A STUDY OF THE CORN LEAF APHID, *RHOPALOSIPHUM MAIDIS* (FITCH), ON GRAIN SORGHUM IN KANSAS

by

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INTRODUCTION

The corn leaf aphid, Rhopalosiphum maidis (Fitch), is an insect with a wide geographical distribution. Its importance on a number of cereal grain crops such as maize, sorghum and barley, has been reported by several workers and recently has become of increasing concern to growers in Kansas. This aroused interest in investigating just how economically important this insect is on grain sorghum. Other areas of interest relating to the development of an integrated control program were also surveyed, including:

(a) The determination and establishment of the economic threshold of the aphid on grain sorghum.

(b) The determination of the effects of temperature and host plant on the reproductive potential of this aphid.

(c) Host plant resistance studies involving the evaluation of the mechanism of resistance shown by certain sorghum varieties and the possibility of incorporating this resistant germ-plasm into commercially acceptable hybrids.

(d) Chemical control methods, geared towards the evaluation of some selected insecticides used for foliar and soil application.

(e) Biological control: the determination of the effect of parasitism shown by a braconid wasp, Lysiphlebus testaceipes (Cresson) in the control of corn leaf aphid population density.

For many insect species, reliable economic thresholds have not been established. This creates problems in the control of such pest species. With such pests, time of the season, growers' fears or apprehension, salesman persuasion, mere presence, visible signs of feeding and other criteria have been utilized to initiate chemical control. So it is important to establish fairly reliable economic thresholds so that growers can be assured that pest populations below these can be tolerated by plants without economic losses of yield or quality occurring.

Insect populations are markedly affected by environmental conditions. In temperate climates, short periods of relatively extreme heat and cold outside the favorable range often occur during the growing season, and may affect insect survival and population growth. Furthermore, temperature differences may explain minor fluctuations in resistance in the field (Horber, 1972). A knowledge of the favorable range of temperature for survival and reproduction of this aphid seemed essential. Insect resistance is not only a control measure but also a tool to study host plant-insect relationship. The most desirable single way to control or suppress insect damage to crops is by breeding insect-resistant varieties. Evaluation of sources of resistance is necessary in the development of agronomically acceptable hybrids.

The wide variety of successful uses of natural enemies in pest management programs aroused interest in investigating the abundance of the parasites of corn leaf aphids in the field and their significance in the natural control of this insect.

REVIEW OF LITERATURE

Corn Leaf Aphid in General

Corn leaf aphid, Rhopalosiphum maidis (Fitch), belongs to the order Hemiptera, suborder Homoptera, family Aphididae. As a pest, it has been observed on a large number of cultivated and wild plants, generally those plants belonging to the family Poaceae. It is cosmopolitan in distribution.

The first recorded observation of this aphid was by Fitch in 1856. He recognized it as a pest of corn in New York. In 1861, Walsh (1865) observed an aphid attacking the roots of corn, and after comparing it with a specimen of Fitch's, decided they were the same species. It was not until 1891, 1894, and 1905 that Forbes proved conclusively the differences between the corn root aphid which he designated *Aphid maidis radicis* (Forbes) and the corn leaf aphid. He pointed out not only the differences in preference of host plants, but also the characters which differentiate the two species. In 1903, Sanderson reported corn injury by corn leaf aphids in Texas, but details of the nature and degree of injury were not elucidated. In 1909, Davis listed some of the host plants of corn leaf aphids but did not mention the details of the life cycle. Parker (1919), after a trip through western Kansas examining sorghum fields, reported that corn leaf aphid had ruined the crops of that area. Hayes (1919) showed appreciable injury in a test of 17 varieties of sorghum which varied from 3.1% in the case of Sudan grass to 96.5% for feterita. McColloch (1921) observed that corn leaf aphid was an economic pest of both corn and sorghum in Kansas. He stated that in corn, damage was commonly caused by the concentration of the aphids in the tassel, where they prevented the shedding of pollen.

Wildermuth and Walter (1932) reviewed the biology of the corn leaf aphid and reported it as a serious pest of barley, and gave the first detailed study of the life history and found the reproduction essentially parthenogenetic.

Snelling et al (1940) observed that a light infestation of the corn grown in Illinois by Aphis maidis prevented maximum development of plants, and heavier infestation caused complete failure of grain formation. Coon et al (1948) recognized that the corn leaf aphid was one of the major field crop pests in Pennsylvania. Viale (1950) demonstrated the inheritance of resistance to corn leaf aphids in corn. Ali (1950) reported that heavy infestation of corn leaf aphids on sorghum heads caused severe injury to the grain. Howitt and Painter (1956) extensively studied the sources and nature of resistance to the corn leaf aphid in sorghum varieties.

Temperature and Host Plant Influences

Cartier (1957) observed in the greenhouse that corn leaf aphids were inactive at a temperature of 60°F but became active at 75°F. Some were said to have survived temperatures as high as 110°F. Pathak and Painter (1962) observed the fecundity of four biotypes of corn leaf aphids at 45°F on Reno barley. They showed that biotype KS1 had significantly lower fecundity than biotypes KS3 and KS4, but no significant differences occurred between KS1 and KS2. Singh and Painter (1963) noted significant differences on the rate of reproduction by each of the biotypes under different temperatures. At each temperature, differences were observed among biotypes on all hosts except on Spartan barley at 55°F. At high temperatures biotype KS2 survived best on most hosts while KS4 survived on most hosts at low temperature.

Varietal Resistance

Yield and quality in crop plants are the chief goals of modern plant breeders, thus it is important for a crop to be free from insect pests. Snelling et al (1940) noted that the breeding of resistant varieties of corn was a necessary economic tool in the control of corn leaf aphids. McColloch (1921) noted that a considerable difference existed in the infestation and degree of injury among different varieties of sorghum attacked by them. Howitt and Painter (1956) tested varieties in the world collection of sorghum germplasm available in the United States for corn leaf aphid reaction. They demonstrated that certain varieties of the Sudan-type sorghum showed a high level of resistance to the aphid in all preference and antibiotic tests conducted.

Chemical Control Studies

No matter what our attitudes are to the use of pesticides, they remain an integral part of our pest management system. When populations of pests approach economic levels, we need pesticides in order to avoid complete damage. Their effect is immediate and they can be applied when needed. Chemical control studies (Burkhardt, 1955b) showed that endrin (.4-.6 lb/acre), malathion (1.0 lb/acre) and lindane (.33 - .5 lb/acre) gave 96 to 100% reduction of corn leaf aphid population in sorghum heads. Spraying to control this pest in the whorl was found ineffective. Tests conducted in 1957 by Burkhardt at the Kansas Agricultural Experiment Station indicated that control in sorghum whorls with granular Thimet at 1.0 lb/acre gave up to 93% control. Similar results were reported by

DePew and Harvey (1957) at the Garden City and Hays branch Experiment Stations.

MATERIALS AND METHODS

Injury Level Determination

Two fields located at the Rocky Ford Experiment Station were used in this study. The fields were divided into small plots. Each plot consisted of 4 rows, 300 feet long; 2 rows were treated and 2 rows remained untreated. Each treated row was separated from the other by 4 untreated rows. This reduced the chance of insecticide drift between treated and untreated rows and allowed the corn leaf aphid population to develop in the untreated rows.

The determination of the number of corn leaf aphids that must be present on grain sorghum to cause significant reduction in yield is dependent on the ability to locate varying populations on plants of different stages of growth.

Thimet, a systemic insecticide, was used as a granular formulation on the treated rows to remove corn leaf aphid populations. Amounts roughly equivalent to 1.0 lb/acre active ingredient were applied. The granules were applied by hand-shaking the material onto the tops and whorls of the plants. The treatment applied on the 3rd of July, 1972 gave efficient initial knock-down plus systemic action to give a season-long control of the aphids in both fields. One initial problem encountered was the menace of greenbugs on both the treated and untreated plots. It was discovered that the greenbugs could be kept in check by using low levels of emulsifiable malathion without affecting the corn leaf aphid population. A weekly spray schedule with low levels of malathion was applied by means of a knapsack compressed air sprayer equipped with two nozzles. The spray nozzles were directed at the base of the plants where the bulk of the greenbugs were concentrated. Prior to treatment, population of corn leaf aphids was determined on July 1 and 3, 1972, respectively, in the two fields. To do this, 10 randomly-selected plants were cut, bagged, and brought to the laboratory where counts were made. After treatment, weekly samples were taken from each row in the above manner to determine aphid populations in the treated and untreated rows. Sampling was discontinued in the two fields after the plants had reached the boot stage and subsequent counts showed that the aphid population had diminished considerably.

