GREENBUG (SCHIZAPHIS GRAMINUM, RONDANI) BIOTYPE - E INTERACTION ON FOUR GENOTYPES OF CORN (ZEA MAYS, L.)

by

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Table of Contents

List of Tables

Part I

Part II

List of Figures

Part I

INTRODUCTION

The greenbug (Schizaphis graminum, Rondani) is capable of infesting many graminaceous plants throughout the world (Michels, 1986). The greenbug was first reported on sorghum in Italy in 1863 (Harvey, 1971). In the United States, greenbugs have been a damaging pest of wheat (Triticum aestivum L.) since 1882. The first report of damage to sorghum in the United States was in Western Kansas during 1916. However, prior to 1968 these insects had not attained the economic status on sorghum that they had on small grains (Harvey, 1971; Kindler et al. 1984; Schweissing and Wilde, 1978).

The polyphagous nature of greenbugs and the appearance of various biotypes (Michels, 1986) defined by response to resistant varieties or to insecticides, have made it difficult to determine the range of its host. Six major greenbug biotypes, designated as A, B, C, D, E, and F have occurred in the United States. Biotype A, the first so designated, was avirulent to Dickinson Selection 28-A wheat. Then B was reported when resistance in the Dickinson Selection was overcome by greenbug (Wood, 1961). In 1968, greenbugs which attacked sorghum, were designated as Biotype C (Harvey and Hackerott, 1969; Wood et al. 1969). Greenbug populations on Texas sorghum resistant to disulfoton were designated as D (Teetes et al., 1975), the only biotype defined in terms of response to pesticide. Biotype E was described based on the ability of Greenbug to damage a previously C-resistant wheat cultivar ('Amigo') on the Texas High Plains (Porter et al., 1982). Biotype E has since been specified to exhibit differences in response among varieties of the

same plant species (Michels, 1986). It affects many of the previously resistant small grains and sorghum genotypes (Stark et al. 1983). Biotype F has recently been described (Kindler and Spomer, 1986) as a variant in the greenbug population that can utilize Canada bluegrass, Poa compressa L., as a host.

The ability for greenbugs to exhibit difference in response among varieties within a plant species, to broaden its host plant range to include new plant species, and to develop insecticide resistance (Michels, 1986) have attracted the attention of many workers. Some corn researchers have even more reasons to express this concern because small groups of greenbugs have been found on the crop. Corn (Zea mays L.) is an important crop grown in many areas in the United States including the Great Plains. In 1985 fifty percent of the World's total production of 490,155,000 metric tons of corn was produced in the United States (FAO Production Year Book, 1985). In the State of Kansas alone, 1985 total harvested acreage of corn was 1,100,000 acres and a production of about 136.5 million bushels (Walters, 1985). One major limiting factor in corn production is insect pest infestations (Mock et al., 1981; Morrison and Stewart, 1984).

Some work has been carried out on the probing behavior of the greenbug using the electronic monitors (Campbell et al. 1982; Montllor et al. 1983). The technique of electronically monitoring the probing behavior of aphids was introduced by McLean and Kinsey in 1964 (Campbell et al. 1982). It was used to monitor the probing behavior of species of aphids feeding on various species of dicotyledons (Kennedy et al. 1978;

Tjallingii, 1978). Basically, a distinctive sequence of waveforms corresponds to salivation and sheath formation, stylet-penetration of sieve elements and continuous period of ingestion (Campbell et al. 1982). Recently Campbell et al. (1982), studied the probing behavior of greenbug on sorghum and rice using the electronic monitor and reported probing behavior as an indication of crop susceptibility and resistance and, an association between reproductive capacity of the greenbug with its ability to ingest from the phloem. Although greenbugs also have been observed on corn, most of these monitoring studies were completed on sorghum and wheat and little if any research have been attempted on corn.

One important factor that determines greenbug growth and development is food quality (Cress and Chada, 1970; Schuster and Starks, 1973). Though it has been reported that greenbug is an effective vector of virus diseases of the corn plant (Starks et al. 1975) little or no such studies involving the ability of these insect pests to survive and develop on corn has been conducted.

The potential for greenbugs to develop new biotypes, defined by difference in response among host plants is thus complex and needs to be elucidated on a specific host basis. Thus, this study converges on two sources of biotype E greenbug and four corn genotypes in an attempt to assess the ability of greenbug to reproduce, develop and survive on corn, and to suggest the potential for biotype development. The first section examines life history characteristics and the second part considers greenbug reproduction, growth, and feeding behavior.

The specific objectives of this study are:

1. To determine how various corn genotypes affect the growth and development, survival and reproduction of biotype E greenbug and to develop age-specific life life tables for greenbugs on these genotypes.
2. To quantify the effect of various corn genotypes on biotype E feeding behavior and correlate feeding behavior with fecundity and growth.
3. To determine effect of previous hosts on life table parameters and feeding behavior of biotype E greenbug.

LITERATURE REVIEW

Life History. The greenbug, Schizaphis graminum (Rondani) is of European origin and has a relatively long history as a major pest of small grains. The first greenbug plague to cereals was reported to have taken place in 1847 in Northern Italy. The greenbug was first reported in the United States in 1882, in Africa in 1907 and in South America in 1937 (Harvey, 1971). The first report of greenbug damage to sorghum (Sorghum bicolor (L.)) in the United States occurred during 1916, in Western Kansas (Harvey, 1971). However, it was not until 1968 that the greenbug was identified as a major pest of sorghum and is now regarded as a key pest of wheat (Triticum aestivum L.), barley (Hordeum vulgare L.), oats (Avena sativa Hauskn) and sorghum (Sorghum bicolor (L.)) (Harvey, 1971; Schweissing and Wilde, 1978; and Kindler et. al., 1984). They are considered the most important pest to small grain and sorghum in the Central and Southwestern States (U.S.D.A., 1978).

The greenbugs are abundant during the months of September, October, and November, and their outbreaks in the fall result from the growth of local summer populations greenbugs or from winged migrants moving into the Central plains on wind currents from the south. Damaging greenbug infestations do not occur at regular interval or in any predictable pattern. The range of host plants of the greenbug is wide. Patch (1938) developed a list of aphids and their food plants, and included 62 plant species associated with the greenbug. Since Patch's work, 33 of the original 57 species have been confirmed as greenbug hosts and 37 new species have been added to the list. An updated list of confirmed graminaceous host plant of greenbugs consists of 70 species in 44 genera

(Michels, 1986).

The polyphagous nature of the greenbug (Michels, 1986) and the existence of biotypes (Eastop, 1973) contribute to the unpredictability and extensive host range of greenbugs. Varieties of plants previously resistant to greenbugs have suddenly become colonized (Eastop, 1973), e.g. Schizaphis graminum on sorghum in the United States (Porter et al., 1982). Many aphid species have been found to consist of a complex of biotypes recognized by differences in life cycles, reaction to light, different host plant preferences, different virus transmitting abilities, different feeding behavior, and differential susceptibility to insecticides (Eastop, 1973). Michels (1986) described three different types of variations in the greenbug population for which greenbug biotypes have been designated: differences in response among varieties within a plant species, broadening of host plant range to include new plant species, and insecticide resistance.

Deihl and Bush (1984) proposed five categories of a more descriptive, genetically-oriented system by which biotypes could be classified: non genetic polyphenism, polymorphic or polygenic variations within populations, geographic races, host races, and species. Michels (1986) asserted that the development of polymorphic or polyphenic host races could function as a mechanism that allows an expansion of the host-plant base. Harvey and Hackerott (1969) demonstrated that plants which were previously host plants of greenbug are conserved as the host plant base expands. They examined 28 grass species including sorghum for differences in survival and reproduction

between biotype B and C greenbug and found only slight, non significant differences except that biotype C greenbug reproduced extremely well on sorghum while biotype B greenbug could not utilize sorghum as a host. The broadening of the host-plant base within a plant species was illustrated by Chedester and Michels (1982) when they examined greenbug resistance in 500 oats accessions. Fifty-one were resistant to biotype C greenbug. When this subset was evaluated for resistant to biotype E, 24 accessions were found to be susceptible to biotype E. The 449 accessions that were susceptible to biotype C greenbugs were also susceptible to biotype E greenbug; no biotype C-susceptible accessions were found that were resistant to biotype E greenbug.

The adaptive success of the greenbug through the development of biotypes is exemplary. Six greenbug biotypes, designated as A, B, C, D, E, and F have been described in the United States (D. L. Kerns et al., 1987). Based on response to resistant wheat, Wood (1961) designated field and greenhouse strains of greenbug as biotypes A and B, respectively. Biotype A, the first so designated, was avirulent to Dickinson Selection 28-A Wheat. Then B was reported when the Dickinson Selection was overcome by greenbugs. In 1968 greenbugs attacked sorghum damaging large areas of grain sorghum in Texas, Oklahoma, Nebraska, and Kansas. These individuals were designated as biotype C (Harvey and Hackerott, 1969). Teetes et al. (1975) described an intermittent mutant of greenbug that was resistant to organophosphate insecticide (disulfoton) and designated this population as biotype D. Biotype E was described based on the ability of greenbug to damage a previously biotype C-resistant wheat cultivar ('Amigo') on Texas high plains and

resistant sorghum (Porter et al., 1982; Kindler et al., 1984; and Dumas and Mueller, 1986). Most recently Kindler and Spomer (1986) described biotype F as a variant in greenbug population that can utilize Canada bluegrass, Poa compressa L., as a host. Michels and Kring demonstrated the ability for specific populations of greenhouse-reared greenbug to survive for numerous generations on corn, Zea mays. Although greenbug has been noted on corn since 1938 (Patch, 1938), it has not been previously reported to survive for multiple generations on this host (Michels, 1986).

Growth and Development. Greenbugs reproduce parthenogenetically (primarily) and viviparously. This insect can produced enormous numbers of aphids during the fall because its natural enemies become inactive or reproduce much more slower than the greenbug during cool periods below 65° F. Greenbug reproduction can occur between 40° and 90° F The optimum temperature for greenbug reproduction and development is approximately 75° F. Under optimum conditions, nymphs move through four stadia in development and become adults in approximately 7 days. The mean adult life span is 25 days and 80 progeny may be produced per adult. The average number of progeny produced per day is 3 (Starks and Burton, 1977; Bottrell et al. 1972; and Wadley 1931). A recent experiment by Summer et al. (1986) showed biotype C on a winter wheat cultivar 'Sturdy', had a 40-day longevity, 20-day reproduction period, and produced 3 offspring per reproductive day.

Campbell and co-workers (1982) studied the growth and development of biotype C greenbug on sorghum for 15 days. They showed that the rate

of greenbug population growth was greater on susceptible lines of sorghum than resistant lines. Montllor et al. (1983) showed that the greenbug biotype E reproduced and grew at approximately twice the rate of biotype C on a greenbug biotype C resistant variety of sorghum, 'IS809'.

Recently Michels et al. (1987) compared progeny production and development of Texas and Arkansas populations of biotype E greenbugs on various host plant including corn, wheat and sorghum. Progeny production and development for both populations were similar on wheat and sorghum, but dissimilar on corn. Means of 2.3, 2.4, and 2.7 Texas greenbug nymphs were produced per day when reared in the laboratory on 'Warner 2188' corn, 'Scout 66' wheat, and 'Warner 839 Dr' sorghum leaves, respectively. Arkansas greenbug collection produced an average of 0.7, 2.3 and 3.1 nymphs per day on the same respective host plants. A similar study was conducted by Beregovoy et al. (1988) using greenbug clones collected in fields from eight localities in the Central United States. They reported that both biotype C and E greenbug did not survive longer than a week on corn.

Greenbug Feeding Behavior and The Insect Feeding Monitor. The feeding behavior of the greenbug is quite similar to that of other aphids. The aphids have piercing sucking mouth parts with which they remove plant sap. Feeding also has a phytotoxic effect on plant tissue (Chatter and Shlehuber, 1951; and U.S.D.A., 1978). During probing of their hosts, aphids lower their heads, protract their rostrum, and extend and vibrate their antennae. The feeding process is accomplished by secretion of saliva (salivary sheath and watery saliva) which helps

them to disrupt plant tissue and insert their stylet bundles (Miles, 1972). The sheath material is secreted continuously along the stylet penetration process to form the stylet sheath. A watery saliva which contains pectinase and cellulase is released to aid in penetration of plant tissue.

Ingestion is primarily from the sieve tubes, but sometimes from the epidermal tissue, mesophyll parenchyma, phloem parenchyma (Chatters and Shlehuber, 1951; Pollard, 1973) and xylem (McLean and Kinsey, 1967). Studies by Chatter and Shlehuber (1951) and Dreyer and Campbell (1984) indicated that the entry of the stylet sheath was predominately intercellular. However, Campbell et al. (1982) and Pennington (1985) reported that the path of saliva sheath of biotype E greenbug through the mesophyll tissue is intercellular. There is a correspondence between the feeding behavior and the digestive enzymes of aphids. Aphids which probe plant tissues intercellularly possess salivary pectinase (Adams and McAllen, 1958) and other carbohydrases capable of degrading other plant matrix polysaccharides, such as cellulose and hemicellulose (Adams and Drew, 1965; Campbell and Dreyer, 1985) whereas aphids without pectinase penetrate directly through cells (McAllen and Adams, 1961). The polysaccharide degrading enzymes in the saliva of aphids facilitate aphid stylet penetration of plant tissue (Pollard, 1973). Supportive of this viewpoint is the observation that susceptibility of sorghum was associated with a greater rate of hydrolysis of sorghum pectic substances by a greenbug and the resistance of sorghum with the duration that a biotype is maintained as a colony on

that variety (Dreyer and Campbell, 1984; Campbell and Dreyer, 1985).

Campbell and co-workers (1982) found distinct differences in the probing behavior of biotype C greenbug feeding on resistant and susceptible lines of sorghum, and the plant tissues on which the greenbug most commonly fed by the use of a electronic feeding monitor (EFM). This technique was first introduced by McLean and Kinsey (1964) on pea aphids, for electronically monitoring the probing behavior of aphids. This technique has been useful in developing new information on the aphid feeding behavior (McLean and Kinsey, 1967).

The insect feeding monitor assesses the feeding behavior of an insect on a plant by recording distinctive sequences in waveforms, corresponding to voltage fluctuations definitively associated with salivation and/or ingestion in specific plant tissues (McLean and Kinsey, 1967). Improvements have been made in the Department of Entomology devices at Kansas State University as described by Brown and Holbrook (1976). Through this system, aphids are connected to an electrical circuit with a fine gold wire attached to its dorsal abdominal region. An alternating current is generated in the potting soil of the plant hosting the experimental aphid. As the aphid feeds it completes the electrical circuit thereby changing the impedance. These differences are are calculated and changed back to voltage differences which are recorded as distinctive sequences in waveforms corresponding to voltage fluctuations associated with different feeding activities (McLean and Kinsey, 1967; Campbell et al., 1982).

