Optimizing lupin production for human consumption in The Netherlands

Prins U, Nuijten E

Agriculture department, Louis Bolk Institute, the Netherlands
Corresponding Author's e-mail: u.prins@louisbolk.nl

Abstract
In a period of 7 years (2007-2013) 25 varieties of lupins were tested on different soil types in The Netherlands, including 20 varieties of *L. angustifolius*, three varieties of *L. albus* and two varieties of *L. luteus*. These varieties were obtained from various seed companies in Germany, Denmark, Poland and the UK,. It seems that relatively small differences in climatic conditions between The Netherlands (northern-european sea climate) and the regions where most of the varieties are bred (north-eastern land climate in Germany or middle European sea climate in the north of France) already result in varieties being less adapted to the growing conditions existing in The Netherlands. An important result is that, although breeding efforts have been focusing on developing low-alkaloid varieties for both feed and food, only a limited number of varieties meet the strict norm of less than 0,02% of alkaloid needed for food. Apart from variety effects, several different crop management factors have clear effect on both yield and grain-quality (alkaloids). Yields appeared to be higher on clayey soils than on sandy soils, although for *L. angustifolius* free calcium levels need to be sufficiently low to avoid having a lack of inoculation and chlorotic reactions. No yield effect was found with the application of K or S, but alkaloid levels tended to be lowered by the application of KSO_4 in soils low in potassium. Early sowing seems to increase the yield potential of both *L. angustifolius* and *L. albus* although early sowing can also cause reduced emergence and increased weed pressures. The application of fungicides did increase the yield of most lupin varieties considerably even in years that fungal-pressure appeared to be low.

Keywords: lupin, varieties, cultivation, crop optimization, human consumption, the Netherlands

Introduction
Lupin has always had the interest of the feed industry due to its high levels of protein, exceeding that of other grain legumes like peas and faba beans. The biggest drawback for lupins, however, has always been the lower and unstable yields making it less attractive for farmers to grow. Recently, the interest of the food industry in lupins has developed not just due to the high protein levels, but also due to high levels of fiber-like carbohydrates linked to improved colon health and a better mouth-feel for the modern-day consumer. Especially upcoming markets like that of meat replacers, plant-based dairy products en low-carb/high protein diets see a lot of potential in lupins as a main ingredient offering new opportunities for the cultivation of lupins in Europe in general and The Netherlands in particular. Due to this increased attention to lupins, The Louis Bolk Institute has been involved in numerous projects aimed at optimizing the production of lupins for human consumption since 2007, for both organic and conventional agriculture. These projects included variety screening and cultivation optimization, looking into the effects of soil type, fertilization (N, K and S), sowing date and fungicide treatment. These projects were conducted in close cooperation with both farmers and food industry. Apart from yield and protein content, an important aspect was to study how lupins with a sufficiently low alkaloid level (<0,02%) could be produced.

Results and discussion
The first demand for investigating regional lupin production for human consumption came in 2007 from a start-up business Meatless in the south-west of Holland. They wanted wanted to use lupins for producing high quality meat replacers. Instead of using imported lupins from Australia they wanted to know whether it was possible to grow lupins regionally. Apart from sufficient yield, sufficiently low alkaloid levels (<0,02%) were an important characteristic for the lupins. In the years that followed we have been testing many different varieties, on different soil types in The Netherlands.

Varieties

Starting from 2007 25 varieties have been tested for yield and yield quality in The Netherlands as a monocrop. Varieties were obtained from Denmark (B. Jørnsgard and S. Jørgensen), Germany (Saatzucht Steinach and Saaten Union), England (Soya UK) and Poland (Hodolwa Roślin Smolice). In table 1 the most frequently tested and most promising varieties are listed.

