INFLUENCE OF BRANCH REMOVAL, PLANT DENSITY AND SPECIES ON POD SET AND SEED YIELD OF LUPINS

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ABSTRACT

Seed yield response of Ultra (**Lupinus albus**) and Unicrop (**L. angustifolius**) grown at 3 plant densities, responded differently when 1-3 auxillary buds were removed at the commencement of mainstem flowering. In Unicrop compensation for bud removal from increased mainstem pod set and pod formation on new lateral branches meant yields were similar. Increased lateral branching did not occur in Ultra plants when buds were removed and severe debudding lowered pod set on the mainstem. Removal of the mainstem inflorescence did not reduce seed yield in either species.

Established plant densities ranged from 10-93 plants m^{-2}, with the highest seed yield (605 gm^{-2}) from Ultra occurring at the highest density. Unicrop, with a maximum yield of 566 gm^{-2} showed little response to increasing density above 53 plants m^{-2}. The proportion of mainstem contribution to seed yield was always greater in Ultra than in Unicrop. Unicrop plants had more pods and seeds per pod, but lower seed weights than Ultra. Pods and seed yield per plant decreased at higher densities for both cultivars. Seed numbers in both species and seed weight for Unicrop, decreased in higher order pods.

INTRODUCTION

Branches on lupin plants are potential pod production sites, hence higher seed yields in lupins might be obtained by increasing the number of fertile lateral branches per unit area (Perry 1975; Withers 1975). Previous experiments showed that plant density influenced the number of 'fertile' branches formed (Withers 1975; Herbert & Hill 1978b). Release of lateral buds from correlative inhibition following removal of the apex has been observed in **Phaseolus vulgaris** and other species (Phillips 1975; Hall & Hillman 1975). However defoliation (including decapitation of the developing mainstem inflorescence) did not increase pod number or seed yield in **Lupinus angustifolius** (Unicrop) (Withers 1975).

Soybeans have shown seed yield compensation to removal of leaves, floral buds and pods from the remaining leaf area and pod production sites (Begum & Eden 1965; Hicks & Pendleton 1969; Beuerlein *et al.*, 1971; Smith & Bass 1972; Thomas *et al.*, 1974; Egli & Leggett 1976). Most pod removal studies showed seed yield compensation by increased mean seed weight.

The growth of lupin plant is characterised by a wave-like pattern of flowering of successive higher order inflorescences. Outgrowth of laterals during the flowering of the subtending inflorescence has been observed and resulting competition between vegetative structures is suggested as a reason for flower abscission in **L. angustifolius** (Greenwood *et al.*, 1975; Perry 1975; Farrington 1976; Herbert & Hill 1978a, 1978b). In this experiement the effect of varying degrees of debudding at the onset of mainstem flowering on pod set and seed yield was investigated at 3 densities in the early flowering cultivars Ultra (**L. albus**) and Unicrop (**L. angustifolius**).

MATERIALS AND METHODS

The experiment was conducted at the Lincoln College Research Farm as part of a larger factorial experiment in a randomised block design with 3 replicates. Early flowering cultivars of two lupin species (**Lupinus albus**, cv. Ultra, and **L. angustifolius**, cv. Unicrop) were sown into a Wakanui silt loam (ex barley) on 23 August 1976. Three populations in plots 2.5 x 20 m were established for both cultivars: Ultra, 10, 65 and 93 plants m^{-2}, Unicrop, 10, 53 and 83 plants m^{-2}. Seed was sown with a Stanhay precision drill with rows 15 cm apart at a sowing depth of 5 cm. A basal dressing of 150 kg ha^{-1} of superphosphate was soil incorporated before sowing, and a pre-emergence application of 1.5 kg a.i. ha^{-1} atrazine effected good annual weed control. The experiment was not irrigated.