Some feeding monitor studies with greenbug have been completed using on monocotyledons by Campbell et al. (1982), Montllor et al.

(1983) and Ryan et al. (1987). Previous works on greenbug feeding behavior involved sorghum and wheat with no study using corn as a host.

Five distinct wave forms have been identified which correspond to the different feeding activities (probing, salivation, non-phloem ingestion, stylet penetration of sieve elements and phloem ingestion) of aphids tested on resistant and susceptible seedling plants. These wave forms were associated with the different feeding activities by locating stylet tips of aphids in the plant through leaf sectioning (Campbell et al., 1982).

Aphids usually make test probes before ingestion begins. Increased numbers of separate probes and increase duration of not probing were associated with greenbugs feeding on resistant sorghum lines. Greenbug monitored on a non-host plant, rice, exhibited non-phloem ingestion, but not phloem ingestion (Campbell et al., 1982). Initially, probing is followed by a salivation event, which is the formation of sheath material from the time of initial probing to the location of vascular bundles. Nielson and Don (1974) reported that the total duration of salivation by aphids feeding on a resistant variety was longer compared to aphid feeding on susceptible varieties. Campbell et al. (1982) did not find any significant difference in the mean duration of salivation between resistant and susceptible varieties. They found that greenbug biotype C probed more frequently, salivated longer, ingested from the phloem for a shorter amount of time and spent less time feeding on resistant than susceptible sorghum plants. Dreyer et al. (1981) reported three chemical compounds that affected greenbug feeding on

sorghum, but Campbell and Dreyer (1985) asserted that these compounds are not involved in reduced ingestion because they are usually compartmentalized in intracellular vacuoles. Since greenbug probe host plant intercellularly (Pollard, 1973) they are able to circumvent these allelochemicals. There was no evidence of any physical barrier within the resistant plant to penetration or location of the phloem by stylets, and they suggested phloem chemistry as a meaningful factor for explaining sorghum resistant to greenbug biotype C.

Montllor and co-workers (1983) studied the probing behavior of greenbug biotype C and biotype E on IS809, a sorghum variety resistant to biotype C, but susceptible to biotype E. The basic behavioral difference they observed between the two biotypes was the rapidity with which they were able to feed efficiently on IS809. They observed that previous exposure of greenbug biotype C to IS809 allowed greenbug biotype C to modify its behavior, enabling it to reach the phloem and achieve CPI (the time to first committed phloem ingestion) in significantly less time. A correspondence also was found between the feeding behavior and fecundity of biotype C versus biotype E on this variety. Dreyer and Campbell (1983) further investigated the feeding behavior of biotype E and C on IS809 and concluded that the increases in methylation of the middle lamellar pectin in plants hinders aphids in penetrating host-plant tissues. Biotype E was able to overcome this host plant barrier in sorghum by having increased pectin methylesterase activity.

Recently Ryan et al. (1987) electronically monitored the feeding behavior, reproduction, and honeydew production of greenbug biotype C

and E on various wheat genotypes. They suggested that there is an association between the greenbug's ability to injure it's host plant and acceptance of nutritionally enriched phloem sap associated with feeding damage which may result in production of larger, more fecund greenbugs.

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PART I

DEVELOPMENT, FECUNDITY, LONGEVITY AND LIFE HISTORY CHARACTERISTICS OF BIOTYPE E GREENBUG (*Schizaphis graminum*, Rondani) ON VARIOUS CORN (*Zea mays* L.) AND SORGHUM (*Sorghum bicolor* (L.) Moench) GENOTYPES.

ABSTRACT

Life tables for the biotype-E greenbug, Schizaphis graminum (Rondani), were constructed to assess the potential for greenbugs to develop, reproduce, and survive on corn, Zea mays. Fifteen corn genotypes were first screened in order to select four which were most susceptible to greenbugs. These four (Antiqua, OH-45, AP-670, and 2570) were used along with a sorghum susceptible (NC+630) and an antixenotic (PI-264453) variety as controls. Two sources of greenbug, corn-reared and sorghum-reared, were tested in a split-split-plot design. Daily mortality and fecundity schedules were established to estimate net reproductive and intrinsic rate of population increase on each host. Development periods for populations from both sources were the same on all selected corn and sorghum genotypes ($P > 0.05$). Mean development periods were 7.6 and 7.7 days for corn-reared and sorghum-reared greenbug, respectively. The average number of progeny produced differed between source and among host genotypes ($P = 0.002$). The highest average peak progeny production, which was 79.08 occurred with corn-reared greenbugs on corn genotype, Antiqua. Juvenile mortality of both corn-reared and sorghum-reared greenbug was low on all corn and sorghum genotypes but mortality was high in the older individuals. The finite rate of increase of corn-reared greenbug was higher on PI264453 and AP670 ($P = 0.02$). Corn-reared greenbug had shorter population doubling time than sorghum-reared greenbug on AP670 ($P = 0.01$). The generation time of corn-reared greenbug was shortest on PI264453 ($P = 0.01$). This was attributed to the combined effect of the reproduction, development rate and longevity on the different host plants. Assessment of the

results from these experiments indicated that corn-reared greenbug has a greater potential to reproduce and survive on corn than sorghum-reared greenbugs.

INTRODUCTION

Life-history studies on aphids including greenbug, Schizaphis graminum (Rondani) have been conducted by many researchers (Aalbersberg and Toit, 1987; Force and Messenger, 1964; Graf et al., 1985 and Walgenbach et. al., 1988). Individual insects are isolated at birth and raised under a defined set of experimental conditions. Then, ages at which they reproduce and die are recorded. Such studies are significant to understanding the population dynamics of a species. They are frequently used to examine the effects of host plant quality on a population's rate of increase or fitness, development times, reproduction, survival and longevity of adults (Chi, 1988; Clark et. al., 1978; Deno and Dingle, 1981 and Rago and Dorrazio, 1984). For a better understanding of the population dynamics of the greenbug on corn, it seemed logical to construct and analyze life tables as the most useful tool in population ecology (Southwood, 1978). The age-specific life table approach appears to be particularly valuable for this purpose (Graf et. al., 1985). It has proven useful in the study of aphid population dynamics.

Greenbug, Schizaphis graminum (Rondani), is an aphid with a host-plant range of at least 60 species of grasses. Presently, it is a key pest of wheat and grain sorghum (Walgenbach et. al., 1988; Michels et al., 1987). Beregovoy et al. (1988) reported that both greenbug biotype C and E did not survive and reproduce for more than one week on corn. However, Michels (1987) reported sightings of greenbug on corn and expressed concern that they may develop a new biotype and become a pest

of corn. Radical differences in the progeny production and longevity of Arkansas and Texas greenbug populations on corn also were reported by Michels (1987).

More in-depth information about the process of greenbug population development on corn will help make more accurate predictions of the population trends and potential for a new biotype developing which is injurious to corn.

Although previous studies focused on the relationships between host plant and greenbug biology, the influence of host plant on age-specific survivorship, age-specific fecundity and demographic statistics for greenbug on corn have not been determined.

Here I describe life history characteristics of two sources of greenbug on corn and develop age-specific life tables for greenbug cultured on various corn and sorghum genotypes to assess potential adaptations of the greenbug on corn.

MATERIALS AND METHODS

Screening Test. Fifteen corn genotypes (DIMBOA-less, Antiqua, 2570, AP-670, AP510, 603, 602, 905, 820, 2545, oh45, CI31A, WF9, RX892, and RX788) were screened in a randomized complete block design to select four which were most susceptible to greenbug biotype E. Plants were grown in 25cm. by 51cm. flats, in the greenhouse at 26 - 29 ^{o} C and 16hr. photoperiod. They were well watered throughout the experiment to prevent differences in greenbug culture from being cause by drought stress. Before the experiment, greenbugs were cultured on a susceptible sorghum (Sorghum bicolor (L.) Moench.) genotype (NC+630x) in a greenhouse. Treatment was set up in six blocks in a randomized complete block. Each treatment was replicated ten times within a block. There were 60 plants per treatment. Seven hundred and fifty biotype-E adult greenbugs were uniformly distributed between rows of three weeks old seedling plants within each block and allowed free choice of host plants. After two weeks the number of greenbugs on each plant was counted and recorded as an indication of preference. Genotypes with the highest number of greenbugs were considered more susceptible.

Life-History Study. Four corn genotypes were selected based on results of the screening test described above: Antiqua, AP-670, 2570, and OH-45. These genotypes were used for life history studies along with a susceptible sorghum (NC+630x) and an antixenotic (PI-264453) genotype as controls. Plants were grown in 20cm. diameter pots, at 26 - 29 ^{o} C with a photoperiod of 16:8 (L:D). Three weeks after emergence plants were transplanted to 35cm. pots.

Greenbugs used in this study were obtained from colonies with

different feeding histories. The initial colony consisted of biotype-E greenbugs cultured on a susceptible sorghum genotype (NC+630x) and maintained in a rearing room at 24°C. A second colony was established on corn by transferring a few greenbugs from the sorghum-reared colony onto corn plants. The corn-reared greenbugs were cultured on corn genotype OH-45 and were maintained in a growth chamber at 23.4 ° C.

The experiment was designed as a split-split-plot randomized complete block design consisting of four corn genotypes, two sorghum genotypes and two sources of greenbug biotype-E. There were a total of four blocks and each treatment was replicated four times within a block. The experiment was repeated three times. Greenbugs were cultured on corn for 175, 379 and 390 days for the first, second and third repetitions of the experiment, respectively, before testing them. When a test plant reached the boot stage, a single adult greenbug was removed from each colony and transferred to the under surface of a lower leaf of the plant. A total of 4 test plants of each genotype was ready at one time.

Greenbugs were confined in cages made of 3mm thick plastic tubing covered with foam. The plastic tubing was 12mm in diameter with a depth of 15mm. The cages were constructed by piercing four wire brads (5/8" by 18") into the bottom surface of the plastic tubing. A cage was placed on the under surface of the lower leaves and secured by the wire brads by piercing them through the leaves and into a square piece of cork attached to the top surface of the leaves. The cage was supported by a wire attached to a bamboo pole positioned in the soil.

After 24 hours on a leaf the adults were carefully removed from the

cage without disturbing the first instar nymphs. The number of nymphs in each cage then was reduced to one. Nymphs were examined daily. Ecdysis was noted and the exuviae were removed to determine developmental times. Once a greenbug began to reproduce, age-specific fecundity (lx) was recorded daily in a manner similar to that used by Laughin (1965) until she died. Newly born nymphs were counted and removed each day. The following statistics were computed from these data, using formulae presented in Birch (1948): intrinsic rate of population increase (rm), finite rate of population increase, gross reproductive rate (GRR), net reproductive rate (Ro), generation time (T) and population doubling time (DT). In addition, the mean developmental time for each stadium, mean total development time (defined as time from birth to first reproduction), mean number of progeny produced from the onset of reproduction until death and mean longevity (time from birth until death) were computed for each source of greenbug.

To facilitate comparison of population growth rate for corn-reared and sorghum-reared greenbug, standard errors were calculated for the population growth statistics. All statistics were computed by PROC GLM (SAS Institute, 1987).

RESULTS

Screening Test. There were no significant differences in number of greenbug found on the different corn genotypes due to the high degree of variability within and between genotypes (Fig. 1). However, some genotypes tended to be more susceptible than other based on the observable degree of damage cause by the greenbugs.

Based on these results four corn genotypes; Antiqua, AP-670, 2570, and OH-45; were selected and used along with a susceptible sorghum (NC+630x)and an antixenotic genotype (PI-264453) as control for the life-history studies.

Development. Development periods for corn-reared and sorghum-reared greenbug were similar on all corn and sorghum genotypes (Table 1), with 6.1, 6.9, 7.5, 8.0, 8.5, 8.5 versus 6.8, 6.4, 7.4, 8.6, 8.1, 8.9 for corn-reared and sorghum-reared populations, respectively, on PI264453, NC+630x, Antiqua, 2570, OH45 and AP670 respectively. The third stadia of corn-reared greenbugs were shorter than sorghum-reared greenbug on corn genotypes and the resistant sorghum genotype (PI-264453).

Reproduction. Greenbug reproduction differed ($P < 0.05$) between corn and sorghum genotypes for both corn-reared and sorghum-reared greenbug (Table 2). The reproduction of corn-reared greenbug was higher on corn genotypes but lower on sorghum genotypes when compared to sorghum-reared greenbugs. The highest average peak progeny production occurred with corn-reared greenbug on corn genotype, Antiqua ($P < 0.05$). The average number of progeny produced by sorghum-reared greenbug on sorghum genotypes, NC+630x and PI-264453 (74.6 and 73.1 respectively)

was greater than that of sorghum-reared greenbug tested on corn genotypes ($P < 0.05$).

Longevity. The average lifespans of corn-reared and sorghum-reared greenbugs on various corn and sorghum genotypes are given in Table 3. Generally, corn-reared greenbug survived longer than sorghum-reared greenbug ($P = 0.03$) Longevity on AP-670 was shorter for sorghum-reared greenbug compared to corn-reared greenbug ($P = 0.006$).

Age-specific Life Table. Mean daily age-specific fecundity (mx), age-specific survival (lx), and reproductive value (Vx=lxmx), are illustrated in Figure 2-19 for corn-reared and sorghum-reared greenbug on corn and sorghum genotypes.

The age-specific fecundity rates, mx (Figure 2-7) take the form of a series of curves in which the mode of the curves varied with host plants and source of greenbugs. The age at first reproduction was nearly the same ranging from 7 - 8 for corn genotypes and 6 -7 for sorghum genotypes. In Figure 8-13, Vx curves show that comparatively, sorghum-reared greenbug production peaked earlier than corn-reared greenbug. The age at peak reproduction (in days) for sorghum-reared greenbug was 14, 11, 12, 11, and 15 for NC+630x, Antiqua, 2570, OH-45, and AP-670 respectively and 16, 19, 14, 13 and 16 for corn-reared greenbug on the respective host plants. Peak reproduction of sorghum-reared greenbug were lower than corn-reared greenbug on corn genotypes but higher on sorghum genotypes.

Age-specific survivorship (lx) curves were mainly convex in shape (Figure 14-19). The lx curves for sorghum-reared greenbug decrease

much more rapidly to zero on Antiqua and AP-670 but were quite similar to corn-reared greenbug on PI-264453, NC+630x, OH-45, and 2570.

