GREENBUG BIOTYPES AND GREENBUG RESISTANT GRAIN SORGHUM FREQUENCIES IN OKLAHOMA DURING 1986

By

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CHAPTER I

INTRODUCTION

The greenbug, Schizaphis graminum (Rondani), is a major economic pest of small grains and sorghums. Since the greenbug was first described in Italy by Rondani in 1852, it has become a cosmopolitan pest. Oklahoma first experienced a serious greenbug outbreak in 1890 (Glenn 1909). Since that time greenbug outbreaks in Oklahoma have followed no set pattern (Rogers et al. 1972). The 1907 and 1951 outbreaks each resulted in about $50 million in losses in Oklahoma, Texas, and Kansas (Walton 1921, Dahms et al. 1955). In 1976, in Oklahoma alone, losses due to greenbugs were estimated at $80 million (Starks and Burton 1977).

The two primary pest management techniques for greenbug control are host plant resistance and chemical control. Sorghum producers have relied heavily on host plant resistance for greenbug control. However, chemical control is still used in many cases where susceptible sorghum is grown, or where a change in biotypes has left resistant hybrids susceptible. Wheat producers have had to rely almost exclusively on chemical control, because sources of wheat resistance were broken by new biotypes before they could be released for commercial use.

With increasing pesticide prices, coupled by decreasing sorghum and wheat prices, producers are looking toward host plant resistance as a more economically feasible means for control of the greenbug. It is

important that producers and plant breeders know which biotypes are most prevalent in the field, and what characteristics these biotypes possess, and what environmental characteristics favor the development of new biotypes.

The objectives of my research were:

1. To conduct a survey to identify the greenbug biotypes in Oklahoma. A survey of all known biotypes of the greenbug would give producers and plant breeders an indication as to what biotypes are presently of most concern, and what biotypes are of potential concern. This survey was conducted during three seasons of 1986: spring, summer, and fall. The spring and fall surveys were conducted on wheat while the summer survey was conducted on sorghum.

2. To test the efficiency of greenbug biotype determining methods. Previous greenbug survey methodologies have varied in specific areas; as new greenbug isolates were reported, new methodologies were developed. These methods were utilized or modified according to need for this research. However, the same method was used throughout each survey for consistency within the individual surveys and to facilitate comparisons among the three surveys.

3. To survey major Southwestern U.S.A. sorghum seed companies. Major seed companies were surveyed to determine what percentage of grain sorghums sold in Oklahoma in 1986 possessed greenbug resistance, and to what biotypes. This information should give insight to selection pressures, in the form of resistant sorghum hybrids, being exerted on greenbug populations, and what effect this pressure could have on biotype frequencies.

4. To conduct preliminary fecundity research on any new isolates

collected in the surveys or elsewhere. I measured the prereproductive development time, nymphs produced, and doubling time of new greenbug isolates and compared them to those of described greenbug biotypes E and F which are most closely related in terms of host plant responses. This preliminary research will help determine if these new isolates should be classified as new biotypes and of what importance they might play in the future of greenbug infestations in Oklahoma.

CHAPTER II

LITERATURE REVIEW

History

The greenbug, Schizaphis graminum (Rondani), is a serious economic pest of small grains and sorghums in the Great Plains of the United States. In 1907 and 1951, greenbug outbreaks in Oklahoma, Texas, and Kansas together totaled more than $100 million in damages (Walton 1921, Dahms et al. 1955). In 1976, the greenbug outbreak on wheat resulted in $80 million in damage and control expenses in Oklahoma alone (Starks and Burton 1977). Year after year, greenbugs continue to cause economic losses for some small grain and sorghum producers.

The greenbug was first described in Italy in 1852. By 1882, the greenbug was reported along the eastern seaboard of the United States. The 1907 outbreak in the Southern Great Plains precipitated major greenbug research efforts in the United States. Initial biological studies were reported by Washburn (1908), Hunter (1909), Glenn (1909), and Webster and Phillips (1912). Wadley (1931) provided a comprehensive review of greenbug ecology in the northern United States.

Biology and Life Cycle

Wadley (1931) reported the life cycle followed that typical of Aphididae, "Winged and wingless females reproducing parthenogenetically and viviparously are the forms usually found". He also added that eggs

laid in the fall may pass the winter and hatch in the spring. Webster and Phillips (1912) reported that greenbugs can produce 20-25 generations per year; thus the rapid increases in field populations.

Biotypes

The term biotype has been defined in several ways: "'Biotype' is a taxonomic concept mostly used by non-taxonomists and has been defined as consisting of all individuals of equal genotype" (Eastop 1973); "Biotype: those individuals of an insect species able to feed and grow significantly better on a normally resistant variety than other genotypes of the same species"[1] or "Biotype: for every major gene for resistance in the host species, there is a corresponding matching gene for virulence in the parasite species." (Hatchett and Gallun 1970). All three definitions imply a variation within a species that can be detected through genetic expression, most often relating to host/parasite relationships. In practice, however, the term biotype has been used to demonstrate whatever biological difference within a species the observer wishes to apply to it (van Emden et al. 1969).

Biotypes have been described in many insect species, most of which are aphids; Eastop (1973) lists many of these aphid species. Biotypes of the greenbug have been described in the United States and in Argentina. In Argentina, Salto (1976) found 'Dickinson Selection 28A' resistant to a 1975 colony but susceptible to a 1976 colony, thus distinguishing these two colonies as seperate biotypes. Arriaga (1963) reported a new biotype in Argentina capable of damaging previously

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[1] Peters, D.C. 1987. Host Plant Resistance to Insects - Lecture notes & outline. ENTO 5612.

resistant 'Insave F.A.' rye. In 1986, Chidichimo et al. (1986) described two greenbug biotypes in Argentina, the "pale green" type and the "dark green" type. In spite of the differences in these morphological color types, the biotype designation was based on plant reactions. 'Insave F.A.' and 'Amigo' were more resistant to the "dark green" type. C.I. 1579 and C.I. 1580 oats were more resistant to the "pale green" type. 'Will' and P.I. 186270 barleys were equally resistant to both biotypes. 'Dickinson Selection 28A' was moderately resistant and C.I. 9058 was susceptible to both biotypes. They also noted that the "pale green" type was collected on sorghum while the "dark green" type was collected on oats.

In the United States, six biotypes of the greenbug have been described thus far, five of which involve host plant reactions. Wood (1961) reported that in the fall of 1958, greenbug resistant, wheat test flats of 'Dickinson Selection 28A' X 'Ponca' and C.I. 9058 were severely injured by a new greenbug, termed biotype B, or the "tiger bug". The previous greenbug was therefore referred to as biotype A. 'Amigo' and 'Amigo' derived lines were reported as resistant to biotype A and B (Sebesta and Wood 1978). Webster et al. (1986) reported 'Largo' susceptible to biotype B. Whether the 'Largo' breaking (overcoming the resistance) biotype B is genotypically the same as the "original" biotype B reported by Wood (1961) is speculative since no continuous cultures of the original biotype B are available. No data is available on the 'Largo' response to biotype A. Wood (1961) reported these two biotypes as being phenotypically identical; both are dark green in body color, possess a dark dorsal stripe, and have one-quarter length of the cornicles darkened apically. Biotype B was the prevalent biotype in the

Southern Great Plains during the early 1960's (Porter et al. 1982).

In 1968 greenbugs were reported to be causing extensive damage to grain sorghum, a previous non-host (Harvey and Hackerott 1969). They termed this sorghum damaging greenbug as biotype C. Biotype C was reported as virulent to biotype A resistant 'Dickinson Selection 28A' and avirulent to 'Largo' (Porter et al. 1982). Joppa et al. (1980) and Harvey et al. (1980) also reported 'Largo' resistant to biotype C. Further resistance to biotype C was reported by Sebesta and Wood (1978) in 'Amigo' wheat germplasm. Several sources of biotype C resistance have been found in sorghum. (Hackerott et al. 1969, Wood 1971, Johnson 1971). Phenotypically, biotype C is quite different from biotype A and B. Biotype C is pale green in body color, possesses a light green dorsal stripe, and has only the very tip of the cornicles darkened (Wood et al. 1969). Biotype C was the most prevalent biotype in the Southwestern Great Plains during the late 1960's, the 1970's, and early 1980's (Kindler et al. 1984).

Biotype D was described by Teetes et al. (1975) as a biotype C greenbug resistant to organophosphate insecticides. Mayo[2] reported that organophosphate resistance is inducible in biotype B. Thus, there is a possibility that biotype D's organophosphate resistance could occur in any greenbug biotype.

Biotype E was reported by Porter et al. (1982) as damaging previously greenbug resistant 'Amigo' derived lines of wheat. Biotype E was also found to be virulent on many biotype C resistant sorghums

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[2] "Influence of Host Plant and Insecticides on Development of Resistant Greenbugs" October 28, 1986, Seminar, Dept. of Entomology, OSU.

(Porter et al. 1982) but they reported 'Largo' as being resistant to biotype E. Resistance to biotype E has also been identified in some sorghums (Porter et al. 1982, Starks et al. 1983, and Peterson et al. 1984). Morphologically, biotype C and E appear to be the same. Biotype E has been the most prevalent biotype since 1982 (Kindler et al. 1984).

Kindler and Spomer (1986) recovered a greenbug capable of utilizing Canada bluegrass, Poa compressa L.; this greenbug was termed biotype F. They reported biotype F as virulent to 'Amigo', C.I. 1579, and C.I. 1580, but avirulent to C.I. 9058 and sorghums. Biotype F was reported virulent to 'Largo' by Puterka and Peters (1987).

Greenbug Surveys

Several surveys of greenbug biotypes have been conducted to determine which biotypes are most prevalent in the field. Puterka et al. (1982) conducted a survey for biotype C and E on wheat in the Texas Rolling Plains. Results showed 75% of the sites sampled were infested by biotype C and 25% biotype E. However, within two years, infestations were 25% biotype C and 75% biotype E in the same geographical area.[3] In 1980-81 Kindler et al. (1984) surveyed for biotypes C and E, on wheat and sorghum, in Kansas, Nebraska, Oklahoma, and the Texas Panhandle. Results showed biotype C dominance, but shifting to biotype E dominance. Another wheat survey for biotype C and E was conducted in Arkansas by Dumas and Mueller (1986); this survey showed predominantly biotype C with some intermingled biotype E.

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[3] Slosser, J.E. 1987. Personal Communication.

Major Crop Hosts and Sources of Resistance

Wheat, Triticum aestivum L.

Atkins and Dahms (1945) observed slight tolerance to severe field infestations of greenbugs in a number of wheat varieties growing at Denton, Texas and Lawton, Oklahoma in 1942. Dahms et al. (1955) found that the hexaploid selection of 'Dickinson Selection 28A', of a durum cultivar, 'Dickinson No. 485' (C.I. 3707), was resistant to the greenbug (biotype A). Daniels and Porter (1958) reported this resistance to be controlled by a single resessive gene pair with modifier genes, which was in agreement with Painter and Peters (1956) and Curtis et al. (1960). Another related line, C.I. 9058, also had a single reccessive gene controlling greenbug resistance (Curtis et al. 1960). In 1958 this resistance was broken by biotype B (Wood 1961). These sources of resistance were also found to be susceptible to biotype C and E (Porter et al. 1982). Salto (1976) found 'Dickinson Selection 28A' to be resistant to one greenbug population in Argentina but susceptible to others. (Kindler and Spomer 1986) reported that 'Dickinson Selection 28A' was resistant to biotype F.

