0971-4693/94 US $ 5.00
Allelopathy Journal 16(2): 273-278 (2005)

Table: 1, Fig : 1

SHORT COMMUNICATION

Weed suppression by winter cover crops

LAURA ERCOLI*, ALESSANDRO MASONI[1] and SILVIA PAMPANA[1]

Scuola Superiore Sant'Anna,
Piazza Martiri della Libertà 33, 56127 Pisa, Italy
E. Mail: ercoli@sssup.it

(Received in revised form: September 15, 2005)

Key words: Allelopathy, brown mustard, cover crops, hairy vetch, rye, weeds.

INTRODUCTION

Annual winter cover crops can be used in environmentally sound agriculture to reduce inputs of chemical fertilizers and pesticides and to increase soil organic matter content (7,8). Decomposition of cover crops biomass also contributes to the weed control by allelopathic effects, releasing the water-soluble inhibitors of weed growth (5,16). Allelopathic potential, defined as the degree of growth inhibiting activity of one plant on another, differs among plant species and cultivars (17) and also among the plant parts of the same plant spp (1,4,14). It may depend on the length of the decomposition period (3,9) and the quantity of the incorporated residue (8,13). Environmentally sound and efficient weed control systems that integrate numerous strategies must be developed. One such system is sowing of cover crops with known allelopathic potential and incorporating its residues in the soil in following spring. The decomposing period of residues is used to control weeds. Thereafter crops are sown, so that the decomposing residues of cover crops do not negatively affect the establishment and growth of the succeeding crop.

Research needs to be conducted to determine the optimal cover crop systems for greater weed suppression, adequate crop establishment and limited phytotoxicity. Environmental conditions play a role in the appearance or disappearance of allelopathic interference over time and may therefore complicate efforts to successfully develop weed management strategies across locations (6,11,16).

Therefore, field experiments were conducted to determine if the incorporation of biomass of *Secale cereale* L., *Vicia villosa* L. and *Brassica juncea* L., exhibits short-term allelopathic control of seeded *Amaranthus retroflexus* L. and *Chenopodium album* L. and volunteer weed species.

MATERIALS AND METHODS

The research was done in an experimental field in Tuscany, Italy (43° 67'N, 10° 30'E, 5 m above sea level), from October 2002 to July 2003. Soil chemical and physical properties were: 42.8% sand; 40.2% silt; 17.0% clay; pH 8.2; 1.6%

*Correspondence author; [1]Dipartimento di Agronomia e Gestione dell'Agroecosistema, Via San Michele degli Scalzi 2, 56125 Pisa, Italy.

organic matter [Walkey Black method (12)]; 2.2‰ total nitrogen [Kjeldahl method (2)]; 16 ppm available P [Olsen method (18)] and 18 ppm available K [Dirks-Sheffer method (10)]. The climate is typically mediterranean, mean annual rainfall is 970 mm (dry-warm period in summer and cool-rainy period in autumn); mean monthly temperatures and rainfall ranges from 7 °C and 78 mm in January to 22 °C and 24 mm in July, respectively. In the experimental period (October 2002 to July 2003) 755 mm rainfall was received and temperature was normal.

A split-plot experimental design with three replications was adopted. The treatments consisted of four main plots [bare soil, rye (*Secale cereale* L.), hairy vetch (*Vicia villosa* L.) and brown mustard (*Brassica juncea* L.)] and two sub-plots that were seeded with weed species (*Chenopodium album* L. and *Amaranthus retroflexus* L.). The size of main plots was: 10 x 10 m (spaced 1 m apart) and sub-plots were: 2.5 x 2.5 m.

On November 4, 2002, the field was ploughed, disked and smoothed with a harrow. On November 11, cover crops were drilled, *Vicia villosa* and *Brassica juncea* at 5 kg seeds ha^{-1} and *Secale cereale* at 150 kg seeds ha^{-1}. The control plots (bare soil) were prepared with the same tillage method used for the cover crops treatments. Cover crops productivity was determined, immediately before their incorporation into the soil, by harvesting 1 m^2 area from each plot. Fresh biomass of cover crops was incorporated into the soil on April 29, 2003 with a disk harrow at depth of 10 to 15 cm; at that time rye was in boot stage, while the other cover crops were in vegetative stage. Plots with no cover crop (bare soil) were also plowed. On May 5, 2003, 500 germinable seeds of *Chenopodium album* L. and *Amaranthus retroflexus* L. were broadcast sown in each subplot. After 90 days from sowing, weed biomass was evaluated by harvesting 1 m^2 in the middle of each weed plot from each subplot. Weeds were separated by species to determine the individual dry weight of sown and volunteer species.

