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EFFECTS OF THE RICE ROOT APHID, *RHOPALOSIPHUM RUFIABDOMINALIS* (SASAKI), ON WHEAT GROWTH AND YIELD

By

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EFFECTS OF THE RICE ROOT APHID,

RHOPALOSIPHUM RUFIABDOMINALIS (SASAKI),

ON WHEAT GROWTH AND YIELD

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CHAPTER I

GENERAL INTRODUCTION

Winter wheat (*Triticum aestivum* L.) is grown in the Southern Plains of the United States with grain only, forage only, or dual-purpose production (forage and grain) goals in mind. The use of winter wheat as a dual-purpose forage and grain crop is important to the agricultural economies of southwestern Kansas, eastern New Mexico, western Oklahoma, southeastern Colorado, and the Texas Panhandle (Epplin et al. 2000). About 10 million ha (25 million acres) are sown annually in the Southern Plains and it is estimated that up to 80% is targeted for cattle grazing (Pinchak et al. 1996). Production of wheat for dual-purpose use is a complicated process involving the interaction of forage and livestock production with wheat grain production. For optimum forage and grain production, it is recommended that grazing should not begin until wheat has developed a secondary root system and that livestock should be removed prior to the first hollow stem (Croy 1984, Krenzer 1994, Redmon et al. 1996). In these systems, production of forage is critical because the value of forage removed by cattle is often the difference between profit and loss (Epplin et al. 2000).

Twenty-seven species of aphids utilize cultivated cereals as hosts in the United States (Pike et al. 1990). Greenbugs (*Schizaphis graminum* Rondani) and bird cherry-oat aphids (*Rhopalosiphum padi* L.) have been shown to limit profitable winter wheat production in the Southern Plains and are considered to be the most abundant and important insect pests of winter wheat in the region (Kindler et al. 2002, Giles et al. 2003, Trent 2003). Another potentially important species of which little is known is the rice root aphid, *Rhopalosiphum rufiabdominalis* (Sasaki). This aphid, which feeds on below ground portions of cereal plants, has been documented throughout many of the wheat growing regions of the United States (Kieckhefer and Gustin 1967, Jedlinski 1981). However, in the Southern Plains, few researchers have regularly sampled for or examined the impact of the rice root aphid on wheat. In 2001, Kindler et al. (2004a) began an investigation of the presence, abundance and potential impact of the rice root aphid in Oklahoma. These researchers found that the rice root aphid was frequently the most common aphid infesting winter wheat during the early fall. Additionally, heavy infestations of rice root aphid on greenhouse grown wheat were shown to significantly reduce forage levels.

These initial studies on the rice root aphid caused concern among researchers and producers about the potential pest status of this aphid in Oklahoma. The studies described in this thesis were initiated to document the distribution of the rice root aphid in Oklahoma and further describe the impact of the rice root aphid in dual-purpose wheat systems.

OBJECTIVES

I. Define the distribution of the rice root aphid across Oklahoma.

II. Describe the effect of increasing rice root aphid infestations on seedling growth of wheat cultivars common to the Southern Plains.

III. Examine the effect of the rice root aphid on winter wheat grain yield in small field plots.

Explanation of Thesis Format

This general introduction is followed by a literature review (chapter II), then chapters III, IV, and V. Lists of references are provided for citations in the literature review and following chapters. In chapter III, the known distribution of the rice root aphid in Oklahoma was defined. In chapter IV, the effect of the rice root aphid on six winter wheat cultivars (Jagger; OK101 and OK102, TAM105, TAM107, and TAM110) was examined in a controlled environment, and damage caused by the rice root aphid was compared to damage caused by the closely related bird cherry-oat aphid. In chapter V, the effect of the rice root aphid on winter wheat (OK101) grain yield in small field plots was examined. These chapters follow the general guidelines of the Entomological Society of America for submission to scientific journals.

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CHAPTER II

LITERATURE REVIEW

WINTER WHEAT PRODUCTION IN OKLAHOMA

Winter wheat (*Triticum aestivum* L.) grain production for the United States was estimated at 1.1 billion bushels in 2002 with an average yield of 37.7 bushels per acre (NASS 2002). With 6 million acres planted and 179 million bushels, worth over $583 million, annually, Oklahoma is regularly the second or third ranked state in winter wheat production (NASS 2005). Most of the wheat is produced in the western half of the state. For the majority of acres planted, winter wheat serves as pasture for cattle (forage only and dual-purpose) during the winter months (Pinchak et al. 1996, Epplin et al. 2000). The use of wheat to provide forage for beef cattle and to produce grain is known as dual-purpose. In dual-purpose systems, wheat is planted at a date earlier than recommended for grain production (Vocke and Allen 2005). The 2004 average target planting date for grain-only production was October 2, while the average targets for dual-purpose and forage-only wheat production were September 20 and 13, respectively (Hossain et al. 2004). When wheat is used as a dual-purpose crop, Oklahoma farmers usually sacrifice some grain production to obtain optimal forage for grazing.

It is recommended that grazing should not begin until wheat has developed a secondary root system. The secondary root system anchors the plant, which makes it difficult for grazing animals to uproot it, and future growth is not critically affected by leaf removal after this growth stage. Also, timing of fall-winter grazing termination is critical to successful dual-purpose wheat production. Removing livestock from wheat prior to the first hollow stem growth stage is important to enable grain production. Studies have shown that the net return per acre to a dual-purpose enterprise declines significantly if grazing continues beyond the presence of first hollow stem (Croy 1984, Krenzer 1994, Redmon et al. 1996, Krenzer 2000, Hossain et al. 2004).

INSECT PESTS OF WHEAT

According to Elliott et al. (1994) wheat has many major and potential pest species from different arthropod orders. Acari: *Eriophyes tulipae* (wheat curl mite), *Petrobia latens* (brown wheat mite); Coleoptera: *Ctenicera* and *Agriotes* spp. (wireworms), *Oulema melanopus* (cereal leaf beetle), *Zabrus* spp. (Carabids); Diptera: *Chlorops pumilionis* (gout fly), *Contarinia tritici* (lemon wheat blossom midge), *Delia coarctata* (wheat bulb fly), *Haplodiplosis equestris* (saddle gall midge), *Mayetiola destructor* (Hessian fly), *Meromyza americana* (wheat stem maggot), *Opomyza florum* (yellow cereal fly), *Oscinella frit* (frit fly), *Sitodiplosis mosellana* (orange wheat blossom midge); Heteroptera: *Blissus leucopterus* (chinch bug), *Eurygaster integriceps* (sunn pest), Homoptera: *Diuraphis noxia* (Russian wheat aphid), *Metopolophium dirhodum* (rose-grass aphid), *Rhopalosiphum maidis* (corn leaf aphid), *Rhopalosiphum padi* (bird cherry-oat aphid), *Rhopalosiphum rufiabdominalis* (rice root aphid), *Schizaphis graminum* (greenbug), *Sitobion avenae* (English grain aphid); Hymenoptera: *Cephus cinctus* (wheat stem sawfly), *Cephus pygmaeus* (European wheat stem sawfly); Lepidoptera: *Agrotis orthogonia* (pale western cutworm), *Euxoa auxiliaries* (army cutworm), *Pseudaletia* *unipuncta* (armyworm), *Spodoptera frugiperda* (fall armyworm); Orthoptera: several species of grasshoppers; and Thysanoptera: *Limothrips denticornis* (grain thrips).

Greenbugs (*S. graminum* Rondani) and bird cherry-oat aphids (*R. padi* L.) have been described as the most abundant and important insect pests of winter wheat in the Southern Plains (Giles et al. 2003). Greenbugs can reach high numbers during the fall, late winter or early spring and can kill plants or inhibit growth, thus reducing grain yields and net returns (Burton et al. 1985, Royer et al. 1997). The bird cherry-oat aphid is also a serious pest and is primarily recognized as an efficient vector of barley yellow dwarf virus, which causes the most economically important viral disease of cereals worldwide (Plumb 1983, Pike and Schaffner 1985). BYDV can reduce grain yields by stunting root and shoot growth (Trent 2003) as well as increasing host susceptibility to fungal pathogens, drought, and other environmental stress.

Another potentially important aphid species about which little is known is the rice root aphid, *R. rufiabdominalis* (Sasaki). This aphid, which feeds on below ground portions of cereal plants, has been documented throughout many of the wheat growing regions of the United States (Kieckhefer and Gustin 1967, Jedlinski 1981). However, in the Southern Plains, few researchers have regularly sampled for, or examined the impact of, the rice root aphid on wheat. Kindler et al. (2004a) initiated an investigation of the presence, abundance and potential impact of the rice root aphid in Oklahoma. Through initial sampling efforts, it was found that the rice root aphid was frequently the most abundant aphid infesting winter wheat during the early fall. Also, infestations of rice root aphids (greater than two per tiller) were shown to significantly reduce forage levels of greenhouse grown wheat.

BIOLOGY AND NATURAL HISTORY OF THE RICE ROOT APHID

According to Doncaster (1956), for several years entomologists in many parts of the world have been aware of an aphid that attacks the roots of rice and other Gramineae. This aphid is commonly referred to as the rice root aphid and is closely related to the bird cherry-oat aphid, *Rhopalosiphum padi* L., and the oat apple aphid, *R. insertum* (Walker). Frequently, the rice root aphid is misidentified as one of these closely related species.

Morphology

The rice root aphid differs from other species of *Rhopalosiphum* in having long, fine hairs on the body and antennae (Doncaster 1956). Like other species of this genus, the rice root aphid has a tendency to produce both apterous and alate forms in which the number of antennal segments is reduced to five.

Apterous viviparous females are usually dark green with reddish blotches around the bases of the cornicles. The antennae, and the apical halves of the femora and cornicles are dark brown; the head, rostrum, coxae, trochanters, basal halves of femora, apices of tibiae, cauda, anal and genital plates are light brown; other portions are light fuscous or colorless. The antenna are normally five-segmented and shorter than the total body length and the rostrum extends to the middle coxae (Hsieh 1970).

Alate viviparous females are dark green with reddish blotches around bases of the cornicles. The antennae, head, thorax, apical rostral segments, coxae, trochanters, femora, apices of tibiae, tarsi, tarsal claws, wing veins, spiracles, thoracic tergites, sternites and lateral sclerites, cornicles, cauda, anal plate, genital plate and sclerites on abdominal terga VI, VII and VIII are dark brown; other portions are light fuscous or colorless (Hsieh 1970).

Plant Feeding Behavior and Life History

Most of the detailed studies on rice root aphid biology were conducted on rice in Asia, however, the feeding behavior and life history traits appear similar on wheat (M.R. Rawlings, personal observations). Rice root aphids are phloem feeders and feed by inserting their stylets into the plant tissue and siphoning nutrients. Though direct injury inflicted by the aphid is usually not severe, a pale yellowing and distorted growth of the plant may result from this feeding. When infestations are heavy, rice plants often wilt and die before they are fully grown and large numbers of aphids can be seen feeding on the roots when these plants are pulled from the soil (Hsieh 1970). Adults and nymphs of the rice root aphid frequently congregate on the upper portions of rice roots, above the soil line, when water is drained from fields. When the population becomes extremely high or when the rice is flooded, the aphids will also feed on stems and leaves (Hsieh 1970). The ability to feed on wheat stems and leaves has been observed when populations are high in greenhouse colonies and in wheat fields (M.R. Rawlings, personal observations).

On rice plants, the rice root aphid is highly fecund and has a short developmental time between 10-25°C (Tsai and Liu 1998). In the mild rice growing regions of central Taiwan, adults continue to reproduce parthenogenetically throughout the entire year; the phenomenon of diapause has not been observed and male aphids do not exist (Hsieh 1970).

