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CHARACTERISTICS OF FOUR AGRICULTURAL CROPS ESTABLISHED AS NORTHERN BOBWHITE BROOD HABITAT

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ABSTRACT

Small plots of agricultural crops are often planted in the Southeast for northern bobwhite (*Colinus virginianus*) management. Often these are viewed as primarily winter habitat, and assumed to provide summer habitat. We evaluated the macroinvertebrate and vegetative structure of millet, sorghum, wheat, and soybean plots on a cotton farm to assess their value as bobwhite brood habitat. During June and July 1999 and June, July, and August 2000, we studied 5 blocks, each planted with all 4 agricultural crops. We measured invertebrate abundance along a 15-meter transect in each plot using vacuum sampling and height/density of vegetation. Visual obstruction readings (VOR) were highest in millet and sorghum, followed by wheat and then soybean ($P < 0.001$). Macroinvertebrate numbers differed among cover types ($P < 0.001$), but macroinvertebrate weights did not ($P = 0.14$). Among important Orders, Coleoptera, Hemiptera, Diptera, and Homoptera were found in greater numbers in millet. Numbers of Hymenoptera did not differ among crops. In most cases, millet yielded the highest biomass and numbers of macroinvertebrates, followed by sorghum. Soybeans and wheat had fewer macroinvertebrates among the crops studied. On our study area it appears that millet provides the best brood habitat, although sorghum appears to provide a second useful crop. Thus, among these crops we recommend use of millet plots as brood habitat for northern bobwhite chicks.

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Key words: agriculture, brood habitat, *Colinus virginianus*, Georgia, insects, macroinvertebrates, millet, northern bobwhite, sorghum, soybean, wheat

INTRODUCTION

Decline of northern bobwhite populations has mirrored the decline of small non-commercial farms (Klimstra 1982). These areas provided hedgerows and borders that made quality brood habitat. Brood habitat is important because the early stages of development of bobwhites are most vulnerable to malnutrition and predation; at this stage, peak mortality occurs (Stoddard 1931, Hurst 1972).

Vegetative cover is an important aspect of brood habitat because it protects chicks from avian predators (Brennan et al. 1996). Availability and abundance of macroinvertebrates, however, are the vital features of quality brood habitat (Rosene 1969, Hurst 1972, DeVos et al. 1992, Guthery 2000). For the first 6 weeks, chicks feed on >80% macroinvertebrates (Handley 1931, Landers and Mueller 1986) to provide the large amount of protein necessary for rapid growth (Nestler et al. 1942, Nestler et al. 1945, Rosene 1969). Immune system problems may result when protein requirements are not met (Lochmiller et al. 1993), and longer foraging times increase the risk of predation (Palmer 1995).

Macroinvertebrates are fundamental to bobwhite chick survival; furthermore, the right types of macroinvertebrates are crucial, because bobwhites are selective about what they will eat (Handley 1931, Jackson et al. 1987). Field borders and plots used as brood habitat must have the proper assemblages of macroinvertebrates. Among those noted as preferred are: beetles (Coleoptera), leafhoppers (Hemiptera: Cicadellidae), true bugs (Hemiptera: Homoptera), spiders (Arachnida), grasshoppers and crickets (Orthoptera), ants (Hymenoptera: Formicidae), various larvae, snails (Mollusca: Gastropoda), and flies (Diptera) (Handley 1931, Hurst 1972, Healey et al. 1985, Jackson et al. 1987, Guthery 2000). Brood habitat, and the selection of specific macroinvertebrate foods by bobwhites, has not been well studied in agricultural ecosystems (J. Carroll, personal communnication, Jackson et al. 1987). Legumes have been found to produce large macroinvertebrate populations (Stoddard 1963, Webb 1963, Jackson et al. 1987), but research is lacking for other agricultural crops in the Southeast. Our objective was to determine previously established row crops, including millet, sorghum, soybeans, and wheat, as bobwhite brood habitat in terms of macroinvertebrate assemblages and cover quality.

