CBCS
http://agrobiol.sggw.waw.pl/cbcs

Communications in Biometry and Crop Science
Vol. 6, No. 1, 2011, pp. 21–30

International Journal of the Faculty of Agriculture and Biology,
Warsaw University of Life Sciences, Poland

REGULAR ARTICLE

Weed seed bank density and composition in a tillage and landscape variability study

Jessica A. Kelton[1], Andrew J. Price[2*], Edzard van Santen[1], Kipling S. Balkcom[2], Francisco J. Arriaga[2], Joey N. Shaw[2]

[1] Department of Agronomy and Soils, Auburn University, Auburn, Alabama, United States.
[2] United States Department of Agriculture, Agricultural Research Service, National Soil Dynamics Laboratory, Auburn, Alabama, United States.
* Corresponding author: Andrew J. Price E-mail: andrew.price@ars.usda.gov

CITATION: Kelton, J.A., Price, A.J., van Santen, E., Balkcom, K.S., Arriaga, F.J., Shaw, J.N. (2011). Weed seed bank density and composition in a tillage and landscape variability study. *Communications in Biometry and Crop Science* 6 (1), 21–30.

Received: 6 April 2010, Accepted: 23 March 2011, Published online: 5 April 2011

ABSTRACT
Research has shown that weed communities are influenced by many factors including cropping systems, tillage practices, and geographical landscape. Evaluating response of the weed seed bank to varying agricultural practices and landscape positions can lead to better site-specific weed control strategies. Therefore, the objective of this study was to evaluate cropping and landscape affects on weed seed bank composition and density. Soil samples were collected from an established experiment located at the E.V. Smith Research and Extension Center near Shorter, AL. The treatment design was a factorial arrangement of two tillage systems (conventional and no-till), two manure (with and without), and three landscape positions, in a corn (*Zea mays* L.) cotton (*Gossypium hirsutum* L.) rotation. A greenhouse study was conducted using soil samples from the experiment to identify weed seedlings from each treatment. Results from this experiment indicate that the inclusion of high residue cover crops into a conservation tillage system can reduce weed seed within the upper 7.6 cm of the soil seed bank.
Key Words: *conservation tillage; cover crops; seed bank dynamics; seedling recruitment.*

INTRODUCTION

Successful weed management methods are an integral part of productive agricultural systems. Research has shown that weed communities are influenced by various factors (Buhler et al., 2000; Cardina et al., 2002); consequently, weed management practices will differ under varying agricultural systems and landscapes. Understanding how and to what extent environmental factors and cropping system methods affect weed population dynamics imparts further knowledge with which to combat problematic weed communities.

As the use of conservation tillage systems increases because of soil and moisture benefits (Tubbs and Gallaher, 2000; Saini et al., 2006), weed control from tillage, in conventional systems is being replaced by chemical weed suppression. Greater inputs of herbicides are required due to increased weed densities in reduced tillage systems compared with conventional systems (Cardina et al., 2002; Sosnoskie et al., 2006).

The use of winter cover crops is a common practice in conservation tillage systems throughout the southeastern United States because of various environmental and agricultural benefits (Reeves et al., 2005). Previous research suggests that one of the advantages of high residue cover crop integration into an agricultural system is the ability to suppress winter and early-season weeds through physical and chemical means (Bárberi and Mazzoncini, 2001; Saini et al., 2006). The allelopathic effects of some cover crop residues may also provide a measure of winter as well as early-season summer weed suppression in crop production.

Variations in topography have often been related to fluctuating crop yields (Terra et al., 2006). Kravchenko and Bullock (2000) reported a negative correlation between elevation and yield during periods of low rainfall; during wet periods there was a positive correlation. These studies have been limited to landscape variability effects on crop yields; however, weed populations could be expected to respond in kind. Weed populations have been determined to differ spatially throughout a field under varying conditions (Dieleman et al., 2000).

In this study, we attempt to understand the relationship between the weed seed bank and multiple agricultural management practices and landscape positions. We also hope to gain knowledge pertaining to weed seed bank dynamics in conservation tillage systems compared with conventionally tilled agricultural land.

