few pests per beneficial) but wheat planted on that same date a year earlier had the least favorable ratio. If taken only one year at a time, the same trend is indicated, i.e., early planting in 1970 gives a ratio of 1 aphid to 3.40 beneficials while later planting gives a 1 aphid to 10.04 beneficials ratio. These ratios depend heavily on the year to year climatological conditions but do indicate a trend favoring early planting and therefore better biological control. Recommendations to plant early cannot be solely based on these ratios but combined with trends of greater aphid abundance the later wheat is planted, suggests early planting may be profitable. The comparison based on the average numbers of insects per sweep per season may not be entirely justifiable since the time of insect occurrence in relation to plant development is extremely important. However, as illustrated in Figures 1 to 4, there are similarities in occurrence of the peaks, again relating to planting dates and may somewhat justify this numbers-per-sweep-per-season approach.

Table 17. Summary of the average number of Aphididae, *Dolichomiris*, Nabidae, *Chrysopa*, Coccinellidae, Syrphidae, and Aphidiidae collected per sweep with a 15-inch sweepnet in wheat planted on nine dates from 1970 to 1972.

Planting date	APHIDIDAE Alate	APHIDIDAE Apterous	DOLICHOMIRIS Nymphs	DOLICHOMIRIS Adults	NABIDAE[a] Total	CHRYSOPA Larvae	CHRYSOPA Adults	COCCINELLIDAE Larvae	COCCINELLIDAE Adults	SYRPHIDAE[b] Total	APHIDIIDAE[c] Total	Total no. of sweeps
4-12-70	0.0311	0.2462	0.0846	0.1530	0.0075	0.0103	0.1132	0	0.0066	0.0037	0.0047	1060
5-27-70	0.2857	4.8053	0.5500	0.2250	-	0.0660	0.0982	0.0769	0.0500	-	0.3017	560
6-21-71	7.7535	96.8071	0.0125	0.0464	0.0142	0.1053	0.1339	0.5000	0.4678	0.0607	0.4107	560
6-30-71	11.8194	105.0722	0.0222	0.0472	0.0527	0.0722	0.0694	0.2777	0.7027	0.0583	0.2361	360
4-20-72	0.2125	3.6214	0.4160	0.2803	0.2071	0.1017	0.1107	0.1035	0.1178	0.1232	0.0928	560
4-22-72	0.1535	2.8875	0.9339	0.3517	0.1553	0.1892	0.1875	0.1017	0.0750	0.0535	0.0714	560
5-4-72	0.8520	16.8375	0.5562	0.3083	0.0354	0.1041	0.0791	0.2750	0.1229	0.1083	0.4312	480
5-26-72	0.5600	15.1750	0.1300	0.1775	0.0775	0.0375	0.0575	0.0725	0.1200	0.0750	0.5075	400
6-30-72	0.4833	5.1194	0.2555	0.0833	0.0944	0.0083	0	0.3000	0.4638	0.0527	0.1388	360

[a] Includes nymphs and adults in each day's counts.
[b] Includes larvae, pupa and adults in each day's counts.
[c] Includes adults and "mummied" aphids in each day's counts.

Table 18. Average number of total Aphididae, *Dolichomiris*, *Chrysopa*, Coccinellidae, total pest, total beneficial, and ratio of total pests to beneficials collected per sweep with a 15-inch sweepnet in wheat planted on nine dates from 1970 to 1972.

Planting date	Average: APHIDIDAE	Average: DOLICHOMIRIS	Average: CHRYSOPA	Average: COCCINELLIDAE	Average: Total pest[a]	Average: Total beneficial[b]	Total pest / Total beneficial (ratio)	Total no. of sweeps
4-12-70	0.277	0.219	0.123	0.006	0.497	0.146	3.40	1060
4-20-72	3.833	0.696	0.212	0.221	4.530	0.857	5.28	560
4-22-72	3.041	1.285	0.376	0.176	4.326	0.833	5.18	560
5-4-72	17.689	0.864	0.183	0.397	18.554	1.156	16.04	480
5-26-72	15.735	0.307	0.095	0.192	16.042	0.947	16.93	400
5-27-70	5.091	0.775	0.164	0.117	5.866	0.583	10.04	560
6-21-71	104.560	0.058	0.239	0.967	104.619	1.692	61.80	564
6-30-71	116.891	0.069	0.141	0.980	117.033	1.469	75.64	360
6-30-72	5.602	0.338	0.008	0.763	5.941	1.058	5.61	360

[a] Total pest includes all Aphididae and *Dolichomiris*.

[b] Total beneficials include all Aphidiidae, *Chrysopa*, Coccinellidae, Nabidae, and Syrphidae.

Initial arrival, interrelationships, and periodicity for each group studied varied year to year, but general trends were evident and will be discussed in their relevance to wheat production. In 1970 aphids were first detected on May 14th and natural enemies on May 22nd (Table 8). Experiments in 1971 were initiated later and aphids were present on the first sampling day, July 19th, and beneficials appeared a week later on July 26th (Table 10). Aphids and natural enemies appeared simultaneously on the earliest sampling day during 1972, May 24 (Table 12). If analyzed by the number of days after planting, the earliest aphid arrival was 25 days after planting (1970) and the latest was 33 days (1972). For natural enemies the earliest was 31 days and latest 47 days after planting.

The first natural enemy of aphids to appear varied each year. Parasitoids tended to arrive early, express a single peak and dissipate later in the season (Tables 10, 11, 12, 13, 16) although sometimes a second peak was expressed (Tables 9, 14, 15). During all 3 years parasitoids correlated negatively with temperature and degree days (-0.20 to -0.55), occasionally negatively with solar radiation (-0.32), insolation (-0.34), and precipitation (-0.25). Correlation between Aphidiidae and total aphids in 1970 (Table 9) were 0.26 (n.s.); in 1971 they were -0.17 and -0.28 (Tables 10, 11 respectively); and in 1972 they varied from 0.85 to -0.11 depending on planting date. Chrysopa sp. and Coccinellidae usually occurred somewhat later than Aphidiidae and very few of either were recorded (Tables 8, 9, 16). In 1970 and 1971 Chrysopa sp. arrived and peaked earlier than the

Coccinellidae (Tables 8, 9, 10, 11). During 1972 Chrysopa sp. demonstrated typical growth patterns but the Coccinellidae were very mobile, with early and/or late peaking being present (Tables 12-16). Correlation of total Chrysopa sp. to total aphids in 1970 were 0.13 (n.s.); in 1971 they were 0.85 (1%) and 0.76 (1%), and in 1972 averaged 0.13 (n.s.). Usually the larvae were correlated more strongly than the adults. The correlation of Chrysopa sp. to Dolichomiris sp. was stronger than that to aphids during 1970 and 1972, being 0.43 (1%) in 1970, and 0.29 (5%) and 0.61 (1%) in 1971 and 0.47 in 1972. During field observations Chrysopa sp. larvae were observed feeding on nymphs of Dolichomiris sp. This relationship is important in that it provides an important alternate host for the Chrysopa sp. larvae when aphids are not numerous. Total Coccinellidae also correlated strongly with the total aphids: 0.49 (1%) in 1970, 0.80 (1%) for both experiments of 1971, and an average of 0.45 in 1972, with larvae Coccinellidae correlating stronger with aphids than adults. The Syrphidae were most erratic; sometimes very few appeared (Table 8, 1970); at times they occurred late in the season (Tables 10 and 11, 1971); or quite early, in 1972 (Tables 12 to 16, and 19). Nabidae were usually first recorded 60 to 70 days after planting and in one case not until 91 days. Their true role as predators of aphids in these studies is not known, but does occur (Nault et al. 1973). During 1972 their pooled correlation for the five fields sampled was strongest with Coccinellidae adults (0.50), then nymphs of Dolichomiris sp. (0.46), Coccinellidae larvae (0.41), Chrysopa sp. larvae (0.36) and adults (0.31), Dolichomiris sp. adults (0.15), and finally with total Aphididae

Table 19. Number of days after planting that each beneficial insect was first collected with a sweepnet in five fields of different planting dates during 1972.

Planting date	NABIDAE Total	CHRYSOPA Larvae	CHRYSOPA Adults	COCCINELLIDAE Larvae	COCCINELLIDAE Adults	SYRPHIDAE Total	APHIDIIDAE Total
April 20	66	39	53	33	53	39	33
22	61	38	52	38	52	32	45
May 4	74	33	53	40	48	40	40
26	64	52	52	52	52	31	52
June 30	68	40	-[a]	33	40	40	33
Average	66.6	40.4	52.5[b]	39.2	49.0	36.4	40.6

[a] No adult *Chrysopa* sp. were collected during entire season in this field.

[b] Average based on insects appearing in four fields.

(0.07). High correlations may not necessarily mean nabids feed on the various insects, but it could make an interesting study. Few conclusions can be made regarding the arrival of natural enemies and planting dates. The planting date-sampling experiment of 1972 indicated that planting dates may not influence arrival of the natural enemies, but conclusions cannot be established on the basis of a single year's data alone (Table 19). It should be remembered that Paraguay is a subtropical country and insects abound year around, thus providing adequate food for natural enemies.

