8-1976

An Evaluation of Treatment Recommendations for the Greenbug, *Schizaphis graminum*, on Susceptible Grain Sorghum in the Clay County, Nebraska Pest Management Project

Bruce John Monke
*University of Nebraska-Lincoln*

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AN EVALUATION OF TREATMENT RECOMMENDATIONS FOR THE
GREENBUG, Schizaphis graminum, ON SUSCEPTIBLE GRAIN SORGHUM
IN THE CLAY COUNTY, NEBRASKA PEST MANAGEMENT PROJECT

by

Bruce J. Monke

A THESIS
Presented to the Faculty of
The Graduate College in the University of Nebraska
In Partial Fulfillment of Requirements
For the Degree of Master of Science
Department of Entomology

Under the Supervision of Professor David L. Keith

Lincoln, Nebraska
August, 1976
ACKNOWLEDGMENTS

The author expresses his appreciation to Mr. George Woolsey, Clay County extension agent, for his cooperation and interest in this study.

Thanks are extended to Dr. Leroy Peters for his help and suggestions regarding this study and interpretations and for providing the author with an opportunity to pursue related research that helped cast light upon the interpretations of this study.

Thanks are also expressed to fellow graduate students, Mr. Robert Roselle, Jr. and Mr. Ron McKie, for their assistance in handling the yield samples, in the field and in the threshing process.

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Thanks are also given to the aerial pesticide applicators of Clay County, especially Mr. Elmer Plettner, for their cooperation in leaving and locating check strips in fields they sprayed for use in this study.
Appreciation is expressed to Mr. Walter Gary for his support, interest and involvement with this study.

Grateful appreciation is expressed to Dr. David L. Keith, the author's major advisor, for providing the opportunity to pursue this study. The invaluable guidance and direction to the entire graduate program is thankfully acknowledged.

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INTRODUCTION

The greenbug, *Schizaphis graminum* (Rondani), has been a perennial problem on grain and forage sorghums, *Sorghum bicolor* (L.) Moench, since 1968. The damage caused by greenbugs has resulted in heavy usage of insecticides on sorghums. The problem is compounded because the extent of greenbug infestations capable of destroying a crop or significantly reducing yields of grain sorghum is uncertain. A further complication is the presence of the corn leaf aphid, *Rhopalosiphum maidis* (Fitch), which also feeds on sorghums. Although the numbers of corn leaf aphids may become quite high they are not considered an economic threat to sorghum and their control is unnecessary (Wilde and Ohiagu 1976). However, because of the greenbug threat there has been a tendency among grain sorghum producers to apply insecticides to their fields at the first indication of insects, regardless of the insect species present or the extent of the population.

The Nebraska Pilot Pest Management project in Clay County, Nebraska, initiated in 1973, was one of 39 USDA (Cooperative Extension Service [CES] and Animal and Plant Inspection Service [APHIS]) funded pest management projects (Thomas 1973). The program was to demonstrate the feasibility of an organized and professionally conducted large scale pest management effort. A goal of the program was to reduce the application of insecticides or limit their use to situations where they were essential to prevent economic damage.

Irrigated and dryland sorghum and irrigated corn were the crops involved in the Clay County Pest Management Program. A total of 82,422 acres (33,369 ha) of corn, 35,147 acres (14,230 ha) of sorghum
and 217 cooperators were involved in the project during its three year duration.

Fields were periodically monitored and the resulting information on the pest situation used to determine if and when insect controls were necessary. The basic concept of pest management requires an understanding of the pest and crop situation to determine the optimum time and method of pest control. Proper control decisions result in an economic advantage to the producer by minimizing expenses and maximizing profits. Pest management can be beneficial to the environment because unnecessary chemical applications may be reduced and alternative control methods often utilized. However, pest management does not necessarily mean a reduction in pesticide usage.

The decision of when to apply pest control methods is based on the economic threshold of the pest, the crop, and the control methods chosen. Thus, economic thresholds are an integral part of the pest management concept.

The effectiveness of this program and thus the feasibility of pest management on sorghum in Nebraska is dependent upon the growers’ benefiting by increased profits as a result of following treatment recommendations. Therefore, this two year study (1974-1975) was designed to determine the accuracy of the economic thresholds upon which these recommendations were based. The objectives of this study were:

1. To determine if accepted economic thresholds (developed in Texas) for greenbugs on grain sorghum are valid under Nebraska conditions.
2. To develop additional economic threshold data for dryland and irrigated grain sorghum at various stages of plant growth.
LITERATURE REVIEW

One of the first uses of the term "pest management" was by Geier (1966). He emphasized a comprehensive and ecological approach to pest population manipulation. However, using knowledge of the pests' biology and applied ecology to protect the threatened commodity is not a new concept (Newsom 1974).

There are many interpretations of pest management. Day (1974) defined it as using a combination of chemical, physical, and biological controls for crop protection and used "pest management," "integrated control," and "integrated pest management" interchangeably. According to Hanson (1975) the use of more than one pest control method is fundamental to pest management. Gonzalez (1971) defined pest management as the use of two or more methods of control to keep pests below economic damage.

Benham (1972), however, indicated that integrated control is just one approach to pest management and that the terms "pest management" and "integrated control" are not synonymous. Pest management can be any form of population manipulation by man. Pest management may involve the utilization of only one method of population control, whereas integrated control requires the use of two or more methods (Rabb et al. 1974). According to Stehr (1972) pest management implies manipulation of the pest population over a wide area, whereas integrated control means only preventing damage. The Food and Agricultural Organization (FAO) defined pest management to include, "... all approaches ranging from a single control method ... repetitious application of broad spectrum insecticides ... to the most sophisticated
integrated control system," (Thomas 1973). The goal of pest management is not to reduce the use of pesticides but to use all control practices, including chemical controls, optimally and efficiently (Robins 1972).

Economic thresholds are fundamental prerequisites for pest management programs (Stern 1975). The economic threshold is the population density at which the pest should be controlled to prevent it from reaching the economic injury level. The economic injury level is the lowest population density that will cause a degree of damage equivalent to the cost of control (Cothran et al. 1974).

Smith (1971) suggests that economic thresholds be continually reviewed. Economic thresholds are not static but vary depending on location, number of previous treatments, agronomic practices, plant variety, value and use of the commodity (Stern 1973).

The greenbug was first reported in the United States in 1882 (USDA 1968) and first damaged wheat in 1890 (Webster 1892, Fookes 1890). It remained a pest of small grains but in 1916 greenbugs destroyed a large acreage of corn and sorghum in Kansas and Oklahoma (Hayes 1922, Kelly 1917).

Wood (1961) reported a greenhouse biotype of the greenbug capable of developing on and destroying the resistant wheat line Dickinson Sel. 28-A. This biotype was later designated as biotype B (Wood et al. 1969). In 1966 and again in 1967 small colonies of greenbugs were found on sorghum leaved in the Texas Panhandle but no damage was sustained (Daniels 1969a). First reports of greenbugs damaging grain sorghum came from Jefferson County, Nebraska in May 1968 (USDA 1969). The 1968 infestation spread throughout the sorghum growing states with
greenbugs infesting over 7.34 million acres (USDA 1969).

Individual greenbugs infesting sorghum weighed less than those from wheat and were paler green (Daniels and Jackson 1968, Daniels 1969a). Specimens sent to Washington D.C. for positive identification differed from the grain greenbug in the number of lateral abdominal tubercles, placement and number of antennal sensoria and the absence of black tips on the cornicles. The fecundity of the grain greenbug was reduced above 75°F (24°C) whereas the sorghum greenbug remained on the plant and reproduced efficiently at temperatures up to 110°F (43°C) (Wood and Chada 1969, Wood et al. 1969). The sorghum greenbug was designated biotype C (Wood et al. 1969). Harvey and Hackerott (1969) reported that the best host for distinguishing the greenbug biotypes was the seedling stage of Piper sudangrass, Sorghum sudanense (Piper) stapf.

Little information exists on economic thresholds for greenbugs on grain sorghum. Most of the available information was derived indirectly from chemical efficacy tests. The following control guidelines presented by Bottrell (1969) were based on sorghum physiology and growth patterns as well as research on chemical greenbug control:

<table>
<thead>
<tr>
<th>Sorghum Growth Stage</th>
<th>When to Treat</th>
</tr>
</thead>
<tbody>
<tr>
<td>emergence to six inches</td>
<td>Visible damage with colonies on lower leaves</td>
</tr>
<tr>
<td>six inches to preboot</td>
<td>Before any entire leaves are killed</td>
</tr>
<tr>
<td>preboot and beyond</td>
<td>Greenbug numbers resulting in death to more than two lower leaves</td>
</tr>
</tbody>
</table>
Elsewhere, Bottrell (1971) stated that economic thresholds for greenbugs on grain sorghum were developed from previous experience with wheat and information on the effects of leaf removal as well as control data by Daniels, Cate, and Bottrell.

Although a number of the following papers do not deal with economic thresholds they demonstrate large yield responses to controlling greenbugs on grain sorghum at various degrees of infestation. Much of the literature on greenbug control presents the data too incompletely to infer possible economic thresholds.

In testing methyl parathion for greenbug control Daniels (1969b) found that 22,000 greenbugs/plant on 31 inch plants resulted in a 5% yield reduction. Pate (1970) reported significant yield differences due to the application of several insecticides but could not correlate yield with greenbug control. Although no tabular data were presented, Teetes et al. (1973) found no significant differences between 22 insecticide treatments applied in three replicates to boot stage sorghum. Cate and Bottrell (1969) reported no significant differences when treating sorghum at different growth stages.

The effects on yield of insecticidal control of greenbugs is highly variable. Cate et al. (1973a) found that yields of treated sorghum ranged from 540 lbs/acre (606 kg/ha) less than to 1382 lbs/acre (1552 kg/ha) greater than the untreated check. None of these differences were significant. Yield increases of 497 lbs/acre (424 kg/ha) and 378 lbs/acre (324 kg/ha) were not significantly different from the untreated checks (Ward et al. 1970, Daniels and Chedester 1971). With foliar insecticide applications on irrigated sorghum Daniels (1972) obtained significantly different yield increases of
584-1071 lbs/acre (665-1201 kg/ha) over the untreated check. Depew (1974) reported yield increases in treated sorghum of 496-1096 lbs/acre (557-1229 kg/ha) were significantly different from the untreated check.

The literature shows that in most of the experiments on sorghum greenbug control the treatments were replicated three to five times (Bottrell and Cate 1970, Daniels 1970b, Depew 1971, 1972, Teetes et al. 1973). Due to extreme sample variation this is generally not enough replication to show significant differences in yield (Cochran and Cox 1957).