MATERIALS AND METHODS

FIELD SITE DESCRIPTION AND EXPERIMENTAL APPROACH

Soil cores were collected in 2006 from an established experiment (Terra et al., 2006) located on a 9-ha Coastal Plain field at the Alabama Agricultural Experiment Station's EV Smith Research Center in Shorter, Alabama. Soils at the field site mostly classify as fine and fine-loamy, siliceous, subactive, thermic Typic, Oxyaquic and Aquic Paleudults (Terra et al., 2006).

Experimental methods were described by Terra et al. (2006). The treatment design was a factorial arrangement of two tillage systems [conventional (CT) and no-till sub-soiling (NT)] with and without manure applications of approximately 10 Mg ha^{-1} yr^{-1} annually and three landscape positions determined by Terra et al. (2006) (summit, drainage way, and side slope). The conventional tillage systems consisted of fall chisel plowing and disking followed by field cultivation and in-row subsoiling in the spring 2 to 3 weeks prior to planting. A corn-cotton rotation with both phases of the rotation present each year was used in the experiment. Six replicates were imposed on 6.1 m by 240 m long strips across the field. Each strip in the field was divided into 6.1 m by 18.3 m cells. Conventional tillage systems were prepared with fall plowing and disking followed by cultivation and in-row sub-soiling to 40 cm with a KMC1 ripper, prior to spring sowing. The conservation tillage systems received only in-row sub-soiling in the same way as conventionally tilled plots.

Conservation tillage plots were sown in a mixture of crimson clover (*Trifolium incarnatum* L.), fodder radish (*Raphanus sativus* L.), and white lupin (*Lupinus albus* L.) prior to corn and rye (*Secale cereale* L.) and black oat (*Avena strigosa* Schreb.) mixture before cotton. Termination of cover crops at anthesis was accomplished by glyphosate at 1 kg ha^{-1} of isopropylamine salt followed by a mechanical roller.

DATA COLLECTION AND GREENHOUSE PROCEDURES

Five soil cores, each with a radius of 3.8 cm, were taken, to a depth of 15.2 cm, from each of 72 cells representing 3 replicates of all treatment combinations. The soil cores were then divided into two depths (0 - 7.6 cm and 7.6 - 15.2 cm). Following the methods of Cardina and Sparrow (1996), samples were washed and sieved to break up soil clods and remove large debris. Each sample was then placed in a 28 x 28 x 5 cm plastic flat on top of a sand bed in an enclosed greenhouse and watered daily. Temperatures were set for day/night values of 25 and 22 C respectively.

As weed seedlings emerged and were identified they were counted and removed from the flats. Seedling identification and removal continued periodically in this manner for approximately 5 months until seedling emergence ceased. At this point, soil samples were individually bagged in 3.7-L plastic bags, which were stored in a cooler at 3 C for three months to simulate winter temperatures. Samples were then returned to flats in the greenhouse under the same conditions. During this second greenhouse period, weed seedling counts continued for approximately four months until seedling emergence had ceased.

DATA ANALYSIS

A relative importance (RI) index value, or relative abundance value, was calculated for individual species in each plot to describe the occurrence of weed species (Table 1). Data analysis proceeded with a separate analysis for each depth using mixed models procedures as implemented in SAS® PROC GLIMMIX. Weed seed density (seed m^{-2}) required the lognormal distribution to arrive at normally distributed residuals, whereas species richness (*S*), evenness (*J*), and diversity (*H'*) were analyzed using a normal distribution function. Factors tillage, landscape position, manure, and crop, and their interactions were considered to be main effects, whereas block from the original experiment (Terra et al., 2006) was the lone random effect.

RESULTS

SPECIES COMPOSITION

We identified 19,087 individual seedlings in this experiment, which belonged to 19 families; a total of 32 species (27 annual, 4 perennial, and 1 annual/biennial) were present (Table 1). The six major weeds were henbit (*Lamium amplexicaule* L.) (15,376), common chickweed [*Stellaria media* (L.) Vill.] (851), annual bluegrass (*Poa annua* L.) (739), smallflowered bittercress (*Cardamine perviflora* L.) (587), carpetweed (*Mollugo verticillata* L.) (539), and purple cudweed [*Gamochaeta purpurea* (L.) Cabrera] (398).