Comparisons of Sampling Techniques

Although sweepnet collections were normally used to establish growth curves, predator-prey interrelationships, and influences of Ekatin(R), two additional sampling methods were employed to limited degrees during 1972. There are numerous works by researchers in the United States indicating the variability of sweepnet samples because of climatological conditions, age and type of crop, and sampler variability. Two unit area methods were employed in 1972 to help interpret the counts obtained with sweepnet sampling.

Sweepnet vs. Linear Foot Sampling. Aphid detection by the linear foot method was not any earlier, but the total numbers detected in young wheat per linear foot was greater than per 10 sweeps. Overall, roughly one aphid per linear foot was found to equal 2.53 aphids collected per 10 sweeps, as indicated by the relationship for three fields sampled by the two methods (Tables 12, 13, 15, 20, 21, 22). The variability is quite evident for the 2 fields planted April 20 and 22. The earlier planted field had an average of more aphids (56.5) per 10 sweeps than did the second (29.75), but the average numbers per linear foot were reversed at 21.9 and 24.3 per linear foot, respectively. The trends for aphid populations to peak and decline were similarly recorded by both methods, but when plants were under 15 centimeters tall, the linear foot method probably gave more accurate results since sweeping small plants is extremely difficult. The populations of natural enemies were recorded at significantly different levels, with the sweepnet method seemingly ensuring a more reliable expression of population levels. Although the data are not definitive and the equivalence of linear foot to sweepnet data may not be entirely accurate because of the population levels present, the relationships from the three fields studied produced the following:

Table 20. Average numbers of Aphididae, Dolichomiris, Nabidae, Chrysopa, Coccinellidae, Syrphidae, and Aphidiidae in one-linear foot samples of wheat planted April 20, 1972.

Date	NODAP	APHIDIDAE Alate	APHIDIDAE Apterous	DOLICHOMIRIS Total[a]	NABIDAE Total[a]	CHRYSOPA Eggs	COCCINELLIDAE Total[b]	SYRPHIDAE Total[c]	APHIDIIDAE Total[d]	Aphids killed by fungi	Average no. of tillers or spikes
May 24	33	0.00	11.50	0.00	0.00	0.00	0.25	0.00	0.00	0.00	21.50
30	39	0.00	39.75	0.00	0.00	0.00	0.00	1.00	0.00	0.00	31.00
June 6	46	1.00	26.50	0.00	0.00	0.50	0.00	0.75	0.00	0.00	26.50
21	61	0.50	56.00	0.00	0.00	0.25	0.25	0.50	0.75	0.00	20.75
26	66	0.50	24.25	0.00	0.00	0.00	0.25	1.25	0.50	5.50	22.25
July 29	99	0.00	4.25	0.00	0.25	0.25	0.00	0.00	0.25	0.00	18.00[e]
Aug. 2	103	0.25	5.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	14.00[e]
9	110	0.00	5.25	0.25	0.25	0.00	0.00	0.00	0.00	0.00	13.25[e]
Total counted		9	692	3	2	4	3	14	6	22	167.25
Avg. no. per foot/season		0.281	21.625	0.093	0.062	0.125	0.093	0.437	0.187	0.687	20.906

[a] Includes nymphs and adults.
[b] Includes larvae and adults.
[c] Includes larvae and pupae.
[d] Includes parasitized aphids and adult parasites.
[e] Average number of spikes per linear foot.

Table 21. Average numbers of Aphididae, *Dolichomiris*, Nabidae, *Chrysopa*, Coccinellidae, Syrphidae, and Aphidiidae in one-linear foot samples of wheat planted April 22, 1972.

Date	NODAP	APHIDIDAE Alate	APHIDIDAE Apterous	DOLICHOMIRIS Total[a]	NABIDAE Total[a]	CHRYSOPA Eggs	COCCINELLIDAE Total[b]	SYRPHIDAE Total[c]	APHIDIIDAE Total[d]	Aphids killed by fungi	Average no. of tillers or spikes
May 24	32	0.25	15.25	0	0	0	0	0	0	-	21.00
June 6	45	2.00	29.25	0	0	0.50	0.25	0	0.25	-	28.25
22	61	1.25	61.75	0	0	0.25	0.75	3.00	0.50	4.75	35.75
July 29	98	0	1.25	0	0.50	0.50	0.25	0.25	0	-	18.50[e]
Aug. 2	102	0.50	14.25	0.25	0	0.75	0	0	0		21.75[e]
9	109	0	20.25	0.25	0	0.25	0	0	0.50		15.25[e]
Total counted		16	568	2	2	9	5	13	5	19	
Avg. no. per foot/season		0.666	23.666	0.083	0.083	0.375	0.208	0.541	0.208	0.791	23.416

[a] Includes nymphs and adults.

[b] Includes larvae and adults.

[c] Includes larvae and pupae.

[d] Includes parasitized aphids and adult parasites.

[e] Average number of spikes per linear foot.

Table 22. Average numbers of Aphididae, *Dolichomiris*, Nabidae, *Chrysopa*, Coccinellidae, Syrphidae, and Aphidiidae in one-linear foot samples of wheat planted May 26, 1972.

Date	NODAP	APHIDIDAE Alate	APHIDIDAE Apter-ous	DOLICHOMIRIS Total[a]	NABIDAE Total[a]	CHRYSOPA Eggs	COCCINELLIDAE Total[b]	SYRPHIDAE Total[c]	APHIDIIDAE Total[d]	Aphids killed by fungi	Average no. of tillers or spikes
June 21	26	0	3.25	0	0	0.25	0	0	0	-	12.00
26	31	0	18.25	0	0	0	0	0	0	-	16.25
July 29	64	0.25	1.75	0	0	0	0	0	1.25	0.25	-
Aug. 2	68	0.50	20.75	0	0	0.50	0	0	2.75	0.75	21.50
16	82	0.75	25.25	0	0	1.00	0	0	1.75	-	16.25
23	89	0.50	46.00	0.25	0	0.25	0.25	0.75	4.50	1.25	15.25
Total counted		8	501	1	0	8	1	3	41	9	81.250
Avg. no. per foot/season		0.333	20.875	0.041	0	0.333	0.041	0.125	1.708	0.375	13.541

[a] Includes nymphs and adults.

[b] Includes larvae and adults.

[c] Includes larvae and pupae.

[d] Includes parasitized aphids and adult parasites.

For each insect counted per linear foot	=	Number of insects counted per 10 sweeps
Aphididae		2.53
Dolichomiris sp.		100.67
Nabidae		26.00
Chrysopa sp.		12.85
Coccinellidae		17.04
Syrphidae		3.00
Aphidiidae		5.32

This strongly indicates that the linear foot sampling method is not very applicable in wheat for Dolichomiris sp., Nabidae, Coccinellidae or Chrysopa sp., which are more likely detected with a sweepnet. Linear foot sampling does yield an added benefit in that the number of aphids killed by entomolphogous fungi can be recorded (Tables 20-22). These limited data indicate that the action of fungi was more important in earlier than in later planted wheat. Additional information on fungi are discussed under the 100 spike sampling method.

100 Spike - Aphididae Counts. Samples of 100 wheat spikes to determine the presence of aphids is widely practiced. In an attempt to employ this method, a fixed sampling day of 110 days after planting was selected for use in all fields. Unfortunately, because of the extended period and growing season variability, the length of the vegetative cycle and developmental stages of spikes and seeds are not equal for all planting dates. Ideally all spikes should have been sampled when they were in the same stage, i.e., complete flowering, milky ripe or mealy ripe

stages (Large 1954 for wheat growth stages). Data indicating the number of live and dead aphids in spikes from distinct planting dates are presented in Table 23. There were clearly many more M. avenae collected on every sampling date than S. graminum, but both were present on most sampling dates. The population levels were greatest in fields planted during May, while low populations occurred in the April planted fields. Aphids were absent in the field planted in late June, but counts were made on only 30 spikes and may not reflect the actual numbers present. The ratio of total aphids to parasitoids seems to indicate that earlier planted fields have a better ratio (fewer aphids per parasitoid) thus favoring natural control. The ratio of aphids killed by fungi was greater in earlier planted than May planted fields. Since fungi are dependent on climatological conditions, further interpretation of these tendencies in Paraguay are needed. If fungi are found to be identical to those on wheat aphids in Chile and Uruguay, then the principles influencing their growth could be investigated in Paraguay. These conditions should be measured in terms of the micro-climate which surrounds the insect and not just the general climatological conditions present in the field. In addition, an analysis of the function aphid population density plays in the development of the fungi should be investigated.

Biotype Determination

Data regarding the biotype determination of the greenbug, S. graminum, are presented in Table 24, indicating the existence of biotype C and the

Table 23. Total number of live and dead aphids found in eight fields by 100 spike samples approximately 110 days after seeding at various dates over a 70 day period during 1972.