STUDY AREA

The Wolf Creek farm is a 900-ha private farm in Turner County, located on the Upper Coastal Plain of Georgia. The site contains both farmland and forested

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areas. The farmland consists of cotton and peanut fields, whereas the unfarmed portion is mostly loblolly pine (*Pinus taeda*) and longleaf pine (*Pinus palustris*), and bottomland hardwoods. Much of the farmland contains sandy soils and some of the fields receive center pivot irrigation. This area was established in 1997 as a demonstration and research area combining agriculture and bobwhite management practices; at the time of the study, about 90 small blocks of agricultural crops were established throughout the farm.

METHODS

We studied plots of millet, sorghum, soybean, and wheat that had been previously established as brood habitat using conventional tillage. These blocks generally had lower chemical inputs than normal crop fields and thereby tended to be ''weedy.'' Using a randomized block design, we studied 5 sets of fields. Each field contained 1 plot of each of the 4 crop types. Although field and plot sized varied, fields were roughly 0.5 ha. Each field was divided into strips of the 4 crops.

Macroinvertebrates and vegetation were assessed during 2 seasons in 1999 (12 July 1999, ''middle''; 2 August 1999, ''late'') and 3 seasons in 2000 (6 June 2000, ''early''; 1 July 2000, ''middle''; and 27 July 2000, ''late''). To assess vegetative cover, we measured VOR to the nearest dm in each cardinal direction at a random location within each plot with a Robel pole (Robel et al. 1970). A random 15-m transect was sampled in each plot with a D-Vac™ vacuum sampler (D-Vac Co., Ventura, CA) (Dietrick et al. 1959, Dietrick 1961). Robel pole readings and vacuum sampling were taken near where human-imprinted chick trials had taken place the previous day, allowing for direct comparisons to the chick study. Macroinvertebrates were euthanized in bags containing ethyl acetate, then frozen and transported to the laboratory. Macroinvertebrate content of each field was separated from the vegetation, identified to order and family, sorted, and counted. Length and width measures of each macroinvertebrate were taken to acquire an estimate of their weights, using previously published formulas (Palmer 1995). We divided macroinvertebrates into the following categories for analyses: Coleoptera, Diptera, Hemiptera, Homoptera, Hymenoptera, Lepidoptera, and miscellaneous. We chose order classifications to include macroinvertebrates traditionally believed important to bobwhites, with ''miscellaneous'' including those which are not. Future studies may reveal which of these orders are most important for bobwhite chicks.

We used a randomized block analysis of variance (ANOVA) to test for variability in the mean weight and number of different macroinvertebrates collected in each field type by year and season, and to assess the mean VOR in each field type by season and year. Linear regression was used to test the relationships between VOR and weight and amount of macroinvertebrates collected with the vacuum sampler in each crop.

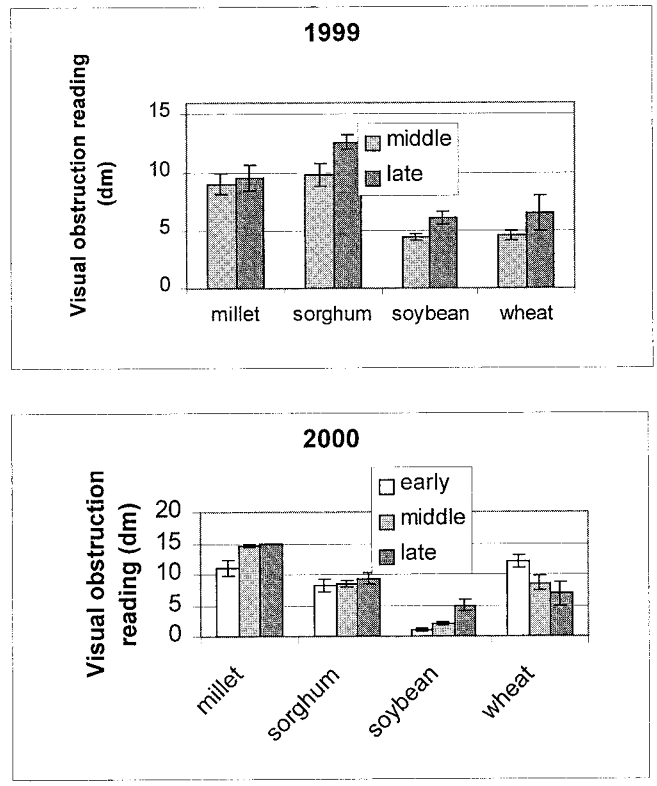

Fig. 1. Mean (± SE) visual obstruction readings (n = 100) taken in 4 different agricultural crops on Wolf Creek Farm, Turner County, Georgia, 1999 and 2000.