Each time a sample was taken, plant growth stage was scored (Vanderlip and Reeves, 1972). Plant height was taken after the heads had formed. Seed yields were obtained by harvesting four 50-ft sections from each row on October 5. Samples were threshed mechanically, cleaned, weighed, and the data converted to pounds/acre at 12.5% moisture. Number of seeds per gram was also determined.

Population Estimation of Corn Leaf Aphid

Two methods were tested in search of a more practical way of obtaining population estimates of this insect other than manual counting. One method was derived from a technique reported by Gray and Schuh (1941) for sampling pea aphid, Acyrthosiphum pisum (Harris). They fumigated corn leaf aphid-infested plants with methyl iso-butyl ketone (4-methyl-2-pentanone) which apparently caused the insects to release their stylets from the plants. Even though this method proved effective on pea aphids, its effectiveness was limited on corn leaf aphids because of their feeding habits. Most of the aphids were entangled in the whorl by the copious honeydew they produced and therefore could not be shaken free.

A second method consisted of removing all leaves from a plant, unrolling the young leaves from the whorls, examining each leaf for corn leaf aphids and brushing the leaves with a small paint brush into a jar containing 95% alcohol. The alcohol-aphid mixture was poured into a graduated cylinder. The cylinder was rotated to settle the insects to the bottom. The number of corn leaf aphids per ml was accurately determined by counting individual aphids contained in one ml. This was repeated several times and a mean number of 1100 corn leaf aphids/ml was recorded. The volume of the corn leaf aphid samples in ml subsequently obtained was multiplied by 1100; this gave the size of the population at any given sampling time. A problem encountered with this procedure was the presence of plant fragments and other insects. Dirty samples were sifted carefully to separate the insects from other materials in the alcohol.

Temperature and Host Plant Effects on Reproduction

Stock cultures of viviparous, parthenogenetic aphids used were collected from the field (KS-5, Wilde and Feese, 1973). The culture was developed and maintained on seedling RS 701 sorghum in a growth chamber maintained at $80 \pm 5^{\circ}$F and 16:8 light and dark photoperiod.

Comanche wheat, Clintland oats, Spartan barley and RS 610 sorghum were tested at constant temperatures of 45°, 55°, 65°, 75°, 80°, 85° and 90°F. Plants of each variety were sown in 4" earthen pots in a growth chamber. Fecundity studies began when plants were about 2 weeks old.

The cage (Plate I) consists of two glass vials, an upper vial 8" long with 1" diam, with open ends; and a lower vial 3 1/2" long, 1" diam, open at one end only. The lower vial was three-quarters filled with nutrient solution, made by dissolving one teaspoonful of Hyponex in one quart of water. Each lower vial was capped with a plastic top with center removed to allow the seedling to protrude. A foam plastic sponge, partially split longitudinally, was fitted through this hole, and served to hold the plant in position, with the root system fully submerged in the nutrient solution. This also served to prevent the escape of aphids.

Seedlings were removed from the earthen pots and caged as described above. Fifth instar nymphs of alate aphids were placed on the seedling plant of the test variety by means of a camel's-hair brush. The upper glass vial with four windows in its wall covered with nylon screen enclosed the upper portion of the seedling. One of the open ends was stoppered with sponge rubber to prevent aphids from escaping. The vials were fitted into holes drilled in a 43x33x8cm wooden block.

Experiments were conducted in a growth chamber 99x63x86cm, with constant light intensity of approximately 150 ft-candle lamps. Two replications of each host plant were tested at constant temperatures, and the experiment repeated twice. Final counts of the aphids were made 10 days after they were caged.

Non-preference Determination

To determine the presence and degree of non-preference of corn leaf aphids for certain sorghum lines, plants were grown separately in 4" earthen pots filled with vermiculite, and kept in a growth chamber at

$80\pm5^{o}F$ and watered as needed. Preference studies were commenced when the plants were about two weeks old. Four Russian sorghum lines (133ST1, 134ST2, 135ST3, and 136ST4) were evaluated with the commercial hybrid lines, NC+70X and RS 610. One seedling of each entry was caged in a circular pattern with those of the commercial hybrids. The experiment was replicated four times. The criterion used for evaluation was the number of aphids attracted to the various lines caged together. The cage (Plate II) consists of a circular plastic container 5 1/2" diam with one-inch holes 1" at the base. Through these holes, the root systems of the test plants were passed through into a nutrient solution in a plastic container and held in position by means of a split plastic foam fitted into these holes.

The plants were infested by dropping 20 adult corn leaf aphids in the center of the circular plastic container. The infested plants were then covered with plastic cages 6" high and 5 1/2" diam. Two 3" holes in the wall of the cage were covered with nylon screen, and the base of the cage was made to fit into the open end of the circular plastic container. The entire set-up was kept in a growth chamber for 24 hr. Counts of the aphids that had infested each seedling were made after 24 hr.

Laboratory Determination of Antibiosis

The same sorghum lines used for the non-preference studies were tested to determine the presence and degree of antibiosis shown by each line. The criteria used for the evaluation of antibiosis were based on nymphal stadia length, mortality of first instar, adult pre-reproductive period and total progeny produced by a given number of aphids confined on a plant.

Sorghum lines were planted in 4" pots filled with vermiculite. The pots were kept in a growth chamber at a temperature of 80°F and watered as needed until required for use after a two-week period. The caging procedure was identical to that used in the temperature determination. Test plant seedlings were inserted into a 23x85mm glass tubing, three-fourths-filled with nutrient solution. The open end of the upper glass tubing was covered with a rubber sponge.

The Russian lines were separately tested with each of the commercial hybrids with different numbers of aphids. Results of preliminary study by Wilde and Feese (1973) to determine the best infestation procedure showed that significant damage occurred in 7 days with 20 aphids. Each entry in the first set-up was accordingly infested with 20 aphids plus a control.

Five aphids were used for the second test. The progeny produced after 7 days were counted, and plant height measured in the first test.

The determination of the nymphal stadia lengths, mortality of first instar and the adult pre-reproductive period was done by caging first instar nymphs on the leaves of each of the sorghum lines (Plate III). The cage consisted of a small clip-on cage made from 1" diam cages (Plate III). A screen-covered hole 3/4" diam on one side of the cage allowed ventilation within the cage.

First instar nymphs were caged on the test plant leaves at random and examined every 24 hr. The nymphal instar length, mortality of first nymphal instars, and the adult pre-reproductive period on each of the sorghum lines was determined and recorded.

Field Resistance Evaluation

Five lines were evaluated under field conditions with natural corn leaf aphid infestation to determine differences in degree of susceptibility. Lines included were 133ST1, 134ST2, 135ST3, 136ST4 and RS 610.

The experiment was carried out on the Agronomy research farm. The single plot consisted of one row 25 ft long. Because of lack of seeds, the plots were not replicated. Planting was done June 20. As a result of heavy infestation of greenbugs on neighboring sorghum plots, the base of the emerging seedlings was sprayed with malathion to keep off greenbugs. The spraying was repeated at 10-day intervals. Weekly corn leaf aphid counts were made on five randomly selected plants from each row from July 6 to August 1, 1972, when aphid numbers diminished considerably.

Insecticide Tests

Foliar application. The study was conducted on a small plot chosen from a large sorghum field near Silver Lake, Kansas. The main purpose was to evaluate the effectiveness of different insecticides applied at different rates and as different formulations on the initial and residual control of corn leaf aphid populations. Each plot was one row 100 ft long and replicated three times. Initial corn leaf aphid populations were determined by cutting ten plants at random. These were bagged and brought to the laboratory where counts were made in the manner already described.

