YIELD AND PREDICTED FEED QUALITY OF DIFFERENT GERMAN CULTIVARS OF BLUE LUPINS (*LUPINUS ANGUSTIFOLIUS*)

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ABSTRACT

In the present work different cultivars of blue lupins were tested at two sites, the experimental farm of the Institute of Organic Farming (IOF-site) at Trenthorst near Hamburg and the experimental station of the Institute of Plant and Soil Science (ICSS-site) at Braunschweig (conventional farming). The field experiments were conducted from 2003-2005 at the IOF-site and in 2006 and 2007 at the ICSS-site. At the IOF-site yield was 2.95 t ha^{-1} on average, whereas the mean yield at the ICSS-site was lower with 2.0 t ha^{-1}. However, a significant interaction between cultivar and year was observed for yield ($P < 0.001$ and $P < 0.01$ for IOF-site and ICSS-site, respectively). At the ICSS-site the cultivars Vitabor, Boltensia, Borlu and Sonet showed the lowest yield. Yield was similar between the branched and determinate cultivars at both sites, but the crude protein content (CP) was in the majority of the cases higher in the branched cultivars. The CP content ranged between 28.2% and 37.8% DM at the IOF-site and between 34.7 and 39.2% DM at the ICSS-site, respectively. The newer cultivars Idefix and Probor, which were tested at ICSS-site in 2006 and 2007, had the highest CP content (39.2 and 38.8% DM). Additionally, the predicted Net Energy for Lactation (NEL) in dairy cow and the predicted Metabolised Energy for pigs (ME) showed interactions between year and cultivar with the exception of ME at the ICSS-site. Cultivars with a high NEL respectively ME were Bora, Boruta, Bolivio and Borlu at the IOF-site and Probor, Borlu, Idefix, Boregine and Boltensia at the ICSS-site.

KEYWORDS

Lupinus angustifolius, cultivar, yield, feed quality, organic farming

INTRODUCTION

Soybean meal is the most important protein source in animal nutrition in Europe. For conventional farming, alternatives are required if the farmers do not want to use genetically modified (GM) feedstuffs. Generally, in organic farming, GM cultivars are not permitted and, in the EU Regulation 2092/91 for Organic Farming, the exclusive use of organically produced animal feedstuffs is fixed for the year 2011. Additionally, the demand for protein rich feed components is very high and the use of synthetically produced amino acids is not allowed in Organic Farming. Therefore, the cultivation of home-grown high-protein grain legumes, especially blue lupins is of increasing relevance. Differences in yield, parameters of feed quality, mineral and amino acid content between the German cultivars have been examined in only a few studies.

MATERIALS AND METHODS

In the years 2003 to 2007, cultivar trials in a quadruplicated randomised block design with up to 12 different German varieties of blue lupins were conducted at two locations in northern Germany: 1) The Research Farm of the Institute of Organic Farming (IOF), located at Trenthorst near Hamburg, is managed organically according to the EU Regulation 2092/91; 2) The Research Station of the Institute of Crop and Soil Science (ICSS) at Braunschweig is managed conventionally. The soil at 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 adequate levels of phosphorus, potassium and magnesium. At the ICSS-site 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 generally applied after sowing. In both years 75 mL ha^{-1} Karate Zeon was used as insecticide and the field was irrigated twice with 30 mm water.

The trials were conducted at the IOF-site from 2003 to 2005, and at the ICSS-site in 2006 and 2007. The seeding rate at both sites was identical but different for the two types of blue lupins. The determinate cultivars (Borweta, Sonet, Prima, and Boruta) were sown with 100 seeds m^{-2} and the branched cultivars (Arabella, Boltensia, Bolivio, Bora, Borlu, Borlana, Boregine, Baron, Idefix, Probor, Vitabor) were sown with 130 seeds m^{-2}.

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The plots were harvested between the middle of August and beginning of September. After sample drying and cleaning, subsamples were milled (Cyclotec 1093, Fa. Foss) through a 1 mm screen. Crude nutrients such as protein (CP), crude fibre, ether extract, crude ash, starch, and sugar were scanned and predicted by near infrared reflectance spectroscopy (NIRS). NIRS analysis on organically grown legumes was carried out 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 with 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 & Böhm, 2008) of the crude nutrients. The conventionally grown samples were analysed with a NIRSystems 6500 spectrophotometer (Foss) in the spectral range from 400-2500 nm. The spectral data were processed by the ISI software. On the basis of crude nutrient analysis and the feed table data of digestibility the ME content for pigs (DLG, 1991) and the Net Energy Lactation (NEL) (GFE, 2001) for dairy cows were calculated.

Statistical analyses were performed with the MIXED procedure of the SAS software package 9.1.3 (SAS Institute 2004). The factors cultivar, year, and replicates were combined in the fixed part of the model.