RESULTS

Vegetation Density

Mean VOR differed among the 4 field types (F = 36.79, 7,92 df, $P < 0.001$), for 1999 (F = 29.77, 7,32 df, $P < 0.0001$, and for 2000 (F = 42.90, 7,52 df, $P < 0.0001$) (Fig. 1). In general, millet and sorghum had higher mean VORs, followed by wheat and soybean. This was true of 1999, when VOR differed among the 4 field types for both middle (F = 21.75, 7,12 df, $P < 0.0001$) and late seasons (F = 18.06, 7,12 df, P = 0.0002). In 2000, mean VOR differed among the 4 field types for early (F = 25.94, 7,12 df, $P < 0.0001$), middle (F = 61.13, 7,12 df, $P < 0.001$), and late seasons (F = 12.09, 7,12 df, $P < 0.0006$). Again, millet had higher mean VOR, this time followed by sorghum, wheat, and soybeans (Fig. 1).

Macroinvertebrate Weights

Total weights of macroinvertebrates did not differ among crop types (Table 1). Among orders of invertebrates, there were differences among crop types. Sorghum and millet contained the heaviest amounts of Coleoptera, with soybean following, and very small amounts in wheat (F = 3.59, 7,72 df, P = 0.02). Total weight of Diptera differed among the 4 crop types, with millet ranking highest, sorghum and wheat intermediate, and soybean last (F = 3.05, 7,72 df, P = 0.03). Millet had greater weight of Hemiptera than the other crops (F = 10.57, 7,72 df, $P < 0.001$). Total

Table 1. Total weight (± SE) of macroinvertebrates sampled with a vacuum sampler in 4 different agricultural crops on Wolf Creek Farm, Turner County, Georgia, 1999 and 2000.

Order Species	$\bar{X}$	SE	F	df	P
Pooled			5.68	7, 72	0.15
millet	0.75	0.22			
sorghum	0.83	0.31			
soybean	0.37	0.30			
wheat	0.14	0.05			
Coleoptera			3.59	7, 72	0.02
millet	0.03	0.009			
sorghum	0.02	0.007			
soybean	0.002	0.001			
wheat	0.008	0.002			
Diptera			3.05	7, 72	0.03
millet	0.02	0.008			
sorghum	0.005	0.002			
soybean	0.001	0.0008			
wheat	0.004	0.002			
Hemiptera			10.57	7, 72	<0.001
millet	0.15	0.04			
sorghum	0.03	0.008			
soybean	0.01	0.007			
wheat	0.02	0.007			
Homoptera			1.78	7, 72	0.16
millet	0.28	0.12			
sorghum	0.28	0.18			
soybean	0.01	0.004			
wheat	0.05	0.03			
Hymenoptera			6.63	7, 72	0.0005
millet	0.14	0.05			
sorghum	0.81	0.18			
soybean	0.04	0.01			
wheat	0.07	0.22			
Lepidoptera			0.79	7, 72	0.51
millet	0.004	0.003			
sorghum	0.02	0.007			
soybean	0.004	0.003			
wheat	0.01	0.12			
Miscellaneous			1.14	7, 72	0.34
millet	0.21	0.15			
sorghum	0.08	0.04			
soybean	0.02	0.006			
wheat	0.06	0.03			

Table 2. Total number of macroinvertebrates sampled with a vacuum sampler in 4 different agricultural crops on Wolf Creek Farm, Turner County, Georgia, 1999 and 2000.