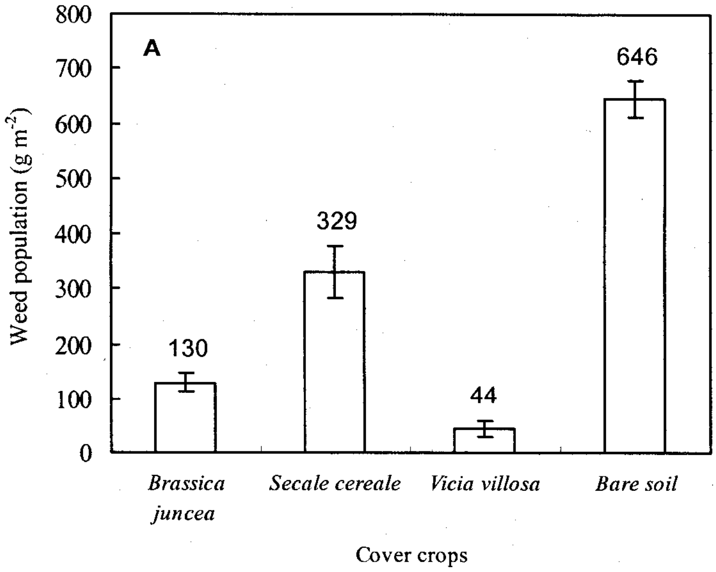
All data were tested to determine if transformations were necessary. No transformation was needed as data were normally distributed. Data were subjected to analysis of variance and a Duncan's test was performed to compare means at the 95% of confidence level.

RESULTS AND DISCUSSION

At 5-months after sowing, the above-ground biomass of the cover crops did not vary substantially among species. Biomass production of brown mustard, rye and hairy vetch was 368, 543 and 438 g m^{-2} respectively.

Total weed dry weight (including both sown and volunteer species) was significantly (0.05 level) reduced by all cover crops compared with the bare soil control, but the magnitude of allelopathic effects varied among crops (Fig. 1 A). *Vicia villosa* provided the best control reducing total weed biomass by 93%, while *Brassica juncea* and *Secale cereale* reduced total weed biomass by 80% and 49%, respectively.

Cover crop biomass incorporated into soil also exhibited a differential ability to inhibit *Amaranthus* and *Chenopodium*, whose biomass in bare soil plots accounted for about 60% of the total weed biomass. *Vicia villosa* completely inhibited *Amaranthus* and *Chenopodium* growth (Fig. 1 B). *Brassica juncea* reduced *Amaranthus* biomass by 71%,



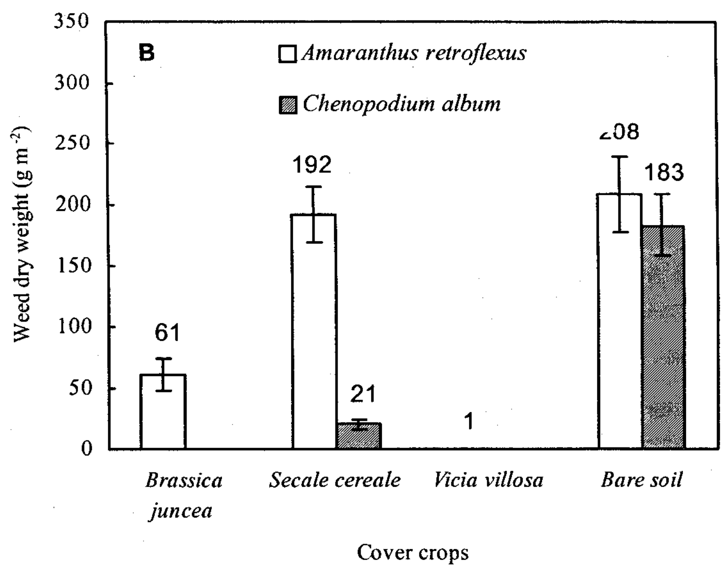


Figure 1. Effect of cover crops residues on (A) total weed population (g m^{-2}) and on (B) dry weight (g m^{-2}) of *Amaranthus retroflexus* and *Chenopodium album*. Vertical bars represent ± standard error of the mean; where not shown, the error bar lies within the symbol.