Sebesta and Wood (1978) released a wheat germplasm line designated 'Amigo' which had a single dominant gene for resistance to biotypes A, B, and C. 'Amigo' (C.I. 17609) was derived from 'Gaucho' (C.I. 15323) an 8X triticale (X Tricosecale Wittmark) which involved 'Insave F.A.' rye (Wood et al. 1974). 'Amigo' resistance was made available to growers in 1984 with the release of 'TAM 107'. 'TAM 107' is a selection from the backcross TAM 105 ④/Amigo (Porter et al. 1985). 'Amigo' was

found to be susceptible to biotype E (Porter et al. 1982), and biotype F (Kindler and Spomer 1986).

Joppa et al. (1980) and Harvey et al. (1980), reported biotype C resistance in certain amphiploids of Triticum turgidium L. and Triticum tauschii (Cosson). 'Largo' (C.I. 17895), one such amphiploid, was found to be resistant to both biotype C and E by Porter et al. (1982) Later it was found to be susceptible to biotype B by Webster et al. (1986), and to biotype F by Puterka and Peters (1987). No data is available on 'Largo' response to biotype A.

Oats, Avena sativa L.

Atkins and Dahms (1945), Walton (1944), and Dahms et al. (1955) screened oat collections for greenbug resistance and found only small differences and no high levels of resistance. Chada et al. (1961) found eight foreign varieties with some substantial resistance to biotype A and B. The resistance in one line, CI 2898, was found to be controlled by a single gene pair. In 1974-75 all these strains except one were found to be susceptible to biotype C (Daniels 1978). Daniels found that the one strain, TX64D23-162R from a cross of P.I. 186270 x P.I. 183990, was only moderately resistant to biotype C; however, he found that C.I. 1579 and C.I. 1580 had the greatest tolerance to biotype C. Wilson et al. (1978) found that P.I. 186270 showed antibiosis, antixenosis, and tolerance to biotype C, and that C.I. 1579 and C.I. 1580 showed antibiosis to biotypes B and C. They also found that C.I. 4888 was the only line to show significantly superior resistance to biotype B. It was concluded that antibiosis, antixenosis, and tolerance in P.I. 186270

was controlled by different genes. Dahms and Woods[4] found C.I. 1579 and C.I. 1580 susceptible to biotype A. Starks et al. (1983) further reported that C.I. 1579 and C.I. 1580 was susceptible to B and resistant to biotype C and E, using damage ratings. Kindler and Spomer (1986) found C.I. 1579 and C.I. 1580 to be susceptible to damage by biotype F.

Barley, Hordeum vulgare L.

A number of barley varieties were reported as resistant to the greenbug by Atkins and Dahms (1945). Dahms et al. (1955) reported that resistance appeared to be dominant and controlled by two or more genes. Most of these varieties originated in the orient except for 'Dicktoo' and 'Kearney' which originated in the United States. Smith et al. (1962) found resistance in 'Omugi', 'Dobaku', 'Kearney' and C.I. 5087 was controlled by a common dominant gene. Other studies by Chada et al. (1961), Gardenhire and Chada (1961), Arriaga (1963), and Gardenhire (1965) supported these findings. Wood et al. (1969) reported 'Will' (from a cross of 'Rogers' by 'Kearney') resistant to biotypes A, B, and C, and Starks et al. (1983) reported 'Will', 'Kerr', 'Kearney', 'Omugi', and 'Post' (from a cross of 'Harrison' by 'Will') as resistant to biotype E. 'Will' was also found resistant to biotype A, B, and C by Starks and Burton (1977). Resistance of 'Will' to biotype E was also confirmed by Porter et al. (1982). Kindler and Spomer (1986) found 'Will' to be resistant to biotype B, C, E, and F. Webster and Starks (1984) tested 15 barley lines for resistance to biotype C and E; of these lines only P.I.426756 showed consistent resistance to both

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[4] Unpublished data, 1953 world oat collection screening.

biotypes as antibiosis, antixenosis, and tolerance. They also reported 'Post' as being resistant to biotype C and E. Some greenbug resistant varieties of barley being grown are 'Kearney'; 'Will', 'Nebar' and 'Post', all with resistance from 'Kearney'; 'Kerr' with resistance from 'Omugi'; and 'Era' with resistance from 'Ludwig' (Gardenhire 1980).

Rye, Secale cereale L.

Several rye cultivars have been found to have greenbug resistance. 'Insave F.A.' rye from Argentina was found to be resistant biotypes A, B, and C (Sebesta and Wood 1978), and E (Porter et al. 1982). 'Insave F.A.' provided the resistance in 'Amigo' wheat (Sebesta and Wood 1978). Starks et al. (1983) found 'Insave F.A.' only provided moderate resistance to biotype E which might explain 'Amigo' susceptibility to biotype E (Porter et al. 1982). Kindler and Spomer (1986) tested 'Amigo' to biotypes B, C, E, and F and found resistance only to biotypes B and C. 'Okema' rye was also resistant to biotypes A, B, and C due to parentage of 'Insave F.A.' (Starks et al. 1983). 'AR-4' was tested against biotype A, B, and C and found to be resistant to all three biotypes (Wood et al. 1969).

Triticale, (X Triticosecale Wittmack)

Kieckhefer and Thysell (1981) tested 20 triticale lines for greenbug resistance and found no differences in greenbug preferences or reproduction. Wood et al. (1974) found biotype A, B, and C resistance in a octoploid triticale, 'Gaucho', which derives it's resistance from 'Insave F.A.' rye. The resistance in 'Gaucho' was used in the x-ray gene transfer technique resulting in 'Amigo' wheat (Sebesta and Wood

1978). 'Gaucho' is susceptible to biotype E (Porter et al. 1982). Webster and Inayatullah (1984) tested triticale lines for resistance to biotype C and E and found six lines to be possible sources of resistance.

Sorghum, Sorghum bicolor L.

Prior to 1968 greenbugs were not considered pests of sorghum. However, in 1968 a new biotype was reported causing economic damage to sorghum in Texas, and was later called biotype C by Harvey and Hackerott (1969). All sorghums are considered resistant to biotype A and B. Harvey and Hackerott (1969) reported 'Pioneer 846' grain sorghum as having intermediate resistance to biotype B and susceptible to biotype C. They also reported 'Piper' sudangrass as resistant to biotype B and susceptible to biotype C. A broomcorn 'Deer' was also shown to separate biotype B and C (Starks et al. 1972). Resistance to biotype C was first found in Sorghum virgatum (Hack.) Stapf derivatives (Hackerott et al. 1969). Wood (1971) found 6 more resistant entries exhibiting antibiosis and antixenosis. Hybrids with six different sources of greenbug resistance: P.I. 264453, P.I. 302236, P.I. 220248, SA 7536-1, 'KS-30' and IS-809 were identified by Johnson (1971). Resistance was shown to be controlled by a single incompletely dominant gene in highly resistant IS-809 (Weibel et al. 1972). Resistance was also shown to increase with temperature (Wood and Starks 1972). Schuster and Starks (1973) reported 6 entries that contained resistance as antibiosis, antixenosis, and tolerance: P.I. 308976, P.I. 229828, IS-809, 'Shallu Grain', P.I. 302178 and P.I. 226096. Johnson et al. (1974) confirmed resistance in IS-809, SA 7536-1, and 'KS-30' and their F_1 hybrids made with susceptible A

lines. 'KS-30' and IS-809 were found to exhibit a higher degree of resistance, as tolerance, than the other biotype C resistant sorghums, P.I. 264453 and SA 7536-1 (Teetes et al. 1974). Starks and Burton (1977) reported IS-809, 'KS-30', SA 7536-1, P.I. 264453, P.I. 229828, P.I. 220248, P.I. 302178, P.I. 302231 and P.I. 226096 as being used to provide resistance to biotype C in commercial hybrids. Porter et al. (1982) reported biotype C resistant TX 2567, SA 7536-1 and 'KS-30', tracing resistance to P.I. 38108, susceptible to biotype E. He also found P.I. 220248 and 'Capbam' to be resistant to both biotype C and E. Resistance to both biotype C and E was reported by Starks et al. (1983) in 'Capbam', P.I. 220248 and P.I. 264453. Peterson et al. (1984) also reported resistance to biotypes C and E in TX 2783. Kindler et al. (1986) reported TX 2783 as only moderately resistant to biotype B, and that all sorghums they tested: 'Piper', 'KS-30', TX 2783, 'CK-60', and 'Capbam' were all highly resistant to biotype F. They also reported 'Capbam' had no antibiosis but may use tolerance to biotype E.

Corn, Zea mays L.

Patch (1938) listed Zea mays as a host of "Toxoptera graminum". However, corn has not been considered a field host of the greenbug, but it may have future capabilities. Biotype E populations collected from Texas and Arkansas were tested on wheat, sorghum, and corn (Michels et al. 1987). They found both populations react the same on wheat and sorghum but differ in their response to corn. The Texas population was successful in using excised corn leaves as a host in the laboratory whereas the Arkansas population could not. However, wide utilization of corn in field by the greenbug has yet to be demonstrated.

Kentucky bluegrass, Poa pratensis L. and Canada bluegrass, Poa compressa L.

Bluegrass is a known host of the greenbug (Webster and Phillips 1912, Wadley 1931, Patch 1938, Robinson and Hsu 1963, and Street et al. 1978). Kindler et al. (1983) found resistance to biotype C and E in 'South Dakota Common', 'Nebraska Common', 'Vantage', 'Sydsport', and 'Reubens'. Biotype F was reported as virulent to 'Reubens' Canada bluegrass by Kindler and Spomer (1986).

CHAPTER III

GREENBUG BIOTYPE SURVEY

Introduction

Six biotypes of the greenbug, Schizaphis graminum (Rondani), have been described thus far: biotypes A and B (Wood 1961); biotype C (Harvey and Hackerott 1969); biotype D (Teetes et al. 1975); biotype E (Porter 1982); and biotype F (Kindler and Spomer 1986). All biotypes are distinguished on the basis of plant reactions with the exception of biotype D which is distinguished on the basis of organophosphate resistance.

With the appearance of new greenbug biotypes and sources of resistance several biotype surveys have been conducted to determine which biotypes were most prevalent in field populations. Puterka et al. (1982), conducted a survey of biotypes C and E in the Texas Rolling Plains and reported that biotype C was the most prevalent (75%). Biotype C and E surveys were conducted in 1980-1981 in Kansas, Nebraska, Oklahoma and Texas Panhandle by Kindler et al. (1984). They found that biotype C was prevalent in Kansas on both wheat and sorghum during 1980 but was being displaced by biotype E by 1981; in 1981, biotype E was the prevalent biotype on both wheat and sorghum in Nebraska. In 1980 they found predominately biotype E on wheat in the Oklahoma and Texas Panhandles, however, as the survey progressed eastward across Oklahoma they found predominately biotype C. In Arkansas, Dumas and Mueller

(1986) found biotype C to be the predominant biotype on wheat during 1984 and 1985.

