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Short Communication

Winter cover crops and fertiliser effects on the weed seed bank in a low-input maize-based conservation agriculture system

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This study investigated the effects of grazing vetch (*Vicia dasycarpa* L.) and oat (*Avena sativa* L.) cover crops and fertiliser on the seed bank of some problematic weeds in a maize-based conservation agriculture system. Soil sampling for seed bank analysis was carried out at the 0–5 and 5–20 cm depths after four years of rotations. The winter cover crops reduced the seed-bank density of *Digitaria sanguinalis* (L.) Scop., *Eleusine indica* (L.) Gaertn., *Amaranthus retroflexus* L. and *Datura stramonium* L. in the 0–5 cm depth by 30–70%. Vetch was more effective on depleting the *D. sanguinalis* seed bank than oat. Fertiliser application reduced the *A. retroflexus* seed bank by 41.6% in the weedy fallow, but had no significant effect in plots grown to the cover crops. The winter cover crops did not significantly affect seed-bank weed species diversity.

Keywords: grazing vetch, mulch effects, oat, problematic weeds

Conservation agriculture (CA) holds potential for reducing land degradation problems resulting from conventional agricultural practices in smallholder farming communities of the Eastern Cape (EC) province of South Africa. However, its adoption by smallholder maize farmers in the EC is in early stages and at best modest because of several factors, including problems of weed management. Maize-based cropping systems tend to select for problematic grass weeds and sedges (Blackshaw 1994) because of a consistently hospitable environment for weeds that have phenological and physiological similarities to the maize crop. *Digitaria sanguinalis* (L.) Scop., *Cyperus esculentus* L. and *Cynodon dactylon* (L.) Pers. are some of the problematic weeds infesting smallholder-farmer maize fields in the EC and, in severe cases, cause abandonment of fields (Fanadzo 2007). These weeds also possess an ability to form runners and tillers for effectively colonising mulched surfaces.

Tillage is important for weed control in smallholder maize production in the EC (Fanadzo 2007). Abandonment of tillage towards CA may pose a challenge for the farmers, who can neither afford herbicides nor possess the equipment and technical expertise required for effective chemical weed control under CA. Proponents of CA, however, argue that herbicide requirement for the farmers would decline over time (FAO 2004). Mulch from cover crops under CA reduces weed problems through various mechanisms such as physical obstruction, shading and allelopathy, thus causing depletion of weed seeds from seed banks. Crop residue mulches encourage biotic activity and this has been shown to increase weed seed losses from seed banks (Gallagher et al. 1999).

Oat and grazing vetch winter cover crops have been shown to provide high amounts of biomass (>6 Mg ha^{-1}) for mulch, and resulted in improved maize yields in irrigated smallholder maize-based systems of the EC (Murungu et al. 2011). Their mulch effects on weed growth and emergence in the maize-based systems have been reported previously (Murungu et al. 2011). Information on oat and grazing vetch mulch effects on seed-bank dynamics of problematic weeds in these low-input maize-based CA systems is also required. This paper is a short communication of preliminary findings on the effects of oat and grazing vetch cover crops and fertiliser application to subsequent maize on the seed-bank density of problematic weeds in a maize-based CA system.

The study was conducted at the University of Fort Hare Farm, as part of a four-year crop-rotation field trial established in 2007. The farm is located at latitude 32°46′ S and longitude 26°50′ E in the EC province of South Africa. The soil type and climate of this research site were described by Murungu et al. (2011) and closely resemble those of smallholder irrigation schemes in the EC. The design of the field trial was a split plot with three replications. Main plots (size 16 m × 8 m) were winter cover crops planted every winter (grazing vetch, oat and weedy fallow) and the subplots (size 8 m × 8 m) were fertiliser application to follow-on maize (planted every summer with and without fertiliser). Planting of maize was carried out using hand-operated *matraca* planters and no tillage was performed. Cover crop seeds were sown by broadcasting and, in every season, the cover crops were terminated at the flowering stage by rolling them with a tractor-mounted roller and applying glyphosate (360 g l^{-1}) at a rate of 5 l ha^{-1}. Fertilised maize plots received 60, 30 and 40 kg ha^{-1} of N, P and K, respectively, as a compound broadcast at planting, to mimic smallholder farmer practice. No weed control was carried out during maize growth. Agronomic details of the trial have been presented by Murungu et al. (2011). Twelve random soil samples were collected from the 0–5 and 5–20 cm depths of each plot at the beginning of the fourth year using a precision auger (7 cm diameter) after cover crop termination and before maize planting. Soil samples were collected from the inner two-thirds of each plot and the soil from each plot was bulked to form one sample. The samples were air-dried and sieved (<2 mm) to remove coarse fragments and roots.

A glasshouse germination test, as described by Gross (1990), was used to determine the weed composition of the seed banks. The weed seedlings emerging from the soil samples over a period of 12 weeks were counted and identified using the weed identification handbook for problematic weeds of South Africa (Bromilow 1995). The raw density data for each species was used to calculate Shannon's diversity index (H') (Shannon 1948), which provides an overall assessment of weed species diversity. Weed count data were subjected to an analysis of variance (ANOVA) to test winter cover crop type, fertiliser and soil-depth effects. Means were compared using least significant differences (LSD; $\alpha = 0.05$).

