INFLUENCE OF COVER CROPS ON INSECT PESTS AND PREDATORS IN CONSERVATION-TILLAGE COTTON

G. Tillman[1*], H. Schomberg[2], S. Phatak[3], and S. Lachnicht[4]

[1]USDA-ARS, P. O. Box 748, Tifton, GA 31793, USA
[2]USDA-ARS, 1420 Experiment Station Road, Watkinsville, GA, 30677, USA
[3]University of Georgia, P. O. Box 748, Tifton, GA 31793, USA
[4]USDA-ARS, 803 Iowa Avenue, Morris, MN, 56267, USA
*Corresponding author's e-mail: pgt@tifton.usda.gov.

ABSTRACT

In the fall of 2000, an on–farm sustainable agricultural research project was established for cotton, *Gossypium hirsutum* L., in Tift County, Georgia. The objective of our 2-yr research project was to determine the impact of several cover crops on pest and predator insects in cotton. The five cover crop treatments included: 1) cereal rye, 2) crimson clover, 3) a legume mixture of balansa clover, crimson clover, and hairy vetch, 4) a legume mixture + rye combination, and 5) no cover crop in conventionally-tilled fields. Three main groups of pests were collected in cover crops and cotton: 1) the heliothines, *Heliothis virescens* (F.) and *Helicoverpa zea* (Boddie), 2) the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), and 3) stink bugs. The main stink bugs collected were the Southern green stink bug, *Nezara viridula* (L.), the brown stink bug, *Euschistus servus* (Say), and the green stink bug, *Acrosternum hilare* (Say). For both years of the study, the heliothines were the only pests that exceeded their economic threshold in cotton, and the number of times this threshold was exceeded in cotton was higher in control cotton than in crimson clover and rye cotton. Heliothine predators and aphidophagous lady beetles occurred in cover crops and cotton during both years of the experiment. *Geocoris punctipes* (Say), *Orius insidiosus* (Say) and red imported fire ants, *Solenopsis invicta* Buren were relatively the most abundant heliothine predators observed. Lady beetles included the convergent lady beetle, *Hippodamia convergens* Guerin-Meneville, the seven-spotted lady beetle, *Coccinella septempunctata* [L.], spotted lady beetle, *Coleomegilla maculata* (De Geer) and the multicolored Asian lady beetle, *Harmonia axyridis* (Pallas). Density of *G. punctipes* was higher in cotton fields previously planted in crimson clover compared to control cotton fields in 2001. Intercropping cotton in live strips of cover crop was probably responsible for the relay of *G. punctipes* onto cotton in these crimson clover fields. Conservation of the habitat of fire ants during planting probably was responsible the higher density of red imported fire ants observed in all conservation-tillage cotton fields relative to control cotton fields. Reduction in the number of times in which economic thresholds for heliothines were exceeded in crimson clover and rye compared to control fields indicated that the build up of predaceous fire ants and *G. punctipes* in these cover crops subsequently resulted in reduction in the level of heliothines in conservation-tillage cotton with these cover crops compared to conventional-tillage cotton without cover crops.

INTRODUCTION

As a result of frequent and intense disturbance, many agricultural systems are recognized as particularly difficult environments for natural enemies (Landis and Marino, 1999). Conservation tillage along with cover crops reduces this frequent disturbance and helps promote year-round natural enemy and pest species interactions by providing alternate prey or hosts, reproductive sites and protection from adverse conditions. Cover crops in reduced tillage systems offer a simple approach to pest management, but more information on the impact of cover crops on targeted pests and predators are needed to facilitate design of appropriate landscapes. A significant amount of research has been conducted on using rye, crimson clover and hairy vetch as cover crops in conservation-tillage systems the south (Reeves, 1994). Further research has focused on the use of these cover crops with conservation tillage in cotton, *Gossypium hirsutum* L., in the south to enhance beneficial insects (Bugg et al., 1991: McCutcheon et al., 1995: Ruberson et al., 1995; Ruberson et al., 1997; McCutcheon, 2000). Most studies have focused on comparisons among single species of legumes and non-legumes (Reeves, 1994). No studies have addressed the impact of using mixtures of legume species as winter cover crops in cotton on natural enemies even though they can provide a more diverse biological habitat through an extension of availability of nectar and other food sources (Altieri, 1995). The objective of our 2-yr on-farm research project in Tift County, Georgia was to determine the impact of cereal rye, crimson clover, a legume species mixture (balansa clover, crimson clover, and hairy vetch) and a combination of this legume mixture and rye on pest and predator insects in cotton.