Greenbug biotype surveys have shown biotype C and E distributions in Nebraska, Kansas, Oklahoma, Arkansas, and northern Texas. However, no surveys have been conducted with the purpose of also sampling for biotypes A, B, and F. This research project was undertaken to detect biotypes A, B, C, E, and F, with the possibility of detecting new biotypes in the wheat and sorghum producing areas of Oklahoma.

General Methods and Materials

Three separate greenbug biotype surveys were conducted: spring 1986, on wheat; summer 1986, on sorghum; and fall 1986, on wheat. the spring 1986 survey included 18 counties in western Oklahoma; the summer 1986 survey included 25 counties in western and northeastern Oklahoma; the fall 1986 survey included 26 counties in western Oklahoma.

Two greenbug samples were taken from each field at intervals of 10-12 miles located along state and federal highways when such locations were available.

In the spring survey, greenbugs were collected from wheat fields by uprooting the infested wheat plants with some intact roots, and placing them into 100 x 15 mm clear plastic petri dishes. Several mls of water were added to each sample to prevent dessication. Greenbugs collected in the summer survey were transferred from the sorghum to petri dishes containing germinated 'Wintermalt' barley seedlings which were growing on moistened blotter paper. Petri dishes containing samples were sealed with masking tape, labeled, and placed in a cooled ice chest for transport to the laboratory. In the laboratory the samples were stored

in a refrigerator at 6°C. Greenbug samples kept under these conditions survived for as long as 28 days.

'Triumph 64' was planted in sandy soil contained in 8 cm. high x 7 cm. diameter styrofoam cups. One greenbug per sample was placed on a wheat seedling in the 1-2 leaf stage. A 17 cm high by 3.5 cm diameter plastic tube cage with the top end enclosed by a thin mesh cloth was placed over the wheat seedling and greenbug for containment. The fall survey on wheat also utilized 'Wintermalt' as well as 'Triumph 64' seedlings. Greenbugs that died before establishing a colony were replaced by a greenbug from the same sample. Colonies were maintained in a temperature regulated laboratory at 21 $\pm$ 3.3°C. Colonies were allowed to increase parthenogenically until they contained approximately 160 aphids, which took up to 25 days. A 14:10(L:D) photoperiod was supplied using a bank of cool white fluorescent and 60W incandescent lamps.

Greenbug samples were screened using various combinations of biotype distinguishing cultivars (depending on the survey). Seeds from these cultivars were planted in sandy soil contained in 14.5 cm high by 15 cm diameter plastic pots. Planting was arranged in a latin square configuration; two seeds were planted at each hill of the square. The pots were covered by 34 cm high x 13 cm diameter plastic tube cages with top and lateral openings covered by mesh cloth to prevent contamination with other aphids. Plants were watered as needed with a 25% concentration of Hoagland's solution. After the plants reached 8 cm in height (1-2 leaf stage), they were thinned to one seedling per hill. Plants exceeding 8 cm in height were trimmed to that height at time of infestation.

Greenbug colonies with sufficient numbers were shaken into the cage at a rate of about 10 aphids/plant. The cage was then placed over the pot and watered along the edge so that the soil would seal the cage. The top of the cage was then gently tapped, distributing greenbugs evenly throughout the pot surface.

Plants were visually rated for damage using a 1 to 6 scale: 1 = 0% damage or no visable damage; 2 = 1-25% damage (chlorosis, necrosis, or white specking), 3 = 26-50% damage; 4 = 51-75% damage; 5 = 76-99% damage; and 6 = 100% damage or dead plant. Ratings of 1 to 3 were regarded as resistant while ratings of 4 to 6 were regarded as susceptible. Plants were rated when at least one plant in the pot rated a 6. Results for each plant were recorded and the biotype determined on the basis of plant responses. Erratic reactions were noted and retested.

Statistical analysis (SAS Institute 1985) consisted of a Duncan's (1955) multiple range test of the seedling damage ratings of each survey, and binomial confidence limits (Steel and Torrie 1980) for the biotype distributions and efficiency of the rapid technique method. Significance was reported at the P=0.05 level of probability throughout all statistical analyses.

Spring 1986 Survey on Wheat

Methods and Materials

This survey was divided into two separate wheat growing regions of Oklahoma: northwest and southwest, each consisting of nine sample counties. Sample sites per county varied between one and four.

Greenbug collecting and basic methods followed those as described in the general materials and methods.

Biotype determination was conducted using screening pots split into two phases, each containing three plant varieties planted in a 3 x 3 latin square arrangement. Phase I contained: susceptible 'Triumph 64' wheat; biotypes A, B, and C resistant, 'TAM 107' wheat, which carried the greenbug resistance from 'Amigo' wheat (Sebesta and Wood 1978); and biotype C, E, and possibly A resistant, 'TAM 105' x 'Largo' (5XL) wheat (Porter et al. 1982). Phase I could distinguish biotype E and F. Since biotype A had not been tested on (5XL) a second phase was used to separate biotype A from B, and A from C. Phase II contained: biotypes C and E resistant, C.I. 1580 oats (Wilson et al. 1978), C.I. 1580 was originally shown to be susceptible to biotype A by Dahms and Wood[5]; biotype A and F resistant C.I. 9058 wheat (Curtis et al. 1960 and Kindler and Spomer 1986); and biotype A resistant 'Piper' sudangrass (Harvey and Hackerott 1969). We found 'Piper' sudangrass to be only moderately resistant to biotype B. Using these two phases in conjunction allowed detection of all five described host-determined biotypes, and also allowed for the possible detection of new biotypes (Table I).

Results and Discussion

Biotypes B, C, and E were collected in this survey, and a new isolate was collected from Stephens County, Oklahoma (SCO). Parasitism of greenbugs was exceptionally high during the survey collection period

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[5] Unpublished data from the 1953 greenbug resistance screening of the world oats collection.

and resulted in the loss of many of the samples. The effect this had on biotype frequency is not known. However, if a relationship between parasite and biotype preference exists, biotype frequency could be altered by the degree of parasitization. Table II is a comprehensive accumulation of the biotype percentages and binomial confidence limits for all three surveys.

The northwest region of Oklahoma consisted entirely of biotype E, and resulted in a binomial confidence limit of 0.83-1.0. The southwest region of Oklahoma was more diverse with isolates that were 28% biotype B, 10% biotype C, 57% biotype E, and 5% SCO isolate. Biotype B was collected in 5 counties: Custer, Jackson, Kiowa, Pottowatomie, and Garvin, and resulted in a binomial confidence limit, of 0.14-0.60. Biotype C was collected in only Lincoln County and resulted in a binomial confidence limit of 0.002-0.28. Biotype E was the most prevalent of the biotypes and was collected in 15 of the 18 counties sampled. It resulted in a binomial confidence limit of 0.31-0.77. The isolate recovered in Stephens County (SCO) exhibited reaction responses similar to biotype F, but had the capability of damaging C.I. 9058 and 'Dickinson Selection 28A'. This isolate was only recovered at one site and has a binomial confidence limit of 0.002-0.28. During the spring of 1986, another new isolate was collected in Wichita County, Texas (WCT), by Bush et al.[6]. This isolate reacted similar to biotype E on wheats but lacked the ability to survive and damage sorghums. The location for the WCT collection is within 100 km of the location where SCO was

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[6] Bush et al. Manuscript, "Status of Greenbug Biotypes in Texas." submitted to Southwestern Entomologist.

collected. The southwest region of Oklahoma consisted mostly of biotype E, but the wide degree of biotype diversity in the area makes it a prime location for possible new greenbug biotype outbreaks, as indicated by the collection of two new isolates in this area.

The survey as a whole consisted of: 11% biotype B, 4% biotype C, 83% biotype E, and 2% SCO isolate. Binomial confidence limits, for these biotypes were as follows: biotype B, 0.06-0.32; biotype C, 0.001-0.15; biotype E, 0.62-0.90; and SCO isolate, 0.001-0.15. Biotype E was the dominant biotype in these regions of the state. However, if some factor suppressed the biotype E population, biotype B could possibly increase and become a major factor.

Seedling injury ratings analysis for each biotype collected in this survey are represented in Table III. Seedling damage ratings for biotype B were not as expected. Harvey and Hackerott (1969), reported 'Piper' as being highly resistant to biotype B which rated 3 on a 0-10 damage rating scale when confined to a plant. In contrast we found 'Piper' to exhibit an intermediate response, rating $\bar{x} = 3.61$, in a confined screening pot. In the screening pot the aphids had a choice among the 'Piper' sudan or the resistant and susceptible small grains; this would seem to encourage a more resistant response in the 'Piper' if it were indeed highly resistant. Webster et al. (1986), reported 'Largo' wheat susceptible to biotype B. Whether or not this is the same biotype B described by Wood (1961) and Harvey and Hackerott (1969) is not known. The rest of the cultivars used, exhibited expected results. There were no significant differences among the susceptible cultivars: C.I. 9058 rated $\bar{x} = 5.67$; C.I. 1580 rated $\bar{x} = 5.50$; 5XL rated $\bar{x} = 5.44$;

and 'Triumph 64' rated $\bar{x}$ = 5.39. 'TAM 107' gave a resistant response as expected and rated $\bar{x}$ = 2.00.

Damage ratings for biotype C were as expected. All designated susceptibles rated susceptible. However, 'Piper' rated $\bar{x}$ = 5.00, was significantly, less damaged than the other two susceptibles, 'Triumph 64' rated $\bar{x}$ = 5.83 and C.I. 9058 rated $\bar{x}$ = 5.50. 'Piper' was reported as being relatively susceptible or intermediately resistant to biotype C (Harvey and Hackerott 1969, Hackerott et al. 1969). There was no significant differences between resistant cultivars; 'TAM 107' and 5XL rated $\bar{x}$ = 2.00 and C.I. 1580 rated $\bar{x}$ = 1.83. However, the resistant cultivars were significantly different from the susceptible cultivars.

Biotype E was distinguished from the other biotypes in the phase I pot and thus data for only three cultivars is given. There were significant differences between all three cultivars, yet, each rated as expected. The susceptible cultivars, 'Triumph 64' rated x = 5.48 and 'TAM 107' rated $\bar{x}$ = 5.33, but 'TAM 107', which is resistant to biotype C, was significantly less damaged than 'Triumph 64'. The resistant cultivar, 5XL which rated $\bar{x}$ = 1.88, was significantly less damaged than the other cultivars and rated resistant as expected.

SCO isolate damage ratings were as expected for biotype F but differed in ability to damage C.I. 9058. 'Piper' which rated $\bar{x}$ = 2.00, was the only cultivar to give a resistant response. 'Piper' was significantly less damaged than the other 5 cultivars. The other 5 cultivars resulted in susceptible responses, but there were significant differences in their susceptibility. C.I. 1580, rated $\bar{x}$ = 4.67, was significantly less damaged than 'TAM 107' which rated $\bar{x}$ = 6.00, but was not significantly different from the other susceptible cultivars;

'Triumph 64' rated $\bar{x}$ = 5.67; 5XL rated $\bar{x}$ = 5.33; and C.I. 9058 rated $\bar{x}$ = 5.33. SCO damage ratings are based on only one screening and 12 d.f. Further testing should be conducted to qualify it as a new biotype.

