THE RESISTANCE OF SORGHUM VARIETIES AND HYBRIDS TO CHINCH BUG BLISSUS LEUCOPTERUS (SAY)

by

JUAN ANTONIO SIFUENTES

Ing. Agronomo, Escuela Superior de Agricultura,
Saltillo, Coah, Mexico, 1952

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1958

TABLE OF CONTENTS

INTRODUCTION

In certain areas where agriculture is not highly developed and where the land distribution among farmers is limited, a principal means of controlling the insect pests at less cost could be the use of resistant, or at least tolerant, varieties or hybrids.

In Mexico, work has been done in the development of varieties resistant to strains of rust which attack wheat; the same has been done with varieties of potatoes which are resistant to the late blight fungus; but little work has been done in the field of varieties resistant to insect pests.

Much of the study included here was done at the agronomy farm of Kansas State College during the summers of 1956 and 1957. In this work observations were made on the ability of hybrids and varieties to withstand the attack of the chinch bug, Blissus leucopterus (Say). This study was to observe the response of each variety or hybrid in the seedling stage to the attack of these insects. Some of the hybrids included are the newest ones that have been released to the farmers in Kansas, Nebraska and Texas.

Studies in the greenhouse and insectary were made at the same time as those in the field to learn in some detail how the insects behave in regard to some of the varieties and hybrids. Studies to learn the kind of resistance involved were carried out on certain varieties or hybrids and their parents because such resistance studies in detail are only possible under

partially controlled conditions. During this work evidence was gathered of the need of selecting resistant varieties as the parents of the new hybrids.

REVIEW OF LITERATURE

Insect Resistance in General

One of the first reports on resistant varieties was given by Lindley (1831), in which an apple variety, winter Majetin, was stated to be resistant to the wooly apple aphid, Eriosoma lanigerum (Hausm). Early reports of wheat varieties resistant to the hessian fly, Phytophaga destructor (Say), were given about 1785. Eighty-nine years ago North American varieties of grapes which were resistant to the grape phylloxera, Phylloxera vitifolia (Fitch) were exported to France, where they saved the wine industry in that country (Painter, 1951). Becker (1918), in studying the wooly apple aphid, Eriosoma lanigerum (Hausm), found this resistance apparently inherited in some cases but not in others. Flint (1921) showed that white Democrat corn carried the same number of chinch bugs as other varieties but was resistant because of the power to tolerate the insect. Davidson (1922) stated that resistance was present in the wild stage on Vicia faba plants and such resistance was largely determined by genetic factors. DeLong and Jones (1926) while working with houghton gooseberry aphid, Mysus houghtonensis, found a strain of gooseberry on which the aphid did not feed. This strain was found while they were working on the chemical

control of the insect. LePelley (1927) working with apple varieties made crosses and found that the factors for immunity were inherited according to the Mendelian laws. Painter (1930) found that the susceptibility of certain wheat varieties was due to the presence of different biological races of hessian fly. Painter et al. (1931) showed that resistance of wheat varieties to hessian fly was inherited independently of most varietal characters. Blanchard and Dudley (1934) showed that pea aphids in alfalfa do not feed when they were placed in a resistant strain of alfalfa. Parnell (1935), in Africa, developed a cotton resistant to leafhoppers of the genus Empoasca; such a strain of cotton constituted the variety U 4, which saved the cotton industry in these areas. Painter (1936) cited examples in which various parts of the same plant have shown apparent differences in respect to insect nutrition.

Resistance of Sorghums to Chinch Bug

Thomas (1879) suggested early planting of spring wheat and the growing of crops on which the chinch bug does not feed. Osborn (1888) recommended different dates of planting to minimize injury, and also mentioned the planting of crops immune to chinch bug such as clover, buckwheat and flax. Cottrell et al. (1900) reported that kafir plants, when small, were killed by the chinch bug but that corn was destroyed more readily. Conner (1911) reported that sorghum plants lodged badly if affected by the chinch bug. Ball (1913) reported

that the kaoliangs seem to be slightly less susceptible to chinch bug injury than the milos. Borman (1914) said that resistance depended upon juiciness of sorghum stalks. Vinall (1920) stated that chinch bugs often did damage to sudan grass. Hayes (1922) reported that a milo cross which exhibited hybrid vigor was not injured by the chinch bug and he attributed this to the occurrence of hybrid vigor. Hayes and Johnston (1925) made observations on over one hundred species of native and introduced grasses and found that different species showed different degrees of resistance to injury and later some of them exhibited marked ability to recover. Daane and Klages (1928) reported that complete failure resulting from chinch bug damage had been the rule with milo and milo hybrids. Parker (1931) described the reaction of sorghum varieties and hybrids to chinch bugs and showed that chinch bug resistance is inheritable. Snelling (1932) stated that apparently chinch bug injury was not closely correlated with any of the morphological characters. Of the sorghum plants he further stated that one of the most feasible methods of controlling the chinch bug is the development of resistant varieties of sorghums. Dahms (1942) stated that no variety of sorghums has been found in which chinch bugs do not feed or maintain a population, but that certain varieties appear to be much less favorable than others. In this same work he reported that the number of eggs that a chinch bug laid depended more upon the host plant than upon any other factor, with the possible exception of

temperature. Snelling et al. (1937) stated that plants which had shown marked hybrid vigor reached maturity without any apparent injury but hybrid plants which did not show hybrid vigor were killed by this insect. Dahms and Martin (1940), while working with eleven F_1 hybrids and their parents, reported that the number of eggs laid is inherited as a dominant character and they showed that the number of eggs laid by the female caged on different strains did not appear to be correlated with hybrid vigor. Painter (1928) showed that the main objective of the chinch bug stylets was the phloem tissue of the vascular bundle. Painter (1951) stated in regard to the resistance of the sorghum plants in the seedling stage, that the most resistant plants would be killed if they were small enough and if there were enough chinch bugs.

MATERIALS AND METHODS

Experiments at the Agronomy Farm in 1956

On June 8, 1956, at the Kansas State College agronomy farm, 33 sorghum varieties and hybrids were planted. Each variety was replicated twice, with the rows 40 inches apart and 25 feet long. A considerable difference in germination was shown by the different kinds of sorghum. This plot was located along a wheat field, so that, when the wheat was harvested the chinch bugs, having no food there, migrated toward the sorghum plants. The attack on the sorghum plants was severe because they were in the very young seedling stage.