RESULTS AND DISCUSSION

With two exceptions (protein content and ME at ICSS-site) the statistical analysis showed interactions between year and cultivar for both sites (Tables 1 and 2).

Table 1. P-values for sources of variation for yield and chosen parameters of predicted feed quality at the IOF-site (2003-2005).

	Denominator d.f.	Yield	CP	Protein yield	NEL	ME
Year	2	< 0.001	< 0.001	0.8122	< 0.001	< 0.001
CV	10	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Year * CV	20	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 2. P-values for sources of variation for yield and chosen parameters of predicted feed quality at the ICSS-site (2006-2007).

	Denominator d.f.	Yield	CP	Protein yield	NEL	ME
Year	1	< 0.001	0.3393	< 0.001	< 0.001	< 0.001
CV	10	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Year * CV	10	0.0044	0.2222	0.0054	< 0.001	0.1391

At IOF-site, the yield reached 2.95 t ha^{-1} with a variation between 2.8 and 3.2 t ha^{-1} on average of the cultivars between the three years (Table 3). At the ICSS-site the yield was lower with a mean of 2.0 t ha^{-1} and ranged between 2.2 t ha^{-1} in 2006 and 1.8 t ha^{-1} in 2007 (Table 4). The yield of the determinate and the branched types of cultivars were similar at both sites. However, preliminary results of Bramm *et al.* (2005) showed a higher yield level at ICSS-site and higher yields of the branched cultivars in comparison to the determinate cultivars. In the present study the cultivars Vitabor, Boltensia, Borlu and Sonet showed the lowest yield at the ICSS-site, whereas such a consistent trend could not be observed at the IOF-site. At the IOF-site cultivars like Borlana, Boltensia, Borweta and Bora were lower yielding than the cultivars Boruta, Prima, Sonet and Arabella.

Table 3. Yield and crude protein content (CP) of the tested cultivars at the IOF-site.

	Yield [t ha^{-1}]			CP [% of DM]		
	2003	2004	2005	2003	2004	2005
Borweta	2.26 a	2.79 bc	3.13 bcde	30.92 a	31.05 a	30.39 bc
Sonet	2.91 ce	3.19 cd	3.41 cde	33.48 bc	30.02 a	29.54 ab
Prima	3.12 de	3.03 cd	3.45 de	32.99 b	29.81 a	28.23 a
Boruta	2.69 bc	3.65 e	3.51 e	36.27 ef	34.99 b	30.84 bc
Arabella	2.79 cd	3.61 e	3.02 ac	36.51 ef	35.38 b	31.53 cd
Boltensia	2.81 cd	2.41 b	2.95 ab	36.30 ef	36.03 bc	31.65 cd
Bolivio	2.79 cd	2.48 b	3.21 bcde	36.55 f	36.93 cd	31.81 cd
Bora	2.31 ab	3.26 de	2.67 a	36.43 ef	35.98 bc	31.53 cd
Borlu	3.28 e	2.39 b	3.33 bcde	37.08 f	36.16 bc	32.34 d
Borlana	2.83 cd	1.76 a	3.06 ad	34.68 cd	37.81 d	31.08 cd
Boregine	2.77 cd	3.27 de	3.30 bcde	35.10 de	34.78 b	28.89 a
Mean	2.78	2.89	3.19	35.12	34.45	30.71

Different characters within a column indicate significant differences ($p < 0.05$).

At the IOF-site crude protein content (CP) ranged between 28.2 and 37.8% DM (Table 3) whereas it was higher at ICSS-site with 34.7-39.2% DM. In the majority of cases, the determinate cultivars at both sites – with exception of Boruta at the IOF-site – had a significantly lower protein content compared to the branched cultivars. The highest protein content was observed in the newer cultivars Idefix and Probor (permitted in 2005), with 39.2 and 38.8% CP DM, which were tested in 2006 and 2007 at the ICSS-site (Table 4).

Table 4. Yield, crude protein content (CP) and protein yield (PY) of the tested cultivars at the ICSS-site.

P1	Yield [t ha^{-1}]		CP [% of DM]	Protein yield [kg ha^{-1}]	
	2006	2007	2006/07	2006	2007
Boruta	2.14 acd	2.16 cde	34.71 a	748.8 ab	749.8 def
Sonet	1.84 a	1.89 bd	34.65 a	649.5 a	643.8 ce
Baron	2.48 de	1.79 bc	36.92 b	909.8 cd	658.8 ce
Idefix	2.43 ce	2.25 de	39.15 c	943.3 cd	880.0 f
Probor	2.21 ace	1.95 be	38.76 c	831.0 bc	776.8 ef
Borlu	2.04 ac	1.67 b	36.31 ab	751.0 ab	594.5 bc
Vitabor	1.80 a	1.00 a	35.64 ab	624.0 a	364.5 a
Bora	2.73 e	1.78 bc	36.40 ab	989.3 d	651.3 ce
Arabella	2.33 bce	1.66 b	36.56 ab	850.5 bd	604.8 cd
Boltensia	1.97 ab	1.23 a	36.76 ab	730.8 ab	441.8 ab
Boregine	2.37 bce	2.32 e	36.69 ab	862.5 db	855.5 f
Mean	2.21	1.79	36.60	808.2	656.5

Different characters within a column indicate significant differences ($p < 0.05$).