Planting dates		Alive					Dead			Total avg. aphids per spike
		Greenbug	English grain aphid		Other aphids[b]	Total	Fungi	Parasites	Total	
		Total[a]	Alate	Apterous						
April 20	109	2	0	53	1	56	29	2	31	0.87
22	110	0	0	7	3	10	5	0	5	0.15
24	109	1	1	62	0	64	7	1	8	0.72
May 4	111	6	12	797	2	817	39	12	51	8.68
6	110	9	5	215	2	231	21	21	42	2.73
12-13	110	5	7	891	3	906	33	8	41	9.47
20[c]	95	5	2	149	1	157	6	1	7	1.64
June 30[d]	110	0	0	0	0	0	-	-	-	-
Averages	108	3.5	3.37	271.7	1.5	280.12	20.0[e]	6.42[e]	26.42[e]	3.03

[a] Only apterous forms found.

[b] Includes corn leaf aphid and apple grain aphid, only apterous forms found.

[c] Originally planted May 3, 1972 but because of infestation by armyworms it was replanted on the 20th.

[d] Only 30 spikes were examined instead of the usual 100.

[e] Averages based on counts from only seven dates.

Table 24. Biotype analysis of greenbugs, Schizaphis graminum, on Piper sudangrass during 1972, using two transfer techniques.

Plant	Replicate	Starting plant height (cms)	Brush transfer of apterous adults		Percent survival
			Starting	Finishing	
A	1	14.5	5	1	20
	2	10.0	5	0	0
B	1	11.0	5	0	0
	2	15.0	5	0	0
C	-	16.7	5	21[a]	420
D	-	16.6	5	12[b]	240

Plant	Replicate	Starting plant height (cms)	Leaf transfer				Percent survival
			Alate	Apterous	Alate	Apterous	
A	-	14.0	15	5	0	0	0
B	1	17.4	15	5	0	0	0
	2	16.2	10	2	0	0	0
C	-	45.5	30	5	20	4	68.6

[a] Of those finishing 4 were apterous adults and 17 apterous nymphs.

[b] All those finishing were apterous nymphs.

probable presence of biotype A and/or B. Aphid transfers by a camel's-hair brush and excised leaf technique show essentially the same results, except in two trials. Harvey and Hackerott (1969) reported the separation of the greenbug biotypes B and C using Piper sudangrass, Sorghum sudanese (Piper) Stapf. In the seedling stage these plants were reportedly highly resistant to the B and susceptible to the C biotypes. Wood (1971) tested all three biotypes and indicated A and B can only be separated using the aphids' reaction to "Dickinson" Sel.28A and C.I. 9058 wheats which are both resistant to A, but susceptible to B. In Paraguay the greenbugs tested usually died on the Piper sudangrass, indicating the presence of the A or B biotype. However, on two occasions using plants approximately 16.65 cms (6.55 in.) tall, apterous adults survived and produced young, indicating the presence of the C biotype. These differences need to be confirmed with a greater number of replications, but less than a dozen seeds of Piper sudangrass were available. If these distinct biotypes do occur, the selection of wheat and sorghum varieties should be conducted wisely, selecting resistant varieties when feasible.

Climatological Influences on Insect Populations

In the Paraguayan studies, analysis of the micro-climatological conditions was not possible and only gross comparisons of basic characteristics were made. Weekly means of climatological conditions corresponding to insect sampling dates during 1970 to 1972 are presented in Tables 25 to 29, and monthly means are presented in Appendix C. These data are averages for the intervals between collection dates, which varied from 2 to 35 days

Table 25. Partial weather data from May 1 to August 1, 1970, corresponding to insect collections made in wheat planted April 12, 1970.

Date	NODAP	Average temperature °C			Degree days[a]		Average relative humidity	Total precipitation (mm)	Total solar		
		Med.	Max.	Min.	Total	Avg.			Insolation[b]	Radiation[c]	Intensity[d]
May 7	25	20.95	27.37	15.46	143.91	20.55	69.28	17.3	37.00	121.6	7.6
14	32	20.80	28.90	13.67	142.20	20.31	75.85	0.0	54.40	156.2	8.4
22	40	17.43	23.78	11.75	111.87	13.98	81.62	33.4	35.10	127.4	7.8
28	46	21.05	28.60	12.85	115.83	19.30	75.16	0.0	54.90	141.8	7.2
June 4	53	24.20	31.77	16.62	178.98	25.56	71.71	0.0	60.55	160.1	6.3
11	60	18.18	23.02	12.68	99.00	14.14	83.71	57.0	26.25	100.7	4.4
19	68	19.42	25.23	13.51	135.00	16.87	81.37	31.3	51.35	133.3	6.1
26	75	13.54	19.14	7.48	41.76	5.96	82.28	30.3	30.30	114.8	5.8
July 3	82	12.94	18.78	5.72	28.44	4.06	73.71	16.5	45.15	119.2	5.2
10	89	13.92	19.58	7.47	44.46	6.35	84.14	11.5	97.50	104.5	5.9
17	96	18.85	24.72	12.54	108.81	15.54	76.42	6.9	55.70	145.6	6.1
24	103	20.15	26.42	13.74	127.08	18.15	76.42	0.0	42.20	103.7	6.6
Aug. 1	111	21.35	27.68	13.95	155.76	19.47	87.75	0.0	62.75	133.3	7.7

a Degree days calculated from maximum and minimum temperatures minus a base temperature of 50°F.

b Total solar insolation measured by number hrs/day of sun.

c Total solar radiation measured by gram calories/cm^2/day.

d Total solar intensity measured by gram calories/cm^2/1 min. exposure.

Table 26. Partial weather data from June 27 to October 5, 1970, corresponding to insect collections made in wheat planted May 27, 1970.

Date	NODAP	Average temperature °C			Degree days[a]		Average relative humidity	Total precipitation (mm)	Total solar		
		Med.	Max.	Min.	Total	Avg.			Insolation[b]	Radiation[c]	Intensity[d]
July 4	38	13.93	19.93	6.88	49.14	6.14	74.25	16.8	45.15	135.8	6.0
13	47	13.74	19.23	7.34	50.28	5.92	85.11	18.1	44.65	141.4	7.2
20	54	20.68	26.33	14.96	134.10	19.16	73.28	0.0	47.60	133.7	6.3
27	61	20.88	27.34	13.87	133.65	19.09	73.14	0.0	55.05	144.6	7.0
Aug. 3	68	22.51	28.73	14.67	147.42	21.06	65.85	0.0	53.80	143.6	7.3
10	75	13.08	19.71	6.47	38.70	5.53	79.14	13.0	44.85	131.6	7.0
17	82	19.11	26.73	11.99	117.90	16.84	68.57	0.0	54.00	149.6	7.3
24	89	20.22	25.16	15.03	127.08	18.15	73.42	36.6	34.25	106.6	5.0
31	96	15.18	21.73	7.91	60.75	8.68	72.28	0.0	54.15	168.1	8.9
Sept. 7	103	18.31	25.66	9.17	93.42	13.35	70.57	0.6	46.55	151.8	8.4
14	110	19.01	24.33	12.06	103.23	14.75	78.28	21.0	33.80	12.4	6.7
21	117	20.28	26.77	13.07	125.01	17.86	81.14	57.9	45.65	145.8	8.5
30	124	23.06	28.36	16.68	202.77	22.53	81.77	109.0	55.30	181.0	10.4
Oct. 5	131	20.92	27.66	12.64	91.35	18.27	71.60	14.3	46.20	133.7	8.1

[a] Degree days calculated from maximum and minimum temperatures minus a base temperature of 50°F.
[b] Total solar insolation measured by number of hours/day of sun.
[c] Total solar radiation measured in gram calories/cm^2/day.
[d] Total solar intensity measured in gram calories/cm^2/1 min. exposure.

Table 27. Partial weather data from July 13 to October 18, 1971, corresponding to insect collections made in wheat planted June 21, 1971.

Date	NODAP	Average temperature °C			Degree days[a]		Average relative humidity	Total precipitation (mm)	Total solar		
		Med.	Max.	Min.	Total	Avg.			Insolation[b]	Radiation[c]	Intensity[d]
July 19	28	18.71	25.52	12.61	114.30	16.32	75.42	0.0	57.00	139.5	6.1
26	35	22.25	29.31	15.40	155.70	20.24	73.14	9.3	65.75	154.1	8.1
Aug. 2	42	18.21	22.30	13.80	101.43	14.49	81.00	97.9	34.75	104.8	5.2
9	49	19.71	24.26	14.81	120.15	17.16	83.00	46.9	32.70	110.7	5.6
16	56	15.08	22.21	7.99	64.26	9.18	78.42	8.3	55.15	156.4	8.9
24	64	18.73	24.18	11.76	114.75	14.34	68.12	49.5	61.30	157.3	9.0
30	70	19.23	24.40	13.72	97.83	16.31	73.83	2.9	45.50	126.0	7.5
Sept. 6	77	22.00	27.93	15.51	147.69	21.10	72.57	8.0	48.80	150.3	8.7
13	84	19.75	26.31	12.26	117.00	16.71	72.85	19.4	57.25	175.3	9.7
20	91	26.07	32.09	19.96	201.87	28.84	57.57	0.0	64.50	195.7	10.8
27	98	20.27	26.13	13.93	126.36	18.05	72.14	0.0	47.50	175.4	8.2
Oct. 4	105	20.55	27.21	12.31	123.03	17.58	71.57	32.5	42.40	162.8	9.1
13	114	16.40	21.92	11.08	104.94	11.66	75.11	65.0	55.90	186.0	11.1
18	119	21.80	29.98	12.66	101.88	20.38	67.60	0.0	48.20	157.4	9.3

a Degree days calculated from maximum and minimum temperatures minus a base temperature of 50°F.
b Total solar insolation measured in number of hrs/day of sun.
c Total solar radiation measured in gram calories/cm^2/day.
d Total solar intensity measured in gram calories/cm^2/1 min. exposure.