At the start of the experiment a total stand count was made and for the later records only the number of living plants was counted. The first count was made eleven days (June 19th) after the planting date and successive counts were made on June 21st, 23rd, 26th and 28th.

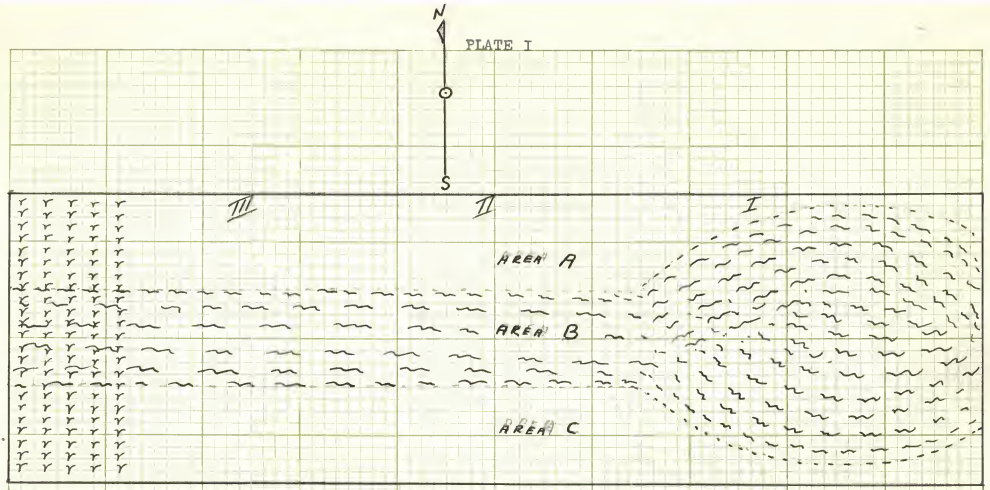
In addition to these two replications an experiment including only 19 varieties and hybrids (most of them also included in the first two replications) were planted at the same time. However, this area was located at some distance from the wheat and separated from it with a barrier of corn. A dieldrin spray was applied as a second barrier, with the objective of letting the seedling plants grow a little more before being subjected to the attack of the chinch bug. The rows were of the same length as in the first experiment, and the counting system was essentially the same, but the first count of the live plants was taken on July 3rd and recording continued through July 27th. This experiment was at first intended to be the number three replication but because of the difference in position, chinch bug attack, and varieties included it was later considered as a separate experiment. Varieties in this experiment were not replicated.

Experiments at the Agronomy Farm in 1957

A similar experiment which had the same plot dimensions was planted on June 12th, 1957, the plot being located about 300 feet from the position of the 1956 plot. This time three

replications were planted the same day. Fifteen of the varieties and hybrids that were planted in the 1956 plot were repeated in these experiments and several new hybrids and varieties were included; a total of 32 sorghum varieties and hybrids were planted. The same system of taking records was followed in order to have data comparable with those taken in 1956. The total stand count was made June 22nd and the first record of the number of plants alive following extensive chinch bug infestation was made on June 24th, or twelve days after planting date. The first 1957 record was taken from plants which were within one day of the same age as the plants in the 1956 experiment. Because the plot was partially flooded and the first replication was almost completely in the water much of the time, the following arrangement was believed necessary: 1. the first replication was not taken into consideration in the final results; 2. the second and third replications were divided into areas A, B, and C, and records were taken in these areas from June 24th to July 12th; 3. later records were taken only in area C. The division into areas A, B and C was made because: 1. area B was the more severely affected by the flood; 2. area C in certain ways escaped the infestation comparable to area A, because the flood in area B served as a barrier when the chinch bugs were coming by foot from the north side of the plot; and 3. area A was the more severely affected by the chinch bugs because it was nearest the wheat field on the north side of the plot.

PLATE I



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Effect of Some Hybrids and Varieties on Chinch Bug Adults

At the time the experiment for oviposition was done it was noticed that males and females died at different rates on the different varieties; therefore, an experiment was designed to determine this difference for each variety. The varieties used were the same as for oviposition but in this experiment care was taken to remove each individual found dead in each variety. This experiment was finished at the end of 25 days. Larger glass tubes (70 X 15 mm.) were used as cages.

Host Preference Studies in the Greenhouse

Small seedling plants, grown until they were 10-15 days old, were replanted in flower pots 12 inches wide and 8 inches tall. Four varieties were used: Atlas, Combine Kafir 60, Plainsman and RS 650 (Combine Kafir 60 x Plainsman). Each variety was replicated nine times, three pots were used and in each pot 12 seedling plants were replanted at random in a circle around the periphery of the pot. Large glass tubes were used to cover the plants. One hundred chinch bug adults were placed in the central part of the flower pot and the counts were made at intervals of 15, 22, 40 and 46 hours after the chinch bugs reached the plants.

Feeding of the Chinch Bug on Certain Sorghum Varieties and Hybrids

In the greenhouse, using the same glass tube as for oviposition, an experiment in feeding the chinch bug (after keeping the chinch bug without food for 24 hours) was done to determine the amount of material that the chinch bug took from plants of each variety after three hours of feeding. For this experiment two different varieties of sorghum were used: Atlas and Dwarf Yellow Milo. A Roller Smith Micro-torsion Balance having a capacity of five milligrams which could read to 0.002 mg. was used to weigh the chinch bugs. The weight was recorded before feeding and after the chinch bug had fed three hours on the plants. The differences in weight before and after feeding were considered to be the amount of material taken in by the insects. During this experiment only males were used. One of the reasons for using males was to avoid errors due to the females laying eggs during the 3-hour period.

A second experiment was carried out in which females and males were used. The following two hybrids and their parents were tested: RS 610 (Combine Kafir 60 x Combine 7078), RS 650 (Combine Kafir 60 x Plainsman), Combine 7078, Combine Kafir 60, and Plainsman. A total of 125 individual adult insects were studied, the weight and periods of time were the same as in the previous experiment. There were five replications for each variety or hybrid studied and 25 individuals for each variety.