Major weeds emerging from the seed bank across all treatments included *D. sanguinalis*, *Eleusine indica* (L.) Gaertn., *Amaranthus retroflexus* L. and *Datura stramonium* L. Other species observed were *Galinsoga parviflora* Cav., *Oxalis latifolia* Kunth., *Capsella bursa-pastoris* (L.) Medik., *Nicandra physaloides* (L.) Gaertn. and *Portulaca oleracea* L. There was a significant ($p < 0.05$) cover crop type × fertiliser interaction on the density of *A. retroflexus*, but not on *D. sanguinalis*, *E. indica* and *D. stramonium* (Table 1). Fertiliser significantly reduced *A. retroflexus* density on the weedy fallow by 41.6%, but the effect was not significant under the winter cover crops.

Winter cover crop type × soil depth interaction effects were significant on *D. sanguinalis*, *A. retroflexus* and *E. indica*, but not on *D. stramonium* (Table 2). Oat and grazing vetch were more effective than the weedy fallow in reducing *D. sanguinalis*, *A. retroflexus*, *E. indica* and *D. stramonium* seed-bank density in the 0–5 cm soil depth (Table 2). When compared to the weedy fallow, grazing vetch reduced the density of these species by 70.5%, 62%, 66.2% and 34.2%, respectively, whereas oat reduced them by 35.3%, 39.9%, 48.9% and 40.5%, respectively. However, grazing vetch effects on *D. sanguinalis* were higher than those of oat at both 0–5 cm and 5–20 cm soil depths. Effects were identical across all winter cover crop types for seed banks of *A. retroflexus* and *E. indica* at the 5–20 cm soil depth (Table 2). All factors and interactions had no significant ($p > 0.05$) effects on weed species diversity at the seed-bank level as measured using Shannon's H'. The overall mean for H' across treatments was 0.86 ± 0.054.

On the basis of these preliminary findings, it appears that the seed-bank density of some problematic weeds can be decreased by including oat and grazing vetch winter cover

Table 1: Interaction means of winter cover crop type and fertiliser on the seed-bank density (weeds m^{-3} soil) of problematic weeds. Seed-bank density was calculated based on soil volume used in the weed seed germination test. Means followed by the same letter within a row are not significantly different ($p > 0.05$)

Species	Seed-bank density (weeds m^{-3} soil)						Interaction *p* value
	Grazing vetch		Oat		Weedy fallow		
	Fertilised	No fertiliser	Fertilised	No fertiliser	Fertilised	No fertiliser	
Digitaria sanguinalis	6 212	8 711	11 638	14 637	17 350	17 493	ns
Amaranthus retroflexus	4 163^{a}	6 305^{ab}	7 261^{b}	5 833^{ab}	8 568^{b}	14 622.7^{c}	0.021
Eleusine indica	3 334	4 998	4 519	7 618	11 067	11 352.6	ns
Datura stramonium	4 405	3 927	4 048	3 334	6 426	6 640.2	ns

ns = Not significant

Table 2: Interaction means of winter cover crop type and soil depth on the seed-bank density (weeds m^{-3} soil) of problematic weeds. Seed-bank density was calculated based on soil volume used in the weed seed germination test. Means followed by the same letter within a row are not significantly different ($p > 0.05$)

Species	Seed-bank density (weeds m^{-3} soil)						Interaction *p* value
	Grazing vetch		Oat		Weedy fallow		
	0–5 cm	5–20 cm	0–5 cm	5–20 cm	0–5 cm	5–20 cm	
Digitaria sanguinalis	7 140^{a}	6 283^{a}	15 708^{c}	10 567^{b}	24 276^{d}	10 567^{b}	0.021
Amaranthus retroflexus	6 190^{ab}	4 284^{a}	9 875^{b}	3 213^{a}	16 422^{c}	6 768^{ab}	0.016
Eleusine indica	5 355^{ab}	2 977^{a}	8 090^{b}	4 048^{a}	15 829^{c}	6 590^{ab}	0.042
Datura stramonium	6 190	2 142	5 591	1 785	9 403	3 663	ns

ns = Not significant

crops in maize-based CA systems, as opposed to leaving the land fallow in winter. Weed seed-bank depletion by winter cover crops can be attributed to several seed loss mechanisms, including mulch effects on predation and pathogenesis (Power et al. 1986). In the absence of mulch on the weedy fallow, fertiliser application was important for depleting *A. retroflexus,* therefore emphasising the importance of fertiliser in weed management, even at low rates of application (i.e. 60 kg N ha^{-1}). Fertiliser application on poor soils generally results in significant increases in crop yield and biomass input, thus increases mulch input for surface cover against weeds. Grazing vetch is preferable with regard to *D. sanguinalis* control because it had greater effects on depleting the seed bank of *D. sanguinalis* than oat.

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