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Research Note

Survival of plants of common sainfoin (*Onobrychis viciifolia* Scop.) in competition with two companion grass species

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Abstract

A 2-year experiment on competition between sainfoin (*Onobrychis viciifolia* Scop.), meadow fescue (*Festuca pratensis*) and tetraploid perennial ryegrass (*Lolium perenne*) was conducted using plants grown in plastic containers outdoors. Root and shoot systems of sainfoin and the grasses were separated in order to investigate full and no competition of root and shoots, at two planting ratios (0·33 grass:0·66 sainfoin and 0·66 grass:0·33 sainfoin). Survival of sainfoin plants was lower at the higher grass:sainfoin ratio. More sainfoin plants died in the winter than during the growing season. Root competition had no effect on survival of sainfoin plants, but shoot competition reduced survival of sainfoin plants during one growing season. Companion grass species had no effect on survival of sainfoin plants, except in the first winter, when fewer sainfoin plants survived when grown with meadow fescue than perennial ryegrass.

Keywords: meadow fescue, tetraploid perennial ryegrass, sainfoin, plant survival

Introduction

Sainfoin (*Onobrychis viciifolia* Scop.) is a leguminous forage crop grown in Europe, Asia and western North America (Frame, 2005) and is commonly sown with various companion species, including meadow fescue (*Festuca pratensis*), timothy (*Phleum pratense*), Russian wild rye (*Psathyrostachys juncea*) and crested wheatgrass (*Agropyron desertorum*) (Bland, 1971; Goplen *et al.*, 1991; Frame *et al.*, 1998).

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Recent field experiments in the UK have investigated the principles of establishment and autumn management of sainfoin, and the productivity of sainfoin–grass mixtures (Liu *et al.*, 2008a,b). No detailed studies on the interactions between sainfoin and companion grasses, however, have been found. Dubbs (1968) compared the performance of sainfoin and sainfoin–grass mixtures, but did not attempt to examine in detail the effects of competition. Others, working with different species, have suggested that below-ground competition has more severe effects than above-ground competition and, since root competition starts earlier, has a greater impact on growth than shoot competition (Wilson, 1988). Studies of plant competition have often used replacement-series experiments (Schreiber, 1967). Based on this approach, a method to study competition which can separate the roots and shoots of two plant species to investigate root and shoot competition was developed by Snaydon (1979) and has been used in competition studies between pasture legumes and grasses (Grieshaber-Otto, 1984; Baines, 1988). A similar method was used in the study reported here, the aim of which was to investigate the effects of root and shoot competition, the effects of two different companion grass species [meadow fescue (*Festuca pratensis)* and tetraploid perennial ryegrass (*Lolium perenne*)], and the ratio of sainfoin and grass plants on survival of sainfoin plants.

Materials and methods

The experiment was carried out between May 2004 and April 2006 outdoors using boxes containing transplanted seedlings of sainfoin with either meadow fescue (MF) or perennial ryegrass (PRG). The site of the experiment was at Coates Manor Farm, Cirencester, UK (51°42′N, 2°01′W; 135 m above sea level). Grey, opaque, 5-mm thick, non-insulated, plastic containers (55 cm × 36 cm × 30 cm deep) were used as the boxes. These were filled with soil and placed on the soil surface in a field away from any shade. The soil used was

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topsoil (to a depth of about 20 cm), classified as Sherborne series, a shallow, stony, well-drained clay loam prevalent in the locality of the experimental site (Findlay *et al.*, 1984). The pH of the soil was 7·5 and the nutrient contents of the soil were: phosphorus, 49·1 mg L^{-1}; potassium, 343·6 mg L^{-1}; and magnesium 100·1 mg L^{-1}. The soil was well mixed before filling the containers. The containers were partitioned using sheets of medium-density fibreboard (MDF) into six equal rows, and drainage holes drilled before the soil was added. A factorial experimental design with two replicates was used. The four factors studied were root competition, shoot competition, grass species and sainfoin:grass ratio. The treatments were: (i) ± root competition [roots of sainfoin and grass that were either associated (+) or not associated (−)]; (ii) ± shoot competition [shoots of sainfoin and grass, either associated (+) or not associated (−)]; (iii) grass species (MF or PRG); and (iv) grass:sainfoin ratios (sainfoin established with each grass species at ratios of 0·33:0·66 and 0·66:0·33).