WEED SEED DENSITY

Weed seed density data analysis indicated that there were significant ($P \leq 0.0191$) differences among main effect levels for tillage, manure application and in the 0 - to 7.6-cm depth range (Table 2). Summit and side slope weed densities differed at a simulation adjusted ($P = 0.0909$). The differences for the deeper soil cores indicated that crop did not play a role ($P = 0.4346$) but the summit zone differed from the other two zones at ($P \leq 0.099$; Table 3). Mean weed seed density for the no-till plots was 23,220 seeds m^{-2} and 53,978 seeds m^{-2} for the conventionally tilled plots in shallow core samples; in deeper core samples, there was 859 seeds m^{-2} in no-till tilled and 14,127 seeds m^{-2} in conventionally tilled plots, showing the tendency of conventional tillage to transport weed seed down the soil profile. Addition of manure to plots increased seed density at both soil core depths, although there were five times as many weeds seeds in the top 7.6 cm than were at the lower soil depth with manure addition (46,240 vs. 8,048 seeds m^{-2}). Corn plots had 42,587 seeds m^{-2} at the shallow depth compared to 29,431 seeds m^{-2} for cotton; densities were an order of magnitude lower in the deep cores and not significantly different between crops.

Table 1. Seed bank weed species composition and relative abundance.

Latin Name	Common Name	Bayer code	Life history*	Relative abundance
Amaranthus spp.	Amaranthus spp.	AMA**	A	0.16
Capsella bursa-pastoris (L.) Medik.	Shepherd's purse	CAPBP	WA	0.82
Cardamine parviflora L.	Smallflowered bittercress	CARPA	WA	3.07
Cerastium fontanum ssp. vulgare (Hartman) Greuter & Burdet	Mouseear chickweed	CERVU	WA	0.08
Chenopodium album L.	Common lambsquarters	CHEAL	SA	0.04
Conyza canadensis (L.) Cronq.	Horseweed	ERICA	A	0.01
Coronopus didymus (L.) Sm.	Lesser swinecress	COPDI	WA	0.75
Dactyloctenium aegyptium (L.) Willd.	Crowfootgrass	DTTAE	SA	0.01
Digitaria ciliaris (Retz.) Koel.	Southern crabgrass	DIGSP	SA	0.01
Eleusine indica (L.) Gaertn.	Goosegrass	ELEIN	SA	0.19
Eragrostis cilianensis (All.) Vign. ex Janchen	Stinkgrass	ERACN	SA	0.02
Eupatorium capillifolium (Lam.) Small	Dogfennel	EUPCP	P	0.02
Chamaesyce maculata L. Small	Spotted spurge	EPHMA	SA	0.20
Geranium carolinianum L.	Carolina geranium	GERCA	WA	0.06
Gamochaeta purpurea (L.) Cabrera	Purple cudweed	GNAPU	A/B	2.10
Jacquemontia tamnifolia (L.) Griseb.	Smallflower morningglory	IAQTA	SA	0.01
Lamium amplexicaule L.	Henbit	LAMAM	WA	80.39
Melochia corchorifolia L.	Redweed	MEOCO	A	0.08
Mollugo verticillata L.	Carpetweed	MOLVE	SA	2.92
Nuttallanthus canadensis (L.) D.A. Sutton	Oldfield toadflax	----------	A	0.01
Oenothera laciniata Hill	Cutleaf evening-primrose	OEOLA	WA	0.06
Oxalis stricta L.	Yellow woodsorrel	OXAST	P	0.01
Physalis angulata L.	Cutleaf groundcherry	PHYAN	A	0.03
Poa annua L.	Annual bluegrass	POAAN	WA	3.87
Polypremum procumbens L.	Rustweed	POEPR	P	0.03
Sisyrinchium rosulatrum Bickn.	Blue-eyed grass	---------	WA	0.01
Spergula arvensis L.	Corn spurry	SPRAR	A	0.24
Stellaria media (L.) Vill.	Common chickweed	STEME	WA	4.45
Triodanis perfoliata (L.) Nieuwl. var. *biflora* (Ruiz & Pavon) Bradley	Small venuslookingglass	TJDBI	WA	0.01
Urochloa texana (Buckl.) R. Webster	Texas millet	URTE2	SA	0.02
Vernonia glauca (L.) Willd.	Broadleaf ironweed	---------	P	0.01
Veronica peregrina L.	Purslane speedwell	VERPG	WA	0.37

* A, annual; WA, winter annual; SA, summer annual; P, perennial; A/B, annual or biennial. Life histories were determined by Radford et al. (1968).