Debudding treatments were imposed at the commencement of mainstem flowering: 14 November 1976 for Ultra, and 28 November 1976 for Unicrop. Five plants for each treatment selected at random in each plot had buds removed in the following combinations:

- C : control, no bud removal
- M : mainstem inflorescence
- 1 : first apical bud below the mainstem inflorescence
- 2 : second apical bud
- 1 2 : first and second apical buds
- 2 3 : second and third apical buds
- 1 2 3 : first, second and third apical buds

Care was taken in bud removal from mainstem leaf axils to leave the mainstem leaf intact. Treatments were colour labelled in the field with thin plastic covered wire loosely tied round the mainstem.

At harvest the five plants per plot with the same treatment factors were pooled for yield component analysis. (The control treatment was the mean of 10 plants.) Seed yield of control plants was estimated by taking two samples each 4 rows wide and 1 m long ($0.6 m^{-2}$) from the centre of each plot. Plants taken for component analysis were separated into mainstem and higher order fractions as described by Farrington and Greenwood (1975).

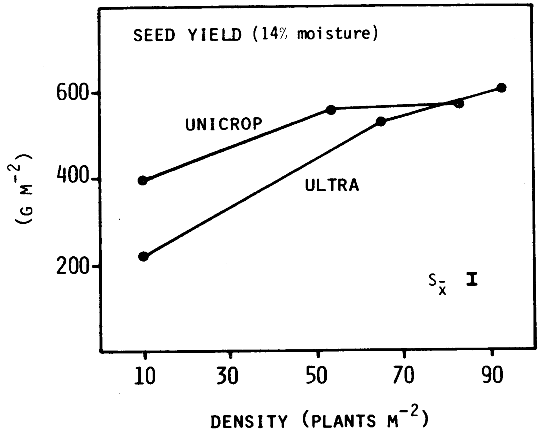

FIG. 1: Seed yield response of Ultra (**Lupinus albus**) and Unicrop (**L. angustifolius**) at different plant densities.

RESULTS

No interactions between debudding treatment and plant density were found but interactions between species and plant density and species and debudding treatment were significant.

Plant Density and Species

Seed yield from populations without debudding treatments are shown in Figure 1. Little increase in yield was evident for **Lupinus angustifolius**, cv. Unicrop when plant density was increased above the medium established density of 53 plants m^{-2}. For Ultra (**L. albus**) seed yield increased with increased plant density to 605 g m^{-2} from an established population of 93 plants m^{-2}.

Analysis of variance showed significant species x density interations for seed yield and pod number per plant (Fig. 2), and average seed weight, but not for seeds per po. and mainstem seed weight. Data presented are means of the debudded treatments. Seed yield per plant and pod number per plant responded in similar ways to increased plant density (Fig. 2). For Unicrop the contribution of the mainstem inflorescence to seed yield was 26% and 55% at the low and the high densities respectively, while in Ultra low density plants, the mainstem provided 40% of the yield and at high density, 60%. The lower contribution by the mainstem of Unicrop is an indication of the greater branching capacity of this species compared to **L. albus**.

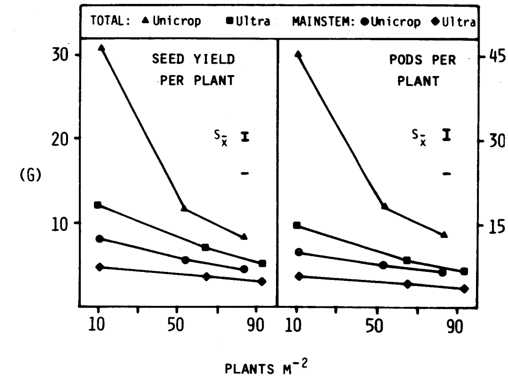

FIG. 2: Influence of plant density on mainstem and total seed yield and pod number per plant of Ultra (**L. albus**) and Unicrop (**L. angustifolius**).

In both species the percentage contribution by mainstem pods was lower compared to mainstem contribution to seed yield. This occurred because pods on branches contained fewer seeds (Fig. 3), and because the weight of these seeds was less in Unicrop (Fig. 4). Seed weight in Ultra did not decrease in higher inflorescence orders except for the A3, but very few plots had plants with A3 inflorescences. Ultra plants had fewer pods, and seeds per pod, but greater seed weight. However, this did not compensate enough, so seed yield per plant was lower. Thus the higher yield from high density Ultra plots (Fig. 1) resulted from the higher plant population. Further increase in density of Unicrop plants would not appear to have increased seed yield.