Protein yield is an important criterion for farms with a high percentage of self-produced feed. The results in Tables 4 and 5 showed variable results between years and cultivars. Only the cultivar Idefix indicated the highest protein yield at the ICSS-site in both years, followed by Baron, Bora, and Boregine. In two of the three years, the cultivars Boruta, Arabella, Bolivio and Borlu reached a high protein yield at the IOF-site, but Boregine also had a high protein yield in average of the three years.

Table 5. Protein yield of the tested cultivars at the IOF-site.

	Protein yield (kg ha^{-1})		
	2003	2004	2005
Borweta	700.8 A	866.0 b	952.3 ab
Sonet	973.5 bc	957.5 b	1007.0 ab
Prima	1029.5 c	902.5 b	974.3 ab
Boruta	978.5 bc	1277.5 c	1080.5 b
Arabella	1017.0 c	1277.8 c	951.3 ab
Boltensia	1024.5 c	869.0 b	933.8 ab
Bolivio	1021.3 c	915.5 b	1022.3 b
Bora	841.0 ab	1173.0 c	844.3 a
Borlu	1218.5 d	865.5 b	1075.0 b
Borlana	982.0 bc	663.8 a	951.8 ab
Boregine	972.8 bc	1137.5 c	952.5 ab
Mean	978.1	991.4	976.8

Different characters within a column indicate significant differences ($p < 0.05$).

Table 6. Predicted Net Energy for Lactation (NEL) for dairy cows and predicted Metabolised Energy for pigs (ME) of the tested cultivars at the IOF-site.

	NEL (MJ kg^{-1} DM)			ME (MJ kg^{-1} DM)		
	2003	2004	2005	2003	2004	2005
Borweta	9.00 ab	8.95 c	8.95 a	14.46 a	14.23 ab	14.29 bd
Sonet	9.00 ab	8.91 ab	8.93 a	14.58 bc	14.18 a	14.19 ab
Prima	8.97 a	8.93 bc	8.94 a	14.53 ab	14.20 a	14.16 a
Boruta	9.03 bc	9.01 d	8.95 a	14.83 ef	14.75 f	14.24 ab
Arabella	9.03 bc	8.91 ab	8.99 c	14.77 de	14.32 bcd	14.37 cde
Boltensia	9.02 bc	8.93 bc	8.99 c	14.76 de	14.36 ce	14.39 de
Bolivio	9.05 cd	8.95 c	8.99 c	14.81 ef	14.41 de	14.39 de
Bora	9.06 cd	9.00 d	8.96 ab	14.92 f	14.77 f	14.29 bd
Borlu	9.02 bc	8.89 a	9.01 cd	14.82 ef	14.38 ce	14.51 f
Borlana	9.03 bc	8.91 ab	9.03 d	14.70 de	14.45 e	14.44 ef
Boregine	9.03 bc	8.91 ab	9.00 cd	14.69 cd	14.29 ac	14.26 abc
Mean	9.02	8.94	8.98	14.72	14.39	14,32

Different characters within a column indicate significant differences ($p < 0.05$).

Table 7. Predicted Net Energy for Lactation (NEL) for dairy cows and predicted Metabolised Energy for pigs (ME) of the tested cultivars at the ICSS-site.

	NEL (MJ kg^{-1} DM)		ME (MJ kg^{-1} DM)
	2006	2007	2006/07
Boruta	9.19 b	9.05 ab	14.73 ab
Sonet	9.10 a	9.04 ab	14.70 a
Baron	9.23 bf	9.07 bc	14.87 bcd
Idefix	9.27 f	9.05 ab	14.92 cd
Probor	9.24 df	9.10 c	15.02 d
Borlu	9.26 ef	9.10 c	14.94 cd
Vitabor	9.24 cdf	9.02 a	14.79 ab
Bora	9.20 bc	9.04 ab	14.84 abc
Arabella	9.20 bc	9.07 bc	14.89 bcd
Boltensia	9.22 bde	9.11 c	14.88 bcd
Boregine	9.25 ef	9.07 bc	14.91 cd
Mean	9.22	9.07	14.86

Different characters within a column indicate significant differences ($p < 0.05$).

The predicted Net Energy for Lactation (NEL) for dairy cows and the predicted Metabolised Energy for Pigs (ME) showed interactions between cultivar and year with exception of the ME at the ICSS-site. Cultivars with a high NEL and ME were Bora, Boruta, Bolivio and Borlu at the IOF-site and Probor, Borlu, Idefix, Boregine and Boltensia at the ICSS-site.

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