Life Table Parameters. Population growth statistics of corn-reared and sorghum-reared greenbug are presented in Table 4. The mean generation (T) for corn-reared greenbug was shortest on PI264453 ($P = 0.01$). The finite rate of increase (FRT) differed between source and among host genotypes ($P = 0.02$). The highest FRT of both corn-reared and sorghum-reared greenbug occurred on PI264453 and the lowest occurred with sorghum-reared greenbug on AP670. Corn-reared greenbug had a higher finite rate of increase than sorghum-reared greenbug on PI264453, AP670 and 2570. The Population doubling time (DT) differed both between source of greenbug and among host plants ($P < 0.05$). Corn-reared greenbug took shorter time than sorghum-reared greenbug to double its population on AP670 ($P = 0.001$). The intrinsic rates of increase (rm) were similar both among genotypes and sources ($P = 0.07$)

DISCUSSION

Some of the most important criteria that can be presumed to influence the adaptive success of the greenbug are development time, reproduction, longevity and age-specific life tables of the adult life. Their relative contributions to the rate of population increase is significant to life pattern characteristics of the two sources of greenbugs used in this study. Assuming that the extent to which the corn plant is a suitable host is reflected in the life history of the greenbug, the less suitable host should have a proportionately greater negative influence on the adaptive success and reproductive fitness, as was approached in this study.

Even though greenbug development time of corn-reared and sorghum-reared greenbug on both corn and sorghum genotypes did not differ significantly, corn-reared greenbugs showed a potential for faster development on corn genotypes (2570 and AP670) and resistant sorghum genotype (PI-264453) than sorghum-reared greenbugs (Table 1), which may have some biological significance. The average number of progeny produced by the greenbug varied significantly ($P = 0.002$) intraspecifically (Table 2). The intraspecific variations I observed in the relationship between the source of greenbug and reproduction on corn and sorghum genotypes strongly suggests a difference in the adaptive potential of the corn-reared and sorghum-reared greenbug on corn genotypes. It also suggests a difference in host quality and the degree of influence on the reproductive potential of the greenbug on corn. The role of reproduction as an adaptation to ensure survival, especially when the probability of death is high, is accepted by many ecologists

(Smith, 1954; Cole, 1954; and Price, 1984). The reproductive success of a species depends to a large extent on how long it survives on its host (Huffaker and Rabb, 1984). Corn-reared greenbugs did not only survive longer on corn genotype (AP670) than sorghum-reared greenbugs, it also showed a potential to survive longest on Antiqua compared to NC+630x and PI264453 (Table 3).

The disparity in the result on development, reproduction and longevity of corn-reared greenbug and sorghum-reared greenbug on corn and sorghum genotypes may be indicative of the greenbug ability to adapt corn as a true host, because longevity provides an indication of an organism ability to persist on a host (Force and Messenger, 1964). This ability is manifested in the higher longevity of corn-reared greenbug on corn genotypes.

Age-specific fertility curves, illustrated in Figure 2-13, show that the highest daily peak reproduction of corn-reared greenbug occurred on corn genotypes and sorghum-reared greenbug occurred on sorghum. This suggests a higher reproductive expectation for corn-reared greenbug on corn compared to sorghum-reared greenbug and an upward trend for better adaptation of the greenbug on corn. Lewontin (1965) and Price (1984) recognized Vx as an important indication of population growth. The age at which reproduction ended was quite similar for both sources of greenbug. Corn-reared greenbugs reproduced longer on antiqua and ap-670 but shorter on nc+. The convex shape of the age-specific survival curves (Figure 14-19) indicates that mortality was low in the juvenile stages but high in the older individuals. The

lx curve shows the vulnerable stages of the greenbug and can be used for exploiting the greenbug for control purposes (Price, 1984).

Parameters such as development time, longevities and age-specific life tables are important not only as essential parts of the life history of the greenbug, but also as a reflection of the capacities for population increase. However, these parameters tell us very little about the reproductive capacity of the greenbug. Fecundity, a measure of reproductivity, does not tell how rapidly new individuals appear (Force and Messenger, 1964).

Since Ro and rm were similar for corn-reared and sorghum-reared greenbugs on the various corn and sorghum genotypes life history statistics such as T, FRT and DT further elucidated specific results of the greenbug potential to adapt corn as a true host. However, since Ro was greater than one for corn-reared and sorghum-reared greenbug on both corn and sorghum genotypes, I conclude that the two populations were growing (see Sedlacek et. al., 1986). It can be misleading to use Ro to assess the population growth because generation time varied (Force and Messenger, 1964) and each was calculated from greenbug populations on different hosts (Price, 1985; and Sedlacek et. al., 1986). The finite rate of increase which is a measure of population fitness (Rago and Dorrazio, 1984) and the population doubling time may be of economic and evolutionary significance for describing the adaptive potential to the greenbug population under the given host conditions. By examining the value of FRT and DT of corn-reared and sorghum-reared greenbug for the various host plants in Table 4, it is apparent that FRT attained a greater value on AP670 and PI264453 and DT on AP670 for corn-reared

greenbug than sorghum-reared greenbug. This difference reflects the influence of the various host plants on the potential rate of population increase and reproductive fitness of both corn-reared and sorghum-reared greenbug. The magnitude of a population's finite rate of increase associates closely with the schedules of reproduction and mortality that are characteristic of its members (Rago and Dorazio, 1984).

Evidently, low juvenile mortality (Figure 14-19) accounts for the high FRT of corn-reared greenbug on AP670 and PI264453 as reductions in age-specific survivorship early in life tend to decrease the value of FRT to a greater extent than if similar reductions were experience later in life because individual contributions to FRT are negatively exponentially weighted with respect to age (cf. Eq. 1; Birch, 1948). Economically, the FRT is essential for providing useful information on the sublethal effects of toxicants applied under field conditions. Theoretically, a corn-reared greenbug population is expected to increase 2.3-fold on ap670 by the time sorghum-reared greenbug had doubled on the same genotype. With the high reproductive fitness of corn-reared greenbug, it is expected that they demonstrate greater colonizing ability in the field than sorghum-reared greenbug on corn.

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Table 1. Development periods of biotype-E greenbugs reared on corn and sorghum genotypes in the greenhouse.

Source	Genotypes	Days 1				
		Stadium				Total development
		1st	2nd	3rd	4th	
CR 2	PI264453	1.4	1.6	1.4	1.7	6.1
	NC+630x	1.5	1.5	1.8	1.8	6.9
	Antiqua	2.0	1.6	1.7	1.6	7.5
	2570	2.0	2.0	2.0	1.5	8.0
	OH45	2.1	2.1	1.8	2.2	8.5
	AP670	2.1	2.5	2.0	2.3	8.5
SR	PI264453	1.5	1.5	1.6	1.6	6.8
	NC+630x	1.1	1.5	1.3	2.1	6.4
	Antiqua	1.6	1.8	2.0	2.0	7.4
	2570	2.1	2.0	2.0	2.0	8.6
	OH45	1.5	2.0	2.1	2.0	8.1
	AP670	2.4	2.1	2.1	2.1	8.9

\1 CR, corn-reared greenbug; SR, sorghum-reared greenbug.
\2 Values of developmental periods are least square means.

Table 2. Mean lifespan fecundity of biotype-E greenbug on corn and sorghum genotypes in the greenhouse. 1

Genotypes	Ave. No. Progeny/female 2		
	Corn-reared	Sorghum-reared	P 3
PI264453	70.33 ac	73.16 c	0.6797
NC+630x	62.33 c	74.66 c	0.0764
Antiqua	79.08 a	50.58 a	0.0001
2570	43.00 b	41.83 b	0.8649
OH45	35.88 b	34.50 b	0.8476
AP670	45.16 b	28.66 b	0.0191

\1 Means followed by the same letter within column are not significantly different ($P < 0.05$; LSD).
\2 All mean values are least squares.
\3 P, defined as probability values. Probability values less than 0.05 indicate significant difference between source of greenbug.

Table 3. Mean longevity of biotype-E greenbug reared on corn and sorghum genotypes in the greenhouse. 1

Genotypes	Ave. Lifetime/individual (days)		
	Corn-reared	Sorghum-reared	P 2
PI264453	33.33	33.33	1.0000
NC+630x	33.08	31.15	0.6364
Antiqua	35.69	30.19	0.1088
2570	25.50	27.58	0.4973
OH45	29.58	26.75	0.3569
AP-670	27.75	18.61	0.0064

\1 All mean values are least squares.
\2 P, defined as probability values. Probability values less than 0.05 indicate significant difference between source of greenbug.

Table 4. Population growth statistics of biotype-E greenbug reared on corn and sorghum genotypes in the greenhouse. 1

Source	Genotypes	GRR	RO	T	Rm	FRT		DT 3		
CR	PI264453	78.62	71.99	12.5b	0.34	1.41c	(a)	2.0c	(a)	2
	NC+630x	63.29	55.80	14.3a	0.28	1.32a	(a)	2.4a	(a)	
	Antiqua	77.68	63.80	15.0a	0.27	1.30a	(a)	2.6ad	(a)	
	2570	53.77	37.35	15.3a	0.24	1.26b	(a)	2.9d	(a)	
	OH45	35.06	29.46	15.4a	0.21	1.24b	(a)	3.2b	(a)	
	AP670	49.69	35.14	15.4a	0.22	1.25b	(a)	3.3b	(b)	
SR	PI264453	78.56	72.37	13.4	0.32	1.37d	(b)	2.2a	(a)	
	NC+630x	77.21	61.78	14.1	0.29	1.34a	(a)	2.3a	(a)	
	Antiqua	57.22	47.39	14.0	0.27	1.32a	(a)	2.5a	(a)	
	2570	46.90	37.38	15.0	0.23	1.25c	(a)	3.1b	(a)	
	OH45	39.74	32.68	14.9	0.22	1.24c	(a)	3.3b	(a)	
	AP670	33.96	18.30	14.8	0.18	1.19b	(b)	4.1c	(e)	

\1 Means followed by the same letter within column are not significantly different ($P < 0.05$;LSD). Means are least squares.

\2 Means followed by the same letter in parenthesis indicated significant difference between sources for a given genotype ($P < 0.05$).

\3 GRR, gross reproductive rate; Ro, net reproductive rate; T, generation time; Rm, intrinsic rate of increase; FRT, finite rate of increase; DT, doubling time; CR, corn-reared greenbug; SR, sorghum-reared greenbug.

Figure 1. Mean number of greenbugs on corn genotypes after fifteen days.

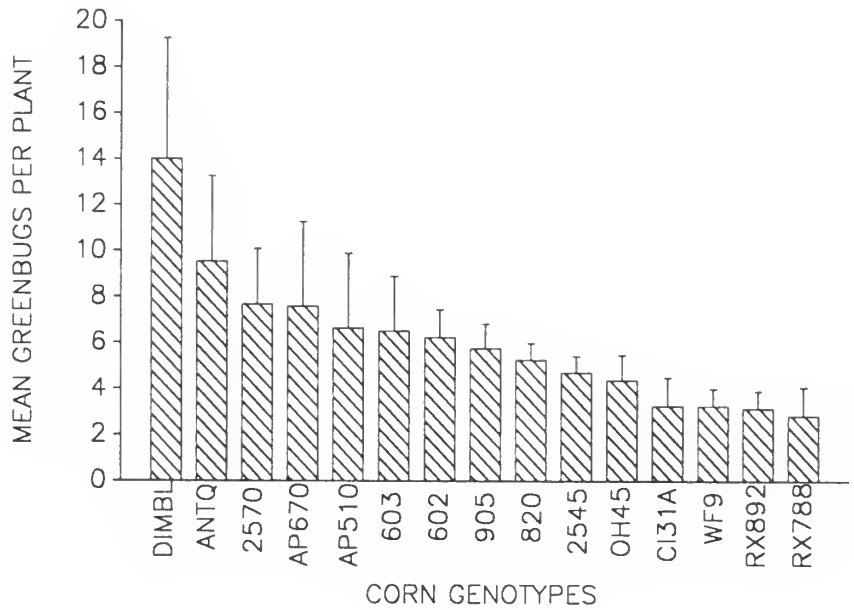

MEAN GREENBUGS PER PLANT
20
18
16
14
12
10
8
6
4
2
0
DIMBL
ANTQ
2570
AP670
AP510
603
602
905
820
2545
OH45
CI31A
WF9
RX892
RX788
CORN GENOTYPES

Figure 2. Comparison of age-specific fecundities (mx) of corn-reared and sorghum-reared biotype E greenbug on resistant sorghum genotype, PI264453.

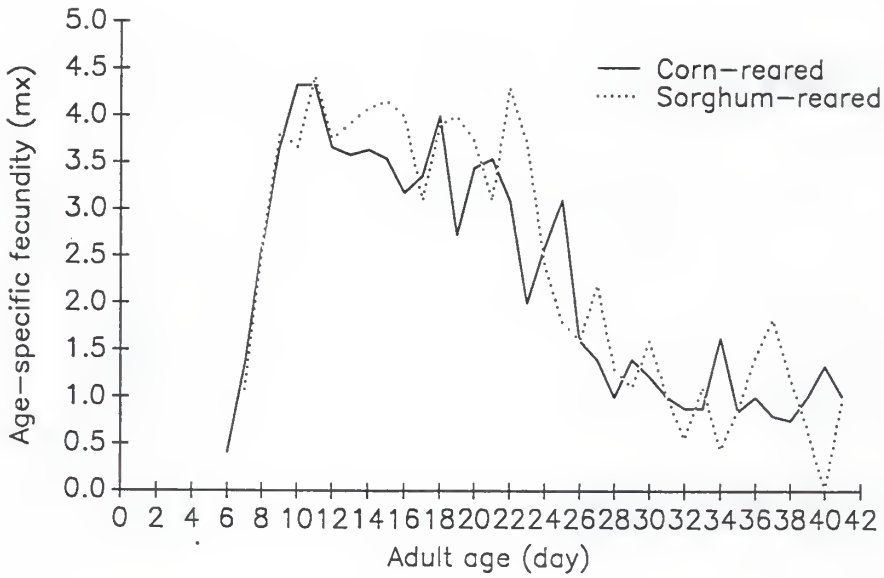

Age-specific fecundity (mx)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Adult age (day)
Corn-reared
Sorghum-reared

Figure 3. Comparison of age-specific fecundities (mx) of corn-reared and sorghum-reared biotype E greenbug on susceptible sorghum genotype, NC+630x.


Corn–reared
Sorghum–reared
Age–specific fecundity (mx)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Adult age (days)

Figure 4. Comparison of age-specific fecundities (mx) of corn-reared and sorghum-reared biotype E greenbug on corn genotype, Antiqua.

