

FACTORS AFFECTING THE YIELD OF WINTER LUPINS

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SUMMARY

The white lupin (*Lupinus albus*) is a temperate legume whose seed contains high levels of protein (36-44%), oil (10-16%) and high quality dietary fibre in the dry matter. Modern varieties contain extremely low levels of alkaloids (<0.01%) and no anti-nutritional factors. Thus their composition is more similar to soya bean than peas and beans, which contain much less protein (23-27%) and no oil. Nitrogen fixation by autumn-sown, determinate varieties is large (ca. 300 kg/ha) and harvest index for nitrogen is high (more than 85% of the crop N is recovered in the grain). Lupins also have the ability to release phosphorus and iron from mineral sources in the soil. These two characteristics make the winter lupin crop an ideal choice as a low input alternative crop, particularly in nitrogen-sensitive areas.

Attempts to introduce spring-sown lupins have failed, mainly due to low yield potential, poor yield stability and late harvest. The release of the first winter-hardy determinate varieties by French breeders in 1994 promised the first real chance of success. The successful introduction of lupins offers the possibility of reducing soya bean imports and replacing it with a high-quality, home-grown protein source, with the added advantage of traceability.

Autumn-sown lupins are capable of producing satisfactory yields (3.7-4.5 t/ha). The crop does require careful management, i.e. early sowing (by mid-September), at the correct seed rate (100 kg/ha), into well-structured free-draining soil and with a pH below 7. Sown in early September, the crop will mature from late August to mid-September.

INTRODUCTION

Lupins are a rich source of plant protein, second only to soya beans in protein content. Protein levels are in the range 38-42% as against 24-28% for beans and peas (Milford and Shield, 1996). Lupins, because of their size, handling characteristics and protein content, are much in demand from feed compounders. The absence of tannins and other anti-nutritional factors opens up the non-ruminant feed market to a home-produced source. On the basis of a 10%

inclusion rate this market alone would absorb the production from about 25,000 hectares (Crowley, 1996).

The successful introduction of lupins into Irish agriculture would provide, for the first time, a home-grown substitute for imported soya protein. Home-grown protein would have the added advantage of traceability.

Attempts to introduce spring-sown lupins have been on-going in the UK and Ireland since the early 1980's with no real success. The main problem associated with spring-sown lupins was late maturity and consequently difficult harvesting. The release of the first winter hardy semi-dwarf varieties in 1994 promised the first real chance of success. Findings from field trials carried out in 1994-1997 with some of these varieties are summarised in this report.

METHODS

Field trials were carried out in Oak Park from 1994 to 1997 to evaluate new semi-dwarf white lupin varieties released by the French breeders.

For maximum production lupins require a light to medium well-drained soil with a pH below 7.0. High levels of free calcium are toxic to lupins. Waterlogging over the winter period can cause high seedling losses (Shield and Milford, 1995). Experimental sites were chosen according to these criteria.

Soil samples were taken in all the trial areas before sowing and based on these results maintenance dressing of phosphate and potassium were applied to the seedbed before sowing and tilled in. On all the sites pH was below 7.0 within the range 6.5 - 6.9. Fertilizer applications used varied from 25 to 35 kg/ha for phosphate and 75 to 120 kg/ha for potassium. The standard seed rate was 40-45 seeds/m², sown at a depth of 3.0 cm in rows 15 cm apart. No nitrogen was applied at any stage. The pre-emergence herbicide Stomp (pendimetholin) at 4 l/ha was applied immediately after sowing as the standard herbicide treatment. Yields are expressed at 14% moisture content (m.c.).

RESULTS AND DISCUSSION

Varieties

The three varieties, Lucyane, Ludet and DTN-20 were sown in early September. Each of the varieties were sown at 40 seeds/sq. m. (approx. 100 kg/ha).

The characteristics of the three varieties evaluated are presented in Table 1.

Table 1: Characteristics of three lupin varieties

Variety	Flower colour	Type	Seed colour	*Size (TGW)	Shape
Lucyane	White	Determinate Semi-dwarf	White	256	Flat
Ludet	Blue	Determinate Semi-dwarf	White	213	Flat
DTN-20	Blue	Determinate Dwarf	White	220	Flat

TGW = thousand grain (seed) weight in grams

Over the three years of trial no serious lodging was encountered. The yield performance, averaged over three years is presented in Table 2. The highest yields of 4.95 tonne/ha were obtained in 1995.