Table 28. Partial weather data from August 8 to October 26, 1971, corresponding to insect collections made in wheat planted June 30, 1971.

Date	NODAP	Average temperature °C			Degree days[a]		Average relative humidity	Total precipitation (mm)	Total solar		
		Med.	Max.	Min.	Total	Avg.			Insolation[b]	Radiation[c]	Intensity[d]
Aug. 14	45	16.98	23.46	10.56	88.29	12.61	81.28	55.2	43.25	132.8	7.2
16	47	12.50	19.90	3.85	6.75	3.38	77.00	0.0	21.45	56.1	3.6
24	55	18.73	24.18	11.76	114.75	14.34	68.12	49.5	61.30	157.3	9.0
Sept. 7	69	20.57	26.22	14.39	259.65	18.55	72.85	10.9	104.50	306.4	7.5
14	76	20.67	27.09	13.54	129.96	18.57	72.00	19.4	56.55	173.4	10.1
21	83	26.08	32.63	19.29	201.06	28.72	58.00	0.0	63.10	203.8	10.3
Oct. 7[e]	99	18.20	23.93	11.44	124.56	13.84	72.88	51.4	48.35	188.1	10.4
13	105	18.05	24.27	12.13	88.56	14.76	75.50	46.1	39.70	128.2	7.9
19	111	21.91	28.98	13.67	122.31	20.39	69.16	0.0	48.20	173.7	10.1
26	118	22.20	26.76	17.34	151.83	21.69	79.57	14.8	41.90	152.9	9.0

a Degree days calculated from maximum and minimum temperatures minus a base temperature of 50°F.

b Total solar insolation measured in number of hrs/day of sun.

c Total solar radiation measured in gram calories/cm^2/day.

d Total solar intensity measured in gram calories/cm^2/1 min. exposure.

e Data based on preceding nine (9) days.

Table 29. Partial weather data from May 18 to October 18, 1972, corresponding to insect collections made in wheat planted during the 1972 growing season.

Date	Average temperature °C			Degree days[a]		Average relative humidity	Total precipitation (mm)	Total solar		
	Med.	Max.	Min.	Total	Avg.			Insolation[b]	Radiation[c]	Intensity[d]
May 24	19.24	23.38	14.68	113.85	16.26	81.85	35.5	18.80	96.4	5.0
30	20.58	26.53	14.43	113.22	18.87	80.66	7.7	44.65	110.1	4.9
June 6	24.58	29.08	19.64	180.99	25.85	77.00	47.0	40.20	130.3	6.2
13	24.05	27.92	19.68	173.97	24.85	81.00	106.1	45.50	121.2	5.5
21	17.47	22.70	11.57	102.78	12.84	77.75	53.6	52.90	127.8	7.6
26	19.86	26.62	12.42	86.22	17.24	72.40	3.0	44.60	112.7	5.5
July 17	16.07	21.25	10.94	246.42	11.73	79.90	38.5	96.25	298.5	16.8
29	20.33	25.85	14.74	222.39	18.53	76.16	9.4	64.10	222.1	9.8
Aug. 2	24.37	28.82	19.92	103.50	25.87	66.50	0.0	24.90	78.5	4.1
9	13.57	20.30	6.52	45.02	6.43	72.57	1.7	41.65	131.4	6.8
16	23.20	29.51	15.91	160.20	22.88	68.85	4.8	62.40	177.0	9.6
23	16.14	20.85	12.11	81.72	11.67	86.00	65.5	21.45	81.1	4.3
29	15.90	20.56	10.86	61.74	10.29	84.83	37.2	18.95	80.7	3.4
Sept. 6	17.70	24.11	10.17	134.55	16.81	57.50	0.0	67.10	137.9	11.8
Oct. 11	21.34	27.13	14.34	676.62	19.33	66.25	72.9	263.25	918.7	51.4
18	22.05	28.70	14.47	145.98	20.85	66.71	76.6	68.70	213.9	12.3

a Degree days calculated from maximum and minimum temperatures minus a base temperature of 50°F.
b Total solar insolation measured in number of hrs/day of sun.
c Total solar radiation measured in gram calories/cm^2/day.
d Total solar intensity measured in gram calories/cm^2/1 min. exposure.

but normally averaged 7 days. Definite conclusions cannot be reached on only three years of limited data, but some trends were noted.

Precipitation at various times was responsible for changes in populations of aphids and other species. Low to moderate insect populations (Tables 8 and 9) were present during 1970 and corresponding weather data are presented in Tables 25 and 26. Rainfall during the weeks prior to August 24 and September 30, 1970, limited the growth or severely reduced the populations of most species studied, especially Aphididae, Dolichomiris sp., and Aphidiidae. The largest aphid populations were recorded during 1971, following a period of above normal spring-summer (Sept.-Feb.) rainfall (Tables 10, 11, and Appendix C), possibly similar to the phenomena for S. graminum documented by Rogers (1972) in Oklahoma. Precipitation played a role in reducing the populations of Aphididae, Dolichomiris sp., Chrysopa sp. and Coccinellidae larvae, and Aphidiidae adults during the weeks prior to August 24, 1971 (Tables 10, 27, and Figure 2). The rainfalls of October 4 and 13 near the end of the season reduced these groups as well as Nabidae and Syrphidae. For wheat planted a week later, June 30, 1971 (Tables 11, 28, and Figure 3), the first rainfall only slightly reduced the aphid populations but the rainfall the week prior to October 13 reduced populations of most species. It is important to note that the total quantities of rainfall are not as important as intensity which probably produced the greatest population reductions. In wheat planted during 1972 (Tables 12 to 16, 29, and Figure 4), the influence of rainfall seemed to be important only for the week before July 17, causing aphid populations to be reduced in three fields but not in a fourth (Table 15 and Figure 4).

The correlation of weekly weather phenomena to weekly insect populations indicates that most factors analyzed one at a time are not highly correlated. Discussion for the correlations between aphids and weather conditions has already been made under the previous section for population studies 1970 to 1972. Generally, for all seven insect groups, the negative influences were usually maximum temperature and average relative humidity. The hymenopterous parasites, as observed during 1972, were the most frequently negatively correlated, especially with median temperature (-0.22), average degree days with a base temperature of 50°F (-0.20), total solar radiation (-0.11) and intensity (-0.12). All other insects usually correlated positively with the above-mentioned climatological conditions.

Preliminary Cost Analysis

Value of Increasing Yields. Yields were extremely variable in part from uneven germination and crop stand, excessive weed growth in various areas, irregular lodging of mature heads, various diseases, and uneven coverage of the insecticide. Based on linear meter yield data presented for one and two Ekatin$^{(R)}$ application tests from 1970 and 1971, the average yield differences (increases or decreases) between the various treatments and check plots were computed (Table 30). Utilizing the yield figures from the plots receiving two Ekatin$^{(R)}$ applications during 1971, the monetary values for yield increases were calculated in Guaranies and Dollars. These values are presented in Table 31 for unit prices ranging in Guaranies from 8₲s to 22 ₲s per kilogram ($1.72 to $4.75 per bushel).

Table 30. Average wheat yield differences in kilograms based on linear meter samples, between treated and untreated plots resulting from one and two Ekatin(R) applications during 1970 and 1971, College of Agriculture and Veterinary Science, Paraguay.

	Differences in yields between treatments, Kg/Ha								
	Double applications				Single applications				
Year	B-A[a]	C-A	D-A	Average	B-A	C-A	D-A	E-A	Averages[b]
1970[c]	475.5	259.4	196.1	310.33	-	-	-	357.8	-
1971[e]	308.8	176.4	186.3	223.83	-	-	-	323.5	-
1971[f]	-	-	-	-	-9.8	-49.0	58.8	149.5	104.15
Averages									
Kilograms	392.15	217.9	191.2	267.08	-9.8	-49.0	58.8	276.9	222.40
Bushels[d]	14.41	8.01	7.03	9.81	-0.36	- 1.80	2.16	10.17	8.17

[a] See pages 17 and 20 for definitions of the treatments A, B, C, D and E (double and single applications, respectively).

[b] Average increases, only includes positive differences.

[c] Differences are based on calculated yields from whole spike weights.

[d] One bushel equals 60 lbs, which is 27.2157 kilograms.

[e] Wheat planted earlier, June 21, 1971.

[f] Wheat planted later, June 30, 1971.

Table 31. Monetary values in Guaranies and Dollars for the increases in yields resulting from two Ekatin(R) treatments, based on 1971 data.