Summer 1986 Survey on Sorghum

Methods and Materials

This survey was divided into three separate sorghum growing regions: northwest Oklahoma, consisting of 10 sampled counties; southwest Oklahoma, consisting of eight sampled counties; and northeast Oklahoma, consisting of seven sampled counties. Sample sites per county varied between one and six. Two methods were used: the rapid technique, and the pot screening method.

Greenbug collecting and basic methods followed those described in the General Materials and Methods.

Biotype determination tests were conducted using two different methods. Due to the high percentage of greenbug parasitism and resulting colony loss in the spring 1986 survey, an alternate method was used in conjunction with the screening pot method.

This method was a modification of the rapid technique for determining greenbug biotypes B, C, E, and F, as described by Puterka and Peters (1987). One greenbug per sample, instead of two, as used by Puterka and Peters, was used to guarantee the homogeniety of the biotype for testing purposes. A single greenbug was randomly placed on either, 'Triumph 64', 'TAM 107' or 'TAM 105' X 'Largo' and confined using a clip cage. Sequence of the varietal use was randomly assigned to a greenbug to prevent any possible plant conditioning response. Each greenbug was confined to each of the three varieties for consecutive 8 to 12 h

periods, then transferred to a 'Triumph 64' seedling for colony establishment and subsequent pot screening. Seventy-two hours after infestation of the clip cage, the biotype was determined by the presence (susceptible) or absence (resistant) of necrotic lesions on the test cultivar. The rapid technique was evaluated by comparing it's results to the pot screening method results which were considered to be more accurate due to varietal replication within the pot. Percentages and binomial confidence limits (P = 0.05) were estimated for accuracy of biotype determination.

Screening pots were also used in conjunction with the rapid technique to insure soundness in the methodology. A single screening pot per sample was used instead of two to reduce time and labor. This pot consisted of four varieties, C.I. 1580 oats, 'TAM 107', 5XL, and C.I. 9058 wheat planted in a 4 x 4 latin square. Response of these four varieties distinguished between all described biotypes, including the SCO isolate, and still permitted the detection of possible new biotypes (Table IV).

Results and Discussion

The rapid technique and the pot screening method resulted in the same results with a binomial confidence limit of 0.79-0.92, and 0.09-0.21 for differing results (Table V). Thus, it could be expected that at least one in ten samples screened using the rapid technique would be inaccurate. The reason for this inconsistency is because the rapid technique over estimated biotype C. This could be due to an altered feeding behavior of parasitized greenbugs, or to the fact that one, instead of two, greenbugs was used. Many parasitized samples were

collected and screened using the rapid technique, and most of these samples established colonies before dying; otherwise, they were not included in the results. For this study, the probability of obtaining wrong results using the rapid technique was too high and didn't allow for detection of many new biotypes. However, after further improvement in the method, the rapid technique could prove to be valuable, because it can quickly, cheaply, and efficiently seperate the major biotypes B, C, E, and F.

Only biotype C and E were collected in the survey. This was expected because no other biotypes, have been described infesting sorghum in the field. The northwest region consisted of only biotype E and resulted in a binomial confidence limits of 0.85-1.0. The southwest region consisted of 90% E and 10% C. Biotype E was collected in all 8 sample counties and biotype C was collected in Tillman, Garvin, and Pottowatomie Counties. Biotype E resulted in a binomial confidence limit of 0.68-0.97, and 0.03-0.32 for biotype C. Biotype B was found oversummering on prairie cupgrass (Eriochloa contracta Hitchc.) in Payne County, Oklahoma, at the time of the summer sorghum survey. The northeast region consisted of 91% biotype E, and 9% biotype C. Biotype E was collected in all 7 sample counties while biotype C was only collected in Craig County. Biotype E resulted in a binomial confidence limit of 0.60-0.98, and 0.01-0.40 for biotype C.

When all three regions were combined, biotype E comprised 94% and biotype C 6% of the samples screened. Biotype E resulted in a binomial confidence limit of 0.82-0.97, and 0.03-0.18 for biotype C. Thus, the biotype of the greatest concern to Oklahoma sorghum growers is biotype

E, and programs utilizing greenbug resistant sorghum hybrids should keep this in mind.

Seedling injury ratings for biotypes C and E were as expected (Table VI). For biotype E, C.I. 9058 and 'TAM 107' proved to be susceptible while 5XL and C.I. 1580 proved to be resistant. However, with 1116 d.f, there were significant differences among all four cultivars. In order of most damaged to least damaged: C.I. 9058 rated $\bar{x}$ = 5.75; 'TAM 107' rated $\bar{x}$ = 5.49; 5XL rated $\bar{x}$ = 1.95; and C.I. 1580 rated $\bar{x}$ = 1.88. C.I. 9058, biotype C and E susceptible, did prove to be the most damaged, and biotype C resistant and E susceptible 'TAM 107' was the second most damaged. C.I. 1580 and 5XL were both reported as being biotype E resistant, but C.I. 1580 was the least damaged. As expected for biotype C, C.I. 9058 rated $\bar{x}$ = 5.79, was susceptible and was significantly more damaged than the other three cultivars. There were no significant differences in damage between the other three cultivars; 'TAM 107' rated $\bar{x}$ = 2.00; 5XL rated $\bar{x}$ = 1.96; and C.I. 1580 rated $\bar{x}$ = 1.92; all rated as resistant as expected.

Fall 1986 Survey on Wheat

Methods and Materials

The survey was divided into two separate wheat growing regions of Oklahoma: the northwest and the southwest, each consisting of 13 counties sampled. Sample sites per county varied from one to four.

Greenbug collecting and basic methods followed those described in the General Materials and Methods. Since results using the rapid technique were less accurate than desired for this study, only the pot screening method was used in this survey. The varietal composition of

the screening pot for the survey was altered to allow the detection of the WCT isolate found in Texas. A single screening pot was used per sample consisting of four differentiating varieties planted in a 4 x 4 latin square arrangement. These four varieties were: 'Piper', 'TAM 107', 5XL, and C.I. 9058 (Table VII). With these cultivars all current biotypes can be distinguished, including SCO and WCT isolates, and new biotypes could possibly be detecting. This varietal composition is very similar to the original 2-phase method but lacks 'Triumph 64' and C.I. 1580. However, it would be desirable to include C.I. 1580 for further detection of possible new biotypes, but it was not possible due the lack of space and time.

Results and Discussion

Biotypes C and E were collected in the survey along with a possible new isolate from Lincoln County, Oklahoma (LCO). Collection from the northwest region consisted entirely of biotype E, and resulted in a binomial confidence limit of 0.89-1.0. The southwest region was more diverse; collections resulted in 4% biotype C, 94% biotype E, and 2% LCO isolate. Biotype C was collected in Caddo and Pottawatomie Counties, and resulted in a binomial confidence limit of 0.009-0.22. Biotype E was the predominant biotype in this region, it was collected in all 12 counties surveyed. Biotype E exhibited a binomial confidence limit, of 0.73-0.98. The LCO isolate was recovered from only one site in Lincoln county and resulted in a binomial confidence limit of 0.0009-0.18. The LCO isolate reacts similarly to the biotype B recovered in the spring of 1986 but lacks the ability to damage 'Piper'. LCO reacts as would be expected of the biotype B characterized by Harvey and Hackerott (1969).

However, LCO does damage wheat with the 'Largo' genotype; whether or not the 1969 biotype B (Wood et al. 1969) could damage 'Largo' is unknown. Thus, LCO could be a recovery of the original biotype B. Since testing of LCO only involved one screening pot and 12 d.f., further testing should be conducted to determine if LCO is actually different from the biotype B collected in 1986 and/or is a recollection of the original B.

The survey as a whole consisted of: 2% biotype C, with a binomial confidence limit of 0.004-0.11; 97% biotype E, with a binomial confidence limit of 0.86-0.99; and 1% LCO isolate, with a binomial confidence limit of 0.0004-0.09. Biotype E was the predominant biotype, with biotype C and the LCO isolate making up only minor portions of the collection in the eastern section of the southwest region. Sexual forms were also collected in this survey and were identified as biotype E using the rapid technique (Puterka and Peters 1987). One oviparious female was collected in Lincoln County, and one oviparious female and one male was collected in Stephens County.

Seedling injury ratings for biotype C were as expected (Table VIII). The resistant cultivars: 'TAM 107' rating $\bar{x}$ = 2.00; and 5XL rating $\bar{x}$ = 1.88, were significantly less damaged than the susceptible cultivars: 'Piper' rating $\bar{x}$ = 5.38; and 'C.I. 9058' rating $\bar{x}$ = 5.25. There were no significant differences, within the resistant and susceptible cultivars.

The biotype E, seedling damage ratings were as expected. The resistant 5XL rating $\bar{x}$ = 1.90 was significantly less damaged than the susceptible cultivars. As expected the susceptible cultivars reacted as susceptible but there were significant differences among them. 'TAM

107' rating $\bar{x}$ = 5.26; and 'Piper' rating $\bar{x}$ = 5.22 were significantly less damaged than 'C.I. 9058' rating $\bar{x}$ = 5.39.

The LCO isolate reacted as might be expected of the original biotype B. The resistant cultivars: 'TAM 107' rated $\bar{x}$ = 2.00 and 'Piper' rated $\bar{x}$ = 1.75 were significantly less damaged than the susceptible cultivars: 5XL rating $\bar{x}$ = 5.75, and 'C.I. 9058' rating $\bar{x}$ = 5.25. There were no significant differences within the resistant and susceptible cultivars.

Summary of the Surveys

The SCO and LCO isolates were sent to M.B. Stoetzel, Systematic Entomology Laboratory, USDA-ARS Beltsville, MD, who confirmed them as Schizaphis graminum. Biotype E was the predominant biotype in all three surveys and in all regions of those surveys. As predicted by Kindler et al. (1984), biotype E has spread eastwardly across Oklahoma and displaced biotype C. Puterka et al. (1982) reported biotype C as being the predominant biotype in the Texas Rolling Plains, but Slosser[7] reported biotype E as being predominant in 1983. This same replacement phenomena may be in the process of taking place in Arkansas where biotype C was reported as being dominant to biotype E, by a 3 to 1 ratio. The reason for biotype C displacement by biotype E is not known, but could be related to acreage of biotype C resistant sorghums, fecundity, and/or general vigor. Starks et al. (1983) reported that biotype E produced significantly more nymphs on 'Payne' wheat at 15°C (60°F) than did biotype C. This would allow biotype E to gain a

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[7] Slosser, J.E. 1987. Personal Communication.

competitive advantage over biotype C in wheat during the spring. In 1980 an estimated 90% of grain sorghum being planted was biotype C resistant and mostly biotype E susceptible (Starks et al. 1983). However, many new hybrid grain sorghums are reported to be biotype E resistant.

Biotype B constituted a major proportion of the greenbug population in southwestern Oklahoma during the spring of 1986. It was not detected in later surveys on sorghum but was found in a sample of prairie cupgrass during the summer of 1986. Biotype B lacks the ability to do well on sorghum or at high temperatures (Wood and Starks 1972). It may oversummer on wild hosts in a natural ecosystem where a large increase in population would be difficult. It would then enter fall wheat plantings in small numbers and populations increase to detectable numbers by spring under milder temperatures. This cycling could also be related to sexual reproduction and overwintering egg survival, or to environmental suppression of the biotype B population in the summer similar to the regular cyclic changes in red-green color morphs of parthenogenic rose aphids (Macrosiphum rosae) reported by Rhomberg et al. (1985). They cite the possible reasons for this cycling to be related to migration of sexuals into the area and environmental selection of particular overwintering eggs. A similar cyclic behavior may be responsible for the increased frequency of biotype B during the spring of 1986. Additional spring surveys should be conducted to determine if the occurrence of biotype B is cyclic or coincidental.