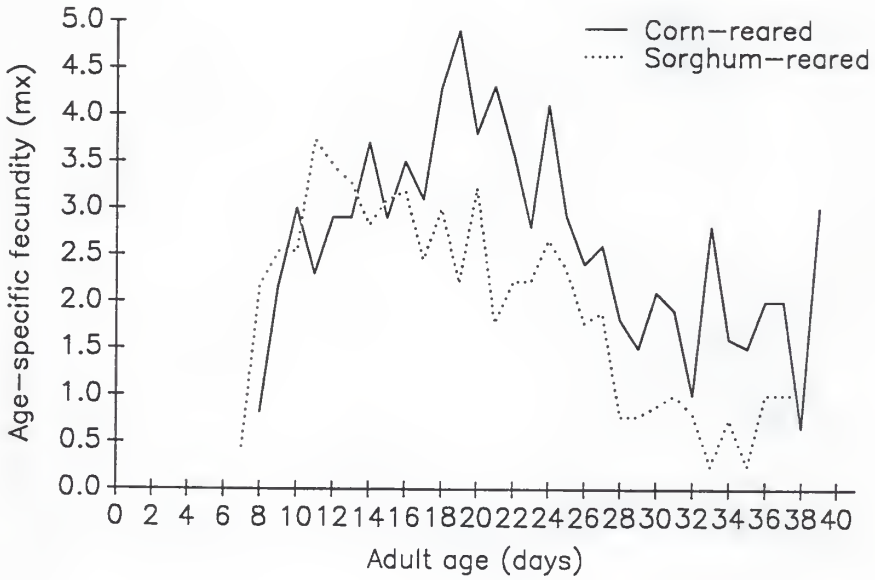

Corn–reared
Sorghum–reared
Age–specific fecundity (mx)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Adult age (days)

Figure 5. Comparison of age-specific fecundities (mx) of corn-reared and sorghum-reared biotype E greenbug on corn genotype, 2570.

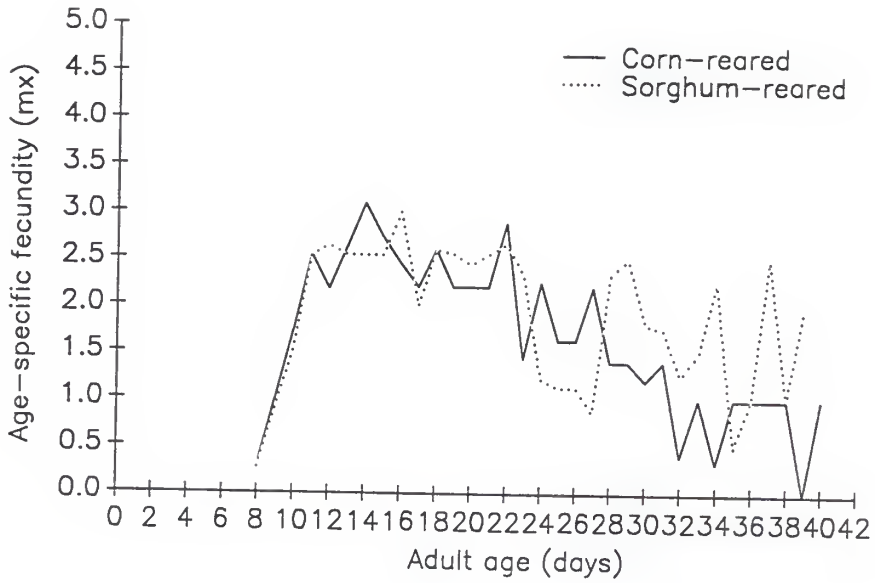

Corn–reared
Sorghum–reared
Age–specific fecundity (mx)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Adult age (days)

Figure 6. Comparison of age-specific fecundities (mx) of corn-reared and sorghum-reared biotype E greenbug on corn genotype, OH45.

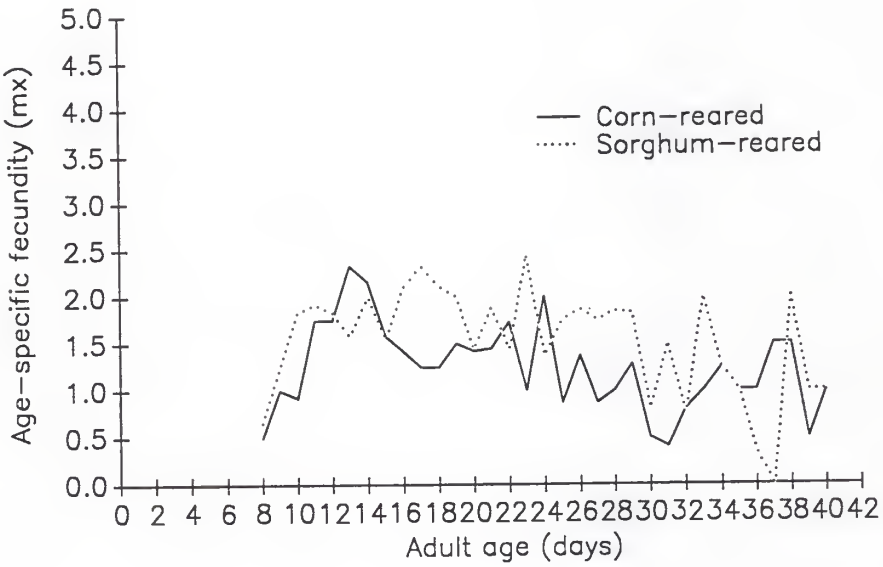

Age-specific fecundity (mx)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Corn-reared
Sorghum-reared
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Adult age (days)

Figure 7. Comparison of age-specific fecundities (mx) of corn-reared and sorghum-reared biotype E greenbug on corn genotype, AP670.

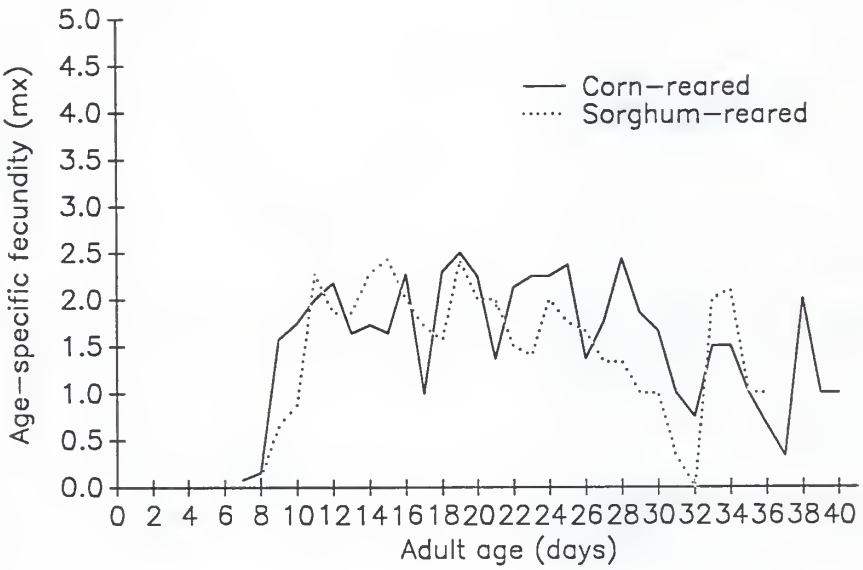

Age-specific fecundity (mx)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Adult age (days)
Corn-reared
Sorghum-reared

Figure 8. Comparison of reproductive values (Vx=lxmx) of corn-reared and sorghum-reared biotype E greenbug on resistant sorghum genotype, PI264453.

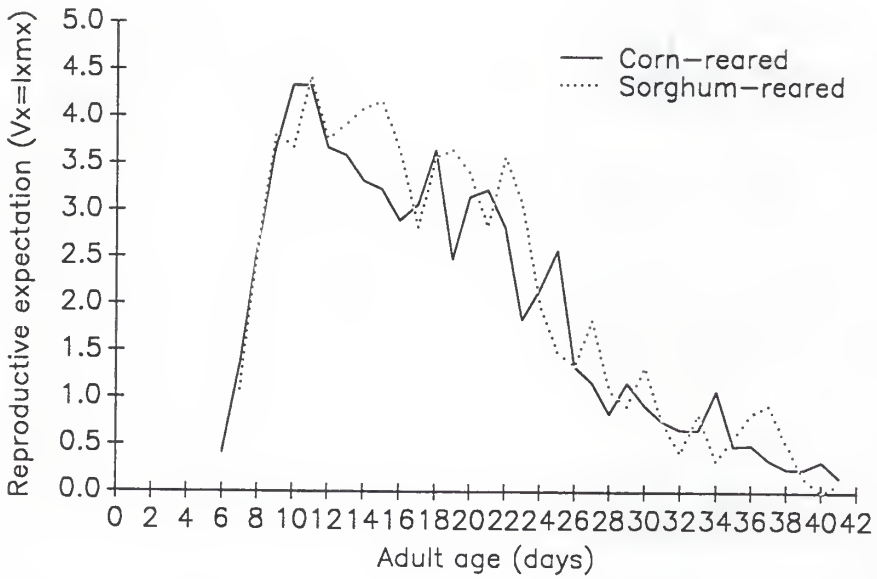

Reproductive expectation (Vx=lxmx)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Adult age (days)
Corn-reared
Sorghum-reared

Figure 9. Comparison of reproductive values (Vx=lxmx) of corn-reared and sorghum-reared biotype E greenbug on susceptible sorghum genotype, NC+630x.

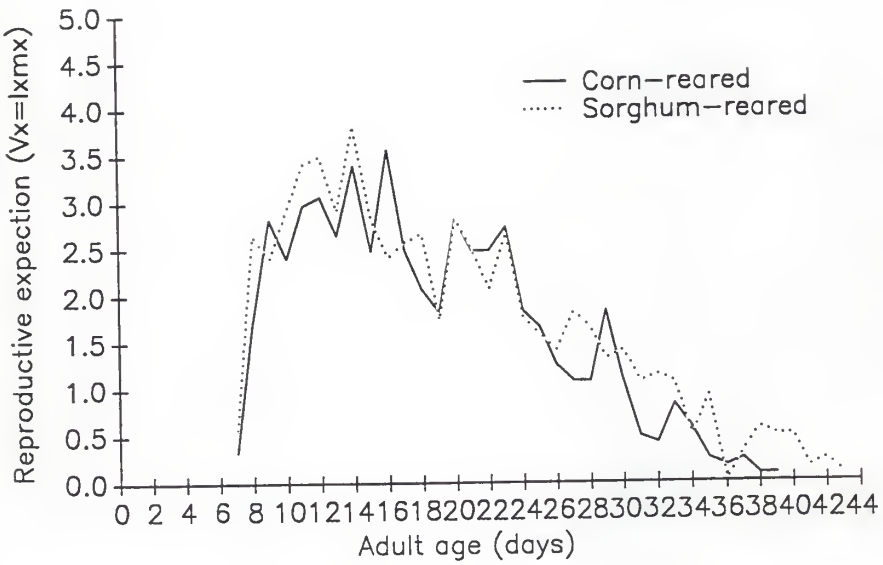

Reproductive expection (Vx=lxmx)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Corn-reared
Sorghum-reared
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Adult age (days)

Figure 10. Comparison of reproductive values (Vx=lxmx) of corn-reared and sorghum-reared biotype E greenbug on corn genotype, Antiqua.

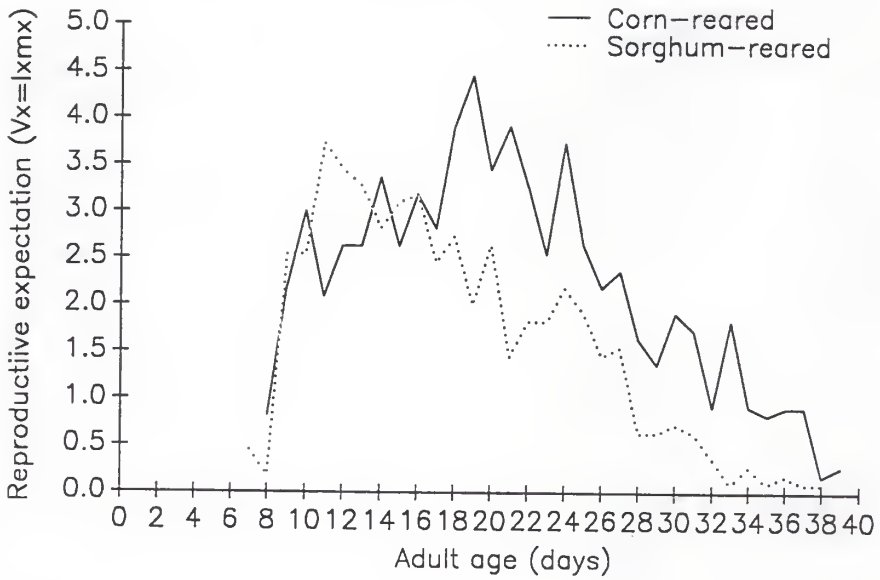

Corn–reared
Sorghum–reared
Reproductive expectation (Vx=lxmx)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Adult age (days)

Figure 11. Comparison of reproductive values (Vx=lxmx) of corn-reared and sorghum-reared biotype E greenbug on corn genotype, 2570.

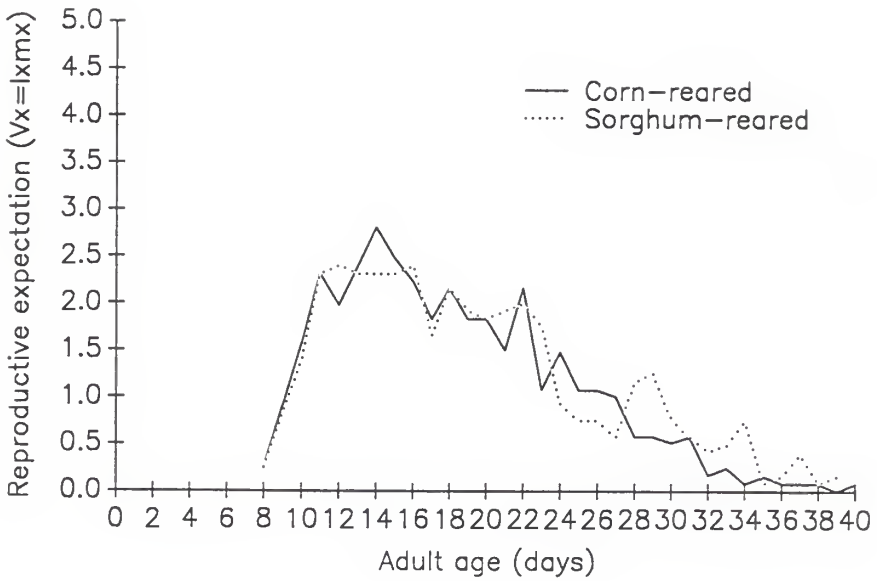

Reproductive expectation (Vx=lxmx)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Adult age (days)
Corn-reared
Sorghum-reared

Figure 12. Comparison of reproductivee values (Vx=lxmx) of corn-reared and sorghum-reared biotype E greenbug on corn genotype,OH45.