Oviposition by Chinch Bugs on the Different Sorghum Varieties and Hybrids in the Greenhouse

A small glass tube (45 x 15 mm.) was used as a cage to determine the number of eggs laid by the chinch bug. The upper part of one of the glass tubes was open and covered with a cloth, the other end of the glass tube (bottom) was filled with water. A small cork was split and a seedling plant 5 to 10 days old was placed between the halves of the cork. The small hole was filled with cotton and in this cotton the chinch bug preferred to lay its eggs. The count of the number of eggs was usually made two times a week and when each plant began to dry it was replaced with another one of the same variety. In each vial was placed a female and a male chinch bug. When a male was found dead it was replaced by another and in case a female was found dead this particular replication was discontinued. The varieties used in this experiment were Combine Kafir 60, Plainsman, Atlas, Dwarf Yellow Milo and RS 650. Four to six replications were used for this experiment.

RESULTS

Results at the Agronomy Farm Experiments at Replications I and II in 1956

Table 1[1] shows the results obtained when 33 hybrids and varieties were tested at the agronomy farm of Kansas State College during 1956. In this table only the number I and II replications are included.

The varieties and hybrids that were more resistant or tolerant to chinch bug attack were: RS 630, Atlas, H-6522, Tx. 611 and H-6511. Greater susceptibility was shown by Dwarf Yellow Milo, H-6520, Reliance, C.E. 5057, Tx. 620, Westland, Martin, Kansas 2210, C.E. 5065 and RS 610. The following were among those showing intermediate resistance: RS 590, Dwarf Kafir 44-14, Nebraska 3, Nebraska 1c, and RS 650.

Results Obtained in Replication III at Agronomy Farm in 1956

The results are shown in Table 2. The variety in which the chinch bug caused the most severe damage at the end of 27 days was Dwarf Yellow Milo with a percent of plants alive of 49 percent. The rest of the varieties and hybrids ranged in percent of plants killed between 0 percent and 15 percent. In this experiment, 19 sorghum varieties and hybrids were studied.

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[1] All Tables in the Appendix.

Results Obtained in 1957 in Areas A, B, and C at the Agronomy Farm

The data given in Table 3 show that the best varieties and hybrids in chinch bug resistance were: Tx. 611, H-7922, RS 501, H-7910, Tx. 601, RS 610 and RS 590. Among the intermediate varieties and hybrids were: N-9, Combine Kafir-60, N-44, and CE 5057. The most susceptible were Plainsman, Caprock, Combine 7078, CE 6031 and Dwarf Yellow Milo. The hybrid RS 610 in the experiment in 1957 was susceptible and the same thing can be said in regard to CE 5057. Club x Day had very poor germination (28 plants) during this test. Therefore the results obtained during this test in regard to this special sorghum should not be taken as representative for this hybrid. In this experiment 32 sorghum varieties and hybrids were included.

Results Obtained in Area C in 1957 Test

The results obtained in the area C (2nd experiment, 1957) are shown in Table 4. These data were recorded from July 12 to July 27. In this test 32 varieties and hybrids were included. Results are mostly similar to the results given in Table 3. The following hybrids were the most tolerant: RS 630 (Combine Kafir 60 x Double Dwarf White Feterita), RS 610 (Combine Kafir 60 x 7078), RS 501 and Tx. 611. The more susceptible sorghums during this test were: Caprock, Dwarf Yellow Milo, CE 6031 (Martin x Caprock), Club x Day, Combine 7078 and Plainsman.

Summary of Results Obtained During 1956-57 at the Agronomy Farm

From Table 5 it is possible to observe that the more resistant varieties for the 1956 experiment were: RS 630, Atlas, H-6522, Tx. 611; and the most susceptible for the same year were: CE 5057, H-6520 and Dwarf Yellow Milo. In the 1957 experiments the more resistant varieties and hybrids were: Tx. 611, H-7922, RS 501, Tx. 601, RS 610 and the more susceptible were: Plainsman, Club x Day, Caprock, Combine 7078, CE 6031 (Martin x Caprock), N-41 and Dwarf Yellow Milo.

Oviposition on Different Sorghum Varieties and Hybrids

The total number of eggs laid by six females during 25 days on different kinds of sorghum plants were recorded as indicated in Table 6.

Atlas was the variety on which the smallest number of eggs were laid and Dwarf Yellow Milo was the variety on which the chinch bug laid the most eggs. Plainsman was the second variety in total number of eggs laid. The F_1 RS 650 was intermediate between Combine Kafir 60 and Plainsman but the number of eggs laid was probably not significantly different in the hybrid and its resistant parent.

Host Preference Studies in the Greenhouse

Four different kinds of sorghums were tested to find out the relative preference of the chinch bug for each (Table 7). Atlas was the variety to which the least number of chinch bugs were attracted. The F_1 hybrid RS 650 was intermediate between its parents, Combine Kafir 60 and Plainsman. More chinch bugs were found on Combine Kafir 60 than on Plainsman but the difference is not great.

Results Obtained When the Chinch Bug Adults Were Fed Individually on Two Hybrids and Their Parents in the Greenhouse

The results obtained when 125 chinch bug adults of both sexes were fed individually on two hybrids and their parents during three hours, using five plants of each variety, are shown in Table 8. Results indicated that the amount of food taken up was generally less when the seedling plant was four days old than when it was five days old. After that time the amount remained more or less the same. The chinch bug took slightly more food from Combine 7078. The F_1 hybrid RS 610 was intermediate between its parents, the Combine Kafir-60 and Combine 7078. From the F_1 hybrid RS 650 the chinch bug took more food than from either of the parents, Plainsman and Combine Kafir-60. From the variety Plainsman the chinch bug took the least amount of food. The differences are probably not sufficient to explain differences in effect of the chinch bugs in the killing rate of sorghum plants under field conditions.

Feeding of the Adult Male Chinch Bugs on Atlas and Dwarf Yellow Milo in the Greenhouse

When studies were made to find out whether different amounts of plant materials were taken by 40 chinch bugs during three hours from a highly resistant and a highly susceptible sorghum variety, the results were obtained as indicated in Table 9. These results indicate that no great difference exists in the amount of plant materials the chinch bug takes from these two varieties.