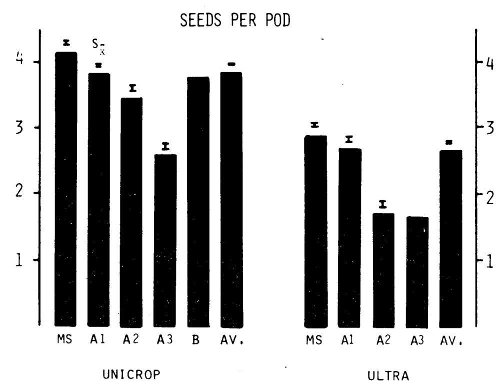

FIG. 3: Seed number per pod for each inflorescence order of Ultra (**L. albus**) and Unicrop (**L. angustifolius**).

Plant density had only a slight effect on seed number per pod. The mean number for both species fell from 3.34 at the low density to 3.11 at the high density. A similar but lesser trend was found for mainstem pods. No response to changing plant density was found for seed weight in Unicrop. For Ultra the mainstem showed no response but the average weight of all seeds from low density plants was less (283 vs. 309 mg) mainly because of a reduction in weight of higher order seeds in response to debudding treatments.

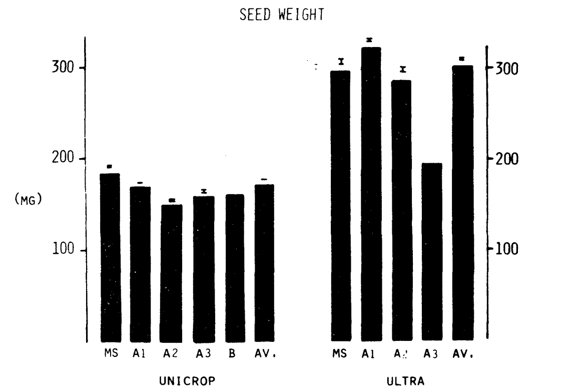

FIG. 4: Seed weight for each inflorescence order of Ultra **(L. albus)** and Unicrop **(L. angustifolius).**

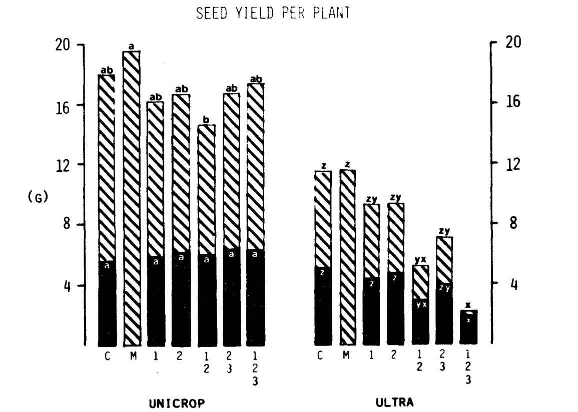

FIG. 5: Influence of bud removal on mainstem and total seed yield per plant of Ultra **(L. albus)** and Unicrop **(L. angustifolius).**

Debudding Treatments

Considerable within-treatment variation masked seed yield response to debudding treatments. Control plants (not debudded) yielded better than all debudding treated plants except where the treatment was the removal of the mainstem inflorescence (Fig. 5). The lower branching capacity of Ultra plants was most evident by lack of seed yield compensation when axillary buds were removed. For Unicrop, no debudding treatment differed significantly ($P < 0.05$) from control plants. Unicrop plants with most severe debudding compensated for seed yield by increased outgrowth from the mainstem of lower apical axillary buds and with greater production of fertile basal branches at the low density. Basal branches were also stimulated to produce seed in medium density plants when either the mainstem or 2 or 3 axillary buds were removed.