Biotype C, SCO, and LCO isolates occured in only small numbers. They were generally detected in the southwest region and also, biotype C, in the northeast region. The large amount of biotype variability in

the southwest region may be due to the presence of sexuals in this area and the resulting development of genetically variable fundatrices. It appears that biotype C is being displaced by biotype E, as earlier noted and SCO, in large numbers, could prove devastating to wheat breeders due to the ability to attack all known sources of resistance. The SCO isolate's ability to reach economical proportions in the field will depend on it's adaptiveness and oversummering capabilities. More research on this isolate is needed to find sources resistant to it and also determine it's potential as an economically important biotype.

LCO is very similar to the originally reported biotype B (Wood 1961) but it is also similar to the biotype B collected in 1986. The degree of differences among these biotype B like greenbugs needs to be investigated.

The reason for the intermediate resistant response of 'Piper' to the spring 1986 collected biotype B may have been due to varietal differences in screening pots. This could reflect preference for 'Triumph 64', which was not present in the summer and fall screening pots. Or, LCO may be a recollection of the "original" biotype B, and the spring 1986 biotype B may be a variant within the population as described for biotype E on laboratory corn (Michels et al. 1987).

CHAPTER IV

SORGHUM SEED COMPANY SURVEY

Introduction

Since 1982 there has been a shift in biotypes of the greenbug, Schizaphis graminum, in the Texas High and Rolling Plains and in Oklahoma. In 1982, biotype C dominated the Texas Rolling Plains (Puterka et al. 1982). However, by 1983, biotype E was most abundant[8]. Kindler et al. (1984), found biotype C only in the eastern half of Oklahoma where it was apparently being displaced by biotype E. The reason for this displacement is not known but it could be related to biotype vigor and the ability to maintain large populations the entire year. Biotype E was reported by Starks et al. (1983) to have a significantly higher reproduction rate than biotype C at 15°C (60°F), temperature similar to what might be expected in Oklahoma during the fall and spring. This would give biotype E a competitive advantage preceding the planting of sorghums. However, at higher temperatures, 24°C (75°F), the reproduction rate of both biotypes C and E increased on susceptible 'Payne' wheat, 'BOK-8' sorghum and 'Piper' sudangrass, but there was no significant difference (Starks et al. 1983). They did however, find that biotype C had a significantly ($P < 0.05$) higher

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[8] Slosser, J.E. 1987. Personal Communication.

reproductive rate than biotype E on 'Dickinson Selection 28A'. This would not influence biotype frequency in the field because 'Dickinson Selection 28A' is not grown commercially.

Biotype frequency is probably most affected by the amount of resistant cultivars grown. By 1980 an estimated 90% of the grain sorghum seeded was biotype C resistant (Starks et al. 1983). Also, in 1980, biotype E was found infesting wheat at Bushland, Texas (Porter et al. 1982). With the planting of biotype C resistant and biotype E susceptible sorghums, biotype E would have had a definite advantage in maintaining large populations during the summer. By 1983, biotype E resistant sorghums were available for commercial planting. The effect these resistant hybrids will have on biotype frequency is not known, but it could be dramatic if planted on large acreages.

The purpose of this paper is to report the results of a survey of major seed companies in the Southwest in a study to determine how much susceptible and resistant sorghum seed was being sold in Oklahoma in 1986.

Methods and Materials

Questionnaires were sent to 22 major southwestern U.S. seed companies asking them to indicate how many 50 lb. bags of grain sorghum were sold in Oklahoma in 1986 and how many of these were greenbug susceptible, only biotype C resistant, only biotype E resistant, or resistant to both biotype C and E. "Haygrazers" were excluded from consideration in this survey because vegetative harvesting makes them unlikely sources of large greenbug populations. Thirteen responses were received.

Results and Discussion

The Oklahoma Department of Agriculture estimated grain sorghum acreage in Oklahoma during 1986 at 490,000 acres (Oklahoma Agricultural Statistics Service 1987). From this we can estimate the number of 50 lb. bags of grain sorghum needed would be 49,000 by using an average planting rate of 5 lb/acre. Out of an estimated 49,000 fifty lb. bags of grain sorghum sold in Oklahoma during 1986, our survey included 35,983, or 73% of this total. Biotype C resistant hybrids were an estimated 91% of the total sorghums sold (Table IX). Susceptible sorghums were only 9% of the total sales. Since antibiosis has been linked to sorghum resistance (Kindler and Spomer 1986), a suppression of the greenbug population would be expected. Thus, biotype C population would be suppressed on 91% of the sorghum acreage. At this time there are no sorghums with only biotype E resistance available, but an estimated 37% of the sorghums being planted were both biotype C and E resistant. Therefore, biotype E still has access to 63% of the sorghum that would be susceptible. Biotype C would appear to be suppressed by the heavy use of sorghums containing biotype C resistance, and thus the probable reason for its displacement by biotype E. Therefore, at this time biotype E still has ample acreage of sorghum on which to maintain a high summer population. As more biotype E resistant sorghums are planted this advantage could be lost which could lead to selection of a new sorghum biotype and/or toward shifts in greenbug biotype frequencies in wheat.

CHAPTER V

FECUNDITY STUDY OF TWO GREENBUG ISOLATES

Introduction

Antibiosis of some host cultivars to the currently available greenbug biotypes was reported by Kindler and Spomer (1986). They reported 'Dickinson Selection 28A' as possessing antibiosis to biotype F, and 'Amigo' as possessing antibiosis to biotype B and C. They also reported 'Piper' sudangrass and 'KS-30' as having antibiosis to biotype B and F, and 'KS-30' to biotype C. Starks and Burton (1977) reported P.I. 264453 sorghum as having antibiotic qualities to biotypes A, B, and C. 'Post' barley was shown to have antibiosis to biotype C and E (Webster and Starks 1984), and C.I. 1580 oats was shown to have antibiosis to biotype C (Wilson et al. 1978). Resistance of host plants to the damage of the greenbug biotypes has also been reported where antibiosis was not tested. 'Largo' was reported as resistant to biotype C and E (Porter et al. 1982). Kindler and Spomer (1986) reported 'Will' barley as resistant to biotype F, C.I. 1580 as resistant to biotype E, and 'Insave F.A.' rye as resistant to biotype B, C, E, and F.

The collection of two new isolates is reported in this thesis. One isolate was collected in Stephens County, Oklahoma and the other isolate

was collected by Bush et al.[9] in Wichita County, Texas. This study was undertaken to examine the effects of fourteen plant cultivars on the rate of nymphal development and reproductive rates of these two isolates in comparison to biotypes E and F and determine their potential biotype status.

Methods and Materials

Table X lists the cultivars used in this study, their source of resistance (if known), and their response to the greenbug biotypes. For each crop species chosen a susceptible entry was included along with the varying sources of resistance. All plants were double seeded in sandy soil in a 8 cm. high X 7 cm. diameter styrofoam cup. When the plants emerged they were thinned to one plant per cup. The plants were grown in a growth chamber with a 14:10, L:D photoperiod, lighted with 40W cool white fluorescent and 60W incandescent lamps. Temperature was maintained at 25°C:20°C, L:D. Plants were watered as needed with 25% Hoagland's solution.

The greenbug colonies to be tested were maintained on caged pots of 'Triumph 64' in separate growth chambers with the same photoperiod and temperatures as the test plants. Colonies consisted of biotype E and F which were obtained from tested laboratory cultures, SCO isolate from wheat in Stephens County, OK. and WCT isolate from wheat in Wichita County, TX.

Two adult greenbugs were placed on the second leaf of a one-week old plant and covered by a clip-cage (Puterka and Peters 1987). Each

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[9] Bush et al. Manuscript, "Status of Greenbug Biotypes in Texas." submitted to Southwestern Entomologist.

plant represented an experimental unit. Five plants per entry per biotype or isolate were used, each representing a possible replication. Each plant was checked every six hours until at least one nymph was produced in the clip-cage. All the greenbugs but one nymph were removed from each clip-cage and the date and time to the nearest hour was recorded. The single nymph remained in the clip-cage for three days. Six-hour interval monitoring continued during this time, if a nymph died the replication was started over by placing two adults of the designated biotype or isolate in the clip-cage. Nymphal establishment was attempted on each entry at least ten, but no more than fifteen, times so that five to six replications could be established. However, in some highly resistant plant entries, none or less than five replications were established. For these entries data was either noted as "no establishment", or analyzed with adjustments for missing data. After 3 days the clip-cage was removed and a 17 cm. high x 3.5 cm diameter plastic tube cage with the top enclosed with mesh cloth was placed over the plant. Thus, the greenbug had no restrictive feeding area on the plant. Six-hour interval monitoring continued until the greenbug produced nymphs. The nymph or nymphs were removed and the number of nymphs and the date and time to the nearest hour was recorded for each plant. The number of hours from first observed nymph to reproductively mature adult was calculated and the reproductively mature greenbug was allowed to remain on the plant this same period of time. Afterwards, the progeny were counted and added to the initial number of nymphs removed. The data was recorded and the plant and greenbugs discarded. The intrinsic rate of increase for each replication was estimated using a modified formula devised by Wyatt and White (1977).

$$r_m = 0.738 \ (\log_e Md)/d$$

r_m = intrinsic rate of natural increase

Md = number of progeny produced in an equal time of d

d = prereproductive time in days (birth to first reproduction).

Wyatt and White (1977) calculated d in days whereas this study used hours. The r_m (in hours) was converted to doubling time for the population by taking the reciprocal ($1/r_m$). Making the formula:

$$Dt = {}^{1}/[0.738 \ (\log_e Mdh)/dh)$$

Dt = doubling time of a given population in hours

Mdh = number of progeny produced in an equal time of dh in hours.

dh = prereproducive time from birth to first reproduction in hours.

Data for Dt, Mdh, and dh were analyzed using SAS, GLM (SAS Institute 1985). The criteria of statistical significance was P = 0.05 for all appropriate comparisons.

Results and Discussion

Tables XI, XII and XIII show the means and indicated differences at significance levels of P = 0.05 for dh, Mdh, and Dt, respectively.

Comparing Wheats

The dh and Dt for biotype E was essentially the same among all four entries. The number of nymphs produced (Mdh) by biotype E was only significantly less on biotype E resistant 5XL. Thus, 5XL must possess antibiotic qualities for nymph production. A possible reason for dh and Dt not being significantly different for biotype E on 5XL may be due to

the amount of variability among the diverse plant materials in the total experiment. Biotype F resulted in a significantly longer dh and lower Mdh, when cultured on biotype F resistant 'Dickinson Selection 28A' as also reported by Kindler and Spomer (1986), but did not have a significantly different Dt when compared to the other wheat entries. Biotype F also had a significantly lower Mdh when on 5XL even though this entry was reported as susceptible to damage by biotype F by Puterka and Peters (1987). Biotype F on 5XL was not significantly different from 'TAM 107' and 'Triumph 64' in dh. There were no significant differences among wheat entries in dh, Mdh, or Dt when infested with SCO. This corresponds with preliminary SCO damage screening, reported in Chapter III of this thesis, which showed all four entries to be susceptible to SCO. There were no significant differences among wheat entries in dh or Dt when infested with WCT. WCT was reported as reacting like biotype E when infesting wheats Bush et al.[10]. As expected, WCT had a significantly lower Mdh on 5XL compared to 'Triumph 64' or 'Dickinson Selection 28A'. However, this value was not significantly different from 'TAM 107', which in turn was also not significantly different from 'Dickinson Selection 28A'. Thus, 'TAM 107' might possess a mild antibiotic affect to WCT, while 5XL must be more pronounced or involve a different form of antibiosis. The Mdh of WCT was significantly greater for 'Triumph 64' than for the other wheat entries.

