Expl Agric. (2009), volume 45, pp. 25–33 © *2008 Cambridge University Press*
doi:10.1017/S0014479708006972 First published online 28 October 2008 *Printed in the United Kingdom*

PRELIMINARY STUDIES OF PEST CONSTRAINTS TO COTTON SEEDLINGS IN A DIRECT SEEDING MULCH-BASED SYSTEM IN CAMEROON

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(*Accepted 19 March 2008*)

SUMMARY

The present study evaluated the pest constraints of an innovative crop management system in Cameroon involving conservation tillage and direct seeding mulch-based strategies. We hypothesized that the presence of mulch (i) would support a higher density of phytophagous arthropods particularly millipedes as well as pathogenic fungi that cause severe damage to cotton seedlings and (ii) would reduce early aphid infestations. The impact of two cover-crop mulches *Calopogonium mucunoides* and *Brachiaria ruziziensis* on the vigour of seedling cotton stands and arthropod damage was assessed in two independent field experiments conducted in 2001 and 2002 respectively. In both experiments the presence of mulch negatively affected cotton seedling stand by 13–14 % compared to non-mulched plots and the proportion of damaged seedlings was higher in mulched than in non-mulched plots supporting the hypothesis that mulch favoured soil pest damage. In both experiments insecticidal seed dressing increased the seedling stand and the number of dead millipedes collected and fungicide had little or no effect on seedling stand and vigour. It was however observed in 2002 that the fungicide seed dressing had a positive effect on seedling stand in non-mulched plots but not in mulched plots suggesting that fungi may have been naturally inhibited by *B. ruziziensis* mulch. The dynamics of aphid colonization was not influenced by the presence of mulch. In 2001 taller seedlings were found in mulched than non-mulched plots probably due to greater water and nutrient availability in *C. mucunoides*-mulched plots than in non-mulched plots.

INTRODUCTION

Conservation tillage and direct seeding mulch-based management strategies have shown success in the preservation or restoration of biodiversity of both soil fauna and microflora (Blanchart *et al.*, 2006, 2007; Brévault *et al.*, 2007; Marasas *et al.*, 2001; Maria de Aquino *et al.*, 2008; Wilson-Rummenie *et al.*, 1999). Mulch serves as a suitable refuge for soil and litter organisms by protecting the habitat against water and wind erosion, regulating environmental conditions and maintaining food availability (Kladivko, 2001; Stinner and House, 1990; Thorbek and Bilde, 2004; Tian *et al.*, 1993). In addition, mulch may significantly reduce insect infestations. For example, mulch interferes with the visual orientation of winged aphids during host plant location (Doring and Chittka, 2007). However, the effects of a direct seeding mulch-based system on crop pests are difficult to predict (Stinner and House, 1990; Ratnadass

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et al., 2006). For example, Madagascar black beetles (*Heteronychus* spp.) are reported to cause significant damage to mulch-grown rice at the onset of the growing season (Ratnadass *et al.*, 2006). Conversely, mulch reduces the infestation of soil-inhabiting herbivores such as the Colorado potato beetle (*Leptinotarsa decemlineata*) by disrupting the emergence and migration of adults (Teasdale *et al.*, 2004).

Cotton (*Gossypium hirsutum*) occupies more than 30% of the agricultural landscape in northern Cameroon and is cultivated by roughly 300 000 farmers (Mbetid-Bessane *et al.*, 2006). Traditional soil management systems include systematic exportation or crop residue burning and reductions in fallow periods. These practices have led to the large-scale depletion of organic matter and soil degradation. As a result, a consistent decrease in cottonseed yields has been observed for over a decade in conventional cotton cropping systems. To increase crop yield sustainability, national research programmes and extension services have implemented soil restoration measures through the 'Eau Sol Arbre' Project. A no-till with mulch soil management strategy is being promoted. The recommended mulch cover applied to cotton comprises plant residues from the previous crop (usually cereal straw) intercropped with a cover crop (Naudin *et al.*, 2003). The introduction of this soil management strategy significantly restores soil fertility (Erenstein, 2003; Ito *et al.*, 2006); however, few detailed studies have focused on mulch pest dynamics, particularly at the cotton seedling stage.

