INTERCROPPING NARROW-LEAFED LUPINS WITH CEREALS FOR WHOLE CROP HARVEST

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ABSTRACT

The competitive ability of various spring-sown cereal species against lupins (*Lupinus angustifolius* L.) were evaluated under the influence of weed harrowing at two experimental sites in the south of Sweden in 2004. A narrow-leafed lupin (cv. Bora) was intercropped with either wheat, barley or a mixture of oats and barley. Weed harrowing was conducted once, before and then after the crop emergence. Non-harrowed control plots were included in the trials. Whole crop harvesting was performed twice with an interval of about two weeks. Each of the two times, half the area of every experimental plot was harvested. Averaged over sites and plant mixtures, the total crop yields increased from 4970 to 7070 kg DM ha^{-1}, at the early and late harvest, respectively. The mixtures of lupins/oats/barley and lupins/barley yielded 470 kg DM ha^{-1} more than lupins/wheat. At early harvest, no significant difference between mixtures was found regarding weight of lupins. Lupin weight increased significantly when harvest was delayed, and was 750 kg DM ha^{-1} higher in mixtures containing barley or wheat than in barley/oats. The proportion of lupins in the harvested crop increased in the order lupins/barley/oats < lupins/barley < lupins/wheat; the order demonstrating reduced competitive ability against lupins at the seed rates used. Based on biomass, weed-harrowing reduced the content of annual broad-leaved weeds in the harvested crop from 7% to 4% without significantly influencing the proportion or weight of lupins.

KEYWORDS

organic farming, competition, harvest time, weed harrowing

INTRODUCTION

Several new varieties of narrow-leafed lupins (*Lupinus angustifolius* L.) mature a few weeks earlier than older ones did. This ability allows cultivation at higher latitudes than before and especially organic farmers have shown an increased interest in lupin cultivation (Boström, 2006). However, under Scandinavian climate conditions there is a risk that low temperature some years prevents the lupin seeds from reaching full maturity before the onset of autumn rains which prevent or complicate the harvest. Also due to low weed-competitive ability, the organic cultivation of narrow-leafed lupins is risky since the use of herbicides is not allowed. By intercropping lupins with competitive cereals for whole-crop silage, the weed flourish may be restrained and a premature harvest is feasible.

Advantages and disadvantages of intercropping lupins with other plant species have been demonstrated in several studies (Carruthers *et al.* 2000; Hauggaard-Nielsen *et al.* 2008; Strydhorst *et al.* 2008). One disadvantage of intercropping is that the companion species are competitive not only against weeds but they may also hamper the growth of lupins. To some extent this drawback may be counteracted by increased seed rate of lupins. However, lupin seed for sowing is expensive, and therefore it is desirable to use companion cereal species that are not too competitive.

In order to further support the biomass production of lupins it may be advantageous to manage weeds not only by cultural means but also mechanically. In crops sown at narrow row distances, i.e. 11-12 cm, pre- and post emergent harrowing are commonly used strategies for weed management in organic farming (Briggs, 2008).

The main objective of this study was to examine the differences between cereal species in competitive ability against weeds and lupins under the influence of weed harrowing. The second objective was to estimate the potential of biomass production of the various crop species mixtures at two times of harvest.

MATERIALS AND METHODS

In 2004, a narrow-leafed lupin (*Lupinus angustifolius* L.; cv. Bora) was intercropped with wheat (*Triticum aestivum* L.; cv. Dacke), barley (*Hordeum vulgare* L.; cv. Orthega) or a mixture of oats (*Avena sativa* L.; cv. Sang) and barley at two experimental sites in the south of Sweden (Table 1). The seed-rates of cereals were reduced to 30% of the rates normally recommended, and were 60 kg ha^{-1} of barley, 70 kg ha^{-1} of wheat and 30 kg ha^{-1} for each of barley and oats when sown together. For lupins, the seed rate was 75 germinable seeds m^{-2}, corresponding to 115 kg ha^{-1}.

