Competitive ability of grain legume-barley intercrops towards volunteer crops and weeds

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***Abstract* - Field pea (*Pisum sativum* L.) and blue lupin (*Lupinus angustifolius* L.) were either sole cropped or intercropped with barley (*Hordeum vulgare* L.) at two levels of nitrogen application to determine the effects of interspecific interaction in an intercrop and nitrogen fertility on competitive ability towards volunteer crops - exemplified by red clover (*Trifolium pratense*). The dynamically change of competitive ability by intercropped species over time was shown to be important in order to reduce opportunities for growth of volunteer crops and weeds.[1]**

INTRODUCTION

Improved competition with weeds has been emphasised as one of the benefits of intercrops (Liebman & Davis, 2000) among various others relevant for organic farming including pest suppression effects, yield quality and quantity (Theunissen, 1997).

Crop species like red clover, cereal rye (*Secale cereale* L.), potato (*Solanum tuberosum* L.), rape seed (*Brassica napus* L.) among others can volunteer in planted crops presenting the farmer with many of the same problems associated with traditional weed management. Weed control in organic systems focuses on management techniques designed to prevent weeds, like mechanical weed control (Rasmussen & Ascard, 1995), as well as establishing a crop stand vigorous enough to suppress weeds (Hauggaard-Nielsen et al., 2001).

Increased interspecific competition comparing intercrops (IC) to sole crops (SC) is assumed to result in a more dynamic intercrop response to a variety of growth conditions including temporal and spatial heterogeneity in growth of volunteer crops (and weeds) throughout a growing season. The main objectives of the present study were to determine 1) the effects of pea-barley and lupin-barley IC on the red clover biomass production as compared to the respective SCs and 2) the effect of crop N use according to red clover biomass production.

MATERIALS AND METHODS

The experiment was carried out in 2003 at the Experimental Farm of The Royal Veterinary and Agricultural University, Denmark on a sandy loam soil. The field was known for its regrowth of volunteer red clover grown for seed in 2001. The site was managed with no use of herbicides and with mechanical weeding two times during emergence.

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Field pea (cv. Agadir) and narrow-leafed lupin (cv. Prima) were grown as sole crops (SC) and in a dual mixed intercrops (IC) with spring barley (cv. Otira) employing a replacement design with 50%:50% ratios, so that an IC consisted of 50% of the SC plant populations of each IC component. Target plant densities were 350, 120 and 90 plants m^{-2} for SCs of barley, lupin and pea, respectively. Crops were grown at two levels of N; without application and with application of 5 g urea-N m^{-2}.

Hand harvesting (0.5 m^2) was conducted six times during the growing season. Total N and ^{15}N was determined on sub-samples of finely ground material using a CFIR-mass spectrometer (MS) (ANCA-SL/20-20, Europe Scientific Ltd., Crewe, UK). Leaf area index (LAI) of the crop components was determined using a light area meter (LI-COR, LI-3110 AREA METER, Glen Spectra Ltd., UK).

RESULTS

In the first 36 days after emergence (DAE) weed dry matter (DM) production was dominated by species such as *Polygonum* spp., *Lolium perenne* L., *Veronica* spp. and *Chenopodium album* L., and characterised by a significantly greater weed accumulation in the fertilized compared to the unfertilized plots. However, the red clover volunteer crop strongly dominated the total weed DM accumulation from 49 DAE and throughout the rest of the growing season. From visual evaluation more than about 90% of the final weed biomass consisted of red clover. At the final harvest the weed DM accumulation in unfertilized pea-barley and lupin-barley ICs was significantly lower than in barley SCs but not different from pea and lupin SCs, respectively.

Grain DM yield of pea SC without N application was significantly higher than in the pea plots with N application and all other SC yields and combined IC yields (Table 1). In contrast, application of 5 g N m^{-2} significantly increased the grain DM and N yield of barley SCs. Independent of N application pea-barley and lupin-barley ICs produced combined grain N yields significantly higher than barley SC and significantly lower than pea and lupin SCs.

Total amount of N_2-fixation in pea IC and lupin IC was significantly lower than the amount when grown as SCs (Table 1). Pea IC without N application fixed a greater amount of N than when N was applied, but with no N application effect in lupin IC.

Land Equivalent Ratio values (LER) for lupin-barley IC without N application were above one from 36 DAE (Table 2), whereas the N application eliminated the intercrop advantages until 79 DAE. Thereafter no difference was found comparing intercrops and N treatment. Judged by the final harvest 107 DAE, 14 % improved use of resources was achieved by lupin-barley IC whereas pea-barley IC showed no major improvements compared to the SCs.