MATERIALS AND METHODS

The five cover crop treatments included: 1) cereal rye 2) crimson clover, 3) legume mixture of balansa clover, crimson clover and hairy vetch, 4) legume mixture + rye combination, and 5) no cover crop in conventionally-tilled fields. The mixture of an early (balansa clover), mid (crimson clover) and late (hairy vetch) flowering legume was chosen to extend the availability of a habitat of flowering plants in the field that could be attained from planting any legume species alone. For the legume mixture-rye treatment, the rye was planted in the center of the row where the cotton would be planted in the summer while the legume mixture was planted on each side of the rye. The combination of the legume mixture and rye was chosen in an effort to combine the benefits of legume nectar production and N fixation with enhanced biomass production of rye.

Cover crops were planted in the fall using a grain drill. Rye and crimson clover treatments were planted at a rate of 56 and 16.8 kg of seeds per ha, respectively. For the legume mixture, rates of 1.01, 3.47, and 2.13 kg of seeds per ha were used for balansa clover, crimson clover, and hairy vetch, respectively. All of the cover crops, except for rye, were strip-killed in the center of the row with an herbicide approximately 2 weeks before cotton planting. In the spring of 2001, a 46-cm strip of cover crop was killed in the center of the row leaving a 46-cm strip of live cover crop between dead strips. In the spring of 2002, a strip of cover crop ca. 53 cm wide was killed in the center of the row leaving 38-cm strips of live cover crop.

Cotton was strip-tilled using cotton producers' strip-till rigs. Cotton was planted at 11.2 kg/ha on all fields using planters either during or after strip-tilling the cover crops. Cotton varieties included DP 458, DP 5415, DP 5690 and Delta Pearl. Cotton was harvested using cotton pickers. Four-row swaths of cotton 120–150 m long were picked in each field. Cotton was weighed immediately after machine harvest in the field to determine seed-cotton yields. Seed-cotton yield data were analyzed by PROC MIXED followed by least significant difference (LSD) separation of means (SAS Institute 1999) where appropriate. Fixed effects were cover crop treatments and random effects were cotton producers' fields and residual error.

Twenty fields were located in various locations in Tift County, Georgia. Large, 4-ha fields were used for each cover crop treatment to limit dispersal of predators from the fields. Each cover crop treatment was assigned randomly to 4 fields similar to a completely randomized design. In the second year of the project, one crimson clover and one rye field were eliminated from the study. The completely randomized design served as the main plot portion of the following split plot description. Each field was completely subdivided into 50 m² sampling plots. Insect pests and predators on plants were sampled each sampling week in each cover treatment for cover crops in the spring and cotton in the summer using sweep nets. In each field, 20 to 21 sampling plots were sampled. The experimental design describes a split plot in space (sampling location) and time (sampling weeks) with subsamples present in the sections.

Exhaustive whole plant sampling was done to monitor heliothine species in cotton. Sampling occurred weekly before the heliothines, *Heliothis virescens* (F.) and *Helicoverpa zea* (Boddie), occurred on cotton and biweekly thereafter. The sampling scheme was similar to that for sweep sampling, except that a single plant was sampled in each of the 50 m^2 sampling areas.

Insect pest and predator density data from sweep and whole plant samples were analyzed by PROC MIXED (SAS Institute, 1999) to obtain least squares means and their associated standard errors. Fixed effects were sample location, sample week, and sample location × sample week. Comparisons between least squares means between cover crop treatments were then performed for each crop type using one-tailed *t*-tests. Comparisons between least squares means were performed using square-root transformed data.

Economic threshold for heliothines was 5% infestation of first instars on cotton plants. For stink bugs (nymphs and adults), the economic threshold was 20% of the medium-sized bolls (ca. 14 d-old) with internal feeding damage. Economic threshold for the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois) (nymphs and adults), was considered to be reached when plants were retaining less than 85% of the pinhead squares. Economic threshold for the cotton aphid, *Aphis gossypii* Glover (all forms), was abundant aphids with slightly curled seedling leaves. The number of dates where the level of *H. virescens* and/or *H. zea* exceeded the economic threshold was analyzed by PROC GLM followed by LSD separation of means (SAS Institute 1999) where appropriate.