Order Species	$\bar{X}$	SE	F	df	P
Pooled			22.95	7, 71	<0.001
millet	138.2	21.66			
sorghum	49.50	9.83			
soybean	15.0	2.95			
wheat	21.10	3.93			
Coleoptera			6.96	7, 72	0.004
millet	4.20	1.00			
sorghum	2.55	0.73			
soybean	0.35	0.13			
wheat	1.00	0.31			
Diptera			4.60	7, 72	0.005
millet	20.85	7.61			
sorghum	5.40	1.73			
soybean	2.70	0.96			
wheat	4.00	1.25			
Hemiptera			14.53	7, 72	<0.001
millet	66.15	14.82			
sorghum	11.45	3.72			
soybean	5.60	1.96			
wheat	4.65	1.61			
Homoptera			10.04	7, 72	<0.001
millet	28.35	5.09			
sorghum	19.85	5.31			
soybean	2.60	0.65			
wheat	5.70	1.59			
Hymenoptera			1.57	7, 72	0.20
millet	8.60	4.75			
sorghum	6.35	2.12			
soybean	1.70	0.52			
wheat	2.45	0.56			
Lepidoptera			2.07	7, 72	0.11
millet	0.30	0.15			
sorghum	0.95	0.46			
soybean	0.15	0.11			
wheat	0.20	0.16			
Miscellaneous			1.35	7, 72	0.27
millet	4.21	1.52			
sorghum	3.00	0.76			
soybean	1.50	0.34			
wheat	4.00	1.21			

weight of Hymenoptera differed among the 4 crop types ($F = 6.63$, 7,72 df, $P = 0.005$), with most Hymenoptera found in sorghum. Total weight of Homoptera, Lepidoptera, and miscellaneous did not vary among the 4 crop types.

Macroinvertebrate Counts

Total number of macroinvertebrates sampled with the vacuum sampler differed among the 4 crop types ($F = 22.95$, 7,71 df, $P < 0.001$) (Table 2). Throughout the study, millet consistently yielded higher numbers of macroinvertebrates, with sorghum intermediate, and soybean and wheat last.

Among orders of invertebrates, there were differences among crop types (Table 2). The most Coleoptera were found in millet, followed by sorghum, wheat, and soybean ($F = 6.96$, 7,72 df, $P = 0.0004$). Diptera counts varied among the 4 crop types, with the most found in millet, followed by sorghum, soybean, and wheat ($F = 4.60$, 7,72 df, $P = 0.005$). Millet contained more Hemiptera than any of the other crop types ($F = 14.53$, 7,72 df, $P < 0.0001$). Millet contained the most Homoptera, followed by sorghum, wheat, and soybean ($F = 10.04$, 7,72 df, $P < 0.0001$). Hymenoptera, Lepidoptera, and miscellaneous counts did not differ among the 4 crop types.

Vegetation Density and Vacuum Sampling

Weight of macroinvertebrates collected with a vacuum sampler was unrelated to VOR in all 4 crops (Table 3). Number of macroinvertebrates collected with a D-Vac vacuum sampler was unrelated to VOR in millet, sorghum, and soybean (Table 4). Number of macroinvertebrates was related to VOR in wheat ($F = 6.96$, $P = 0.02$, $R^2 = 0.28$).

Table 3. Test results comparing visual obstruction reading and total weight of macroinvertebrates sampled with a vacuum sampler in 4 different agricultural crops on Wolf Creek Farm, Turner County, Georgia, 1999 and 2000.

Species	*F*	*df*	*P*	R^2	Equation
Overall					
millet	0.43	18	0.52	0.02	
sorghum	5.39	18	0.03	0.23	$y = -1.7408+0.25456$
soybean	0.05	18	0.83	0.003	
wheat	0.39	18	0.54	0.02	

Table 4. Comparisons of visual obstruction reading and total number of macroinvertebrates sampled with a vacuum sampler in 4 different agricultural crops on Wolf Creek Farm, Turner County, Georgia, 1999 and 2000.

Species	*F*	*df*	*P*	R^2	Equation
Overall					
millet	3.36	18	0.08	0.16	
sorghum	0.03	18	0.87	0.002	
soybean	0.17	17	0.69	0.01	
wheat	6.96	18	0.02	0.28	$y = 41.1978-2.41391x$