First stage nymphs are usually born shortly after the adults have reached maturity. The nymphs molt four times (body size increases with each subsequent molt) and are quite active before they are fully mature. Individuals reared above 35°C are unable to develop beyond the third instar (Tsai and Liu 1998). During the fourth molt, the nymph becomes either an alate or an apterous adult. In the alate form, the wing pads appear on the second instar as flattened backward outgrowths of the body wall along the lateral margins of the dorsal tergites of the pterothorax. The pads increase in size with each subsequent molt with little change in structure. At emergence, the wings are somewhat soft and pleated, but will straighten and harden as they become functional. Generally, alates are poor fliers, but occasionally are carried long distances by wind or animals.

Under laboratory conditions, the rice root aphid develops 53-58 generations per year with many generations overlapping. Rice root aphid survival appears to be greatest at lower temperatures. According to Tsai and Liu (1998) the average female rice root aphid achieves greatest longevity at 10°C (29.73 ± 1.19 days), and shortest longevity occurs at 30°C (9.42 ± 0.61 days).

HOST PLANTS OF THE RICE ROOT APHID

The rice root aphid has been reported on various hosts in North America in 26 different states and Canada (Kieckhefer and Gustin 1967, Jedlinski 1981). Host genera of the rice root aphid include *Arundo*, *Avena*, *Bromus*, *Cyperus*, *Gnaphalium*, *Gossypium*, *Hordeum*, *Iris*, *Lolium*, *Prunus*, *Solanum*, and *Triticum* species (Doncaster 1956). Cultivated cereals such as wheat and barley are generally better hosts for the rice root aphid than forage grasses; important crops such as rice and sorghum have been found to be poor hosts while corn was found to be a non-host (Jedlinski 1981, Kindler et al. 2004b). All scouting reports from Oklahoma indicate that the rice root aphid is associated with wheat and no other cultivated cereals (VanCleave 1970, Royer 1999, Kindler et al. 2004b).

EFFECT OF THE RICE ROOT APHID ON WHEAT

In a greenhouse study, Kindler et al. (2004a) compared forage yields of wheat plants infested with rice root aphids to non-infested plants. In this study, dry root weights, dry plant weights, and the total number of tillers per wheat plant were significantly reduced. When comparing grain yield components of infested wheat plants to non-infested, the number of tillers and the number of fertile heads were significantly reduced, while the number of infertile tillers was significantly increased (Kindler et al. 2004a). However, seed weights were not statistically different despite a 12% decrease for infested plants.

The rice root aphid is an efficient vector of the PAV (most non-specific isolate), RPV (*R. padi* specific virus isolate), and RMV (*Rhopalosiphum maidis* specific virus isolate) isolates of barley yellow dwarf virus in South Carolina (Gray et al. 1998). Jedlinski (1981) found that subterranean rice root aphids are capable of overwintering on seedling wheat and transmitting BYDV in Illinois and suggested that undetected colonies may explain disease outbreaks in the absence of conspicuous aphid populations.

REARING AND SAMPLING METHODS

A culturing method for the rice root aphid was described by Kindler et al. (2004b). In general, the rearing methods developed by Starks and Burton (1977) were used with two modifications. First, seeds used in primary culture pots are covered with cedar chips instead of potting soil mixture. This creates a microenvironment at the base of the host plants (‘Elbon’ rye, *Secale cereale*) that is conducive to aphid establishment, reproduction, and survival. Second, aphids are transferred to new cultures when alate forms begin to collect at the tops of cages (mesh-vented cellulose nitrate tubes). A transfer is accomplished by exchanging a cage of an infested pot with that of a non-infested pot; several transfers can be made, until the original culture is exhausted.

A wide variety of methods have been used to sample arthropod populations in wheat, rice and other vegetables. Some sampling methods require no special equipment while other methods require equipment developed especially for sampling small grain arthropods (Elliott et al. 1994).

Three major types of population estimates can be determined from sampling; absolute, relative, and population indices. Absolute population densities are estimated by counting every individual in a population in a given area (Flint and Gouveia 2001). Most frequently, methods of estimating relative population density include sweep netting; beating sheet; use of a sampling frame; or counting the number of individuals on a portion of a plant, on an entire plant or a natural cluster of stems, or in a prescribed length of row (Elliott et al. 1994). Population indices are obtained by sampling for evidence of or damage caused by an organism rather than sampling for the organism itself.

Some of the most difficult arthropods to quantify are those which feed below the soil surface, such as the rice root aphid. Extensive destructive sampling and soil removal, designed to quantify population levels of subterranean insects, is both tedious and economically damaging. Few growers are willing to tolerate removal of substantial numbers of plants and soil in the absence of evident plant stress. Royer and Edelson (1991) described a method of root sampling of cabbage and broccoli for *Pemphigus populitransversus* (poplar petiolegall aphid) that was not detrimental to the plant. On each sampling date, soil core samples (10 cm deep, 15 cm diameter) centered on individual plant roots were collected and removed from each plot. The soil cores containing plant roots were washed in a calcium chloride solution (15 ml $CaCl_2$ added to 3.75 liters H_2O). Any aphids that were dislodged would float to the surface and were then counted (Royer and Edelson 1991).

Kindler et al. (2004a) described a method for collecting rice root aphids in wheat. In this study, samples were collected by placing a spade (15.24 cm wide blade) next to wheat plants within a row and digging to remove the plants within the width of the blade along with their roots and associated soil. Each sample was placed carefully into a zip lock plastic bag, kept cool, and returned to the laboratory. At the laboratory, each sample was placed individually onto a 15.24 cm plastic tray that was placed into a Berlese funnel. The Berlese funnels were constructed from the following: an 8 in. diameter PVC pipe (13 in. long), a wooden lid with a ceramic light fixture and a 40 watt bulb, a 6 quart plastic funnel, and a 2 ounce glass collection jar (Figure 2.1). The 40 watt light bulbs were used to slowly dry out the samples and cause any aphid feeding on the plant or root material to abandon its host and fall into the antifreeze and water solution (Kindler et al. 2004a). Plant samples remained inside the funnels up to seven days to ensure that all aphids were removed and the plant material was thoroughly dry.

Figure 2.1. Berlese funnel used to remove aphids from wheat seedlings

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CHAPTER III

DISTRIBUTION OF THE RICE ROOT APHID, *RHOPALOSIPHUM RUFIABDOMINALIS* (SASAKI), ACROSS OKLAHOMA

INTRODUCTION

Winter wheat (*Triticum aestivum* L.) is grown in the Southern Plains of the United States with grain only, forage only, or dual-purpose production (forage and grain) goals in mind. The use of winter wheat as a dual-purpose crop is important to the agricultural economies of southwestern Kansas, eastern New Mexico, western Oklahoma, southeastern Colorado, and the Texas Panhandle. In these systems, production of forage is critical because the value of forage removed by cattle is often the difference between profit and loss (Epplin et al. 2000). Oklahoma normally ranks second in United States winter wheat production with over 2.2 million ha (5.5 million acres) of wheat planted annually across the state (Kindler et al. 2002, NASS 2005). Epplin (2000) estimated that over 2/3 of the wheat planted in Oklahoma is used as forage for cattle (forage only or dual-purpose). To produce sufficient forage for beef production, wheat must be planted relatively early. The 2004 average target planting date for grain-only production was October 2, while the average targets for dual-purpose and forage-only wheat production were September 20 and 13, respectively (Hossain et al. 2004). Early planting for forage production often leads to increased levels of greenbug (*Schizaphis graminum* Rondani) and bird cherry-oat aphid (*Rhopalosiphum padi* L.), and potentially barley yellow dwarf virus infections (Araya et al. 1987, Hunger et al. 1997). During periods of heavy aphid infestation, the economic cost (yield losses and insecticide costs) associated with aphids infesting winter wheat in the Southern Plains easily exceed $100 million (Starks and Burton 1977, Webster 1995, Kindler et al. 2002). In recent years, greenbug and bird cherry-oat aphid management in wheat in the Southern Plains has received considerable attention. These studies focused on above ground aphids but ignored the activity of the rice root aphid, *R. rufiabdominalis* (Sasaki). Because sampling the subterranean habitat of the rice root aphid was incompatible with greenbug and bird cherry-oat aphid studies, the ecology and distribution of the rice root aphid was not described (Kindler et al. 2002).

Kindler (2002) recently initiated studies to describe the pest status of the rice root aphid in Oklahoma. Preliminary survey results from this study indicated that the rice root aphid was present in a few Oklahoma counties (Garfield, Okfuskee, Payne, and Stephens) where winter wheat is widely grown. To accurately define the potential pest status of the rice root aphid in Oklahoma, a more comprehensive distribution study was needed. The objective of the study was to further define the distribution of the rice root aphid across the wheat growing counties in Oklahoma.

MATERIALS AND METHODS

The distribution study of the rice root aphid in Oklahoma was initiated in 2003 and continued through the fall of 2005. Experience indicated that the rice root aphid would be found in high numbers during the fall on the earliest planted wheat (Kindler et al. 2004a), therefore I selected early, well-established fields in each county sampled.

The selected wheat fields in each county were evaluated prior to rice root aphid sampling. In these fields we attempted to identify areas that exhibited signs of high rice root aphid infestation; i.e. stunted plants with aphids concentrated on the stems at ground level. Occasionally, aphid presence was not evident in some of the fields that were sampled. In each county evaluated, between one and three fields were sampled.

In each field, three or four samples were collected by using a 15.24 cm sharp shooter garden shovel to carefully remove plants from a single row of wheat. Individual samples were placed into labeled, small (15×28.5×10 cm) paper bags and then in a cooler for transport. Samples included the root mass so aphids feeding on the roots could be collected and identified. In a greenhouse, each sample was placed individually on a 15.24 cm plastic tray and placed into a Berlese funnel. The Berlese funnels were constructed from the following: an 8 in. diameter PVC pipe (13 in. long), a wooden lid with a ceramic light fixture and a 40 watt bulb, a 6 quart plastic funnel, and a 2 ounce glass collection jar (Figure 3.1). In each funnel a 40 watt bulb was used to slowly dry (4-7 days) the samples and force any aphids feeding on the plant or root material to abandon its host and fall into a collection jar below. In each collection vial, a 1:1 Prestone® antifreeze and water solution preserved the aphids prior to counting and identification (Kindler et al. 2004a). Aphids were identified with the aid of an Olympus SZ-TR stereo microscope and species descriptions described by Pike et al. (1990). One key distinguishing feature between the common *Rhopalosiphum* species is that the rice root aphid has five antennal segments whereas the bird cherry-oat aphid has six. Additionally, the rice root aphid has dense setae on their antennae (Pike et al. 1990).

RESULTS AND DISCUSSION

In 2003, the known distribution of the rice root aphid in Oklahoma consisted of four counties. Based on the current survey, the rice root aphid is present throughout the wheat growing regions of the state. Twenty-eight of the remaining 73 counties were surveyed and rice root aphids were recovered from 19 additional counties (68% of those surveyed) (Figure 3.2) and eight of nine agricultural districts (Figure 3.3a) as defined by the Oklahoma Agricultural Statistics Service. The Oklahoma Grain and Livestock Producers combine four districts to create six regions (Figure 3.3b), all of which are now known to be infested by the rice root aphid. In most positive samples only a few rice root aphids were found despite the widespread distribution throughout the state (M.R. Rawlings, personal observation).

