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First quantitative study of rove beetles in Oklahoma winter wheat fields

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Abstract. Adult rove beetles (Staphylinidae) were sampled every 7–14 days from one winter wheat field located in each of the four major wheat growing regions of Oklahoma during the 1999–2000 and 2000–2001 growing seasons. The number of cereal aphids per tiller, wheat plant growth stage, and wheat tiller density also were estimated. A total of 12 genera representing 13 species of beetles were collected from the field. The density of rove beetles was generally low, ranging from 0.003 beetles per m^2 in fall to 0.106 beetles per m^2 in spring. Rove beetle communities differed among seasons. After accounting for the effect of season, there was no statistically significant association between rove beetle community structure and field location, aphid density, wheat plant growth stage, or wheat plant density. Most rove beetle species showed no association with a particular season, however, *Aleochara notula* Erichson, *Lathrobium* sp., and *Oxypoda* sp. were present predominantly in fall, while *Bisnius inquitus* Erichson was associated with winter. *Oxypoda* sp. was the most abundant rove beetle in winter wheat fields in spring and was relatively abundant in winter, but was not collected from wheat fields in fall. *Tachyporus jocosus* Say was present in wheat fields during all seasons. *T. jocosus* was the most abundant rove beetle species in the winter wheat fields in fall and winter and was the second most abundant species during spring.

Key words: biological control, cereal aphids, predatory insect, Staphylinidae, *Triticum aestivum*, wheat

Introduction

Cereal aphids, including the greenbug, *Schizaphis graminum* (Rondani), and bird cherry-oat aphid, *Rhopalosiphum padi* L., infest winter wheat fields in Oklahoma and can cause significant injury to plants and losses in grain and forage yields (Kindler et al., 2002, 2003, 2004). Insecticides are relied upon almost exclusively for cereal aphid control in Oklahoma. While insecticides are currently essential for effective control of cereal aphids, their use has well known and documented drawbacks (e.g., Wratten et al., 1995), and alternatives to their widespread use are desirable. In addition to cereal aphids, winter wheat fields are also inhabited by numerous other arthropod species, some of which are natural enemies of cereal aphids and other pest insects (French and Elliott, 1999a, b; Giles et al., 2003). Recent research in winter wheat in Oklahoma has focused on the role of aphid specific natural enemies, such as Coccinellidae and the parasitoid *Lysephlebus testaceipes* (Cresson), in controlling cereal aphid populations (Jones, 2001; Giles et al., 2003; Jones et al., 2003). However, generalist predators, such as predaceous Carabidae and Staphylinidae (rove beetles), also occur in winter wheat fields.

Some rove beetles feed on cereal aphids encountered on wheat plants (Dennis and Sotherton, 1994) and on the soil surface as the result of intentional dispersal among plants or unintentional dislodgment from plants caused by wind, rain, activity of predators and parasitoids, and other factors (Winder, 1990; Gowling and van Emden, 1994). In Europe, the ground dwelling generalist predator fauna, including rove beetles, play an important role in controlling cereal aphid populations (Edwards et al., 1979; Sunderland and Vickerman, 1980; Dennis and Wratten, 1991; Schmidt et al., 2003). Predation by rove beetles and other generalist predators during the early stages of aphid colonization can be important in maintaining cereal aphid infestations below economically damaging levels (Wratten and Powell, 1991).

Wheat is typically planted during September and October in Oklahoma and harvested the following June. Cereal aphids usually colonize the wheat crop soon after emergence in fall and persist in the crop until it matures the following May. Aphid infestations vary widely from year to year, ranging from barely detectable levels in some years to severe outbreaks in others (Wratten et al., 1995). There are no published studies of the rove beetles in Oklahoma and their role in biological control of cereal aphids in winter wheat in Oklahoma is not understood.

Methods appropriate for sampling rove beetles and other epigeal predators to determine their population density were thoroughly reviewed by Sunderland et al. (1995). D-vac suction sampling within enclosures followed by hand search of the plants, soil surface, and loose soil layer provides reasonably good estimates of density for most epigeal predatory arthropods, at least that fraction of populations occurring on the soil surface or within the loose surface layer of soil (Sunderland et al., 1995; Greenstone, 2001). We sampled rove beetles in this manner in winter wheat fields in the four major wheat-growing regions of Oklahoma for two growing seasons. Our first objective was to gain information on the structure (density, relative abundance, and species composition) of rove beetle communities in winter wheat fields in Oklahoma. Our second objective was to determine if rove beetle communities varied with respect to factors such as geographic location, season, aphid density, and wheat plant growth stage.