Soil treatments for greenbug control at planting and cultivation often resulted in significant yield increases (Daniels 1970a, 1972, Daniels and Chedester 1971, Depew 1971). In four experiments using seed furrow and sidedress treatments Cate et al. (1973b) had extremely variable results. The authors concluded, however, that seed furrow treatments could provide season long control, but did not recommend it as part of a pest management system.

One of the few papers dealing specifically with economic threshold studies of greenbugs on grain sorghum was presented by Teetes and Johnson (1973). The authors concluded that their data were consistent with previously published findings and that they supported the established treatment guidelines for greenbug control on grain sorghum. The authors further concluded that no significant yield loss occurred until greenbug populations reached a level of 1300-1500/plant and killed more than three leaves/plant at the bloom stage. This conclusion appears to be inconsistent with the data presented in the same paper.
Teetes and Johnson (1974) tested early and medium-late maturity sorghum for the relative effects of greenbugs on plant damage and yield. Treatments were made on seven dates from June 12 through July 31. On the early maturity hybrid, treating at or before the boot stage with less than 428 greenbugs/plant resulted in significant yield differences ranging from 938-1326 lbs/acre (1052-1488 kg/ha) greater than the untreated check. Sorghum treated at the boot stage with 1706 greenbugs/plant outyielded the untreated check by 376-413 lbs/acre (422-463 kg/ha) but the differences were not significant. Teetes and Johnson concluded from this information that on early maturing hybrids, 1000 greenbugs/plant will result in a yield reduction. Yields of later maturing hybrid were significantly greater than the untreated check when it was treated at or before the boot stage. These differences ranged from 1262-4050 lbs/acre (1416-4544 kg/ha). Maximum yield increases were obtained by treating with 122 greenbugs/plant. Yields of sorghum treated with 3106 greenbugs/plant were less than that of plants treated with fewer greenbugs but were still greater than the untreated check. For both comparisons the differences were significant. The authors concluded that later maturing hybrids suffered significant yield reduction with 3000 greenbugs/plant, and observed that boot stage sorghum may be more sensitive to greenbug damage.

Harvey and Hackerott (1970) reported a 45% yield reduction when two-thirds of the leaves were lost in the milk stage due to greenbug feeding. This large reduction was in contrast to a much smaller (25%) yield reduction when leaves were mechanically removed at the same stage (Li and Liu 1935). Harvey and Hackerott suggested
that their studies may indicate that greenbug feeding affects the physiology of the plant. They also noted that it was economically justifiable to use insecticides to prevent the loss of one leaf in the whorl stage or several leaves on headed plants. Starks (1974) reported research indicating that mechanical damage did not completely explain greenbug injury. Testes and Johnson (1973) reported that the mechanical removal of two lower leaves did not affect yields. Their data also showed that only at preboot and bloom stages was yield reduced by removing four leaves.
MATERIALS AND METHODS

All fields involved in this study were located in Clay County, Nebraska and were farmed by cooperators in the Pest Management Project. Many of the field procedures were adapted from those used by the University of Nebraska Agronomy Department Outstate Testing Service.

The purpose of this study was to examine, under Nebraska conditions, the accuracy of the currently accepted guidelines for determining the necessity of greenbug control on grain sorghum. The control guidelines used in 1974 (Table 1) were adapted from Bottrell (1969).

Table 1. 1974 Nebraska Guidelines for treating greenbugs on grain sorghum (adapted from Bottrell[1969] ).

<table>
<thead>
<tr>
<th>Plant Growth Stage</th>
<th>When to Treat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergence to 6 inches</td>
<td>Visible yellowing with greenbugs on lower leaves.</td>
</tr>
<tr>
<td>6 inches to Preboot</td>
<td>Before any entire leaves are killed.</td>
</tr>
<tr>
<td>Preboot and Larger</td>
<td>When greenbug numbers are sufficient to cause loss of function of 3 or more lower leaves and parasitism is less than 20%.</td>
</tr>
</tbody>
</table>

In 1975 new treatment guidelines (Table 2) were developed by Keith, Peters, Roselle, and Monke.*

*Personal communication with David L. Keith, Leroy L. Peters and Robert Roselle, Sr., Department of Entomology, University of Nebraska, Lincoln, Nebraska.
Table 2. 1975 Nebraska Guidelines for Treating Greenbugs on Grain Sorghum.

<table>
<thead>
<tr>
<th>Plant Growth Stage</th>
<th>When to Treat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 6 inches tall</td>
<td>Greenbugs present; visible yellowing.</td>
</tr>
<tr>
<td>6 to 11 inches tall</td>
<td>When greenbugs average 50/plant.</td>
</tr>
<tr>
<td>12 inches to Preboot</td>
<td>When greenbugs average 100/plant.</td>
</tr>
<tr>
<td>Preboot</td>
<td>When greenbugs average 250/plant.</td>
</tr>
<tr>
<td>Boot, Bloom, and Soft Dough</td>
<td>When 1 large mature leaf has been killed and less than 20% of the greenbugs are parasitized.</td>
</tr>
</tbody>
</table>

Yield comparisons between sprayed and unsprayed sorghum were made in a large number of fields with widely varying levels of greenbug infestation. Most of these fields did not require treatment, according to published treatment guidelines. If controlling greenbugs at levels below the economic threshold resulted in yield increases or controlling greenbugs at the economic threshold did not increase yields, the guidelines were inadequate.

Determination of the need for greenbug control in pest management fields was made by the scout supervisor and county extension agent on the basis of the field scouting reports. Therefore, evaluation of the thresholds is based upon the daily scouting report. Approximately once a week, field scouts trained in pest identification and sampling methods surveyed each sorghum field for greenbug infestations, degree of plant damage, and plant growth stage. Time and temperature
were noted at each sampling and, early in the growing season, plant stand and row spacings were recorded. Two damage rating scales were used (Table 3) depending upon the date of observation.

Table 3. Rating scale used to determine degree of damage to grain sorghum by greenbugs. Clay County, Nebraska pest management project, 1974, 1975.

<table>
<thead>
<tr>
<th>Damage Rating</th>
<th>Degree of Damage</th>
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</thead>
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<tr>
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<td>Early Season (Before July 10)</td>
</tr>
<tr>
<td>1</td>
<td>no visible damage</td>
</tr>
<tr>
<td>2</td>
<td>leaf stippling or yellowing on most plants</td>
</tr>
<tr>
<td>3</td>
<td>dying leaf tips or edges</td>
</tr>
<tr>
<td>4</td>
<td>one dead leaf/plant</td>
</tr>
<tr>
<td>5</td>
<td>two dead leaves/plant</td>
</tr>
<tr>
<td>6</td>
<td>more than two dead leaves/plant</td>
</tr>
</tbody>
</table>

During the early part of the season (before July 10), 10 plants each at four locations were sampled in each field. After July 10, two plants each at five locations in the field were evaluated. After about July 10 greenbug populations usually become so large that the time necessary to count greenbugs on 40 plants is prohibitive. Each time a field was sampled, the field scout entered at a different site. The first sample in each field was taken 50 paces into the field from the margin and subsequent samples at intervals of 10 paces each
moving toward the center of the field.

Plant growth stages were designated differently in 1974 and 1975 (Table 4). Growth stages used in 1975 were taken from Vanderlip (1972).

Table 4. Ratings used to designate plant growth stages during 1974 and 1975. Clay County, Nebraska, pest management project.

<table>
<thead>
<tr>
<th>Growth Stage</th>
<th>1974</th>
<th>1975</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Emergence</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Seedling (less than 6&quot;)</td>
<td>Third leaf visible</td>
</tr>
<tr>
<td>2</td>
<td>Preboot</td>
<td>Fifth leaf visible</td>
</tr>
<tr>
<td>3</td>
<td>Boot</td>
<td>Growing point differentiation</td>
</tr>
<tr>
<td>4</td>
<td>Heading</td>
<td>Final leaf visible in whorls</td>
</tr>
<tr>
<td>5</td>
<td>Blooming (50% of plants)</td>
<td>Boot</td>
</tr>
<tr>
<td>6</td>
<td>Milk stage</td>
<td>Half bloom</td>
</tr>
<tr>
<td>7</td>
<td>Soft dough</td>
<td>Soft dough</td>
</tr>
<tr>
<td>8</td>
<td>Hard dough</td>
<td>Hard dough</td>
</tr>
<tr>
<td>9</td>
<td>Physiological maturity</td>
<td></td>
</tr>
</tbody>
</table>

Insecticide treatments in each field were either hand sprayed or made by ground or aerial application. Hand treated plots were paired with neighboring untreated check plots. Untreated check strips were left in fields treated by cooperating growers and aerially sprayed fields. In those fields with hand-sprayed treatments somewhat different field procedures were used in 1975 than in 1974.
1974 Procedures for Manual Insecticide Application and Harvesting of Yield Samples

Most of the fields in this study were selected by examining daily scouting reports. Early in the 1974 season some fields with infestations higher than average were selected. Fields with average and less than average greenbug infestations, according to daily scouting reports, were included so a broad range of situations could be studied in each sorghum growth stage. When a field was selected the cooperator was contacted for permission to work in his field and an explanation of the study was given.

Four single row plots, each 25 feet (7.62 m) long, were chosen haphazardly (as defined by Cochran [1963]) in each field. Location of plots within the field were noted on field forms (Appendix I). Each plot was also marked with 12 inch (30.5 cm) garden stakes. Locations of the untreated check plots were not designated until harvest. Dimethoate (Cygon 267) was applied with a 3 gal (11.4 liter) Hudson sprayer at the rate of approximately 12 oz (.36 liter) AI in 110 gal (416 liters) water per acre. The spray was directed into the whorl or top of the plant and onto the underside of leaves on both sides of the row. Each field was checked two days after spraying to determine the effectiveness of the insecticide treatment. At least 90% control was achieved in every field. Starting July 18 the average number of greenbugs from two plants at each treatment site was also recorded.

Harvest began September 11 and was completed September 25. Heads on all plants were removed from 20 feet (6.1 m) of row within the treated plots. Samples were not taken from plants on the ends of
plots because of the likelihood of their having been reinfested sooner than the remainder of the plot.