Problems were encountered with a greenbug population which was also present in the field. However, control of the greenbugs was effected without reducing corn leaf aphid populations by spraying with low rates of malathion at the base of the plants. The rows were treated on June 26. First sample after treatment was taken on the 4th of July, by cutting four plants per 100-ft row. These samples were bagged separately and brought to the laboratory for counting. Further sampling and counting was done on July 13 on the rows indicated in the table. No further samples were taken after this date since aphid numbers diminished considerably through parasitism and predation. No yield data were obtained since the farmer harvested the plots before harvest samples could be taken.

Soil application. Treatments were arranged in a randomized complete block design. Individual plots were four rows wide by 300 ft long and each treatment was replicated twice, including a control plot. Two granular systemic insecticides, Disyston and Thimet, were applied at planting time June 1, 1972. The seed furrow treatment was applied with a tractor-mounted applicator in a 5" band. Amounts equivalent to 1.0 lb/acre were applied.

Corn leaf aphid counts were begun July 7, 1972. Samples were taken at 10-day intervals. Ten plants were selected at random from each row, cut, bagged and brought to the laboratory for counting. Samples were taken on three different dates before aphid population diminished considerably.

Each time samples were taken, plant growth stage was recorded. Seed yields were obtained by harvesting four 50-ft sections from each row October 10, 1972. Samples were threshed mechanically, cleaned, weighed and the data converted to pounds per acre at 12.5% moisture content.

Parasitic Effects of *Lysiphlebus testaceipes*

A laboratory test was set up to determine the effect of a parasitic braconid wasp, *L. testaceipes* (Cresson), on the population build-up of corn leaf aphid.

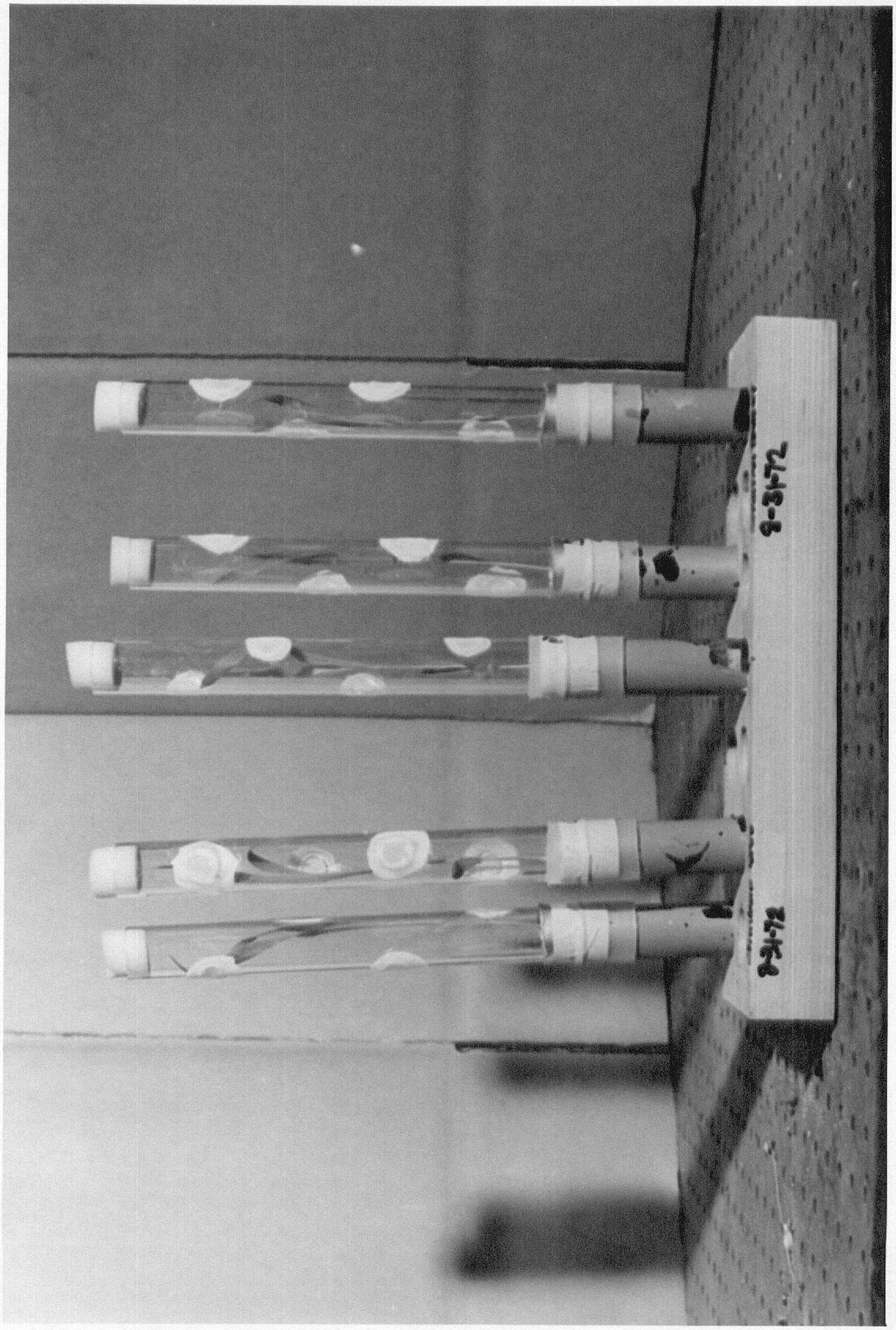
Approximately 50 to 60 701 sorghum seeds were sown in vermiculite in two 4" pots. The seeds were watered as needed, and set apart in a growth chamber for germination. When the plants were about two weeks old, the bases of the plants in the pots were covered with river sand to enable aphids and mummies which might eventually drop from the plants to be picked up easily. Into each of the pots were introduced 50 adult aphids, and inverted over the plants in each pot was a plastic cage 12" long and 4" diam, with two windows covered with nylon screen (Plate IV). These plastic cages were firmly inserted into the river sand covering the base of the plants. Each cage was covered at the top with a tight-fitting cover to prevent the escape of aphids or parasites.

A number of mummies on sorghum leaves were collected from a laboratory parasite colony and were placed individually in small plastic vials for emergence. About 24 hr later, depending on the age of the mummies collected, a number of L. testaceipes adults were observed in the containers. These were sexed by identifying the long ovipositor in the female. Mating was accomplished by isolating single males and females in small vials. When mating was observed, the females were taken out and introduced into each pot infested with 50 corn leaf aphids, making sure that the plastic cage was tightly closed afterwards. The pots were then kept in different growth chambers under 16:8 photoperiod and 80°F. Watering of the plants was done as needed. One pot was evaluated at 14 days and the other at 18 days by counting the number of parasitized aphids (mummies) on each plant. Also, the number of live corn leaf aphids was counted and recorded in both infested and control pots.

EXPLANATION OF PLATE I

Cages used to confine corn leaf aphids on single plants for fecundity studies.