Table 2: Average yield (t/ha) @ 14% moisture content of three lupin varieties

Variety	Yield t/ha	Date of maturity	Protein content
Lucyane	3.63	1 Sept.	35.5
Ludet	4.75	28 August	38.9
DTN-20	3.50	13 Sept.	36.8
S.E. \pm	± 0.41	-	0.15

Of the three varieties evaluated to-date Ludet is the most promising. It has a high yield potential, adequate winter hardiness, good standing ability and the earliest maturity date. On the basis of the data above, the varieties evaluated required a full twelve months growing period to mature, i.e. sown in early

September and harvestable the following early September. Seed moistures ranged from 12.7% in 1995 to 21.5% in 1997. Varieties capable of maturing in mid-August, on average, are required to secure producer confidence in the crop.

Crop development

Lupin seeds germinate and establish within 10 days and grow slowly until early November. During this time only four to five sets of leaves are produced, most of the growth taking place in the root system. A strong deep tap root is formed with a heavy epidermal layer, allowing the young plants to survive frozen soils. Growth is slow in spring with complete ground cover not being achieved until April. The physiological switch from vegetative leaf production to inflorescence production is triggered by short day length and occurs around late October in winter lupin varieties. To achieve maximum yields these lupins require a minimum of 28 leaf primordia to be initiated before inflorescence initiation occurs. Flowering can start as early as 23 March and last until late July (Table 3), a very extended flowering period compared to most agricultural crops grown in Ireland.

Table 3: Crop development and yield of the lupin variety Lucyane as influenced by season

Year	Start of flowering	End of flowering	Date of maturity	M.c. at harvest	Yield t/ha
1995	28 March	26 June	20 August	12.6	4.84
1996	2 May	28 July	29 September	25.5	3.96
1997	23 March	17 June	10 September	17.8	4.83

Lupins do not require desiccation prior to harvest. Natural senescence sets in quickly once the crop has achieved maximum seed dry matter accumulation. The seed will dry down to 12% moisture content in good drying conditions. Once mature, the crop is relatively weather proof and does not easily suffer seed or pod losses.

Sowing date

To establish the optimum sowing date for Ireland date of sowing trials were carried out in 1995, 1996 and 1997. In September to October 1994 the varieties Lucyane and Ludet were sown at 45 seed/m². Seedling counts in November and April showed very small (<10%) seedling losses in all treatments.

1995 was an exceptional growing season, with the result that all plots were harvested without difficulty on 22 August 1995. Neither time of sowing nor variety had any significant effect on seed moisture content at harvest. Moisture contents ranged from 12.7 to 14.4%. The yield data is presented in Table 4.

Table 4: Yield (t/ha) of two determinate winter hardy lupins sown on three dates in autumn 1994

Sowing date	Variety		Mean
	Lucyane	Ludet	
23 September, 1994	4.10	4.84	4.47
5 October 1994	4.13	4.39	3.03
26 October 1994	3.33	2.72	3.03
S.E. \pm	0.30	0.52	0.54

The yields obtained are very encouraging with the blue flowered Ludet producing on average 4.5 t/ha from the 23 September sowings. Although a delay in sowing until 5 October did cause a small loss in yield, the yield figures indicate that the sowing window may be wider in Ireland than in the UK where a significant reduction in yield occurs after mid-September. Sowing later in October does result in a very significant reduction in yield, ranging from 20% for Lucyane variety to 40% for Ludet.

The trial was repeated in autumn 1995. Seedling counts taken in October and the following April (Table 5) show very high seedling losses in the October-sown crop.

Table 5: Effect of date of sowing on winter survival, 1995

Date of sowing	Variety	Plant density (p/m ²)	
		18 October 1995	17 April 1996
13 September	Lucyane	44.5	32.6
	Ludet	44.3	30.5
29 September	Lucyane	42.5	33.5
	Ludet	46.3	24.7
15 October	Lucyane	20.5	4.3
	Ludet	22.4	0

The high seedling losses (36%) were due to an attack of Bean Seed Fly (*Deliaflorilege*) in the September-sown plots. The losses in the October-sown plots were due to poor seedling development as a result of late sowing, as losses due to Bean Seed Fly were prevented in the October sowings by spraying with an insecticide just after crop emergence.

