'Grasslands Maku' Lotus (*Lotus pedunculatus* (Cav.)) Seed Production. 2. Effect of Row Spacings and Population Density on Seed Yields[1]

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ABSTRACT

'Grasslands Maku' (*Lotus pedunculatus* (Cav.), syn. *L. uliginosus* (Schkuhr.)) seed yields of over 85 g m^{-2}, in the first year after transplanting, were produced in small plots established in 0.30 to 0.45 m spaced rows at population densities of 22 and 33 plants m^{-2}. Seed yields were significantly reduced in 0.15 m spaced rows at population densities of 66 and 133 plants m^{-2}. Wide row spacings and low population densities had significantly more seeds per stem by producing more umbels per stem. Pods per umbel, seeds per pod, and 1,000 seed weight were not affected by row spacing and population density.

Additional index words: plant population; row spacing.

INTRODUCTION

'Grasslands Maku' (*Lotus pedunculatus* (Cav.), syn. *L. uliginosus* (Schkuhr.)) is an expensive seed crop to grow, with some growers having to wait up to 30 months before getting a return on their investment (Neal, 1983). High sowing rates are recommended and commonly used by Maku lotus seed growers to establish seed crops (Neal, 1983; Lancashire et al., 1980). These high sowing rates of up to 4 kg ha^{-1} of seed are expensive.

Wide rows and low population densities have resulted in high seed yields in other herbage legumes (Red clover, Clifford, 1974; Lucerne, Kowithayakorn and Hill, 1982). Given the small seed size of both lucerne and red clover, seeding rates of less than one kilogram per hectare could produce enough plants for maximum seed yields.

Seed yield per unit area is a function of seed yield per plant and population density. It is proposed that population density may be one of the most important components governing Maku lotus seed production. The objective of this experiment was to investigate the possibility of achieving maximum seed yields from reduced population densities. It is hypothesized that Maku lotus plants at low population densities will compensate by producing more umbels to give higher seed yields per unit area than at high population densities.

MATERIALS AND METHODS

Inoculated Maku lotus seed was planted into 150 mm long by 25 mm wide paper tubes on 16 December 1981 and established in a glass-house for two months. In February 1982 the 'tubelings' were taken outside to 'harden up' before planting in the field in March on a Wakanui soil complex (Hare & Lucas, 1984).

In February 1982 the area was plowed, grubbed and harrowed, and trifluralin at 1.0 kg a.i. ha^{-1} incorporated into the soil to control annual grasses and broadleaf weeds. No fertilizer was applied. The Maku lotus tubelings were planted in the second week of March 1982 in a randomized block design with five replications and six treatments. The treatments consisted of three inter-row spacings of 0.15, 0.30 and 0.45 m and two intra-row spacings of 0.05 and 0.10 m. Each plot consisted of five rows with variable plot size (Table 1).

Table 1. Row spacings, plant populations and plot sizes for Maku lotus plant population trial.

Treatment	Inter-tow spacing	Intra-row spacing	Plant population	Plot size
	(m)	(m)	(No. m^{-2})	(m)
1	0.15	0.05	133	1.5 × 0.9
2	0.15	0.10	66	1.5 × 0.9
3	0.30	0.05	66	1.5 × 1.8
4	0.30	0.10	33	1.5 × 1.8
5	0.45	0.05	44	1.5 × 2.7
6	0.45	0.10	22	1.5 × 2.7

Water was applied to the plots by spray irrigation on 15 March 1982 to assist tubeling establishment. Plots were hand-weeded in May and July 1982. Ioxynil at 1.6 kg a.i. ha^{-1} was applied twice in August, two weeks apart, and carbetamide at 1.5 kg a.i. ha^{-1} was applied twice in Spetember, two weeks apart. Two hives of honey bees were placed alongside the trial in November 1982. Bromophos at 0.4 kg a.i. ha^{-1} was applied on 16 December to control potato mirids (*Calocoris norvegicus* Gmel).