Differential Death Rate of Chinch Bugs on Certain Varieties

The number of chinch bugs found dead during the 25 days of maintaining six pairs on each variety for recording oviposition rate (Table 6) are recorded in Table 10. During this period on Atlas 73 adults were found dead, while in the same period on Combine Kafir-60 43 chinch bugs were dead. RS 650 was intermediate in death rate between Combine Kafir-60 and Plainsman. Plainsman and Dwarf Yellow Milo were the varieties on which the least number of adults died.

DISCUSSION

During the experiment at the agronomy farm a wheat field which was a source of chinch bug infestation was located a few feet from the ends of the sorghum plots. When the chinch bugs migrated on foot from the wheat field the sorghum plants were small and the chinch bug population was numerous. Painter

(1951) recorded that the most resistant plants may be killed by the chinch bug if the sorghum is small and the chinch bug population is high. The chinch bugs migrated from the wheat field on foot, and as expected, in both years the most severe damage was near the end of the rows next to the wheat field. Thus the way in which the chinch bug was distributed influenced the results because the chinch bug population was not distributed uniformly throughout the entire field. However, after some days the chinch bugs became distributed all over the experimental field.

In the 1956 experiment at the agronomy farm only two replications were planted instead of three because of lack of seed. With some seed which remained from the two replications, a third experiment involving only part of the varieties was planted. This experiment is called throughout this work replication III. The first two replications are called the first experiment throughout this work.

The first experiment was subjected to a heavy attack of chinch bugs at an early stage. The second experiment was subjected to a later attack of chinch bugs because a barrier of Dieldrin was sprayed around the plot. Consequently due to the barrier of Dieldrin the chinch bug attack was not severe and it was difficult to measure the real damage that was caused by the chinch bugs on the more resistant varieties or those intermediate for resistance. However in the varieties which are the more susceptible, for example, Plainsman and Dwarf Yellow Milo,

the damage caused by the chinch bug was more evident.

In the 1957 test, because the plot was flooded from rains, it was necessary to divide the experiment into areas designated as A, B and C. These areas corresponded to parts of the replications II and III. The first replication was under the water most of the time so no records were taken on this replication.

Under field conditions the hybrids RS 610, RS 650 and CE 5057 tended to be more resistant than their parents, however, this difference when measured by the percent of plants alive is not high. This resistance may be due in part to the fact that they are tolerant to the attack of the chinch bug because of the hybrid vigor that is usually present in hybrids.

Some differences from results recorded here are expected to occur in the future work with the same varieties and hybrids studied. This is especially true if the special kind of conditions such as high rainfall to which the varieties were subjected in 1957 are taken into consideration.

During recent years there has been a tendency to use susceptible parents for the new hybrids that have been developed. An example is the variety Combine 7078 which has been used as one parent of hybrids such as RS 610. This variety and the hybrid were both more susceptible under both field and insectary conditions than Combine Kafir 60, the female parent, indicating that susceptibility was inherited as a dominant character in this hybrid. The same thing can be said in

regard to the variety Martin and the hybrid, CE 6031, although the Martin variety has shown more resistance than the variety Combine 7078. In both cases the female parent was more resistant.

The results obtained when studies were made in the insectary to determine the quantity of plant material taken by 125 chinch bugs, both sexes, from some hybrids and their parents showed that apparently no difference in this respect exists between the hybrids and either resistant or susceptible parents. Similar results were secured when 40 chinch bug males were fed on Atlas which is a highly resistant sorghum and Dwarf Yellow Milo which is highly susceptible. In the above two experiments the youngest sorghum plant leaves were selected to feed the insects, therefore, differences do not exist in this respect. Since differences were not found in the amount of plant material that the chinch bug took in from the different sorghum varieties and hybrids, and since the number of eggs laid, especially on Atlas and Dwarf Yellow Milo, were different, being greater in Dwarf Yellow Milo, the possibility exists that the materials contained in Atlas and Dwarf Yellow Milo, especially carbohydrates, proteins and minerals, are different in quantity or quality.

When studies were made at the insectary to determine the number of eggs laid by the chinch bug on Dwarf Yellow Milo, Plainsman, RS 650, Combine Kafir 60 and Atlas the data showed that resistance (antibiosis as measured by eggs laid) is

inherited as a dominant character. This agrees with the results obtained by Dahms and Martin (1940) using other parents and hybrids.

When studies of preference or non-preference were carried out with Atlas, the hybrid RS 650 and its parents, Combine Kafir 60 and Plainsman, differences were not found in the number of chinch bugs attracted to the hybrid and the parents, but a great difference was found in the number of chinch bugs attracted to Atlas as compared to the two varieties and the hybrid mentioned. According to these results, when resistance is measured as preference or non-preference, the hybrids and their parents react as more or less susceptible and Atlas as highly resistant.

When studies on preference, antibiosis and tolerance were carried out with Combine Kafir-60, the hybrid RS 650, and Plainsman variety, it appeared that the only mechanism of resistance actually present in Combine Kafir-60 is tolerance, also some degree of antibiosis. Thus this variety possesses the ability to withstand higher insect populations of chinch bug without showing any apparent damage than other varieties. In preference this variety was about equal to Plainsman and the hybrid RS 650, and in the degree of antibiosis was again about equal to the hybrid RS 650 but showed a greater degree of antibiosis than Plainsman variety.

The variety Combine 7078, one of the parents of the hybrid RS 610, is susceptible in the field and under greenhouse

conditions; the other parent of this hybrid is Combine Kafir-60, which is tolerant. This F_1 hybrid under field and greenhouse conditions was susceptible to the chinch bug attack, indicating that susceptibility was inherited as a dominant character when resistance was measured for tolerance.

The different varieties and hybrids tested during 1956-57 at the agronomy farm were classified into resistant, intermediate, and susceptible categories in Table 11. This table does not include some sorghums whose reactions were not clearly shown; however, one exception was made with the hybrid RS 610. In the 1956 test this hybrid reacted as tolerant, but in the 1957 test it was susceptible. When this same hybrid was submitted to a tolerance and preference test in the greenhouse it was again susceptible. The tolerant reaction obtained in the 1956 test field test could be explained by the possibility of uneven field distribution of the chinch bug. Due to the latter tests, a tentative classification as susceptible was made. It can be seen that some of the sorghum varieties and hybrids were tested only one year and some others were tested both years. This may influence to a certain extent the average in the percent of plants alive if the final judgment is based on the average percent of plants alive.