Wheat price		Difference in value of yield by treatments, Guaranies per Hectare				Average value[c]	
Guaranies[a]	Dollars[b]	B - A (308.8 Kg/Ha)	C - A (176.4 Kg/Ha)	D - A (186.3 Kg/Ha)	E - A (323.5 Kg/Ha)	₲s/Ha	$/Ha
8 ₲s/Kg	$1.72/Bu	2470.4	1411.4	1490.4	2588.0	1989.5	$15.79
10.7[d]	2.31	3304.1	1887.4	1993.4	3461.4	2661.1	21.12
12.0	2.59	3705.6	2116.8	2235.6	3882.0	2984.9	23.69
14.0	3.02	4323.2	2469.6	2608.2	4529.0	3481.4	27.63
16.0	3.45	4940.8	2822.4	2980.8	5176.0	3979.1	31.58
18.0[e]	3.88	5558.4	3175.2	3353.4	5823.0	4476.8	35.53
20.0[e]	4.32	6176.0	3528.0	3726.0	6470.0	4974.5	39.48
22.0	4.75	6793.6	3880.8	4098.6	7117.0	5472.2	43.43

[a] Actual and potential Guaranie farm prices per kilogram of wheat.

[b] Corresponding dollar value per bushel.

[c] Officially 126 Guaranies equal one U. S. dollar.

[d] Official wheat price 1965 to 1972.

[e] Latest estimated prices for 1973 crop, will be between 18₲s and 20₲s.

As previously mentioned, yield samples were not made during the 1972 experiments on planting date variation and one can only speculate as to the yields obtained from the various areas in relation to their corresponding insect populations.

Cost of Increasing Yields. The cost involved in new management strategies for controlling insects with a full dosage of Ekatin$^{(R)}$ would vary in 1973 between 1,015 to 1,200 ¢s/Ha ($8.05 to $9.52/Ha). This includes Ekatin$^{(R)}$ costs of 950 ¢s/Lt ($7.54) with Ekatin$^{(R)}$ applied at the rate of one liter per hectare. Application costs vary depending on farm size and location, type of applicator used, transportation of needed insecticide and equipment, and labor costs (Bieber 1971). On farms of large expanse, aerial application may be employed but small producers may be limited to a manually operated backpack sprayer, thus the relative efficiency of plant coverage and application time utilized will also vary. Small farms are usually owner-operated and more restricted by their limited economic means, while large farms depend extensively on employing extra labor and/or applicators. Total application costs, including a charge for all labor, were 65 ¢s to 250 ¢s per hectare per application for small and large farms, respectively. Wage rates were higher for large farms, because of opportunity costs of labor and higher technical skills of workers.

Comparing these costs to the value of increased yields (Table 31) indicates the application of Ekatin$^{(R)}$ at 100% the recommended dosage (1 Lt/Ha) is usually an economically sound investment, depending on the number of aphids present, stage of plant growth, cost of application, difference in yield obtained, and price received. Henning (1973) indicated prices paid to producers per kilogram for the 1973 crop may range from 18 to 22 ₲s as compared to the previous price of 10.7 ₲s per kilogram which was paid from 1965 to 1972. Utilizing a 20 ₲s per kilogram price, a yield increase of only 60 kilograms (2.204 bushels) would be required to pay for the most costly single application at 100% the recommended dosage. Yield increases of only 18 kilograms and 36 kilograms (0.661 and 1.323 bushels) would be required to offset control costs if the insecticide was employed at 30% and 60% the recommended dosage. Table 30 indicates that, under most conditions, the use of Ekatin$^{(R)}$ is economically feasible. If insecticide and/or application costs, or prices paid per kilogram of wheat, are different than those utilized in these calculations, then the profit margins should be adjusted accordingly.

Yield data reflecting the effect of cultural practices (i.e., early planting) were not available to the writer. Results of these entomological experiments do indicate, however, a trend toward higher yields and lower pest populations in earlier planted wheat (Tables 1, 2, 3). In addition, beneficial insects and entomophogous fungi were more abundant in proportion to aphids when wheat was planted early. Utilizing the yield data obtained from check plots in fields planted May 27, 1970; June 21, 1971; and June 30, 1971 (Tables 1, 2, 3) a trend is evident for increased yields with earlier planting dates. Analysis of this variable should be conducted, if not already analyzed, by the Center for Rural Economics and Statistics in the College of Agriculture and Veterinary Science (Centro de Economía Rural y Estadistica, FAV) in collaboration with technical personnel from the College and Ministry of Agriculture.

Wheat lands under good management are normally not under cultivation with other crops during mid-April, and therefore the early planting dates should not adversely affect cropping practices. This would ensure earlier wheat harvests and facilitate the preparation of fields for the seeding of soybeans during September and October, whereas late wheat planting in June and subsequent harvests in late October limits seedbed preparation time for soybeans.

SUMMARY

Paraguay must make numerous improvements in wheat production techniques to reach self sufficiency, including effective pest management. Entomological investigations had not been conducted previously on wheat to any extent; this research should provide the initial basis for future endeavors.

Fifteen insects were identified from wheat of which the English grain aphid, *Macrosiphum avenae* (F.), was the most prevalent, followed by the greenbug, *Schizaphis graminum* (Rond.). Populations of seven groups of insects were based on samples obtained by linear foot, 100 spike, and sweepnet collections. Linear foot counts gave precise data on numbers and types of aphids in addition to numbers affected by parasites or fungi. Samples of 100 spikes, 110 days after planting also provided this information but unfortunately the vegetative cycle and developmental stages of wheat were not equal for all planting dates sampled. Sweepnet collection provided the basis for the majority of sampling during the three years of experiments. This method can only be used when plants are over 15 cms tall and may produce variable results but was the most accurate method employed for determining population densities and interdependencies among the seven groups.

Data collected indicated that in the Central Zone early planting of wheat and judicious use of the systemic insecticide-acaracide Ekatin$^{(R)}$ may facilitate control of important insect pests. During the extended wheat growing season, mid-April through mid-October, aphid population growth and total numbers, partially depended on planting date. Three fields planted before May 1, 1970 and 1972 expressed only a single peak of aphids, comprised basically of S. graminum. Wheat in four fields planted from May 4 to June 21, 1970 to 1972 expressed bimodal peaks, the second curve by M. avenae consisting of a much larger number than the first by S. graminum. Two fields planted on June 30, 1971 and 1972 expressed single peaks consisting basically of M. avenae.

Natural enemies studied included one Chrysopidae, three Coccinellidae, a Nabidae, two Syrphidae, and two Aphidiidae and the average number per sweep of beneficial insects to aphids was greater, proportionally, in early planted fields. Although not proved in these studies, natural enemies appear to arrive in wheat irrespective of planting date, probably resulting from their nearly year-round activity in sub-tropical Paraguay. Density of natural enemies depended on host population size and climatological influences. Rainfall, relative humidity, degree days and temperature were found to be significantly related to several insects, but data from three years provide an insufficient basis for firm conclusions. Entomophogous fungi of aphids were also somewhat favored in fields planted before May 7th, as determined by linear foot and 100 spike samples. Further investigations are needed to confirm this apparent trend.

Pest control by the systemic insecticide-acaracide Ekatin(R) at 30% its recommended dosage provided variable control of aphids up to three weeks, depending on the numbers of aphids present and time of application. Most beneficial insects were only slightly affected by this insecticide. Effectiveness of Ekatin$^{(R)}$ was tested during 1970 and 1971 in three experiments which were of randomized, replicated block design. A single treatment variable based on the number of days after planting was established. Both single and double applications were tested during 1971, whereas only double applications were made during 1970. Aphids were not numerous in 1970 and the greatest yield increases were obtained when Ekatin$^{(R)}$ was applied twice to plants, once each at 45 and 78 days after planting. A single application at 90 days after planting yielded more than plots treated twice at 60 and 90 days and 78 and 105 days. In 1971 aphid populations were extremely large, but somewhat similar results were obtained. The double application experiment (1971) indicated best yields with a single application at 91 days, followed by the double application at 47 and 77 days after planting. Results of the single application experiment during 1971 under intense aphid populations demonstrated that the 90 day after planting treatment was again the best. Results suggest that the relationship between insect populations and stage of plant growth is extremely important. Although the economic threshold and economic injury level were not determined, they should now be determined for the critical plant growth periods near 45 and 90 days after planting. Protection of the plant near the 45-day period is important since tillering and stem extension occur during this period, whereas spike emergence, flowering, and initial seed development occur around the 90-day period. Specific time periods for the exact stages of growth were not determined because of the variability in plant stand and developmental stages present at any given time.

A yield increase of only 60 Kg/Ha (2.204 Bu/Ha) was found to be necessary to offset cost of control measures employing Ekatin(R) at 100% its recommended dosage. Yield increases of only 18 Kg/Ha and 36 Kg/Ha (0.661 and 1.323 Bu/Ha) would be required to offset control costs if the insecticide was employed at 30% and 60% the recommended dosage.

Early planting of wheat appears to be a potential component of pest management in Paraguay since it stresses an ecological approach to maintain pest populations below economic damage levels with a minimum of cost and adverse effects. In addition to the use of more viable seed and improved disease resistant plants, weed control should be encouraged to increase the extremely low spike density per unit area, and subsequent yields. Cultural practices should be studied to accurately determine their interacting effects on yield and insect populations.

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LITERATURE CITED

Adams, J. B. 1960. Effects of spraying 2,4-D amine on coccinellid larvae. Can. J. Zool. 38: 285-288.

