Quantifying the yield-density relationship for narrow-leafed lupin (*lupinus angustifolius*) in Tasmania

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Summary. Narrow-leafed lupin cultivars, Yandee, Geebung, and 75A329 can all be successfully cultivated for grain in Tasmania. Field experiments to examine yield responses to density were conducted in 1989 and 1990 at Elliott (North West Tasmania) and Cressy (Midlands). Seeding rates were used to approximate target plant densities 10, 20, 40, 80, and 160 plants/m2 in 1989 and 10, 40, and 160 plants/m2 in 1990. At harvest, all pods were removed, the number of pods and pods/plant counted, and grain yield/ha calculated. Poorer plant growth at Elliott resulted in failure to reach an optimum density for yield, whereas at Cressy under better growth conditions, yield peaked at approximately 40 plants/m2. Due to the determinate characteristic of cv. 75A329, a much higher plant density may be required as it did not reach its maximum yield in any of the experiments. The plant density/grain yield data collected in 1989 was used to derive a set of regression equations (second order) to quantify the responses of yield to plant density in these environments.

INTRODUCTION

The narrow-leafed lupin (*Lupinus angustifolius*) is one of three lupin crop types that originated in Europe (3). In Tasmania, narrow-leafed lupins have been grown as a green manure crop since the 1940's. During the 1970's, Dr John Gladstones established a breeding program for lupins in Western Australia producing cultivars with non-shattering pods and sweet, soft seeds (2). This resulted in the establishment of a lupin grain industry in Western Australia. Tasmania started importing small quantities of lupin grain for stock feed. At the same time, the Department of Primary Industries and Fisheries (DPIF) started to examine the feasibility of cropping its own sweet lupins for grain to replace expensive imports. Several screening evaluations were conducted during 1985 and 1986 to assess the agronomic suitability in Tasmania of a range of improved lines from Dr Gladstones' breeding program. The interest of Tasmanian farmers in growing lupins for grain over this period is demonstrated by the increase in area sown from 80 to 1300 ha between 1984 and 1989 (1).

The overall purpose of the study was to examine growth and development of narrow-leafed lupin under environmental conditions in Tasmania in order to assess their potential for grain production in the State. In this paper, we aim to identify the importance of lupin plant density to lupin crop grain yield in Tasmania and to develop relationships quantifying the response of yield to plant density.

MATERIALS AND METHODS

The field experiments were conducted in 1989 and 1990 at Elliott (North West Tasmania) and Cressy (Midlands). Lupin cvv. Yandee (indeterminate branching type), Geebung (indeterminate branching type), and 75A329 (a determinate branching type which should have yield advantages under short season conditions) were planted in plots measuring 20x1.5 m, replicated four times in a randomised complete block design. Seeding rates employed in 1989 targeted densities of 10, 20, 40, 80, and 160 plants/m2 and in 1990 densities of 10, 40, and 160 plants/m2. The experiments were sown in June 1989 and May 1990 at Elliott, and June 1989 and May 1990 at Cressy. Seed was inoculated with Group G inoculum and 250 kg/ha superphosphate (9.1% P) was applied at each site. Simazine was applied as a pre-emergence herbicide at 250 g a.i./ha, except at Elliott in 1989 where metribuzin was used at 140 g a.i./ha.

In each experiment, rainfall, evaporation (Class A pan), and temperature data were collected from meteorological stations at Elliott (1989, 1990), Cressy (1989), and Launceston airport (1990), which was approximately 20 km north east of the experiment at Cressy.

At maturity, all plots were sampled by collecting all plants from a 1 m2 quadrat buffered on all sides. Plants were pulled from the ground and the roots were cut just above ground level and discarded. A sub-sample of plants was collected as a proportion by weight of the total sample and separated into stem and pod. The outside rows of each plot were removed and the remaining 10 m was headed using a Nurserymaster? small plot header to obtain data on grain yield.

RESULTS AND DISCUSSION

Plant density and grain yield

At Elliott in 1989, grain yield (calculated from quadrat sample) increased significantly with plant density. The increased number of plants/m2 resulted in fewer pods/plant, but pods/m2 still increased with density (Table 1). As a result, maximum yield occurred at over 100 plants/m2.