Table 2. Mean seed density for each treatment within the upper soil core samples (0-7.6-cm). Data were analyzed using a lognormal distribution function, hence confidence intervals are provided for the back-transformed means to indicate the precision of the estimate.

				Simulation adjusted *P*-value vs.	
Factor	Level	Count	90% CI	Level 2	Level 3
		Seeds m^{-2}			
Tillage	Non-inversion	23,220	(18936, 28473)	0.0001	
	Conventional	53,978	(43564, 66879)		
Manure	Yes	46,240	(37507, 57005)	0.0012	
	No	27,106	(21991, 33409)		
Crop	Corn	42,587	(34050, 53262)	0.0191	
	Cotton	29,431	(24201, 35790)		
Zone	Summit	40,554	(31859, 51620)	0.9981	0.0909
	Drainage way	40,074	(30297, 53004)		0.1470
	Side slope	27,304	(21455, 34746)		

Table 3: Mean seed density for each treatment within the lower soil core (7.6-15.2-cm) samples. Data were analyzed using a lognormal distribution function, hence confidence intervals are provided for the back-transformed means to indicate the precision of the estimate.

				Simulation adjusted *P*-value vs.	
Factor	Level	Count	90% CI	Level 2	Level 3
		Seeds m^{-2}			
Tillage	Non-inversion	859	(304, 2417)	0.0001	
	Conventional	14,127	(5049, 39522)		
Manure	Yes	8,048	(2867, 22581)	0.0001	
	No	1,508	(536, 4238)		
Crop	Corn	3,000	(1071, 8398)	0.4364	
	Cotton	4,045	(1430, 11435)		
Zone	Summit	5,245	(1798, 15287)	0.9969	0.0418
	Drainage way	5,018	(1659, 15171)		0.0986
	Side slope	1,606	(569, 4529)		

SPECIES RICHNESS, DIVERSITY, AND EVENNESS

Species richness (*S*) was influenced by landscape position and manure application in soil cores down to 7.6-cm with manure application significantly increasing species richness and drainage way > summit > side slope (Table 4). In deeper soil cores species, richness was influenced by all main effects except crop (Table 5). There were significant interactions for the 0 to 7.6 cm soil samples between landscape position and tillage practice as well as between landscape position and crop (Fig. 1). While the ranking of summit and slide slope relative to each other remained the same between conventionally tilled and no-till plots, the drainage way had significantly higher species richness in conventionally tilled plots. Species richness for side slope samples from no-till plots had significantly lower species richness than the two other zones. The zone x crop interaction was due to both changes in rank as well as magnitude. Cotton plots from the drainage way zone had the highest species richness values.

No significant main effects were observed for species evenness (*J*) at either soil depths but there was a significant interactions between tillage and manure application in the upper soil cores as conventional tillage apparently caused a mixing of weed seed resulting at a greater evenness when manure was applied, whereas no significant difference was observed under no-till (Fig. 2). In the 7.6 to 15.2 cm soil cores, *J* was lower in no-till plots when planted to corn.

Species diversity, as defined by the Shannon-Wiener index (*H*′), was significantly different for all zones with drainage way > summit > side slope (Table 4). The ranking for *H*′ was maintained in the deeper cores, but only side slope was significantly different from the other two (Table 5). Interactions occurred in the 0 to 7.6-cm soil cores between tillage and landscape position as well as tillage and manure application (Fig. 3). Drainage way position had the highest diversity index under conventional tillage; under no-till tillage the side slope had a significantly lower index than the other landscape positions (Fig. 3). The effect of manure application on *H*′ was the opposite under no-till compared to conventional tillage. Thus no broad generalization of manure application on species diversity may be made.