SUMMARY

The biological control of chinch bugs in sorghum varieties and hybrids by means of host plant resistance has been studied

extensively for a period of nearly 35 years. One of the first recommendations for controlling this insect biologically was made in 1879 by Thomas (Painter, 1951).

The data presented includes observations on tolerance, antibiosis, and preference in sorghum varieties and hybrids carried out under field and greenhouse conditions for a period of two years.

The range in average percentage of plants alive in 50 sorghum varieties and hybrids tested at the agronomy farm for two-year periods was from 47 for the most resistant to 0 (zero) for the most susceptible. A total of 9818 different individual plants were tested during this period and some of the sorghum varieties were tested for the first time against chinch bug attack since they are the newest hybrids or varieties released to farmers in the last few years.

In F_1 hybrids having as one parent Combine Kafir 60, the resistance was inherited either as a dominant or recessive character. This could be explained by the possibility of ephistatic factor or factors for susceptibility or resistance, or the possibility of having different selections of the Combine Kafir 60 variety.

The number of eggs laid and mortality in the chinch bugs were influenced by the resistant or susceptible varieties, being highest in Atlas and lowest in Dwarf Yellow Milo varieties. It has been stated (Dahms, 1942) that antibiotic effects of sorghum varieties on the rate of mortality or rate

of fecundity are affected by the same factor or by factors which are closely linked.

The amount of plant material taken in by 165 chinch bugs, of both sexes and also by the males alone in seedling sorghum plants, were recorded in the two hybrids, RS 650 and RS 610, and their parents Combine Kafir-60, Plainsman variety and Combine 7078, and also in the highly susceptible Dwarf Yellow Milo, and in the highly resistant Atlas sorghum. The chinch bugs were left without food for a period of time of 24 hours. The weights of the chinch bugs were recorded individually, using a Roller Smith microtorsion balance which could be read to 0.002 mg. before and after feeding for a period of three hours. The first leaves of the seedling plants were used to feed the insect. No apparent differences were found in the amount of plant material taken in from the different varieties, but an indication is given that the quality of the plant material is different since this is suggested by the difference in the number of eggs laid on the highly susceptible and the highly resistant sorghum varieties.

When resistance was measured by the number of chinch bugs which were attracted to Atlas, the hybrid RS 650 and its parents, Combine Kafir-60 and Plainsman, the hybrid and its parents were more or less susceptible but Atlas reacted as highly resistant.

During preliminary studies it was also shown that the only mechanisms of resistance actually present in Combine

Kafir-60 are tolerance and, to a lesser extent, antibiosis.

A tentative classification of sorghum varieties and hybrids into resistant, intermediate and susceptible is presented in Table 11. This classification does not pretend to be complete, and it is expected that more work may change the relative position of the sorghums whose reactions are not yet well known.

Some of the sorghum hybrids and varieties were tested only one year and some others were tested both years. This can influence in a certain degree the final judgment if it is based only on average percent of plants alive.

ACKNOWLEDGMENTS

The writer is grateful to Dr. Reginald H. Painter, major advisor, for help and assistance both in thesis direction as well as throughout his graduate studies, and for aid in orientation during his stay in the United States of North America.

The writer is also grateful to Dr. Herbert Knutson, Head of the Department of Entomology, for his careful review and criticism of this thesis.

The writer is also indebted to the Rockefeller Foundation for granting a fellowship which made this graduate study possible.

Thanks are due Mr. Alfred J. Casady of the Agronomy Department for help with the plots and for supplying the sorghum seed needed during this experiment.

Many thanks are given to my wife, Mrs. P. Irma de Sifuentes, for help any time when it was needed.

The writer is indebted to Mrs. Fred McCoy, Mr. Robert Dempsey, and Mrs. Theodore Hopkins for help with English and the typing of this thesis.

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APPENDIX

Table 1. Sorghum plants alive at stated times during chinch bug test. Agronomy farm, Manhattan, Kansas, 1956.

Variety or Hybrid	Pedigree	Original no. of plants	Percent plants alive on June 19	21	23	26	28
RS 630	Combine Kafir 60 x Double Dwarf-white feterita	108	100	96	88	63	53
Atlas		196	90	87	79	47	46
H-6522*		34	100	97	80	65	36
Tx. 611	Combine Kafir 60 x Tx. 74	69	100	94	82	47	36
H-6511*		49	98	84	63	42	35
RS 590	Combine-Kafir 60 x Redbine 60	86	100	98	73	38	26
Neb. 3	AK 110**	182	99	94	75	33	25
Neb. 1c		157	97	93	83	30	23
Redlan		135	92	85	55	32	21
RS 650	Combine Kafir 60 x Plainsman	86	99	98	77	31	20
M.S. Combine Kafir 60		149	99	93	69	33	19
Kansas 2209	Plainsman**	158	89	71	54	30	18
Tx. 601	Combine-Kafir 60 x Tx. 04	87	97	92	67	26	18
Combine Kafir 60		178	87	76	55	18	18
Dwarf Kafir 44-14		199	89	89	67	25	17
Kansas 2212	Redbine-60**	121	97	92	65	34	16
Midland		205	99	92	73	27	16
Plainsman		85	89	79	42	21	12
Tx. 620	Combine Kafir 60 x Tx. 07	105	82	75	53	30	12
Kansas 2211	Combine 7078**	139	81	54	35	15	8
Reliance		133	83	61	45	17	8

Table 1. (Concl.)

Variety or Hybrid***	Pedigree	Original no. of plants	Percent plants alive on June 19	21	23	26	28
	Combine Kafir 60 x						
RS 610	7078	94	95	78	50	8	7
Martin		196	99	88	40	12	5
Redbine 60		149	92	73	33	8	5
	Combine Kafir 60 x						
Neb. 2	Plainsman	146	88	80	36	5	4
CE 5065		64	73	42	29	8	3
Norghum		164	99	92	43	6	2
Kansas 2210	Caprock**	111	81	62	35	4	2
Westland		159	94	61	15	1	1
	Combine Kafir 60 x						
Tx. 660	Caprock	67	88	62	23	3	1
Dwarf Yellow Milo		121	84	67	31	2	1
H-6520*		45	86	55	26	0	0
	Martin x						
CE 5057	Club-day	74	83	63	23	7	0
Total plants		4051					

* Experimental hybrids.