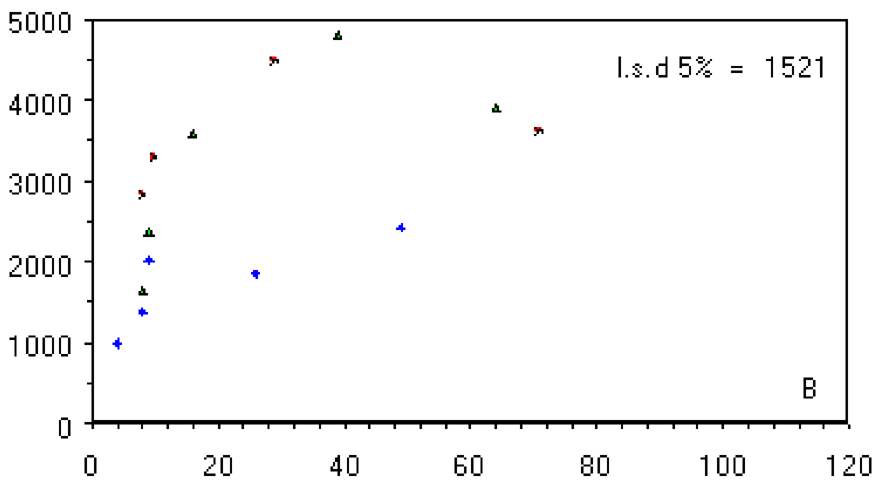
Table 1. Pod and grain yield data for lupin cvv. Yandee, Geebung, and 75A329 at Cressy (C) and Elliott (E) respectively in 1989 (ns = not significant).

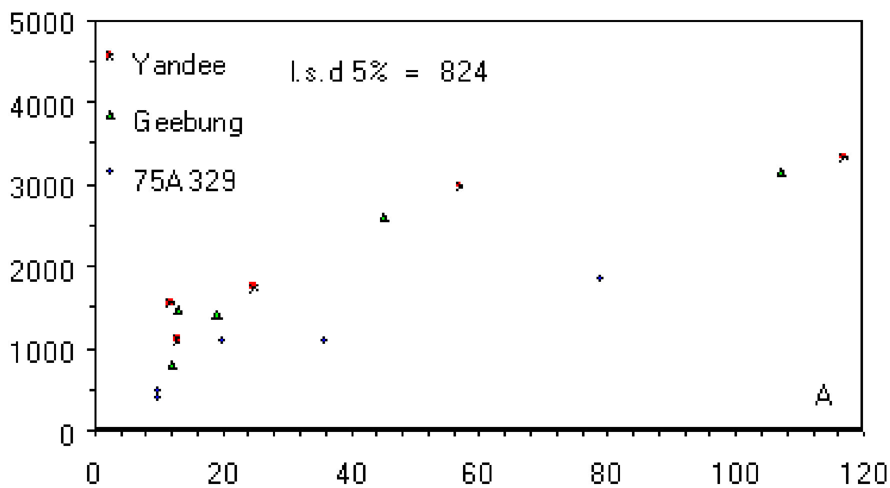
Cultivar	Target density (plants/m2)	Pods/m2		Pods/Plant		Grain yield (quadrat harvest kg/ha)	
		C	E	C	E	C	E
Yandee	10	428	233	57.1	19.1	2830	1544
Yandee	40	652	281	25.2	11.5	4482	1739
Yandee	160	524	509	7.3	4.4	3615	3324
	l.s.d 5%	ns	103	21.5	4.9	ns	685
Geebung	10	508	230	60.3	16.9	1638	1475
Geebung	40	513	239	31.4	13.0	3590	1421
Geebung	160	565	506	10	5	3893	3143
	l.s.d 5%	ns	58	25	5	ns	376
75A329	10	148	106	37.3	10.4	989	485
75A329	40	322	224	30.5	11.1	1377	1088
75A329	160	452	430	10.3	5.5	2413	1855

l.s.d 5%	199	159	20.3	3	1419	638

At Cressy, grain yields and the numbers of pods/m2 were greater than at Elliott for all densities. The number of pods/m2 was maintained as plant density increased by compensating decreases in pods/plant. These data indicate grain yield was a function of pods/m2 rather than pods/plant.