The corresponding untreated check sample of 20 feet (6.1 m) of row was taken five rows away from the treated sample. Because prevailing summer winds are from the south or west the untreated check was taken from either the south or west of the treated plot depending upon the direction of the rows. The untreated check samples were thus, taken up-wind of the treatment plots. Therefore, untreated checks were less likely to have been affected by insecticide drift. Compensation for gaps (missing plants) in the 20 feet (6.1 m) of row was made by sampling from plants in the remaining five feet (1.52 m) of row in the treated plots. This ensured that the sample was consistently 20 feet (6.1 m) of row. Grain heads were cut with a pruning shears and deposited in a burlap bag with a tag identifying the treatment, plot, and field number. All burlap bags were tied and transported to Lincoln, Nebraska for drying and storage in a forced air drying bin. Grain heads were threshed on a portable mechanical thresher. The grain was weighed and moisture content determined so that samples threshed on different dates could be adjusted to constant moisture for weight comparisons. Yield comparisons were made in grams per 20 feet (6.1 m) of row at zero percent moisture. Yields were later converted to pounds per acre and kilograms per hectare.

1975 Procedural Changes

In 1975 the experimental unit remained 25 feet (7.62 m) of row and was again replicated four times in each field. An additional
treatment using nicotine sulfate was included in an attempt to identify a possible stimulatory effect of the organo-phosphate insecticide, dimethoate, on yield. This was added because yield increases due to treatments at low greenbug populations were obtained in some fields in 1974. The nicotine sulfate treatment was discontinued because the percent control achieved was extremely low. However, at least 96% control was achieved with dimethoate in 1975.

In 1975 the untreated check plots were designated and marked at the time of treatment. Depending upon the wind direction at the time of spraying, the untreated plots were located in the fifth adjacent row or in the same row as the treated plot but separated by 10 feet (3.05 m). Wind direction determined the placement of the untreated check to minimize the possibility of spray drift. Greenbugs were counted on five plants in every untreated check and treatment plot before spraying. These counts were recorded on the field data form reproduced in Appendix II and the average of the counts transferred to the general field form (Appendix III).

Harvesting and threshing procedures were the same as 1974 except that the untreated check plot samples were taken from those designated at the time of treatment. Harvesting of the field plots began on September 9 and was completed on September 28.

Untreated Check Strips in Fields Treated by Commercial Applicators or by Growers

In some fields treated by ground or aerial application, large untreated areas or check strips, were left for later yield comparisons. Untreated areas varied from 6 to over 40 rows wide and usually
extended the length of the field. If the field was sprayed aerially, the untreated portion was left on the windward side of the field. Check strips left by farmers were usually not on the edge of the field. Insecticides used with this treatment technique were either disulfoton concentrate, disulfoton granules, phorate granules, parathion, or dimethoate. The applicators later reported the location of the check strip. Two days after treatment the location was confirmed and the extent of greenbug control determined. At harvest, four untreated check samples were haphazardly selected from within the check strip and in the remainder of the field four 20 foot (6.1 m) samples were chosen for the treated plots. Because of the haphazard sampling procedures no attempt was made to sample for paired comparisons by choosing corresponding treated and untreated check samples from the same vicinity. The same procedures were used for both 1974 and 1975 in those fields with check strips.
RESULTS AND DISCUSSION

There were 10,576 acres (4283 ha) of grain sorghum, farmed by 106 growers, in the pest management program during 1973. In 1974 the total acreage of grain sorghum in the program was increased to 13,398 acres (5426 ha), representing 111 growers. In 1975, 105 cooperators committed 11,173 acres (4525 ha) to the pest management program. During the 1973 and 1974 growing seasons fields were scouted a total of 2196 and 3036 times, respectively. In 1975, however, only 1351 field surveys were performed. Because so many fields were treated or had been recommended for greenbug control no fields were scouted from July 24 through August 5 in 1975.

Figures 1, 2, and 3 demonstrate the development of greenbug populations during the three growing seasons, 1973-1975. Points on the graphs represent the daily average number of greenbugs per plant for all fields scouted during the growing seasons. Also depicted on each graph is the percent of the greenbug population parasitized and killed by the braconid wasp, Lysiphlebus testaceipes (Cress). The parasite population lags behind the greenbug population and chemical controls are often necessary because greenbugs become economically damaging before the parasites bring them under control. In previous years (1968-1973), natural control of the greenbugs by the parasites was generally achieved by August 10, as indicated by the graph (1973) in Figure 1. However, in 1974 (Figure 2) by August 10 the percent of parasitism was still well below 5%. The greenbug population remained exceedingly high, averaging over 500/plant. Although unconfirmed in the Clay County area, it was believed that hyperparasites were
Figure 1. Daily means of greenbugs per plant, corresponding population curve, and percent parasitism of greenbugs by *L. testaceipes* during the 1973 growing season in the grain sorghum fields of the Clay County, Nebraska pest management project.
Figure 2. Daily means of greenbugs per plant, corresponding population curve, and percent parasitism of greenbugs by *L. testaceipes* during the 1974 growing season in the grain sorghum fields of the Clay County, Nebraska pest management project.
Figure 3. Daily means of greenbugs per plant, corresponding population curve, and percent parasitism of greenbugs by L. testaceipes during the 1975 growing season in the grain sorghum fields of the Clay County, Nebraska pest management project.
PERCENT PARASITISM

GREENBUGS/PLANT

PERCENT PARASITISM
preventing *L. testaceipes* from controlling the greenbug populations. Heavy hyperparasitism of *L. testaceipes* was observed in northeastern Kansas in 1974 (Brooks and Gates 1975).

During the 1974 and 1975 growing seasons weather conditions were vastly different. In 1974, hot dry winds severely stressed all crops, especially those grown on dryland. An early frost further limited the yields of crops whose normal development and maturity was delayed by drought conditions. During the 1975 growing season, moisture was adequate and temperatures more moderate. A relative measure of the amount of moisture stress on sorghum in 1974 and 1975 in Clay County is given in Table 5 (U.S. Department of Commerce 1974, 1975). This table shows the evaporation indices and amounts of precipitation received for the months of June through September.

Table 5. Monthly precipitation and evaporation index for June through September, 1974 and 1975, 5 miles west of Clay Center, Nebraska.

<table>
<thead>
<tr>
<th></th>
<th>Precipitation*</th>
<th>Evaporation Index*</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>2.20 (5.59)</td>
<td>6.29 (15.98)</td>
</tr>
<tr>
<td>July</td>
<td>0.68 (1.73)</td>
<td>4.75 (12.07)</td>
</tr>
<tr>
<td>August</td>
<td>1.75 (4.45)</td>
<td>1.05 (2.67)</td>
</tr>
<tr>
<td>September</td>
<td>0.31 (0.79)</td>
<td>0.81 (2.06)</td>
</tr>
<tr>
<td>Total</td>
<td>4.94 (12.56)</td>
<td>12.90 (32.78)</td>
</tr>
</tbody>
</table>

* inches of water (cm of water)

Measurements were taken five miles (8.05 km) west of Clay Center, Nebraska. The evaporation index represents the amount of water evaporated from a pan four feet (1.22 m) in diameter during a 24 hour
period. The index is indicative of the evapotranspiration stress experienced by growing plants. A comparison of the daily evaporation index during 1974 and 1975 is portrayed graphically in Figure 4. Graphs of the daily minimum and maximum temperatures from June through September for 1974 and 1975 are given in Figures 5 and 6, respectively. Individual daily temperatures, as well as the overall seasonal curves, are noted.

Numbers of cooperators and fields involved in this study during 1974 and 1975 are listed in Table 6.

Table 6. Numbers of cooperators and fields involved in evaluation of greenbug control guidelines for grain sorghum in the Clay County, Nebraska pest management project during 1974 and 1975.

<table>
<thead>
<tr>
<th></th>
<th>1974</th>
<th>1975</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperators</td>
<td>50</td>
<td>47</td>
<td>75</td>
</tr>
<tr>
<td>Total Number of fields in which treatment plots were established</td>
<td>105</td>
<td>99</td>
<td>204</td>
</tr>
<tr>
<td>Dryland fields used in evaluation analyses</td>
<td>50</td>
<td>59</td>
<td>100</td>
</tr>
<tr>
<td>Irrigated fields used in evaluation analyses</td>
<td>22</td>
<td>19</td>
<td>41</td>
</tr>
<tr>
<td>Total Number of fields used in evaluation analyses</td>
<td>72</td>
<td>69</td>
<td>141</td>
</tr>
</tbody>
</table>

Some growers were involved in the study only one year whereas others cooperated both years. The total number of participants was 75. A field involved in the study both years was regarded as two separate fields. Although work was done in a total of 204 fields, only 141 were useable in the final analysis. It was necessary to disregard several fields because after plots were established the entire field
Figure 4. A graphical representation of the amount of water in inches evaporating from a pan 4 feet (1.22 m) in diameter, 5 miles (8.02 km) west of Clay Center, Nebraska, during June through September 1974 and 1975.
Figure 5. A graphical comparison of the 1974 and 1975 minimum daily temperatures for June through September, 5 miles (8.02 km) west of Clay Center, Nebraska; daily temperatures and seasonal curves.
Figure 6. A graphical comparison to the 1974 and 1975 maximum daily temperatures for June through September, 5 miles (8.02 km) west of Clay Center, Nebraska; daily temperatures and seasonal curves.
was sprayed, thus negating the effects of the untreated check for the original treatment. Other fields could not be used because they were harvested before yield samples were removed, treated plots could not be located, or obvious differences in soil type or plant varieties would have confounded yield comparisons. Data from dryland and irrigated fields were analyzed separately to determine if there were differences in the responses to greenbug control.

For the purpose of this evaluation, an increase in yield of 200 lbs/acre (224 kg/ha) was considered necessary to recover the cost of treatment. The actual cost to the producer for treating grain sorghum was approximately $3.00 to $4.50/acre ($7.41 to $11.12/ha) whereas the value of 200 lbs (90.9 kg) of sorghum grain ranged from approximately $8.00 to $11.00. The 200 lb (90.9 kg) "break even" figure is purposely conservative. The actual cost of an insecticide treatment can be more than the dollar value of the material and its application. Non-measurable but potentially economic factors, such as pest resurgence, the development of secondary pests, and the hazards of pesticide usage, are often the results of insecticide applications. In consideration of some of these factors, 200 lbs/acre (224 kg/ha) may not be enough. It is also possible that a difference of 200 lbs/acre (224 kg/ha) would not be detectable by a farmer in the field and thus, any recommendations that provided such a meager yield increase would not be necessary.