** Male parents.

(1) RS Regional Sorghum.

(2) CE Hybrids from Chillicothe.

Table 2. Sorghum plants alive at stated times during chinch bug test. Agronomy farm, Manhattan, Kansas, 1956. Replication III.

Variety or Hybrid	Pedigree	Original no. of plants	Percent plants alive on July 3	5	9	17	27
Kansas 2210	Caprock**	48	100	100	100	100	100
Martin		49	100	100	100	100	100
Dwarf Kafir 44-14		50	100	100	100	100	98
Redlan		51	100	98	98	98	98
Kansas 2209	Plainsman**	51	100	100	98	98	98
Norghum	Combine Kafir 60	46	100	100	100	98	98
RS 650	Plainsman	49	100	100	98	98	96
Atlas		57	100	100	98	98	96
Neb. 1c		50	100	100	100	96	96
Redbine 60		37	100	100	95	95	95
Combine Kafir 60		50	100	98	98	98	94
Neb. 3	AK 110**	48	100	100	94	94	94
Kansas 2211	Combine 7078**	49	100	100	98	98	92
Reliance		35	100	97	97	91	91
Kansas 2212	Redbine 60**	46	100	100	93	93	89
Midland		55	100	98	93	89	87
Plainsman		52	100	98	90	90	85
Neb. 2	Combine Kafir 60 x Plainsman	49	100	95	95	95	86
Dwarf Yellow Milo		47	100	100	98	81	49
Total		919					

* Experimental hybrids.

** Male parents.

Table 3. Sorghum plants alive at stated times during chinch bug test. Agronomy farm, Manhattan, Kansas, 1957. (This table includes the results obtained in the areas of A, B and C in replication II and III.)

Variety or Hybrid	Pedigree	Original no. of plants	Percent plants alive on June 24	June 28	July 1	July 4	July 8	July 12
Tx. 611	Combine Kafir 60 x Tx. 74	150	100	92	88	73	60	54
H-7922*		149	99	93	79	68	57	53
RS 501(1)	Combine Kafir 60 x Norghum	150	100	99	87	72	53	50
H-7910*		141	99	90	78	63	51	46
Tx. 601	Combine Kafir 60 x Tx. 04	150	100	95	91	71	55	45
RS 610	Combine Kafir 60 x 7078	150	100	96	79	62	46	44
RS 590	Combine Kafir 60 x Redbine 60	149	100	91	78	67	50	44
RS 630	Combine Kafir 60 x Double Dwarf-white feterita	96	99	90	78	71	49	42
Tx. 620	Combine Kafir 60 x Tx. 07	146	100	93	82	71	47	41
CE 5057(2)	Martin x Club-Day	95	100	86	82	67	51	38
N-9		98	99	92	73	72	50	36
H-6542*		99	100	87	69	63	50	36
N-44		100	100	92	80	67	45	35
CE 6074	A 5330 x R 396	100	100	91	75	62	42	35
H-7853*		149	99	88	77	64	49	34
Reliance		100	100	86	72	46	35	32
RS 650	Combine Kafir 60 x Plainsman	150	100	94	73	64	40	31
CE 6078		102	100	95	88	77	42	30

Table 3. (Concl.)

Variety or Hybrid	Pedigree	Original no. of plants	Percent plants alive on June 24	June 28	July 1	July 4	July 8	July 12
Combine Kafir 60		100	100	86	61	49	34	29
Martin		97	100	86	61	43	32	29
Midland		93	100	81	57	54	42	28
Tx. 660	Combine Kafir 60 x Caprock	148	99	89	73	57	36	27
CE 6075		86	100	86	59	47	35	26
H-7854*		148	100	88	72	60	39	25
Dwarf Yellow Milo		89	100	86	72	51	28	21
CE 6031	Martin x Caprock	97	100	80	66	53	33	19
N-41		93	99	85	57	38	21	15
H-6545*		27	100	85	70	59	26	15
Combine 7078		150	99	90	67	47	28	12
Caprock		92	100	86	70	50	24	11
Club x Day		28	100	87	54	36	15	10
Plainsman		97	99	76	65	36	14	9
Total		3619						

* Experimental Hybrids.

** Male parents.

(1) RS Regional Sorghum.

(2) CE Hybrids from Chillicothe.

Table 4. Sorghum plants alive at stated times during chinch bug test. Agronomy farm, Manhattan, Kansas, 1957. Area C.

Variety or Hybrid	Pedigree	Original no. of plants	Percent plants alive on July 12	20	27
RS 610[1]	Combine Kafir 60 x 7078	41	92	89	85
RS 501	Combine Kafir 60 x Norghum	43	90	88	88
Tx. 611	Combine Kafir 60 x Tx. 74	43	87	87	87
RS 630	Combine Kafir 60 x Double Dwarf-white Feterita	46	85	82	82
N-9		38	75	74	72
H-6542*		42	85	72	72
H-7910		45	81	72	69
Tx. 620	Combine Kafir 60 x Tx. 07	36	76	70	70
Martin		34	82	70	57
CE 6074[2]	A 5330 x R 3916	39	75	70	70
RS 590	Combine Kafir 60 x Redbine 60	42	83	69	67
Reliance		32	81	67	67
Tx. 660	Combine Kafir 60 x Caprock	30	71	66	62
H-7922*		51	77	65	65
CE 5057	Martin x Club-Day	48	78	62	55
N-44		44	72	61	54
Combine Kafir 60		41	64	57	55
CE 6078		40	65	55	45
Tx. 601	Combine Kafir 60 x Tx. 04	44	73	54	50

Table 4. (Concl.)

Variety or Hybrid	Pedigree	Original no. of plants	Percent plants alive on July 12	20	27
Midland		46	57	50	50
RS 650	Combine Kafir 60 x Plainsman	40	55	42	42
CE 6075		33	52	41	29
H-7854*		34	57	41	35
H-6545*		11	36	27	27
N-41		29	46	26	21
Dwarf Yellow Milo		33	57	25	13
H-7853*		31	55	25	20
Caprock		34	28	24	19
CE 6031	Martin x Caprock	40	47	22	17
Club x Day		8	42	16	16
Plainsman		24	23	7	4
Combine 7078		36	21	7	2
Total		1178			

* Experimental Hybrids.