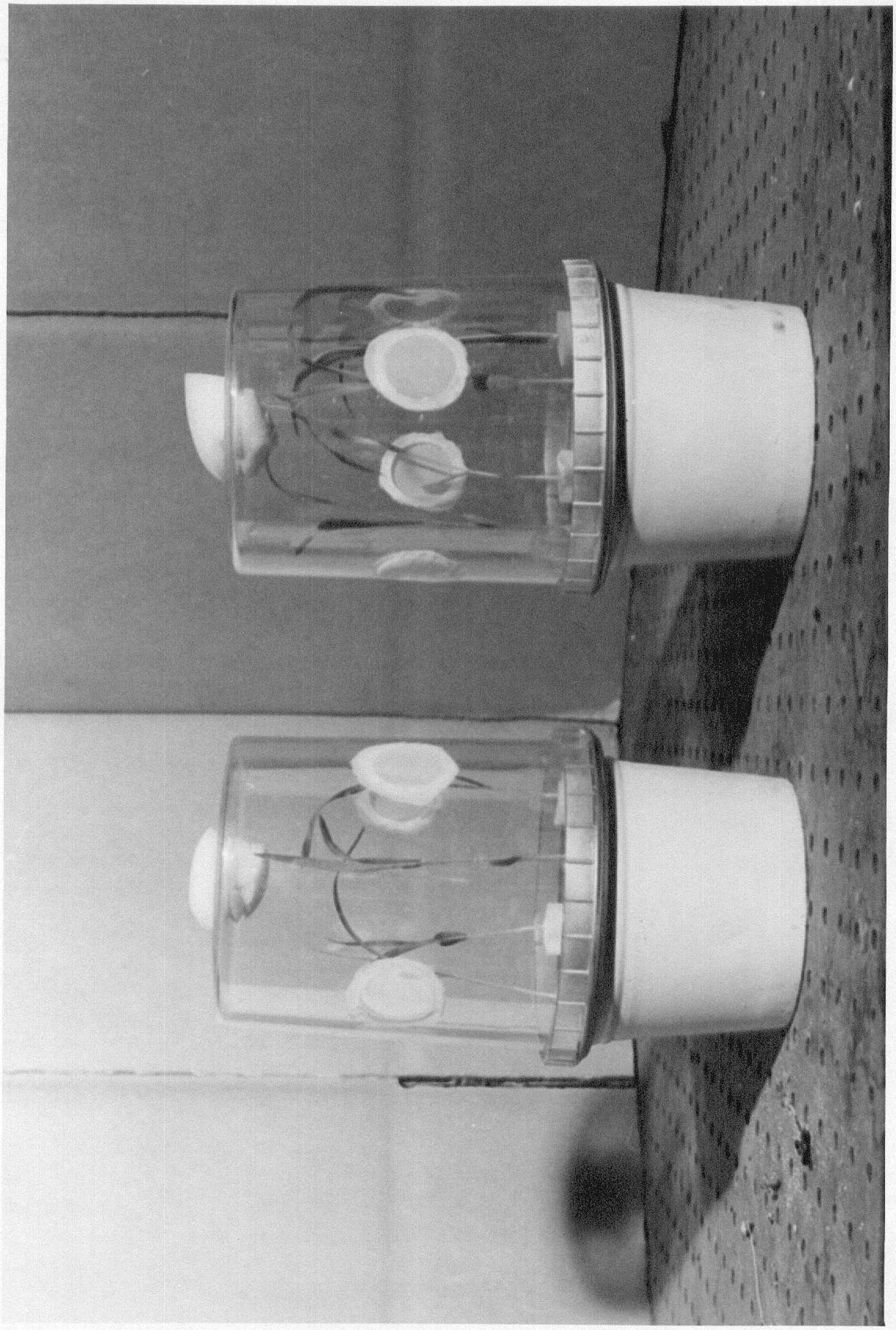
PLATE I



EXPLANATION OF PLATE II

Cages containing different sorghum varieties for non-preference determination.

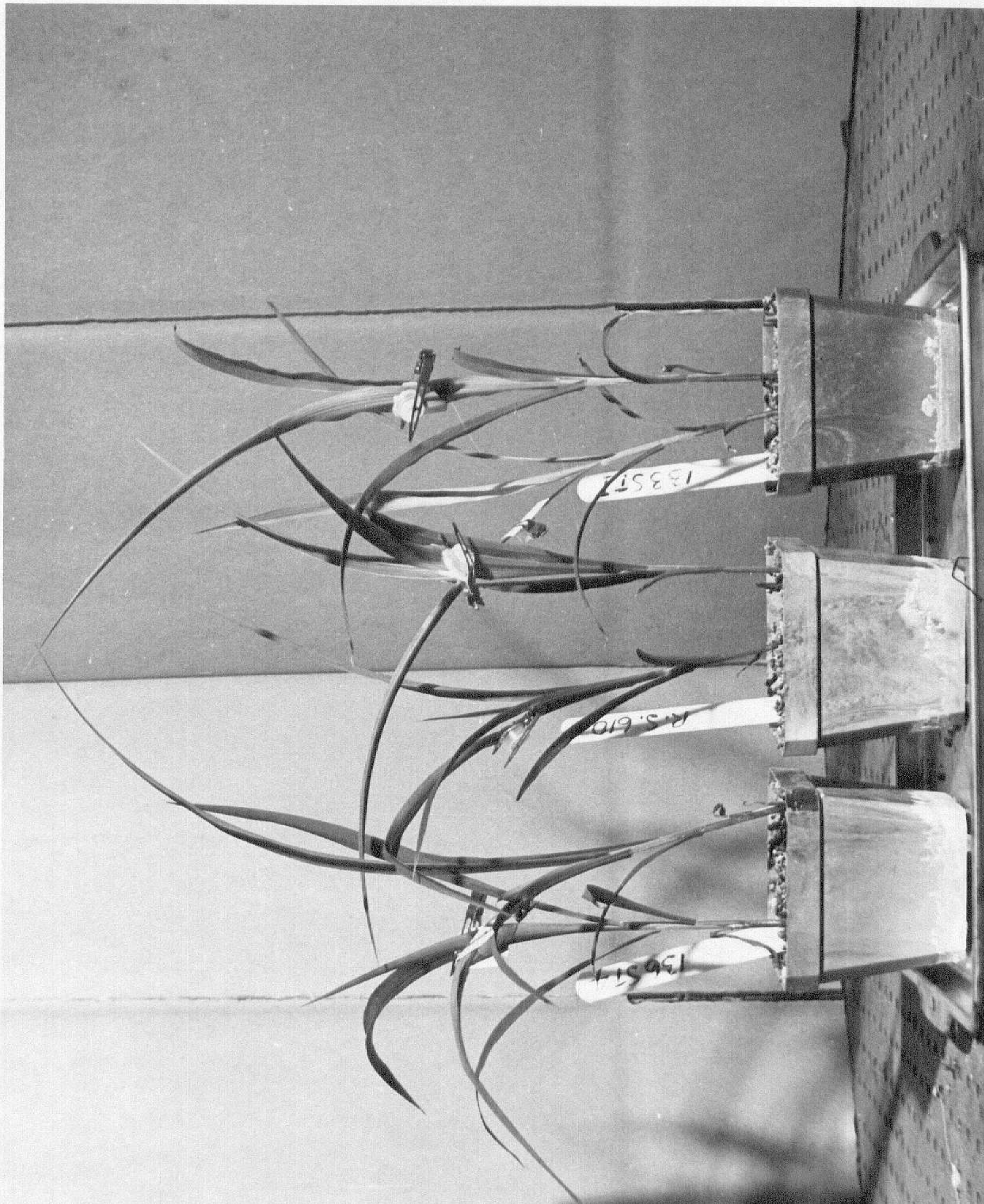
PLATE II



EXPLANATION OF PLATE III

Clip-on cages used to confine single first instar corn leaf aphid nymphs on different sorghum lines for antibiotic studies.