The objective of this study was to evaluate the levels of damage caused by major cotton seedling pests, including soil arthropods, soil fungi and aphids (*Aphis gossypii*). We hypothesized that the presence of mulch (i) would support a higher density of phytophagous arthropods, particularly millipedes (Julidae), as well as pathogenic fungi that cause severe damage to cotton seedlings, and (ii) would reduce early aphid infestations. The vigour of cotton seedling stands and arthropod damage were assessed according to soil cover (with or without mulch) and seed dressing (with or without insecticide or fungicide) treatments. The results provide valuable data to use in designing effective crop management practices for cotton farmers interested in direct seeding mulch-based systems.

MATERIAL AND METHODS

Experimental design

Two independent field experiments were conducted during the 2001 and 2002 growing seasons at the IRAD and SODECOTON Research Stations near Garoua (9°23′N, 13°45′E). In both experiments, three factors were studied: (i) presence or absence of mulch, (ii) seed dressing with Marshal 35 DS, a systemic insecticide (carbosulfan, carbamate with contact and stomach action to control a wide range of soil dwelling pests, including millipedes, 3 g active ingredient (a.i.) kg^{-1} lint seeds), and (iii) seed dressing with Caltir 80 WS, a broad-spectrum fungicide (thiram, dimethyldithiocarbamate with protective contact action to prevent damping-off from *Pythium* and *Fusarium* spp., 1 g a.i. kg^{-1} lint seeds). The study employed a total of eight treatments designed from the following combinations: non-tilled soil with (M) or without (S) cover-crop mulch, seed dressing with insecticide (I), fungicide (F), insecticide and fungicide (IF) or untreated control (C). Six and five replicates of each treatment were applied to six 4.8 m wide and 10 m long rows, in 2001 and 2002, respectively. The experiment was designed to apply a randomized complete block for subsequent data analysis.

Cover-crop mulches included *Calopogonium mucunoides* (Fabaceace) in the 2001 study, and *Brachiaria ruziziensis* (Poaceae) in the 2002 study, intercropped with maize established late in the previous season. Seven days prior to cotton planting, living plants were killed by the application of a post-emergence herbicide (glyphosate, 720 g a.i. ha^{-1}) on the entire experimental surface; the residue was left on the soil surface. A superficial scraping was performed to clean the plots assigned to direct seeding in the absence of mulch. A previously coated 10 l vessel with a lid was used to dress 2 kg of seeds with a powder formulation. The cotton variety 'Irma A1239' was planted on 17 July 2001 and 22 June 2002. Twenty-five mounds per row were constructed with special hoes equipped with a flap to obtain a 2 cm homogeneous planting depth. Five seeds were deposited in each of the 25 mounds (40 cm between successive mounds).

Sampling and data analysis

Cotton seedling stands (i.e. number of seedlings) were observed at 10, 15 and 20 days after sowing (DAS) along the three central rows of each plot, to avoid interactions with neighbouring plots. Damaged cotton seedlings from pests evidenced by a wounded or dried hypocotyl were observed at 7, 10 and 15 DAS along the same rows. Major injuries to cotton seedlings are observed at this period. Dead millipedes, the most harmful arthropods for cotton seedling, were collected daily within the same rows. To assess the effect of treatments on the plant vigour, the height of 20 randomly selected plants along the three central rows was measured at 20 DAS. In addition, aphids were counted from five terminal leaves from four sets of five consecutive plants per plot. Data were analysed using analysis of variance (ANOVA), with SAS GENMOD for binomial and negative binomial distributions and SAS GLM for Gaussian distributions (SAS Institute, 1989).

RESULTS

Cotton seedling stands

In both experiments, the presence of mulch cover crop negatively impacted cotton seedling stand by 13.3 and 13.9 % at 20 DAS in 2001 (*C. mucunoides*) and 2002 (*B. ruziziensis*), respectively (Table 1). In both experiments, seedling stand increased significantly when the insecticidal seed dressing was applied (Table 1). In 2002, a significant interaction between mulch and insecticidal seed dressing was observed: insecticide seed application had a greater effect on seedling stand in mulched plots (+25.2%) than in non-mulched plots (+9.8%). In 2002, the fungicidal seed dressing significantly increased cotton seedling stand (Table 1). In addition, a significant

Table 1. Cotton seedling stand (%) as a function of mulch and seed dressing under two cover crops.