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At time of sowing, lupin seeds were inoculated with *Bradyrhizobium*.

Plots were weed-harrowed at one occasion before, and at one occasion after crop emergence (Table 2). Non-harrowed control plots were included for each crop combination. Plots were harvested at two times; here referred to as early and late harvest. At each time of harvest, half the area of each experimental plot was cut at a stubble height of 8 cm, and the whole-crop biomass was estimated. From each plot, a representative sub-sample of ca. 2 kg of the harvested plant material was collected, dried and weighed. Another representative sub-sample of the harvested plant material from each plot was collected, separated into the components lupins, cereal species and weeds where after each fraction was weighed. At the two times of harvest, one sample from each crop mixture was analysed for content of crude protein (Cp) by the Kjeldahl method (Cp concentration = N concentration × 6.25).

The early harvest was made at when 50% of the lupin pods had reached full size, while the late harvest took place two weeks later at Vinslöv and three weeks later at Högåsa.

The experimental design was a split-plot with three blocks, where weed harrowing and intercrop were assigned to whole-plots and the two times of harvest to subplots. The analysis of data (Proc Mixed in SAS vs. 8.02) took into account the fixed effects of all main effects, all two- and three-way interactions as well as the random effects of blocks, whole plots and residuals. The two trials were analysed together. Comparisons of treatments were based on the least square means (LSD), with a significance level of $P < 0.05$.

Table 1. Location and characteristics of the two experimental sites where lupins were intercropped with cereals.

Site	Location	Soil type	Precrop	Fertiliser	Dominating weeds
Vinslöv	56.1°N, 13.9°E	Sand	Pea/oats	20 tons slurry ha^{-1}	*Chenopodium album* L., *Stellaria media* (L.) Vill., *Viola arvensis* Murr.
Högåsa	58.5°N, 15.5°E	Heavy clay	Winter-wheat	Not applied	*Bilderdykia convolvulus* (L.) Dum., *Chenopodium album* L., *Viola arvensis* Murr.

Table 2. Dates for implementation of treatments at the two experimental sites.

Site	Date for sowing	Weed-harrowing		Harvest time	
		Before c.e.*	After c.e.	Early	Late
Vinslöv	22 April	29 April	17 May	16 July	30 July
Högåsa	21 April	3 May	13 May	8 July	29 July

* Crop emergence.

RESULTS AND DISCUSSION

WEED MANAGEMENT

Lupins have been found tolerant to intense weed harrowing during a rather wide range of development stages (Jensen *et al.* 2000) and was also fairly tolerant to soil covering caused by weed harrowing (Jensen *et al.* 2004). The tolerance to weed harrowing was confirmed in the two trials reported here, where harrowing reduced weed biomass in the harvested crops from 7 to 4% ($P < 0.05$) without significantly influencing the weight or proportion of lupins in the harvested material. However, weed harrowing reduced total crop yields by 5%.

In low competitive crops, weed control may be profitable although it does not straightforwardly increase crop yields. That is, the purpose of weed management is not only to reduce yield loss caused by weeds the current year, but also to restrict the addition of new weed seeds to the soil seed bank. Otherwise, seed from weeds that becomes reproductive before crop harvest may cause problems during several years afterwards (Wilson and Lawson, 1992). Also, since it is impossible to separate weeds from crop plants at whole crop harvests for fodder, some weed species may cause problems due to low nutritive value or due to the production of substances toxic to animals. Commonly occurring, annual weed species, like black nightshade (*Solanum nigrum* L.), field penny-cress (*Thlaspi arvense* L.) and common groundsel (*Senecio vulgaris* L.) have all been reported as being toxic to livestock (Bassett and Munro, 1985; Warwick *et al.* 2002; Moyano *et al.* 2006).

WHOLE-CROP YIELDS

When the harvest was delayed, the whole-crop yields increased significantly from 4970 to 7070 kg DM ha-1 ($P < 0.05$). At Högåsa, the dry matter (DM) content in the harvested material increased from 15.7% at early harvest to 18.8% at the late harvest (P < 0.05), while at Vinslöv the DM content was 18% at both harvest times. The DM content was 2 percentage points lower in the intercrop lupins/wheat than in other intercrops; possibly an effect of the longer maturing time for wheat compared to the other cereal species.