** Male parent.

(1) RS Regional Sorghum.

(2) CE Hybrids from Chillicothe.

Table 5. Comparison of per cent sorghum plants alive at stated dates during chinch bug tests. Agronomy farm, Manhattan, Kansas, 1956-57.

Variety or Hybrid	Pedigree	Original no. of plants both years	Percent of plants alive in June 1956	Percent of plants alive in June-July 1957	Average Plants alive 2 years
	Combine Kafir 60 x				
RS 630(1)	Double Dwarf-white Feterita	204	53	42	47
Atlas		196	46	--	--
H-6522*		34	36	--	--
	Combine Kafir 60 x				
Tx. 611	Tx. 74	219	36	54	45
H-6511*		49	35	--	--
	Combine-Kafir 60 x				
RS 590	Redbine 60	235	26	44	35
Neb. 3	AK 110**	182	25	--	--
Neb. 1c		157	23	--	--
Redlan		135	21	--	--
	Combine Kafir 60 x				
RS 650	Plainsman	236	20	31	26
M.S. Combine Kafir 60		149	19	--	--
Kansas 2209	Plainsman**	158	18	--	--
	Combine Kafir 60 x				
Tx. 601	Tx. 04	237	18	45	32
Combine Kafir 60		278	18	29	23
Dwarf Kafir 44-14		199	17	--	--
Kansas 2212	Redbine-60**	121	16	--	--
Midland		298	16	28	22
Plainsman		182	12	9	10
	Combine Kafir 60 x				
Tx. 620	Tx. 07	251	12	41	26
Kansas 2211	Combine 7078**	139	8	--	--
Reliance		233	8	32	20

Table 5. (Contd.)

Variety or Hybrid	Pedigree	Original no. of plants both years	Percent of plants alive in June 1956	Percent of plants alive in June-July 1957	Average plants alive 2 years
	Combine Kafir 60 x				
RS 610	7078	244	7	44	26
Martin		343	5	30	17
Redbine 60		149	5	--	--
	Combine Kafir 60 x				
Neb. 2	Plainsman	149	4	--	--
CE 5065(2)		64	3	--	--
Norghum		164	2	--	--
Kansas 2210	Caprock**	111	2	--	--
Westland		159	1	--	--
	Combine Kafir 60 x				
Tx. 660	Caprock	215	1	27	14
Dwarf Yellow Milo		210	1	21	11
H-6520*		45	0	--	--
	Martin x				
CE 5057	Club-Day	169	0	38	19
H-7922*		149	0	53	--
	Combine Kafir 60 x				
RS 501	Norghum	150	--	50	--
H-7910*		141	--	46	--
N-9		98	--	36	--
H-6542*		99	--	36	--
N-44		100	--	35	--
CE 6074	A 5330 x R 3816	100	--	35	--
H-7853*		149	--	34	--
CE 6078		102	--	30	--
H-7854*		148	--	25	--
	Martin x				
CE 6031	Caprock	97	--	19	--
CE 6075		86	--	26	--

Table 5. (Concl.)

Variety or Hybrid	Pedigree	Original no. of plants both years	Percent of plants alive in June 1956	Percent of plants alive in June-July 1957	Average plants alive 2 years
N-41		93	--	15	--
H-6545*		27	--	15	--
Combine 7078		150	--	12	--
Caprock		92	--	12	--
Club x Day		26	--	10	--
Total Plants		1721			

* Experimental Hybrids. (1) RS Regional Sorghum. (2) CE Hybrid from Chillicothe.

** Male Parents.

Table 6. The number of eggs laid on six plants of each variety by maintaining one pair of chinch bugs on each plant for 25 days. Insectary, Manhattan, Kansas, in 1956.

Variety or Hybrid	Pedigree	Number of eggs laid in July 20	22	24	26	28	30	August 2	4	6	8	10	13	15	Total Eggs	Average per female per day
Dwarf Yellow Milo		17	9	27	14	42	14	15	4	28	7	5	12	13	207	8
Plainsman		17	8	11	21	16	15	12	15	12	2	19	7	2	157	6
RS 650*	Combine Kafir-60 x Plainsman	8	0	2	3	8	2	8	3	8	2	5	2	4	55	2
Combine Kafir-60		4	1	5	4	10	2	5	0	7	7	3	1	0	47	2
Atlas		0	0	0	0	0	0	0	0	1	1	0	2	0	4	0.16

* RS Regional Sorghum.

Table 7. Host preference studies with both sexes of chinch bugs, recorded on four sorghum varieties after various periods of time. Insectary, Manhattan, Kansas, 1956.

Variety or Hybrid	Pedigree	Average number of chinch bugs found on each sorghum plant after hours indicated**				Average per plant
		15hr.	22hr.	40hr.	46hr.	
Atlas		.9	.6	.8	.4	.67
Combine Kafir-60		6	5	3	2	4.0
RS 650*	Combine Kafir 60 x Plainsman	5	4	3	2	3.5
Plainsman		4	4	4	3	3.7

* RS Regional Sorghum.

** Each figure represents average of nine replications.

Table 8. The amount of material that 125 chinch bug adults, both sexes, took from two hybrids and their parents after feeding for 3 hours. Manhattan, Kansas, 1957.

Variety or Hybrid*	Pedigree	Total amount of material (mg.) taken in by 5 chinch bugs from seedling aged in days**					Total in mgs. for 25 bugs	Average for insects in mg.
		4	5	6	8	9		
Combine 7078		.5	2.24	1.70	1.28	1.32	7.10	0.280
RS 610	Combine Kafir 60 x 7078	1.4	1.24	1.26	1.02	1.78	6.70	0.260
Combine Kafir 60		.6	1.02	1.40	1.48	1.72	6.26	0.250
RS 650*	Combine Kafir 60 x Plainsman	.5	1.72	1.51	1.32	1.64	6.71	0.260
Plainsman		.69	1.01	1.40	1.18	1.70	5.98	0.230

* RS Regional Sorghum.