Experiment		2001 *C. mucunoides* Seedling stand (%)			2002 *B. ruziziensis* Seedling stand (%)		
Cover-crop mulch		10 DAS	15 DAS	20 DAS	10 DAS	15 DAS	20 DAS
Mulch	With	46.7	42.8	39.7	56.8	54.0	52.8
	Without	53.0	49.9	46.1	61.1	61.4	60.9
		**	**	**	**	**	**
Insecticide	With	55.5	51.8	47.9	62.5	61.8	61.2
	Without	44.2	41.0	37.9	55.4	53.6	52.5
		**	**	**	**	**	**
Fungicide	With	50.8	47.9	44.6	60.3	59.6	59.0
	Without	48.9	44.9	41.1	57.6	55.8	54.7
						*	*
Interaction	I × F						
	M × I					*	*
	M × F				*	*	*

DAS: days after sowing.
I: insecticide; F: fungicide; M: mulch.
SAS ANOVA GENMOD, $^{*}p < 0.05$ and $^{**}p < 0.01$.

interaction was observed between mulch and fungicidal seed dressing: fungicide seed application significantly increased seedling stand only in non-mulched plots (13.1 %).

Cotton seedling vigour

In both experiments the proportion of damaged seedlings was significantly higher in mulched plots than in non-mulched plots (Table 2). However, the number of dead millipedes collected was significantly higher in mulched plots than in plots without mulch only in 2001 (*B. ruziziensis*). In both experiments, insecticidal or fungicidal seed dressing had no effect on the proportion of damaged seedlings. However, in both experiments, significantly more dead millipedes were collected on plots where seeds had been coated with insecticide (Table 2). In 2002 (*B. ruziziensis*), a significant interaction between mulch and insecticidal seed dressing showed that insecticide had a greater effect in mulched plots. In both experiments, mulch had a positive effect on seedling height in (Table 2). Insecticide had a positive effect on seedling height only in 2001 (*C. mucunoides*) while fungicide had no effect in either experiment.

Aphid infestation

The temporal observation of aphids on cotton seedlings did not show any significant effect of mulch or seed dressing on the dynamics of field colonization, compared to control plots. However, in the 2001 experiment, qualitatively more aphids were observed on cotton leaves in plots covered with *C. mucunoides* mulch than in bare soil plots at 38 DAS (Table 3).

Table 2. Cotton seedling vigour according to mulch presence and seed dressing under two cover crops.

Experiment	Cover-crop mulch	2001 *C. mucunoides* Damaged seedlings (%) 7 DAS	2001 *C. mucunoides* Damaged seedlings (%) 10 DAS	2001 *C. mucunoides* Damaged seedlings (%) 15 DAS	2001 *C. mucunoides* Mean number of dead millipedes	2001 *C. mucunoides* Seedling height (cm)	2002 *B. ruziziensis* Damaged seedlings (%) 7 DAS	2002 *B. ruziziensis* Damaged seedlings (%) 10 DAS	2002 *B. ruziziensis* Damaged seedlings (%) 15 DAS	2002 *B. ruziziensis* Mean number of dead millipedes	2002 *B. ruziziensis* Seedling height (cm)
Mulch	with	8.6	9.9	7.0	0.9	9.2	5.8	6.5	2.4	4.2	16.3
	without	2.9	5.8	4.4	0.6	7.2	1.0	2.0	0.2	1.3	13.1
		**	**	**		**	**	**	**	**	**
Insecticide	with	5.0	7.4	5.0	1.5	9.0	2.6	3.4	0.9	5.1	14.7
	without	6.5	8.4	6.4	0.0	7.4	4.1	5.2	1.6	0.4	14.7
					**	**				**	
Fungicide	with	5.2	7.5	5.2	0.7	8.4	3.8	4.6	1.1	2.6	14.1
	without	6.3	8.3	6.3	0.8	8.1	3.0	4.0	1.5	2.9	15.3
Interaction	I × F										
	M × I									**	
	M × F										

DAS: days after sowing.