compared to bare soil control and *Chenopodium* entirely, while *Secale cereale* was pratically ineffective against *Amaranthus* (8% of control) but suppressed *Chenopodium* by 89%.

Volunteer weed species, developed both from seed or rhizomes, varied in their response to cover crop residues and their response was also a result of the competition with the seeded weeds (Table 1). Differences among cover crops in the species composition of the volunteer weed communities were observed. Also in this case, *Vicia* gave the best results (biomass reduction about 83%), the inhibiting effect of *Brassica* was about 73% and that of *Secale* was about 54%. The volunteer species were different: in bare soil the predominant species were *Convolvolus arvensis*, *Datura stramonium*, and *Solanum nigrum*, in the plots with *Brassica* and *Vicia* residues the predominant weed was *Convolvolus arvensis*, while in the plots with *Secale* residues *Datura stramonium*, *Heliotropium europaeum* and *Solanum nigrum* were the most prominent. In the plots with *Secale*, the development of *Equisetum spp.*, *Heliotropium europaeum* and *Portulaca oleracea*, which were not detected in bare soil, may be the result of a reduced growth of other weeds (both seeded and volunteer) owing to the inhibiting effect of *Secale* residues. However, the experimental design of the research do not allow to attribute the weed inhibition solely to cover crop since we can not exclude a site effect and an interference effect (both allelopathic or competitive) of volunteer or sown weeds.

Table 1. Effect of cover crops on the biomass production of volunteer weed species

Weed	Cover crop			
	Bare soil	*Brassica juncea*	*Secale cereale*	*Vicia villosa*
	Biomass (g m^{-2})			
Convolvulus arvensis L.	49.0 c	67.8 a	0 c	43.0 b
Cyperus spp.	3.1 a	0.5 c	1.8 b	0.1 c
Datura stramonium L.	187.1 a	0 c	57.1 b	0 c
Equisetum spp.	0 b	0.7 b	2.9 a	0 b
Heliotropium europeum L.	0 b	0 b	23.7 a	0 b
Portulaca oleracea L.	0 b	0 b	0.7 a	0 b
Sinapis spp.	0 a	0.2 a	0 a	0 a
Solanum nigrum L.	15.7 b	0 c	30.3 a	0 c
Total volunteer weeds	254.9 a	69.2 c	116.3 b	43.2 d

Means within the same row followed by the same letter are not different at P<0.05 probability level.

The extent and duration of weed suppression by allelopathy is likely dependent upon the concentration of allelochemicals in the zone of weed emergence and the rate of breakdown of these chemicals. The degree of control by cover crops observed in our research, however, was not associated with the amount of residues, with *Secale* giving the highest biomass and *Vicia* the highest weed control. The low effect of *Secale cereale* recorded in the present research may be related to the long time elapsed from residue incorporation to the harvest of weeds (about 9 weeks) since, according to Masiunas *et al.* (9) and to Smeda and Weller (15) degrading residue of rye produced effective weed control for 4 to 8 weeks after initial desiccation with herbicides.

CONCLUSIONS

Field experiments were conducted to determine the ability of soil-incorporated cover crops (*Secale cereale* L., *Vicia villosa* L. and *Brassica juncea* L.) to control weeds. Growth of seeded *Chenopodium album* was completely inhibited by all cover crop residues, *Amaranthus retroflexus* development, in comparison to bare soil control, was reduced only by *Vicia villosa*. Volunteer weed species also varied in their response to residues. *Vicia* and *Brassica* controlled all species except *Convolvolus*, while *Secale* had a weaker effect.