At weekly intervals from 3 December 1982, when first flowers appeared, a small frame, 0.30 × 0.45 m in size, was placed on a marked position in the center row of each plot. Umbels with newly opened yellow flowers were counted in order to establish the flowering pattern in Maku lotus. The same 0.30 × 0.45 m sample area was harvested for seed yield. The sample was cut and the harvested material dried outside in cloth bags before threshing and

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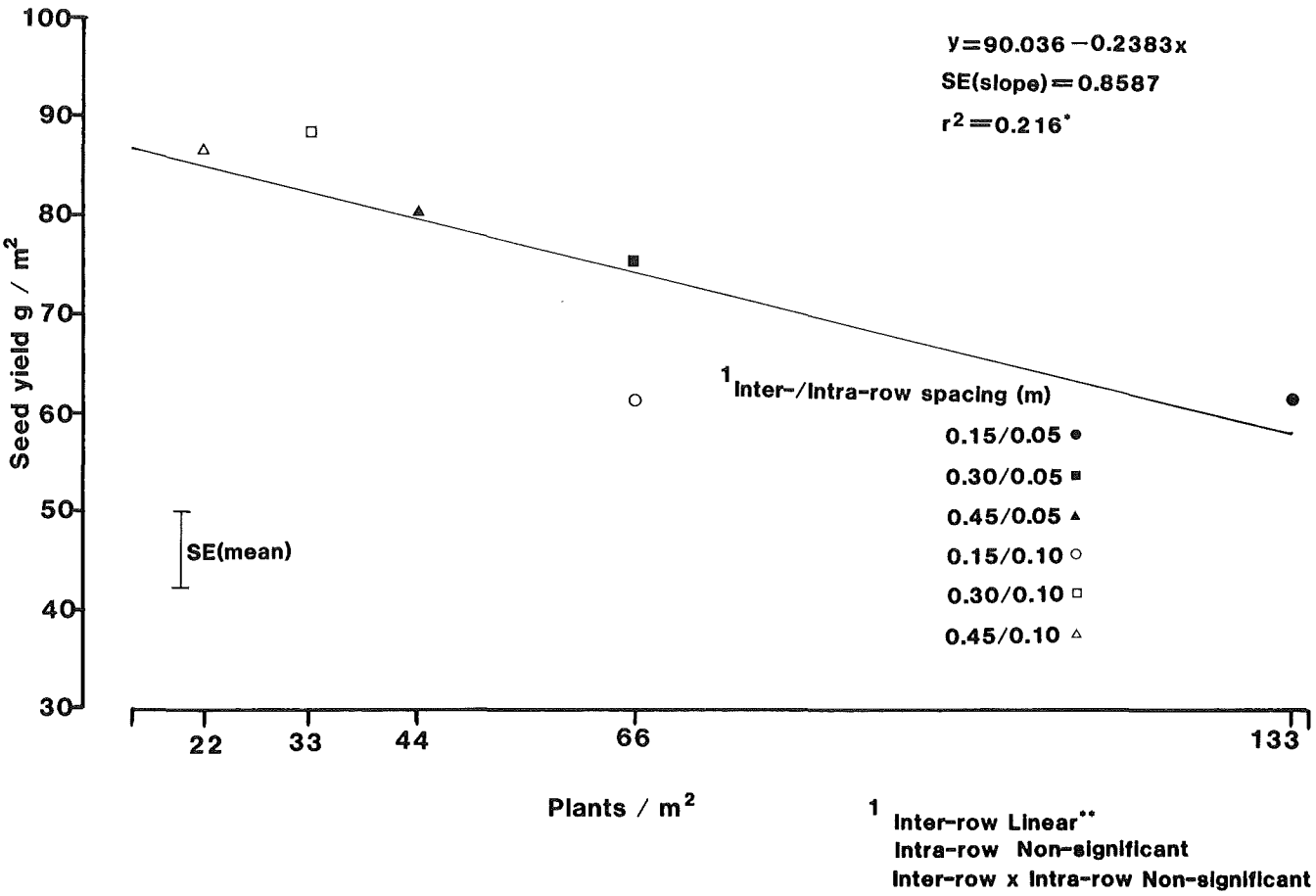


Figure 1. Flowering emergence (umbels m^{-2}) in Maku lotus during summer 1982/83.

cleaning. Cut stems within the harvested area were counted. Harvesting took place during the last week of January 1982 and the first week of February 1982. Pods in low population density plots ripened first and so were harvested one week before the high population density plots. Ten stems were randomly taken from immediately outside the edge of the frame plot at the time of seed harvest and the components of seed yield measured. Statistical interpretation was done by regression analysis.

RESULTS

Flower emergence

Flowers first appeared at the beginning of December and peak flowering occurred ten days later (Figure 1). Flowering then decreased until the end of January, when no more flowers were formed before seed harvest. Population densities had no significant effect on flowering pattern.

Pods from late flowering umbels were still green and very immature at harvest. As these pods were approximately two to three weeks younger than the brown and purple pods from peak flowering, it was not possible to delay harvest until they were mature, otherwise the brown and purple pods would have shattered. The seed harvest, therefore, took place when 36% of the pods were brown, 19% were purple, and 45% were green.