This survey indicates that the rice root aphid is present among a diverse set of environmental and agricultural habitats having been found in counties that receive less than 20 in. (Texas) and as much as 52 in. (Choctaw) of precipitation each year (Figure 3.4); it was found in counties where up to 380,000 acres of wheat were planted (Garfield) and where as little as 4,300 acres (Choctaw) of wheat was planted (Figure 3.5); it has been found in regions that are dominated by grain-only (Panhandle Region), forage-only (South Central-East Region), and dual-purpose (Central Region) practices. The apparent distribution pattern coincides with the presence of wheat in nearly every county and covers the entire state. The rice root aphid is clearly an adaptable species that can thrive in all climatic conditions that exist in Oklahoma. The ability of the rice root aphid to withstand rain, drought, and freezing conditions gives this aphid the potential to be a major pest species for the Oklahoma wheat economy. Future surveys of rice root aphid population distribution throughout the Southern Plains could be important if this species is found to be a pest.

Figure 3.1. Berlese funnel used to remove aphids from wheat seedlings

Figure 3.2. Rice root aphid (*Rhopalosiphum rufiabdominalis* (Sasaki)) distribution across Oklahoma

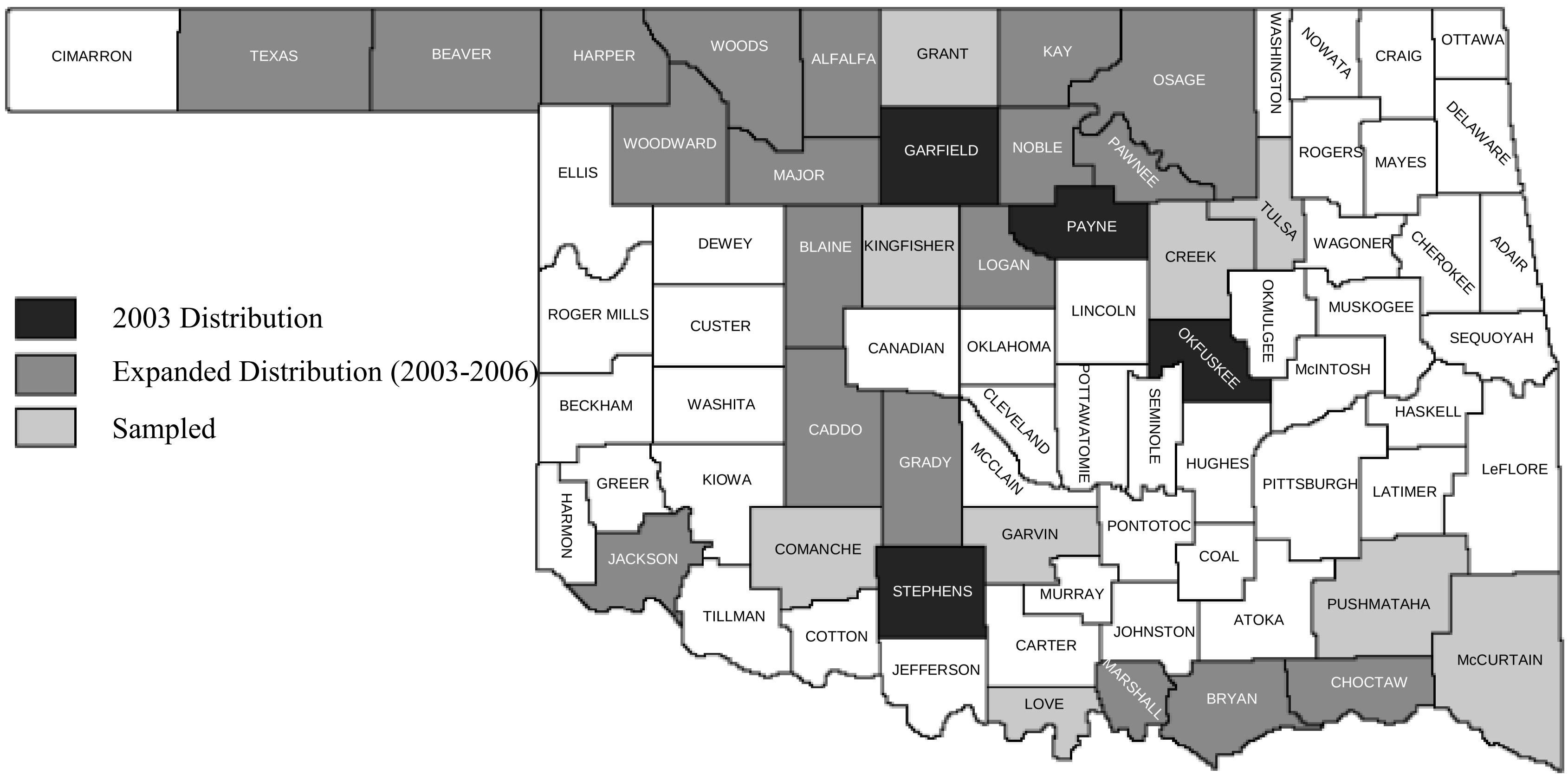


Figure 3.3a. Agricultural districts of Oklahoma as defined by the Oklahoma Agricultural Statistics Service

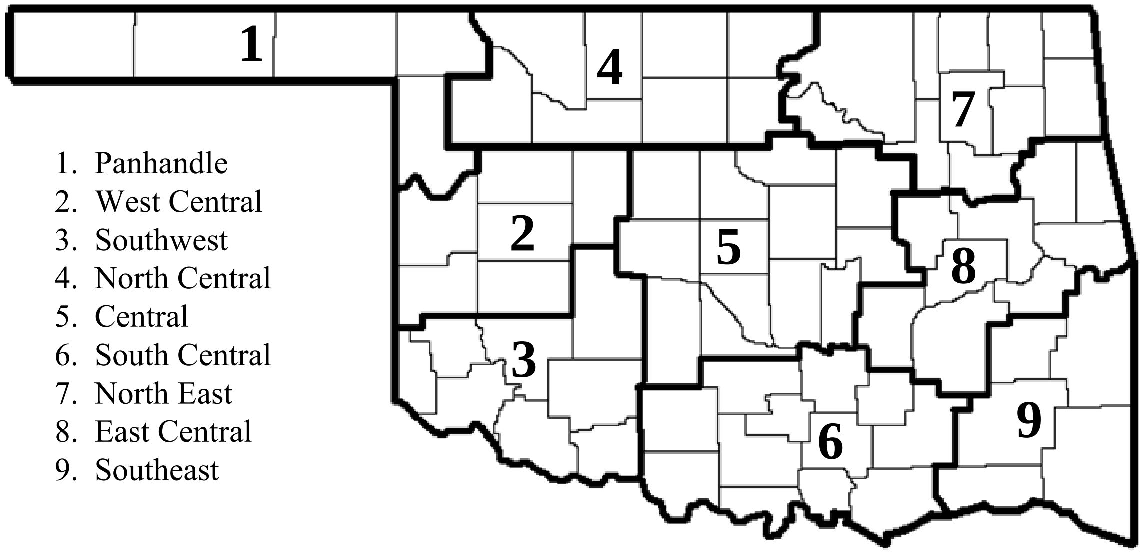


Figure 3.3b. Agricultural regions of Oklahoma as defined by Oklahoma Grain and Livestock Producers