Table 7 is a summary of the simple statistics of the 141 fields studied, separated by years and irrigation. From this information the success of chemical applications and project recommendations for greenbug control can be measured. The data for this study will first be
Table 7. A tabulation of yield responses to insecticide treatment in irrigated and dryland sorghum in the evaluation of greenbug treatment guidelines. Clay County, Nebraska pest management project, 1974 and 1975.

<table>
<thead>
<tr>
<th></th>
<th>1974</th>
<th></th>
<th>1975</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irrigated</td>
<td>Dryland</td>
<td>Irrigated</td>
<td>Dryland</td>
</tr>
<tr>
<td>Total number of fields</td>
<td>22</td>
<td>50</td>
<td>19</td>
<td>50</td>
</tr>
<tr>
<td>Fields with treated mean yields greater than untreated check mean</td>
<td>17</td>
<td>44</td>
<td>16</td>
<td>35</td>
</tr>
<tr>
<td>Fields with treated mean yields greater than untreated check mean by 200 lbs/acre (224 kg/ha)</td>
<td>17</td>
<td>39</td>
<td>12</td>
<td>28</td>
</tr>
<tr>
<td>Fields in which treated mean yields were significantly different from untreated check mean at .05 level</td>
<td>9</td>
<td>8</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Fields in which untreated check mean yield significantly greater than treated mean at .05 level</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Number of fields recommended for treatment</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>Recommended fields in which treated mean yield was greater than untreated check</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>17</td>
</tr>
</tbody>
</table>
Table 7 (continued). A tabulation of yield responses to insecticide treatment in irrigated and dryland sorghum in the evaluation of greenbug treatment guidelines. Clay County, Nebraska pest management project, 1974 and 1975.

<table>
<thead>
<tr>
<th></th>
<th>1974</th>
<th></th>
<th>1975</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irrigated</td>
<td>Dryland</td>
<td>Irrigated</td>
</tr>
<tr>
<td>Recommended fields in which treated mean yield was greater than untreated check by 200 lbs/acre (224 kg/ha)</td>
<td>2</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Recommended fields in which treated mean yield was significantly greater than untreated check at .05 level</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Percent of fields in which treated mean outyielded untreated check by 200 lbs/acre (224 kg/ha) that were recommended for treatment</td>
<td>12%</td>
<td>10%</td>
<td>42%</td>
</tr>
<tr>
<td>Average yield increase treated over untreated check</td>
<td>702 lbs/acre (788 kg/ha)</td>
<td>507 lbs/acre (569 kg/ha)</td>
<td>562 lbs/acre (631 kg/ha)</td>
</tr>
<tr>
<td>Range of treated mean minus control mean</td>
<td>-900 to 220</td>
<td>-408 to 1825</td>
<td>-326 to 1585</td>
</tr>
<tr>
<td></td>
<td>1 lbs/acre</td>
<td>1 lbs/acre</td>
<td>1 lbs/acre</td>
</tr>
<tr>
<td></td>
<td>(-1010 to 2173)</td>
<td>(-458 to 2048)</td>
<td>(-366 to 1778)</td>
</tr>
<tr>
<td></td>
<td>kg/ha)</td>
<td>kg/ha)</td>
<td>kg/ha)</td>
</tr>
</tbody>
</table>
discussed separately by years. In later sections the data will be combined and an attempt will be made to interpret any differences or similarities between the years.

**Discussion of 1974 Data**

In 61 of the 72 fields evaluated the treated sorghum outyielded the untreated checks. The average difference was greater than 200 lbs/acre (224 kg/ha) in 56 (92%) of those fields. In 17 (28%) of the 61 fields in which the treated mean outyielded the untreated check the difference was statistically significant at the .05 probability level with Student's t-test.

A total of 80 fields in the pest management program were recommended for treatment to control greenbugs. This represented 3147 acres (1246 ha) or 24% of the sorghum acreage in the program. Of the 72 fields involved in this study only 9 were recommended for treatment to control greenbugs. Recommendations were based on the guidelines in Table 1. The treated sorghum outyielded the untreated check by 200 lbs or more per acre (224 kg/ha) in six of the nine fields recommended for treatment, and in only one of these was the difference statistically significant at the .05 level. Of the 56 fields in this study in which treated sorghum outyielded the untreated checks by 200 lbs/acre (224 kg/ha), only 6, or 11% were recommended for treatment.

For both irrigated and dryland sorghum the average yield increase due to insecticide treatment for greenbugs in 1974 was 567 lbs/acre (636 kg/ha). Greenbug control resulted in a more dramatic response in the irrigated sorghum. This response may have been due to the
extreme stress upon the dryland sorghum and the greater yield potential of the irrigated sorghum. This difference in yield response of irrigated and dryland sorghum to greenbug control has not been previously noted in the literature.

The average yields of the treated and untreated sorghum are found in Table 8.

Table 8. Mean yields*** of treated and untreated checks in irrigated and dryland sorghum in the evaluation of treatment guidelines for controlling greenbugs. Clay County, Nebraska pest management project, 1974 and 1975.

<table>
<thead>
<tr>
<th></th>
<th>Treated Mean lbs/acre (kg/ha)</th>
<th>Untreated Check Mean lbs/acre (kg/ha)</th>
<th>Yield Difference lbs/acre (kg/ha)</th>
<th>Number of Fields (Replications)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dryland</td>
<td>2435 (2731)</td>
<td>1930 (2165)</td>
<td>505 (567)**</td>
<td>50</td>
</tr>
<tr>
<td>Irrigated</td>
<td>3745 (4202)</td>
<td>3043 (3414)</td>
<td>702 (788)**</td>
<td>22</td>
</tr>
<tr>
<td>1975</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dryland</td>
<td>4018 (4508)</td>
<td>3629 (4072)</td>
<td>389 (436)*</td>
<td>50</td>
</tr>
<tr>
<td>Irrigated</td>
<td>5399 (6058)</td>
<td>4837 (5427)</td>
<td>562 (631)**</td>
<td>19</td>
</tr>
</tbody>
</table>

***0.0% moisture
*significant at .05
**significant at .01

Yields in pounds per acre (kg/ha) are presented at 0.0% moisture. The field means of the treated sorghum exceeded the untreated check means in both irrigated and dryland fields. In both situations the overall average differences were significant at the .01 level by analysis of covariance. The number of grain heads per sample plot was used as the
covariate, and all yields were adjusted to a constant number of heads for comparison.

A more detailed evaluation of the 1974 fields is found in Table 9 where the data were considered on the basis of growth stages.

Table 9. Yield results and field data on the basis of growth stage at the time of treatment for all fields used in 1974 for the evaluation of treatment guidelines for greenbugs on grain sorghum. Clay County, Nebraska pest management project.

<table>
<thead>
<tr>
<th>Growth Stage</th>
<th>No. of fields</th>
<th>Avg no. of greenbugs/ plant at treatment</th>
<th>No. of fields with mean of treated greater than untreated check by 200 lbs/acre (224 kg/ha)</th>
<th>Mean of treated greater than untreated check lbs/acre (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Seedling</td>
<td>48</td>
<td>161</td>
<td>15</td>
<td>452 (507)</td>
</tr>
<tr>
<td>2 Preboot</td>
<td>17</td>
<td>475</td>
<td>15</td>
<td>861 (966)</td>
</tr>
<tr>
<td>3 Boot</td>
<td>5</td>
<td>814</td>
<td>5</td>
<td>705 (791)</td>
</tr>
<tr>
<td>4 Heading</td>
<td>2</td>
<td>888</td>
<td>1</td>
<td>463 (519)</td>
</tr>
<tr>
<td>5 Blooming</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Milk Stage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Soft Dough</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Hard Dough</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Maturity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There were 12 irrigated fields treated at the preboot stage (Table 4) with an average of 123 greenbugs/plant. The yields in the treated portion of these 12 fields averaged 602 lbs/acre (675 kg/ha) greater than the untreated check. The treated plots outyielded the untreated check by 990 lbs/acre (1111 kg/ha) in nine irrigated fields in which greenbugs were controlled in the boot stage with 519 greenbugs/plant.
In 36 dryland fields treated in the preboot stage with an average of 173 greenbugs/plant the treated sorghum outyielded the untreated check by 399 lbs/acre (448 kg/ha). There were 8 fields treated in the boot stage with an average of 427 greenbugs/plant. The yield of the treated sorghum averaged 717 lbs/acre (804 kg/ha) more than the untreated check. The treated sorghum outyielded the untreated check by 705 lbs/acre (791 kg/ha) in 5 fields treated in growth stage four with an average of 814 greenbugs/plant. One irrigated and one dryland field were treated in growth stage five with 1450 and 325 greenbugs/plant, respectively. In the irrigated field the untreated check outyielded the treated sorghum by an average of 900 lbs/acre (1010 kg/ha), but in the dryland field the yield was 1825 lbs/acre (2048 kg/ha) less in the untreated check.

There were 66 fields during 1974 in which the treatments were hand sprayed and thus, paired comparisons could be made between the individual treated plots and their corresponding untreated checks. In Table 10 these fields have been grouped on the basis of the average number of greenbugs per plant at the time of treatment. An analysis of variance was performed on the data from fields in each category comparing the yields of the treated and untreated plots. The categories were 0-100, 101-500, 501-1000, and more than 1000 greenbugs/plant at the time of treatment. Variation due to differences between fields was accounted for in the analysis of variance.

Treating sorghum with less than 100 greenbugs/plant in the irrigated fields resulted in a yield that was less than 200 lbs/acre (224 kg/ha) greater than the untreated check. The difference was not significant at the .05 level. Treating sorghum with over 1000 greenbugs/
Table 10. A tabular summary of statistical analyses of sorghum yields in treated and untreated plots at various levels of greenbug infestation. Clay County, Nebraska pest management project, 1974 and 1975.

