EFFECT OF DIFFERENT SOWING DENSITIES IN MIXED CULTIVATION OF BLUE LUPIN (*L UPINUS ANGUSTIFOLIUS*) WITH SPRING CROPS ON YIELD AND QUALITY

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ABSTRACT

The aim of this investigation was to optimise the yield percentage of blue lupins in mixed cropping systems. Field experiments were conducted at two locations in Northern Germany (Institute of Organic Farming near Hamburg and Institute of Plant and Soil Science at Braunschweig). Two types of blue lupins, the determinate and branched type were cultivated together with spring barley, spring wheat or fodder peas in different seeding ratios (SR): 50% : 50%, 62.5% : 37.5 % and 75% : 25% of the respective pure cropping seeding rate. We present data on total grain yield, yield of blue lupins, yield percentage of blue lupins, protein content, and protein yield. Total grain yield decreased with increasing SR of blue lupins whereas, in contrast, the yield of blue lupins, protein content and protein yield increased. This shows the low competitive ability of blue lupins against the mixed cropping partners, particularly cereals. Therefore, the yield percentage of blue lupins in mixed cropping with cereals did not reach more than 25%. From the view of plant production and the purpose of animal nutrition the percentage of grain legumes should be higher and comparable to those of other crop mixtures like peas with spring barley or beans with oat.

KEYWORDS

Lupinus angustifolius, mixed cropping, yield, quality, organic farming

INTRODUCTION

In Germany, much experience has been gained in respect to the mixed cultivation of spring cereals with beans or fodder peas, but not with blue lupins. First results presented by Bramm *et al*. (2006) gave some information about the low competitive capability of blue lupins in mixed cropping with spring cereals. In addition, blue lupins often show high weed infestation in pure stands due to slow juvenile development. Weed infestation can be very effectively reduced by mixed cropping systems. But the yield percentage of blue lupins in mixed cropping systems with a sowing density of 50% of the pure cropping density was very low (Bramm *et al*. 2006). For this reason, the sowing density was varied in field experiments to incorporate higher percentages of blue lupins to check the effect on total grain yield, yield percentage of blue lupins, and chosen quality parameters.

MATERIALS AND METHODS

In the years 2005 to 2007, field trials investigating blue lupins grown in mixtures with other crops were conducted at two locations in Northern Germany: the IOF-site of the Institute of Organic Farming at Trenthorst near Hamburg and the ICSS-site of the Institute of Crop and Soil Science at Braunschweig, which was managed conventionally. The soil of the IOF-site is a sandy loam with a high content of silt and a pH of 5.6–6.3, the soil of the ICSS-site is a sandy loam with a pH of 5.7–5.9. Both sites had a good nutrient level of phosphorus, potassium and magnesium. At the ICSS-site, generally 40 kg N ha^{-1}, 130 kg K ha^{-1} and 4.0 L ha^{-1} of the herbicide Stomp (equivalent to 1.6 kg ha^{-1} Pendimethalin) were applied after sowing. In both years 75 mL ha^{-1} Karate Zeon was used for insect control and the field was irrigated two times with 30 mm water. The crop mixtures consisted of lupins, either the determinate cultivar 'Boruta' (BL-D, pure stand: 130 seeds m^{-2}) or the branched cultivar 'Bora' (BL-B, pure stand: 100 seeds m^{-2}), combined with spring barley (SB, pure stand: 300 (IOF), 370 (ICSS) seeds m^{-2}), spring wheat (SW, pure stand: 420 (IOF), 460 (ICSS) seeds m^{-2}), and fodder peas (FP, pure stand: 70 seeds m^{-2}) in different seeding ratios: 50% : 50%, 62.5% : 37.5 %, and 75% : 25% of the respective pure cropping seeding rate. Each trial was a randomised block design with four replicates.

Grain was harvested from each plot between the middle of August and beginning of September. After drying and cleaning of the harvest samples, sub-samples were ground (Cyclotec 1093, Fa. Foss) to a particle size of 1 mm. Crude nutrients were scanned and predicted by near infrared reflectance spectroscopy (NIRS). NIRS analysis on organically grown legumes was carried out

