RESIDUAL ALLELOPATHIC EFFECTS OF PASTURE GRASSES AND LEGUMES ON NODDING THISTLE SEEDLING EMERGENCE AND GROWTH

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SUMMARY

Artificial pure swards of six pasture grass species and four legume species were established in a growth medium of 50% soil: 50% pumice. After 3 months this medium was separated from the root material of each species and stored. At various time intervals following this separation subsamples of this medium were planted with nodding thistle (*Carduus nutans*) seeds, and thistle seedling emergence and growth were subsequently monitored. The grass species all demonstrated residual allelopathic effects on nodding thistle, while the legume species often exerted stimulatory effects. It is concluded that grass species may reduce thistle establishment and growth through residual toxicity in the soil.

Keywords: allelopathy, bioassay, *Carduus nutans*, nodding thistle, pasture

INTRODUCTION

In considering control of weed species, there has been an increasing interest in non-herbicidal management strategies. One such approach has been to select crop or pasture species or varieties which may demonstrate negative allelopathic effects against the weeds in question (e.g. Putnam and Duke 1974; Peters and Luu 1985). This approach is rapidly finding favour amongst the protagonists of organic and sustainable agricultural systems (Altieri 1987; Putnam 1988).

Nodding thistle is an important weed in pastures throughout New Zealand, and management of this weed is frequently difficult. It is problematic primarily because it may inhibit pasture (especially clover) growth (Thompson *et al* 1987; Nicholson *et al* 1990) and may itself demonstrate strong allelopathic tendencies (Wardle *et al* 1991). The purpose of this study was to compare a range of commonly grown pasture grasses and legumes with regard to their relative residual allelopathic effects on nodding thistle seedling establishment and growth.

MATERIALS AND METHODS

Six grass and four legume species were selected for this study. The grasses included: cocksfoot (*Dactylis glomerata* cv. Wana), phalaris (*Phalaris tuberosa* cv. Maru), prairie grass (*Bromus catharticus* cv. Matua), perennial ryegrass (*Lolium perenne* cv. Yatsyn), tall fescue (*Festuca arundinacea* cv. Au Triumph), and Yorkshire fog (*Holcus lanatus* cv. Massey Basyn). The legumes included: lucerne (*Medicago sativa* cv. Oranga), red clover (*Trifolium pratense* cv. Pawera), subterranean clover (*T. subterraneum* cv. Woogenellup), and white clover (*T. repens* cv. Pitau). For each species, eight replicate 332 x 202 x 85 mm deep trays were set up, filled to the surface with a 1:1 mixture of pumice and soil, and planted with seeds of that species at approximately field sowing density. The soil used was a Horotiu sandy loam (pH = 5.7; organic C = 9.1%). Pumice was used to ease the separation of growth substrate from root material later in the study.

Following set-up, the swards were left to establish in glasshouse conditions, and were amended weekly with appropriate levels of nutrient solution (Smith *et al* 1983). Glasshouse temperature conditions varied between 10°C and 30°C, and the day:night light ratio varied between 16 h:8 h and 10 h:14 h throughout the experimental period.

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When the swards were sufficiently dense (84 d. after planting for the grasses, 140 d. for the legumes) the soil + pumice substrate was carefully removed from the root tissue of each species. This soil + pumice was collected and stored at 10-15 °C in the dark. Although some fine roots remained in the soil, it can be presumed that over 98% of the root biomass was effectively removed. At various time intervals following collection of soil + pumice from the roots (0, 70 and 162 days for the grasses; 0, 92 and 180 days for the legumes), six 15 cm diameter pots were filled with the soil + pumice collected from each species, along with six corresponding control pots consisting of soil + pumice without previous planting. Each pot was planted with 15 nodding thistle seeds, maintained in glasshouse conditions, and amended with nutrient solution every 2 weeks (Smith *et al* 1983). Every 3-5 days for approximately 1 month the total number of thistle seedlings which emerged from each pot was counted. These data were used to calculate the percent emergence of each species, and the speed of emergence index "S" (Wardle *et al* 1991). Briefly the index S ranges from 100 (if all seedlings emerge within 1 day of planting) to 0 (if no seedlings ever emerge). By 1 month after planting no further seedlings emerged, and the number of thistle seedlings per pot were thinned to one. These thistles were left to grow for a further 2 months, after which the oven-dry weight (24 h at 80 °C) of the root and shoot tissue (and the root:shoot ratio) of each thistle was determined.

RESULTS

Residual allelopathic effects were identified for all six grass species during at least some stage of the study (Table 1). Allelopathic effects were typically strongest against shoot growth, and were most noticeable at the 70 d. and 162 d. plantings. These effects often enhanced the root:shoot ratio. However, some species, typically ryegrass (0 d. and 70 d.) and tall fescue and Yorkshire fog (162 d.) were also effective inhibitors of thistle seedling emergence.

All of the legume species tended to stimulate thistle growth, and in some cases emergence, relative to the control (Table 2). Lucerne and subterranean clover demonstrated the strongest stimulatory effects. These effects were significant at all sampling times, and influenced both seedling emergence and subsequent growth.