The plots regrew again after harvest and flowers formed in April. Some flowers did form small pods, but frosts in May prevented these pods from developing.

Seed yield

There was a significant linear decrease in seed yield from the low population densities (22, 33 and 44 plants m^{-2}) to the high population densities (66 and 133 plants m^{-2}) (Figure 2). The highest seed yield of 88 g m^{-2} was from 33 plants m^{-2}, but this was not significantly different to 86 g m^{-2} from 22 plants m^{-2}. There was also a linear decrease in seed yield from the wide row spacings, 0.30 and 0.45 m, to the narrow row spacing, 0.15 m. There was no significant difference in seed yield between the two intra-row spacings except at the 0.30 m inter-row spacings where seed yield was significantly greater at the 0.10 m intra-row spacing (88 g m^{-2}) than the 0.05 m intra-row spacing (75 g m^{-2}).

Plants at population densities of 22 plants m^{-2} had significantly higher seed yields of 3.9 g $plant^{-1}$ than other population densities. Narrow inter-row spacings, 0.15 m, and narrow intra-row spacings, 0.05 m, significantly reduced seed yields per plant.

Components of seed yield

Maku lotus at wide row spacings and low population

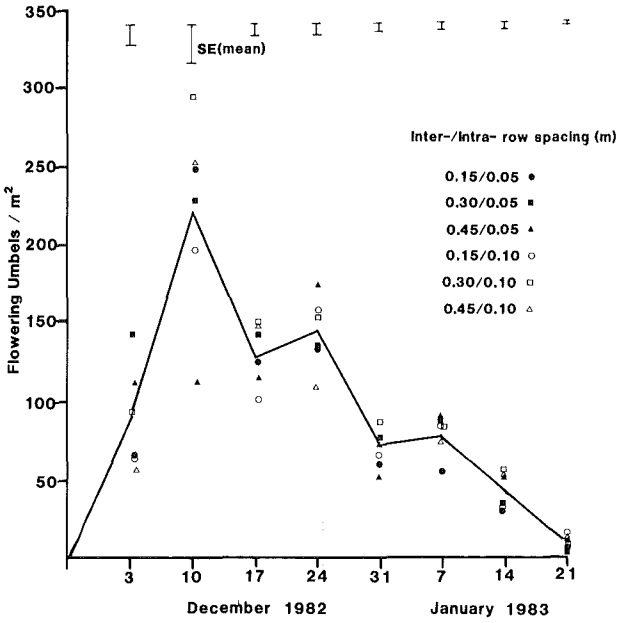


Figure 2. Relationship between Maku lotus seed yield and plant population density.

densities produced significantly more seeds per stem as a result of the increased number of umbels per stem (Table 3). Pods per umbel, seeds per pod, and 1,000 seed weight were not affected by row spacing and plant population.

Stems m^{-2} and stems $plant^{-1}$ were affected by row spacing and by plant population. The 0.15 m inter-row spacings had significantly fewer stems $plant^{-1}$ than the 0.30 and 0.45 m inter-row spacings. Intra-row spacings at 0.10 m had significantly fewer stems m^{-2}, but significantly more stems $plant^{-1}$ than 0.05 m intra-row spacings (Table 3).

DISCUSSION

Maku lotus plants compensated for low plant population densities by producing more umbels per stem and stems per plant. Thus seed yields per stem, per plant and per m^{-2} were increased significantly at low plant population densities.

Maku lotus showed no significant seed yield difference between crops planted at densities of 22 and 33 plants m^{-2}. This is probably due to the slow establishment of Maku lotus with the populations at 22 plants m^{-2} not fully branching in the first year. Kowithayakorn and Hill (1982) and Clifford (1974) found in quicker establishing lucerne and red clover, that population densities which have significant seed yields were below 25 plants m^{-2}.

Flowering emergence of Maku lotus was not affected by plant population densities and spacing treatments. Flowering peaked in mid-December and then gradually decreased, until by the end of January no more flowers were produced. With closing in early spring (September) maximum flower production was in 16 hour photoperiods before the longest day, making Maku lotus similar to Huia white clover (Clifford, 1979), *Lotus corniculatus* (Joffe, 1958; McKee, 1963) and a north German variety of *Lotus pedunculatus* (Forde and Thomas, 1966).

Table 2. Effect of plant population and row spacing upon seed yield per plant.