RESULTS AND DISCUSSION

Four main groups or species of pests were collected in sweep samples: 1) aphids, 2) tarnished plant bugs, 3) stink bugs and 4) the heliothines, *H. virescens* and *H. zea*. In our study the cotton aphid infested only cotton plants. The main stink bugs collected in this study were the Southern green stink bug, *Nezara viridula* (L.), the brown stink bug, *Euschistus servus* (Say) and the green stink bug, *Acrosternum hilare* (Say). For both years of the study, the heliothines were the only pests that exceeded their economic threshold in cotton. The number of times in which the heliothines exceeded their economic threshold in cotton was significantly higher in control cotton than in crimson clover and rye cotton in 2001 (F = 3.04, df = 4, 13, P = 0.05) and 2002 (F = 3.07, df = 4, 13, P = 0.05) (Table 1).

The main predators in cover crops and cotton during both years of the experiment were heliothine predators and aphidophagous lady beetles. The major heliothine predators were *G. punctipes*, *O. insidiosus* and red imported fire ants, *Solenopsis invicta* Buren. Lady beetles included the convergent lady beetle, *Hippodamia convergens* Guérin-Méneville, the seven-spotted lady beetle, *Coccinella septempunctata* [L.], spotted lady beetle, *Coleomegilla maculata* (De Geer) and the multicolored Asian lady beetle, *Harmonia axyridis* (Pallas).

Red imported fire ants were highest in the legume mixture and lowest in the rye in comparisons among the four cover crop treatments in the spring of 2001 (Table 2). Crimson clover was the only cover crop in which fire ants were present every sampling period. The next spring, fire ants were not significantly different in crimson clover, the legume mixture and the legume-rye combination, but significantly lower in the legume mixture compared to the other three cover crops (Table 3). In the summer of both years of the study, red imported fire ant were significantly greater in conservation-tillage cotton fields planted with cover crops than in conventional-tillage cotton fields left fallow during the winter (Tables 2 and 3). In the summer of 2001, crimson clover and rye cotton harbored significantly higher numbers of the red imported fire ants than legume and legume-rye cotton. The next cotton season, though, numbers of this predator were significantly lower in rye than in the other three treatments with cover crops.

For both years, crimson clover and the legume mixture cover crops harbored significantly higher numbers of *G. punctipes* and *O. insidiosus* compared to the two cover crop treatments with rye, and numbers of these two predators were significantly greater in the legume-rye combination treatment than in rye (Tables 2 and 3). Only the crimson clover and legume cover crop treatments harbored significantly higher numbers of *G. punctipes* in the cover crops in the spring compared to cotton in the summer. All legume treatments harbored significantly higher numbers of *O. insidiosus* in the cover crops compared to cotton. In the spring of 2001, *G. punctipes* was significantly higher in crimson clover treatments than in any of the other cover crop treatments indicating that this predator was highly attracted to this legume (Tables 2). In 2001, density of *G. punctipes* was significantly higher in cotton fields previously planted in crimson clover compared to control cotton fields. In contrast, for both years of the study there was no significant difference in number of *O. insidiosus* between crimson clover cotton and control cotton.

For both years, crimson clover and the legume mixture harbored significantly higher levels of lady beetles compared to the two cover crop treatments with rye indicating that the legumes were a more suitable habitat for lady beetles than the grass in the spring (Tables 2 and 3). In 2001, the number of lady beetles was significantly higher in cotton for all cover crop treatments, except the legume mixture, than for the cover crops in the spring. Nevertheless, the number of lady beetles in control fields was still significantly higher than in the other four cover crop treatments in cotton. In 2002, the number of lady beetles was significantly higher in cotton than in cover crops for only the legume-rye and rye treatments. In cotton, lady beetles were significantly higher in rye cotton than in cotton intercropped in the three other cover crops, but no significant differences occurred in numbers of lady beetles between the fields with cover crops and control fields.

Seed-cotton yields were significantly different among treatments for 2001 (F= 4.07, df = 4, 25, P = 0.01) and 2002 (F = 6.2, df = 4, 17, P = 0.01) (Table 4). In the first year of the test, seed-cotton yields were significantly higher for cotton with crimson clover and legume mixture-rye combination than for control cotton without cover crops while the yields for the legume mixture and rye treatments were not significantly different from those for the controls. In 2002, all cover crop cotton fields, except for the rye fields, had significantly higher seed-cotton yields compared to control fields. Since yields for cover crop treatments were never lower than those for control cotton, we concluded that planting cotton in strip-killed/tilled cover crops did not adversely affect cotton production.