I: insecticide; F: fungicide; M: mulch.

SAS ANOVA GENMOD, $^{*}p < 0.05$ and $^{**}p < 0.01$.

Table 3. Dynamics of aphid infestation according to mulch presence and seed dressing.

Experiment		2001 *C. mucunoides* Aphids per leaf			2002 *B. ruziziensis* Aphids per leaf		
Cover-crop mulch		24 DAS	31 DAS	38 DAS	41 DAS	48 DAS	55 DAS
Mulch	with	0.6	4.0	12.6	0.8	3.6	11.2
	without	0.7	3.0	6.8	0.7	4.0	9.2
				**			
Insecticide	with	0.5	3.1	9.8	0.7	3.9	8.8
	without	0.8	3.9	9.5	0.8	3.7	11.5
Fungicide	with	0.6	3.6	10.4	0.9	4.2	10.8
	without	0.7	3.4	8.9	0.6	3.4	9.5
Interaction	I × F						
	M × I						
	M × F						

DAS: days after sowing.
I: insecticide; F: fungicide; M: mulch.
SAS ANOVA GENMOD, $^{*}p < 0.05$ and $^{**}p < 0.01$.

DISCUSSION

In both experiments, cotton seedling stands were negatively affected by the presence of mulch cover crop. In addition, the proportion of damaged seedlings was higher in mulched than in non-mulched plots, supporting the hypothesis that mulch favoured the presence of soil arthropod pests. In both experiments, insecticidal seed dressing increased the seedling stand and the number of dead millipedes collected, particularly in 2002 in *B. ruziziensis*-mulched plots, As reported by House and Del Rosario Alugaray (1989), mulch provides a suitable habitat for soil arthropods, including detritivores and, less often, herbivores. A disequilibrium between phytophagous and predator communities may follow mulched cropping systems and the adoption of certain mulched cropping systems by farmers may lead to pest outbreaks, particularly of soil-associated pest populations (Brown *et al.*, 2001). In Cameroon, the major risks associated with sowing in mulch-based systems are soil-borne pests, particularly millipedes, which in traditional crop management systems have been controlled by insecticidal protection with carbosulfan (SODECOTON, 2004). Ratnadass *et al.* (2006) point out that following implementation of such crop management practices, it may take time to reach a new biological equilibrium among functional arthropod communities. In Australia, it has been reported that reduced or zero-tillage did not increase the incidence of insect pests on emerging seedlings (Wilson-Rummenie *et al.*, 1999).

In both experiments, fungicide had little or no effect on seedling stand and vigour, indicating that the fungicide used did not suppress seedling diseases caused by soil fungi or that there was no seedling disease. It was, however, observed in 2002 that the fungicide seed dressing had a particular positive effect on seedling stand in non-mulched plots. Accordingly, it may be hypothesized that fungi may have been naturally inhibited under *B. ruziziensis* mulch. Consistent with these results, Doupnik and Boosalis (1980) reported that mulch protected sorghum seedlings from *Fusarium moniliforme* by reducing water stress and the effects of high temperatures that usually favour its activity. Another explanation assumes that mulch-based systems enhance natural microbial antagonist regulation (Altieri, 1999).

The hypothesis suggesting that natural mulch would have been a deterrent to aphids was not clearly supported by this research. Several authors have suggested that mulch background spectral reflectance impedes migrant aphids from landing on cotton plants (Costello, 1995; Doring and Chittka, 2007; Summers *et al.*, 2004) or limits aphid population growth by increasing light intensity on the underside of plant leaves (Rummel *et al.*, 1995). In our two-year experiments, the dynamics of aphid colonization were not influenced by the presence of mulch. In 2001, taller seedlings were documented in mulched plots than in non-mulched plots, probably due to greater water and nutrient availability in the mulched treatment. The more robust seedlings may have enhanced the attractiveness or appetence to aphids. The risk of aphid infestation could be reduced by early sowing and adequate systemic seed protection (Deguine *et al.*, 1994).