Seeds of sainfoin (cv. Cotswold Common) and the two grasses (MF cv. Rossa and PRG cv. Condesa) were sown in plastic plug trays containing soil of the Sherborne series described above, on 20 May 2004, in a greenhouse. The seedlings were transplanted outside into the plastic containers on 1 July 2004. All treatments were maintained at the same density of 273 plants m^{-2} (fifty-four plants per container). Plants were arranged in nine rows of six plants or six rows of nine plants as most convenient. Root competition (+) was effected by the MDF divisions within the containers. Shoot competition (+) was effected by white reflective non-transparent plastic film (40-cm high), to create the association or non-association of the shoots of sainfoin and the grasses. The separation of roots and shoots in the containers thus created root-, shoot-, full- and no-competition treatments. The two planting densities were achieved by planting alternate single or double rows of grass or sainfoin plants, so that either one grass plant was competing against two sainfoin plants (0·33:0·66) or one sainfoin plant against two grass plants (0·66:0·33).

After transplanting, the seedlings were watered and left to establish. After 1 week, seedlings were clipped to about 5 cm, and then separated above-ground by the plastic film as indicated previously. Above-ground partitions were always arranged in a north-south direction to minimize shading. The containers were regularly watered. One harvest was taken in the establishment year, on 1 November 2004. Containers were then left outside over the 2004–2005 winter without the above-ground film partitions (giving no shoot separation during the winter period). Dead plants were counted and replaced with well-established seedlings in the following spring, on 10 April 2005, and the film replaced to partition shoots as before. Four harvests were taken in the second year: on 28 May, 13 July, 28 August and 1 November 2005. The containers were left outside during the 2005–2006 winter, again without film partition. Plant survival and losses were also recorded on 26 October 2004, 10 November 2005 and 20 April 2006.

During the experimental period, the containers received phosphorus and potassium fertilizer as triple superphosphate (44% P_2O_5) and muriate of potash (60% K_2O) applied to the soil surface. In April 2004, P_2O_5 fertilizer at 5 g m^{-2} (equivalent to 50 kg ha^{-1}) was applied and an additional 3 g m^{-2} (30 kg ha^{-1}) after the 2004 harvest. In 2005, P_2O_5 fertilizer at 2 g m^{-2} (20 kg ha^{-1}) and K_2O fertilizer at 3 g m^{-2} (30 kg ha^{-1}) were applied after the first harvest in June and an additional 3 g m^{-2} of K_2O fertilizer after the second harvest.

Data on rates of plant survival were transformed by square root of arcsine to create a normal distribution before statistical analysis (Snedecor and Cochran, 1980). Analysis of variance was carried out using GENSTAT 7 (Payne *et al.*, 2003). Multiple comparisons of treatment means were performed by applying Fisher's least significant difference test (LSD).

Results

The survival of sainfoin plants and the various effects of root competition, shoot competition, companion grass species, and of different ratios of grass and sainfoin plants, are summarized in Tables 1–4. On average, the proportion of sainfoin plants that survived was 0·86 on 26 October 2004, 0·46 on 10 April 2005, 0·79 on 10 November 2005 and 0·37 on 20 April 2006.

Sainfoin survival was most strongly influenced by the ratio of grass:sainfoin, the proportion that survived being consistently greater at the higher (0·66:0·33)

Table 1 Proportion of sainfoin plants surviving at successive sampling dates in boxes with and without the effects of root competition.

	+ Root competition	− Root competition
First growing season	0·84[a]	0·87[a]
First winter	0·44[a]	0·47[a]
Second growing season	0·75[a]	0·82[a]
Second winter	0·35[a]	0·38[a]

Plant survival was assessed on 26 October 2004, 10 April 2005, 10 November 2005 and 20 April 2006.
Values on the same row followed by the same letter are not significantly different at $P < 0·05$.