Mainstem seed yield contribution was not significantly increased by axillary bud removal (Fig. 5). For Ultra mainstem seed yield was reduced with greater debudding but for Unicrop the control and debudded plants yielded similarly. Mainstem pod number per plant was increased in Unicrop with bud removal, the greatest increase occurring when the three uppermost apical buds were removed (Fig. 6). Control plants of Ultra had greatest mainstem pod set, while those with most severe debudding had the lowest mainstem pod numbers.

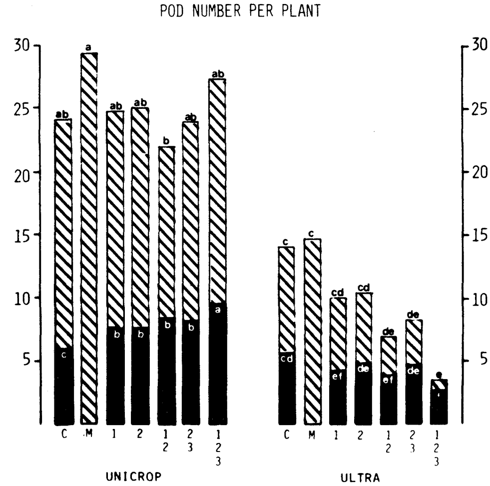

FIG. 6: Influence of bud removal on mainstem and total pod number per plant of Ultra **(L. albus)** and Unicrop **(L. angustifolius).**

Total pod production from debudded Unicrop plants was not significantly different from control plants (Fig. 6). Removal of any potential pod formation site led to compensation from other formation sites. Unicrop plants growing at low density with the three uppermost buds removed still produced 3-4 fertile apical branches compared with 4-5 in control plants. In addition most severely debudded Unicrop plants produced 4-5 basal branches with 3rd order basal pods, compared to 3-4 basal branches in control plants with mostly first order basal pods. A similar pattern of decreasing seed yield with greater debudding in Ultra was seen for total pod number per plant (Fig. 6). The mean contribution of less than one branch pod from Ultra plants with 3 buds removed shows the general lack of compensation in this species. Four branches arising from the mainstem was the maximum number to form pods in Ultra in plants grown at the lowest density.

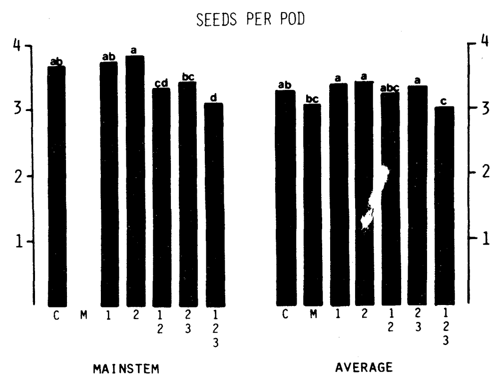

FIG. 7: Influence of bud removal on mainstem and average seed number per pod (means of both species).

Response of seed number per pod to debudding was similar for both species showing a decline when most buds were removed (Fig. 7). This reduction in seeds per pod was the reason for lack of increased mainstem seed yield from debudded plants. Control and debudded Unicrop plants had similar seed weights but decreases in seed weight (270 mg vs 323 mg) were observed in Ultra when 2 or 3 axillary buds were removed.

DISCUSSION

A previous experiment (Herbert & Hill 1978b) found no seed yield advantage when plant density of an early flowering **L. angustifolius** cultivar was increased above 27 plants m^{-2}. Compensation for lower plant numbers was by more branching and more pods per plant. A similar result has been found in this experiment between the medium and high densities but the population of 10 plants m^{-2} was too low for plants to compensate fully. Response of both species to different plant densities and the development of pods and seeds are similar to those reported before (Herbert 1977; Herbert & Hill 1978a; 1978b). The lack of seed yield plateau with Ultra **(L. albus)** at these high densities is interesting and indicates still higher plant populations need investigation in this species.