This study identified risks associated with direct mulch seeding. The results of this work should aid farmers in transitioning to new farming practices. The preliminary results of this research provide a springboard to further evaluate the effects of different parameters such as mulch composition, biomass, previous crop and age of the cropping system on seedling pest constraints. In addition, attention should be given to soil-inhabiting natural enemies that may assist in the regulation of aerial pests (Peachey *et al.*, 2002; Rypstra and Marshall, 2005). In cotton systems, Tillman *et al.* (2004) reported that ants and *Geocoris punctipes* contribute to the management of *Heliothis virescens* and *Helicoverpa zea* in conservation tillage with crimson clover and rye cotton cover crops. Similarly, in vegetable crops it was demonstrated that fire ants were more abundant in cover-crop mulch plots and were important predators of weed seed and insect pests (Pullaro *et al.* 2004). Accurate sampling and measures of the impact of soil pests and beneficial organisms should be assessed to further define effective pest control strategies for sustainable crop management systems.

Acknowledgements We are grateful to the Projet ESA (Eau-Sol-Arbre) and SODECOTON (Société de Développement du Coton au Cameroun) for providing financial support for this project.

REFERENCES

Altieri, M. A. (1999). The ecological role of biodiversity in agroecosystems, *Agriculture, Ecosystems and Environment* 74:19–31.

Blanchart, E., Villenave, C., Viallatoux, A., Barthès, B., Girardin, C., Azontonde, A. and Fellera, C. (2006). Long-term effect of a legume cover crop (*Mucuna pruriens* var. utilis) on the communities of soil macrofauna and nematofauna, under maize cultivation, in southern Benin. *Applied Soil Ecology* 42: 136–144.

Blanchart, E., Bernoux, M., Sarda, X., Siqueira Neto, M., Cerri, C. C., Piccolo, M., Douzet, J. M., Scopel, E. and Feller, C. (2007). Effect of direct seeding mulch-based systems on soil carbon storage and macrofauna in Central Brazil. *Agriculturae Conspectus Scientificus* 72: 81–87.

Brévault, T., Bikay, S., Maldes, J. M. and Naudin, K. (2007). Impact of no till with mulch on soil macrofauna communities in a cotton cropping system. *Soil and Tillage Research* 97:140–149.

Brown, G., Pasini, A., Benito, N. P., Aquino, A. M. and Correia, E. (2001). Diversity and functional role of soil macrofauna communities in Brazilian no-tillage agroecosytems. In *Proceedings of the International Symposium on Managing Biodiversity in Agricultural Ecosystems, 8–10 November 2001, Montreal, Canada*.

Costello, J. (1995). Spectral reflectance from a broccoli crop with vegetation or soil as background: influence on immigration by *Brevicoryne brassicae* and *Myzus persicae*. *Entomologia Experimentalis et Applicata* 75:109–118.

Deguine, J. P., Goze, E. and Leclant, F. (1994). Incidence of early outbreaks of the aphid *Aphis gossypii* Glover in cotton growing in Cameroon. *International Journal of Pest Management*. 40:132–140.

Doring, T. K. and Chittka, L. (2007). Visual ecology of aphids – a critical review on the role of colours in host finding. *Arthropod-Plant Interactions* 1:3–16.

Doupnik, B. and Boosalis, M. G. (1980). Ecofallow: A reduced tillage system, and plant diseases. *Plant Disease* 64: 31–55.

Erenstein, O. (2003). Smallholder conservation farming in the tropics and sub-tropics: a guide to the development and dissemination of mulching with crop residues and cover crops. *Agriculture, Ecosystems and Environment* 100: 17–37.

House, G. J. and Del Rosario Alugaray, M. (1989). Influence of cover cropping no-tillage practices on community composition of soil arthropods in a North Carolina agroecosystem. *Environmental Entomology* 18:302–307.

Ito, M., Matsumoto, T. and Quinones, M. A. (2006). Conservation tillage practice in sub-Saharan Africa: the experience of Sasakawa Global 2000. *Crop Protection* 26:417–423.

Kladivko, E. J. (2001). Tillage systems and soil ecology. *Soil and Tillage Research* 61:61–76.

Marasas, M. E., Sarandon, S. J. and Cicchino, A. C. (2001). Changes in soil arthropod functional group in a wheat crop under conventional and no tillage systems in Argentina. *Applied Soil Ecology* 18:61–68.