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[10] Bush et al. Manuscript, "Status of Greenbug Biotypes in Texas." submitted to Southwestern Entomologist.

Comparing greenbug entries on wheat

Biotype E had a significantly shorter dh than biotype F when on 'Triumph 64'. SCO and WCT had dh's that were not significantly different from biotype E or F, or each other when on 'Triumph 64'. Biotype F on 'Dickinson Selection 28A' had a significantly longer dh than the other greenbug entries and a lower Mdh than biotype E but did not differ in Dt. Dt did not significantly differ among greenbug entries when on any of the wheats. 'Dickinson Selection 28A' exhibits an antibiotic effect on biotype F but not enough to greatly influence the doubling time of the population when compared to the other greenbug entries. Biotype E had a significantly shorter dh than WCT and biotype F when on 'Dickinson Selection 28A', but was not significantly different than SCO. SCO and WCT were not significantly different in dh when on 'Dickinson Selection 28A'. The Mdh for biotype E, SCO, and WCT on 'Dickinson Selection 28A' were not significantly different. Thus, while 'Dickinson Selection 28A' proves to possess antibiosis and possibly some tolerance to biotype F, it is a suitable host for biotype E, SCO, and WCT. When compared to other greenbug entries, biotype F had a significantly longer dh when on biotype F susceptible 'TAM 107', but was able to maintain a Mdh that was not significantly different than biotype E or SCO. This is somewhat different than what Kindler and Spomer (1986) found. They found when comparing biotype E and F that dh (they reported as days to reproductive maturity) was not significantly different but biotype F had a significantly lower fecundity. Biotype E, SCO, and WCT had dh's that were not significantly different when on 'TAM 107', but WCT's Mdh was significantly lower than the other three greenbug entries. Thus 'TAM 107' must have antibiosis to WCT as earlier

suggested. Biotype E had a significantly greater Mdh than SCO, and WCT on 'TAM 107', but was nonsignificant when compared to biotype F. Biotype F and SCO were not significantly different in Mdh when on 'TAM 107'. There were no significant differences among the greenbug entries for dh, Mdh, or Dt when on 5XL. This relationship supports the idea that 5XL may possess tolerance to the "toxin" of avirulent greenbugs as well as antibiosis to virulent greenbugs. 5XL showed antibiosis to biotype E and WCT when compared to the other wheat entries.

Comparing Barleys

There were no significant differences in greenbug dh or Dt when comparing 'Wintermalt' and 'Post' barleys. However, biotype F produced a significantly greater Mdh on susceptible 'Wintermalt' than on resistant 'Post' which is consistent with the report of Kindler and Spomer (1986). There were no significant differences among the Mdhs of biotype E, SCO, or WCT when comparing 'Wintermalt' to 'Post'. Tolerance would seem to be the primary mechanisms of action in 'Post'; Webster and Starks (1984) reported 'Post' tolerance to biotype E, however, they also reported antibiosis as a factor in resistance, but I was not able to confirm their observations in this experiment.

Comparing Greenbug Entries on Barley

There was no significance in Dt between the greenbug entries when on either 'Wintermalt' or 'Post'.

Biotype E had a signficantly shorter dh on 'Wintermalt' than the other greenbug entries. There was no significant differences in dh among biotype F, SCO, and WCT on 'Wintermalt'. On 'Post', SCO had a

significantly longer dh than biotype E and WCT. However, there was no significant difference in the dh among biotype F and SCO or biotype E, F, and WCT. Biotype E had a significantly greater Mdh than the other greenbug entries when on 'Wintermalt' and 'Post' except for WCT on 'Post'. Biotype E may be more fit to utilize barleys in general. SCO had a significantly lower Mdh than biotype F and E but not WCT when on 'Wintermalt', and was not significantly different than biotype F or WCT when on 'Post'. SCO appears to be the poorest utilizer of barley of the four greenbug entries. WCT also appears to be somewhat less able to use barleys than biotype E, but appears to be better than SCO.

Comparing Oats

Biotype F, SCO, and WCT failed to establish on C.I. 1580 which indicates its high antibiosis or antixenosis. SCO also failed to establish on 'Nora' which has been considered a greenbug susceptible oats. SCO may lack the necessary capabilities to feed on oats in general. Comparing the Mdh of biotype E on C.I. 1580 and 'Nora', there was no significant difference; however, dh, and Dt were significantly greater for C.I. 1580, which indicated antibosis of C.I. 1580 to biotype E.

Comparing Greenbug Entries on Oats

Biotype E was the only biotype to establish on C.I. 1580, and SCO also failed to establish on 'Nora'. There was no significant difference in in Mdh between biotype E, F, and WCT on 'Nora'. However, biotype E did have a significantly shorter dh and Dt than biotype F and WCT, indicating biotype E as being better fit on 'Nora'. There was no

significant difference in dh between biotype F and WCT, but there was in Dt. WCT had a significantly shorter Dt than did biotype F; yet, neither biotype seemed to utilize 'Nora' very well. C.I. 1580 was reported as susceptible to biotype F damage by Kindler and Spomer (1986), but, biotype F under the experimental conditions of this experiment lacked the ability to establish a colony on C.I. 1580. It would thus seem that virulence of a pest toward a host does not necessarily indicate a lack of effective plant resistance. C.I. 1580, though susceptible to biotype F damage, is highly resistant to biotype F population growth and development.

Comparing Ryes

There were no significant differences between 'Insave F.A.' and 'Elbon' ryes when comparing dh and Mdh of all four greenbug entries. Biotype A,B,C, and E resistant 'Insave F.A.' rye had a significantly longer Dt than 'Elbon' when infested with biotype E; there were no significant differences among the other greenbug entries.

Comparing Greenbug Entries on Rye

There was no significance when comparing dh of the greenbug entries when on 'Insave F.A.'. WCT had a significantly greater Mdh than biotype E on 'Insave F.A.'; however, biotype E had a Dt that was significantly longer than SCO. When on 'Elbon', biotype E had a significantly shorter dh than biotype F. There were no significant differences in Mdh or Dt among any of the greenbug entries when on 'Elbon'. 'Insave F.A.' rye showed antibiosis to biotype E as expected, while the other greenbug

entries seemed to be little affected. 'Elbon' rye seemed best suited as a host of biotype E and SCO.

Comparing Sorghums

There were no significant differences of dh and Dt of biotype E among any of the sorghum entries. The dh for biotype F was significantly longer for 'Piper' than 'Pioneer 8300', both of which are reported to be susceptible to biotype C and E. SCO had a significantly longer dh for 'Piper' than the other entries except 'KS-30', and a significantly shorter dh for 'Pioneer 8300' than 'Piper' and 'KS-30'. The dh of SCO on 'KS-30' and 'Pioneer 8493' were not significantly different. WCT also had a significantly longer dh on 'Piper' than when on the other sorghum entries. The Mdh for biotype E was significantly smaller on 'Pioneer 8493' than on 'KS-30', however, it wasn't significantly different from 'Piper' or 'Pioneer 8300'. 'Pioneer 8493' (PI 264453 resistance source) didn't seem to have a high antibiosis effect or was not detected in this study, it's resistance may be more linked to tolerance. 'Piper' and 'Pioneer 8300' were also nonsignificant in their Mdh on biotype E compared to 'KS 30'. There were no significant differences in the Mdh of biotype F, SCO or WCT on any of the sorghum entries except for a significantly greater Mdh on 'Pioneer 8300' exhibited by WCT. None of the sorghum entries showed significant difference in the Dt for biotype E and SCO. However, biotype F had a Dt that was significantly longer on 'Piper' and 'KS-30' than 'Pioneer 8300'. 'Pioneer 8493' was not significantly different from 'KS-30' or 'Pioneer 8300' but was significantly less than 'Piper'

in the Dt of biotype F. WCT on 'Piper' also had a significantly longer Dt than the other sorghum entries.

Comparing Greenbug Entries on Sorghum

Biotype E had a significantly shorter dh than the other greenbug entries when on any of the sorghum entries. The dh of the other greenbug entries were not significantly different on any of the sorghum entries. The Mdh and Dt of Biotype E was significantly greater and shorter, respectively, than the other greenbug entries on 'Piper', with the exception for the Mdh of SCO which was nonsignificant. Biotype E was also significantly greater in Mdh and shorter in Dt on 'KS-30' than the other greenbug entries.

There were no significant differences among the Mdh or Dt of the greenbug entries on 'Pioneer 8300' or 'Pioneer 8493'. Biotype E seemed to do best on 'KS-30'. Biotype F, SCO, and WCT didn't seem to do well on any of the sorghums, but especially not on 'Piper' sudan.

Comparing All Cultivars

Biotype E had a dh on C.I. 1580 that was significantly longer than all the other entries except 'Insave F.A.'. Biotype E had a dh on 'Insave F.A.' that was significantly longer than 'TAM 107', 'Wintermalt', 'Triumph 64' and 'Pioneer 8300'. The Mdh for biotype E on C.I. 1580 was significantly less than the other entries except for 'Insave F.A.', 'Pioneer 8493' and 'Nora'. The other entries had varing degrees of significance with the greatest Mdh being on 'TAM 107' which was not significantly different than 'Wintermalt', 'Triumph 64', and 'Dickinson Selection 28A'. The Dt for biotype E was significantly

longer on C.I. 1580, and 'Insave F.A.', and compared to all other cultivars. 'Insave F.A.' was significantly greater than the other entries except for 'Pioneer 8493'. There were no significant differences for biotype E among the other entries. However, if the significance level was changed to (P = 0.10) the Dt for biotype E on 'Pioneer 8493' would have been significantly higher than 'TAM 107', 'Wintermalt', 'Triumph 64' and 'Dickinson Selection 28A'; thus, 'Pioneer 8493' may possess mild antibiosis to biotype E. In general the biotype E resistant cultivars 'Insave F.A.', C.I. 1580, and 'Pioneer 8493', seem to be the least fit hosts, while the susceptible wheats and barley seem to be the best fit hosts.