In this on-farm study, we compared conventional tillage and winter-fallow practices to strip-tillage with four diverse cover crops designed to enhance natural enemies in cotton by promoting the increase of populations of these natural enemies in the spring and encouraging these natural enemies to relay from the spring cover crops into cotton. The goal of mixing the three legume species was to extend flowering to promote better relay of predators from the cover crop to cotton. Timing of initial flowering and seasonal succession of flowering for these cover crops occurred so that the numbers of *G. punctipes*, *O. insidiosus* and lady beetles built up in the spring in the cover crops especially in the legume mixture and crimson clover treatments. By strip-killing and strip-tilling the legume cover crops, a live strip of cover crop was available as a habitat for the natural enemies in the late spring when cotton was planted.

Enhancement of *G. punctipes* in conservation-tillage cotton has not been previously reported for this predator for any cover crop. Gaylor et al. (1984) reported that at the time of peak heliothine population density on cotton, significantly more predators, *Geocoris* spp. and spiders, existed on cotton in the conventional tillage treatments than in the conservation tillage treatments with cover crops. The stressed condition of the cotton grown under conservation-tillage with crimson clover as a cover crop may have been responsible for the lower populations of these predators observed in crimson clover cotton compared to control cotton. Ruberson et al. (1995) reported that in the summer of 1994 populations of *G. punctipes* were reduced in a conservation-tillage cotton field relative to a conventional-tillage cotton field. In a second study conducted by Ruberson et al. (1997) no differences in *G. punctipes* populations were detected between crimson clover cotton and conventional-tillage cotton without a cover crop. In our study, we maintained a strip of live crimson as a habitat for *G. punctipes* whereas in the other reported studies the crimson clover was completely killed before planting the main crop. Maintaining this live strip of cover crop was probably responsible for the relay of *G. punctipes* in crimson clover cotton fields.

Conservation of habitat of fire ants during planting probably was responsible the higher density of red imported fire ants in conservation-tillage cotton with cover crops relative to control cotton. Similarly, Ruberson et al. (1995) reported that the presence of red imported fire ants in clover fields might have been a function of reduced tillage than use of the cover crop. McCutcheon et al. (1995) demonstrated that densities of the red imported fire ant were highest in cotton in non-cultivated plots that had a crimson clover cover than in cultivated plots. In a later study, McCutcheon (2000) determined that fire ants were more abundant in rye/no-till treatments than in rye/disk treatments.

Reduction in the number of dates in which economic thresholds for heliothines were exceeded in crimson clover and rye compared to control fields indicates that the build up of predaceous fire ants and *G. punctipes* in crimson clover and rye subsequently resulted in reduction in the level of heliothines in these cover crop compared to control cotton fields. *Geocoris punctipes* is known to be one of the most predominant and effective predators of *H. zea* and *H. virescens* in cotton (Bell and Whitcomb, 1963; Lopez et al., 1976), and fire ants have been reported to be excellent predators of a variety of cotton pests (Showler and Reagan, 1987). McCutcheon et al.'s (1995) report that the higher densities of fire ants in non-cultivated compared to cultivated plots possibly resulted in the reduced densities of heliothine eggs in non-cultivated plots versus cultivated ones is in agreement with our conclusions about the suppressive activity of fire ants against heliothines in conservation tillage cotton.

ACKNOWLEDGMENTS

We thank the Sustainable Agriculture Research and Education Program of CSREES, USDA for financial support of this research.

REFERENCES

Altieri, M. A. 1995. Agroecology, the science of sustainable agriculture, 2nd ed. Westview Press, Boulder CO.

Bell, K. O, Jr., and W. H. Whitcomb. 1963. Field studies on egg predators of the bollworm, *Heliothis zea* (Boddie). Fla. Entomol. 47: 171-180.

Bugg, R. L., F. L. Wäckers, K. E. Brunson, J. D. Dutcher, S. C. Phatak. 1991. Cool-season cover crops relay intercropped with cantaloupe: Influence on a generalist predator, *Geocoris punctipes* (Hemiptera: Lygaeidae). J. Econ. Entomol. 84: 408–416.

Gaylor, J. G., S. J. Fleischer, D. P. Muehleisen, and J. V. Edelson. 1984. Insect populations in cotton produced under conservation tillage. J. Soil Water Conserv. 39:61:64.

Landis, D. A., and P. C. Marino. 1999. Landscape structure and extra-field processes: impact on management of pests and beneficials, pp. 79–104. *In* J. Ruberson (ed.), Handbook of Pest Management. Marcel Dekker, New York.