This study shows the potential of cover crops biomass for suppression of *Amaranthus, Chenopodium* and other weeds. It also indicates that, since the allelopathic suppression is a species-specific phenomenon, the weed spectrum present at any given site must be considered in evaluating the optimal fall cover crop. However further research is needed, to elucidate the relationships among environmental conditions, weeds species and the decay rate of residue to determine the optimum weight of cover crop biomass needed for effective weed suppression.

REFERENCES

1. Chon, S.U., and Kim, J.D. (2002). Biological activity and quantification of suspected allelochemicals from alfalfa plant parts. *Journal of Agronomy and Crop Science* **188** : 281-285.
2. Bremner, T. M. (1965). Total nitrogen. In: *Methods for Soil Analysis*. Part 2. (Ed., C.A. Black *et al.*). 1st ed. Agronomy Monograph **9**: 1149-1179. Madison, WI, USA: American Society of Agronomy.
3. Dabney, S.M., Shreiber, J.D., Rothrock, C.S., and Johnson, J.R. (1996). Cover crops affect sorghum seedling growth. *Agronomy Journal* **88** : 961-979.
4. Economou, G., Tzakou, O., Gani, A., Yannitsaro, A. and Bilalis, D. (2002). Allelopathic effect of *Conyza albida* on *Avena sativa* and *Spirodela polyrhiza*. *Journal of Agronomy and Crop Science* **188** : 248-253.
5. Inderjit and Keating, K.I. (1999). Allelopathy: principles, procedures, processes and promises for biological control. *Advances in Agronomy* **67** : 141-231.
6. Inderjit (2001). Soils: environmental effect on allelochemical activity. *Agronomy Journal* **93** : 79-84.
7. Kuo, S. and Jellum, E.J. (2002). Influence of winter cover crop and residue management on soil nitrogen availability. *Agronomy Journal* **94** : 501-508.
8. Liebman, M. and Davies, A.S. (2000). Integration of soil, crop and weed management in low-external-input farming systems. *Weed Research* **40** : 27-47.
9. Masiunas, J.B., Weston, L.A. and Weller, S.C. (1995). The impact of rye cover crops on weed populations in a tomato cropping system. *Weed Science* **43** : 318-323.
10. Melich, A. (1953). Determination of P, Ca, Mg, K, Na, and NH_4. *North Carolina Soil Testing Division*. Raleigh, North Carolina USA: NC State University.
11. Mohler, C.L. and Teasdale, J.R. (1993). Response of weed emergence to rate of *Vicia villosa* Roth and *Secale cereale* residue. *Weed Research* **33** : 487-499.
12. Nelson, D.W. and Sommers, L.E. (1982). Total carbon, organic carbon, and organic matter. In: *Methods for Soil Analysis*. Part 2. Ed. 2. (Ed., A.L. Page *et al.*). Agronomy Monograph **9**: 539-577. Madison, WI, USA: American Society of Agronomy.
13. Ohno, T. and Dolan, K.L. (2001). Effects of red clover decomposition on phytotoxicity to wild mustard seedling growth. *Applied Soil Ecology* **16** : 187-192.
14. Oueslati, O. (2003). Allelopathy in two durum wheat (*Triticum durum* L.) varieties. *Agriculture, Ecosystems and Environment* **96** : 161-163.
15. Smeda, R. J. and Weller, S. C. (1996). Potential of rye (*Secale cereale*) for weed management in transplanted tomatoes (*Lycopersicon esculentum*). *Weed Science* **44**: 596-602.

16. Weston, L.A. (1996). Utilization of allelopathy for weed management in agroecosystems. *Agronomy Journal* **88** : 860-866.
17. Wu, H., Pratley, J., Lemerle, D. and Haig, T. (2000). Evaluation of seedling allelopathy in 453 wheat (*Triticum aestivum*) accessions against annual ryegrass (*Lolium rigidum*) by the equal-compartment-agar method. *Australian Journal of Agricultural Research* **51** : 937-944
18. Zandstra, H. G. (1968). Automated determination of phosphorus in sodium bicarbonate extracts. *Canadian Journal of Soil Science* **48**: 219-220.