<table>
<thead>
<tr>
<th>Categories of greenbug numbers/plant at treatment</th>
<th>Yield increase over untreated check lbs/acre (kg/ha)</th>
<th>ANOVA F-test</th>
<th>Replications</th>
<th>Number of fields</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1974 Irrigated:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-100</td>
<td>143 (160)</td>
<td>NS</td>
<td>30</td>
<td>8,</td>
</tr>
<tr>
<td>101-500</td>
<td>1213 (1361)</td>
<td>**</td>
<td>32</td>
<td>8,</td>
</tr>
<tr>
<td>501-1000</td>
<td>976 (1095)</td>
<td>*</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>over 1000</td>
<td>1493 (553)</td>
<td>NS</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td><strong>Dryland:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-100</td>
<td>344 (386)</td>
<td>**</td>
<td>74</td>
<td>19</td>
</tr>
<tr>
<td>101-500</td>
<td>632 (709)</td>
<td>**</td>
<td>79</td>
<td>20</td>
</tr>
<tr>
<td>501-1000</td>
<td>712 (799)</td>
<td>**</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>over 1000</td>
<td>544 (610)</td>
<td>NS</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td><strong>1975 Irrigated:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-100</td>
<td>470 (527)</td>
<td>*</td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td>101-500</td>
<td>245 (275)</td>
<td>NS</td>
<td>18</td>
<td>5</td>
</tr>
<tr>
<td><strong>Dryland:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-100</td>
<td>217 (243)</td>
<td>*</td>
<td>75</td>
<td>21</td>
</tr>
<tr>
<td>101-500</td>
<td>312 (350)</td>
<td>*</td>
<td>56</td>
<td>14</td>
</tr>
<tr>
<td>501-1000</td>
<td>697 (782)</td>
<td>NS</td>
<td>8</td>
<td>2</td>
</tr>
</tbody>
</table>
Table 10 (continued). A tabular summary of statistical analyses of sorghum yields in treated and untreated plots at various levels of greenbug infestation. Clay County, Nebraska pest management project, 1974 and 1975.

1 NS - Not significant

2* - Significant at .05 probability level

3** - Significant at .01 probability level
plant resulted in a yield that was 493 lbs/acre (553 kg/ha) greater than the untreated check, which would more than pay for the treatment, but the difference was not significant. Since this high level of infestation occurred in only one field there were only four replications of the treatment. The coefficient of variation was 48%. This degree of variation would have required a difference of 2659 lbs/acre (2983 kg/ha) for treatment means to be significantly different at the .05 level, 90% of the time, on the basis of four replications (Cochran and Cox 1957).

Yield differences of treated dryland sorghum were significantly different from the corresponding untreated checks at the .01 probability level in all categories through 1000 greenbugs/plant. In the two fields treated with over 1000 greenbugs/plant a difference of 544 lbs/acre (610 kg/ha) was not significant. With a coefficient of variation of 58% and only 8 replications, as in the category of over 1000 greenbugs/plant, a difference of 1317 lbs/acre (1478 kg/ha) is necessary to be significant at the .05 level.

Whether evaluating mean yield differences on the basis of growth stages or greenbugs per plant at the time of treatment it is apparent that the irrigated sorghum responded to the insecticide treatment more dramatically. In dryland sorghum, however, the yield response to greenbug control was much more consistent, with significant differences resulting even when less than 100 greenbugs per plant were controlled. The two dryland fields treated with more than 1000 greenbugs/plant with nonsignificant yield differences were in the heading and bloom growth stages at the time of treatment. Nonsignificance could be due to insufficient replication or to the possibility that at these late
developmental stages the damage may have already been done and the sorghum was past the critical stage when removing greenbugs could improve yield potential. The response of the nonirrigated sorghum to treatment may be attributed to the severe drought conditions. Controlling greenbugs removed a stress factor, perhaps giving the plants the opportunity to compensate somewhat for moisture stress when the greenbug pressure was removed.

Results in irrigated fields may provide a picture more indicative of the effects of greenbug control. At low infestation levels, below 100 greenbugs/plant, the plants were able to withstand greenbug damage and because of an adequate moisture supply, compensate for greenbug feeding. The irrigated sorghum also had a greater yield potential because of adequate moisture and thus produced more grain in the absence of both greenbugs and moisture stress.

Discussion of 1975 Data

Different treatment guidelines were used during 1975 (Table 2) and many more pest management fields were recommended for treatment during the second year of this study. A total of 5744 acres (2326 ha), or 51% of the acreage in the program, were recommended for greenbug control in 1975. More fields were recommended for greenbug control during 1975 than 1974 despite the fact that the peak greenbug population was lower in 1975 and persisted at the maximum level for a much shorter period of time (Figures 2 and 3).

Yield comparisons were evaluated with analysis of covariance, using the number of heads per plot as the covariate. In both irrigated and dryland fields the treated sorghum outyielded the control
by differences that were significant at the .05 level (Table 8). The average increase in yield due to treating both irrigated and dryland sorghum was 427 lbs/acre (479 kg/ha).

It is difficult to compare results of the two years on the basis of growth stage because different growth stage scales were used each year (Table 4). On the 1975 scale, the combined stages 0, 1, and 2 are equivalent to the stage 1 on the 1974 scale. Stages 3 and 4 are also combined and equivalent to the preboot stage of the 1974 scale. The 1974 stage 3 is the same as stage 5 on the 1975 scale. The 1975 fields were evaluated on the basis of growth stages converted to the 1974 scale (Table 11).

In 1975 there were a total of 9 fields treated in the seedling stage. The irrigated and dryland fields averaged 3 and 10 greenbugs/plant, respectively, and the average increase in yield over the untreated check was less than 35 lbs/acre (39 kg/ha). There were 11 irrigated fields treated in the preboot stage with an average of 179 greenbugs/plant. The average yield in the treated sorghum was 612 lbs/acre (587 kg/ha) greater than the untreated check, only 10 pounds (4.54 kg) different from the 1974 results. With an average of 467 greenbugs/plant in five irrigated fields treated in the boot stage the treated sorghum outyielded the untreated check by 748 lbs/acre (839 kg/ha). There was a total of four irrigated and dryland fields treated in the soft dough stage. With approximately 300 greenbugs/plant, the untreated check plots outyielded the treated sorghum by 90 lbs/acre (101 kg/ha) in the four fields.

There were 25 dryland fields treated in growth stage two with an average of 169 greenbugs/plant. The treated sorghum outyielded the
Table 11. Yield results and field data on the basis of the growth stage at the time of treatment for irrigated and dryland fields used in 1975 for the evaluation of treatment guidelines for greenbugs on grain sorghum. Clay County, Nebraska pest management program. 1975 growth stages adjusted to 1974 scale.

<table>
<thead>
<tr>
<th>Growth Stage</th>
<th>No. of fields</th>
<th>Avg no. of greenbugs/plant at treatment</th>
<th>No. of fields that treated avg outyielded untreated check by 200 lbs/acre (224 kg/ha)</th>
<th>Treated avg outyielded untreated check lbs/acre (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Seedling</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>26 (29)</td>
</tr>
<tr>
<td>2 Preboot</td>
<td>11</td>
<td>179</td>
<td>8</td>
<td>612 (687)</td>
</tr>
<tr>
<td>3 Boot</td>
<td>5</td>
<td>467</td>
<td>4</td>
<td>748 (838)</td>
</tr>
<tr>
<td>4 Heading</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Bloom</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Silk stage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Soft dough</td>
<td>1</td>
<td>195</td>
<td>0</td>
<td>194 (218)</td>
</tr>
<tr>
<td>8 Hard dough</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Maturity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dryland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Seedling</td>
<td>7</td>
<td>10</td>
<td>3</td>
<td>34 (38)</td>
</tr>
<tr>
<td>2 Preboot</td>
<td>25</td>
<td>169</td>
<td>14</td>
<td>453 (508)</td>
</tr>
<tr>
<td>3 Boot</td>
<td>13</td>
<td>406</td>
<td>9</td>
<td>526 (590)</td>
</tr>
<tr>
<td>4 Heading</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Bloom</td>
<td>2</td>
<td>315</td>
<td>1</td>
<td>307 (344)</td>
</tr>
<tr>
<td>6 Silk stage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Soft dough</td>
<td>3</td>
<td>340</td>
<td>1</td>
<td>-184 (-206)</td>
</tr>
<tr>
<td>8 Hard dough</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Maturity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
untreated check by 453 lbs/acre (508 kg/ha). The average yield was 526 lbs/acre (590 kg/ha) greater than the untreated check in 13 dryland fields treated with an average of 406 greenbugs/plant in the boot stage. When 315 greenbugs/plant were controlled in two dryland fields treated in the bloom stage, the average yield difference was 307 lbs/acre (344 kg/ha) greater in the treated sorghum.

There were 46 fields in 1975 with hand-sprayed plots, from which 178 paired comparisons were made. The yield results were evaluated by analysis of variance on the basis of the numbers of greenbugs per plant at the time of treatment (Table 10). In six irrigated fields treated when greenbugs numbered 100 or fewer per plant the untreated check plots averaged 470 lbs less per acre (527 kg/ha), a difference significant at the .05 level. A yield increase of 245 lbs/acre (275 kg/ha) in the treated sorghum was not significantly different from the untreated check in five fields treated with an average of 101-500 greenbugs/plant. There were 18 pairs of treated and untreated plots in the above analysis which would have required an average yield difference of 393 lbs/acre (441 kg/ha) to obtain 90% confidence of being significantly different at the .05 probability level (Cochran and Cox 1957).

Analysis of variance of 75 replications representing 21 dryland fields treated during 1975 with less than 100 greenbugs/plant resulted in a 217 lbs/acre (243 kg/ha) increase in yield over the untreated check that was significantly different. In 14 dryland fields treated with 101-500 greenbugs/plant treated sorghum outyielded the untreated check by 312 lbs/acre (350 kg/ha), a difference statistically significant at the .05 level. However, a yield difference of 697 lbs/acre
was not statistically significant for treated sorghum outyielding the untreated in eight replications in two fields with over 500 greenbugs/plant. Because of too few replications and a high coefficient of variation, a difference of 743 lbs/acre (834 kg/ha) is required for statistical significance at the .05 probability level, 90% of the time (Cochran and Cox 1957).

Comparisons of 1974 and 1975 Results

The yield increases due to treating may have been less in the 1975 dryland sorghum than in 1974 because with adequate moisture the plants were not under as much stress and the control plants were able to compensate for some of the greenbug feeding pressure. The difference in the yield response to treating irrigated sorghum cannot be explained as easily. In 1974 irrigated fields the treated sorghum outyielded the untreated check by approximately 150 lbs/acre (168 kg/ha) more than in the 1975 irrigated fields. Maturity of greenbug-damaged sorghum appeared delayed and an early frost in 1974 on September 3 curtailed growth and maturation of plants. Therefore, grain sorghum was not able to catch up or compensate for lost yield after that date. Under stress from drought and greenbugs the development of sorghum plants was halted or severely limited. Thus, when growth was halted by frost, the treated plants, whose development had proceeded uninterrupted by greenbug feeding, were able to produce grain. In 1975, growth of the sorghum in greenbug-infested, untreated check plots was not curtailed by early frost and was able to develop to full physiological maturity with the treated sorghum. Also, the larger and more persistent greenbug population in 1974 may be reflected in the more dramatic yield response to greenbug control in
that year.