Lopez, J. D., Jr., R. L. Ridgway, and R. E. Pinnell. 1976. Comparative efficacy of four insect predators of the bollworm and tobacco budworm. Environ. Entomol. 5: 1160-1164.

McCutcheon, G. S, P. J. Bauer, J. G. Alphin, and J. R. Frederick. 1995. Population dynamics of insect pests and beneficial arthropods in a crimson clover/cotton ecosystem with conservation tillage cotton, pp. 103–107. *In* Proceedings, Southern Conservation Tillage Conference for Sustainable Agriculture, 26–27 June 1995, Jackson, MS. Mississippi Agricultural & Forestry Experiment Station, Mississippi State, MS.

McCutcheon, G. S. 2000. Beneficial arthropods in conservation tillage cotton – a three year-study, 1302–1306. *In* Proceedings, Beltwide Cotton Conferences. National Cotton Council, Memphis, TN.

Reeves, D. W. 1994. Cover crops and rotations, pp.125–172. *In* J. L. Hatfield and B. A. Stewart [eds.], Crops residue management. Advances in soil science. Lewis Publishers, Boca Raton, FL.

Ruberson, J. R., W. J. Lewis, D. J. Waters, O. Stapel, P. B. Haney. 1995. Dynamics of insect populations in a reduced-tillage, crimson clover/cotton system, pp. 814–821. *In* Proceedings, Beltwide Cotton Conferences. National Cotton Council, Memphis, TN.

Ruberson, J. R., S. C. Phatak, and W. J. Lewis. 1997. Insect populations in a cover crop/strip till system, pp. 1121–1124. *In* Proceedings, Beltwide Cotton Conferences. National Cotton Council, Memphis, TN.

SAS Institute. 1999. SAS/STAT user's guide, version 8. SAS Institute, Cary, NC.

Showler, A. T., and T. E. Reagan. 1987. Ecological interactions of the red imported fire ant in the southeastern United States. J. Entomol. Sci. Suppl. 1: 52-64.

Table 1. Mean number of dates in which heliothines exceeded the economic threshold in cotton for all cover crop treatments in 2001 and 2002

Treatment	Times exceeded economic threshold in 2001		Times exceeded economic threshold in 2002	
	n[a]	Mean	n[a]	Mean
Control	4	2.0 ± 0.41a	4	3.3 ± 0.63a
Legume mixture[b] + rye	3	1.3 ± 0.33ab	4	2.3 ± 0.48ab
Legume mixture	4	1.0 ± 0.41 ab	4	2.0 ± 0.41ab
Crimson clover	4	0.75 ± 0.25b	3	1.7 ± 0.33b
Rye	3	0.3 ± 0.33b	3	1.0 ± 0.33b

Means within a column followed by the same letter are not statistically different between treatments (PROC GLM, LSD, $P > 0.05$).
[a]Refers to the number of fields for each cover crop treatment.
[b]Legume mixture = balansa clover, crimson clover and hairy vetch.

Table 2. Least squares means for predators in sweep samples in all cover crops treatments in 2001

Crop type	Treatment	n[a]	Fire ants	N	*G. punctipes*	n	*O. insidiosus*	n	Lady beetles
Cover crop	Legume mixture[b]	1067	0.61 ± 0.02a2	1067	0.77 ± 0.03b1	780	1.55 ± 0.06a1	1067	0.96 ± 0.03a1
	Crimson clover	1004	0.56 ± 0.01b2	1004	0.86 ± 0.02a1	1004	0.97 ± 0.03b1	1004	0.74 ± 0.02b2
	Legume[c] + rye	738	0.56 ± 0.02b2	738	0.53 ± 0.01c2	536	0.70 ± 0.03c1	738	0.67 ± 0.02c2
	Rye	724	0.51 ± 0.01c2	362	0.51 ± 0.01d2	724	0.55 ± 0.01d1	724	0.65 ± 0.02c2
Cotton	Legume mixture	439	1.00 ± 0.06b1	439	0.66 ± 0.03ab2	439	0.51 ± 0.01b2	439	0.88 ± 0.04c1
	Crimson clover	384	1.22 ± 0.07a1	384	0.75 ± 0.03a2	384	0.54 ± 0.02a2	384	0.91 ± 0.04bc1
	Legume + rye	315	1.04 ± 0.06b1	315	0.65 ± 0.03b1	315	0.52 ± 0.01ab2	315	0.90 ± 0.04bc1
	Rye	315	1.23 ± 0.07a1	315	0.67 ± 0.03ab1	315	0.54 ± 0.02ab1	315	1.01 ± 0.06b1
	Control	420	0.76 ± 0.03c	420	0.63 ± 0.03b	420	0.59 ± 0.02ab	420	1.19 ± 0.04a

Least squares means within a column followed by the same number are not significantly different between crop types for a single cover crop treatment, and least squares means within a column followed by the same letter are not significantly different between cover crop treatments for a single crop type (one-tailed *t*-statistics of least squares means applied to square-root transformed data, $P >$ 0.05).