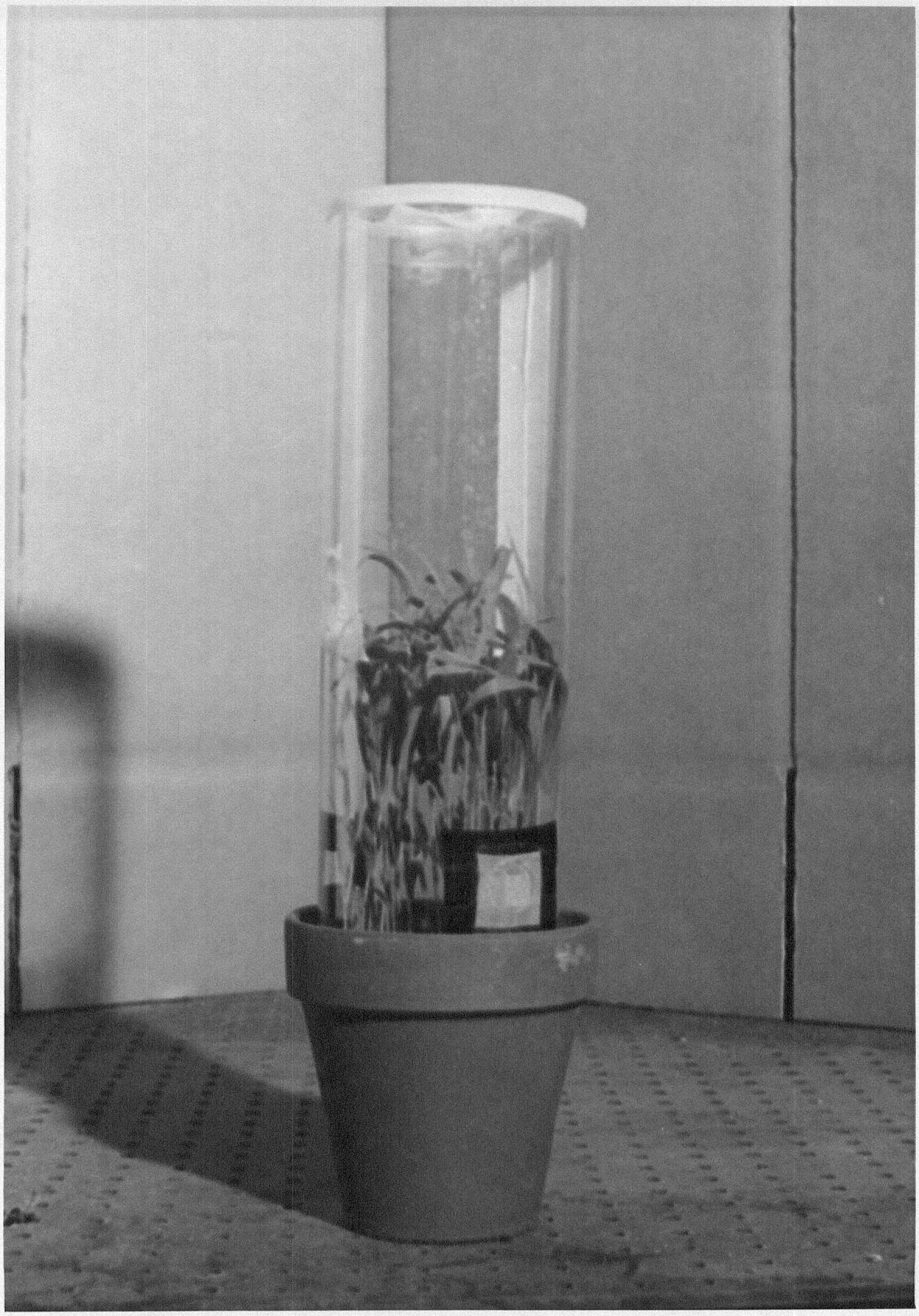
PLATE III



EXPLANATION OF PLATE IV

Plastic cage used to confine aphids and a fertilized *Lysiphlebus testaceipes* female to determine level of parasitism.

PLATE IV



Evaluation of Parasitism in the Field

Samples were taken from rows where greenbugs were adequately controlled throughout the season by the use of low rates of malathion sprayed at the bases of the plants. Sampling was done on July 13, the peak infestation date, and nine days later (July 22) when the aphid population had virtually disappeared.

Samples were taken from rows 50 ft long replicated three times. Three plants were taken per 50-ft row, brought to the laboratory, and the number of live aphids and mummies on three leaves per plant counted and recorded. Counts were taken from one leaf each from the top, middle and bottom of each plant sampled.

RESULTS AND DISCUSSION

Injury Level Determination

Tables 1 and 2 depict the results of the study conducted at two sites in Kansas. The two fields showed moderate (just over 1000 and 1500 corn leaf aphids per plant) populations of corn leaf aphids prior to treatment on July 1 and July 3, 1972, respectively. Treatment was on the 3rd of July, and sampling was done on three later dates, during which time the population of aphids in the check rows diminished and by July 24 had nearly disappeared in the two fields. There were no differences in the heights of plants in treated and untreated rows.

Yield data were taken on October 5, 1972, and the yields between the treated and untreated rows were not significantly different when analyzed statistically at the 5% level of probability (F-test). In test 1 (Table 1), the untreated rows outyielded the treated rows by 400 lbs, while in test 2 (Table 2), the treated outyielded the check by about 500 lbs. In both tests, the untreated rows yielded a higher average number of seeds per gram than the treated rows, but again these were not significant.

There is strong suggestion from the data that no significant reduction in yield should be expected with population levels of about 1000 and 1500 corn leaf aphids per plant. These results also suggest that average numbers of corn leaf aphids can be tolerated in grain sorghum without economic loss, especially when environmental conditions for good plant growth are adequate. Rainfall and temperature figures from May to October, 1972 in Manhattan, Kansas are listed in Table 3.

Temperature and Host Plant Effects on Reproduction

Table 4 summarizes the results of the reproduction of corn leaf aphids on different host plants. Seventy-five degrees F was optimum for reproduction of corn leaf aphids on Clintland oats, Spartan barley and Comanche wheat. On RS 610 sorghum, the optimum for reproduction was 85°F. There was increase in fecundity with each 10° rise in temperature, until the optimum was reached at 75° for Spartan barley, Clintland oats and Comanche wheat, and 85° for RS 610 sorghum. There was no difference in reproduction rate on Spartan barley at temperatures of 75° and 80°. A similar trend was shown on Comanche wheat, but on Clintland oats reproduction was virtually nil above 75°. On sorghum, highest reproduction occurred at 85° (Table 4 and Fig. 1). The aphids showed some measure of uniformity in reproduction on Spartan barley from temperature ranges of 65°-85°, indicating that the host influences temperature effects.

Table 1. Determination of corn leaf aphid (CLA) injury level to grain sorghum. Rocky Ford, Riley County, Kansas. Site 1.

Date sampled	Date treated	Avg No. of CLA/plant a/		Stage of plant development b/	Plant data: Height (cm)		Plant data: Avg No. seed/gram c/		Plant data: Avg yield/acre d/	
		Treated	Check		Treated	Check	Treated	Check	Treated	Check
									(lbs)	
1972										
July 1	--	1047	1047	3	45	45				
	7-3-72	--	--							
July 10	--	5.5	330	3	45	45				
July 17	--	< 2.6	242	5	48	48				
July 24	--	0	0	6-7	48	48				
Oct. 5	--	--	--	--			35.4 e/	38.0 e/	5,500 e/	5,900 e/

a/ Mean number/plant. Average of 4 replications.

b/ Stage (1-7): 1 = 3 leaf stage; 2 = 5 leaf stage; 3 = growing point differentiation; 4 = final leaf visible in whorl; 5 = boot stage; 6 = half bloom; 7 = soft dough.

c/ Average No. of seeds/4 replicates.

d/ Average yield/acre/4 replicates.

e/ No significant difference at 5% level, F-test.

Table 2. Determination of corn leaf aphid (CLA) injury level to grain sorghum. Rocky Ford Experiment Station, Site II.

Date sampled	Date treated	Avg No. of CLA/plant a/		Stage of plant development b/	Plant data					
					Height (cm)		Avg No. seed/gram c/		Avg yield/acre d/ (lbs)	
		Treated	Check		Treated	Check	Treated	Check	Treated	Check
1972										
July 3	--	1540	1540	3	45	45	--	--	--	--
	7-3-72	--	--							
July 10	--	10	375.5	3-4	47	47	--	--	--	--
July 17	--	0	330	4-5	48	47				
July 24	--	0	0	5-6	50	50	--	--	--	
Oct. 5	--	--	--	--	--	--	42.6e/	44.1e/	3,960e/	3,416e/

a/ Mean number/plant. Average of 4 replications.

b/ Stage (1-7): 1 = 3 leaf stage; 2 = 5 leaf stage; 3 = growing point differentiation; 4 = final leaf visible in whorl; 5 = boot stage; 6 = half bloom; 7 = soft dough.

c/ Average No. seeds/gram/4 reps.

d/ Average yield/acre/4 reps.

e/ Calculated at 12.5% moisture. Not significant at 5% level, F-test.

Table 3. Monthly rainfall and average monthly temperatures, May-October, 1972, Manhattan, Kansas.