In 1975 only 51 or 74% (Table 7) of the fields in the study yielded more in the treated plots, compared to 85% in 1974. Again, this could be attributed to the premature cessation of growth in the untreated check plots due to the early frost in 1974. In 1975 treated sorghum outyielded the untreated check by 200 lbs or more per acre (224 kg/ha) in 58% of the fields compared to 78% in 1974. Of the 51 fields in which the treatment outyielded the untreated check in 1975 the difference was significant at the .05 level in 16%. In 1974 the yield increase due to treatment was significant in 28% of the fields in which the treated sorghum outyielded the untreated check.

Greenbug control was recommended in 30 out of 69 fields in the 1975 study. This increase was due primarily to the modified guidelines for determining when greenbug infested sorghum should be treated. The 1974 greenbug population rose to higher numbers and remained there longer than in 1975, a situation which should have precipitated a higher frequency of treatment. The percentage of 1974 field scouting reports that fell within the 1975 treatment guidelines was 26% compared to 6.6% of the 1975 scouting reports that required treatment. Of the 30 fields recommended for treatment during 1975 the treated sorghum outyielded the untreated in 23 or 77%. Treatment yields averaged at least 200 lbs/acre (224 kg/ha) more than the untreated check in 60% of the recommended fields. This compares favorably with the 66% of the 1974 fields recommended for treatment in which the treated sorghum outyielded the untreated check by over 200 lbs/acre (224 kg/ha). The difference was significant in 23% of the 1975 fields recommended for treatment. The improvement in the 1975 treatment
recommendations is apparent when it is seen that of the 40 fields with at least a 200 lbs/acre (224 kg/ha) increase over the untreated check, 18 of them or 45%, were recommended for treatment. Therefore, the 1975 treatment recommendations were still inadequate, but with the new treatment guidelines, improved over 1974. In 1975, 55% of the fields that should have been treated were not recommended for treatment whereas in 1974, 89% of the fields that resulted in a yield increase of 200 pounds or more per acre (224 kg/ha) were not recommended.

A close evaluation of the fields in this study at the time of treatment revealed that for both years many of the fields recommended for treatment did not conform to the guidelines in use. In 1974 none of the nine fields that were recommended for treatment in this study required it according to the guidelines. There were, however, two dryland fields which should have been but were not recommended for treatment. Treatment plots outyielded the untreated check plots in these two fields by an average of 455 lbs/acre (511 kg/ha). This re-evaluation indicates that the guidelines used in 1974 were even poorer than first suspected (Table 12). Of the 17 irrigated fields in which the treated sorghum outyielded the untreated check by 200 pounds or more per acre (224 kg/ha) none of them displayed damage extensive enough to require treatment. Of 39 dryland fields in which the treated sorghum outyielded the untreated check by over 200 lbs/acre (224 kg/ha), only two or 5% required treatment according to the 1974 guidelines.

Only 18 of the 30 fields recommended for treatment in 1975 actually required it by the revised guidelines used that year. In
addition, there were two dryland fields that should have been recommended for treatment but were not. Of the 12 irrigated fields in which the untreated checks averaged over 200 lbs/acre (224 kg/ha) less than the treated plots, only 4 or 33% should have been recommended for treatment by the revised guidelines. In the five irrigated fields that were in accordance with the treatment guidelines, the treated sorghum outyielded the untreated by an average of 711 lbs/acre (798 kg/ha).

Table 12. The number of fields in the 1974 and 1975 evaluation of greenbug treatment guidelines in the Clay County, Nebraska pest management project that met the guidelines at the time of treatment and resulted in a yield increase of at least 200 lbs/acre (224 kg/ha) as a result of controlling greenbugs.

<table>
<thead>
<tr>
<th></th>
<th>1974</th>
<th></th>
<th>1975</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irrigated</td>
<td>Dryland</td>
<td>Irrigated</td>
<td>Dryland</td>
</tr>
<tr>
<td>No. of fields</td>
<td>22</td>
<td>50</td>
<td>19</td>
<td>50</td>
</tr>
<tr>
<td>No. of fields recommended for treatment</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>No. of fields in which treated mean outyielded untreated by 200 lbs/acre (224 kg/ha)</td>
<td>17</td>
<td>39</td>
<td>12</td>
<td>28</td>
</tr>
<tr>
<td>No. of fields in which treated mean outyielded untreated by 200 lbs/acre (224 kg/ha) and met current treatment guidelines</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

There were 13 dryland fields out of 23 recommended for treatment in which the infestations and damage actually fit the 1975 guidelines,
plus two more that should have been recommended. In only 6 of these 15 did the treated sorghum outyield the untreated check by 200 pounds or more per acre (224 kg/ha). Only 21% of the 28 dryland fields in which the treated sorghum outyielded the untreated check by 200 lbs/acre (224 kg/ha) sustained greenbug populations or damage extensive enough to warrant treatment by the 1975 guidelines.

An evaluation of all the field scouting forms in 1974 and 1975 and the greenbug situations in the fields recommended for treatment revealed that guidelines were not strictly followed in either year, to the benefit of the producers. Table 13 lists the total times that fields were scouted, and whether or not the fields met the criteria for treatment according to field scouting reports and treatment guidelines.

Of the 73 fields recommended for treatment in 1974 only 19 actually required treatment according to the guidelines in Table 1. The remaining 54 fields had not reached the economic threshold. An additional 97 field reports should have prompted recommendation for treatment, according to 1974 guidelines. However, some of those 97 scouting reports were duplications of fields that met the treatment criteria more than once when they were scouted and others were from fields that had been previously recommended for treatment and the recommendation was not made again. There were a total of 42 fields that met the treatment guidelines but were not recommended for treatment. However, this may be an inaccurate evaluation of how closely the guidelines were followed. Many of the fields were rechecked and it was determined subjectively that treatment was not justified. The primary criterion for determining the need for green-
Table 13. Summary of field scouting reports and fields that were recommended for treatment or met criteria of 1974 and 1975 treatment guidelines in the Clay County, Nebraska pest management project.

**1974:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of field scouting reports</td>
<td>3036</td>
</tr>
<tr>
<td>Number of fields recommended for treatment</td>
<td>73</td>
</tr>
<tr>
<td>Number of fields recommended for treatment that met 1974 guidelines</td>
<td>19</td>
</tr>
<tr>
<td>Number of fields recommended for treatment that did not meet 1974 guidelines</td>
<td>54</td>
</tr>
<tr>
<td>Number of field scouting reports with survey data that met 1974 treatment guidelines but did not result in a treatment recommendation being given</td>
<td>54</td>
</tr>
<tr>
<td>Number of fields that met 1974 treatment guidelines but were not at any time recommended for treatment</td>
<td>42</td>
</tr>
<tr>
<td>Total number of field scouting reports with survey data that met 1974 treatment guidelines</td>
<td>118</td>
</tr>
<tr>
<td>Total number of fields that at sometime during the growing season met the 1974 treatment guidelines</td>
<td>61</td>
</tr>
<tr>
<td>Number of field scouting reports that met the 1975 treatment guidelines</td>
<td>776</td>
</tr>
<tr>
<td>Number of fields that met 1975 treatment guidelines</td>
<td>248</td>
</tr>
</tbody>
</table>

**1975:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of field scouting reports</td>
<td>1356</td>
</tr>
<tr>
<td>Number of fields recommended for treatment</td>
<td>140</td>
</tr>
<tr>
<td>Number of fields recommended for treatment that met 1975 treatment guidelines</td>
<td>69</td>
</tr>
<tr>
<td>Number of fields recommended for treatment that did not meet 1975 treatment guidelines</td>
<td>71</td>
</tr>
<tr>
<td>Number of field scouting reports with survey data that met 1975 treatment guidelines but did not result in a treatment recommendation being given</td>
<td>16</td>
</tr>
</tbody>
</table>
Table 13 (Continued). Summary of field scouting reports and fields that were recommended for treatment or met criteria of 1974 and 1975 treatment guidelines in the Clay County, Nebraska pest management project.

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of fields that met 1975 treatment guidelines but were not at any time recommended for treatment</td>
<td>7</td>
</tr>
<tr>
<td>Total number of field scouting reports with survey data that met 1975 treatment guidelines</td>
<td>90</td>
</tr>
<tr>
<td>Total number of fields that at sometime during the growing season met the 1975 treatment guidelines</td>
<td>76</td>
</tr>
<tr>
<td>Number of field scouting reports that met the 1974 treatment guidelines</td>
<td>11</td>
</tr>
<tr>
<td>Number of fields that met the 1974 treatment guidelines</td>
<td>11</td>
</tr>
</tbody>
</table>
bug control with the 1974 guidelines (Table 1) was based on plant damage. Thus, 1974 damage ratings were often confounded by drought and plants could have lost three or more leaves due to the poor moisture situation and have few or no greenbugs. Because of the severe damage caused by drought many farmers did not treat sorghum that fell within the guidelines or was recommended for treatment. They were uncertain that any grain would be produces.

In 1975 the revised treatment guidelines were followed more closely. Fields were scouted a total of 1356 times and treatment recommendations were made 161 times. Some fields were recommended for treatment more than once, so a total of 140 fields were recommended for treatment, of which 69 or 49% met the 1975 guidelines. The remaining 71 fields had not reached the economic threshold when they were recommended for treatment. Only 7 fields met the criteria of the 1975 guidelines but were not recommended for treatment.

Table 13 reveals some of the differences in the extent of greenbug infestations between 1974 and 1975. In 1974, 25.6% of the scouting reports revealed field situations that would have required treatment according to 1975 guidelines. In 1975 only 6.6% of the fields met the same guidelines. However, some of the differences may be accounted for by the fact that for a period of two weeks during 1975 at the peak of the greenbug infestations, fields were not scouted. Also, in the latter part of the 1975 season, fields were no longer scouted if they had been recommended for treatment. The 776 reports from 1974 that met the 1975 treatment criteria included some fields twice or more.
Regression Analyses

The best record of treatment guidelines proved to be only 33% reliable (1975) so it appears that the evaluation criteria for determining when greenbugs should be controlled are inaccurate. Other factors, in addition to greenbug numbers and plant damage, must play important roles in the yield responses to insecticide applications. Therefore, to determine what factor or set of factors were most important in bringing about an increased yield with insecticide applications, a series of regression analyses were performed. The regression of the yield difference between treated and untreated sorghum on independent variables should reveal the combination of factors that contributed most toward the variability of the yield data. This could lead to the development of predictive mathematical models which would be more accurate than economic thresholds, which on the basis of greenbug populations alone, appear difficult if not impossible to develop.