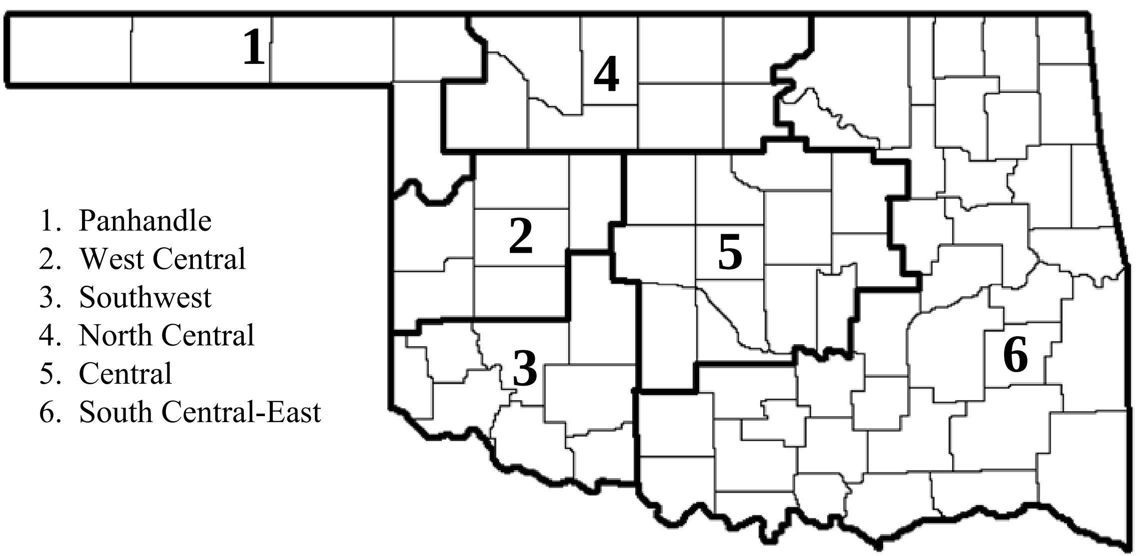


Figure 3.4. Average annual precipitation for Oklahoma

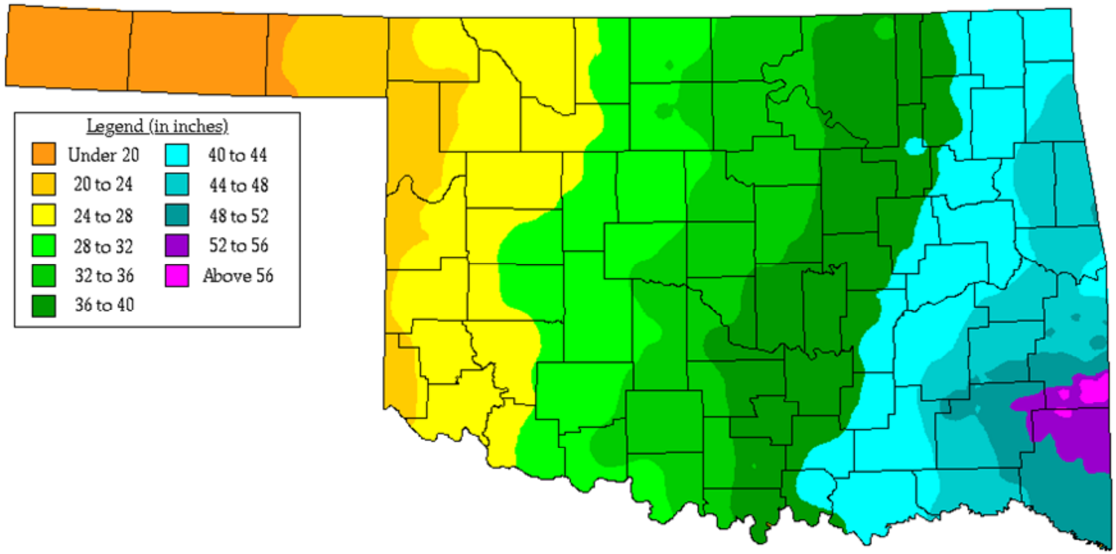
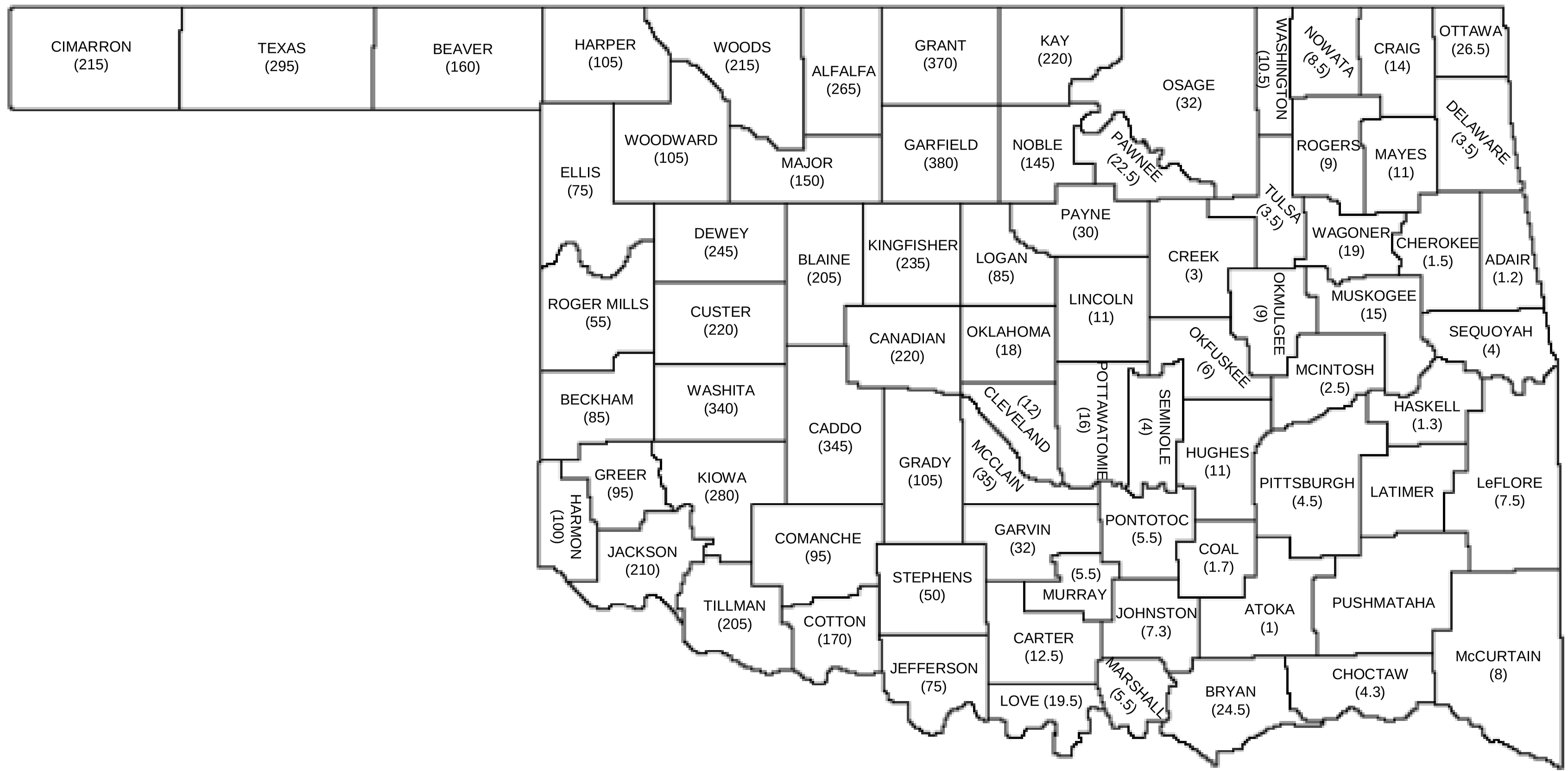


Figure 3.5. Acreage of wheat planted per Oklahoma County (× 1000)



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CHAPTER IV

EFFECTS OF THE RICE ROOT APHID, *RHOPALOSIPHUM RUFIABDOMINALIS* (SASAKI), ON SEEDLING WHEAT FORAGE

INTRODUCTION

In the United States, 27 species of aphid utilize cultivated cereals as hosts. Some species such as the greenbug (*Schizaphis graminum* Rondani) and the bird cherry-oat aphid (*Rhopalosiphum padi* L.) are widely distributed and regularly damage cereal crops while sporadic pests like the rice root aphid (*Rhopalosiphum rufiabdominalis* (Sasaki)) are found less frequently at high numbers on cereal crops. In recent years, greenbug and bird cherry-oat aphid management on wheat in the Southern Plains has received considerable attention. Research on novel sampling approaches for aphids, biological control, economic thresholds, and the interaction between grazing and aphid impacts has been incorporated into a comprehensive integrated management program (Giles et al. 2000b, 2000a, Jones 2001, Kindler et al. 2002, Ismail et al. 2003, Elliott et al. 2004). The rice root aphid, however, has not been considered due to its subterranean habitat (Kindler et al. 2002).

Winter wheat is grown in the Southern Plains of the United States with grain-only, forage-only, or dual-purpose production (forage and grain) goals in mind. The use of winter wheat as a dual-purpose crop is important to the agricultural economies of eastern New Mexico, southeastern Colorado, southwestern Kansas, the Texas Panhandle, and western Oklahoma. In these systems, production of forage is critical because the value of forage removed by cattle is often the difference between profit and loss (Epplin et al. 2000). To produce sufficient forage for beef production wheat must be planted relatively early. The 2004 average target planting date for dual-purpose and forage-only wheat production was September 20th and 13th respectively (Hossain et al. 2004). However, early planting for forage production often leads to increased aphid infestations, and potentially barley yellow dwarf virus infections (Araya et al. 1987, Hunger et al. 1997).

In a recently completed one-year preliminary study on the seasonal abundance of aphids on early fall planted winter wheat in central Oklahoma, the rice root aphid was found to be the most abundant species collected from September through October (S.D. Kindler unpublished data). It is possible that seedling damage on early planted wheat may be frequently caused by the rice root aphid. Therefore, the objective of this experiment was to describe the relationship between rice root aphid infestations and early wheat development. Because early stand establishment is critical to wheat forage systems, damage at the seedling and early growth stages of wheat was investigated. Additionally, damage caused by the rice root aphid was compared to damage caused by the closely related bird cherry-oat aphid.

MATERIALS AND METHODS

Aphid Colonies

A colony of the rice root aphid was maintained in the Controlled Environmental Research Laboratory (CERL) at Oklahoma State University (Stillwater, OK), whereas a colony of the bird cherry-oat aphid was maintained in the Entomology and Plant

Pathology Department at OSU. These separate colonies were necessary to produce the high numbers of aphids needed for this experiment and to prevent any possible cross contamination.

Rice Root Aphid Colony

Primary culture pots (15.24 cm) were filled with a mixture of Scott's Redi Earth® and Absorb-N-Dry (1:1 ratio by volume). 'Elbon' rye, *Secale cereale*, was used as the host plant and the sown seeds (≈30) were covered with cedar chips instead of a potting soil mixture. The cedar chips created a microenvironment conducive to aphid establishment, reproduction, and survival. At planting, the pots were covered with fine-mesh vented cellulose nitrate tubes (cages) to prevent infestation by thrips and to later contain the aphids and prevent escape. Aphids were transferred to new seedlings when alate forms began to collect at the tops of the cages of older primary culture pots (≈3 weeks after infestation). A transfer was accomplished by exchanging the cage of an infested pot with that of a non-infested pot; several transfers could be made each day, until the original culture was exhausted. Pots were planted every three weeks so that healthy plants would be ready for infestation. Each pot had a "life-span" of approximately twelve weeks; three weeks of plant growth, three weeks of population expansion, and about six more weeks until the plants died. The pots were placed in trays and watered by filling the trays and letting capillary action pull the water into the soil. Pots were watered to keep the soil moist but not saturated; usually three times a week. The entire colony was kept inside a walk-in environmental chamber (Conviron® CMP 3244) at 20°C and with a photoperiod of 14:10 (L:D) hours (Starks and Burton 1977, Tsai and Liu 1998, Kindler et al. 2004b).

Bird Cherry-Oat Aphid Colony

Primary culture pots (15.24 cm) were filled with Scott's Redi Earth®. A mixture of 'Karl-92' and 'O-Kay' oats was used as host plants in the primary culture pots (≈30 seeds). At planting, pots were covered with mesh-vented cellulose nitrate tubes to prevent infestation by thrips and to later contain aphids and prevent escape. Aphids were transferred to new cultures on a weekly basis. A transfer was accomplished by clipping an infested tiller or two and placing them amongst the tillers of a non-infested pot. Pots were planted every week so that healthy plants would be ready for infestation. Each pot had a "life-span" of four weeks; one week of plant growth, two weeks of population expansion, and one week until the plants died. Pots were placed on trays and watered as described for the rice root aphid colony. The entire colony was kept at room temperature (≈23°C) with a photoperiod of 13:11 (L:D) hours.

Experimental Design

Seedling Establishment

A replicated study was conducted in a walk-in environmental chamber (Conviron® CMP 3244) at the CERL (OSU). A range of cultivars important to wheat production systems in the Southern Plains (Jagger, OK101, OK102, TAM105, TAM107, and TAM110) were evaluated. Jagger is the most commonly grown winter wheat cultivar in Oklahoma (NASS 2005). The cultivars OK101 and OK102 are relatively new to Oklahoma; OK101 is a hard red winter wheat variety targeted for dry-land and irrigated production systems in the western third of Oklahoma and is well adapted to an early-planted dual-purpose management system (OFSS 2006). The production area for OK102 extends throughout Oklahoma with greatest potential in the central corridor

(OFSS 2006). OK102 grows best in irrigated areas of the High Plains and is suitable for both grain-only and dual-purpose management systems (OFSS 2006). The TAM cultivars (105, 107, and 110) are recommended for more arid wheat systems in the panhandles of Oklahoma and Texas (NASS 2005). TAM107 and 110 are resistant to Greenbug biotypes C (Qureshi and Michaud 2005) and E-I-K (Kindler et al. 2002, Trostle et al. 2002), respectively, however, little information is available on their interactions with the rice root aphid.

Single seeds of each wheat cultivar were planted in 4 × 20 cm cone- tainers$_{TM}$ (Stuewe & Sons Inc., Corvallis, Oregon) and covered with 30 cm tall mesh-vented cellulose nitrate tubes. The soil mixture was a 1:1 ratio of Scott's Redi Earth® and Absorb-N-Dry. The outside rim of each cone-tainer$_{TM}$ was wrapped with four layers of labeling tape to ensure a tight fit and to prevent aphids from entering or escaping after infestation. Cone-tainers$_{TM}$ were organized in a rack that stood in a 6 × 32 × 60 cm tray that would allow easy watering. Cone-tainers$_{TM}$ were watered as needed with RO (reverse osmosis) water to ensure that the tips remained submerged. To prevent cross infestation, each replication of cone-tainers$_{TM}$ were organized in separate racks for rice root aphid and bird cherry-oat aphid. For each aphid, a replication consisted of randomly arranged cone-tainers$_{TM}$, each with a single cultivar seedling infested with one of four aphid levels (see below). From six to seven replications for each aphid × aphid level × cultivar treatment were evaluated during this study. Cone-tainer$_{TM}$ racks were maintained at 18°C with 10 hours of light, and at 11°C with 14 hours of darkness to simulate fall conditions in Oklahoma.

Aphid Infestations

Twenty days after planting, aphids were taken from colonies of rice root aphid and bird cherry-oat aphid and used to infest the individual wheat seedlings. Individual cone-tainers$_{TM}$ of each cultivar were infested with aphids; 0, 15, 25, or 35 rice root aphids, and 15, 25, or 35 bird cherry-oat aphids. Only late instars and adults were used for infestation. Cone-tainers$_{TM}$ were checked daily and maintained as previously described for an additional 30 days. This length of time was chosen to simulate typical fall infestations of aphids on seedling wheat prior to grazing initiation in wheat forage systems.