Month	Monthly rainfall (inches)	Avg temperature (^{o}F)
May	3.02	62.5
June	3.00	76.1
July	7.96	76.4
August	4.04	77.8
September	5.79	70.9
October	2.21	--

Table 4. Colony size produced in 10 days by five last nymphal instars of corn leaf aphids on varieties of small grains at different temperatures.

Host plant	Average number of aphids after 10 days at ^{o}F 1/						
	45°	55°	65°	75°	80°	85°	90°
Clintland oats	2.0 a 2/	4.5 a	5.16 a	7.65 a	0.0 a	0.0 a	0.0 a
Spartan barley	0.0 a	5.0 a	42.25 b	64.05 b	63.3 c	37.75 b	5.65 a
Comanche wheat	0.0 a	5.5 a	6.0 a	15.15 a	14.0 b	0.8 a	0.65 a
RS 610 sorghum	4.0 a	12.0 a	13.65 a	48.0 b	58.0 c	62.7 b	14.5 b

1/ Each number represents the average of three replications with experiment repeated twice.

2/ Means followed by the same letter are not significantly different at 5% level.

EXPLANATION OF FIG. 1

Graph showing effect of temperature and host plant on the fecundity rate of the corn leaf aphid.

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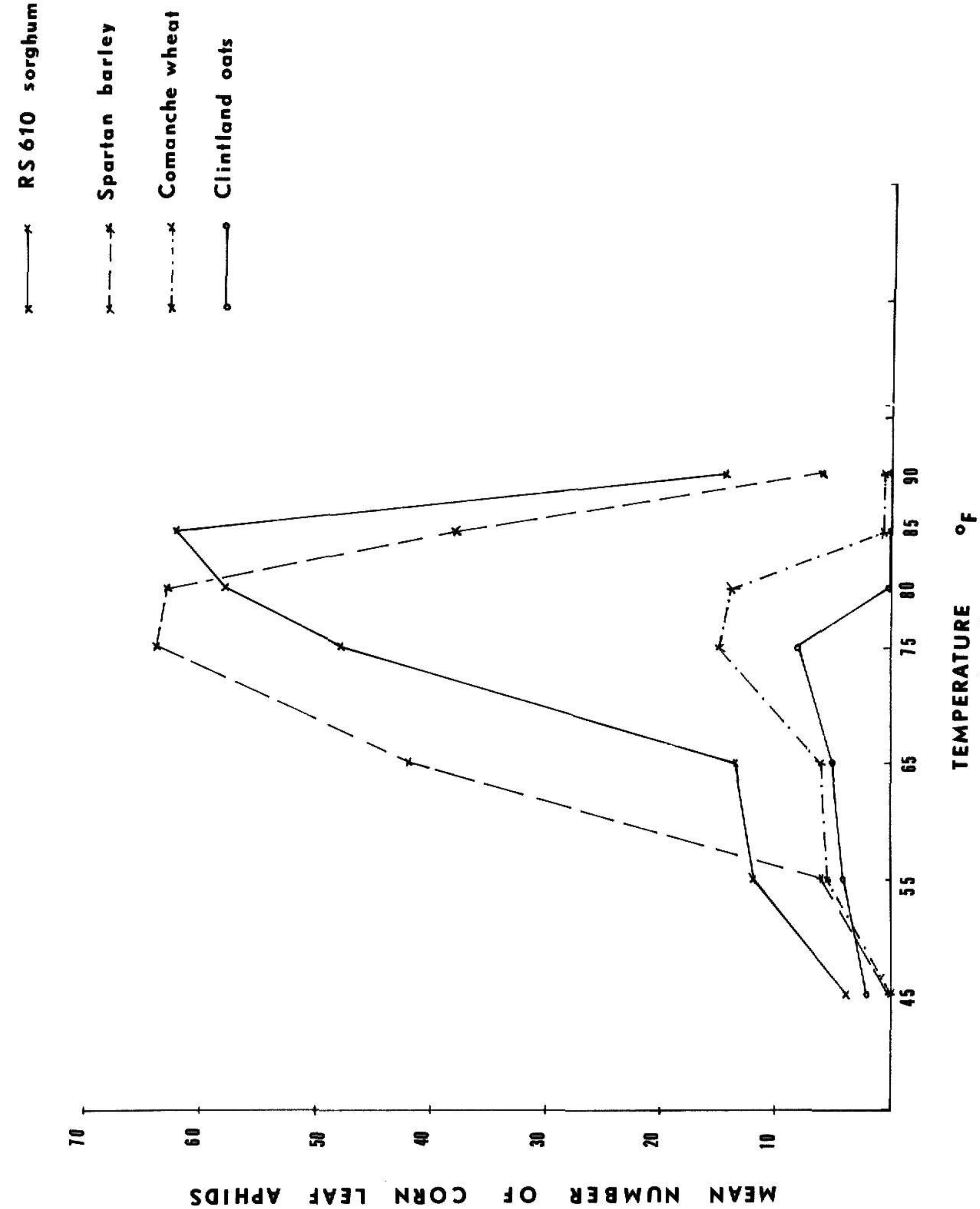

RS 610 sorghum
Spartan barley
Comanche wheat
Clintland oats
MEAN NUMBER OF CORN LEAF APHIDS
70
60
50
40
30
20
10
45
55
65
75
80
85
90
TEMPERATURE °F

Fig. 1

Wilde and Feese (1973) reported the optimum temperature for reproduction of this aphid on sorghum to be 85°. The results of this experiment on sorghum is in agreement with their findings.

These results show that different temperatures definitely had differential effects on aphid colony size, which in turn was affected by the host plants. Reproduction on Comanche wheat and Clintland oats was least affected and essentially uniform throughout the temperature range used in the experiment. At the highest temperature of 90°, fecundity and survival were reduced on all host plants; the same was true at the lowest temperature of 45° used in the experiment. Studies by Harrison and Barlow (1970) on the population growth of the pea aphid, _A. pisum_ (Harris), showed that exposures to extremes of temperature may result in fewer progeny and later attainment of peak fecundity.

From the responses shown on wheat and oat varieties, it seems obvious that these small grains do not support significant aphid population at any temperature, and this seems to be the case under natural conditions wherever these two crops are grown in Kansas.

Non-preference Determination

Tables 5 and 6 show an obvious non-preference of corn leaf aphid for the lines 133ST1, 135ST3, 134ST2 when infested with 20 aphids as compared with the susceptible line, NC+70X. When these lines were tested individually with this hybrid, the same non-preference was shown. However, among the resistant lines tested, 135ST3 was least preferred (Table 5) while there was no significant difference in the number of aphids on the lines 133ST1 and 134ST2.

Table 5. Non-preference shown by some Russian lines compared with the commercial hybrid NC+70X sorghum (4 reps).

Entries[a/]	Avg no. aphids/entry 24 hr after infestation
133ST1	3.25
134ST2	3.88
135ST3	2.13
NC+70X	5.35**

a/ Two-week-old seedlings used.

** Significant at the 5% level, F-test.

Table 6. Non-preference determination showing individual comparison between NC+70X and the Russian lines (3 reps).

Entries	Avg no. aphids/entry 24 hr after infestation	Mean diff.
133ST1	3.33	
versus		1.33
NC+70X	4.66	
134ST2	2.66	
versus		1.09
NC+70X	3.75	
135ST3	2.35	
versus		1.98
NC+70X	4.33	

When these Russian lines were caged with another commercial hybrid, RS 610, the same trend of infestation was manifested (Tables 7 and 8). RS 610 was most preferred while among the Russian lines the number of aphids on 134ST2 and 136ST4 was significantly higher than on 135ST3 and 133ST1, respectively. However, 135ST3 was least preferred. It is apparent that this particular line carries a high degree of non-preference.

The attraction of the aphids to the individual plants and the number per plant per day, measures preference or non-preference. These results indicate that non-preference is one of the mechanisms of resistance shown by these four Russian lines. However, total avoidance of these lines did not occur and subsequent tests showed that corn leaf aphids can be maintained on these lines.

Laboratory Determination of Antibiosis

The study was designed to determine the degree of antibiosis exhibited by the Russian germplasm (Tables 9 and 10). Table 9 shows the average number of progeny produced by 20 last instar nymphs of corn leaf aphids within a 7-day period on each of the lines indicated. The percentage reduction in plant height was also recorded.