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on the ground samples using the Fourier-Transform NIR spectrometer (NIRLab N-200, Fa. Büchi, Essen) in the spectral range from 1000 to 2500 nm applying a 1 nm stepping. Each sample was scanned three times and the spectra were averaged. Spectral data were exported to the NIRCal software (Büchi). Calibration equations developed for each constituent separately by partial least square regression technique (PLS) were used for prediction (Aulrich and Böhm, 2008) of the crude nutrients. The conventionally grown samples were analysed with the NIRSystems 6500 spectrophotometer (FOSS) in the spectral range from 400-2500 nm. The spectral data were treated by the ISI software. The relative yield total value (RYT) was calculated according to de Witt and van den Bergh (1965) to describe the productivity of the mixed cropping systems. The relative yield (RY) is defined as Y_{MC}/Y_{PS} (Y_{MC} = yield of a crop in mixed cultivation, Y_{PS} = yield of the same crop in pure stand). The RYT for an MC of two crops A and crop B is the sum of the RY values for crop A and B. RYT values > 1 indicates a higher yield of mixed cultivation compared to pure stand.

Statistical Analysis was performed with the MIXED procedure of the SAS software package 9.1.3 (SAS Institute 2004). Seeding ratio (SR), mixing crop partner (MCP), and location (LOC) were regarded as fixed effects, and year as a random factor.

RESULTS AND DISCUSSION

Fig. 1 shows the total grain yield of each crop in pure stand, and of each mixture with blue lupins, averaged over the two locations and the three years. The pure stands of spring barley, spring wheat and fodder peas produced comparable yields. The two cultivars of blue lupins produced significantly lower yields. Mixed cropping plots with cereals produced similar yields to pure stands of barley, wheat, and peas. Lower yields were produced by mixed cropping blue lupins with fodder peas. A mixture of fodder peas and spring barley was also tested. This mixture produced a higher yield than other mixtures (Fig. 1).

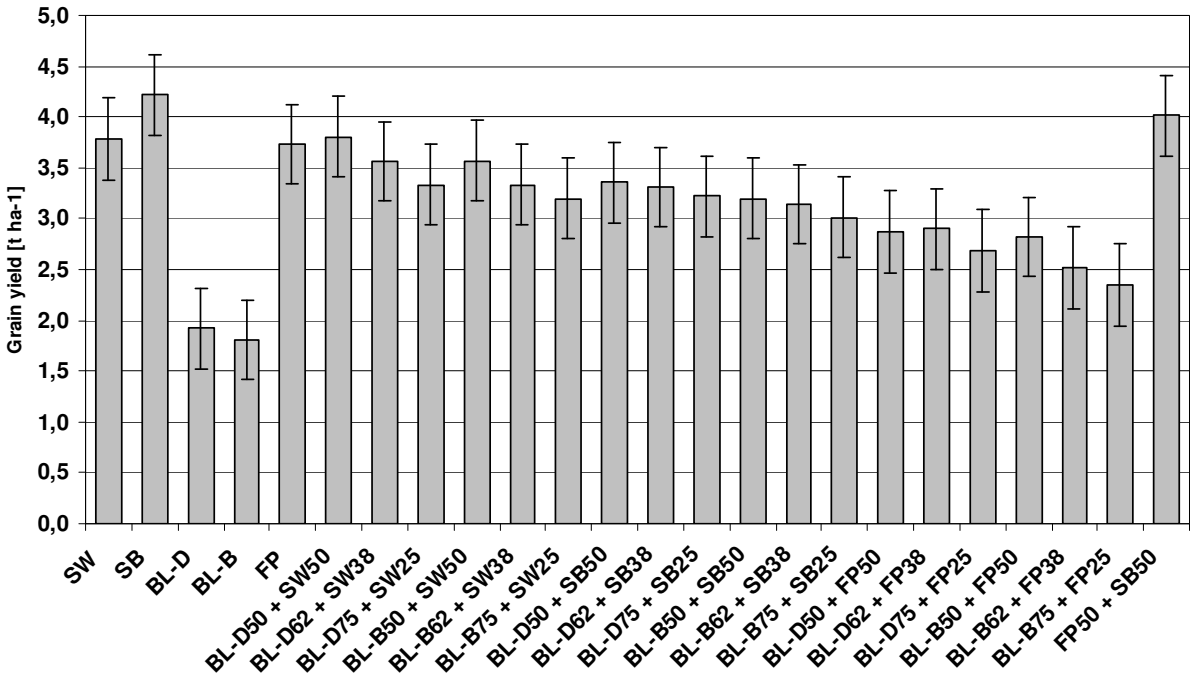

Fig. 1. Grain yield (t ha^{-1} DM) of pure stand of spring wheat (SW), spring barley (SB), blue lupin determinate type (BL-D) and branched type (BL-B), fodder peas (FP) and the combinations of mixed cropping applying different seeding ratios. Means over the years 2005–2007 and the two locations. Vertical bars represent the standard error.