The dh for biotype F was significantly longer on 'Piper' than on 'Wintermalt', 'Triumph 64' 5XL, 'Post', 'Pioneer 8300', 'Elbon' and 'Nora'; it was not significantly different from the other entries. Biotype F failed to establish on C.I. 1580. The dh for Biotype F was significantly longer on 'Pioneer 8493', 'KS-30', 'Dickinson Selection 28A', 'TAM 107', 'Insave F.A.', 'Nora', 'Elbon' and 'Pioneer 8300', than on 'Post', 5XL, 'Triumph 64' and 'Wintermalt'. Mdh for biotype F varied greatly, but seemed to be least for the oats and sorghums and greatest for susceptible wheats and barleys. Dt for biotype F was significantly longer when on 'Nora' than when on the other entries except 'Piper'. The Dt of biotype F on 'Piper' was not significantly different than 'KS 30', but significantly longer than the other entries. The Dt of biotype F on 'KS-30' was not significantly different from 'Pioneer 8493', and 'Post', but 'Pioneer 8493' was significantly longer than 'Triumph 64', 'Wintermalt', and 'TAM 107'. In general biotype F did poorly on oats, sorghums, and 'Dickinson Selection 28A'. Biotype F seemed to do the

best on susceptible wheats and barleys.

SCO failed to establish on either oats, C.I. 1580 or 'Nora'. SCO had a dh on 'Piper' that was significantly longer than all the entries except 'KS-30'. SCO on 'KS-30' also had a dh significantly longer than the remaining entries except for 'Pioneer 8493'. The dh of SCO when on 'Dickinson Selection 28A' and 'TAM 107' was significantly lower than all the sorghums, but was not significantly different than 'Triumph 64', 'Elbon', 5XL, 'Wintermalt', 'Insave F.A.' or 'Post'. The Mdh for SCO was significantly less on 'Piper', and 'KS-30', than when on 'Insave F.A.', 'Elbon', 'Dickinson Selection 28A', 'TAM 107', and 'Triumph 64'. The comparisons of SCO on 5XL were not significantly different from any of the other entries. The Dt of SCO was signficantly longer on 'Piper' than when on 'Triumph 64', 'TAM 107', 'Dickinson Selection 28A', 'Elbon', 5XL, and 'Insave F.A.'; and significantly longer on 'KS 30' than when on 'Triumph 64', 'TAM 107', and 'Dickinson Selection 28A'. In general SCO seemed least suited on oats, sorghums, and barleys, but best on the rye entries.

WCT failed to establish on C.I. 1580. The dh and DT for WCT on 'Piper' was significantly longer than any of the other entries. 'Triumph 64' and 'Post' had significantly shorter dh than any of the sorghums or oats. Significant differences in Mdh values for WCT varied greatly, with all the sorghums (except 'Pioneer 8300') and 'Nora' showing significantly lower Mdh than the rest of the entries except for 5XL. 'Piper' was the only sorghum to have a Mdh significantly lower than 5XL. 'Triumph 64' had a significantly greater Mdh than the other entries. The Dt of WCT on 'Nora' was significantly longer than the other entries except 'Piper', 'KS-30', and 'Pioneer 8493'. In general

WCT seemed least fit on oats and sorghums, and intermediately fit on 5XL and 'Insave F.A.', but much better fit on the other wheats and barley.

Nymphal Survival

The percentages of nymphal survival for the four greenbug entries is given in Table XIV. Values of 100%, 83%, and 71% in Table XIV occurred when 0,1 or 2 nymphs needed replacement and such losses were considered to be due to experimental error and not necessarily effects due to host plant. Biotype E had difficulty surviving only on C.I. 1580 and 'Insave F.A.'. Biotype F had the most difficulty establishing on C.I. 1580, 'Nora', 'Elbon', 'Piper', 'KS-30', 'Dickinson Selection 28A' and 5XL. SCO had the most difficulty establishing on C.I. 1580, 'Nora', 'Elbon', and 'Insave F.A.'. WCT had the most difficulty establishing on C.I. 1580, 'Nora', 'Piper', and 'KS-30'. Survival of the greenbugs to reproductive maturity is essential on any plant which might serve as a potential host. If the survival values observed in this test applied to field populations, the effect of host plants would be important to biotype fitness.

Conclusion

SCO and WCT probably deserve to be distinguished as new biotypes. SCO differs from biotype E in sorghum and oat responses from biotype F in 'Dickinson Selection 28A' response, and from WCT in response to 5XL and 'Insave F.A.'. WCT differs from biotype E in response to oats and sorghum, and from biotype F in response to 'Dickinson Selection 28A'. Further research on antixenosis and tolerance should be conducted before these isolates are termed as new biotypes.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Greenbug biotype E was the most prevalent biotype in Oklahoma during 1986. Biotype C was detected in small amounts in the northeast and southwest regions of the state. Biotype B was collected in moderate amounts in the southwest region of the state during the spring. It was also found oversummering on prairie cup grass in Payne County. The biotype B population may be cyclic in nature moderated by natural selection and/or formation through sexual cycles. Two new isolates were collected in the Southwest region of the state: SCO, from Stephens County; and LCO, from Lincoln County. LCO may be a variant of the biotype B population. Another isolate was collected in a Texas survey in Wichita County, Texas, approximately 100 km from the SCO collection site. The wide range of diversity in the southwest region could be due to sexual reproduction, as sexual forms were collected in this region.

The 1986 sorghum seed company survey indicated that 91% of sorghum seed being sold was biotype C resistant; 37% was biotype C and E resistant and only 9% was greenbug susceptible. Sorghum plantings still favor the biotype E population growth which may explain it's year-round dominance. Biotype shifts in wheat and sorghum may result with increased plantings of biotype C and E resistant sorghums. SCO and WCT probably deserve to be distinguished as new biotype, but antixenosis and tolerance studies should be conducted first. SCO differs from biotype E

in sorghum and oat responses; and from biotype F in 'Dickinson Selection 28A' response; and WCT in it's response to 5XL and 'Insave F.A.'. WCT differs from biotype E in it's response to oats and sorghums; and from biotype F in it's response to 'Dickinson Selection 28A'.

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APPENDIX

TABLES

TABLE I

EXPECTED AND/OR OBSERVED RESPONSE OF SIX CULTIVARS TO SIX GREENBUG BIOTYPES OR ISOLATES, SPRING 1986 SCREENING POTS, COMPOSED OF TWO SEPARATE PHASES[a]

	Phase I Cultivar		
Biotype or Isolate	'Triumph 64'	'TAM 107'	5XL
A	S	R	--[b]
B	S	R	S
C	S	R	R
E	S	S	R
F	S	S	S
SCO	S	S	S

	Phase II Cultivar		
Biotype or Isolate	'Piper'	C.I. 9058	C.I. 1580
A	R	R	S
B	I	S	S
C	S	S	R
E	S	S	R
F	R	R	S
SCO	R	S	S

[a] R = Resistant, S = Susceptible, and I = Intermediate.

[b] Response not known.

TABLE II

RESULTS OF THE 1986 SPRING, SUMMER AND FALL GREENBUG BIOTYPE SURVEYS GROUPED BY REGIONS

Region		Northwest				Southwest				Northeast[e]				Total of the Regions			
Survey	Biotype or Isolate	n[a]	t[b]	%[c]	C.I.[d]	n[a]	t[b]	%[c]	C.I.[d]	n[a]	t[b]	%[c]	C.I.[d]	n[a]	t[b]	%[c]	C.I.[d]
Spring 1986 on Wheat	B	0	0	0	0	6	6	28	0.14-0.60	-	-	-	-	6	6	11	0.06-0.32
	C	0	0	0	0	1	2	10	0.00-0.28	-	-	-	-	1	2	4	0.00-0.15
	E	19	33	100	0.83-1.0	9	12	57	0.31-0.77	-	-	-	-	28	45	83	0.62-0.90
	SCO	0	0	0	0	1	1	5	0.00-0.28	-	-	-	-	1	1	2	0.00-0.15
Summer 1986 on Sorghum	C	0	0	0	0	3	4	10	0.03-0.32	2	2	9	0.01-0.40	5	6	6	0.03-0.18
	E	23	37	100	0.85-1.0	21	36	90	0.68-0.97	12	20	91	0.60-0.98	56	93	94	0.82-0.97
Fall 1986 on Wheat	C	0	0	0	0	2	2	4	0.01-0.22	-	-	-	-	2	2	2	0.00-0.11
	E	31	56	100	0.89-1.0	26	47	94	0.73-0.98	-	-	-	-	57	103	97	0.86-0.99
	LCO	0	0	0	0	1	1	2	0.00-0.18	-	-	-	-	1	1	1	0.00-0.09

[a] The number of sample sites resulting in that particular biotype.

[b] The number of samples screened resulting in that particular biotype.

[c] The percentage of the total screened of a biotype.

[d] The bionomial confidence limits of a biotype based on the number of sample sites (P = 0.05; Steel and Torrie's [1980] bionomial confidence limits table).

[e] This region was not surveyed during the Spring or Fall.

TABLE III

SEEDLING - INJURY RATINGS AND RATING COMPARISONS WITHIN THE GREENBUG BIOTYPES B, C, E, AND SCO FEEDING ON SIX CULTIVARS, SPRING 1986 SURVEY CONDUCTED ON WHEAT

	Average Rating[a,b] Biotype or Isolate			
Cultivar	B	C	E	SCO
Phase 1				
'Triumph 64'	5.39a	5.83a	5.48a	5.67ab
'TAM 107'	2.00c	2.00c	5.33b	6.00a
5XL	5.44a	2.00c	1.88c	5.33ab
'Piper'	3.61b	5.00b	--[c]	2.00c
C.I. 9058	5.67a	5.50a	--[c]	5.33ab
C.I. 1580	5.50a	1.83c	--[c]	4.67b
Degrees of Freedom	72	24	270	12
Mean Square Error	0.20	0.17	0.19	0.39

[a] Means followed by the same letter in a column are not significantly different (P = .05; Duncan's [1955] multiple range test).

[b] Damage values from 1-6 (1 = 0%, 2 = 1-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-99%, 6 = 100%), % damage as chlorosis and/or necrosis.

[c] Biotype E was not tested on these phase II cultivars.

TABLE IV

EXPECTED AND/OR OBSERVED RESPONSES OF FOUR CULTIVARS TO SIX GREENBUG BIOTYPES, SUMMER 1986 SCREENING POT[a]

Biotype or Isolate	C.I. 9058	'TAM 107'	5XL	C.I. 1580
A	R	R	--[b]	S
B	S	R	S	S
C	S	R	R	R
E	S	S	R	R
F	R	S	S	S
SCO	S	S	S	S

[a] R = Resistant, and S = Susceptible

[b] Response not known.

TABLE V

RESULTS AND COMPARISONS OF TWO GREENBUG BIOTYPE DETERMINING METHODS, RAPID TECHNIQUE VS. POT. SCREENING, USING GREENBUG BIOTYPES C AND E, SUMMER 1986 SURVEY CONDUCTED ON SORGHUM[a]

Biotype	P.S.[b]	R.T.[c]	C.R.T.[d]	%R.T.C.[e]	C.I.[f]
C	6	20	6	100	0.09 - 0.21
E	93	79	79	84.95	0.77 - 0.91
Total	99	99	85	85.86	0.79 - 0.92

[a] Comparison values based on the assumption that the pot screening method gives the correct response.

[b] The number of a particular biotype as indicated by the pot screening method.

[c] The number of a particular biotype as indicated by the rapid technique method.

[d] The number of correct responses using the rapid technique method.

[e] The % correct responses using the rapid technique method.

[f] The bionomial confidence limits of correct responses using the rapid technique method (P = 0.05; Steel and Torrie's [1980] binomial confidence limits table).