Maria de Aquino, A., Ferreira da Silva, R., Mercante, F. M., Fernandes Correia, M. E., Fatima Guimaraes (de), M., and Lavelle, P., 2008. Invertebrate soil macrofauna under different ground cover plants in the no-till system in the Cerrado. *European Journal of Soil Biology*. 44:191–197

Mbetid-Bessane, E., Havard, M. and Djondang, K. (2006). Evolution des pratiques de gestion dans les exploitations agricoles familiales des savanes cotonnières d'Afrique centrale. *Agricultures* 15:555–561.

Naudin, K., Husson, O., Rollin, D., Guibert, H., Charpentier, H., Abou Abba, A., Njoya, A., Olina, J. P. and Seguy, L. (2003). No-tillage smallholder farms in semi-arid areas (Cameroon and Madagascar). In *Proceedings of the IInd World Congress on Conservation Agriculture, 11–15 August 2003, Iguassu Falls, Parana, Brazil*, vol. I, 46–49 (Extended Summary).

Peachey, R. E., Moldenke, A., William, R. D., Berry, R., Ingham, E. and Groth, E. (2002). Effect of cover crops and tillage system on symphylan (Symphyla: *Scutigerella immaculata* Newport) and *Pergamasus quisquiliarum* Canestrini (Acari: Mesostigmata) populations, and other soil organisms in agricultural soils. *Applied Soil Ecology* 21: 59–70.

Pullaro, T. C., Marino, P. C., Jackson, D. M., Harrison, H. F. and Keinath, A. P. (2004). Effects of killed cover crop mulch on weeds, weed seeds, and herbivores. *Agriculture, Ecosystems and Environment* 115:97–104.

Ratnadass, A., Michellon, R., Randriamanantsoa, R. and Séguy, L. (2006). Effects of soil and plant management on crop pests and diseases. In *Biological Approaches to Sustainable Soil Systems*, 589–602, Boca Raton, FL, USA: CRC Press.

Rummel, D. R., Arnold, M. D., Slosser, J. E., Neece, K. C. and Pinchak, W. E. (1995). Cultural factors influencing the abundance of *Aphis gossypii* Glover in Texas high plains cotton. *Southwest Entomologist* 20:395–406.

Rypstra, A. L. and Marshall, S. D. (2005). Augmentation of soil detritus affects the spider community and herbivory in a soybean agroecosystem. *Entomologia Experimentalis et Applicata* 116:149–157.

SAS Institute (1989). SAS/STAT User's guide, version 6. 4th ed., Vol. 2. SAS Institute Inc., Cary, NC, USA.

SODECOTON (2004). Rapport annuel. *Société de Developpment du coton du cameroun Garoun, Cameroun*.

Stinner, B. R. and House, G. J. (1990). Arthropods and invertebrates in conservation tillage agriculture. *Annual Review of Entomology* 35:299–318.

Summers, C. G., Stapleton, J. J. and Mitchell, J. P. (2004). Non-chemical insect and disease management in cucurbit production systems. *Acta Horticulturae* 638:119–125.

Teasdale, J. R., Abdul-Baki, A. A., Mills, D. J. and Thorpe, K. W. (2004). Enhanced pest management with cover crop mulches. *Acta Horticulturae* 638:135–140.

Thorbek, P. and Bilde, T. (2004). Reduced numbers of generalist arthropod predators after crop management. *Journal of Applied Ecology* 41:526–538.

Tian, G., Brussaard, L. and Kang, B. T. (1993). Biological effects of plant residues with contrasting chemical composition under humid tropical conditions: effects on soil fauna. *Soil Biology and Biochemistry* 25:731–737.

Tillman, G., Schomberg, H., Phatak, S., Mullinix, B., Lachnicht, S., Timper, P. and Olson, D. (2004). Influence of cover crops on insect pests and predators in conservation tillage cotton. *Journal of Economic Entomology* 97:1217–1232.

Wilson-Rummenie, A. C., Radford, B. J., Robertson, L. N., Simpson, G. B. and Bell, K. L. (1999). Reduced tillage increases population density of soil macrofauna in a semi-arid environment in central Queensland. *Environmental Entomology* 28:163–172.