Data Collection and Analysis

Fifty days after planting, the cone-tainers$_{TM}$ were removed from the environmental chamber and each plant was graded using the Zadok and Feeke's Scale to ensure that each plant was in the same stage of development. Each cone-tainer$_{TM}$ was then carefully split down the side with a pair of scissors so that the entire root mass would remain intact and could be removed. Each plant and root mass was then placed individually onto 15.24 cm diameter plastic trays that were set inside Berlese funnels. The Berlese funnels were constructed from the following: an 8 in. diameter PVC pipe (13 in. long), a wooden lid with a ceramic light fixture and a 40 watt bulb, a 6 quart plastic funnel, and a 2 ounce glass collection jar (Figure 4.1). Forty watt light bulbs were used to slowly dry the samples and allow any aphid feeding on the plant or root material to abandon its host and fall into a 1:1 Prestone® antifreeze and water solution (Kindler et al. 2004a). Plant samples remained inside the funnels up to seven days to ensure that all aphids were removed and the plant material was thoroughly dry. Individual plants were cut at the soil surface and dry forage weights were recorded.

Aphids collected from each Berlese sample were identified and counted using an Olympus® SZ-TR stereo microscope. Based on initial infestations and total aphids present after 30 days, aphid days were calculated. An aphid day is a measure that integrates aphid density and the duration of an infestation (Kindler et al. 2002). All analyses were performed using SAS version 9.1 for Windows® (SAS Institute 2006). A 0.05 significance level was chosen for all statistical analyses. Relationships between dry forage weights and aphid days (for rice root aphid and bird cherry-oat aphid) were investigated using PROC REG and PROC MIXED.

RESULTS AND DISCUSSION

Few studies have been conducted with the rice root aphid on winter wheat despite its widespread distribution and documented abundance during the early fall (M.R. Rawlings unpublished data, chap. 3). Kindler et al. (2004a) found that under greenhouse conditions, the rice root aphid significantly reduced plant height and yield components including; the number of tillers, the number of seeds per head, and the average seed weight. The results of our study attempt to expand upon the findings of Kindler et al. (2004a) to include the reduction in initial forage production as a potential limiting factor in grazing systems.

It was surprising that no significant linear relationships between aphid days and dry forage weights were detected for either aphid species on any of the wheat cultivars tested (Table 4.1). As noted earlier, Kindler et al (2004a) documented reduction in plant height and the number of tillers in rice root aphid infested wheat compared with non-infested controls. A recently completed field study on wheat infested with bird cherry-oat aphid indicated significant reduction in dry forage weights for plants infested with bird cherry-oat aphid (K.L. Giles unpublished data). In this bird cherry-oat aphid study, weak but significant negative linear relationships were detected between aphid days and dry forage yields. In my study, I achieved relatively low rice root aphid numbers, but I was able to establish peak bird cherry-oat aphid numbers up to 218 aphids per tiller. These numbers are comparable to other studies. Perhaps, additional replications would have provided the data required to describe linear relationships between forage and bird cherry-oat aphid levels.

An interesting trend was observed when dry weights were separated by cultivar and means were calculated for non-infested plants, plants infested with rice root aphid, and plants infested with bird cherry-oat aphid. In all but TAM105, bird cherry-oat aphid infested plants had a lower dry weight than non-infested plants and plants infested with rice root aphid (Figure 4.2). No consistent trends in dry weights were observed when comparing non-infested plants to those infested with rice root aphid. Based on these results, I further investigated how plant dry weights may be influenced by aphid infestation. I conducted two types of analyses. First, an analysis of variance (ANOVA) (Table 4.2) was conducted by categorizing all plants with aphids as infested with either rice root aphid or bird cherry-oat aphid; non-infested controls were included in the analysis as the third treatment. Dry weights were then compared among aphid species, infestation, and cultivar. For the second analysis (Table 4.3), initial infestation levels were included as a variable for the ANOVA. For each ANOVA, the effect of aphid infestation was significant. When grouping all infestation levels together within aphid species, dry weights were significantly reduced for bird cherry-oat aphid infested OK102 and TAM110 when compared to rice root aphid infested plants of the same cultivars (Figure 4.2; $P < 0.02$). Inclusion of initial aphid infestation into the analysis indicated that the negative effect of bird cherry-oat aphid was most pronounced at the highest initial infestation level (35 per plant) (Table 4.4). Kieckhefer and Kantack (1988) showed that the bird cherry-oat aphid caused reductions of at least 40% in grain weight with 210 aphid days per tiller. Trent (2003) showed that bird cherry-oat aphid significantly reduced root and shoot length, root weight, number of tillers, fertile head counts, number of seeds, and seed weight with only 10 aphid days per tiller. These trends and observations indicate that my assay was sensitive enough to detect the negative impact of bird cherry-oat aphid as observed by other researchers (K.L. Giles unpublished data, Kieckhefer and Kantack 1980, Pike and Schaffner 1985, Kieckhefer and Kantack 1988, Trent 2003), and likely sensitive enough to demonstrate that rice root aphid has little or no impact on early wheat forage.

The results from this study suggest the rice root aphid has no impact on wheat seedling development and forage weights. The levels of rice root aphid established for this study may have been low compared to those established by Kindler et al (2004a), however, the soil and growing conditions used in this study are more comparable to natural field conditions. Kindler et al (2004a) used wood chip media which may have artificially enhanced survival, reproduction, and subsequent impact on wheat. A field study with higher levels of rice root aphid infestation that examines the impact on forage and yield components may more clearly define the potential pest status of this aphid in the Southern Plains.

Table 4.1. Analysis of regression (PROC REG) for rice root aphid, *Rhopalosiphum rufiabdominalis* (Sasaki), and bird cherry-oat aphid, *R. padi* L., infested wheat cultivars.

Species	Maximum Aphid Days	Cultivar	R^2	df	P
R. rufiabdominalis	585	Jagger	0.0007	26	0.8991
	660	OK101	0.0041	27	0.7458
	630	OK102	0.0400	27	0.3077
	780	TAM105	0.0495	26	0.2646
	570	TAM107	0.0130	26	0.5712
	825	TAM110	0.0000	27	0.9869
R. padi	2070	Jagger	0.0000	26	0.9946
	2205	OK101	0.0496	26	0.2642
	2265	OK102	0.0053	24	0.7299
	2190	TAM105	0.0364	26	0.3407
	1350	TAM107	0.0256	26	0.4256
	2040	TAM110	0.0036	27	0.7613

Table 4.2. Analysis of variance (ANOVA) results (PROC MIXED) for wheat seedling dry plant weights when infested with rice root aphid (*Rhopalosiphum rufiabdominalis* (Sasaki)) or bird cherry-oat aphid (*R. padi* L.) or no aphid

	Tests of fixed effects				
	Source of Variation	Num df	Den df	F	P
Plant Weight	Cultivar	5	262	12.49	<.0001
	Aphid	2	262	4.76	0.0094
	Cultivar × Aphid	10	262	0.83	0.6014

Cultivars were Jagger, OK101, OK102, TAM105, TAM107, and TAM110.

Table 4.3. Analysis of variance (ANOVA) results (PROC MIXED) for wheat seedling dry plant weights with varying levels of infestation of rice root aphid (*Rhopalosiphum rufiabdominalis* (Sasaki)) and bird cherry-oat aphid (*R. padi* L.)

	Tests of fixed effects				
	Source of Variation	Num df	Den df	F	P
Plant Weight	Cultivar	5	270	15.96	<.0001
	Aphid	1	270	5.33	0.0217
	Cultivar × Aphid	5	270	0.86	0.5111
	Infestation	3	270	0.77	0.5127
	Cultivar × Infestation	15	270	0.56	0.9065
	Aphid × Infestation	3	270	1.27	0.2853
	Cultivar × Aphid × Infestation	15	270	0.83	0.6472

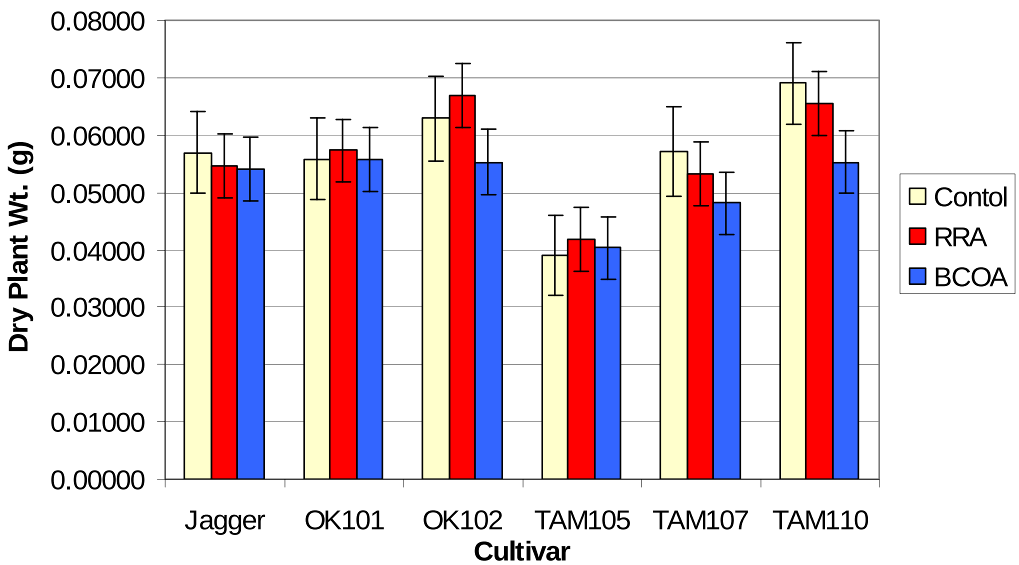
Cultivars were Jagger, OK101, OK102, TAM105, TAM107, and TAM110.
Infestations were 0, 15, 25, and 35 aphids on a single plant.

Table 4.4. Mean and standard error for wheat seedling dry plant weights with varying levels of infestation of rice root aphid (*Rhopalosiphum rufiabdominalis* (Sasaki)) and bird cherry-oat aphid (*R. padi* L.)