Poor plant growth at Elliott resulted in failure to show an optimum plant density based on machine harvested yield, whereas at Cressy under better growth conditions, yield peaked at approximately 40 plants/m2 (Fig 1). Due to the determinate characteristic of 75A329, a much higher plant density may be required as it did not reach its maximum yield (Fig 1a, 1b, and 1c) in any of the experiments.





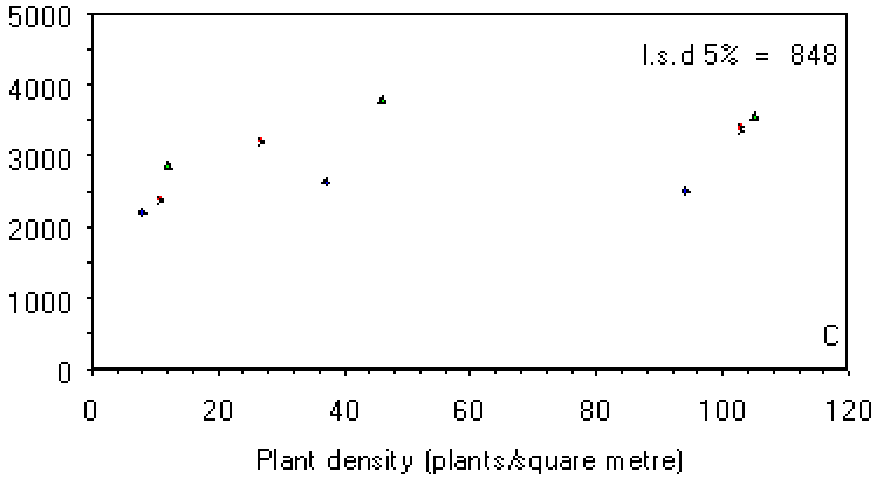


Figure 1. Relationship between grain yield at harvest (kg/ha) and actual lupin plant densities at Elliott in 1989 (A), Cressy in 1989 (B), and Cressy in 1990 (C).

Only three density points were available in the second season and grain yield measured only at Cressy. Fig. 1C demonstrates a trend only. The plot indicates an optimum density of 40-50 plants/m2 for maximum grain yield for both indeterminate cultivars. The highest densities of both Geebung and 75A329 showed a slight decrease in yield due probably to competitive effects.

Quantifying the Yield-density Relationship

Quantifying the relationships (Table 2) between density and grain yield was identified optimum planting densities for lupin plants to maximise yield, under specific local conditions. Variability between the equations across both sites and between cultivars indicates application of this relationship is site specific. Although site, and possibly seasonal variations, will effect the relationship, the data does indicate the general ranges for optimum planting density applicable to the two potential lupin production areas (North-west, Midlands) in Tasmania. The development of a lupin growth model quantifying relationships between plant size, ability to intercept light and water, density, and yield would provide a more general and universally acceptable set of predictive relationships.

Table 2. Regression equations (second order) for plant density/ crop grain yield based on field data collected during 1989.

Site	Cultivar	Equation	R2	Observations
Elliott	Yandee	Yld = 658.17 + 55.40 (den) - 0.28 (den)2	0.98	20
Elliott	Geebung	Yld = 322.63+ 68.25 (den) - 0.39 (den)2	0.97	20
Elliott	75A329	Yld = 163.93 + 37.08 (den) - 0.20 (den)2	0.96	20
Cressy	Yandee	Yld = 2004.40+ 129.90 (den) - 1.51 (den)2	0.99	20

Cressy	Geebung	Yld = 473.46 + 213.6 (den) - 2.51 (den)2	0.97	20
Cressy	75A329	Yld = 1111.90 + 45.86 (den) - 0.41 (den)2	0.82	20

CONCLUSIONS

Yandee, Geebung, and 75A329 can all be successfully cultivated for grain in Tasmania. Yandee and Geebung produced higher grain yields than the determinate 75A329, a cultivar that at the time of the study had not been bred specifically for high grain yield. In autumn sowings, Geebung is the preferred cultivar producing a higher yield in Tasmania. Agronomic data of the type collected in these experiments can be used to quantify yield density relationships empirically but a dynamic crop growth model is required to do this in a general way

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