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Table 1. P-values for sources of variation in total grain yield (Y-tot), yield of blue lupin (Y-BL), yield of mixed cropping partner (Y-MCP), crude protein content (XP), yield of protein (XP-yield), yield percentage of blue lupin (%Y-BL), and the relative yield total (RYT). Figures in bold are significant at P < 0.05.

	DF	Y-tot	Y-BL	Y-MCP	%Y-BL	RYT	XP	XP-yield
SR	2	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	0.2499	**< 0.0001**	**0.0146**
MCP	2	0.2840	0.6208	0.2504	0.1194	0.3052	**0.0022**	0.1745
LOC	1	0.4441	0.5920	0.4325	0.8054	0.9651	**0.0474**	0.2666
REP	3	0.7400	0.2924	0.6208	0.4279	0.5804	0.2099	0.8576
MCP * SR	4	0.4319	**0.0429**	0.1350	**< 0.0001**	0.6709	0.3028	0.2224
LOC * MCP	2	0.7200	0.8710	0.7469	0.9707	**0.0404**	0.0955	0.7424
LOC * SR	2	0.8445	0.3601	0.7278	0.9790	0.5743	0.3270	0.5628
LOC * MCP * SR	4	0.1562	0.8794	0.4463	0.5427	0.2858	0.7505	**0.0363**

SR = seeding ratios, MCP = Mixed cropping partner, LOC = location.

Table 2. Main effect means for mixed cropping partner (MCP), location (LOC), and seeding ratios (SR) of total grain yield (Y-tot), yield of the blue lupin (Y-BL), yield of the mixed cropping partner (Y-MCP), yield percentage of blue lupin (%Y-BL) and the relative yield total (RYT).

		Y-tot [t ha^{-1} DM]	Y-BL [t ha^{-1} DM]	Y-MCP [t ha^{-1} DM]	%Y-BL [%]	RYT
SR	50:50	3.26 c	0.42 a	2.84 c	14.45 a	0.98
	63:37	3.13 b	0.59 b	2.54 b	20.70 b	0.99
	75:25	2.97 a	0.82 c	2.16 a	30.20 c	1.01
MCP	SW	3.46	0.61	2.85	18.03	1.09
	SB	3.21	0.56	2.64	18.24	0.95
	FP	2.70	0.66	2.04	29.06	0.93
LOC	IOF	2.86	0.59	2.27	22.35	0.99
	ICSS	3.39	0.63	2.75	21.20	0.99

Different letters indicate significant differences within the main factors SR, MCP and LOC.

To quantify the effects of the different seeding ratios (SR) and mixed cropping partners (MCP) further statistical analyses were only carried out for the mixtures of blue lupins with cereals or fodder peas, respectively. The p-values of the statistical analysis are summarised in Table 1. They show that seeding ratio (SR) had significant effects on all parameters except RYT, and MCP and LOC also had significant effects on crude protein content (XP). There were significant interactions between mixed cropping partners (MCP) and SR for yield of blue lupins (Y-BL) and yield percentage of blue lupins (%Y-BL). There was a significant interaction between LOC and MCP for RYT. The only significant 3-way interaction between LOC, MCP, and SR was for XP-yield.

The main effect means for SR, MCP, and LOC are presented in Tables 2 and 3. The total grain yield of the mixtures decreased significantly with increasing SR-percentage of blue lupins. Whilst yields of MCP decreased with increasing SR, yields of blue lupins in these mixtures increased. The effect of the interaction between MCP and SR on blue lupin yield is shown in Figure 2. Seeding ratio affected yield of blue lupins in the same way with each MCP, but in the case of spring barley there was no significant difference between the ratio 50 : 50 and 63 : 37. The yield percentage of blue lupins was significantly affected as well (Table 2). The effect of the interaction between MCP and SR on yield percentage of blue lupin is shown in Table 4. It was lowest with 11.8 to 18.1 % in the 50 : 50 SR and highest for a blue lupin seeding percentage of 75%. The effect of the SR was similar for the two cereals, but different in mixtures with fodder peas where the highest yield percentage of blue lupin was 41.8%, with SR 75 : 25, compared to 24.1% and 24.6% in the two cereals. Therefore, it is possible to increase the yield percentage of blue lupin, but it is more difficult in mixtures with cereals than peas. Increasing the yield percentage of blue lupins will be associated with decreased total yield (Table 2). This results from the poor competitive ability of blue lupin in mixed cropping systems, particularly with cereals. It was observed that the good tillering ability and faster early growth of cereals suppressed blue lupins. The high N-mineralisation of the IOF-site and N-fertilisation at the ICSS-site stimulated these effects. On light, sandy soils the competition of cereals