The same three varieties, Ludet, DTN-20 and Lucyane were again sown on four dates, 6 September, 13 September, 20 September and 2 October 1996. The effects of sowing date on the number of plants established are shown in Fig. 1.

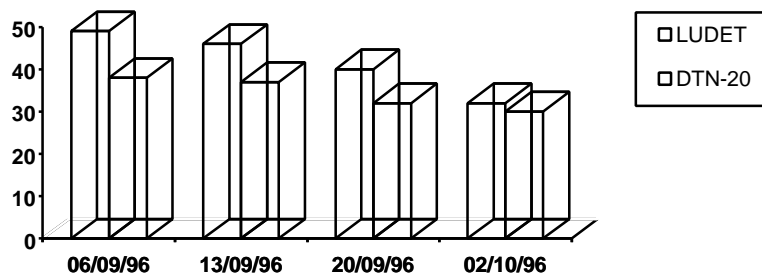


Fig. 1: The effect of date of sowing on plant establishment in three white lupin varieties

A delay in sowing of approximately one month, from early September to early October, resulted in a significant reduction in the number of seedlings established

in each of the varieties. However, even the early October sowing achieved sufficient seedling numbers to produce maximum yield.

A similar picture is obtained when seed yield is considered. Fig. 2 summarises the yield data obtained.

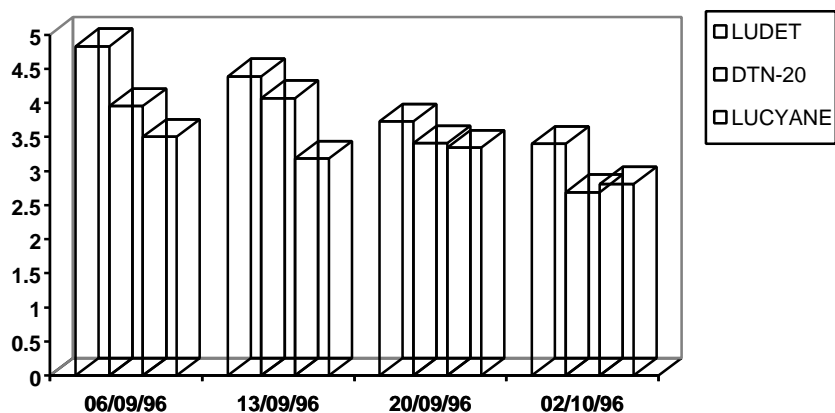


Fig. 2: Yield (t/ha) response of three white lupin varieties to sowing date

Each week delay in sowing results in a reduction in yield of approximately 0.35 t/ha. Ludet was the highest yielding variety at each sowing date. Combined with its early flowering and maturity, Ludet performed significantly better in these trials than either Lucyane or DTN-20 (Table 6).

Table 6: The effect of variety and sowing date on maturity date in lupins, 1996

Sowing date	Variety		
	Ludet	DTN-20	Lucyane
06 September	25 August	12 September	02 September
13 September	01 September	16 September	08 September
20 September	10 September	24 September	13 September
02 October	17 September	N.R.	20 September

In this trial the variety DTN-20 did not reach a harvestable maturity in the October sowing. Both Ludet and Lucyane matured in good time when sown in early September.

The three years results show that for consistent performance winter white lupins must be sown not later than mid-September. Later-sown crops are liable to high seedling losses over the winter and even where high seedling survival is achieved the yield potential is significantly lower than early-sown crops.

Seed rate

Five seed rates were compared using the variety Lucyane sown on 13 September 1995. The range of densities achieved are presented in Table 7. Percentage establishment was high at an average of 89.8% in October and with over wintering losses low at 12.8% in April. There is a tendency for the higher seeding rates to have overall lower seedling losses.

Table 7: The effect of five seed rates on plant density (plant/m²)

Seed rate		18 October 1995		17 April 1996	
Seed/m ²	Kg/ha	P/m ²	% Est.	P/m ²	% Est.
20	53	17.5	87.5	13.1	65.5
30	70	24.3	81.0	20.98	69.6
40	106	34.9	87.3	33.1	82.7
50	132	46.6	93.2	42.2	84.4
60	158	60.0	100.0	52.2	87.0

The yield data in Table 8 shows no increase in yield due to seeding rate beyond 40 seeds/m² or 106 kg/ha.