Cultivar	Aphid	Infestation	Mean (mg)	Standard Error	Cultivar	Aphid	Infestation	Mean (mg)	Standard Error
Jagger	BCOA	0	57.00	0.007406	TAM105	BCOA	0	39.00	0.007406
Jagger	BCOA	15	58.43	0.007406	TAM105	BCOA	15	43.71	0.007406
Jagger	BCOA	25	55.85	0.007751	TAM105	BCOA	25	38.00	0.007406
Jagger	BCOA	35	47.86	0.007406	TAM105	BCOA	35	39.14	0.007406
Jagger	RRA	0	57.00	0.007406	TAM105	RRA	0	39.00	0.007406
Jagger	RRA	15	51.77	0.007751	TAM105	RRA	15	38.71	0.007406
Jagger	RRA	25	53.00	0.007406	TAM105	RRA	25	42.91	0.007751
Jagger	RRA	35	58.57	0.007406	TAM105	RRA	35	44.57	0.007406
OK101	BCOA	0	55.86	0.007406	TAM107	BCOA	0	56.93	0.008210
OK101	BCOA	15	59.61	0.007751	TAM107	BCOA	15	44.14	0.007406
OK101	BCOA	25	51.14	0.007406	TAM107	BCOA	25	51.00	0.007406
OK101	BCOA	35	58.57	0.007406	TAM107	BCOA	35	49.14	0.007406
OK101	RRA	0	55.86	0.007406	TAM107	RRA	0	56.93	0.008210
OK101	RRA	15	64.71	0.007406	TAM107	RRA	15	58.43	0.007406
OK101	RRA	25	55.29	0.007406	TAM107	RRA	25	48.71	0.007406
OK101	RRA	35	51.86	0.007406	TAM107	RRA	35	52.71	0.007406
OK102	BCOA	0	62.83	0.007751	TAM110	BCOA	0	69.00	0.007406
OK102	BCOA	15	57.51	0.007751	TAM110	BCOA	15	57.29	0.007406
OK102	BCOA	25	57.29	0.007406	TAM110	BCOA	25	57.86	0.007406
OK102	BCOA	35	50.51	0.007751	TAM110	BCOA	35	50.71	0.007406
OK102	RRA	0	62.83	0.007751	TAM110	RRA	0	69.00	0.007406
OK102	RRA	15	57.57	0.007406	TAM110	RRA	15	65.71	0.007406
OK102	RRA	25	71.86	0.007406	TAM110	RRA	25	61.00	0.007406
OK102	RRA	35	71.14	0.007406	TAM110	RRA	35	69.86	0.007406

Figure 4.1. Berlese funnel used to remove aphids from wheat seedlings

Figure 4.2. Comparison of dry plant weight means with standard error bars for wheat seedlings infested with rice root aphid (*Rhopalosiphum rufiabdominalis* (Sasaki)), bird cherry-oat aphid (*R. padi* L.), or no aphids (Control)



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CHAPTER V

EFFECT OF THE RICE ROOT APHID, *RHOPALOSIPHUM RUFIABDOMINALIS* (SASAKI), ON WINTER WHEAT GRAIN PRODUCTION IN FIELD PLOTS

INTRODUCTION

Oklahoma normally ranks second in winter wheat (*Triticum aestivum* L.) production in the United States with over 2.2 million ha (5.5 million acres) planted annually across the state (Kindler et al. 2002, NASS 2005). In the Southern Plains of the United States, winter wheat is grown with grain-only, forage-only, or dual-purpose production (forage and grain) goals in mind. Epplin (2000) estimated that approximately 2/3 of Oklahoma's wheat is planted as for grain production (grain only and dual-purpose).

Greenbugs (*Schizaphis graminum* Rondani) and bird cherry-oat aphids (*Rhopalosiphum padi* L.) are two of the most important insect pests of winter wheat in the Southern Plains. These aphids often reduce yields of small grains, particularly when infestations occur during early plant growth stages (Burton et al. 1985, Kieckhefer and Kantack 1988, Kieckhefer et al. 1995, Riedell et al. 1999, Kindler et al. 2002, Ismail et al. 2003). During heavy aphid infestations, the economic costs (yield losses and insecticide costs) associated with aphids infesting winter wheat in the Southern Plains easily exceeds $100 million (Starks and Burton 1977, Webster 1995, Kindler et al. 2002). In recent years, greenbug and bird cherry-oat aphid management in wheat in the Southern Plains has received considerable attention. For example, (1) quantitative studies havebeen conducted on alternative sampling techniques for these aphids and their natural enemies, (2) economic thresholds in grain only systems have been developed, (3) incorporating natural enemy thresholds into aphid management decisions has been done, and (4) the impact of grazing wheat on aphid populations has been documented (Giles et al. 2000b, 2000a, Jones 2001, Kindler et al. 2002, Ismail et al. 2003). The rice root aphid, *Rhopalosiphum rufiabdominalis* (Sasaki), is primarily a subterranean species that has not been considered as a wheat pest because of the sampling difficulties due to it's habitat and also its often misidentification as the bird cherry-oat aphid (Kindler et al. 2002).

In a recently completed one-year preliminary study on the seasonal abundance of the rice root aphid on fall planted winter wheat in central Oklahoma, the rice root aphid was found to be the most abundant aphid species collected during the fall months (Kindler et al. 2004a). It is possible that crop damage that is often attributed to the bird cherry-oat aphid may sometimes be caused by the rice root aphid. Based on results from a recent greenhouse study by Kindler et al (2004a), the rice root aphid has potential to significantly reduce wheat yields in grain production systems. Therefore, the objective of this experiment was to examine the effect of the rice root aphid on winter wheat grain yield in field plots.

MATERIALS AND METHODS

Field Design

This study was repeated for two years (2003/2004 and 2004/2005 growing seasons) in a field located near Perkins, OK. Each year, OK101 winter wheat was planted during the recommended planting interval (October 1-15) for grain-only in central Oklahoma (Cuperus et al. 1985). Fertilizer requirements were based on soil tests for available nitrogen made each year before planting with a yield potential of 5,400 kg/ha (Kindler et al. 2002). Wheat was planted at a rate of 67 kg/ha in rows spaced 17.8 cm apart. Fifty experimental units (60 × 90 cm plots) were established in ten rows (five plots per row) within the wheat field. Each plot was then subdivided into three equal subsections (60 × 30 cm) and covered with a mesh tent. The mesh tents were used to assist in the establishment of the aphids in the field.

Rice root aphids from a greenhouse colony were used to infest the plots. These aphids were reared in a greenhouse located at the USDA-ARS in Stillwater, OK on seedling 'Elbon' rye (*Secale cereale*) plants (≈30 seedlings per pot) grown in a mixture of Scott's Redi-Earth® and Absorb-n-Dry (1:1 ratio) in plastic pots (15.24 cm diameter). Similar to the approach of Kindler et al (2002), five initial infestation treatments were randomly established within each replicate (10 replications per infestation treatment): (1) no aphids (non-infested); (2) aphids from approximately one-fourth of the foliage and root mass from a pot of heavily infested rye seedlings; (3) aphids from approximately one-half of a pot of heavily infested rye seedlings; (4) aphids from one pot of heavily infested rye seedlings; and (5) aphids from two pots of heavily infested rye seedlings. Aphids were released only into a randomly determined outer subsection (60 × 30 cm) of each plot. Based on previous observations, this infestation approach allows for the movement of rice root aphids to the center subsection for subsequent destructive sampling within the plot (see below). The outer subsection that was not infested with aphids was periodically treated with Marathon® 1%G (0.55 kg/ha (AI)) to ensure that aphids did not establish in this "control" subsection.

Aphid Sampling

Samples were taken from the center subsection (60 × 30 cm) of each plot using a 15.24 cm sharp shooter garden shovel. Only the center subsection of each plot was sampled because sampling for rice root aphids requires plot destruction; the adjacent subsections (infested and non-infested) were not sampled and were left undisturbed for yield evaluations. The aphid samples (15.24 cm of row) contained the root systems as well as the leafy portion of the plants. During the 2003/2004 growing season samples were taken from plots 21 and 77 days after infestation, whereas during the 2004/2005 growing season samples were taken after 18, 35, an 76 days. Each sample was collected in small (15 × 28.5 × 10 cm) paper bags for transport. Individual samples were then placed onto a 15.24 cm plastic tray placed within a Berlese funnel. The Berlese funnels were constructed from the following: an 8 in. diameter PVC pipe (13 in. long), a wooden lid with a ceramic light fixture and a 40 watt bulb, a 6 quart plastic funnel, and a 2 ounce glass collection jar (Figure 5.1). 40 watt light bulbs were used in the funnels to slowly dry samples and allow any aphids feeding on the plant or root material to abandon its host and fall into a 1:1 Prestone® antifreeze and water solution (Kindler et al. 2004a). The plants remained inside the funnels for four to seven days to ensure that all aphids were removed and the plant material was thoroughly dry.

When all sampling was completed and the cages had been removed, the field was regularly inspected for residual aphid populations. If any aphids were present in the field, plots were treated with malathion insecticide (1.1 kg/ha (AI)) (Kindler et al. 2002).

Aphid Days

Aphid days is a way of indicating infestation levels over a period of time and is a measure that integrates aphid density and the duration of an infestation (Kindler et al. 2002). One aphid feeding for 24 hours equals one aphid day. We calculated aphid days per subsection of plot (0.18 m^2) by combining the numbers of rice root aphid and the few bird cherry-oat aphids that naturally infested the plots in the fall. This combined *Rhopalosiphum* infestation was undesirable for experimental purposes, but ecologically realistic because both species are found together infesting wheat in the early spring (Kindler et al. 2004a).

Harvesting

On days 208 and 230 after infestation for years one and two respectively, the mature wheat was harvested from the undisturbed infested and non-infested subsection of each plot by using a pair of florist scissors. All of the plants were cut at the same height by placing a 35 cm tall shovel next to each row and cutting along the top edge of the shovel. The tillers from each subsection were placed into paper bags and taken to the lab for threshing. Each tiller was counted with the longest and shortest being measured and then carefully threshed by hand so every seed could be counted. All seeds from each subsection were dried in an oven to reduce grain moisture. Three 100 seed counts per subsection were used to estimate average seed weights and the total number of seeds. The test weight for each subsection was estimated by using a test weight funnel and Seedburo Model 8800 Computer Grain Scale. Grain yields taken in year two were too small for test weights to be estimated.

Statistical Analysis

All analyses were performed using SAS version 9.1 for Windows® (SAS Institute 2006). A 0.05 significance level was chosen for all statistical analyses. Regression analysis (PROC REG) was performed to describe linear relationships between aphid days per subsection and the following yield components for each year of the study: tiller numbers, test weights, average seed weights, and seed numbers. A T-test (PROC MIXED) was also performed to describe differences in yield components (mean number of tillers, mean sample weights, mean seed weights, mean number of seeds per subsection, and mean test weights) between subsections that were infested with aphids and subsections that were treated with insecticide.

RESULTS AND DISCUSSION

Despite the widespread distribution in Oklahoma, few studies have been conducted with the rice root aphid on wheat. Kindler et al. (2004a) found that under greenhouse conditions, the rice root aphid significantly reduced the mean number of tillers and the number of fertile heads, while the number of infertile tillers was significantly increased. Mean plant height, number of infertile heads, number of seeds and seed weight were reduced but not significantly different from the control means. Another wheat pest, the greenbug, was shown by Burton et al. (1985) to significantly reduce all yield components; grain yields, tiller counts, number of seeds per plant, and fertile tillers. Kieckhefer and Kantack (1988), over the course of a two year study, showed that both the greenbug and the bird cherry-oat aphid caused reductions of at least 40% in grain weight in winter wheat with population densities of 30 aphids per tiller for seven days.

Regression analyses of the field data revealed no significant relationships between aphid infestations and yield measures (Table 5.1 and Figures 5.2-5.8). The differences in results between these analyses and the study conducted by Kindler et al. (2004a) could be attributed to the differences between greenhouse and field conditions. During my study, conditions in the field were ideal for growing and moisture was not a limiting factor. Greenhouse studies on plant growth are often constrained by artificial components such as soil characteristics, pot size, and watering schedules. Pot size and soil structure can artificially influence root growth and subsequent colonization by the rice root aphid to levels not observed in field situations.

Compared to other field studies that established quite high aphid levels (Kieckhefer and Kantack 1988, Kieckhefer et al. 1995), I was only able to establish relatively low infestations of rice root aphid. The highest infestation level observed in my study peaked at 16,604 aphid days per subsection (15.24 cm of row) during the 2003/2004 season, and 63,348 aphid days per subsection during the 2004/2005 season (Figures 5.2 and 5.6), this comes down to 111 and 960 aphid days per tiller respectively. Even with such low infestations, I did observe significant differences for the 2003/2004 growing season in mean number of tillers, mean sample weights, and mean seed weights between aphid infested subsections and subsections treated with insecticide (Table 5.2). The mean number of tillers was actually significantly higher in rice root aphid infested subsections, which is contradictory to the finding of Kindler et al (2004a), and other aphid studies on wheat (Burton et al. 1985, Kieckhefer and Kantack 1988). Despite this increase in tiller numbers, the rice root aphid infested subsections still produced fewer seeds and lower test weights, though not significantly. The 2004/2005 growing season T-test data may have been skewed by extremely high weed pressure that reduced all yield components. No significant differences in yield measures were observed between infested and non-infested subsections during the second growing season (Table 5.2).