Table 1. Average grain dry matter (DM) production (g m^{-2}) in sole crops (SC) and combined intercrops (IC) of pea, lupin and barley. Nitrogen (N) fixation in pea and lupin SC and IC (g shoot N m^{-2}) estimated by the ^{15}N natural abundance method. Values followed by the same letter are not significantly different (P<0.05)

Species	Parameter	Fertilization	
		0 g N m^{-2}	5 g N m^{-2}
Pea SC	Grain DM	678^{A}	514^{A}
Lupin SC		$431^{A}B$	429^{AB}
BarleySC		138^{E}	335^{CD}
Pea-barley IC		361^{BCD}	350^{BCD}
Lupin-barley IC		293^{D}	394^{BC}
Pea SC	N_2-fixation	22.6^{A}	13.2^{C}
Lupin SC		10.3^{D}	4.5^{E}
Pea IC		18.5^{B}	17.1^{B}
Lupin IC		4.8^{E}	6.9^{E}

Table 2. Land equivalent ratio (LER)[1] for pea-barley and lupin-barley intercrops based on total crop shoot dry matter production. Values are the mean (n=4) ± SE

DAE	Pea-barley		Lupin-barley	
	0 g N m^{-2}	5 g N m^{-2}	0 g N m^{-2}	5 g N m^{-2}
22	0.96±0.10	0.97±0.07	1.00±0.07	0.96±0.05
36	1.11±0.02	1.07±0.09	1.09±0.08	0.95±0.07
49	1.21±0.12	1.08±0.04	1.10±0.04	0.99±0.07
64	1.12±0.15	1.02±0.04	1.27±0.24	0.99±0.13
79	1.24±0.20	1.12±0.06	1.10±0.12	1.11±0.10
107	0.93±0.08	1.05±0.14	1.15±0.07	1.13±0.12

[1]LER>1 indicate an advantage from intercropping in terms of the use of environmental resources for plant growth. LER of pea-barley IC = $Y_{barleyIC}/Y_{barleySC} + Y_{peaIC}/Y_{peaSC}$

Discussion

Early responses to improved competitive ability towards weeds may be determined by a greater uptake of soil mineral N (Hauggaard-Nielsen et al. 2001). Until 49 DAE barley was very competitive related to efficient soil nitrogen uptake. At later growth stages red clover enlarged biomass production and competition for light and access to atmospheric N through symbiotic N_2-fixation, became more important. A negative linear correlation between LAI 22 DAE and weed DM 36 DAE found for each level of N application indicated strong early effects of crop canopy size (Fig. 1). Furthermore, the greatest final red clover growth was found in plots with the lowest leaf area (data not shown).

At later growth stages red clover enlarged biomass production and competition for light and access to atmospheric N_2 through fixation, became more important than competition for a very limited amount of soil mineral N. Contrary to the general picture that yields of grain legume components in legume-cereal ICs are depressed by the cereal components (Hauggaard-Nielsen et al., 2001) the greatest grain yields and grain N yields was achieved by pea and lupin SCs (Table 1).

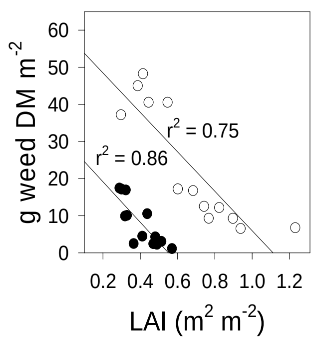

Figure 1. Total weed dry matter accumulation (DM) (including volunteer red clover crop) 36 days after emergence in relation to total crop leaf area index (LAI) measured 22 days after emergence. Regression lines are separated with application of 5 g urea-N m^{-2} (open symbols) or without (closed symbols) N application.

Obviously, low soil mineral N levels and infestation of N_2 fixing volunteer crop improved grain legume dry matter production and thereby competitive ability. However, utilization of environmental resources for plant growth resources is shown to dynamically change over time (Table 2) indicating temporal variations in the crops ability to empty resource niches and thereby capture local plant growth resources according to intercropped species, which seems to be important traits for the ability to reduce weed biomass production.

Conclusions

The greatest grain yields were achieved by pea SC and lupin SC, while the ICs used environmental resources for plant growth only slightly more efficient. However, the ICs ability to respond to actual growth conditions due to the crop components different responds to a variety of growth factors is important to secure stable yields in fields with strong interspecific competition from volunteer crops (and/or weeds).

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