Table 8: Effect of seed rate on the yield of the white lupin variety Lucyane

Seed rate		Yield t/ha	Relative yield %
Seed/m ²	Kg/ha		
20	53	2.21	72
30	70	3.17	103
40	106	33.4	1078
50	132	3.35	109
60	158	3.33	108

In autumn 1996, the study of seed rate effects was expanded to include 3 varieties, Ludet, DTN-20 and Lucyane, sown at four seeding rates, 26, 34, 42 and 50 seeds/m². The randomized split plot field trial was sown on 6 September. Plant counts carried out on 13 March 1997 gave the following results (Table 9).

Table 9: Plants/m² in March 1997 of three autumn lupin varieties sown in September 1996

Seed rate Seed/m ²	Variety		
	Ludet	DTN-20	Lucyane
26	24	24	26
34	34	32	32
42	40	38	38
50	48	46	48

In all three varieties establishment and winter survival was very satisfactory, achieving the desired range of plant densities.

The plots were scored on 10 September 1997 to evaluate the effects of plant density on the standing ability (lodging) and maturity of the three varieties. The results are summarised in Table 10.

Table 10: Seed rate effects on lodging and maturity of three white lupin varieties

Seed rate Seed/m ²	Ludet		DTN-20		Lucyane	
	*Lodging	*Maturity	Lodging	Maturity	Lodging	Maturity
26	0	9	4	6	0	9
34	0	9	6	4	0	9
42	4	9	8	1	2	8
50	6	9	9	1	6	6

*Score 0-9 0 = No lodging 9 = Fully lodged
 0-9 0 = Green 9 = Fully ripe

Lodging increased with plant density in each of the three varieties, with DTN-20 more prone to lodging than the other two varieties. Increasing plant density also delayed maturity except for Ludet. All plots of this variety were fully mature

when scored on 10 September. Seed rate in the range measured had only a small effect on yield. Fig. 3 summarises the results.

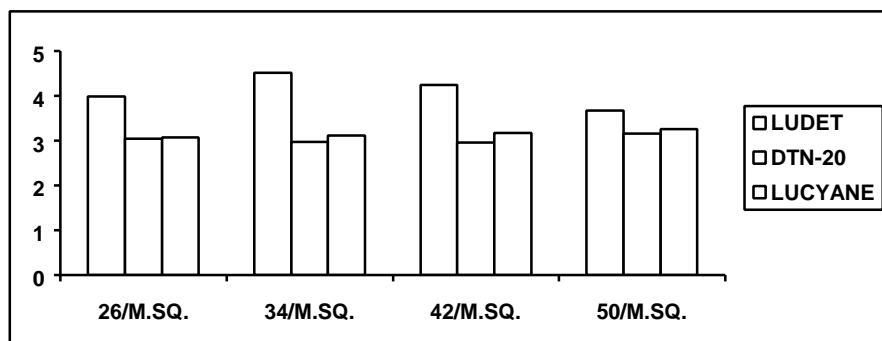


Fig. 3: The effect of seed rate on yield (t/ha) in three white lupin varieties

The varieties DTN-20 and Lucyane show no response over the seeding rate range tested (26 to 50 seeds/m²). There is a more variable but non-significant response with the variety Ludet.

The results show clearly that achieving the optimum plant density, 25-35 plants/m² is essential in achieving maximum yields in autumn-sown white lupins. Higher densities can delay maturity and increase the likelihood of lodging as well as increasing seed costs.

Depth of sowing

Seed size in lupins is approximately half that of the more familiar field beans, the thousand grain weight for field beans is in the range 490-560 gms with lupins in the range 210-260 gms. Using a seeder developed at Oak Park the lupin variety Lucyane was sown at a depth of 2.5, 5.0, 7.5 and 10 cms on the 20 September 1995. On 2 November 20 seedlings from each treatment were cut-off at ground level and then carefully lifted. The coleoptile lengths were measured to establish the sowing depth in each treatment. The results are presented in Table 11.