Table 10 shows the average number of progeny also produced with 5 last instar nymphs within a 7-day period of infestation. Here, the commercial hybrid RS 610 sorghum is compared with the Russian lines. Visual observation of the various lines indicated no difference in the height of the plants and therefore the percentage height reduction was not determined.

Table 7. Non-preference shown by some Russian lines compared with the commercial hybrid RS 610 sorghum (4 reps).

Entries [a/]	Avg no. aphids/entry 24 hr after infestation
133ST1	3.5
134ST2	5.5
135ST3	1.89
136ST4	5.5
RS 610	7.5**

a/ Two-week-old seedlings used.
** Significant at 5% level, F-test.

Table 8. Individual comparison between RS 610 and the Russian lines (3 reps).

Entries	Avg no. aphids/entry 24 hr after infestation	Mean diff.
133ST1	4.0	
versus		4.5
RS 610	8.5	
134ST2	2.0	
versus		9.5
RS 610	11.5	
135ST3	3.5	
versus		5.0
RS 610	8.5	
136ST4	5.0	
versus		0.5
RS 610	4.5	

Table 9. Determination of the fecundity rates of 20 apterous corn leaf aphids after 7 days exposure to sorghum lines (6 reps).

Entries	Total no. aphids after 7 days	Avg no. aphids	Avg ht (cm) Infested	Avg ht (cm) Non-infested	% Reduction plant ht
133ST1 R/	353	58.8	187.5	236.7	20.8
134ST2 R/	360	60.0	186.0	240.0	22.5
135ST3	355	59.1	174.2	222.5	20.1
NC+70X C/	850	141.6**	171.3	224.5	23.7

R/ Russian germplasm.

C/ Commercial hybrid.

** Significant at the 5% level, F-test.

Table 10. Fecundity of 5 apterous corn leaf aphids after 7 days exposure to different sorghum lines (3 reps).

Entries	Total no. aphids/entry after 7 days	Avg no. aphids after 7 days
133ST1 R/	99	33.0
135ST3	84	26.0
136ST4	88	29.3
RS 610 C/	232	77.3**

R/ Russian germplasm.

C/ Commercial variety.

** Significant at the 5% level, F-test.

The average number of progeny produced by the aphids on the commercial hybrid NC+70X (141.6) was significantly greater than the 58.8, 60.0, and 59.1 observed on lines 133ST1, 134ST2, and 135ST3, respectively. However, a comparison of the numbers of progeny produced on the different Russian lines showed no significant difference. Even though there seems to be some difference in percentage height reduction between the commercial hybrid and the Russian lines, this difference is not statistically significant.

In Table 10, where the different entries were exposed to 5 aphids for 7 days, the same trend in progeny occurred. Highest progeny production was 77.3 on RS 610 and significantly greater than that on the Russian lines. Of the Russian lines, 135ST3 supported the lowest aphid population.

Based on duration of nymphal developmental period, corn leaf aphids reared on these Russian lines required a longer development period than those reared on the commercial hybrid RS 610 (Table 11). On line 133ST1 the aphids required 7.0 days to reach the adult stage while only 5.0 days were required on RS 610. The duration of the pre-reproductive period did not reveal any obvious trends. There was higher mortality of the first instar nymphs on the Russian lines than on RS 610. The number of moults undergone by the aphids on each entry was hard to determine mainly because of the translucent nature of the cages used. However, a count of the cast skins left inside the cages showed that aphids caged on the Russian lines underwent more moults than those caged on RS 610.

From all the tests and observations, it appears that the Russian germ plasm carried some level of resistance in the form of antibiosis. The level of resistance, however, is not extremely high since these aphids did maintain some populations on these lines.

Table 11. Laboratory determination of antibiosis based on nymphal developmental period length, adult pre-reproductive period and mortality rate of first instars.

Entry	Mortality of 1st instars [a/]	Nymphal developmental period (days)	Adult pre-reproductive period (days)
133ST1	2	7.0	1
134ST2	2	6.0	1
135ST3	3	6.5	1
136ST4	2	6.0	1
RS 610	0	5.0	1

a/ Each number represents an average of 4 cages/plant.

Field Resistance Evaluation

Table 12 shows the result of the natural infestation of corn leaf aphids and their performance on certain Russian lines of grain sorghum when compared with the commercial hybrid RS 610. Four sample dates are shown on the table and the average number on the different lines for the four sampling dates indicated. The highest figure of 638 corn leaf aphids per plant was recorded on July 6, 1972, on RS610 sorghum. This was significantly greater than on all other entries on the same date even though the highest numbers of aphids were recorded on this date on all the entries. Thereafter, the numbers decreased progressively and were almost eliminated by August 1.

The average number of aphids on each entry over the four sampling dates indicated that RS 610, with an average of 228.25 corn leaf aphids per plant had a significantly higher population than that on the other lines.

Among the Russian lines, 136ST4 with an average of 135.45 seemed to have the highest infestation.

This trend in field infestation seemed to confirm the laboratory tests already described. However, the field infestation on this particular field was very low, and it was difficult to see any visible damage either in plant height reduction or leaf damage as a result of corn leaf aphid feeding activity. These Russian lines of sorghum did show some degree of resistance both in the seedling stage in the laboratory and in the mature stage in the field. Since the infestation, or lack of infestation, in sorghum varieties by corn leaf aphids appears to be a

Table 12. Evaluation of resistance of certain sorghum lines to naturally occurring infestations of corn leaf aphid (CLA) in the field.

Entry	No. of CLA/plant on observation dates a/				Avg over 4 samplings
	6-VII-72	18-VII-72	25-VII-72	1-VIII-72	
133ST1	220.0	75.0	30.0	10.0	83.75
134ST2	293.4	50.0	36.66	14.7	98.69
135ST3	330.0	63.5	17.66	5.56	104.18
136ST4	420.0	52.5	56.66	12.66	135.45
RS 610	638.0	125.0	100.0	50.0	228.25**

a/ Each figure represents an average of 5 plants/25-ft row.

** Significant at the 5% level, F-test.

Damage on the leaves was insignificant at this infestation level.

heritable trait (Howitt and Painter, 1956), it would be possible to incorporate these resistant germplasms into a sorghum breeding program. These Russian sorghum lines have been made available to the sorghum breeders of Kansas State University.

Insecticide Tests

<u>Foliar application</u>. Table 13 depicts the results of the test. Although no yield data were available the results do give some practical and valuable information. The different insecticides gave some measure of control 9 days after treatment, July 4, 1972. The best control was given by Thimet granules applied over the whorls at the rate of 1.0 lb/acre.

Cygon gave good control applied as liquid spray over the whorl at the rate of 0.3 lb and 20 gallons of water per acre. These two rows were further sampled on July 13, and as shown in Table 13, Thimet gave a better residual effect on aphid population than Cygon 18 days after treatment. It appears that Thimet, when applied over the whorl as granular formulation, gave the best initial and residual control.

<u>Soil application</u>. This study was designed to test the residual effect of Disyston and Thimet granules applied at planting time. Table 14 shows corn leaf aphid populations on different sampling dates and at different stages of plant development. Greenbugs, <u>Schizaphis graminum</u> (Rond), were also present in this test. Disyston granules gave a 92.3% control of corn leaf aphids as compared with 88.4% control given by Thimet granules. Yield data analyzed statistically indicated that yield values associated with various treatments were not significantly different from the check at the

Table 13. Corn leaf aphid (CLA) control. Foliar application of different rates and different formulations of selected insecticides.