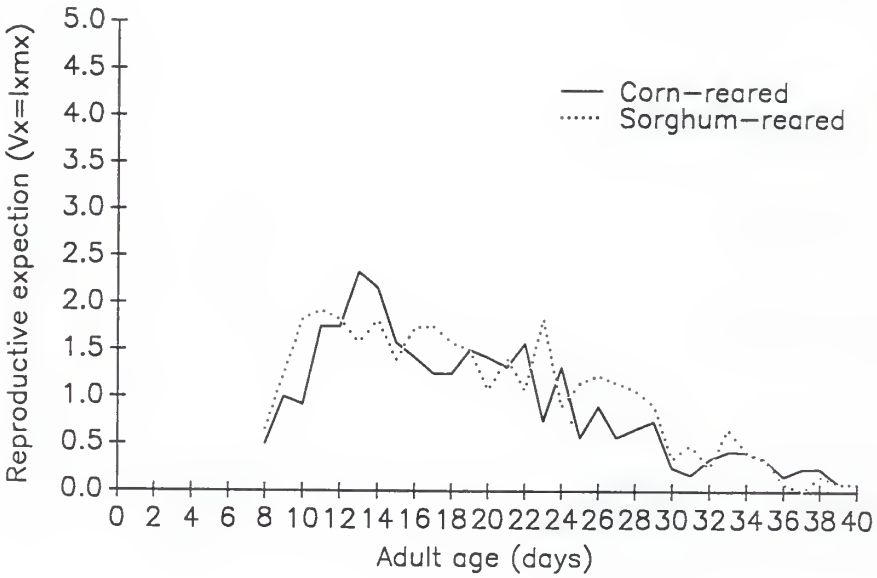

Reproductive expection (Vx=lxmx)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Adult age (days)
Corn-reared
Sorghum-reared

Figure 13. Comparison of reproductive values (Vx=lxmx) of corn-reared and sorghum-reared biotype E greenbug on corn genotype, AP670.

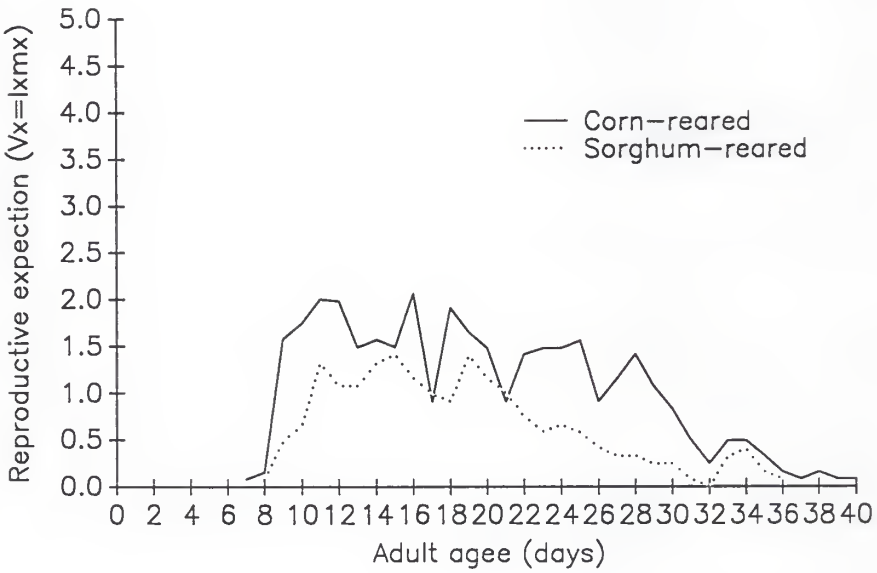

Reproductive expection (Vx=lxmx)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Adult agee (days)
Corn–reared
Sorghum–reared

Figure 14. Comparison of age-specific survivorship (lx) of corn-reared and sorghum-reared greenbug on resistant sorghum genotype, PI264453.

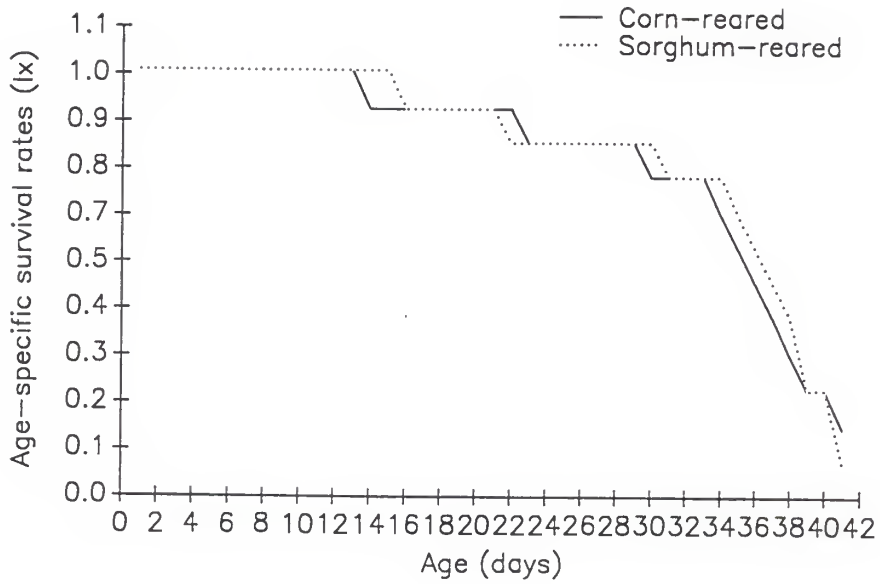

Corn–reared
Sorghum–reared
Age–specific survival rates (lx)
1.1
1.0
0.9
0.8
0.7
0.5
0.4
0.3
0.2
0.1
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Age (days)

Figure 15. Comparison of age-specific survivorship (lx) of corn-reared and sorghum-reared greenbug on susceptible sorghum genotype, NC+630x.

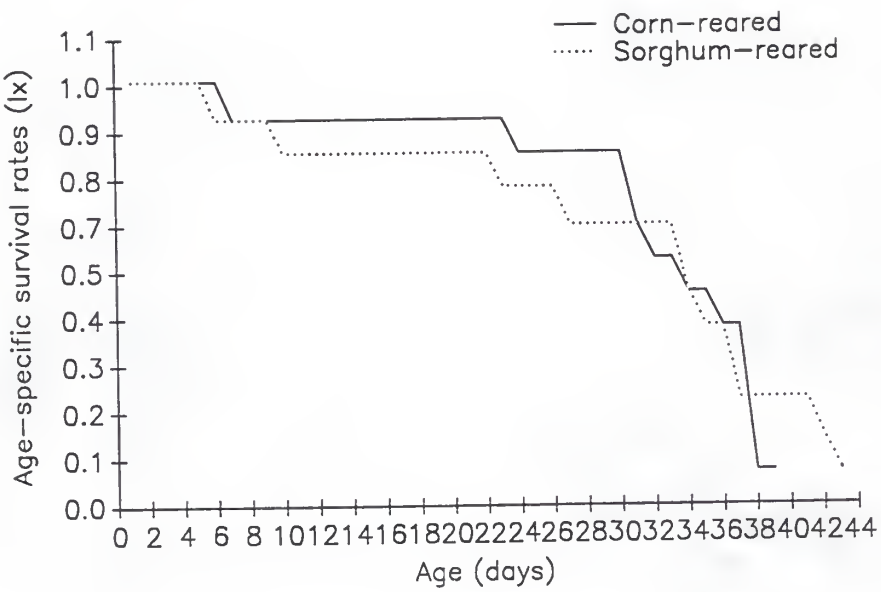

Corn–reared
Sorghum–reared
Age–specific survival rates (lx)
1.1
1.0
0.9
0.8
0.7
0.5
0.4
0.3
0.2
0.1
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Age (days)

Figure 16. Comparison of age-specific survivorship (lx) of corn-reared and sorghum-reared greenbug on corn genotype, Antiqua.

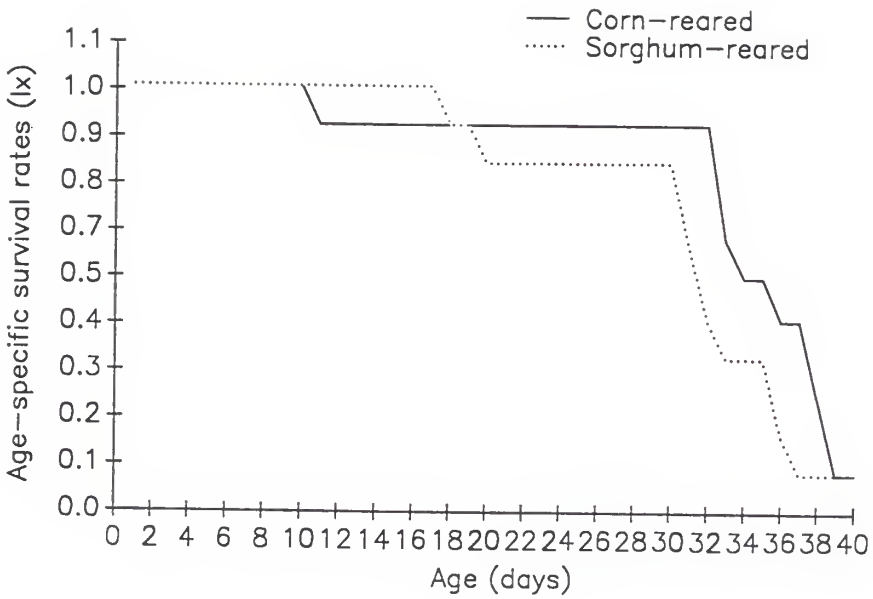

Corn–reared
Sorghum–reared
Age–specific survival rates (lx)
1.1
1.0
0.9
0.8
0.7
0.5
0.4
0.3
0.2
0.1
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Age (days)

Figure 17. Comparison of age-specific survivorship (lx) of corn-reared and sorghum-reared greenbug on corn genotype, 2570.

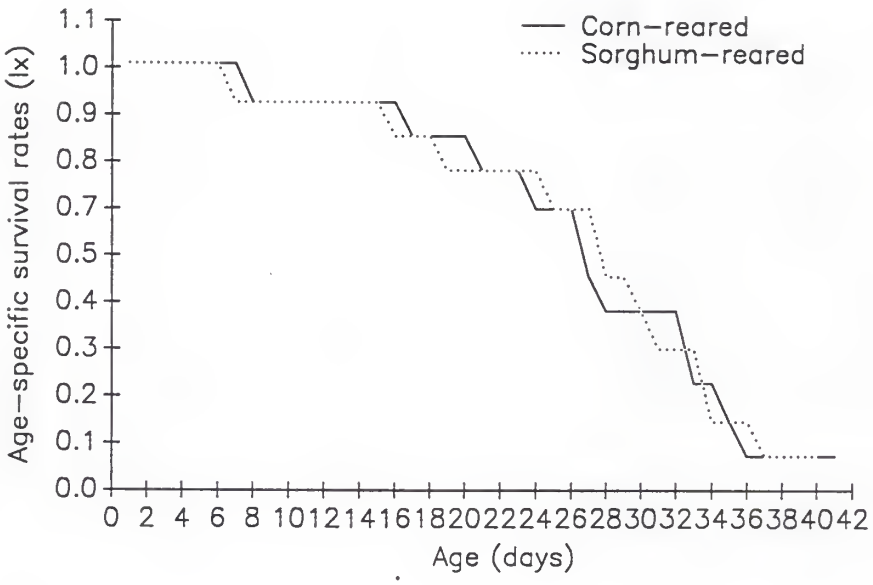

Corn–reared
Sorghum–reared
Age–specific survival rates (lx)
1.1
1.0
0.9
0.8
0.7
0.5
0.4
0.3
0.2
0.1
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Age (days)

Figure 18. Comparison of age-specific survivorship (lx) of corn-reared and sorghum-reared greenbug on corn genotype, OH45.

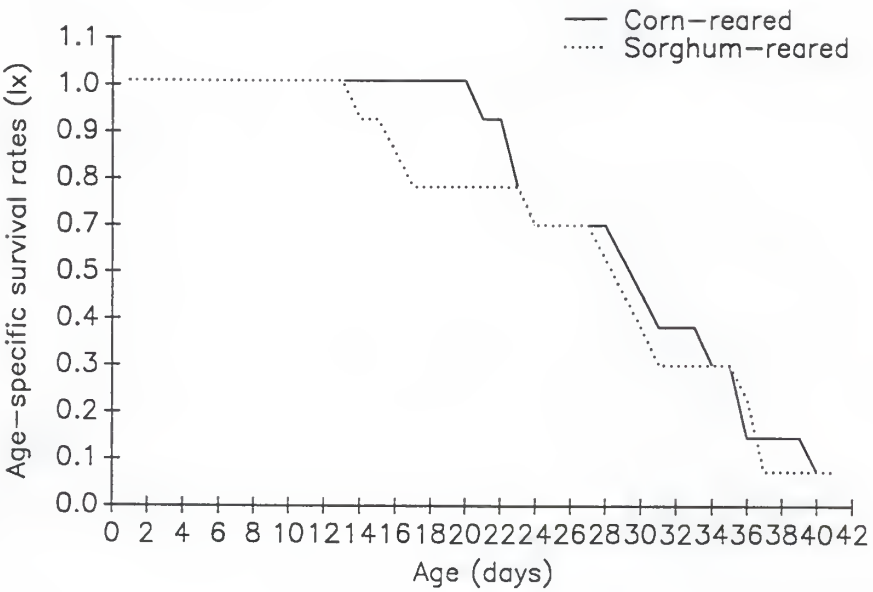
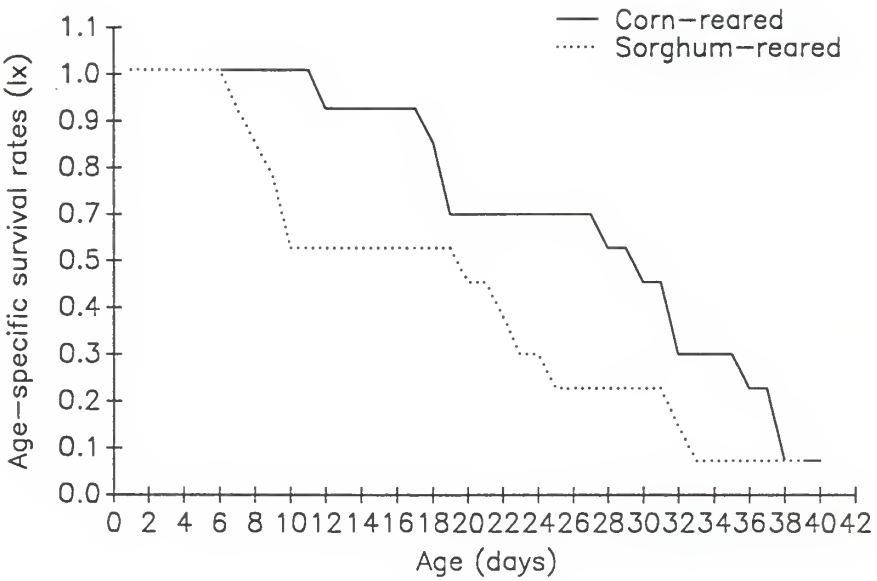

Corn–reared
Sorghum–reared
Age–specific survival rates (lx)
1.1
1.0
0.9
0.8
0.7
0.5
0.4
0.3
0.2
0.1
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Age (days)

Figure 19. Comparison of age-specific survivorship (lx) of corn-reared and sorghum-reared greenbug on corn genotype, AP670.