[a]Refers to the number of sweep samples for each cover crop treatment field for each sampling location for each sampling week. Degrees of freedom for rye and legume mixture + rye treatments are n-30 for cover crop type. Degrees of freedom for crimson clover and the legume mixture are n-33 for cover crop type. Degrees of freedom for all treatments in the cotton crop type are n-15.

[b]Legume mixture = balansa clover, crimson clover and hairy vetch.

[c]Legume mixture.

Table 3. Least squares means for predators in sweep samples in all cover crops treatments in 2002

Crop type	Treatment	n[a]	Fire ants	n	*G. punctipes*	n	*O. insidiosus*	n	Lady beetles
Cover crop	Legume mixture[b]	891	0.53 ± 0.01b2	891	0.90 ± 0.02a1	891	0.94 ± 0.02b1	891	0.75 ± 0.02a1
	Crimson clover	729	0.58 ± 0.01a2	729	0.88 ± 0.02a1	729	1.03 ± 0.02a1	729	0.76 ± 0.02a1
	Legume[c] + rye	891	0.57 ± 0.01a2	891	0.54 ± 0.01b1	891	0.58 ± 0.01c1	891	0.61 ± 0.01b2
	Rye	729	0.57 ± 0.01a2	405	0.51 ± 0.01c2	567	0.55 ± 0.01d1	729	0.57 ± 0.01b2
Cotton	Legume mixture	336	0.86 ± 0.03ab1	336	0.58 ± 0.01a2	192	0.55 ± 0.01a2	336	0.71 ± 0.02b2
	Crimson clover	264	0.87 ± 0.03ab1	264	0.60 ± 0.01a2	120	0.51 ± 0.01b2	264	0.70 ± 0.03b2
	Legume + rye	336	0.91 ± 0.03a1	264	0.53 ± 0.01b1	264	0.53 ± 0.01b2	336	0.75 ± 0.02b1
	Rye	264	0.80 ± 0.03b1	192	0.59 ± 0.02a1	264	0.55 ± 0.01a1	264	0.88 ± 0.03a1
	Control	192	0.59 ± 0.02c	336	0.58 ± 0.01a	336	0.56 ± 0.01a	336	0.77 ± 0.02ab

Least squares means within a column followed by the same number are not significantly different between crop types for a single cover crop treatment, and least squares means within a column followed by the same letter are not significantly different between cover crop treatments for a single crop type (one-tailed *t*-statistics of least squares means applied to square-root transformed data, $P > 0.05$).

[a]Refers to the number of sweep samples for each cover crop treatment field for each sampling location for each sampling week. Degrees of freedom for all treatments are n-27 for cover crop type. Degrees of freedom for all treatments in the cotton crop type are n-12.

[b]Legume mixture = balansa clover, crimson clover and hairy vetch.

[c]Legume mixture.

Table 4. Least squares means for seed-cotton yield for all cover crop treatments in 2001 and 2002

	Seed-cotton yield (kg/ha) 2001		Seed-cotton yield (kg/ha) 2002	
Treatment	**n[a]**	**Mean ± SE**	**n**	**Mean ± SE**
Crimson clover	**3**	**3778.2 ± 249.6a**	**3**	**2026.2 ± 235.8a**
Legume mixture[b] + rye	**3**	**3586.0 ± 249.6ab**	**3**	**2161.3 ± 164.1a**
Rye	**3**	**3304.2 ± 249.6abc**	**3**	**1390.4 ± 222.8b**
Legume mixture	**4**	**3045.4 ± 222.8bc**	**4**	**2031.0 ± 244.4a**
Control	**4**	**2822.2 ± 222.8c**	**4**	**1072.4 ± 57.3b**

Least square means within a column followed by the same letter are not significantly different between treatments (PROC MIXED, LSD, $P > 0.05$).
[a]Refers to the number of fields for each cover crop treatment.
[b]Legume mixture = balansa clover, crimson clover and hairy vetch.