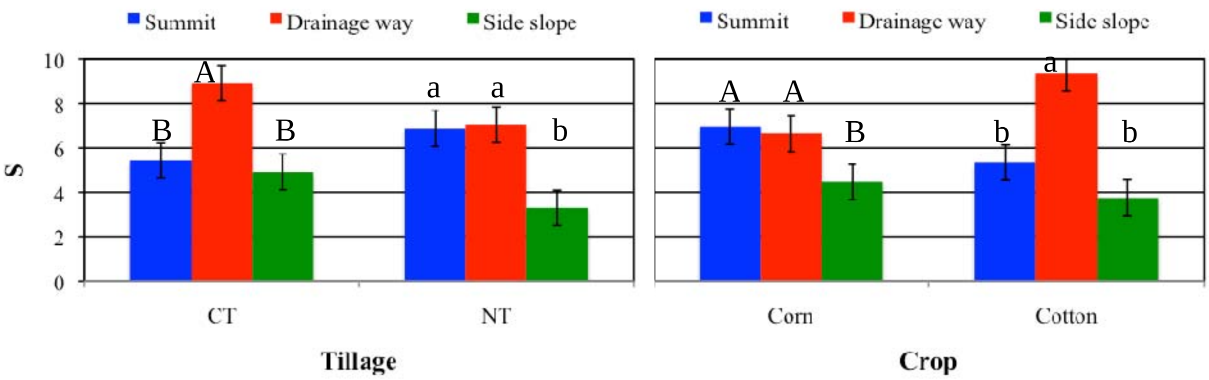

Figure 1. Species richness (*S*) from the 0 to 7.6 cm soil cores as determined by slope position and tillage or crop. Means within a tillage or crop treatments with different letters are different at a simulation adjusted $P \leq 0.10$.

Table 4: Calculated values for richness (*S*), evenness (*J*), and the Shannon-Wiener diversity index (*H*') for main treatments among the 0- to 7.6-cm soil cores. Significant differences between values within treatments at simulation adjusted $P < 0.10$ are identified by a different letter following the value.

Treatment	Richness (*S*)	Evenness (*J*)	Diversity Index (*H*')
Tillage			
Conventional	6.42	0.37	0.69
Non-inversion	5.74	0.39	0.66
SE	0.42	0.03	0.05
Manure			
Yes	6.61 a	0.36	0.67
No	5.54 b	0.40	0.68
SE	0.40	0.03	0.05
Crop			
Corn	6.01	0.35	0.63
Cotton	6.14	0.41	0.72
SE	0.44	0.03	0.06
Zone			
Summit	6.15 b	0.39	0.70 b
Drainage way	7.98 a	0.40	0.81 a
Side slope	4.10 c	0.36	0.51 c
SE	0.51	0.04	0.07

Table 5: Calculated values for richness (*S*), evenness (*J*), and the Shannon-Wiener diversity index (*H*') for main treatments among the 7.6-to 15.2-cm soil cores. Significant differences between values within treatments at simulation adjusted $P < 0.10$ are identified by a different letter following the value.

Treatment	Richness (*S*)	Evenness (*J*)	Diversity Index (*H*')
Tillage			
Conventional	4.93 a	0.38	0.56 a
Non-inversion	2.04 b	0.41	0.40 b
SE	0.34	0.06	0.07
Manure			
Yes	4.17 a	0.40	0.52
No	2.81 b	0.40	0.44
SE	0.32	0.06	0.07
Crop			
Corn	3.17	0.42	0.47
Cotton	3.81	0.38	0.49
SE	0.35	0.06	0.07
Zone			
Summit	3.40 b	0.41	0.50 a
Drainage way	4.75 a	0.46	0.65 a
Side slope	2.31 c	0.32	0.30 b
SE	0.41	0.08	0.09