Corn–reared
Sorghum–reared
Age–specific survival rates (lx)
1.1
1.0
0.9
0.8
0.7
0.5
0.4
0.3
0.2
0.1
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Age (days)

PART II.

FEEDING BEHAVIOR, FECUNDITY AND GROWTH OF TWO SOURCES OF BIOTYPE E OF (S. GRAMINUM) ON VARIOUS CORN AND SORGHUM GENOTYPES.

ABSTRACT

Electronically monitored feeding behavior of corn-reared and sorghum-reared biotype E greenbug was studied on four corn genotypes (Antiqua, 2570, OH45 and AP670), one susceptible (NC+630x) and one resistant (PI264453) sorghum genotype for a period of 12-hr. with the computerized electronic insect feeding monitor (IFM) to determine how various corn genotypes alter the feeding behavior of biotype E greenbug, and to assess the correspondence of feeding behavior with greenbug fecundity and growth. The susceptible and resistant sorghum genotypes were used as controls. Corn-reared greenbugs were found to be more fecund and had higher growth than sorghum-reared greenbugs on corn genotypes and resistant sorghum (PI264453). Corn-reared greenbug established committed phloem ingestion (CPI) (i.e. ingestion from the phloem lasting > 15 min.) in a significantly ($P < 0.05$) shorter amount of time on corn genotype (2570) and resistant sorghum (PI264453) genotype than sorghum-reared greenbugs. Time to CPI of corn-reared greenbugs also was shorter on other corn genotype (Antiqua, AP670) and susceptible sorghum (NC+630x) than sorghum-reared greenbugs. The percentage of the total duration of phloem ingestion during the 12-hr. period was significantly higher on corn genotype (2570) and resistant sorghum (PI264453). The data suggest a modification in the feeding behavior of corn-reared greenbugs and a correspondence with fecundity and growth.

INTRODUCTION

The greenbug, Schizaphis graminum is a phloem-feeding insect (Ryan et al., 1987; Campbell et al., 1982). A major pernicious effect of this phloem-feeding insect is the disease-like symptoms its feeding induces in the foliar tissue of susceptible hosts (Ryan et al., 1987). In addition, greenbug is an effective vector of virus diseases of corn, Zea mays L. (Starks et al., 1975). Plant pathogenesis and reproductive capacity are directly related to the ability of these insects to penetrate host plant tissues (Dreyer and Campbell, 1987).

In 1964, Mclean and Kinsey introduced a novel technique of electronically monitoring the probing behavior of aphids (see Campbell et al., 1982). This technique was used to monitor the probing behavior of aphid species feeding on various dicotyledons (Kennedy et al. 1978; Tjallingii, 1978). Campbell and co-workers (1982) studied the probing behavior of the greenbug on sorghum and rice, Oryza sativa using the electronic monitor. They reported probing behavior as an indication of host-plant susceptibility and resistance. By the use of electronic monitoring of probing behavior of biotype C of S. graminum, Campbell and co-workers (1982) showed that phloem ingestion was a least 10 times longer on a susceptible sorghum than on several biotype C resistant lines. They also noted an association between reproductive capacity of the greenbug with its ability to ingest from the phloem.

In 1980, a new biotype, E, of S. graminum was discovered which feeds and reproduces on sorghum, and wheat resistant to biotype C (Porter et al., 1982; Starks et al. 1983). Montllor et al. (1983)

compared the probing behavior of biotype C and biotype E on 'IS809' which is a sorghum variety. They observed biotype E ingested from the phloem of 'IS809', previously resistant to biotype C, significantly longer than did biotype C greenbugs, and an association was found between the probing behavior and fecundity of C versus E. They also noted that previous exposure of biotype C to 'IS809' sorghum allowed biotype C to modified its behavior, enabling it to reach the phloem and time to CPI (committed phloem ingestion) in significantly less time.

Biotype E greenbugs have since been shown to exhibit differences in response among varieties of the same plant species (Michels, 1986). It affects many of the previously resistant small grains and sorghum genotypes (Starks et al., 1983). Greenbugs have been observed on corn in the field and concerns have been expressed that they may develop a new biotype injurious to corn (Michels et al., 1987). Despite the tendency for greenbug to develop new biotype and broaden its host-plant range to include new plant species (Michels, 1986), no attempts have been made to assess the effect of corn genotypes on the feeding behavior of these aphids.

The objective of this study is to quantify the effect of various corn genotypes on biotype E feeding behavior and to assess how feeding behavior is associated with greenbug fecundity and growth.

MATERIALS AND METHODS

Agronomic Practice and Insect Culture. Four corn genotypes (Antiqua, AP-670, 2570 and OH-45) selected on the basis of screening test results (see Chapt. 1) were used in these studies. These genotypes were used along with susceptible (NC+630x) and resistant (PI-264453) sorghum genotypes as controls. Plants were grown in 20cm diameter pots in a greenhouse at 70-80^{o}F with a photoperiod of 16:8 (L:D). Three weeks after emergence the plants were transplanted into larger pots, 35cm in diameter. The plants were watered with a solution of complete fertilizer as often as needed to avoid drought stress.

Two sources of greenbugs were used in these experiments. They were obtained from separate colonies, one of which was corn-reared and the other sorghum-reared greenbugs. The colony of corn-reared greenbugs was established by removing a few biotype E greenbugs from a colony of sorghum-reared biotype E greenbug and placing them on corn plants. Corn-reared greenbugs were cultured on corn genotype (OH-45) and maintained in a growth chamber at 23.4 ^{o}C for 11 months. The sorghum-reared greenbugs were cultured on sorghum susceptible genotype (NC+630x) and maintained in a rearing room at 24 ^{o}C.

Greenbug Progeny Production. The fecundity of corn-reared and sorghum-reared greenbugs was measured on the four corn genotypes and two sorghum genotypes in a split-split-plot randomized complete block design with four replications. Time was the whole plot, plants were used as sub-plots and sources as sub-sub-plots. The experiment was repeated twice. When the experimental plants reached the booting stage, five apertous adults of corn-reared and sorghum-reared greenbugs were

carefully removed with a camel-hair brush from respective cultures, and transferred to the under surface of lower leaves on each test plant. The five adult greenbugs from each culture were confined to separate leaves on the same test plant in cages similar to those used by Ryan et al., 1987. Nymphs produced were counted every other day and then carefully removed with a camel-brush without disturbing the adults. One-day old nymphs were weighed each day for the first 7 days of adult reproduction with an Electronic Analytical Balance (Satarorius, Westbury, New York). Nymphs collected were grouped together according to source and genotype. Weights were taken in batches of five and treated as samples from two greenbug populations (corn-reared and sorghum-reared greenbugs). A minimum of four weight samples were taken on each day for the various corn and sorghum genotypes. Weight data were not collected in a manner which allowed for a split-split-plot analysis. Because nymphs of a source were grouped together for each genotype the weight data was analyzed in the manner of a completely randomized design with one replication. Reproduction and weight were recorded for each treatment. The test continued until all adults died.

Greenbug Growth. The growth of corn-reared and sorghum-reared greenbugs was measured in a split-plot randomized complete block design with four replications. Infestation of the various corn and sorghum genotypes and stage of plants used was similar to the progeny production study. After twenty-four hours adults were carefully removed with a camel-hair brush without disturbing the nymphs; the number of nymphs in each cage was standardized to five. Nymphs were allowed to

develop to adulthood. At the age of first reproduction, weight of each greenbug was recorded.

Feeding Behavior. The feeding behavior of corn-reared and sorghum-reared biotype E greenbug were monitored for a 12-hour period on the various corn and sorghum genotypes. The monitor system used in this study was adapted from Brown and Holbrook (1976) modified version of the electronic insect feeding monitor designed at Oklahoma State University and computerized at the Entomology Department, Kansas State University.

In this system, a 250 mV and 25Hz alternating current from an alternating voltage oscillator of the IFM was applied across a greenbug feeding on a plant contained in potting soil. As the greenbug feeds and makes electrical contact with the plant, the resistance changes. The changing impedance is detected as voltage fluctuations associated with various feeding activities (Campbell et al., 1982). The signals from the IFM are amplified as voltage differences sent to a Metra Byte Dash-8 digital to analog converter (A/D converter). In the Metra Byte Dash-8 digital voltage differences were converted into real values. Values of voltage differences were examined every 0.01 sec. Maximum and minimum values were recorded by a Zenith 151 computer every 0.95 sec. and saved to a hard disk. The computer kept track of all times and represented wave-forms (real values) graphically. Identification of waveforms and the calculation of the durations and frequencies of the events were determined and printed out as a summary on Okidata 292 printer.

The experimental design was a split-plot completely randomized design with eight replications. The whole plot was the plant and the

sub-plot was the source of greenbug. Each genotype/greenbug source combination was randomly assigned to a monitor. Adults of corn-reared and sorghum-reared greenbugs were carefully removed from their respective cultures with a camel-hairbrush. The dorsum of each was affixed to a 3-cm length of gold wire (0.0127mm dia.) (Johnson and Matthey Inc., Seabrook, New Hampshire) with Pelco colloidal silver (Ted Pella, Tustin, Calif.). The greenbug was placed on the upper surface of the lower leaf of booting stage corn and sorghum test plants within ten minutes of removal from the culture plants.

Twelve parameters of greenbug feeding behavior were measured for a period of twelve hours: total duration of non feeding activity or baseline (Base), probing (probe), salivation (SAL), non-phloem ingestion (NPI), phloem ingestion (PI), time to first committed phloem ingestion at least 15 min. (CPI), and the frequencies of occurrence of baseline (OB), probing (OP), salivation (OS), non-phloem ingestion (ONPI), x-wave (phloem penetration (OX)), and phloem ingestion (OPI).

Statistical Analyses. Results from the feeding monitor studies were subjected to PROC ANOVA and GLM. Data from the progeny production studies were subjected to PROC GLM for a split-split-plot randomized complete block design. Results from the growth studies were subjected to PROC GLM for both a split-plot randomized complete block and completely randomized design. All means were separated with a protected least significant difference (LSD) test (SAS Institute, 1987).

RESULTS

Progeny Production. Reproduction of corn-reared and sorghum-reared greenbugs is summarized in Table 5. Corn-reared greenbug reproduction was higher than sorghum-reared greenbug on corn genotypes (Antiqua and OH45), resistant sorghum (PI264453) and susceptible sorghum (NC+630x) ($P = 0.01$). The average total number of progeny produced by corn-reared greenbugs was more than sorghum-reared on almost all corn and sorghum genotypes. Reproductive variation within both sources of greenbugs across all genotypes did not differ significantly ($P < 0.05$). However, the highest average number of progeny produced by both corn-reared and sorghum-reared greenbug was on sorghum resistant (PI264453) and corn (Antiqua) genotypes.

Greenbug Growth. The average weights of 1-day old nymphs of corn-reared and sorghum-reared greenbug on various corn and sorghum genotypes are presented in Table 6. Weights of corn-reared greenbugs did not differ from sorghum-reared but tended to be greater on all corn genotypes and sorghum susceptible (NC+630x) genotype ($P = 0.06$). The average daily weight of corn-reared and sorghum-reared greenbugs on the various corn and sorghum genotypes are illustrated in Figure 20-25. The weight (mg) values of corn-reared greenbug on day one was 0.015, 0.017, 0.016, 0.018, 0.007, and 0.021 for PI264453, NC+630x, Antiqua, 2570, OH45 and AP670, respectively, and 0.029, 0.024, 0.016, 0.021, 0.023, 0.018 for sorghum-reared greenbug on the respective genotypes. On the 7th day, the weight values of corn-reared greenbug were 0.040, 0.041, 0.032, 0.035, 0.027, 0.033 for PI264453, NC+630x, Antiqua, 2570, OH45,

AP670, respectively, and 0.031, 0.031, 0.020, 0.012, 0.011, 0.016, for sorghum-reared greenbug on the respective genotypes. The mean weight of 1-day old adults of corn-reared and sorghum-reared greenbugs on the various corn and sorghum genotypes are given in Table 7. The weight of corn-reared greenbugs on all 2570 was greater than sorghum-reared greenbugs ($P = 0.01$). The highest weight value of greenbug on corn and sorghum genotypes occurred with corn-reared greenbugs on corn (Antiqua) genotype.

Greenbug Probing Behavior. Waveforms of S. graminum on corn resembled those previously recorded for S. graminum on other monocotyledons host plants (see Campbell et al., 1982). The analyses of variance for the various probing events monitored for corn-reared and sorghum-reared biotype E greenbug feeding on different corn and sorghum genotypes are presented in Table 8; durations of baseline (base), probing (probe), salivation (SAL), phloem ingestion (PI), non-phloem ingestion (NPI), time to first committed phloem ingestion (CPI), and Table 9 frequency of occurrence of baseline (OB), probing (OB), salivation (OS), x-wave (OX), phloem ingestion (OPI), non-phloem ingestion (ONPI). There was significant varietal effect for durations of NPI, PI and CPI ($P < 0.05$). The difference between corn-reared and sorghum-reared greenbugs for the duration of time to first committed phloem ingestion was significant ($P < 0.05$). There was no significant variation in the occurrence of probing events (probing, salivation, phloem ingestion) between corn-reared and sorghum-reared greenbug for both corn and sorghum genotypes. However, there was a significant ($P < 0.05$) varietal effect on the frequency of occurrence of non-phloem

ingestion.

Corn-reared greenbugs took less time to establish CPI on all corn (Antiqua, 2570, and AP670) and sorghum (NC+630x and PI264453) genotypes, except for OH45 (Table 10) than did sorghum-reared greenbugs. The shortest time to first committed phloem ingestion occurred with corn-reared greenbug on sorghum resistant (PI264453) genotype and the longest time occurred with sorghum-reared greenbug on corn genotype (AP-670) ($P = 0.02$).

The results of the various probing events and the frequency of occurrence of these events monitored for two sources of biotype E greenbug on various corn and sorghum genotypes, are given in Table 11. The variation between corn-reared and sorghum-reared greenbug for these probing events and their frequency for occurrence were not significant ($P < 0.05$). However, corn-reared greenbugs showed a greater potential then sorghum-reared greenbugs to have shorter frequency of occurrence in baseline, probing, and salivation on corn (Antiqua, AP670, and 2570) genotypes and sorghum resistant (PI264453) genotype, but longer on sorghum susceptible (NC+630x) genotype. Although the length of time the greenbugs fed from the phloem did not differ within or between source populations, there was significant difference in the percentage of the total time spent feeding from the phloem within and between sources (corn-reared and sorghum-reared) of greenbug for the various corn and sorghum genotypes ($P < 0.05$; Table 12). The longest percentage of the total time spent in phloem ingestion on all genotypes occurred with corn-reared greenbug on PI264453 ($P = 0.02$). Corn-reared greenbug spent

a longer percentage of its time feeding from the phloem then sorghum-reared greenbug on 2570 ($P = 0.02$). The shortest percentage of time spent feeding from the phloem occurred with sorghum-reared greenbug on AP670 ($P = 0.02$).