Plant population	Row spacing inter/intra	Seed yield per plant
(No. m^{-2})	(m)	(g)
22	0.45/0.10	3.9
33	0.30/0.10	2.8
44	0.45/0.05	1.8
66	0.30/0.05	1.1
66	0.15/0.10	0.9
133	0.15/0.05	0.5
	Significance	[1]Q**
	SE (mean)	0.23
Inter-row	0.45	2.8
	0.30	1.9
	0.15	0.7
	Significance	[2]L**
	SE (mean)	0.16
Intra-row	0.10	2.5
	0.05	1.1
	Significance	**
	SE (mean)	0.13
Interaction Inter-row × Intra-row		L**

[1]Quadratic
[2]Linear

There are approximately 1,200,000 seeds in one kilogram of Maku lotus seed. Establishment of Maku lotus is very variable with approximately 30-40% of seed sown producing seedling plants (M. Scheffel, Lincoln College, pers. comm.). Even if only 30% of seeds sown produced seedling plants farmers can, therefore, reduce costs by lowering their seed sowing rates from 2 - 4 kg of seed per hectare down to between 0.5 and 0.75 kg of seed per hectare in 0.30-0.45 m rows for maximum Maku lotus seed yields. It also raises the possibility that with time, Maku lotus seed stands through stem and rhizome production may become too dense for maximum seed yields. Farmers may then have to inter-row cultivate or disc the seed stands in the winter, in order to reduce stem and rhizome populations, and produce a larger population of reproductive stems. Wide row spacings, besides giving the highest seed yields in Maku lotus, have also been found to make management of herbage seed crops easier (P.T.P. Clifford, pers. comm.). Inter-row cultivation, spraying, and fertilization can be carried out effectively without crop damage. It is recommended that Maku lotus be planted in 0.30-0.45 m inter-rows for ease of seed crop management.

Small trial plots can exaggerate harvestable yields of herbage seeds and establishment methods (transplanting tubelings) may have affected seed yields by uniform plant distribution and vigor. The seed yields obtained in this trial were equivalent to 860 to 880 kg ha^{-1}. These yields are far in excess of the national average for Maku lotus in 1982 of 89 kg ha^{-1} (M.A.F. 1983) or even 200 to 300 kg ha^{-1} some

Table 3. Effect of plant population and row spacing on Maku lotus components of seed yield.

Plant population m^{-2}	Row spacing inter/intra	Stems $plant^{-1}$	Stems $meter^{-2}$	Seed yield $stem^{-1}$	Umbels $stem^{-1}$	Pods $umbel^{-1}$	Seeds pod^{-1}	1000 seed weight (12% moisture)
	(m)			(g)				(g)
22	0.45/0.10	13.32	293	0.38	6.9	5.9	10.6	0.88
33	0.30/0.10	11.18	369	0.46	8.2	5.8	11.2	0.87
44	0.45/0.05	5.95	262	0.34	6.3	5.7	11.2	0.85
66	0.30/0.05	6.53	431	0.27	5.6	5.5	10.5	0.83
66	0.15/0.10	4.77	311	0.27	5.7	5.9	9.4	0.84
133	0.15/0.05	3.45	459	0.20	4.7	5.2	9.4	0.87
Significance		[2]Q**	[1]L**	L**	L**	[3]N.S	N.S	N.S
SE (mean)		0.82	33.1	0.04	0.85	0.33	1.11	0.02
Inter-row								
(m)	0.45	9.64	278	0.36	6.6	5.8	10.9	0.87
	0.30	8.85	400	0.37	7.0	5.7	10.8	0.85
	0.15	4.08	385	0.24	5.2	5.6	9.4	0.86
	Significance	L*	Q*	L*	N.S	N.S	N.S	N.S
	SE (mean)	0.58	23.4	0.029	0.60	0.23	0.78	0.02
Intra-row								
(m)	0.10	9.74	324	0.36	6.9	5.9	10.4	0.86
	0.05	5.31	384	0.27	5.6	5.5	10.4	0.85
	Significance	*	*	**	*	N.S	N.S	N.S
	SE (mean)	0.47	19.1	0.024	0.49	0.19	0.64	0.01
Interaction Inter-row × Intra-row		L**	L*	N.S	N.S	N.S	N.S	N.S

[1]Linear
[2]Quadratic
[3]Non-significant

farmers regularly harvest (Neal, 1983). Given the potential high yields of Maku lotus from this small plot trial, ways for farmers to harvest a greater part of the potential yield must be investigated. Harvesting time (Hare and Lucas, 1984) and plant population density are two factors that given good management practices will enable farmers to increase seed yields.

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