Table 1. Yield index and alkaloid content of 10 varieties tested in The Netherlands in 2007-2013

		Variety	No. of years tested	Average yield index	Yield index (alkaloid content) 2007	2008	2009	2011	2012	2013
L. angustifolius	non-branching	**Primadonna**	1	99						99
		(S. Jørgensen, Dk)								(0,019%)
		Haags Blaue	4	80			113	58	49	101
		(SZ Steinach, D)					(0,009%)	(0,010%)	(0,013%)	(0,024%)
		Boruta	6	76	83	84	68	58	65	99
		(SZ Steinach, D)			(<0,01%)	(0,010%)	(0,009%)	(0,006%)	(0,010%)	(0,013%)
		Iris	6	100	100	100	100	100	100	100
		(B. Jørnsgard, Dk)			(<0,01%)	(0,015%)	(0,009%)	(0,003%)	(0,004%)	(0,017%)
	branching	**Boregine**	3	85	72	89	94			
		(SZ Steinach, D)			(0,015%)	(0,037%)	(0,014%)			
		Sanabor	4	66			74	41	51	99
		(SZ Steinach, D)					(0,009%)	(0,013%)	(0,020%)	(0,046%)
		Regent	1	99						99
		(HR Smolice, Pl)								(0,009%)
L. albus branch.		**Dieta**	3	65				69	54	73
		(Soya-UK, UK)						(0,005%)	(0,007%)	(0,017%)
		Volos	3	61				51	57	76
		(Soya-UK, UK)						(0,009%)	(0,012%)	(0,019%)
				100 = t/ha	**4,4**	**4,3**	**2,7**	**2,7**	**3,1**	**4,2**

The criteria for selecting suitable varieties were yield, yield stability, earliness in ripening and alkaloid levels. For earliness we were looking for varieties to ripen before mid-september as risks of bad harvesting conditions grow rapidly after that. Alkaloid levels need to be below 0,02% to be used for human consumption. Some varieties were only tested for one or two years, as they didn't meet one of the criteria mentioned. L. angustifolius varieties Arabella, Probor and Boregine and L. albus variety Feodora were too late in ripening at least in some of the years tested. L. luteus variety Erantis and L. angustifolius varieties Galant, Boregine, Sanabor, Sonet and Haags Blaue proved to be unreliable in alkaloid contents to meet the criteria for human consumption in some of the years tested. A lot of varieties also turned out to be poorly adjusted to the fungal diseases dominating in The Netherlands making them unreliable in yield potential (eg. Haags Blaue, Boruta, Sonate, Vitabor, Haagena, Bojar and Dalbor). The best yielding variety and most reliable in sufficiently low alkaloid contents over almost all years tested turned out to be a Danish variety Iris from B. Jørnsgard.

Soil type

In 2008 and 2009 different varieties were tested on two different soil types: acid sandy soils and calcium poor clayey soils. Average yields turned out to be 16% higher on clayey soils than on sandy soils in 2008 and 67% higher in 2009. The most likely explanation seems to be that the better moisture supply on clayey soils assures a higher and more stable yield over the years than sandy soils.

Table 2. Yields of L. angustifolius varieties on sandy and clayey soils in 2008 and 2009

	2008			2009		
	Sand	Clay	Clay/Sand	Sand	Clay	Clay/Sand
Variety	t/ha		%	t/ha		%
Viol	2,9	3,6	122%	1,8	2,9	162%
Haags Blaue				3,0	4,0	134%
Boruta	3,6	3,7	102%	1,8	3,3	182%
Iris	4,3	4,8	113%	2,7	3,4	126%
Vitabor	1,8	2,6	143%	1,4	3,2	225%
Sanabor				2,0	4,0	201%
Boregine	3,8	3,7	99%	2,5	3,8	153%
Probor				2,0	3,1	156%
			116%			**167%**

Potassium fertilization and soil type

Based on the work of Gremigni etal. (2001) experiments were started in 2008 on the effect of potassium on alkaloid and yield in lupin.

Table 3. Effect of K_2SO_4 fertilization on yield and alkaloid levels of L. angustifolius (cv. Boregine) on sandy and clayey soils in 2008

	Yield		Alkaloide	
Fertilization	**Clay**	**Sand**	**Clay**	**Sand**
	t/ha		*ppm*	
0 kg K_2O eq./ha	3,6	3,9	317	500
100 kg K_2O eq./ha	3,5	3,5	267	450
200 kg K_2O eq./ha	3,7	3,8	317	367