DISCUSSION

When one considers the effect of the various corn and sorghum genotypes on corn-reared and sorghum-reared biotype E greenbug with respect to the difference in weight, reproduction, time to first committed phloem ingestion, the frequency of occurrence of baseline, salivation and probing, it becomes obvious that the corn plant is not a non-host and the greenbug is a potential threat for becoming a pest of corn. The features that distinguish a host plant from a non host (feeding or non-feeding) or a resistant plant from a susceptible (presence or absence of plant injury) are associated with greenbug fecundity, size and ingestion from the phloem. The relatively higher fecundity (Table 5) and the larger size (1-day old nymphs and 1-day old adults) (Table 6&7) of corn-reared greenbugs, compared to sorghum-reared greenbugs, on corn genotypes and resistant sorghum genotype, PI264453 indicate that these genotypes, while maintaining some resistance to sorghum-reared greenbug, were suitable for corn-reared greenbugs. It is known that the size of an aphid is determined by the relative effect of the quantity and quality of food ingested (Dixon, 1985), and ingestion depends on the food being accepted (Huffaker and Rabb, 1984).

Observed differences in the mean durations of salivation, baseline, probing, phloem ingestion and non phloem ingestion (Table 11) of corn-reared and sorghum-reared greenbug feeding on various corn and sorghum genotypes were not definitively correlatable to fecundity (Table 5) and size (Table 6). For example, the mean duration of phloem ingestion for corn-reared greenbug feeding on Antiqua was (276.36min.) and OH45 (273.78min.), and for sorghum-reared greenbug was (372.65min. and

411.60min.) on the respective host plants: whereas, the mean reproduction and weight (mg) (1-day old nymphs and 1-day old adults) of corn-reared greenbugs was (54.02, 0.020 and 0.39, respectively) on Antiqua and (32.16, 0.017, and 0.29, respectively) on OH45. The mean reproduction of sorghum-reared greenbugs on Antiqua and OH45 was 38.08 and 15.79, respectively. The mean weight (1-day old nymphs and 1-day old adults) on Antiqua was 0.015 and 0.32, respectively and 0.016 and 0.23 on OH45.

The relatively shorter time taken by the corn-reared greenbugs, compared to sorghum-reared greenbug, to establish CPI on all 2570 and PI264453, and the decrease in the frequency of occurrence of baseline, probing and salivation on corn (Antiqua, 2570, and AP670) genotypes and sorghum resistant (PI264453) genotype may be important factors in explaining the acceptability of the corn plant since there is not exact correspondence in the difference of the mean duration of phloem ingestion between the two sources (corn-reared and sorghum-reared) of greenbugs with respect to fecundity and growth.

The amount of probes may be a significant part of the behavioral repertoire of the greenbug, by which it gathers the necessary information to determined whether it is on an acceptable host (Montllor et al., 1983). Reduction in the number of separate probes (Campbell et al., 1982) and time to first committed phloem ingestion (Ryan et al., 1987; Montllor et. al., 1983) has been associated with host acceptability and susceptibility. Campbell et al. (1982) found that the fewest probes were recorded when greenbug fed on susceptible sorghum

plants (NC+70x) compared to when greenbugs fed on plant of resistant lines. It took biotype C greenbug a longer time to establish CPI on 'IS809' (resistant to biotype C but susceptible to biotype E) sorghum variety, compared to biotype E greenbug (Montllor et al., 1983).

The length of time spent in phloem ingestion by corn-reared greenbug was not significantly different from sorghum-reared greenbug. However, corn-reared greenbug, spent significantly greater ($P = 0.02$) percentage of its time ingesting from the phloem of resistant sorghum (PI264453) and corn genotypes (2570) compared to sorghum-reared greenbug. This suggests a modification in the probing behavior of the corn-reared greenbug as the result of being previously cultured on corn and that the corn plant is a more suitable host for corn-reared greenbug than the sorghum-reared greenbug. On less suitable host-plants, pre-CPI probing may be very extensive, and on non-hosts, phloem ingestion may never occur (Montllor et al., 1983). Several studies have been conducted to investigate aphid feeding behavior on non-host plants. Probing by strawberry aphid, Chaetosiphon fragaefolii (Cockerell) was stimulated on a nonhost plant that was treated with extracts of strawberry leaves (Shanks and Finnigan, 1970). Acyrthosiphon spartii (Koch) fed on leaves of pea (nonhost) after leaves were treated with sparteine, an alkaloid from its host plant, broom (Smith, 1966). In none of these studies, however, was it determined if there was ingestion from the phloem of the nonhost plants (Campbell et al., 1982). Similarly, aphids feeding on resistant cultivars of their host plant tend to cease feeding shortly after the phloem is penetrated (Nielson and Don, 1974).

It is possible that the differences in reproduction, growth and probing behavior of the two sources (corn-reared and sorghum-reared) of biotype E greenbug on the various corn and sorghum genotypes are genetically based. The effect of previous experience on the behavior of aphid have been observed in relation to culture and/or previous feeding experience on plants or artificial diet (Mclean, 1971; Lowe, 1973; Ryan et al., 1987). When aphids are confined to a relatively unacceptable host-plant, it may cause partial starvation or sensory adaptation, either of which may lessen the acceptance of the aphid (Montllor et al. 1983). The ability for such behavioral modification may represent an important step in the process of genetic adaptation such as that shown by corn-reared greenbug in its reproduction, growth and probing behavior on corn and sorghum genotypes. Physiological adaptation such as changes in activity of salivary enzymes of aphids raised on plants with different physiological conditions (Adams, 1967) also may be involved in the apparent behavioral modification of greenbugs. Undoubtedly, physical factors such as epidermal hairs on the upper surface of the leaves of the corn plant influenced the probing behavior of the greenbugs.

The differences in the reproduction, growth and time to first committed phloem ingestion of corn-reared greenbugs, compared to sorghum-reared greenbugs, on some corn genotypes and sorghum resistant genotype suggest that the changes in behavior made by corn-reared greenbug are reflected in the future performance of greenbug on the corn plant.

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Table 5. Average Progeny Production of Corn-reared and Sorghum-reared Biotype E Greenbug on Corn and Sorghum Genotypes.

Genotype	Av. Total No. Progeny/Indiv. 1	
	Corn-reared	Sorghum-reared
PI264453	61.36 a	42.56 b
NC+630x	52.76 a	34.33 b
Antiqua	54.02 a	38.08 b
2570	20.44 b	26.33 b
OH45	32.16 b	15.79 a
AP670	26.34 b	18.41 b

\1 Means followed by the same letter between column are not significantly different (P < 0.05;LSD).

Table 6. Average weight of one-day-old nymphs of biotype-E greenbug on corn and sorghum genotypes.

Genotypes	Ave. weight (mg)/batch of five	
	Corn-reared	Sorghum-reared
PI264453	0.024	0.027
NC+630x	0.025	0.020
Antiqua	0.020	0.015
2570	0.021	0.014
OH45	0.017	0.016
AP670	0.021	0.015

Table 7. Average weight of greenbug biotype-E one-day old adults reared on corn and sorghum genotypes. 1

Genotypes	Average Weight (mg)		
	Corn-reared	Sorghum-reared	P 2
PI264453	0.35	0.34	0.82
NC+630x	0.34	0.37	0.44
Antiqua	0.39	0.32	0.08
2570	0.32	0.23	0.01
OH45	0.29	0.23	0.13
AP670	0.24	0.17	0.07

\1 Mean values are least squares.
\2 P, probability values. Probability values less than 0.05 indicate difference between means across columns.

Table 8. Analyses of Variance for Durations in Baseline (BASE), probing (PROBE), Salivation (SAL), Phloem Ingestion (PI), Non-phloem Ingestion (NPI), and Time to First Committed Phloem Ingestion (CPI) of Corn-reared and Sorghum-reared Biotype E Greenbug on Corn and Sorghum Genotypes.

		Events					
Source	df	BASE	PROBE	SAL	PI	NPI	CPI
		Mean square					
Variety (V)	5	13850.62	154.27	17472.15	90820.31*[1]	29010.05*	73591.43*
Source2 (S)	1	5732.10	1.52	15287.11	17467.66	8640.64	87906.51
V Vs. S	5	12434.81	193.00	17409.02	73877.56	11145.90	72307.93*
Error	42	6495.29	145.35	16223.77	36928.42	9342.83	23401.95
C.V.		125.75	137.89	66.61	109.95	55.65	61.28

\1 *, $P < 0.05$.
\2 Source refers to corn-reared and sorghum-reared greenbugs.

Table 9. Analyses of Variance for Frequencies of Baseline (OB), Probing (OP), Salivation (OS), Phloem Ingestion (OP), and Non-phloem Ingestion (ONPI) of Corn-reared and Sorghum-reared Biotype E Greenbug on Corn. and Sorghum genotypes.

		Event				
Source	df	OB	OP	OS	OPI	ONPI
		Mean square				
Variety (V)	5	99.50	102.71	90.01	2.61	12.21* 1
Source 2 (S)	1	22.04	61.76	77.04	4.59	3.37
V Vs. S	5	156.74	179.51	134.09	4.64	6.65
Error	42	108.31	105.57	110.01	10.94	3.93
C.V.		90.49	90.91	80.42	92.59	120.56

\1 *, P < 0.05.
\2 Source refers to corn-reared and sorghum-reared greenbugs.

Table 10. Effect of Various Corn and Sorghum Genotypes on The Time to First Committed Phloem Ingestion (CPI) of Corn-reared and Sorghum-reared Biotype E Greenbugs. 1

Genotypes	CPI (Minutes) 3		
	corn-reared	sorghum-reared	P-value 2
PI264453	117.50 a	288.50 ac	0.0307
NC+630x	160.50 a	235.00 ac	0.3356
Antiqua	176.25 a	273.37 ac	0.2111
2570	152.37 a	340.50 ac	0.0181
OH45	334.12 b	153.62 a	0.0230
AP670	375.37 b	388.25 bc	0.8671

\1 Mean values are least squares.
\2 P-value, probability values. Probability value less than 0.05 indicates significant difference between means accross column for a given variable.
\3 Means followed by the same letter within column are not significantly different (P < 0.05;LSD).

Table 11. Effect of Various Corn and Sorghum Genotypes on Duration of Baseline (BASE), Probing (PROBE), Salivation (SAL), Phloem Ingestion (PI), and Mean Frequency of Baseline (OB), Probing (OP), and Salivation (OS), of Corn-reared and Sorghum-reared Biotype E Greenbugs. 1

Source	Genotypes	Waveforms						
		Minutes				Frequency		
		BASE	PROBE	SAL	PI	OB	OP	OS
2								
CR	Pi264453	12.23	2.52	129.12	528.21	8.25	4.87	8.37
CR	Nc+630x	42.49	6.95	220.51	372.15	10.25	10.25	13.50
CR	Antiqua	41.27	18.43	177.22	276.36	9.50	9.87	10.62
CR	2570	72.18	5.54	150.86	415.89	7.00	7.37	11.37
CR	Oh45	117.46	10.60	165.86	273.78	16.62	16.62	14.75
CR	Ap670	52.51	7.62	227.79	286.10	14.50	14.00	14.25
SR	Pi264453	34.66	7.29	255.80	385.41	13.37	13.25	16.12
SR	Nc+630x	20.33	5.18	200.64	413.08	7.75	8.25	9.50
SR	Antiqua	102.14	8.72	160.14	372.65	10.62	10.75	11.75
SR	2570	115.13	14.45	231.06	229.26	15.12	15.25	17.25
SR	Oh-45	39.78	5.68	123.10	411.60	7.12	7.25	8.62
SR	Ap-670	118.82	11.87	252.25	178.63	17.87	17.87	20.37

\1 Mean values are least square.
\2 CR, corn-reared; SR, sorghum-reared.

Table 12. Percentage of Time Spent Ingesting from Phloem by Corn-reared and Sorghum-reared Biotype E Greenbug on Various Corn and Sorghum Genotypes. 1

Genotypes	Percentage (%) 2		
	Corn-reared	Sorghum-reared	P-value 3
PI264453	64.32 b	38.84 a	0.0195
NC+630x	45.04 a	46.15 ad	0.9173
Antiqua	33.16 a	38.87 ad	0.5945
2570	47.84 a	22.88 ad	0.0220
OH45	27.49 a	46.55 a	0.0784
AP670	27.96 a	17.62 d	0.3363

\1 Percentage values are least square means.
\2 P-value, probability value. Probability value less than 0.05 indicates significant difference between means accross column for a given variable.
\3 Means followed by the same letter within column are not significantly different (P < 0.05; LSD).

Figure 20. Average daily weight of 1-day old nymphs of biotype E corn-reared and sorghum-reared greenbugs on resistant sorghum genotype, PI264453.

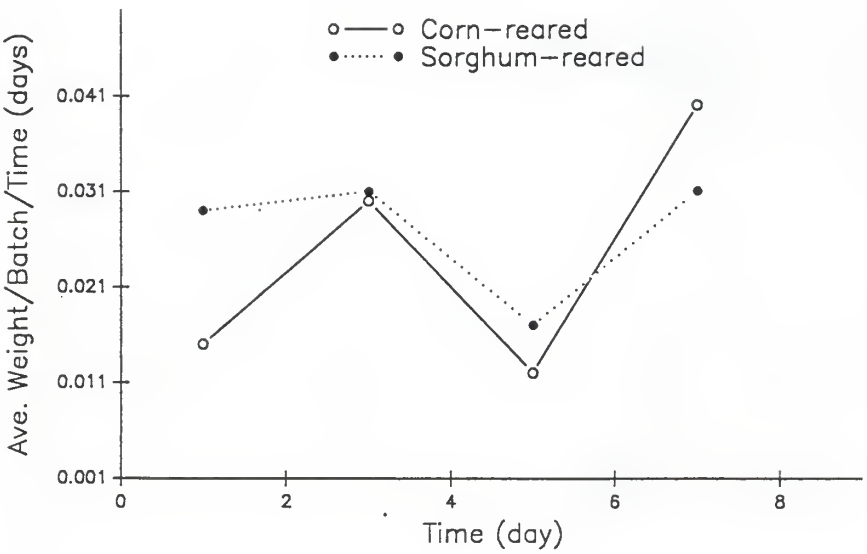

Corn–reared
Sorghum–reared
Ave. Weight/Batch/Time (days)
0.041
0.031
0.021
0.011
0.001
0
2
4
6
8
Time (day)

Figure 21. Average daily weight of 1-day old nymphs of biotype E corn-reared and sorghum-reared greenbugs on susceptible sorghum genotype, NC+630x.