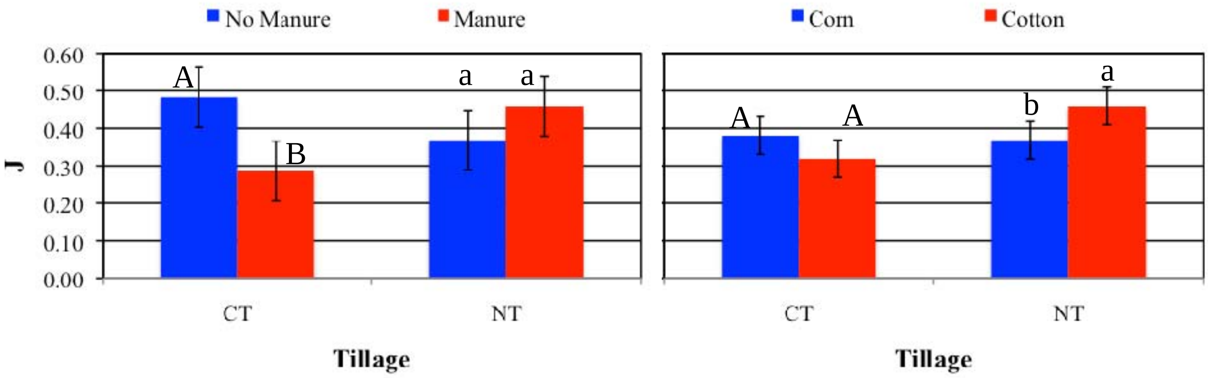

Figure 2. Species evenness (*J*) from the 0 to 7.6 cm soil cores as determined by tillage and manure application (left panel) or from the 7.6 -15.2 cm soil cores as determined by tillage and crop (right panel). Means within a tillage or crop treatments with different letters are different at a simulation adjusted $P \leq 0.10$.

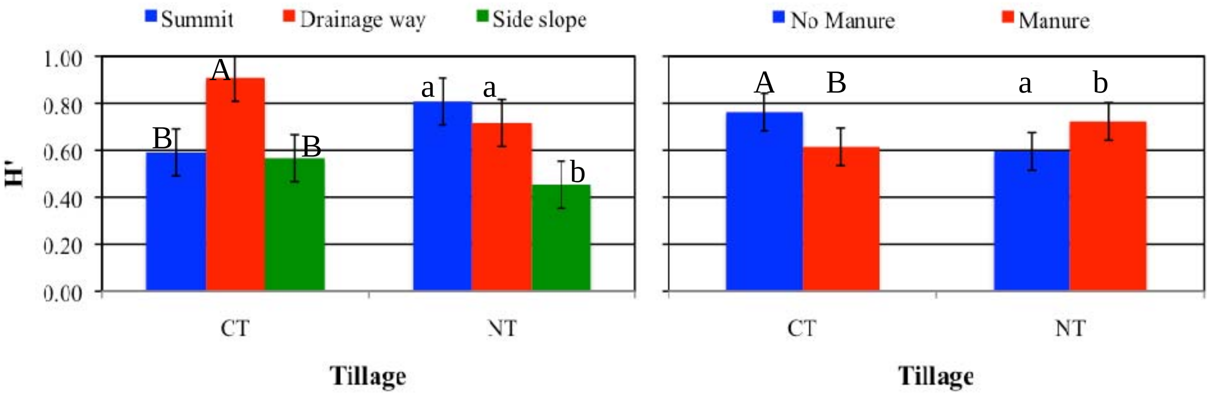

Figure 3. Species diversity (*H'*) from the 0 to 7.6 cm soil cores as determined by tillage and slope position or crop. Means within tillage treatments with different letters are different at a simulation adjusted $P \leq 0.10$.

RESULT IMPLICATIONS FOR WEED MANAGEMENT

Previous research has noted species composition shifts in response to varying treatments and environmental factors (Barberi and Mazzoncini, 2001; Guretzky et al., 2005). Further research is needed to determine weed community trends based on treatments and potentially offer predictions of future weed species composition in the respective treatments, specifically cover crop systems.

Winter and early-season summer weed seed density in this experiment saw a significant reduction in the shallow no-till sub-soiled plots where both clover and rye cover crops were planted when compared to conventionally tilled plots. This finding agrees with previous publications that demonstrated a reduction in weed density when cover cropping is integrated into a conservation system (Bárberi and Mazzoncini, 2001; Saini et al., 2006).

Previous research reported increased weed densities as tillage intensity was reduced (Cardina et al., 2002; Sosnoskie et al., 2006). Other research reports different responses by individual species under varying tillage practices and over time (Chhokar et al., 2007; Steckel et al., 2007). In these experiments, the research was focused on determining the difference in seed bank densities between reduced tillage and conventional tillage systems; no research reported the inclusion of high residue cover crops into reduced tillage practices. Our findings, however, contradict Bárberi and Mazzoncini (2001) who found lower input systems with cover crops had increased weed seed densities in subsequent years compared with conventional systems. These results show that the use of cover crops in reduced tillage systems may offer the potential to adopt a conservation tillage system without an increase herbicide usage to keep overall weed density in check. Further research is needed to determine if long-term adoption of cover crops could lead to an eventual reduction in herbicide applications once the soil seed bank has been sufficiently depleted.