Alarcóne L., E. 1972. Personal interview in College of Agriculture and Veterinary Science, San Lorenzo, Paraguay, on Nov. 17, 1972.

Apablaza, J. U.; A. G. Robinson. 1967. Effect of three species of aphids on barley, wheat, or oats at various stages of plant growth. Can. J. Pl. Sci. 45: 367-373.

Apablaza, J. U. 1972. Personal conversations about research in Chile on wheat aphids, at the College of Agriculture and Veterinary Science, San Lorenzo, Paraguay, from April 17 to 22, 1972.

Aranda, B.; and T. Granovsky. 1971. Introducción al conocimiento de las plagas agrícolas en el Paraguay. Revista Peruana de Entomol. (Anals de 1° Congreso Latinoamericana de Entomología) 14(2): 397-398.

Arnold, A. F. 1968. Structure and performance of Paraguayan agriculture 1956-1967 with implications for development policy. USAID/Paraguay, mimeo, 68pp.

Arnold, C. Y. 1960. Maximum-minimum temperatures as a basis for computing heat units. Proc. Amer. Soc. for Hort. Sci. 76: 682-692.

Bieber, J.; and A. Obara. 1971. A study of wheat cost variability. NMSU/USAID/Paraguayan Min. of Agric. & Livestock, Asuncion, Paraguay, mimeo, 25pp.

Blanchard, E. E. 1940. Estudio sistematico de los Aphidoides Argentinos. Physis 17(49): 857-1003.

Bosq, J. M. 1943. Coccinelidos utiles para la fruticultura Tucumana. Revista Soc. Entomol. Argentina 11(5): 461-470.

Bruch, C. 1917. Desarrollo de Chrysopa lanata Banks. Physis III: 361-369.

Caballero V., C. 1972. Incidencia del ataque del pulgón de los cereales Methopolophium dirhodum (Walker-1848) en los rendimientos de trigo. Revista Peruana de Entomol. (Anals de 1° Congreso Latinoamericana de Entomologia) 15(1): 195-200.

Candia, J. D. 1971. Las plagas del algodon en Bolivia. Revista Peruana de Entomol. (Anals de 1° Congreso Latinoamericana de Entomologia) 14(2): 395-397.

Carrasco Z., F. 1962. Coccinellidos predatores en la Region del Cuzco. Revista Peruana de Entomol. 5(1): 91-93.

Carrillo L., J. R. 1972. Personal conversations about research in Chile on wheat aphids, at the College of Agriculture and Veterinary Science, San Lorenzo, Paraguay, from April 17 to 22, 1972.

Casella, E. M.; and M. S. Moratorio. 1971. Morfología larval de dos Noctuidae perjudiciales al trigo (Lepidoptera: Noctuidae, Hadeninae). Revista Peruana de Entomol. (Anales del 1° Congreso Latinoamericana de Entomologia) 14(2): 259-263.

Ceuppens, H. D. 1971. Paraguay año 2000. Artes Graficas Zamphiropolos, Asuncion, Paraguay, 285pp.

Costa Lima, A. 1927. Segundo Catálogo de Insectos. Vol. VIII, N° 1 & 2.

Costa, C. L.; N. F. Eastop; and A. S. Costa. 1972. A list of the aphid species (Homoptera: Aphidoidea) collected in Sao Paulo, Brazil. Revista Peruana de Entomol. (Anals del 1° Congreso Latinoamericana de Entomología) 15(1): 131-134.

Covarrubias, R.; J. A. Sifuentes, and others. 1969. Fluctuacion de poblaciones de plagas e insectos benéficos del trigo en la Costa de Hermosillo. Agricultura Técnica en México, Julio, Vol. II (11): 492-495.

Delfin, F. T. 1900. Datos para el conocimiento. Revista Chilena de Historia Natural Año IV (2): 19-21.

DeSantis, L. 1967. Catálogo de los Hymenoptera Argentinos. 337pp.

Fagundes, A. C. 1971. Especie de pulgao verde pradominante em trigo no Rio Grande de Sul, Acyrthosiphon dirhodum (Walker) (Homop: Aphididae), descricao e controle com insecticidas sistemicos. Separata de Agronomia Sul Rio Grandense V: 99-113.

Fagundes, A. C.; and W. Schramm. 1972a. Susceptibilidade de variedades e linhagens de trigo ao pulgao verde Acyrthosiphon dirhodum (Walker). Agronomia Sul Rio Grandense VIII (1): 15-20.

Fagundes, A. C. 1972b. Como controlar o pulgao da espiga do trigo. Secretaria da Agricultura Unidade de Divulgacao e Informacao Agricola, 2pp.

Farm Chemicals Magazine. 1970. Farm chemicals 1970 handbook. Pub. Meister Publishing Co., Willoughby, Ohio.

Forbs, A. R. 1962. Aphid populations and their damage to oats in British Columbia. Can. J. Pl. Sci. 42: 660-666.

Guido, S. A.; and E. Conde Jahn. 1945. El pulgón verde de los cereales del Uruguay. Rev. de la Fac. de Agron. N° 41:35-85.

Harper, A. M. 1973. English grain aphid: Effect on yield of wheat in Alberta. J. Econ. Entomol. 66(6): 1326.

Harvey, T. L.; and H. L. Hackerott. 1969. Recognition of a greenbug biotype injurious to Sorghum. J. Econ. Entomol. 62(2): 776-779.

Hayward, K. J. 1941. Insectos de importancia económica en la region de Concordia (Entre Rios). Rev. Soc. Entomol. Argent. Tomo XI (2): 68-109.

Hayward, K. J. 1942. Primera lista de insectos Tucumanos perjudiciales. Est. Exp. Agric. Tucuman, Pub. Misc. 110pp.

Henning, R. G. 1973. Memo to Dr. V. Plath, "Information on wheat for Ted Granovsky," USAID/Paraguay, Marketing Advisor USAID/PASA, 2pp.

IIA (Instituto de Investigaciones Agropecuarios, Chile). 1970. Investigaciones Agropecuaria 1946-1970, Santiago, Chile.

Kanal, M. 1926. A study of some hymenopterous parasites of aphidophagous Syrphidae. J. Econ. Entomol. 19(5): 721-730.

Kolbe, W. 1969. Studies on the occurrence of different aphid species as the cause of cereal yield and quality losses. Pflanzenschutz-Nachrichtin, Vol. XXII (2): 171-204.

Korytkowski G., C. 1967. Diplazon laetatorius (Fabr.) (Hym: Ichneumonidae), Ichneumonido Syrphidofago poco conocido en el Peru. Rev. Peruana de Entomol. 10(1): 54-58.

Large, E. C. 1954. Growth stages in cereals. Plant Pathology 3(4): 128-129.

MacPherson, D. D.; and A. F. Arnold. 1969. Paraguay's potential for the export of selected commodities in a world setting, with reference tables. USAID/Paraguay, mimeo, 133pp.

Martins F., L. 1970. Estudo da acão de insecticidas granulados sistemicos e da profundidae, no contrôle de pulgônes em Trigo. Separata de Pesquisa Agropequaria Brasileira Vol. 5, Boletim Tec. N° 68, 259-264.

Mendoza, S. J. 1972. Influencia de los pesticidas sobre la fauna benéfica del Arroz. Revista Peruana de Entomol. (Anales 1° Congreso Latinoamericano de Entomologia) 15(2): 370-372.

Mesa Carrion, F. 1947. Medio de lucha contra las principales plagas agricolas. Min. de Gan. y Agric., Pub. N^{o} 88, 23pp (Montevideo).

Millan, E. 1956. Metamorfosis y ecología de Aphidius platensis Brethes (Hymenoptera: Aphidiidae). Revista de Investigaciones Agrícolas X(3): 243-280.

Mineiro Kober, E. A. 1971. Combate aos pulgônes que atacam o Trigo. Secretaria da Agric. Do Estado do Rio Grande do Sul, SPV/UNIDEF/EDF, mimeo, 9pp.

Min. de Agric. 1966. Programa nacional de Trigo, cartilla de orientación N^{o} 2. Asunción, Paraguay, 22pp.

Min. de Agric. 1968. Manual estadistico del Paraguay 1962-1967. Asunción, Paraguay. 141pp.

Min. de Agric. 1970a. Encuesta agropecuaria por muestreo 1970. Asunción, Paraguay, 55pp.

Min. de Agric. 1970b. Tres años de ensayos con variedades de trigo en el Paraguay. Boletin de Investigación N^{o} 1, 24pp, Asunción, Paraguay.

Min. de Agric. 1971a. Paraguay, agropecuario y forestal, órgano oficial del Ministerio de Agricultura y Ganadería, Año 1, N^{o} 2, Enero-Febrero. 85pp.

Min. de Agric. 1971b. Producción y conservación de semilla certificada de trigo. Boletín de Divulgacion N^{o} 4, 25pp, Asunción, Paraguay.

Mosqueira, J. 1969. Personal conversation in the College of Agriculture and Veterinary Science, San Lorenzo, Paraguay, when he was the auxillary secretary for the Dean of the FAV.

Munro, J. A. 1955. Insectos de Bolivia identificados por el Departamento de Agricultura de Estados Unidos. Pub. Especial N^{o} 7, Julio, 5pp.