It is possible that the rice root aphid cannot exist at sufficiently high densities in the field to affect wheat growth and yield when adequate rain and moisture is available. However, the 2005/2006 growing season was much drier than the previous two growing seasons and rice root aphid numbers appeared to be much higher (M.R. Rawlings, personal observations). Kindler et al (2002) showed that drought conditions exaggerate the effects of greenbugs on wheat grain yield production and it is likely these same environmental conditions enhance the ability of the rice root aphid to do the same. Based on data from this study, rice root aphid, although common and occasionally prevalent on winter wheat in the Southern Plains, does not appear to be as serious a pest as greenbug and the bird cherry-oat aphid.

Table 5.1. Analysis of regression (PROC REG) for wheat yield measures per plot over a two year period.

	Yield Measure	df	R^2	P
Year 1 (2003-2004)	Tillers	49	0.007	0.5527
	Seed Weight	49	0.002	0.7386
	Number of Seeds	49	0.007	0.5588
	Test Weight	37	0.023	0.3674
Year 2 (2004-2005)	Tillers	47	0.002	0.7899
	Seed Weight	47	0.061	0.0898
	Number of Seeds	47	0.007	0.5659
2 Year (2003-2005)	Tillers	97	0.020	0.1707
	Seed Weight	97	0.000	0.9394
	Number of Seeds	97	0.022	0.1443
	Test Weight	37	0.023	0.3674

Table 5.2. T-test (PROC MIXED) of mean wheat yield measures for two growing seasons

		Treatment Means				
	Yield Measure	Aphids	Insecticide	df	t Value	Pr > |t|
2003/2004	Tillers	139.78	130.08	98	2.26	0.0260
	Sample Weight	63.6431	68.9808	98	-2.20	0.0300
	Seed Weight	0.03013	0.03125	98	-2.62	0.0101
	Number of Seeds	2121.47	2212.71	98	-1.11	0.2700
	Test Weight	61.5027	61.5797	80	-0.40	0.6870
2004/2005	Tillers	60.4375	57.913	92	0.67	0.5057
	Sample Weight	27.9385	26.6639	92	0.61	0.5424
	Seed Weight	0.02599	0.02587	92	0.32	0.7502
	Number of Seeds	1067.19	1028.06	92	0.52	0.6040

Figure 5.1. Berlese funnel used to remove aphids from wheat seedlings

Figure 5.2. 2003/2004 effect of aphid days by rice root aphid, *Rhopalosiphum rufiabdominalis* (Sasaki), on number of tillers per 1800 cm^2

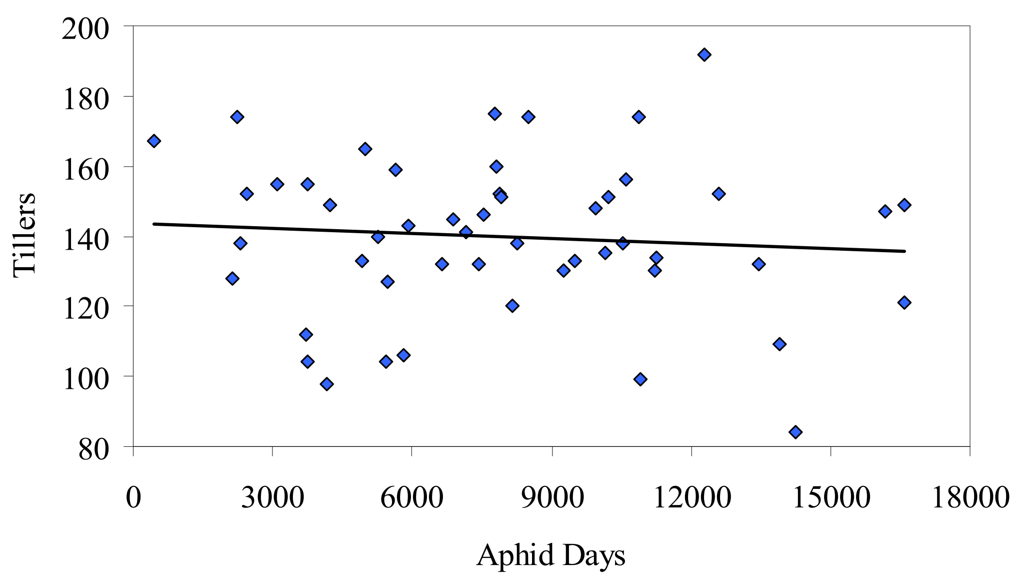


Figure 5.3. 2003/2004 effect of aphid days by rice root aphid, *Rhopalosiphum rufiabdominalis* (Sasaki), on average single seed weight per 1800 cm^2

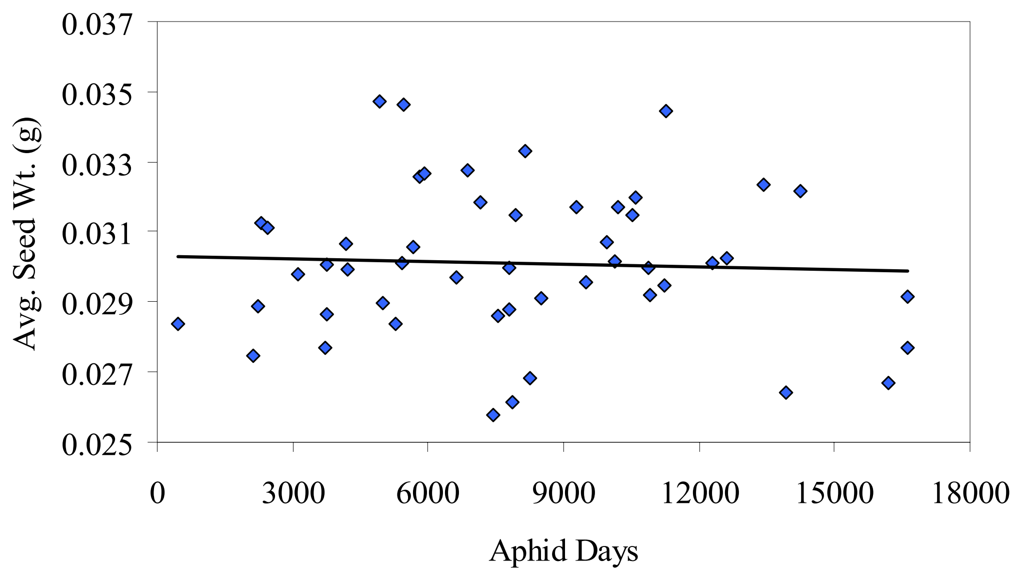


Figure 5.4. 2003/2004 effect of aphid days by rice root aphid, *Rhopalosiphum rufiabdominalis* (Sasaki), on estimated total number of seeds per 1800 cm^2

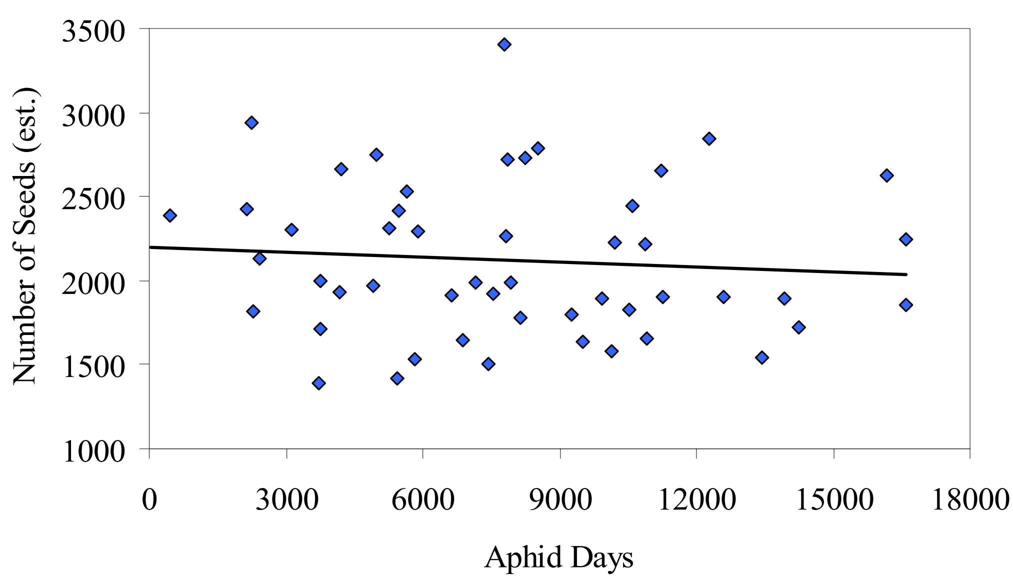


Figure 5.5. 2003/2004 effect of aphid days by rice root aphid, *Rhopalosiphum rufiabdominalis* (Sasaki), on test weight per 1800 cm^2

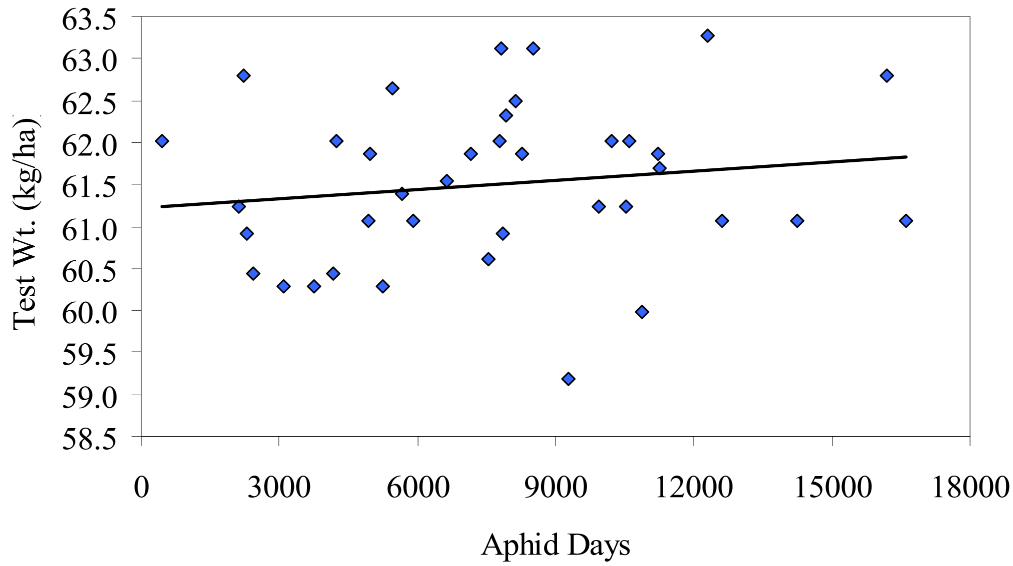


Figure 5.6. 2004/2005 effect of aphid days by rice root aphid, *Rhopalosiphum rufiabdominalis* (Sasaki), on number of tillers per 1800 cm^2