DISCUSSION

Biologists have developed many techniques to assess habitat quality. As macroinvertebrates are the key feature in bobwhite brood habitat (Rosene 1969, Hurst 1972, DeVos et al. 1992, Guthery 2000), macroinvertebrate sampling should be the focus of brood habitat assessment. Various methods of sampling invertebrates include sweep-nets, drop cloths, funnels, sticky traps, and other methods (Byerly et al. 1978, Nuessly and Sterling 1984, Schotzko and O'Keefe 1986, Cooper and Whitmore 1990, Mommertz et al. 1996). Comparisons among methods have been inconsistent. It has been cautioned by some that sweepnet and vacuum sampling may overestimate insect abundance, and furthermore that vacuum sampling estimates are generally higher than those of sweepnets (Race 1960, Byerly et al. 1978); other studies have shown vacuum sampling more accurate in predictive power and estimates of population density than sweepnets (Ellington et al. 1984). Other studies show no differences among dropnet, sweep net, or vacuum sampling (Schotzko and O'Keefe 1986, Gillespie and Kemp 1996). Vacuum sampling, however, yields good abundance estimates (Ellington et al. 1984), is appropriate for foliage macroinvertebrates, and has been used in a variety of agricultural settings (Cooper and Whitmore 1990), including sampling of bobwhite brood habitat. When selecting a macroinvertebrate sampling method, it is important to consider the foraging method of the species in question (Cooper and Whitmore 1990). Because chicks forage along the ground and at low heights of vegetation, vacuum sampling is most appropriate.

Other studies have used a vacuum sampler to test the suitability of different habitats as brood habitat, but research is lacking for comparing agricultural crops in general. In a comparison of organic and conventional farms, sampling revealed no difference between farms, but more insect biomass was found in wheat, oats, clover, and clover/oat plots than in corn, soybeans, and alfalfa (Whitmore 1982). Using a vacuum sampler, conventionally tilled soybeans have been shown inferior in invertebrate abundance to Conservation Reserve Program (CRP) plantings (Burger et al. 1993), and greater invertebrate biomass has been found in disked plots compared to undisked plots (Manley et al. 1994). However, old fields, fertilized old fields, and fertilized Kobe lespedeza fields showed no difference in density and biomass of invertebrates (Jackson et al. 1987). Using sweep nets, fescue fields have been found not to contain sufficient biomass of insects to support bobwhite broods (Barnes et al. 1995). In comparing various combinations of treatments of brood habitat plots including mowing, chopping, burning, and use of herbicides, vacuum sampling did not reveal any differences (Welch 2000), although differences had previously been found on burned vs. unburned plots using both sweep nets and vacuum sampling (Hurst 1972).

Utilizing vacuum sampling, we found differences among our plots. Millet appeared most suitable as brood habitat, followed by sorghum, due to the large number of macroinvertebrates. In comparison, wheat and soybean were poor brood habitat. In terms of weight, there were no differences until the macroinvertebrates were sorted by Order. In most cases, millet ranked highest, with sorghum second; again, wheat and soybean were poor. In terms of macroinvertebrate numbers, millet generally had the most, followed by sorghum, soybean, and wheat. The same was true when the samples were sorted by order.

Using similar methods to compare various CRP plantings and conventionally tilled soybeans, Burger et al. (1993) consistently ranked red clover highest in comparison to all other plantings. We found higher biomass and number of macroinvertebrates in our millet plots than Burger et al. (1993) did in their red clover plots. Our sorghum plots did not contain as many macroinvertebrates as their clover plots, but had more than their other CRP plantings. Our wheat plots were comparable in biomass to their lowest ranked planting, soybeans. Their CRP plantings were dominated in terms of biomass by Homoptera, Hemiptera, and when present, Orthoptera; by number, Homoptera and Diptera were dominant. In contrast, we found Hymenoptera, Homoptera, and miscellaneous to account for the majority of biomass in our samples, whereas Hemiptera and Homoptera dominated in numbers. However, it must be cautioned that in both studies, annual differences in abundance were apparent. Regional differences may also be present, as we found higher macroinvertebrate biomass and numbers in our soybean plots.

Because millet also ranked highest in VOR and sorghum ranked second, this suggests that millet would be the most preferential crop for bobwhite brood habitat, and sorghum would be a good second choice. Soybean and wheat provide little benefit of macroinvertebrates or cover in comparison. Because legumes have been found to be a good producer of invertebrates, both historically and in recent research (Burger et al. 1993), we would suggest that including legumes within or nearby might increase invertebrate production.

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