Clay soil: 167 mg K/kg soil and pH 6,4 Sandy soil: 35 mg K/kg soil and pH 5,2

A sweet, but relatively high alkaloid variety Boregine was fertilized with three levels of K_2SO_4 on a clayey soil with high levels of naturally available potassium and on a sandy soil with low levels of naturally available potassium. On both soil types no yield effects were found due to the fertilization, however alkaloid levels decreased on the sandy soil when fertilized with potassium, but no decrease was found on the clayey soil. This seems to indicate that when levels of naturally available potassium in the soil are high, no effect can be expected from additional potassium fertilization. In the years that followed we have further investigated the effects of potassium fertilization on both yield and alkaloids. We have been looking into the form in which potassium can be administered: as K_2SO_4 or as KCl. The effect of lowering alkaloid levels is more consistent with K_2SO_4 than with KCl. In some varieties (eg the variety of L. albus: Dieta) KCl even seems to be elevating the alkaloid levels rather than decreasing them. If the effect of lowering alkaloid levels should therefore be subscribed to potassium or sulphur still remains point of study.

Sowing date

In 2012 we were able to compare yields of a great number of varieties sown mid-March vs. mid-April. Although one variety showed a yield increase when sown later, the average yield loss due to late sowing was 16% with a maximum yield loss of 38% for the variety Sanabor. We intended to replicate this experiment, but the weather in spring 2013 did not allow us to do so.

Table 4. Yield effect of early and late sowing of 5 varieties of L. angustifolius and 2 varieties of L. albus in 2012 on sandy soil

	Yield (t/ha)		Yield
	16-mrt	21-apr	reduction
Haags Blaue	3,1	2,1	31%
Boruta	3,5	2,4	31%
Sanabor	2,6	1,6	38%
Sonate	1,2	1,5	-19%
Iris	3,1	2,9	5%
Dieta	3,2	2,4	25%
Volos	3,0	2,9	4%
			16%

Fungicides

In the years 2011-2013 we tested the effect of fungicide treatment on yield for different varieties of L. angustifolius and L. albus. The fungicides used were 1,2 l/ha Caramba (72 g/ha metconazool) en 1,6 kg/ha Signum (427 g/ha boscalid and 107 g/ha pyroclostrobin).

Table 5. Yield effect of the use of fungicides in the years 2011-2013 on sandy soils

	2011			2012			2013		
	Yield (t/ha)		Yield	Yield (t/ha)		Yield	Yield (t/ha)		Yield
	no-fung.	fung.	increase	no-fung.	fung.	increase	no-fung.	fung.	increase
Haags Blaue	1,6	1,9	24%	1,5	1,9	26%	3,4	4,2	22%
Boruta	1,5	1,9	21%	2,0	2,2	10%	3,7	4,1	12%
Sanabor	1,1	1,0	-8%	1,6	1,7	6%	3,3	4,1	26%
Iris	2,7	2,8	3%	3,1	3,2	4%	3,7	4,2	13%
Dieta				1,6	1,9	18%	2,5	3,0	24%
Volos				1,8	2,2	24%	2,7	3,1	17%
Av of first 4 varieties			**10%**			**11%**			**18%**

The fungicides were only applied to the crop in the early podfilling stage in 2011 and 2012. However in 2013 the application was done early in the early flowering stage and a second time in the podfilling stage. Although fungal pressures were higher in 2011 and 2012 than in 2013, the early and repeated fungicide treatment have resulted in considerable yield increases in nearly all varieties whereas in 2011 and 2012 some varieties only showed minor yield increases due to the fungicide treatment.

Conclusions

Due to extensive field testing, lupin production for human consumption in The Netherlands is getting more and more feasible. Although the varietal choice for suitable lupin varieties with guaranteed sufficiently low levels of alkaloid is still limited low alkaloid levels does not seem to exclude good production levels. The most suitable variety so far under Dutch conditions seems to be a Danish variety Iris. Early sowing, clayey soils and fungicidal treatments all seem to increase the yield potential considerably. Fertilizing with K_2SO_4 does not affect the yield but seems to decrease the alkaloid levels in most years, especially on soils low in naturally available potassium. As KCl sometimes has the opposite effect it still remains a question whether it is the potassium or the Sulphur that is responsible for that.

References

Gremigni P., M. T. F. Wong, N. K. Edwards, D. Harris and J. Hamblin (2001) Potassium nutrition effects on seed alkaloid concentrations, yield and mineral content of lupins (*Lupinus angustifolius*): Plant and Soil 234: p. 131–142