TABLE VI

SEEDLING - INJURY RATINGS AND RATING COMPARISONS WITHIN THE GREENBUG BIOTYPES C AND E FEEDING ON FOUR CULTIVARS, SUMMER 1986 SURVEY CONDUCTED ON SORGHUM

	Average Rating[a,b] Biotype or Isolate	
Cultivar	C	E
C.I. 9058	5.79a	5.75a
'TAM 107'	2.00b	5.49b
5XL	1.96b	1.95c
C.I. 1580	1.92b	1.88d
Degrees of Freedom	72	1116
Mean Square Error	0.08	0.12

[a] Means followed by the same letter in a column are not significantly different (P = 0.05; Duncan's [1955] multiple range test).

[b] Damage values from 1-6 (1 = 0%, 2 = 1-15%, 3 = 26-50%, 4 = 51-75%, 5 = 76-99%, 6 = 100%), % damage as chlorosis and/or necrosis.

TABLE VII

EXPECTED AND/OR OBSERVED RESPONSES OF FOUR CULTIVARS TO EIGHT GREENBUG BIOTYPES OR ISOLATES FALL 1986 SCREENING POT[a]

	Cultivar			
Biotype or Isolate	C.I. 9058	'TAM 107'	5XL	'Piper'
A	R	R	--[b]	R
B	S	R	S	I
C	S	R	R	S
E	S	S	R	S
F	R	S	S	R
SCO	S	S	S	R
LCO	S	R	S	R
WCT	S	S	R	R

[a] R = Resistant, S = Susceptible, and I = Intermediate.

[b] = Response not known.

TABLE VIII

SEEDLING - INJURY RATINGS AND RATING COMPARISONS
WITHIN THE GREENBUG BIOTYPES C, E, AND LCO
FEEDING ON FOUR CULTIVARS, FALL 1986
SURVEY CONDUCTED ON WHEAT

	Average Rating[a,b]		
	Biotype or Isolate		
Cultivar	C	E	LCO
C.I. 9058	5.25a	5.39a	5.25a
'TAM 107'	2.00b	5.26b	2.00b
5XL	1.88b	1.90c	5.75a
'Piper'	5.38a	5.22b	1.75b
Degrees of Freedom	24	1224	12
Mean Square Error	0.27	0.18	0.19

[a] Means followed by the same letter in a column are not significantly different (P = 0.05; Duncan's [1955] multiple range test).

[b] Damage values from 1-6 (1 = 0%, 2 = 1-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-99%, 6 = 100%), % damage as chlorosis and/or necrosis.

TABLE IX

THE ESTIMATED NUMBER OF 50 LB. BAGS OF SORGHUM SEED WITH POSSIBLE GREENBUG BIOTYPE C AND/OR E RESISTANCE AND THEIR PERCENTAGES OF THE ESTIMATED TOTAL SOLD

Greenbug Reaction	No. 50 lb. bags of Grain Sorghum Sold	Percent
Susceptible	3,322	9
Biotype C resistant only	19,184	53
Biotype E resistant only	0	0
Biotypes C/E resistant	13,477	37
Total surveyed	35,983	73
Estimated total sold	49,000	

TABLE X

GREENBUG RESISTANCE STATUS OF FOURTEEN ENTRIES FROM FIVE CROP SPECIES, AND SOURCE OF RESISTANCE (IF ANY)

Crop	Cultivar	Resistance Status	Source of Resistance	Reference
Wheat, Triticum aestivum L.	'Triumph 64'	No Resistance		
	'Dickinson Selection 28A'	Resistant to A and F	C.I. 3707	Wood (1961) Kindler and Spomer (1986)
	'TAM 107'	Resistant to A,B, and C	'Amigo' C.I. 17609	Sebesta and Wood (1978)
	'TAM 105' x 'Largo'	Resistant to C and E (No Data available for A)	C.I. 17895	Porter et al. (1982)
Barley, Hordeum vulgare L.	'Wintermalt'	No Resistance		
	'Post'	Resistant to A,B,C, and E	'Will' C.I. 11652	Webster and Starks (1983) Porter et al. (1982)
Oat, Avana sativa L.	'Nora'	No Resistance		
	C.I. 1580	Resistant to C and E		Starks et al. (1983)

TABLE X (Cont.)

Crop	Cultivar	Resistance Status	Source of Resistance	Reference
Rye, *Secale cereale* L.	'Elbon'	No Resistance		
	'Insave F.A.'	Resistant to A,B,C, and E		Sebesta and Wood (1978) Porter et al. (1982)
Sudangrass, *Sorghum sudanense* (Piper) Stapf	'Piper'	Resistant to A and B		Starks and Burton (1977)
Grain Sorghum, *Sorghum bicolor* (L.) Moench	'Pioneer 8300'	No Resistance to C or E; Not established for A,B, or F		
	'KS-30'	Resistant to B, and C; Not established for A or F	*Sorghum virgatum*	Hackerott et al. (1972)
	'Pioneer 8493'	Resistant to C and E; Not established for A,B, or F	P.I. 264453	Porter, K.S. personal communication

TABLE XI

EFFECT OF FOURTEEN CEREAL CULTIVARS ON THE PREREPRODUCTIVE DEVELOPMENT TIME (dh) OF FOUR GREENBUG BIOTYPES[a]

	Cultivar[b]													
	Wheat			Barley			Oat		Rye		Sorghum			
Biotype or Isolate	'Triumph 64'	'Dickinson Selection 28A'	'TAM 107'	5XL	'Wintermalt'	'Post'	'Nora'	C.I. 1580	'Elbon'	'InSave F.A.'	'Piper'	'Pioneer 8300'	'KS-30'	'Pioneer 8493'
E	136 aA	141 abA	139 aA	159 abA	136 aA	156 abA	151 abA	192[d] c	146 abA	169 bcA	143 abA	132 aA	147 abA	155 abA
F	173 abB	207 cdC	202 bcdB	175 abA	170 aB	177 abAB	192[d] abcB	--[c]	190[d] abcB	201[d] bcdA	229[d] dB	182 abcB	208[d] cdB	209 cdB
SCO	165 abAB	158 aAB	160 abA	171 abA	181 abcB	187 abcB	--[c]	--[c]	167 abAB	182 abcA	235 eB	188 bcB	219 deB	203 cdB
WCT	156 aAB	172 abcB	164 abA	165 abA	166 abB	156 aA	191[d] bcdeB	--[c]	175 abcdAB	196 cdeA	248[d] fB	210 eB	204[d] deB	200 cdeB

[a] Means, in hours, of three to six replications.

[b] Means in a column followed by the same capitol and means in a row followed by the same lower case letters are not significantly different (P = 0.05; SAS Institute [1985]).

[c] Ten or more replications of nymphs failed to survive on this host.

[d] These values are based on less than five replications.

TABLE XII

EFFECT OF FOURTEEN CEREAL CULTIVARS ON THE NUMBER OF NYMPHS PRODUCED IN TIME EQUIVALENT TO dh (Mdh)[a] OF FOUR GREENBUG BIOTYPES

	Cultivar[b]													
	Wheat			Barley			Oat		Rye		Sorghum			
Biotype or Isolate	'Triumph 64'	'Dickinson Selection 28A'	'TAM 107'	5XL	'Wintermalt'	'Post'	'Nora'	C.I. 1580	'Elbon'	'InSave F.A.'	'Piper'	'Pioneer 8300'	'KS-30'	'Pioneer 8493'
E	38.6 efAB	36.4 defB	43.0 efC	20.0 bcA	39.4 efC	29.6 deB	14.2 abA	6.7[d] a	20.4 bcA	11.6 abA	21.2 bcB	18.8 bcA	27.8 cdB	13.2 abA
F	34.0 fgA	24.4 efA	37.2 gBC	15.4 abcdeA	28.6 fgB	14.2 abcdA	4.7[d] aA	--[c]	17.7[d] bcdeA	22.3[d] cdefAB	5.3[d] aA	12.8 abcA	6.3[d] aA	9.4 abA
SCO	29.8 cA	27.6 cAB	28.8 cB	21.2 abcA	17.4 abA	15.8 abA	--[c]	--[c]	22.8 bcA	21.8 bcAB	11.6 aAB	15.5 abA	11.6 aA	14.0 abA
WCT	45.0 fB	30.8 eB	20.8 cdeA	15.4 bcA	21.6 cdeAB	26.2 deA	7.2[d] abA	--[c]	22.4 cdeA	25.4 cdeB	4.0[d] aA	20.6 cdA	8.0[d] abA	10.4 abA

[a] Means, in hours, of three to six replications.

[b] Means in a column followed by the same capitol and means in a row followed by the same lower case letters are not significantly different (P = 0.05; SAS Institute [1985]).

[c] Ten or more replications of nymphs failed to survive on this host.

[d] These values are based on less than five replications.

TABLE XIII

EFFECT OF FOURTEEN CEREAL CULTIVARS ON THE POPULATION DOUBLING TIME (Dt) OF FOUR GREENBUG BIOTYPES[a]

	Cultivar[b]													
	Wheat			Barley			Oat		Rye		Sorghum			
Biotype or Isolate	'Triumph 64'	'Dickinson Selection 28A'	'TAM 107'	5XL	'Wintermalt'	'Post'	'Nora'	C.I. 1580	'Elbon'	'InSave F.A.'	'Piper'	'Pioneer 8300'	'KS-30'	'Pioneer 8493'
E	51 aA	53 aA	50 aA	72 aA	51 aA	65 aA	79 aA	186[d] c	77 aA	136 bcB	65 aA	63 aA	60 aA	102 abA
F	68 aA	91 abA	76 aA	92 abA	69 aA	112 abcA	263[d] eC	--[c]	98[d] abA	89[d] abAB	221[d] deC	99 abA	163[d] cdB	141 bcA
SCO	67 aA	68 aA	67 aA	76 abA	89 abcA	93 abcA	--[c]	--[c]	74 abA	82 abA	137 cB	96 abcA	124 bcB	106 abcA
WCT	56 aA	69 aA	74 aA	86 abA	73 aA	65 aA	171[d] cB	--[c]	82 abA	86 abAB	306 dD	95 abA	138[d] bcB	125 bcA

[a] Means, in hours, of three to six replications.

[b] Means in a column followed by the same capitol and means in a row followed by the same lower case letters are not significantly different (P = 0.05; SAS Institute [1985]).

[c] Ten or more replications of nymphs failed to survive on this host.

[d] These values are based on less than five replications.

TABLE XIV

RESULTS OF THE NYMPHAL SURVIVAL OF FOUR GREENBUG BIOTYPES ON FOURTEEN CEREAL CULTIVARS[a,b]

	Biotype or Isolate			
Cultivar	E	F	SCO	WCT
'Triumph 64'	100	100	100	100
'Dickinson Selection 28A'	83	63	100	100
'TAM 107'	100	83	83	100
5XL	100	63	100	100
'Wintermalt'	100	71	100	100
'Post'	71	50	83	71
'Nora'	100	25	7	45
C.I. 1580	36	9	0	0
'Elbon'	83	27	30	100
'Insave F.A.'	50	25	63	83
'Piper'	100	25	83	50
'KS-30'	83	31	83	33
'Pioneer 8300'	100	100	83	100
'Pioneer 8493'	83	100	71	83

[a] Between five and fifteen replications attempted per biotype/cultivar combination.

[b] The percentage of the total replications attempted in which the nymph became adult and actually produced a nymph.

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