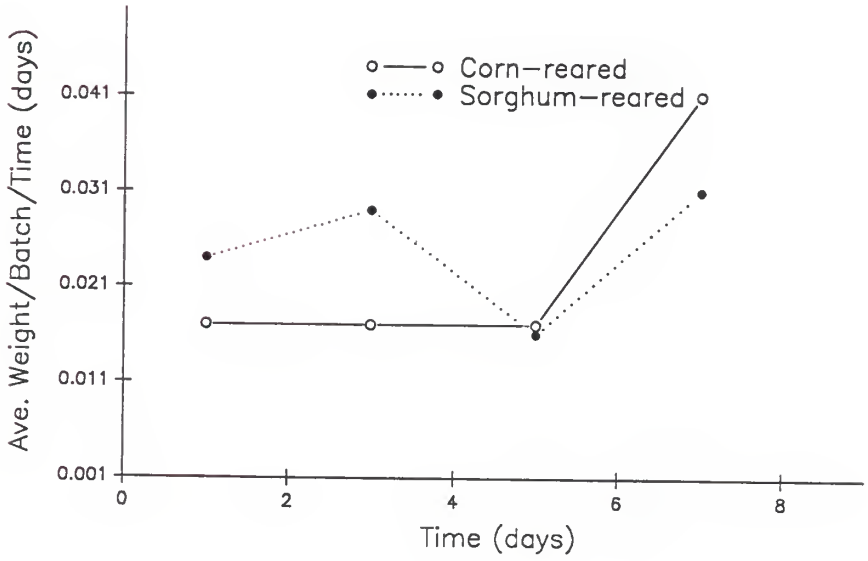

Corn—reared
Sorghum—reared
Ave. Weight/Batch/Time (days)
0.041
0.031
0.021
0.011
0.001
0
2
4
6
8
Time (days)

Figure 22. Average daily weight of 1-day old nymphs of biotype E corn-reared and sorghum-reared greenbugs on corn genotype, Antiqua.

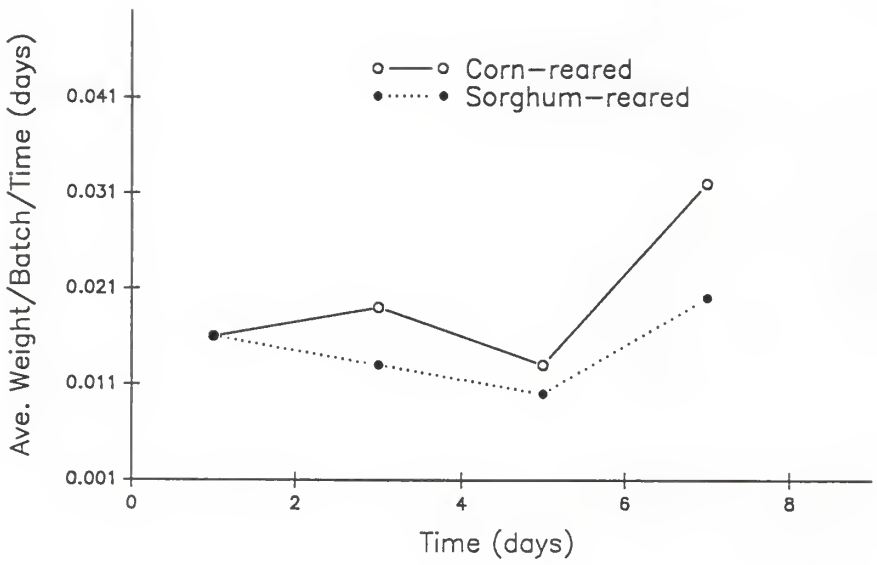

Corn—reared
Sorghum—reared
Ave. Weight/Batch/Time (days)
0.041
0.031
0.021
0.011
0.001
0
2
4
6
8
Time (days)

Figure 23. Average daily weight of 1-day old nymphs of biotype E corn-reared and sorghum-reared greenbugs on corn genotype, 2570.

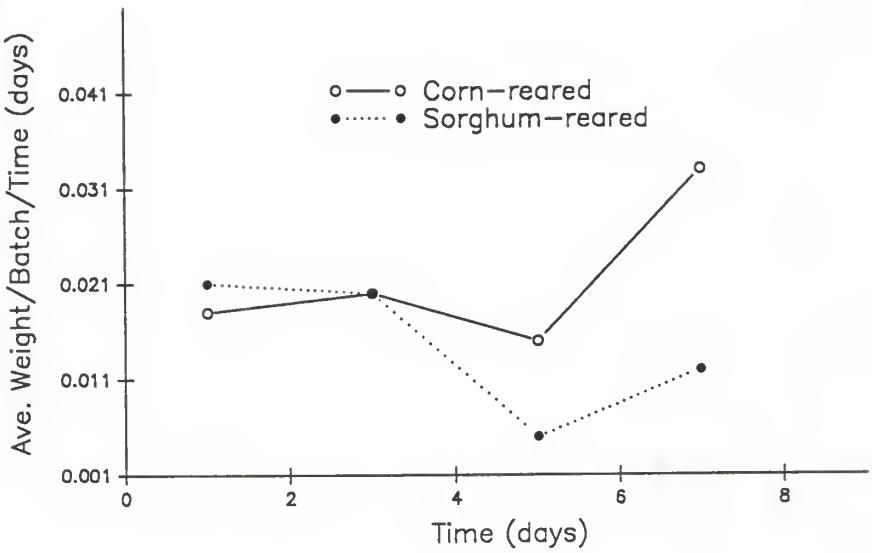

Ave. Weight/Batch/Time (days)
0.041
0.031
0.021
0.011
0.001
0
2
4
6
8
Time (days)
Corn–reared
Sorghum–reared

Figure 24. Average daily weight of 1-day old nymphs of biotype E corn-reared and sorghum-reared greenbugs on corn genotype, OH45.

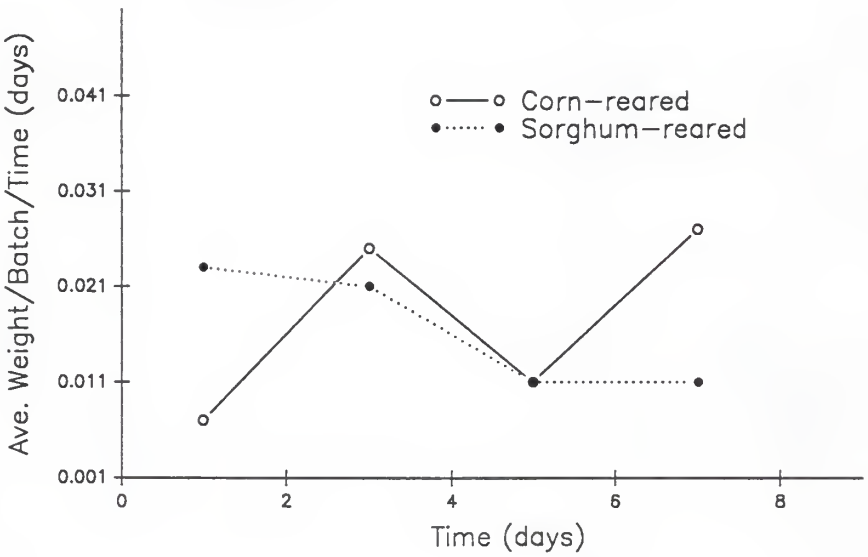
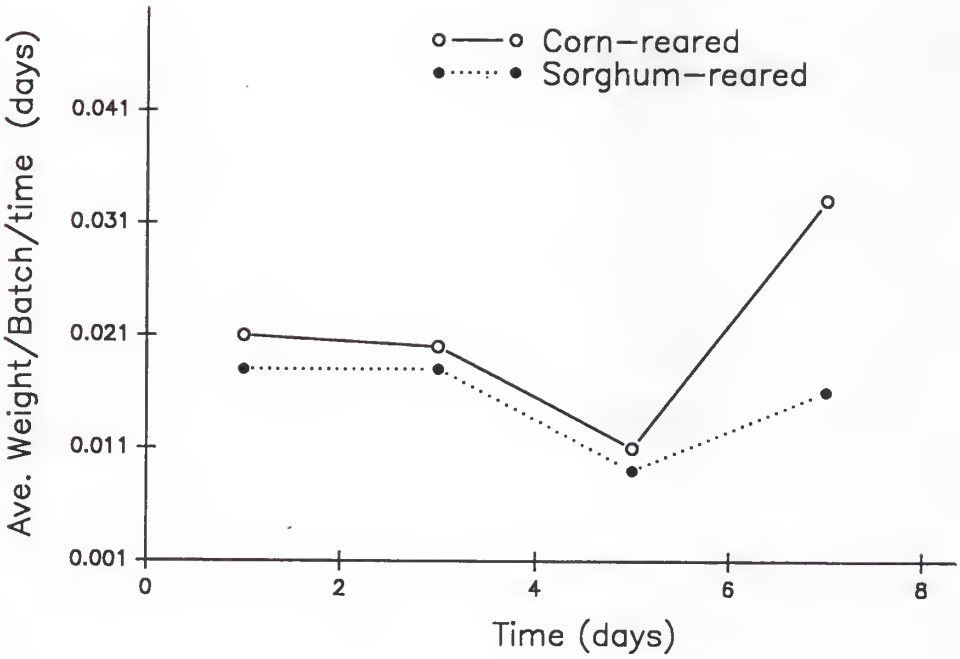

Ave. Weight/Batch/Time (days)
0.041
0.031
0.021
0.011
0.001
0
2
4
6
8
Time (days)
Corn-reared
Sorghum-reared

Figure 25. Average daily weight of 1-day old nymphs of biotype E corn-reared and sorghum-reared greenbugs on corn genotype, AP670.


Corn–reared
Sorghum–reared
Ave. Weight/Batch/time (days)
0.041
0.031
0.021
0.011
0.001
0
2
4
6
8
Time (days)

SUMMARY AND CONCLUSIONS

Biological assessment of biotype E greenbug was made on corn by measuring life table parameters and feeding behavior of corn-reared and sorghum-reared biotype E greenbug on various corn and sorghum genotypes.

Corn-reared greenbug was similar to sorghum-reared greenbug in development time, net reproductive rate, intrinsic rate of increase and exhibited low juvenile mortality on all genotypes. However, there were major differences in the reproduction, longevity, finite rate of increase, population doubling time, time to first committed phloem ingestion (CPI), and percentage of time spent feeding from the phloem between source of greenbug and among host genotypes. Corn-reared greenbug produced more progeny than sorghum-reared greenbug on corn genotypes Antiqua, AP670 and OH45. Corn-reared greenbug survived longer and doubled its population in a shorter time on corn genotypes than sorghum-reared greenbug. Not only did corn-reared greenbug exhibit higher reproductive fitness on AP670 and PI264453 than sorghum-reared greenbug, corn-reared greenbug reached CPI in a shorter time and fed from the phloem for a longer percentage of time on PI264453 and 2570 than sorghum-reared greenbug. This indicates there was a relationship between feeding, reproduction and survival. The ability of the corn-reared greenbug to have higher reproduction and survive longer than sorghum-reared greenbug can be attributed to the shorter time it took corn-reared greenbug to reach CPI and the longer percentage of time spent feeding from the phloem of the genotypes.

The greenhouse conditions of 26-29^{o}C and photoperiod of 16:8 (L:D)

under which this study was conducted are quite similar to conditions found in the field in the months of September, October, and November when greenbug are abundant. Besides, during this period the greenbug can produce enormous number of progeny because its natural enemies become inactive or reproduce much more slower than the greenbug (U. S. D. A., 1978). Outbreaks in the fall from local summer populations or winged migrants moving into the Central Plains on wind currents from the south could get into corn. Plant varieties previously resistant to greenbugs have suddenly become colonized e.g. greenbug on sorghum (Porter et al., 1982). During this period any colonization of biotype E greenbug on corn could be of economic importance. In the summer, higher temperatures (above 90^{o}F) and natural enemies can reduce or keep greenbug population levels low. Corn-reared greenbugs did not do worse on sorghum than sorghum-reared greenbug which is indicative of a host range expansion from sorghum to corn. The ability of biotype E greenbug to expand its host range was demonstrated by Chedester and Michels (1982) when they examined greenbug resistance in 500 oats accessions out of which, 51 were resistant to biotype C greenbug, but when evaluated for resistant to biotype E. The 449 accessions that were susceptible to biotype C greenbug were also susceptible to biotype E greenbug; no biotype C-susceptible accessions were found that were resistant to biotype E greenbug.

The biological differences between corn-reared and sorghum-reared greenbugs observed in this study makes it possible to assess the relative potential for biotype E greenbug to colonize and adapt corn as

a true host, and develop a biotype of economic importance to the corn plant. In this respect I conclude that corn-reared greenbug displayed a greater potential to adapt corn as a true host and develop a biotype of economic status on corn.

GREENBUG (SCHIZAPHIS GRAMINUM, RONDANI) BIOTYPE - E INTERACTION ON FOUR GENOTYPES OF CORN (ZEA MAYS, L.)

by

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Abstract

Studies were conducted to assess the potential for greenbug to adapt corn, Zea mays L. as a true host and suggest potential for biotype development. This was done by measuring development, reproduction, survival and quantifying the effect of corn on biotype E feeding behavior. Fifteen corn genotypes were first screened in order to select four which were most susceptible to greenbug. The four selected were Antiqua, OH45, AP670, and 2570. They were used along with susceptible (NC+630x) and resistant (PI264453) sorghum genotypes as controls. Two sources of greenbug, corn-reared and sorghum-reared were tested on these genotypes. Results of life tables studies indicated that development time of corn-reared greenbug and sorghum-reared greenbug were similar, 7.6 and 7.7 days respectively. Corn-reared greenbug produced more progeny than sorghum-reared greenbug on corn genotypes, Antiqua, OH45 and AP670. The reproductive fitness of corn-reared greenbug was higher than sorghum-reared greenbug on PI264453 and AP670. Corn-reared greenbug doubled its population in a shorter time (3.3days) than sorghum-reared greenbug (4.1days) on AP670 and corn-reared greenbug had the shortest generation time (12.5days) on PI264453.

Feeding behavior of biotype E corn-reared and sorghum-reared greenbug monitor for twelve hours with the computerized insect feeding monitor (IFM) found significant quantitative differences between source of greenbugs and among host genotypes for time to first committed phloem ingestion (CPI) and percentage duration of phloem ingestion. Corn-reared greenbug established committed phloem ingestion in a shorter amount of time on one corn genotype (2570) and resistant sorghum

(PI264453) than did sorghum-reared greenbugs. The percentage of the total duration of phloem ingestion was also higher on 2570 and PI264453. The data suggest a modification in the feeding behavior of corn-reared greenbugs and a correspondence with fecundity and growth. Assessment of the results also indicated that corn-reared greenbug has a greater potential to adapt corn as a true host and develop a biotype specific to corn.