The mixtures of lupins/oats/barley and lupins/barley yielded 470 kg DM ha-1 more than lupins/wheat in both harvests. No significant interaction *Site*×*Intercrop* was found (P > 0.05) for the total weight of crop yields.

Despite shorter time interval between the two harvests at Vinslöv (two weeks) than at Högåsa (three weeks), the increase of lupin biomass was twofold higher at Vinslöv (P < 0.05). At Vinslöv the proportion by weight of lupins increased from 61% at the early harvest to 73% at the late, while at Högåsa the proportion of lupins was 50% at both harvest times. The sandy, and thereby comparatively dry, soil at Vinslöv may have favoured lupins more than the cereals, in contrast to the heavier clay soil at Högåsa, recognised by higher available water capacity. The adaption by lupins to drought has been described by, e.g. French and Buirchell (2005). The interaction *Intercrop*×*Harvest time* showed (P < 0.05) that delayed harvest favoured lupins most when intercropped with barley (Fig. 1).

The response to companion species by lupin weight in the harvested crop varied significantly between sites (Fig. 2). At Vinslöv the companion species had no significant influence on lupin weight. At Högåsa, barley was the least competitive companion, and allowed lupin biomass to increase by 46%, from 2378 kg DM ha-1 in lupins/barley/oats to 3478 kg DM ha-1 in lupins/barley. Also, wheat was less competitive against lupins than the mixture of barley/oats. That oats yielded more than barley, despite equal seed rates were sown on both sites (Figs 1 and 2).

Averaged over sites and treatments the proportion of lupins in the harvested crop increased significantly in the order lupins/barley/oats (51%) < lupins/barley (59%) < barley/wheat (66%) (P < 0.05) indicating that intercropping with wheat favoured lupins more than intercropping with other companion species did. A similar hierarchy of weed suppressive ability in winter cereals was noted by Seavers and Wright (1999); oats was the most suppressive cereal, followed by barley and then wheat as the least competitive species.

The concentration of crude protein was 11.2% in lupins/barley/oats, 12.1% in lupins/barley and 12.6% in lupins/wheat, but differences between treatments (*Intercrop* and *Harvest time*; *Site* treated as random) was not statistically significant (P > 0.05). The absence of replicated protein analyses, resulting in few degrees of freedom, may have contributed to the absence of statistically significant treatment effects concerning protein concentration. For that reason, it is not feasible to draw any conclusion about differences between intercrops in total protein yields.

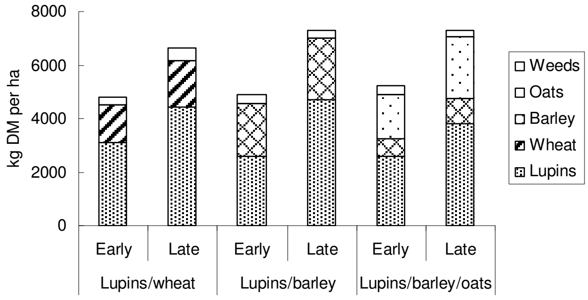

Fig. 1. The whole-crop yields of intercrops harvested early and late, as average over two experimental sites in southern Sweden. LSD for weight of lupins 573.

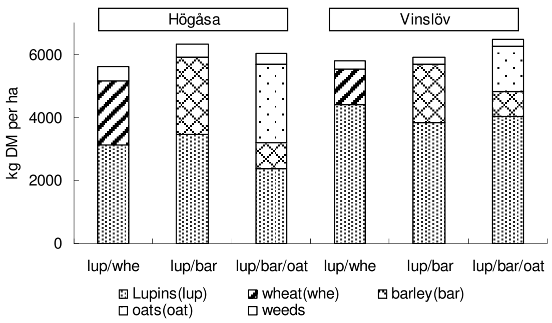

Fig. 2. The whole-crop yields of intercrops grown at two experimental sites in southern Sweden, average over two times of harvests. LSD for weight of lupins 776.