Treatment	Rate AI and water/acre	Corn leaf aphids[a] on		
		July 4	July 13	
		CLA/plant	CLA/lower leaf	CLA/plant
Cygon	.3 & 40 gal. over whorl	550	27.25	b/
Malathion	.1 & 20 gal. at base	1540	--	--
Pencap	.25 & 20 gal. over whorl	1320	16.0	--
Disyston	.5 & 20 gal. over whorl	660	19.3	--
Cygon	.3 & 20 gal. over whorl	440	12.0	440
Malathion	1.0 & 20 gal. over whorl	682	15.1	--
Thimet 15G	1.0 over whorl	82.5	0.6	176
Disyston 15G	1.0 over whorl	880	0.5	--
Cygon	.5 & 20 gal. over whorl	1540	5.0	--
Cygon	.5 & 40 gal. over whorl	660	2.1	--
Check row	-----	2490	--	1741

a/ Initial No. CLA/plant taken from 10 random samples from untreated rows on June 29, 1972 = 2303.
b/ Not sampled.

Table 14. Effect of Disyston and Thimet on corn leaf aphid and greenbug populations applied at planting time in 5" band as granular formulation.

Sampling date	Corn leaf aphids/plant			Greenbugs/bottom leaf			Stage 2/ of plant development
	Disyston 1.0 lb	Thimet 1.0 lb	Untreated	Disyston 1.0 lb	Thimet 1.0 lb	Untreated 1/	
July 7	46.75	58.25	855	-	-	-	2
July 17	29.63	47.93	235.0	3.2	75.8	200	4
July 28	19.41	34.65	124.0	-	-	-	5-6
Oct. 10 (yield data in lbs/acre	4910	5793	5040 3/				

1/ Each number represents average of three replicates.

2/ 2 = leaf stage; 4 = final leaf visible in whorl; 5 = boot stage; 6 = half bloom.

3/ Not significant at 5% level, F-test.

5% level, suggesting that the plants can withstand population levels of both insects as they occurred in this test without affecting yield.

Parasitic Effects of *Lysiphlebus testaceipes*

Table 15 shows the results of the laboratory tests carried out on different dates and different exposure periods. Within a period of 14 and 18 days, respectively, the aphid populations in both cases were markedly reduced. In the first case, where a single fertilized female parasite was introduced and the experiment allowed to run for 14 days, the number of live aphids in the control, 2310, was almost double that in the parasite-infested pot, 1410, and the number of parasitized aphids counted was 14. At the time the experiment was discontinued, some adult parasites were seen flying around within the cage.

The reduction in the numbers of live aphids was more dramatic on the cages allowed to run for 18 days. Here, the number of mummies counted was 32; and the number of live aphids in the control was 1391, 6 times as many as in the parasite-infested cage. However, corn leaf aphid multiplication seemed to have been higher on the plants caged for 14 days than on those run for 18 days. It is difficult to offer a satisfactory reason for this difference in numbers, but since the experiments were carried out in two different growth chambers minor temperature differences might have been responsible for the higher aphid numbers in the cage held for 14 days.

In the field test (Table 16) sampling on July 13 showed that mummified aphids formed 15.07% of the total aphid population of the plants sampled. Nine days later, July 22, the entire aphid population had been decimated and the leaves sampled had over 100 mummies each. This total disappearance

Table 15. Laboratory determination of the effect of Lysiphlebus testaceipes (Cresson) on the population of corn leaf aphid.

Date infested	Date of final count	No. days exposure	No. aphids before	No. aphids after: No parasite present	No. aphids after: Parasite present	No. mummies
18-II-72	3-III-72	14	50	2310	1410	14
28-II-72	17-III-72	18	50	1391	252	32

Table 16. Field observation of the effect of Lysiphlebus testaceipes on corn leaf aphid population.

Sampling date	Mean No. aphid/leaf a/	Mean No. mummies/leaf a/	Mean % of aphid population
13-VII-72	252.7	44.9	15.07
22-VII-72	0	> 100	--

a/ Each number represents the average of 3 replications.

of corn leaf aphid population cannot be wholly attributed to parasitism by L. testaceipes. Other density governing factors such as disease and predation by existing lady beetles, Hypodermia convergens, probably contributed to the corn leaf aphid elimination. Both the laboratory and field tests indicated that L. testaceipes has the ability to effectively reduce corn leaf aphid numbers.

SUMMARY AND CONCLUSION

The main objective of this study was to determine the economic importance of the corn leaf aphid, Rhopalosiphum maidis (Fitch), on grain sorghum in Kansas. If important, what simple measures could be taken to achieve economic control?

The results of the field tests to determine the injury level of this aphid, under natural infestation, on grain sorghum in two sites in Kansas, showed that populations of corn leaf aphids of about

1000-1500 per plant can be tolerated by grain sorghum under good growing conditions without significant reduction either in yield or seed weight.

The result of the evaluation of the effect of temperature on the survival and population growth of this insect under laboratory conditions showed that reproduction on RS 610 sorghum was highest at a temperature of 85°F. At temperatures of 90°F and above, reproduction was reduced. Also at low temperatures of about 55°-65°F, reproduction diminished greatly. Similar results were shown on other small grains (Comanche wheat, Spartan barley and Clintland oats) tested in this experiment. The results indicated that different temperatures had differential effects on colony size, which in turn was affected by the different host plants.

The determination of the mechanism of resistance shown by four Russian sorghum lines was carried out. These lines were compared with sorghum varieties commonly used by farmers in Kansas, namely, RS 610 and NC+70X. These are commercial hybrids which are high yielding but susceptible to corn leaf aphid attack. Non-preference and antibiosis were indicated as the mechanisms of resistance shown by the different Russian lines. Least preferred both in the laboratory and in field tests was 135ST3. Antibiosis was indicated in both 133ST1 and 135ST3. Since resistance is a heritable trait (Howitt and Painter, 1956), the possible incorporation of these germplasms into the sorghum breeding program might be worthwhile.

Chemical control, by the use of Thimet and Disyston granules applied in bands at planting time, gave control of both corn leaf aphid and greenbug populations. Foliar applications of Thimet and Disyston granules, and other liquid formulations, gave poor to satisfactory control of aphid population. Thimet granules applied in the whorl of the plants gave the best initial and residual control.

Both the laboratory test and field observations indicated that *L. testaceipes* effectively parasitizes corn leaf aphids. Its effectiveness is limited somewhat by the habitat of the aphids in the whorl of the plants.

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A STUDY OF THE CORN LEAF APHID, *RHOPALOSIPHUM MAIDIS* (FITCH), ON GRAIN SORGHUM IN KANSAS

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The three main objectives in this study were:

1. Determination of the economic threshold of corn leaf aphids on grain sorghum.

2. Determination of the effect of temperature on the survival and population growth of this aphid on small grain crops (sorghum, barley, wheat, and oats).

3. Evaluation of various methods of control of the corn leaf aphid if it is determined as an economic pest of grain sorghum.

Studies to determine economic threshold were conducted in two fields in Riley County, Kansas which had an average of about 1000 and 1500 corn leaf aphids/plant, respectively. Corn leaf aphid populations were controlled in check plots by treating with granular Thimet in the whorls at the rate of 1.0 lb active ingredient per acre. No significant reduction either in yield or seed weight was demonstrated.

The laboratory tests demonstrated that different temperatures had differential effects on population size which in turn was affected by different host plants. Optimum temperatures for reproduction were 85°F in RS 610 sorghum, and 75°F on Spartan barley, Comanche wheat and Clintland oats.

Mechanisms of resistance in four Russian sorghums, 133ST1, 134ST3, and 136ST4, were evaluated to determine the potential for incorporation of this germ plasm into a sorghum breeding program. In all preference or non-preference and antibiosis tests, these Russian lines, especially 135ST3 and 133ST1, demonstrated a higher level of resistance to the corn leaf aphid than the commercial hybrids, RS 610 and NC+70X, commonly grown in Kansas.

Chemical control tests with two granular insecticides, Thimet and Disyston, showed that these insecticides applied at planting time at the rate of 1.0 lb/acre gave initial and residual control of corn leaf aphids. Foliar application of various rates and formulations of contact insecticides demonstrated that Thimet granules at 1.0 lb/acre applied over the whorl of the plants gave the best initial and residual control.

Both laboratory and field tests demonstrated conclusively that the parasitic braconid wasp, *Lysiphlebus testaceipes* (Cresson) effectively parasitizes corn leaf aphids and depresses their populations. Its effectiveness is somewhat hampered by difficulty in reaching the habitat of the aphids in the whorl of the plants.