There was so much variability and inconsistency from irrigated and dryland fields and from one year to the next that each year was separated into dryland and irrigated and analyzed separately.

A number of preliminary correlations and regressions were performed to determine which factors had the greatest relationship to yield difference. The different variables and the sets of data in which they were included in the final regressions are given in Table 14. The numerical values used were the means of four samples from each field. Accumulative greenbug days refers to the sum of the greenbug numbers on a plant each day for a specified period of time.
Table 14. Independent variables included in regressions to determine factors influencing the yield difference (dependent variable) of treated and untreated sorghum. From 1974 and 1975 data in the evaluation of treatment guidelines for controlling greenbugs on grain sorghum in the Clay County, Nebraska pest management project.

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Data and variables that were included in the regressions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenbugs numbers per plant</td>
<td>X</td>
</tr>
<tr>
<td>Damage rating at treatment</td>
<td>X</td>
</tr>
<tr>
<td>Growth stage at treatment</td>
<td>X</td>
</tr>
<tr>
<td>Treatment date</td>
<td>X</td>
</tr>
<tr>
<td>Accumulative greenbug days before treatment</td>
<td>X</td>
</tr>
<tr>
<td>Accumulative greenbug days after treatment</td>
<td></td>
</tr>
<tr>
<td>Percent parasitism on August 9</td>
<td>X</td>
</tr>
<tr>
<td>Accumulative greenbug days through June 30</td>
<td>X</td>
</tr>
<tr>
<td>Accumulative greenbug days before treatment in plant growth stage 2</td>
<td>X</td>
</tr>
</tbody>
</table>
Table 14 (continued). Independent variables included in regressions to determine factors influencing the yield difference (dependent variable) of treated and untreated sorghum. From 1974 and 1975 data in the evaluation of treatment guidelines for controlling greenbugs on grain sorghum in the Clay County, Nebraska pest management project.

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Accumulative greenbug days after treatment in plant growth stage 2</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accumulative greenbug days after treatment in plant growth stage 3</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of plant days in growth stage 2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Number of plant days in growth stage 3</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of plant days in growth stages 4 and 5</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interaction of growth stage by greenbug numbers at time of treatment</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Greenbug numbers per plant squared</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Table 14 (continued). Independent variables included in regressions to determine factors influencing the yield difference (dependent variable) of treated and untreated sorghum. From 1974 and 1975 data in the evaluation of treatment guidelines for controlling greenbugs on grain sorghum in the Clay County, Nebraska pest management project.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Interaction of accumulative greenbug days before treatment by greenbug numbers per plant at time of treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interaction of accumulative greenbug days before treatment by number of days between field survey and treatment</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This number is determined by adding the number of greenbugs per plant on the initial and final day of sampling, dividing the sum by two and then multiplying the dividend by the number of days within the period. The number of plant days in a specific growth stage are arrived at by subtracting the Julian date that the field is first noted in that stage from the Julian date that the plants are last recorded in that growth stage. Growth stages are adjusted to the 1974 scale.

The regression analyses were made with the means of those fields with four samples. Yield differences in pounds per acre of the treated means minus the control means was used as the dependent variable.

Because variances of the samples in fields were not independent, but tended to be positively correlated with the means, transformations of the dependent variable were used to normalize the distribution of the data. The most successful transformation used was a power transformation described by Hinz and Eagles (1976). The transformation is based on the partial regression coefficient of the regression of the log of the variance on the log of the mean. The power with which the dependent variable, yield difference in pounds per acre, was transformed, was calculated for each set of data:

\[
\begin{align*}
1974 \text{ irrigated} & = x^{1.171948} \\
1974 \text{ dryland} & = x^{0.769485} \\
1975 \text{ irrigated} & = x^{0.326235} \\
1975 \text{ dryland} & = x^{1.122145} \\
1974-75 \text{ irrigated} & = x^{1.3271} \\
1974-75 \text{ dryland} & = x^{0.788985}
\end{align*}
\]

A backward regression analysis was used. The analysis was made and the independent variable with a regression coefficient having the highest probability of equalling zero was dropped. The data were re-
analyzed with the remaining variables and the process was repeated with the least significant variable being dropped. This continued until the partial regression coefficients of all variables were significant at the .10 probability level. The results of the regressions are given in Table 15. Each of the six sets of data were analyzed separately. Listed are the coefficients of determination, number of samples in the analysis and those variables with significant partial regression coefficients. The independent variables in each model are listed in ascending order of the highest probability of the partial regression coefficients equalling zero.

The only analysis that resulted in a coefficient of determination that afforded some confidence in the model was that of the data for the 1975 irrigated sorghum. However, because there are 6 parameters and only 14 replications the high coefficient of determination may result from an insufficient number of samples. There may be too few observations to derive an adequate error sum of squares because a disproportionate amount of the total sum of squares is attributed to regression.

Different expressions of greenbug numbers per plant occurred in all of the models. Accumulative greenbug days, \((\text{Greenbug numbers per plant})^2\) and other measurements of greenbug numbers could be considered forms of transformations. The fact that \((\text{Greenbug numbers per plant})^2\) occurs in three of the models, often before or in place of the linear measurement of greenbug numbers may indicate that a transformation of the independent variable, greenbug numbers per plant may be necessary. The quadratic relationship between yield difference and greenbug numbers per plant suggests that there is an optimum time to control
Table 15. Regression models of transformed yield differences on significant independent variables. Analyses of data from evaluation of the 1974 and 1975 treatment guidelines for greenbugs on grain sorghum in the Clay County, Nebraska pest management project.

<table>
<thead>
<tr>
<th>Groups of data</th>
<th>Independent variables significant at the .10 probability level (Transformed Yield Difference)</th>
<th>R²</th>
<th>Replications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974 Irrigated*</td>
<td>$-472.24625 - 0.02043(\text{Greenbug numbers per plant})^2 + 23.48104(\text{Greenbug numbers per plant}) + 0.67583$ (Accumulative greenbug days before treatment in growth stage 2).</td>
<td>.643</td>
<td>20</td>
</tr>
<tr>
<td>1974 Dryland</td>
<td>$118.51389 + 4.88612(\text{Damage rating}) - 0.12480(\text{Percent population on Aug. 2}) - 5.72515(\text{Number of days plants were in growth stage 3}) - 3.20626(\text{Number of days plants were in growth stage 2}) - 0.00007(\text{Greenbug numbers per plant})^2$.</td>
<td>.459</td>
<td>46</td>
</tr>
<tr>
<td>1975 Irrigated</td>
<td>$-4.26049 + 0.08578(\text{Number of days plants were in growth stage 2}) + 0.09836(\text{Damage rating}) + 0.00181(\text{Accumulative greenbug days before treatment}) + 0.00608(\text{Greenbug numbers per plant}) - 0.00124(\text{Accumulative greenbug days before treatment in growth stage 2}) - 0.00046(\text{Interaction of growth stage by greenbug numbers per plant})$.</td>
<td>.765</td>
<td>14</td>
</tr>
<tr>
<td>1975 Dryland</td>
<td>$861.47591 + 5.04948(\text{Accumulative greenbug days through June 30})$.</td>
<td></td>
<td>43</td>
</tr>
<tr>
<td>1974-1975 Irrigated*</td>
<td>$-18595.71628 - 0.06093(\text{Greenbug numbers per plant})^2 + 73.38899(\text{Greenbug numbers}) + 516.08589(\text{Number of days plant was in growth stage 2})$.</td>
<td>.478</td>
<td>36</td>
</tr>
</tbody>
</table>

*Analysis with untransformed dependent variable resulted in higher $R^2$ value but model is not displayed here.
Table 15 (continued). Regression models of transformed yield difference on significant independent variables. Analyses of data from evaluation of the 1974 and 1975 treatment guidelines for greenbugs on grain sorghum in the Clay County, Nebraska pest management project.

<table>
<thead>
<tr>
<th>Groups of data</th>
<th>Independent variables significant at the .10 probability level (Transformed Yield Difference)</th>
<th>$R^2$</th>
<th>Replications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974-1975 Dryland</td>
<td>$-109.43276 + 0.01218(\text{Accumulative greenbug days after treatment in stage 3}) + 0.13629(\text{Accumulative greenbug days before treatment}) - 0.12691(\text{Accumulative greenbug days after treatment in stage 2}) + 6.11277(\text{Growth stage})$.</td>
<td>.453</td>
<td>31</td>
</tr>
</tbody>
</table>
greenbugs. At low population levels relatively little yield is lost but as the greenbug population increases the yield losses increase until a maximum greenbug level is reached. Beyond that point the amount of yield increase due to controlling greenbugs declines as the greenbugs increase. When the greenbugs reach a certain level the damage has been done and controlling them at higher populations will prevent losses but the response would not be as great as if the greenbugs had been controlled earlier.

Greenbug numbers per plant occurs in the three models for irrigated sorghum. The positive relationship of greenbug numbers per plant to yield difference is not surprising. Accumulative greenbug days before treatment in growth stage two is significant in the models of data from both years in the irrigated sorghum. When accumulative greenbug days before treatment in growth stage two was included in the regression analysis of the combined data for 1974-75 the coefficient of determination was increased to over .70. However, the partial regression coefficient of the independent variable, accumulative greenbug days before treatment in growth stage two, was significant at only the .25 probability level. The relationship to yield of accumulative greenbug days before treatment in growth stage two is positive for 1974, but negative for 1975.

The variable, number of days plants were in growth stage 2, is significant in three of the models. The positive relationship in the 1975 irrigated sorghum data may indicate that a greater potential for yield is developed in the preboot stage, and by controlling greenbugs, more of that potential is realized. This may be especially true in the irrigated sorghum where the effect of removing greenbug
stress is not masked by moisture stress. The same probability holds true for the combined data for irrigated sorghum. However, in the model of the 1974 dryland data the relationship to yield difference is negative, not only for number of plant days in growth stage 2 but for number of days plants were in growth stage 3 as well. The drought conditions of 1974 severely stressed the dryland sorghum, slowing growth and limiting yield potential. As yield potential was reduced the effects of controlling greenbugs was negated. As stress increased in individual fields growth was further retarded and plants were in preboot and boot stages for an extended period of time. Therefore, as an indirect measurement of stress, there should be less yield difference as the stress or time in those growth stages increases.