Table 2 Proportion of sainfoin plants surviving at successive sampling dates in boxes with and without the effects of shoot competition.

	+ Shoot competition	− Shoot competition
First growing season	0·82[a]	0·89[a]
First winter	0·43[a]	0·49[a]
Second growing season	0·70[b]	0·86[a]
Second winter	0·32[a]	0·42[a]

Values on the same row followed by the same letter are not significantly different at $P < 0·05$.

Table 3 Proportion of sainfoin plants surviving at successive sampling dates in boxes with either meadow fescue (MF) or tetraploid perennial ryegrass (PRG) as the companion grass.

	Grass Species	
	MF	PRG
First growing season	0·89[a]	0·82[a]
First winter	0·39[b]	0·53[a]
Second growing season	0·78[a]	0·79[a]
Second winter	0·35[a]	0·38[a]

Values on the same row followed by the same letter are not significantly different at $P < 0·05$.

Table 4 Proportion of sainfoin plants surviving at successive sampling dates in boxes planted with two ratios of grass:sainfoin plants.

	Grass:sainfoin ratio	
	0·33:0·66	0·66:0·33
First growing season	0·94[a]	0·76[b]
First winter	0·66[a]	0·30[b]
Second growing season	0·85[a]	0·71[b]
Second winter	0·49[a]	0·26[b]

Values on the same row followed by the same letter are not significantly different at $P < 0·05$.

sainfoin:grass ratio (Table 4). Most sainfoin plants died in the second winter when, at the high ratio of grass:sainfoin, the proportion that survived was only 0·26 (Table 4). Grass species had a significant effect on survival of sainfoin at the sampling date in the first winter period, when the proportion of sainfoin plants that survived was only 0·38 when grown with meadow fescue, compared with 0·53 of those grown with tetraploid perennial ryegrass (Table 3). At other sampling dates the proportion of surviving sainfoin plants was similar for both companion grasses. Root competition had no significant effects on survival of sainfoin (Table 1). Shoot competition had a significant effect in the second growing season when the effect of shoot competition led to fewer sainfoin plants surviving, compared with plants which were not subjected to shoot competition.

Discussion and conclusions

From the literature on plant competition in general, it might have been expected that root competition would have had an effect on survival of sainfoin plants. This proved not to be the case, however, and the major effect of factors on survival of sainfoin observed in this study was between treatments with different ratios of grass:sainfoin plants.

There was also an indication, in 2006, that above-ground (shoot) competition during the growing season was also having an effect. Although meadow fescue has been widely recommended as a companion grass for sainfoin, in this experiment it did not prove to be beneficial, compared with perennial ryegrass, for the survival of sainfoin, and on one sampling date the perennial ryegrass treatment had a higher survival rate. The early-heading date and erect growth habit of cv. Rossa compared with the later heading and more prostrate growth habit of cv. Condesa observed elsewhere in field experiments (Liu *et al.*, 2008a,b) could provide an explanation for this. Variable reductions in root reserves of sainfoin as a result of competition from grasses probably led to the greater mortality of sainfoin plants during the winter periods.

This study was conducted in plastic containers, which were placed above-ground, the shoots separated by white plastic film and the plants regularly watered. This probably created a slightly different micro-climate and soil conditions compared with ambient field conditions, and higher temperatures in the containers could have affected the outcomes. Kallenbach *et al.* (1996) reported that sainfoin growth is low after a period of high temperatures, and that high temperatures coupled with defoliation leads to reduced photosynthesis and the utilization of carbohydrate reserves to support high metabolic rates, resulting in the death of many sainfoin plants.

From this limited study it can be concluded that survival of sainfoin was negatively affected as a result of excessive competition from companion grasses, both during the growing season and during the subsequent winter periods. It can also be concluded that meadow fescue cv. Rossa appeared to be a marginally less suitable companion grass for sainfoin than tetraploid perennial ryegrass cv. Condesa. If sainfoin is to become more widely used in order to exploit its nutritional and

potential environmental benefits, then further detailed studies of this type, including further evaluation of the effects of companion grasses, will be necessary.

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