TABLE 1: Influence of soil from under six grass species on nodding thistle seedling emergence and growth

Time (days) ¹		Species						
		CF	PH	PG	RG	TF	YF	Control
0	% E ²	66.7a	71.1a	76.7a	38.9b	83.3a	67.8a	77.8a
	S ³	3.94b	3.82bc	4.23ab	2.41c	5.51a	4.31ab	4.92ab
	shoot d.w. (g)	0.83ab	0.72abc	0.95a	0.31c	0.55abc	0.51bc	0.46bc
	root d.w. (g)	0.48ab	0.45ab	0.57a	0.19c	0.47ab	0.30bc	0.29bc
	r:s ⁴	0.58a	0.50a	0.60a	0.62a	0.67a	0.70a	0.64a
70	% E	44.6ab	57.8a	52.2ab	30.0b	63.4a	47.8ab	42.2ab
	S	3.08ab	3.58ab	3.26ab	1.94b	4.16a	3.16ab	2.68ab
	shoot d.w. (g)	1.03bc	1.53ab	1.05ab	0.56c	0.81c	0.58c	2.05a
	root d.w. (g)	0.86abc	1.34a	0.68bc	0.42c	0.66bc	0.42c	0.98ab
	r:s	0.84a	0.89a	0.77a	0.75ab	0.82a	0.72ab	0.45b
162	% E	2.2a	2.2a	7.7a	6.7a	2.2a	2.2a	7.7a
	S	0.33ab	0.30ab	1.01a	0.47ab	0.18b	0.19b	0.77a
	shoot d.w. (g)	2.52b	2.24bc	2.12bc	0.88bc	1.57bc	0.62c	4.69a
	root d.w. (g)	1.72ab	2.00a	1.42ab	0.71b	1.55ab	1.06ab	1.81ab
	r:s	0.64b	0.86ab	0.68ab	1.00ab	0.91ab	1.30a	0.37b

¹Time (days) since removal of soil from plant roots.

²Percent emergence.

³Speed of germination index.

⁴Root:shoot ratio (g/g).

Species: CF = cocksfoot; PH = phalaris; PG = prairie grass; RG = perennial ryegrass; TF = tall fescue; YF = Yorkshire fog.

Numbers in each row followed by different letters are significantly different at P = 0.05 (Tukey's test with unequal n).

TABLE 2: Influence of soil from under four legume species on nodding thistle seedling emergence and growth.

Time (days)		Species				
		LU	RC	SC	WC	Control
0	% E	34.5ab	22.3b	50.0a	44.0ab	38.9ab
	S	2.30a	1.36a	2.88a	2.65a	2.77a
	shoot d.w. (g)	1.95ab	1.89b	2.28ab	3.01a	1.38b
	root d.w. (g)	1.14a	0.91ab	1.27a	1.36a	0.52b
	r:s	0.56a	0.47ab	0.56a	0.45ab	0.36b
92	% E	15.6a	15.0a	6.7a	11.0a	8.9a
	S	2.80a	1.20ab	0.58b	1.05ab	0.57b
	shoot d.w. (g)	2.02bc	2.48ab	3.48a	2.86ab	1.52c
	root d.w. (g)	1.33a	1.26a	2.02a	1.28a	0.51b
	r:s	0.67a	0.46ab	0.58ab	0.41b	0.42b
180	% E	7.8a	10.0a	6.7a	10.0a	4.4a
	S	0.67ab	1.00a	0.64ab	0.89a	0.18b
	shoot d.w. (g)	3.28a	2.18b	3.55a	2.21b	ND ¹
	root d.w. (g)	3.13a	2.61a	3.55a	2.61a	ND
	r:s	1.13a	1.24a	1.26a	1.44a	ND

Legend as for Table 1.

Species: LU = lucerne; RC = red clover; SC = subterranean clover; WC = white clover. ¹ND = not determined due to insufficient seedling survival.

DISCUSSION

All six grass species demonstrated at least some degree of residual allelopathy. Ryegrass was particularly allelopathic, and this is consistent with the study by Nicholson *et al* 1990, indicating that nodding thistle may be heavily suppressed by ryegrass. Despite these allelopathic effects, thistle plants still grew (albeit at a reduced rate) indicating that the allelopathic mechanisms of the various grass species were potentially capable of slowing thistle growth rather than stopping it completely. The results of this study reflect previously identified allelopathic potentials of most of these species (Wardle 1987). Many studies have identified tall fescue as being particularly allelopathic (see Wardle 1987), but the present study did not demonstrate a very high allelopathic potential for this species.

The soil from all six species was most toxic to thistle shoot growth after the pumice + soil had been stored for 162 d. This indicates that thistle growth may be potentially reduced even in areas which have been devoid of grasses for several months. Furthermore it suggests that the soil + pumice become increasingly toxic to thistles during storage. Because nearly all of the grass root material was removed from the growth substrate it appears that this residual allelopathy is probably due to decomposition of exudates, leachates and fine root fragments initially released from the grasses, and possibly adsorbed onto clay and humus particles (Rice 1984).