Materials and methods

Adult rove beetles were sampled for two growing seasons from a single winter wheat field located in each of the four major wheat growing regions of Oklahoma: near Tipton in the southwest (Tillman Co.), Chickasha in the south central (Grady Co.), Perkins in the north central (Payne Co.), and Goodwell in far western panhandle region of the state (Texas Co.). The winter wheat fields were planted to locally adapted wheat cultivars during October of 1999 and 2000. Each field was $\approx$2 ha in size and was sampled every 7–14 days during the growing season except when prevented by inclement weather. Sampling was initiated in fields in mid to late October each year, when wheat plants began tillering [Feekes stage 2 (Royer and Krenzer, 2001)], and was terminated in mid-May, when wheat grain was ripening (Feekes stage 11). Recommended Oklahoma grain production practices were followed except that no insecticides were applied and the crop was not pastured.

Each study field was divided into 10 equal sized subplots. Each time a field was sampled, a total of 10 sub-samples were taken, one from each subplot. Sampling each subplot was accomplished using a circular, 20 cm deep, 0.5-m^2 toothed sampling frame (Greenstone, 2001). The frame was located arbitrarily within a subplot, placed toothed side down, and pressed into the soil to block arthropods from escaping. The area within the frame was sampled with a D-vac® (Rincon-Vitova Insectaries, Inc., Ventura, CA) equipped with a ventilated 60-cm long cylindrical metal extension. The D-vac was used to sample within the frame for approximately 2 min., followed by hand searching for rove beetles within the frame for 7–10 min. Plants, the soil surface, and underneath loose soil were inspected until no rove beetles could be found. All rove beetles encountered in a frame were captured in a hand-held aspirator. Upon arrival at the laboratory, rove beetles from the 10 sub-samples were placed in a single polyethylene vial filled with 70% ethyl alcohol. Beetles were later mounted on insect pins and identified to species.

Aphids also were sampled in each field by inspecting 80–200 tillers during each visit. More tillers were inspected when aphid population density was low and fewer tillers were inspected when density was high. Tillers were collected by walking a u-shaped transect through the 10 subplots and removing equal numbers of tillers from each subplot along the route. Each tiller was cut at ground level and the number of aphids on it was counted and recorded in the field.

Ordination of species densities with respect to potential explanatory variables (e.g., aphid population density, field location, and season) was done by canonical correspondence analysis (CCA) using CANOCO version 4.5 (ter Braak and Smilauer, 2002). The square root of each species density was taken and used in CCA analysis. Explanatory variables were entered into the CCA in order of the percentage variation in the species–environment relationship explained by the variable using the forward selection algorithm built into CANOCO. The variable that accounted for the greatest percentage of the variation in community structure was entered first followed by the variable accounting for the second most variation and so on. Because of the limited size of the dataset, only main effects were included in the model, i.e. interactions among environmental variables were not considered. *F*-statistics based on Monte Carlo randomization (250 random permutations) were used to test the significance of each explanatory variable (ter Braak and Smilauer, 2002). The only significant variable ($\alpha = 0.05$) among the environmental variables was season (fall, winter, and spring), which was subsequently included in a final CCA. For purposes of visual comparison, means and standard errors of species densities were calculated for each season using the Means Procedure (SAS Institute, 1988) because season had a significant effect on community structure.

Results and discussion

Adults of 13 rove beetle species were collected from the four fields (Figure 1). The eigenvalues of the CCA were 0.315, 0.159, and 0.097 for axes 1–3, respectively. Axis 1 explained 44.1% of the variation in the species density–environment relationship, and axes 2 and 3 explained 22.3% and 13.5% of the variation, respectively. Forward stepwise inclusion of explanatory environmental variables in the CCA