CONCLUSIONS

It can be concluded that weed harrowing before and after crop emergence reduced significantly the weed biomass without reducing the weight of lupins in the harvested crop. By delaying the time of harvest 2-3 weeks, the crop yields increased considerably. The suppression of lupin biomass increased in the order wheat ≤ barley < oats but the total crop yield of lupins/wheat was 8% lower than the yield of other intercrops.

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LITERATURE CITED

Bassett, I.J. and D.B. Munro. 1985. The biology of Canadian weeds. 67. *Solanum ptycanthum* Dun., *S. nigrum* L. and *S. sarrachoides* Sendt. Canadian Journal of Plant Science 65: 401-414.

Boström, U. 2006. Weed management in organically-grown narrow-leafed lupin. pp. 89-92. *IN* E. van Santen, and G.D. Hill (eds.) Mexico, where old and new world lupins meet. Proceedings of the 11th International Lupin Conference, Guadalajara, Jalisco, Mexico, 4-9 May, 2005. International Lupin Association, Canterbury, New Zealand.

Briggs, S. 2008. Organic cereal and pulse production. The Crowood Press Ltd. United Kingdom. 432 pp.

Carruthers, K., B. Prithiviraj, Q. Fe, D. Cloutier, R.C. Martin and D.L. Smith. 2000. Intercropping corn with soybean, lupin and forages: yield component responses. European Journal of Agronomy 12(2): 103-115.

French, R.J. and B.J. Buirchell. 2005. Lupin: the largest grain legume crop in Western Australia, its adaptation and improvement through plant breeding. Australian Journal of Agricultural Research 56(11): 1169-1180.

Hauggaard-Nielsen, H., B. Jørnsgaard, J. Kinane and E.S. Jensen. 2008. Grain legume–cereal intercropping: The practical application of diversity, competition and facilitation in arable and organic cropping systems. Renewable Agriculture and Food Systems 23(1): 3–12.

Hauggaard-Nielsen, H., B. Jørnsgaard, J. Kinane and E.S. Jensen. 2008. Grain legume–cereal intercropping: The practical application of diversity, competition and facilitation in arable and organic cropping systems. Renewable Agriculture and Food Systems 23(1): 3–12.

Jensen, R.K., B. Melander and N.H Callesen. 2000. Mechanical weed control in lupin. pp. 76-78. *IN* E. van Santen, M. Wink, S. Weissman and P. Roemer (eds). Lupin, an Ancient Crop for the Millennium. Proceedings of the 9th International Lupin Conference, Klink/Muritz, 20-24 June, 1999. International Lupin Association, Canterbury, New Zealand.

Jensen, R.K., J. Rasmussen and B. Melander. 2004. Selectivity of weed harrowing in lupin. Weed Research 44(4): 245-253.

Moyano, M.R., A. García, A. Rueda, A.M. Molina, A. Mendez and F. Infante. 2006. *Echium vulgare* and *Senecio vulgaris* poisoning in fighting bulls. Journal of Veterinary Medicine Series A: Physiology Pathology Clinical Medicine 53(1): 24-25.

Seavers, G.P. and K.J. Wright. 1999. Crop canopy development and structure influence weed suppression. Weed Research 39(4): 319-328.

Strydhorst, S.M., J.R. King, K.J. Lopetinsky and K.N. Harker. 2008. Forage potential of intercropping barley with faba bean, lupin, or field pea. Agronomy Journal 100: 182-190.

Warwick, S.I., A. Francis and D.J. Susko. 2002. The biology of Canadian weeds. 9. *Thlaspi arvense* L. (updated). Canadian Journal of Plant Science 82(4): 803-823.

Wilson, B.J. and H.M. Lawson. 1992. Seedbank persistence and seedling emergence of seven weed species in autumn-sown crops following a single year's seeding. Annals of applied Biology 120: 105-116.