Nault, L. R.; L. J. Edwards; and W. E. Styer. 1973. Aphid alarm pheremones: secretion and reception. Envir. Entomol. 2(1): 101-105.

Navis, L. 1929. Insectos de la Argentina. Revista Soc. Entomol. Argen. II(5): 219-225.

Navis, L. 1930. Insectos de la Argentina. Revista Soc. Entomol. Argen. III(2): 125-132.

Navis, L. 1931. Insectos de la Argentina. Revista Soc. Entomol. Argen. IV(6): 313-320.

Navis, L. 1932. Insectos de la Argentina y Chile. Revista Soc. Ent. Argen. V(22): 79-86.

Nickel, J. 1958. Agricultural insects of the Paraguayan Chaco. J. Econ. Entomol. 51(5): 633-637.

Nuñez, A. 1940. El trigo, instrucciones prácticas para su cultivo. Direc. de Agron. Nº 47, 35pp. (Min. de Ganadería y Agric., Uruguay).

Ojeda Peña, D. 1971. Biología y hábitos de Nabis capsiformis Germar (Hemip: Nabidae). Revista Peruana de Entomol. (Anals 1º Congreso Latinoamericano de Entomología) 14(2): 297-303.

Olazarri, J.; and E. Alzaga. 1970. El pulgón verde de los cereales y su control. La Hacienda, Enero: 26-27.

Ong, E. R. 1962. Como combatir las plagas, su control químico y natural. Ed. Victor Leru, S.R.L., Buenos Aires, 236pp.

Pincus, J. 1968. The economy of Paraguay. F. A. Prager Publ., New York, 518pp.

Piscucci, S. 1967. Pulgón verde de los cereales. La Chacra, Enero: 48-49.

Ratkovich, M. 1950. Primera lista de insectos Tucumanos útiles. Est. Exp. Agric. Tucuman, Pub. Misc. Nº 5, 23pp.

Rautapää, J. 1966. The effect of the English grain aphid, Macrosiphum avenae (F.), (Homop.: Aphididae) on the yield and quality of wheat. Ann. Agric. Fenniae 53: 334-341.

Rizzo, H. F. E. 1970. Catálogo de insectos perjudiciales en cultivos de la Argentina. Boletín Técnico Nº 9, Centro de Estudiantes de Agronomía de Buenos Aires, Argentina.

Rockefeller Foundation. 1957. Directors' annual report 1956-1957, Mexican Agricultural Program.

Rockefeller Foundation. 1958. Directors' annual report 1957-1958, Mexican Agricultural Program.

Rockefeller Foundation. 1959. Directors' annual report 1958-1959, Mexican Agricultural Program.

Rogers, C. E.; R. D. Eikenbary; and K. J. Starks. 1972. A review of greenbug outbreaks and climatological deviations in Oklahoma. Envir. Entomol. 1(5): 664-668.

Samudio, R.; and R. Bianchi. 1971. Control de malezas en trigo. College of Agriculture and Veterinary Science, Paraguay, mimeo, 2pp.

Sandoz S. A., Basilea. 1966. Ekatin(R), Datos tecnicos, Agro. Slk. N^o S-2641/A.

Snedecor, G. W.; and W. G. Cochran. 1967. Statistical methods. 6th ed. The Iowa State University Press, Ames, Iowa. 593pp.

Stauffer, A. 1972. Personal conversations during the author's stay in Paraguay especially during 1972. He is a Plant Pathologist working full time in the Dept. de Fitopatología, College of Agriculture and Veterinary Science, San Lorenzo, Paraguay.

Tarsia, L. Undated. Catalog of Latin-English and local names of economic insects. STICA, Asunción, Paraguay, 5pp.

Thomson, W. T. 1973. Agricultural Chemicals, Book I. Insecticides 1973 Revision, Thomson Publications, Indiana. 300pp.

U.S.A.I.D. 1969. Data prepared for the visit of Governor Rockefeller to Paraguay, June 19-20, 1969; Agriculture, mimeo, 5pp.

U.S.D. Comm. 1968. Overseas Business Reports, basic data on the economy of Paraguay. Overseas Business Reports, July, 12 pp.

Vazquez, M.; J. L. Carrillo S.; and J. A. Sifuentes. 1971. Efecto de diversos insecticidas sobre la fauna benéfica que ocurre in el cultivo del Trigo, en Mexicali, B.C. Agricultura Tecnica en Mexico, January, III(2): 77-80.

White, S. 1972. Historical resume of national wheat program, RDO/USAID/PARAGUAY. Asuncion, Paraguay, mimeo, 18pp.

Wood, E. A. 1965. Effect of foliage infestation of the English grain aphid on yield of Triumph wheat. J. Econ. Entomol. 58(4): 778-779.

Wood, E. A. 1971. Designation and reaction of three biotypes of the greenbug cultured on resistant and susceptible species of sorghum. J. Econ. Entomol. 64(1): 183-185.

Zazueta N., A. 1964. Resultados del control legal y control biológico natural en Algodonero. Fitofilo Año XVII(43): 21-25, Julio-Sept.

Zeleny, J. 1966. The effect of four organophosphorous insecticides on Coccinellidae and Chrysopids, pp. 337-340 in Ecology of Aphidophagous Insects, Ed. I. Hodek, Academia, Publishing House of the Czechoslovak Academy of Science, Prague. 360 pp.

Zuñiga S., E. 1969. Lista preliminar de afidos que atacan cultivos en Chile, sus huespedes y enemigos naturales. Fitotecnia Latinoamericana 6(2): 131-155.

VITA

Theodore A. Granovsky, son of Dr. and Mrs. A. A. Granovsky, was born February 27, 1945, in St. Paul, Minnesota. In June 1963 he was graduated from Murray High School, St. Paul, Minnesota.

In June 1968 he received his B. S. with a Plant Pathology major and Entomology minor from the University of Minnesota. During his attendance at the University of Minnesota he was employed by the Department of Entomology for three and a half years where he managed plant virus and insect cultures for classroom use; assisted in research on Kentucky bluegrass, clover, and alfalfa through application of insecticides, data collection, and partial data analysis. In addition he aided in management and maintenance of honey bee colonies and equipment during his last year at the University of Minnesota. Active in numerous campus organizations, he received the annual Dean E. M. Freeman Medallion, awarded for outstanding student leadership on the St. Paul Campus, in May 1967.

In June 1968, he enrolled in the Graduate School, Kansas State University, while working half time between the Department of Entomology and Plant Pathology on the transmission of barley yellow dwarf virus by the corn leaf aphid. At Kansas State University he joined an Intern Program for the American Peace Corps and subsequently left school June 1969 to become a volunteer in Paraguay, South America. From September 1969 to November 1972 he worked in the College of Agriculture and Veterinary Science, National University of Asuncion, San Lorenzo, Paraguay. In the College he established the first Entomological Laboratory, converted from an old kitchen; constructed collection equipment for student and laboratory use; taught (in Spanish for three years) groups of 40-50 students of the 3rd year class in general and applied entomology; directed individual and group research projects of students in 1971 and 1972; and initiated a program of Extension Entomology in diverse crops and livestock. During this three-year period he also collected data forming the basis of this thesis.

In January 1973, he reentered Kansas State University, where he was initially employed with the Department of Plant Pathology as a collaborator on a NASA/KSU project to test the application of the ERTS-I satellite in the detection of plant diseases, water relationships, insect damage, and soil deficiencies in wheat. In August he became a Graduate Teaching Assistant in the Department of Entomology and was responsible for laboratory sections of General Entomology. Beginning January 1974 he became an Assistant Instructor with the Entomology Department, where he again taught laboratory sections and investigated the influences acclimating stored wheat has on insects, their survival, fecundity, and intra-species competition.

APPENDICES

APPENDIX A

Map A-1. Latin America, actual boundaries.


CUBA
HAITI
SANTO DOMINGO
HONDURAS
NICARAGUA
TRINIDAD
COSTA RICA
PANAMA
VENEZUELA
COLOMBIA
ECUADOR
BRAZIL
PERU
BOLIVIA
PARAGUAY
CHILE
ARGENTINA

APPENDIX A

Map A-2. Asuncion, Paraguay
and surrounding area indicating
the location of the College of
Agriculture and Veterinary Science
(FAV).


M.R. ALONSO
Zeballos Cue
AEROPUERTO
Arroyo Itay
D.G.I.
Chaco-i
LUQUE
Pto Timbo
Pto Elsa
R. Negro
CLORINDA
ASUNCION
Rio Pilcomayo
Antolco
F. de la MORA
LAMBARE
CUATRO MOJONES
San LORENZO
TRES BOCAS
College of Agriculture
and Veterinary Science (FAV)
ITA ENRAMADA
Pto. Pilcomayo
V. Elisa
Pto. Pabla
REFINERIA de PETROLEO
ÑEMBY

APPENDIX B

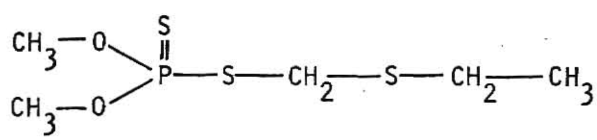
Technical Data for Ekatin(R), A Systemic Phosphate Insecticide-Acaracide

CHEMICAL INFORMATION

Names - Common: Ekatin and Thiometon

- Chemical: 0,0-Dimethyl S-2-(ethylthio) ethyl phosphorodithioate

Formula - Structural:



- Empirical: $C_6H_{15}O_2PS_3$

Origin:
1953, Sandoz Limited of Switzerland and Bayer AG of Germany.