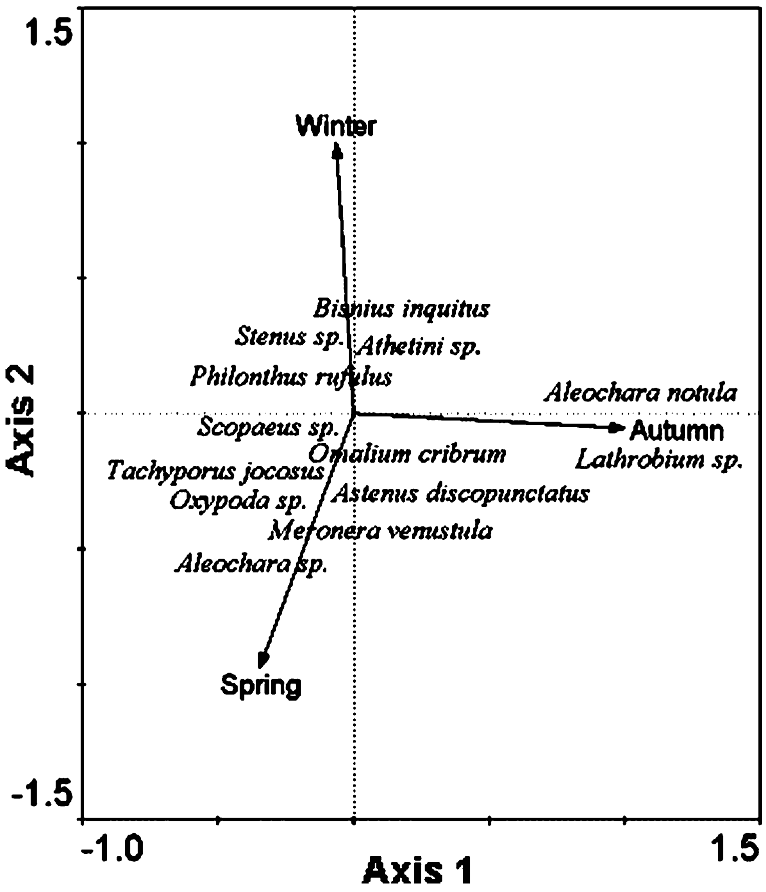

Figure 1. CCA biplot of rove beetle density scores and season of sampling. Abbreviations are the first four letters of the generic name followed by the first three letters of the specific name (see Appendix 1).

demonstrated that season was the only variable related to rove beetle community structure (Table 1). Rove beetle community structure was unrelated to aphid density, indicating that rove beetles did not exhibit detectable change in density in response to aphids. The vectors in the CCA biplot (Figure 1) represent particular seasons, and species density scores are represented by species names. Rove beetle species that appear near the origin of the biplot axes are species that were present in similar densities in all seasons, whereas those located close to the end of a particular vector were strongly associated with that single season. Most species were not strongly associated with a particular season. Notable exceptions were *Aleochara notula* Erichson and *Lathrobium sp.*, which were present only in fall; *Oxypoda* sp., which

Table 1. Results of forward stepwise selection of explanatory variables in CCA of rove beetle communities in Oklahoma winter wheat fields.

Explanatory variable[a]	*F*-ratio	$P > F$
Season	2.22	0.004
Aphid density	0.89	0.270
Wheat growth stage	0.78	0.490
Wheat tiller density	0.76	0.518
Location	0.72	0.586

[a]Variables are listed in their order of selection based on overall of variance in the species–environment relationship accounted for by the variable.

was predominantly present in winter and spring; and *Bisnius inquitus* Erichson, which was more strongly associated with winter than with spring or fall.

Densities of the five most abundant species, other species, and of all rove beetles are listed in Table 2. *Oxypoda* sp. was the most abundant rove beetle in the winter wheat fields in spring and was relatively abundant in winter, but was not collected from wheat fields in fall. In fact, *Oxypoda sp.* represented more than half of all rove beetles captured in the winter wheat fields during spring (Table 2). *Tachyporus jocosus* Say was present in wheat fields during all seasons, as was *Athetini* sp. *Tachyporus jocosus* was the most abundant rove beetle species in the winter wheat fields in fall. The density of rove beetles in the winter wheat fields was low in all seasons, ranging from 0.003 beetles per m^2 in fall to 0.106 beetles per m^2 in spring (Table 2).

In Europe, where staphylinids in wheat have been relatively well studied, *Tachyporus* and *Philonthus* species are believed to be particularly important in reducing cereal aphid numbers in wheat fields (Dennis and Wratten, 1991; Holland et al., 1996; Holland and Thomas, 1997). Their importance rests primarily from the fact that unlike aphid specialist predators, such as Coccinellidae, Staphylinidae and other generalist predators can persist in the field in the absence of aphids and are therefore present in wheat fields when cereal aphids initially colonize the fields. This early season predation can markedly reduce aphid density at population peaks later in the season. Predation pressure, particularly by *Tachyporus* spp., on aphids during this time is believed to play a key role in cereal aphid suppression in wheat (Winder, 1990). *Tachyporus jocosus* was consistently present in winter wheat fields in Oklahoma throughout the growing season and was among the most abundant Staphylinidae occurring in wheat.

Table 2. Mean number of rove beetles per m^2 in Oklahoma winter wheat fields sampled during fall, winter, and spring

Location/Species	Number of samples[a]	$\bar{X}$ beetles/m^2	SE
Fall	28		
Athetini sp.		0.001	0.001
Omalium cribrum		0.000	0.000
Oxypoda sp.		0.000	–
Stenus sp.		0.000	–
Tachyporus jocosus		0.001	0.001
Other species		0.001	0.001
Total		0.003	0.002
Winter	25		
Athetini sp.		0.001	0.001
Omalium cribrum		0.002	0.001
Oxypoda sp.		0.006	0.004
Stenus sp.		0.002	0.001
Tachyporus jocosus		0.006	0.002
Other species		0.000	–
Total		0.016	0.006
Spring	46		
Athetini sp.		0.004	0.002
Omalium cribrum		0.015	0.008
Oxypoda sp.		0.061	0.036
Stenus sp.		0.002	0.001
Tachyporus jocosus		0.017	0.005
Other species		0.006	0.003
Total		0.106	0.049

[a]An individual sample consists of the rove beetles collected from 10 0.5-m^2 frames from a field on a particular date.

Philonthus rufulus Horn was also present in winter wheat but was never abundant during our study. The role that Staphylinids, particularly *T. jocosus*, play in cereal aphid control in winter wheat in Oklahoma warrants further investigation.

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