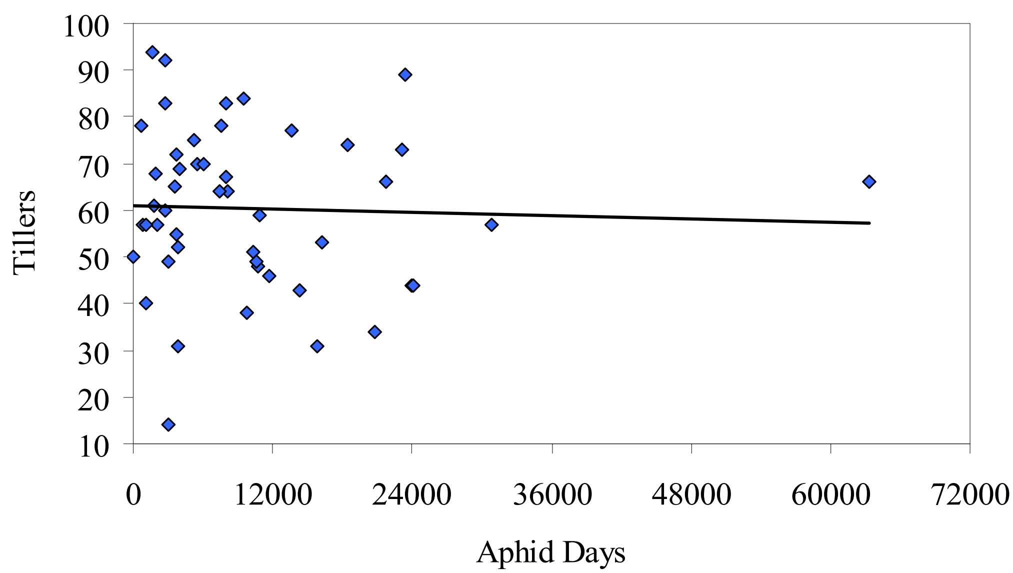


Figure 5.7. 2004/2005 effect of aphid days by rice root aphid, *Rhopalosiphum rufiabdominalis* (Sasaki), on average single seed weight per 1800 cm^2

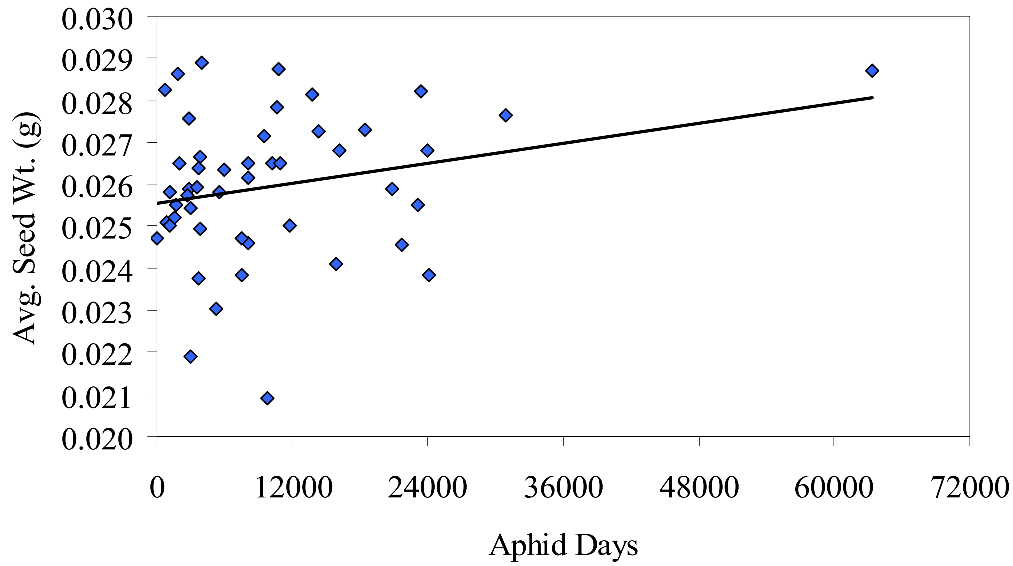
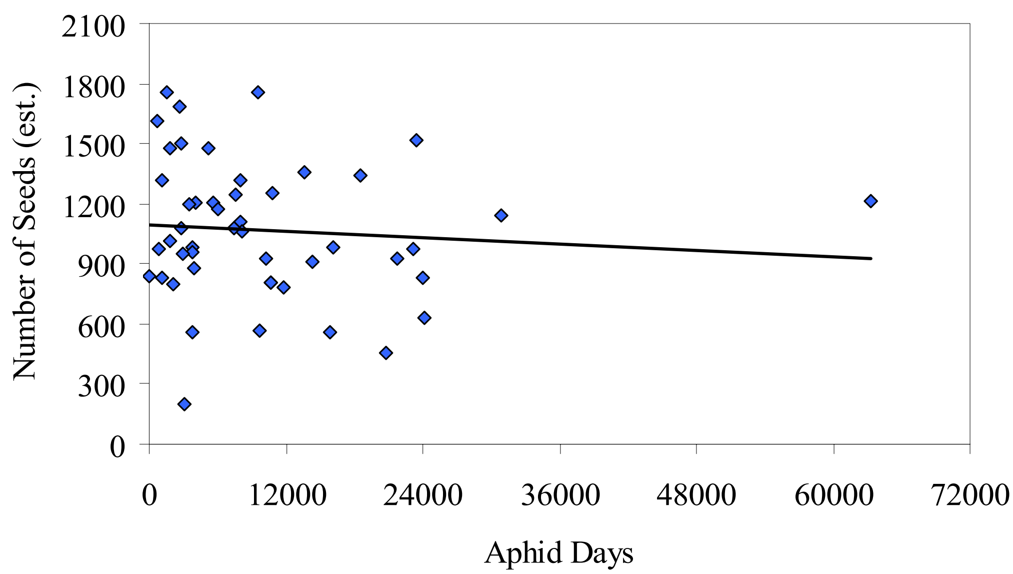


Figure 5.8. 2004/2005 effect of aphid days by rice root aphid, *Rhopalosiphum rufiabdominalis* (Sasaki), on estimated total number of seeds per 1800 cm^2



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CHAPTER VI

SUMMARY AND CONCLUSION

The rice root aphid, *Rhopalosiphum rufiabdominalis* (Sasaki), has recently been identified on wheat in Oklahoma. This aphid is easily misidentified as the bird cherry-oat aphid (*Rhopalosiphum padi* L.) and initial observations by Kindler et al (2004a) suggested that it might be a serious pest in the Southern Plains. In an attempt to more accurately define the potential pest status of the rice root aphid in Oklahoma a more comprehensive set of studies was conducted.

The rice root aphid is clearly an adaptable species that can thrive in all climatic conditions that exist in Oklahoma. Because of its subterranean biology, its ability to withstand rain, drought, and freezing conditions, this aphid has the potential to be a major pest of wheat. During my study on defining the distribution of rice root aphid, it was found feeding in Oklahoma counties that receive from as little as 20 to as much as 52 inches of precipitation each year; it was found feeding in counties that plant as much as 380,000 and as little as 4,300 acres of winter wheat per year; it was found in regions that are dominated by grain-only, forage-only, and dual-purpose practices. Eight of nine agricultural districts as defined by the Oklahoma Agricultural Statistics Service and all six agricultural regions as defined by the Oklahoma Grain and Livestock Producers are now known to be infested by the rice root aphid.

The use of winter wheat as a dual-purpose crop is important to the agricultural economy of western Oklahoma. The production of forage is critical because the value of forage removed by cattle is often the difference between profit and loss (Epplin et al. 2000). To produce sufficient forage for beef production, wheat must be planted relatively early. However, early planting often leads to increased aphid infestations, and potentially barley yellow dwarf virus infections (Araya et al. 1987, Hunger et al. 1997). It is possible that seedling damage caused by the rice root aphid on early planted wheat has been attributed to other aphid species due to its subterranean habits. Because of the potential for rice root aphid to reduce wheat forage, I conducted an experiment to describe the relationship between rice root aphid infestation and early forage development of six commonly grown wheat cultivars in Oklahoma. Additionally, I compared damage caused by rice root aphid to damage caused by the closely related bird cherry-oat aphid.

The results from these studies suggest that the rice root aphid has no impact on wheat seedling development and forage weights. Kieckhefer and Kantack (1988) concluded that bird cherry-oat aphid can significantly reduce grain yield in winter wheat if they feed for only a week at densities of 15-20 aphids per tiller during the seedling stage. In this study I could only get relatively low rice root aphid numbers but I was able to get bird cherry-oat aphid numbers that ranged from 2-218 aphids per tiller. These numbers are comparable to other studies. The levels of rice root aphid established for this study may have been low compared to those established by Kindler et al. (2004a), however, the soil and growing conditions used in this study were more comparable to natural field conditions. Kindler et al. (2004a) used wood chip media, which may have artificially enhanced survival, reproduction, and subsequent impact on wheat.

Based on results from a greenhouse study by Kindler et al. (2004a), the rice root aphid has the potential to significantly reduce wheat yields in grain production systems. Therefore, I conducted a two year experiment to examine the effect of the rice root aphid on winter wheat grain yield in field plots.

Regression analyses of my field data revealed no significant relationships between aphid infestations and yield measures. A T-test, which compared infested vs. non-infested subsections, revealed significant decreases for the 2003/2004 growing season in only mean sample weights and mean seed weights. The 2004/2005 T-test data was skewed by extremely high weed pressure that reduced all yield components, however no significant differences were observed between infested and non-infested subsections. The differences in results between my study and the study conducted by Kindler et al. (2004a) could be attributed to the differences between greenhouse and field conditions. During my study, conditions in the field were ideal for growing and moisture was not a limiting factor. Greenhouse studies on plant growth are often constrained by artificial components such as soil characteristics, pot size, and watering schedules. Pot size and soil structure can also artificially influence root growth and subsequent colonization by the rice root aphid to levels not observed in field situations. It is possible that the rice root aphid can not exist at high enough densities in the field, when adequate rain and moisture is available, to affect wheat growth and yield. However, the 2005/2006 growing season was much drier than the previous two growing seasons and rice root aphid numbers appeared to be much higher (M. Rawlings, personal observations). Kindler et al. (2002) showed that drought conditions exaggerate the effects of greenbugs on wheat grain yield production and it is likely these same environmental conditions enhance the ability of the rice root aphid to do the same. Rice root aphid, although prevalent, does not appear to be as serious a pest as greenbug and bird cherry-oat aphid in the Southern Plains.

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VITA

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Master of Science

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Scope and Method of Study: The rice root aphid, *Rhopalosiphum rufiabdominalis* (Sasaki), (Homoptera: Aphididae), has recently been identified on winter wheat (*Triticum aestivum* L.) in Oklahoma. Oklahoma regularly plants more than 5.5 million acres of wheat annually with up to 80% being used for cattle grazing. Therefore, any pest that affects early wheat growth could affect forage yields and can potentially reduce weight gains of the cattle industry. Previous studies have shown that the rice root aphid is most prevalent during the early growth stages of winter wheat. This aphid is easily misidentified as the bird cherry-oat aphid (*R. padi* L.) and subsequent observations suggest it may be a more serious pest than previously believed. A survey of Oklahoma counties was done in order to expand the known distribution of the rice root aphid. Field and laboratory experiments were conducted to determine the effects this potential pest species may have on wheat cultivars commonly grown in Oklahoma.

Findings and Conclusions: The rice root aphid has been found on winter wheat across Oklahoma in all agricultural regions with precipitation ranging from less than 20 in. to as much as 52 in. per year. Under ideal conditions in a laboratory setting, the rice root aphid had no impact on wheat seedling development and forage weights of six cultivars commonly grown in Oklahoma. In a field setting, over a two year period without moisture as a limiting factor, a T-test revealed significant decreases in mean sample weights and mean seed weights. However, during the fall of 2005, Oklahoma experienced drought conditions and the rice root aphid was observed at much higher infestation levels than ever before. It is possible that under drought-like conditions the rice root aphid will significantly affect the forage and grain yields of winter wheat in the state of Oklahoma.

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