Table 11: Effect of sowing depth on rate and percentage establish of lupins

Depth of sowing (cms)		Date of assessment					% final est.
Target	Actual	3 Oct	8 Oct	12 Oct	18 Oct	2 Nov	
		% of total plants established					
2.5	3.9	54	94	98	100	100	88
5.0	5.5	0	82	94	100	100	83
7.5	8.0	0	49	72	83	100	73
10	9.5	0	10	40	70	100	53

A high level of accuracy was generally achieved in depth control. Plant counts carried out on a weekly basis established both the rate of seedling emergence and the final numbers established. The data in Table 11 shows that the shallower the drilling the quicker the plants appear above soil level. The data strongly indicates that sowing lupins deeper than 5.0 cms (2 inches) will both delay emergence and significantly reduce the number of plants established.

Weed control

With any autumn-sown crop good early and persistent weed control is essential. The products available for lupins are very limited. The six treatments evaluated during 1995/'96 were (1) Gesatop 500SC (simazine) at 1.5 l/ha, (2) Stomp (pendimethalin) at 4 l/ha, (3) simazine at 1 l/ha + Kerb 50W (propyzamide) at 0.9 l/ha tank mixed, (4) Opogard (terbuthylazine + terbutryn) at 2.5 l/ha, (5) Opogard at 2.5 l/ha and simazine at 1 l/ha in February/March and (6) no autumn herbicide but simazine at 2.0 l/ha in spring. The graminicides Fulisade (fluzilop-P-butyl) and Stratos (cycloxydim) were also tested. Both graminicides proved safe to use on lupins. Of the herbicide and herbicide combinations tested Stomp (pendimethalin) gave the best and longest lasting control. None of the products or product combinations tested caused any crop damage.

Pests and diseases

Over the three year trial period only one pest and one disease were identified as causing potentially serious damage to lupins.

Bean Seed Fly (*Deliaflorilega*, *D. platara*) caused very high seedling losses in the 1995 crop. The flies lay eggs in the decaying surface trash and the larvae tunnel into young soft stems of the emerging lupins at or below ground level. Once inside the stem the larvae are protected from insecticide sprays and will very quickly cause the seedling to die. A heavy infestation can wipe out 70% of the seedlings over a period of a few weeks. Attacks of this magnitude are probably rare or at least infrequent but cannot be controlled after the symptoms appear. It is probably necessary to take routine precautions by spraying an insecticide such as Dursban (chlorpyrifos) onto the seedbed just before sowing. This will give complete protection against any significant losses.

Yellow rust (*Puccinia lupinicola*) can occasionally attack lupins in early spring causing very significant yield losses if not controlled. Yellow rust was not a significant problem in 1994-1996. However, crops should be monitored regularly in spring/early summer and treated with an appropriate fungicide where necessary.

Bird damage

The experience to-date indicates that lupins are not subject to significant bird damage. Neither crows at emergence or pigeons at harvest caused damage.

CONCLUSIONS

- White lupin offers the possibility of reducing the quantities of soya bean meal imported and replacing it with a high quality traceable source of animal feed protein.
- Winter hardy autumn sown lupins are capable of producing satisfactory yields (up to 4.5 t/ha) in Ireland.
- Site selection, avoiding both high pH soils (above 7.0) and soils or fields liable to water logging in winter is essential.
- Sowing before mid-September at 45 seeds/m² equal to approximately 100 kg/ha of seed is essential in achieving maximum yield.
- Lupins can be produced for around £100/tonne.
- Improved varieties which mature earlier are less dependent on early sowing and tolerant to high soil pH values are being developed and should be evaluated in future investigations.

REFERENCES

Crowley, J.G. 1996. Performance and prospects for alternative crops. *In: National Tillage Conference*, Seven Oaks Hotel, Carlow, 113-119.

Milford, G.F. and Shield, I.F. 1996. The potential of lupins for UK Agriculture. *Journal of the Royal Agricultural Society of England*, 84-91.

Shield, I.F. and Milford G.F.J. 1995. The performance of autumn-sown determinate genotypes of the white lupin (*Lupinus albus*) in different regions of the U.K. *Proceedings of the 2nd European Grain Legume Conference, Copenhagen*, 1995. p.144.