Type:
This product is an organic phosphate insecticide-acaricide that processes systemic activity.

Molecular Weight: 246.3

Specific Weight: 0.971

Boiling Point: 110-111^{o}C

Inflammation Point: Approximately 80^{o}C

Appearance: An oily liquid which is dark blue in color.

Refraction Index n_D^{20}: 1.5515

Specific Gravity: 1.208 at 20^{o}C

Solubility in Water: 0.02 grams of this product is dissoluble in 100 cc of water at 20^{o}C

Toxicity - Oral: White Rat, Male 105-120 mg/kg
Female 120 mg/kg

- Dermal: White Rat, Female 560 mg/kg

APPENDIX B (concluded)

Antidote: Atropine and PAM

Composition: 25% active ingredient and 75% solvents and carriers

Formulation: Emulsifiable concentrates of 20 and 25%, Dust of 2%

FIELD INFORMATION

Phytotoxicity: Considered non-phytotoxic except on such ornamentals as ferns, cyclamen, Baccarat, Roslandia, and Polyantha roses under glass.

Uses: Used outside the United States as a foliar spray on all crops and ornamentals.

Important Pests Controlled: Aphids, mites, white flies, thrips, and many other sucking insects.

Rates: Apply at a 0.1% concentration. In extensive crops use 1 to 2 Liters of product per Hectare (0.855 to 1.710 Liters per Acre).

Field Preparation: Add product at the recommended dosage to water, agitating to ensure a good mixture which is indicated by a uniform faded blue color.

Application: Application should be made when the plant is actively growing for the maximum systemic activity. Treat as early as possible to prevent an insect population build up. The systemic action will kill the hidden insects in two to three days. Repeat when necessary. May also be used as a soil drench or seed treatment.

Precautions: Should not be mixed with strong alkaline compounds. Do not use in the United States. Is compatible with most fungicides, nevertheless each mixture should be tested before extensive field useage.

Additional Information: Control may last for ten to twenty days. May be applied in the irrigation water where it is taken up in the plant's root system. Translocated within the plant. The di-thio analog of methyl demethon.

APPENDIX C

1970 Monthly Climatological Conditions

	Average temperature °C			Average relative humidity	Total precipitation (mm)	Total solar		
	Med.	Max.	Min.			Insolation	Radiation	Intensity
January	26.2	32.6	18.9	76	79.1	316.25	30.0	1.6
February	26.2	32.6	18.9	76	74.0	262.25	29.3	1.6
March	25.8	31.3	19.7	79	186.0	197.50	22.5	1.2
April	23.8	30.9	16.3	76	63.8	254.00	24.3	1.4
May	20.5	27.5	13.9	75	50.7	210.40	19.8	1.1
June	17.7	23.5	11.4	80	135.1	171.10	16.5	0.7
July	17.6	23.7	10.7	76	18.4	215.50	18.9	0.9
August	17.8	24.1	11.2	72	49.6	211.35	19.9	1.0
September	20.4	26.4	13.0	78	193.9	186.50	20.1	1.1
October	23.1	29.0	15.9	76	79.2	259.15	26.2	1.5
November	22.6	29.0	13.8	65	103.3	299.40	26.6	1.8
December	26.7	33.3	19.3	68	133.6	218.15	29.0	1.6
Yearly averages	23.11	28.65	15.25	74.75	97.22	233.46	23.59	1.29

APPENDIX C (cont'd)

1971 Monthly Climatological Conditions

	Average temperature °C			Average relative humidity	Total precipitation (mm)	Total solar		
	Med.	Max.	Min.			Insolation	Radiation	Intensity
January	26.3	31.2	20.2	82	447.0	257.25	28.2	1.5
February	25.9	31.5	20.3	79	119.4	210.30	25.6	1.5
March	24.1	29.4	18.9	86	270.6	180.05	22.1	1.2
April	20.4	26.7	14.1	79	131.2	211.15	22.0	1.3
May	17.4	23.1	11.7	80	97.8	211.15	19.1	1.1
June	14.6	20.2	8.3	75	88.2	169.00	15.7	0.8
July	15.0	24.3	12.5	75	118.5	229.25	18.8	0.9
August	18.3	23.8	12.1	76	107.6	216.05	19.5	1.1
September	22.0	28.3	15.1	68	27.4	246.15	25.8	1.4
October	20.7	26.5	14.1	74	112.3	219.50	24.0	1.4
November	24.6	31.3	16.6	64	54.7	284.25	28.9	1.8
December	25.9	31.6	19.2	70	122.7	293.50	29.4	1.7
Yearly averages	21.26	27.32	15.25	75.66	141.45	227.30	23.25	1.30

APPENDIX C (concluded)

1972 Monthly Climatological Conditions

	Average temperature °C			Average relative humidity	Total precipitation (mm)	Total solar		
	Med.	Max.	Min.			Insolation	Radiation	Intensity
January	26.7	33.3	19.5	68	128.9	283.00	30.5	1.7
February	26.2	32.2	19.6	71	123.1	264.50	30.4	1.6
March	25.0	30.5	18.4	74	135.1	230.15	27.6	1.5
April	20.0	26.9	13.9	79	165.6	239.15	24.6	1.4
May	22.0	27.4	15.9	79	44.7	204.35	20.1	1.0
June	21.0	25.8	15.7	76	215.9	207.40	17.6	0.8
July	17.2	22.5	11.8	78	42.0	148.25	15.8	0.8
August	17.3	22.9	11.5	76	109.2	176.55	18.1	1.0
September	22.2	27.8	14.9	66	75.5	219.10	24.8	1.3
October	22.0	27.9	15.2	67	100.3	258.35	28.3	1.6
Yearly averages	21.96	27.72	15.64	73.40	114.03	223.08	23.78	1.27

STUDIES ON PEST AND BENEFICIAL INSECTS OF WHEAT
FROM 1970 THROUGH 1972 AT THE
COLLEGE OF AGRICULTURE AND VETERINARY SCIENCE,
NATIONAL UNIVERSITY OF ASUNCION, SAN LORENZO, PARAGUAY

by

THEODORE ALEXANDER GRANOVSKY

B. S., University of Minnesota, 1968

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1974

Fifteen insects were identified from wheat of which the English grain aphid *Macrosiphum avenae* (F.) was the most prevalent, followed by the greenbug *Schizaphis graminum* (Rond.). Populations of seven arbitrarily selected insect groups were based on samples obtained by linear foot, 100 spike, and sweepnet collections. Linear foot counts gave precise data on numbers and species of aphids and numbers affected by parasites or fungi. Spike samples also provided this information but value was somewhat limited because the vegetative cycle and developmental stages of wheat 110 days after planting were not equal for all planting dates sampled. Sweepnet collections provided the basis for the majority of sampling during the three years of experiments and although this method can only be used when plants are over 15 cms tall and may produce variable results, it was the most accurate method employed for determining population densities and interdependencies among the seven groups.

In the Central zone early planting of wheat and judicious use of the systemic insecticide-acaracide Ekatin(R) may facilitate the control of important insect pests. During the extended wheat growing season, mid-April through mid-October, aphid population growth and total numbers, depended partially on planting date. Three fields planted before May 1, 1970 and 1972 expressed only a single peak of aphids, comprised primarily of *S. graminum*. Wheat in four fields planted from May 4 to June 21, 1970 to 1972, expressed bimodal peaks, the second curve by *M. avenae* consisting of a much larger number than the first by *S. graminum*. Two fields planted on June 30, 1971 and 1972 expressed single peaks consisting primarily of *M. avenae*.

The average number of natural enemies of aphids was greater, proportionally, in early planted fields. Although not proved in this limited study, natural enemies appear to arrive in wheat irrespective of planting date probably resulting from their nearly year-round activity in subtropical Paraguay. Density of natural enemies depended on host population size and climatological influences. Entomophogous fungi of aphids were somewhat favored in fields planted before May 7th, as determined by linear foot and 100 spike samples.

Pest control by the insecticide at 30% its recommended dosage provided variable control of aphids up to three weeks, depending on the numbers of aphids present and time of application. Most beneficial insects were only slightly affected by the insecticide. Both single and double applications were tested during 1971, whereas only double applications were made during 1970. The economic threshold and economic injury levels, although not determined for the critical plant growth period, should be near 45 and 90 days after planting. A yield increase of 60 kilograms/Ha (2.204 bushels/Ha) was necessary to offset cost of control measures employing Ekatin(R) at 100% its recommended dosage.

Early planting of wheat appears to be a potential component of pest management in Paraguay because it stresses an ecological approach to maintain pest populations below economic damage levels with a minimum of cost and adverse effects. In addition to the use of more viable seed and improved disease resistant plants, weed control should be encouraged to increase the extremely low spike density per unit area, and subsequent yields.