** Each figure in the table represents total amount taken up by 5 chinch bugs.

Table 9. The average amount of plant materials taken in by 40 chinch bugs, males, (20 in each variety) from each of the two sorghum varieties after 3 hours of feeding. Greenhouse, Manhattan, Kansas, 1957.

Variety	Total weight of 20 chinch bugs		Total amount of food taken in	Average per insect
	Before feeding in mg.	After feeding in mg.		in mg.
Dwarf Yellow Milo	24.83	29.21	4.38	0.219
Atlas	26.38	30.12	3.76	0.188

Table 10. The number of chinch bugs, Blissus leucopterus (Say), both sexes, replaced in each of five sorghum varieties in order to maintain six pairs on each for 25 days. Insectary, Manhattan, Kansas, 1956.

Variety or Hybrid	Pedigree	Total
Atlas		74
Combine Kafir 60		43
RS 650*	Combine Kafir 60 x Plainsman	37
Plainsman		27
Dwarf Yellow Milo		23

* RS Regional Sorghum.

Table 11. Classification of sorghum varieties and hybrids according to degree of resistance or susceptibility to the chinch bug attack. Agronomy farm, Manhattan, Kansas, 1956-57.

Variety or Hybrid	Pedigree	Resistant	Intermediate	Susceptible
Atlas (1)***		1		
RS 630 (2)	Combine Kafir 60 x Double Dwarf-white Feterita	1		
H-6522* (1)		3		
Tx. 611 (2)	Combine Kafir 60 x Tx. 74	2		
H-6511* (1)		3		
H-7922* (2)		3		
RS 501 (1)	Combine Kafir 60 x Norghum	2		
H-7910* (1)		3		
Tx. 601 (2)	Combine Kafir 60 x Tx. 04	4		
RS 590 (2)	Combine Kafir 60 x Redbine 60			1
Dwarf Kafir 44-14 (1)				3
Nebraska 3 (1)	AK 110**			3
Nebraska 1c (1)				3
N-9 (1)				1
Combine Kafir 60 (2)				3
H-6542 (1)				1
CE 6074 (1)	A 5330 x R 396			1
H-7853 (1)				2
CE 6078 (2)				3
RS 650 (2)				3
CE 6075 (1)				3

Table 11. (Concl.)

Variety or Hybrid	Pedigree	Resistant****	Intermediate	Susceptible
Dwarf Yellow Milo (2)				4
H-6520* (1)				4
Reliance (2)				2
CE 5057 (2)	Martin x Club-day			2
Tx. 620 (2)	Combine Kafir 60 x Tx. 07			1
Westland (1)				3
Martin (2)				2
Kansas 2210 (1)	Caprock**			3
CE 5065 (1)	Combine Kafir 60 x 7078			3
RS 610 (2)				2
Plainsman (2)				3
Caprock (1)				4
Combine 7078 (1)				3
CE 6031 (1)	Martin x Caprock (A 5330 x R 7000)			2
Club-day (1)				2

* Experimental Hybrids. RS Regional Sorghum. CE Hybrids from Chillicothe.

** Male Parents.

*** The numbers in parentheses are the number of years tested.

**** (1) Most resistant in the class. (2-3) Intermediate. (4) Most susceptible.

THE RESISTANCE OF SORGHUM VARIETIES AND HYBRIDS TO CHINCH BUG BLISSUS LEUCOPTERUS (SAY)

by

JUAN ANTONIO SIFUENTES

Ing. Agronomo, Escuela Superior de Agricultura,
Saltillo, Coah, Mexico, 1952

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1958

The behavior of sorghum varieties and hybrids in the presence of chinch bugs has been studied extensively for a period of about 35 years, but still much remains to be known, especially because every year new hybrids and varieties have been released to the farmers.

Studies on 50 sorghum varieties and hybrids, with a total of 9818 individual plants, were carried out for a period of two years at the agronomy farm of Kansas State College. Some of the new hybrids and new varieties that have been released to farmers recently were exposed for the first time to the chinch bug attack in experiments, and their reactions were compared with the well known varieties or hybrids that have been tested for a long period of time and whose reactions are already known.

Counts of seedling plants were made after various periods of time before and after the chinch bug infestation. These data gave the percentage of plants alive and are an evaluation of the total degree of resistance possessed by each individual variety.

The average percent of plants alive in the 50 sorghum varieties and hybrids ranged from 47 for the most resistant to 0 (zero) for the most susceptible varieties, at different days after infestation.

When the selected sorghum varieties, Atlas and Dwarf Yellow Milo, and the hybrid RS 650 and its parents, Combine Kafir 60 and Plainsman, were tested for antibiosis (by counting

the number of eggs laid by females fed on the respective strains and rate of mortality) it was found that this component of resistance was inherited as a dominant.

As a result of preliminary studies of antibiosis, tolerance and preference with the variety Combine Kafir 60, it was found that the only mechanism of resistance actually present in this variety is tolerance, and to a lesser extent antibiosis.

The amount of plant material taken in by 165 chinch bugs, both sexes and also by the males from seedling sorghum plants, was recorded in the two hybrids, RS 650 and RS 610, and their parents Combine Kafir-60, Plainsman variety and Combine 7078, and also in the highly susceptible Dwarf Yellow Milo, and in the highly resistant Atlas sorghum. The chinch bugs were left without food for a period of 24 hours. The weights of the chinch bugs were recorded individually using a Roller Smith micro-torsion balance which could be read to 0.002 mg. before and after feeding for a period of three hours. The first leaves of the seedling plants were used to feed the insects. No apparent differences were found in the amount of plant material that the chinch bugs took in from the different varieties, but an indication is given that the quality of the plant material is different since this is suggested by the difference in the number of eggs laid on the highly susceptible and the highly resistant sorghum varieties.

In F_1 hybrids, RS 610 and RS 650, both having as one parent Combine Kafir 60, the resistance (tolerance) was

inherited either as dominant or recessive character. This could be explained by the possibility that the factors for susceptibility were ephistatic to resistance in one case (RS 610), or the possibility of having different selections of the Combine Kafir 60 variety used as female parents.

A tentative classification of some of the sorghum varieties and hybrids is presented here. It is expected that more work may change the relative position of the sorghums whose reactions are not yet well known.

Some of the hybrid sorghums or varieties were tested two years and some others only one year. This may influence the difference, if only the average percent of plants alive is considered.