The positive relationship between yield difference and damage rating in the data for 1975 irrigated and 1974 dryland sorghum may be misleading. Some limits should be put on this independent variable (Damage rating) because if too much damage is sustained it will be too late to save the plants.

A positive relationship between yield difference and accumulative greenbug days after treatment in the untreated check should be expected. An increase or decrease in the amount of greenbug pressure on the untreated check should cause a corresponding increase or decrease in the yield reduction experienced. Therefore, the positive relationship of accumulative greenbug days before treatment may be a function of the amount of stress put on the untreated check after treatment because the larger the population is before treatment the greater it should become on the untreated check.
The variable, percent of greenbugs parasitized on August 9, was included only in the 1974 data analysis because there were many fields that were not scouted after July 25 in 1975. The negative relationship to yield difference in the 1974 dryland model is not surprising. As the percent of parasitized greenbugs increases, the damage sustained in the untreated check decreases, and thus, the difference in yield between the treated and the untreated check is diminished. This is somewhat inconsistent, however, with the data that implies that much of the damage and effects on yield is sustained in the early growth stages. For example, the only variable with a significant regression coefficient in the analysis of 1975 dryland sorghum data was accumulative greenbug days through June 30.

Although it would seem to be an important factor, the only model in which plant growth stage was a significant independent variable was in the combined analysis of all dryland data. This may be due to the extreme variability in a few growth stages and not enough samples from a broad range of growth stages. The relationship of growth stage to yield difference is positive which implies that with advancing maturity of the plant, the greater will be the effects of treating. If this is true it cannot be concluded that the preboot stage is the most critical, as suggested previously. Limits should be placed on this factor also, depending upon which stages are most sensitive to greenbug feeding. The positive relationship of accumulative greenbug days after treatment in stage 3 and negative relationship of accumulative greenbug days after treatment in stage 2 are completely inconsistent. Greenbug feeding after treatment would influence varying yield difference because different degrees of damage
sustained by the untreated checks would be directly related to the size and period of the infestation, whereas the treated sorghum should all be virtually unharmed.

The inconsistencies and the absence of common independent variables, emphasizes the variability of the data and the differences in conditions between the two years. Using variables that logically relate to the influence of greenbugs and greenbug control on yield, the lack of fit of the models as demonstrated by the low coefficients of determination, suggests that there may be some effects due to treating that are not being considered. Testes and Johnson (1973) suggested that certain phosphate insecticides may act as growth stimulants, and that control of greenbugs may not be entirely responsible for yield increases. However, an attempt during 1975 to detect this possibility failed. An experiment under more controlled conditions might provide the precision necessary to explain more of the variation produced by factors already considered in this study.

The results of controlling greenbugs before their populations reached the damaging levels specified in the 1974 treatment guidelines indicated that those guidelines were inadequate under Nebraska conditions. Although the 1974 guidelines given in Table 1 are worded somewhat differently from the treatment thresholds developed in Texas, they are virtually the same. The only differences might appear if the treatment for preboot stage and beyond was interpreted from Texas thresholds as being required if two whole leaves and any part of a third leaf were dead. The Nebraska guidelines did not specify treatment until at least three leaves had been killed by greenbugs. However, the two sets of guidelines are
similar enough that both can be deemed inaccurate by the results presented here, especially when the poor, but improved, performance of the more conservative, revised 1975 standards are considered.

The data presented by Teetes and Johnson (1973), in the only published work specifically designed to measure effects of greenbugs on yield, do not differ vastly from the results reported in this study. Insecticide treatments applied to irrigated sorghum at seven times during the growing season were replicated four times. Sorghum treated with 1, 16, 99, 476, and 706 greenbugs/plant outyielded the untreated check by 955-1594 lbs/acre (1072-1788 kg/ha). These yields were significantly different from the untreated check. Earliest treatment was on June 14 at growing point differentiation. The latest treatment that resulted in a yield increase significantly different from the untreated check was on July 19 when the plants were in the soft dough stage. Maximum yield increase was realized from treating with 16 greenbugs/plant with the final leaf visible in the whorl. Sorghum treated on July 26 in the soft dough stage with 1281 greenbugs/plant outyielded the untreated check by 473 lbs/acre (531 kg/ha) but the difference was not significant. In a similar test in 1972, treated sorghum outyielded the untreated check by 682-1610 lbs/acre (765-1806 kg/ha) but the difference was not significant. Greenbug infestations ranged from 15-1060 greenbugs/plant with the maximum yield increases in plots treated at growing point differentiation with 63 greenbugs/plant. In a 1972 test on dryland sorghum, treatments with 5 and 31 greenbugs/plant at growing point differentiation, resulted in respective yield increases of 835 and 943 lbs/acre (927 and 1058 kg/ha) which were significantly
different from the untreated check. With less than 290 greenbugs/plant, sorghum treated in the whorl and boot stage outyielded the untreated check by 521-720 lbs/acre (585-808 kg/ha) but the difference was not significant. Teetes' and Johnson's interpretation does not explain the data, however. They believed that the data support the Texas guidelines, and suggest that sorghum plants can sustain even more greenbug feeding and leaf loss than allowed for in the Texas thresholds. Teetes and Johnson have drawn their conclusions from experiments with too few replications to statistically detect practical differences among extremely variable material. For example, sorghum with 2.8 dead leaves per plant was outyielded 604-880 lbs/acre (678-987 kg/ha) by treated sorghum with no dead leaves. Because these differences were not significant at the .05 level the authors could find no reason for treating greenbugs before sorghum had sustained at least three dead leaves. The authors also overlooked the fact that yields of some of the earliest treated sorghum outyielded the untreated checks by a difference that was significant. Their interpretation was apparently based on the treatments that were significantly different from each other rather than those that were significantly different from the untreated check.
CONCLUSIONS

The greenbug control guidelines for grain sorghum, developed in Texas, and used in the Nebraska Pilot Pest Management Program during the 1973-74 growing seasons provided poor results in this study. Most greenbug susceptible grain sorghum treated before the Texas economic thresholds had been reached significantly outyielded the untreated checks. The revised, more conservative, 1975 treatment guidelines, were still inadequate.

The data in this study do not support specific guidelines based only on greenbug populations or plant damage sustained due to greenbug feeding, for controlling greenbugs on susceptible grain sorghum.

The data do suggest, based upon additional factors, that an optimum time to control greenbugs probably exists. The timing, however, may depend upon growth stage of the plant and length of time in that stage, previous levels and duration of the greenbug infestation, available moisture, amount of damage already sustained by the sorghum, and the number of greenbugs present.

In evaluating treatment guidelines for greenbugs on grain sorghum a number of important facts became apparent. There appears to be a high degree of inherent variability in the experimental material. This variation (greenbug populations, grain production, varietal differences, fertility, and moisture) would require that sufficient replication be used in any further evaluations to ensure enough precision to derive meaningful conclusions. Most of the previously reported studies of greenbugs on grain sorghum did not utilize enough replications to overcome the high variability of the experimental
During both years of this study, 1974-75, irrigated sorghum responded differently than dryland. The irrigated sorghum that was treated outyielded the untreated check by 175-200 lbs/acre (196-224 kg/ha) more than the dryland yield was increased due to treatment. Apparently the irrigated sorghum that was treated came closer to realizing its full yield potential. Among the dryland sorghum inadequate moisture was more of a limiting factor to yield than was greenbug feeding.

It appears that prevention of significant yield loss would have resulted from chemical control of greenbugs in most pest management grain sorghum fields during 1974-75. Because of inadequate treatment guidelines used during 1973-74 the success of the sorghum aspect of the Nebraska Pilot Pest Management Program appears poor from an economic point of view. One of the objectives of the program was to increase profits by reducing unnecessary pesticide applications by the participating cooperators. However, this study indicates that most fields should have been treated for greenbugs, and in reality most fields were not recommended for treatment.

Although absolute control guidelines would appear to be more convenient and efficient, a certain amount of subjectivity is often necessary in making pest management decisions. This fact is emphasized when it is realized that in many of the Nebraska pest management fields recommended for treatment when guidelines did not call for treatment, treated sorghum outyielded the untreated check.

Finally, this study demonstrates the importance of using local data in developing treatment guidelines. Enough variation exists
in climate, plant varieties, and insect populations that insect control guidelines from one geographic area may not work elsewhere.
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U.S. Department of Commerce National Oceanic and Atmospheric Administration Environmental Data Service 1975 Climatological Data, Nebraska. 80(6-9, 13).


APPENDIX
Appendix I. 1974 Field Data form used in the evaluation of control guidelines for greenbugs on grain sorghum in the Clay County, Nebraska pest management project.
GREENBUG CONTROL FIELD DATA

I) 1. Date __________ 2. Cooperator __________ 3. Field # __________
4. Township __________ 5. Section __________
6. Legal Description __________

II) Sample area: 1. Treated 2. Control 3. Treated twice
Location of sample in field:

III) 1. Recommended 2. Not recommended
3. Greenbug count before treatment __________
4. Greenbug count after treatment __________
5. Greenbug damage: 1 2 3 4 5 6
   1 - no damage 4 - most plants with one
   2 - Yellowing or red spots 5 - two dead leaves/plant
   3 - Dying leaf tips or edges 6 - more than two dead
      leaves/plant

IV) 1. Stage of growth: 1 2 3 4 5 6 7 8
   1 - seedling 2 - preboot 3 - boot 4 - heading 5 - bloom
   6 - milk stage 7 - soft dough 8 - hard dough
2. Plant stand __________ 3. Row width __________

7. Weather __________

VI) Significant weather after treatment __________

VII) 1. Yield of treated area __________
2. Yield of untreated area __________
Appendix II. Form used in the field during 1975 to record greenbug infestation and plant damage from five samples for each plot.
Appendix III. 1975 Field Data form used in the evaluation of control guidelines for greenbugs on grain sorghum in the Clay County, Nebraska pest management project.
GREENBUG EVALUATION FIELD DATA

Date _______ Cooperator _______________ Field No. _______
Township_________________ Section _______ Legal Descr. _______
Row Spacing _______________
Scout __________ Rpt. Date _______ Gbg. No. ____ Damage____

Location Gbgs/Plant
Before Trmt.

Repl. 1:
Cygon
Check
N.S.

Repl. 2:
Cygon
Check
N.S.

Repl. 3:
Cygon
Check
N.S.

Repl. 4:
Cygon
Check
N.S.

Control:
No. of Greenbugs/Plant from 5 plants at site of 2 or more replications.
Cygon: ________ % Control: __________
N. S.: ________ % Control: __________