CONCLUSIONS

To conclude, determining how, and to what extent, weed communities are affected by agricultural management systems is a complex and challenging undertaking. With each new experiment, progress is made toward understanding how the agricultural community can direct and influence the weed seed bank. In future, with greater insight, it is likely that we will be able to accurately predict and plan for weed species and species shifts in most agricultural settings.

SOURCES OF MATERIALS

[1] KMC ripper, Kelly Manufacturing Company, 80 Vernon Drive, Tifton, GA 31793.
[2] SAS software, version 9.2, Statistical Analysis Systems Institute Inc. Cary, NC 27513.

ACKNOWLEDGMENTS

The authors wish to thank Mr. Jarrod Jones, Mr. Jason Ward, Mr. Carl Mannschreck, and Mrs. Maria Stoll for their invaluable assistance with sample collection and project execution.

REFERENCES

Bárberi, P., Mazzoncini, M. (2001). Changes in weed community composition as influenced by cover crop and management system in continuous corn. *Weed Science* 49, 491–499.

Buhler, D.D., Liebman, M., Obrycki, J.J. (2000). Theoretical and practical challenges to an IPM approach to weed management. *Weed Science* 48, 274–280.

Cardina, J., Regnier, E., Harrison, K. (1991). Long-term tillage effects on seed banks in three Ohio soils. *Weed Science* 39, 186–194.

Cardina, J., Herms, C.P., Doohan, D.J. (2002). Crop rotation and tillage system effects on weed seedbanks. *Weed Science* 50, 448–460.

Chhokar, R.S., Sharma, R.K., Jat, G.R., Pundir, A.K., Gathala, M.K. (2007). Effect of tillage and herbicides on weeds and productivity of wheat under rice-wheat growing system. *Crop Protection* 26, 1689–1696.

Dieleman, J.A., Mortensen, D.A., Buhler, D.D., Ferguson, R.B. (2000). Identifying associations among site properties and weed species abundance. II. Hypothesis generation. *Weed Science* 48, 576–587.

Guretzky, J.A., Moore, K.J., Brummer, E.C., Burras, C.L. (2005). Species diversity and functional composition of pastures that vary in landscape position and grazing management. *Crop Science* 45, 282–289.

Kravchenko, A.N., Bullock, D.G. (2000). Correlation of corn and soybean grain yield with topography and soil properties. *Agronomy Journal* 92, 75–83.

Radford, A.E., Ahles, H.E., Bell, C.R. (1968). *Manual of the Vascular Flora of the Carolinas*. Chapel Hill, NC: University of North Carolina Press.

Reeves, W., Price, A.J., Patterson, M.G. (2005). Evaluation of three cereals for weed control in conservation-tillage nontransgenic cotton. *Weed Technology* 19, 731–736.

Saini, M., Price, A.J., van Santen, E. (2006). Cover crop residue effects on early-season weed establishment in a conservation-tillage corn-cotton rotation. *Proceedings of the 28th Annual Southern Conservation Systems Conference. Amarillo, TX, 26 – 28, June*. 175-182.

Sosnoskie, L.M., Herms, C.P., Cardina, J. (2006). Weed seed bank community composition in a 35-yr-old tillage and rotation experiment. *Weed Science* 54, 263–273.

Steckel, L.E., Sprague, C.L., Stoller, E.W. Wax, L.M., Simmons, F.W. (2007). Tillage, cropping system, and soil depth effects on common waterhemp (*Amaranthus rudis*) seed-bank persistence. *Weed Science* 55, 235–239.

Terra, J.A., Shaw, J.N., Reeves, D.W., Raper, R.L., van Santen, E., Schwab, E.B., Mask, P.L. (2006). Soil management and landscape variability affects field-scale cotton productivity. *Soil Science Society of America Journal* 70, 98–107.

Tubbs, R.S. Gallaher, R.N. (2005). Conservation tillage and herbicide management for two peanut cultivars. *Agronomy Journal* 97, 500–504.