might be not so pronounced. Other mixed cropping systems, e.g. fodder peas with barley or beans with oat are more balanced, so that the percentage of legumes reached 50% with a SR of 50 : 50 (Berk and Böhm, 2006). SR, MCP, and LOC only had small effects on RYT. RYT differed significantly between MCP at the IOF-site, where mixtures with spring wheat were significantly higher than with spring barley or fodder pea (Fig. 3).

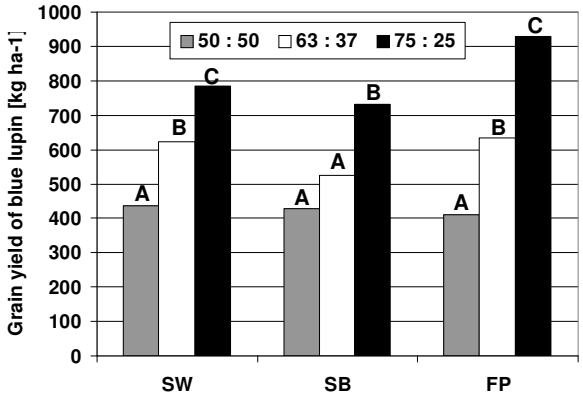

Fig. 2. Interaction between mixed cropping partner (MCP) (spring wheat (SW), spring barley (SB) and fodder peas (FP)) and seeding ratio (SR) for yield of blue lupins. [Different upper case letters indicate significant differences within the same MCP.]

Table 3. Main effect means of mixed cropping partner (MCP), location (LOC) and seeding ratio (SR) for crude protein content (XP), protein yield (XP-yield).

		XP [% DM]	XP-yield [kg ha^{-1} DM]
SR	50:50	18.50 a	587 a
	63:37	19.99 b	612 b
	75:25	21.59 c	623 b
MCP	SW	18.15 a	627
	SG	16.06 a	507
	FE	25.87 b	686
LOC	IOF	19.19 a	523
	ICSS	20.87 b	691

Different characters indicate means that are significantly different within the main factors SR, MCP and LOC.

Table 4. Interaction between mixed cropping partner (MCP) (spring wheat (SW), spring barley (SB), and fodder peas (FP)) and seeding ratio (SR) for yield percentage of blue lupins.

		Mixed cropping partner (MCP) of blue lupin		
		SW	SB	FP
Seeding ratio (SR)	50:50	11.80 a A	13.41 a A	18.14 a A
	63:37	18.19 a B	16.69 a B	27.20 a B
	75:25	24.09 a C	24.63 a C	41.83 b C

Different upper case characters indicate significant differences between SR within the same MCP, different lower case characters indicate significant differences between MCP within the same SR.

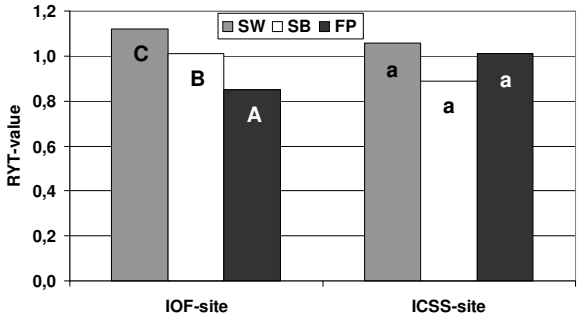

Fig. 3. Interactions between location (IOF-site and ICSS-site) and mixed cropping partner (spring wheat (SW), spring barley (SB) and fodder peas (FP)) for RYT. [Different upper case letters indicate significant differences within the IOF-site, different lower case letters indicate significant differences within the ICSS-site.]

The XP increased with increasing SR of blue lupins (Table 3). Similar was the effect on XP-yield, the SR of 63 : 37 and 75 : 25 reached the significantly highest XP-yield (Table 3). Mixed cultivation of blue lupin with fodder pea showed the highest XP, but due to the lower yield of these mixtures, no significant influence on the XP-yield was observed. The effect of LOC on XP and XP-yield is caused by the higher total yield and XP at the ICSS-site, which may be an effect of the N-fertilisation.

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