Although allelopathy is the most likely mechanism inhibiting thistle growth, other possible means of inhibition associated with this type of bioassay may be nutrient depletion by the grass before removal, or enhanced nutrient immobilisation by the soil microflora in the presence of organic exudates and materials released from the grasses (Wardle 1987). However, these mechanisms are unlikely to inhibit thistle growth to the level observed in the present study, because (i) visible grass roots were almost completely removed before the thistles were planted, making the enhancement of soil organic C by the grass roots small and probably negligible; and (ii) optimal nutrient solutions were applied to each container weekly, probably negating any immobilisation which might have occurred.

All four legume species demonstrated stimulatory effects on nodding thistle, even at 180 d. following separation of roots from soil. Although "stimulatory allelopathic" effects have been detected in some previous studies (Rice 1986) such results are relatively

unexpected, especially when the results of previous studies, demonstrating negative allelopathic effects of these legumes, are considered (Wardle 1987). These stimulatory effects may be due to growth-enhancing chemicals released from the legumes (Rice 1984). Another possibility could be the nature of organic and mineral nitrogen release from the legumes to the soil before separation of the soil + pumice from the roots. Legume tissues can release a variety of nitrogenous compounds to soil systems, which may influence the plant-available soil nitrogen level for several months (Wardle and Greenfield 1991). While it is unlikely that the stimulation of thistles is a direct consequence of mineral nitrogen release from leguminous compounds (mineral N was added to the thistles every 2 weeks in the nutrient solution) the possibility remains that nitrogenous compounds originating from the legumes may stimulate certain groups of micro-organisms which themselves can stimulate thistle growth (Whipps and Lynch 1986).

Many of the grass and legume species which have been identified by earlier studies as highly allelopathic did not demonstrate high allelopathic potential in the present one. This is probably because the present study involved assaying soil directly removed from under established pasture swards, rather than assessing the susceptibility of test (receiver) species to shoot and root leachates and exudates. Allelopathy bioassays performed directly on the soil from under donor plants are probably more indicative of ecological reality (Wardle, 1987).

In conclusion, the results of this study indicate that most grass species can inhibit nodding thistle seedling establishment and suppress growth through residual allelopathic means, while legumes do not. Perennial ryegrass, the principal component of pastures where thistles occur, appears to be more allelopathic than the other five grass species tested. This reinforces the results of Nicholson *et al* (1990), and suggests that pasture management techniques which most effectively inhibit nodding thistle are those which promote a strong and continuous component of ryegrass in the pasture.

REFERENCES

- Altieri, M.A., 1987. Agroecology — the scientific basis of alternative agriculture. Boulder, U.S.A.: Westview Press. p. 224.
- Nicholson, K.S., Rahman, A. and Wardle, D.A., 1990. Interactions between establishing nodding thistle and pasture seedlings. *Proc. 43rd N.Z. Weed and Pest Control Conf.*: 225-228.
- Peters, E.J. and Luu, K.T., 1985. Allelopathy in tall fescue. Pp. 207-218. *In: The Chemistry of Allelopathy — Biochemical Interactions in Plants*. A.C. Thompson (Ed.). ACS symposium series no. 268.
- Putnam, A.R., 1988. Allelopathy: problems and opportunities in weed management. *In: Weed Management and Agroecosystems: Ecological Approaches*. Altieri, M.A. and Liebman, M. (Eds). Boca Raton, Florida: CRC Press.
- Putnam, A.R. and Duke, W.B., 1974. Biological suppression of weeds: evidence for allelopathy in accessions of cucumber. *Science* 185: 370-372.
- Rice, E.L., 1984. Allelopathy. 2nd Edition. Orlando, Florida: Academic Press. p. 424.
- Rice, E.L., 1986. Allelopathic growth stimulation. *In: The Science of Allelopathy*. Putnam, A.R. and Tang, C.S. (Eds). New York: John Wiley and Sons.
- Smith, G.S., Johnson, C.M. and Cornforth, I.S., 1983. Comparison of nutrient solutions for growth of plants in sand culture. *New Phytol.* 94: 537-548.
- Thompson, A., Saunder, A.E. and Martin, P., 1987. The effect of nodding thistle (*Carduus nutans* L.) on pasture production. *Proc. 40th N.Z. Weed and Pest Control Conf.*: 222-225.
- Wardle, D.A., 1987. Allelopathy in New Zealand grassland/pasture ecosystem. *N.Z. J. Exp. Agr.* 15: 243-25.
- Wardle, D.A. and Greenfield, L.G., 1991. Release of mineral nitrogen from plant root nodules. *Soil Biol. Biochem.* 23: in press.
- Wardle, D.A., Ahmed, M. and Nicholson, K.S., 1991. Allelopathic influence of nodding thistle (*Carduus nutans* L.) seeds on germination and radicle growth of pasture plants. *N.Z. J. Agric. Res.* 34: in press.
- Whipps, J.M. and Lynch, J.M., 1986. The influence of the rhizosphere on crop productivity. *Adv. Microb. Ecol.* 9: 187-244.