Initiation of A1 branches in Ultra would seem to be determined before mainstem flowering, since removal of axillary buds at this stage did not promote growth of other axillary buds at lower leaf nodes. Ultra only formed axillary buds at the 3-4 upper leaf nodes whereas Unicrop had twice as many mainstem nodes from which almost all grew branches. In Unicrop control plants most of these branches remained quite small and did not form an inflorescence. However with the removal of buds near to the mainstem inflorescence other buds immediately below and some basal buds (depending on density) were released from inhibition and grew. Under the field conditions of this experiment Ultra did not form any basal branches. Earlier flowering of Ultra at a lower mainstem node number than Unicrop has already been reported (Herbert 1977; Herbert & Dougherty 1978).

The improvement of mainstem pod set by removal of lateral buds supports the hypothesis that the outgrowth of these buds during mainstem flowering competes with the mainstem inflorescence for available assimilates, thus leading to lower pod numbers (Greenwood *et al.,* 1975; Perry 1975; Farrington 1976; Herbert & Hill 1978a). Most of the assimilates required by the mainstem inflorescence in **L. angustifolius** are thought to come from only a few mainstem leaves immediately below the raceme (Farrington pers. comm.). Removal of competing axillary buds could thus possibly improve nutrition of the mainstem inflorescence. The fact that Ultra did not show a similar response emphasises the fact that generalisations cannot be made between species. Branches in Ultra which tended to be more advanced than those of Unicrop at the beginning of mainstem flowering, may have made a positive contribution to mainstem inflorescence nutrition. This may be important for flowers higher up the raceme which are fertilised later when earlier formed pods are growing rapidly (unpublished data). Whether influences from laterals are simply competitive, or complimentary, or a result of hormonal controls, or both, needs further investigation.

Reduced seed set in mainstem pods of Ultra may also be caused by the reduction in assimilate supply from laterals when they are removed. In Unicrop greater mainstem pod numbers may reduce the number of seeds in mainstem pods. Another possibility is that pods higher up the raceme are less competitive and hence form fewer seeds per pod. These pods were fertilised when lower pods were actively increasing in size.

Ultra, unlike Unicrop, was unable to compensate for reductions in leaf area through severe debudding treatments and this was reflected in mean seed weight.

Removal of laterals in either species is not likely to increase seed yield because of a compensation from other laterals in Unicrop and a definite lack of compensation in Ultra. Removal (or failure) of the mainstem inflorescence will not necessarily lower seed yield since removal of its apical dominance allows greater production from lateral inflorescences. Reduction of a limited number of lateral branches by hail or insect attack may likewise not seriously affect seed yield in Unicrop, but could possibly produce drastic reductions in Ultra.

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REFERENCES

Begum, A. and Eden, W. G. 1965. Influence of defoliation on yield and quality of soybeans. Journal of Economic Entomology **58:** 591-2.

Beuerlein, J. E., Pendleton, J. S., Bauer, M. E. and Ghorashy, S. R. 1971. Effect of branch removal and plant populations at equidistant spacings on yield and light use efficiency of soybean canopies. Agronomy Journal **63:** 317-9.

Egli, D. B. and Leggett, J. E. 1976. Rate of dry matter accumulation in soybean seeds with varying source-sink ratios. Agronomy Journal **68:** 371-4.

Farrington, P. 1976. Fruit development and associated changes in the distribution of dry weight and nitrogen in **Lupinus angustifolius** cv. Uniharvest and **L. cosentinii** selection CB_{12}. Australian Journal of Experimental Agriculture and Animal Husbandry **16:** 387-93.

Farrington, P. and Greenwood, E. A. N. 1975. Description and specification of the branching structure of lupins. Australian Journal of Agricultural Research **26:** 507-10.

Greenwood, E. A. N., Farrington, P. and Beresford, J. D. 1975. Characteristics of the canopy, root system and grain yield of a crop of **Lupinus angustifolius** cv. Unicrop. Australian Journal of Agricultural Research **26:** 497-510.

Hall, S. M. and Hillman, J. R. 1975. Correlative inhibition of lateral bud growth in **Phaseolus vulgaris** L. Timing of bud growth following decapitation. Planta (Berl.) **123:** 137-43.

Herbert, S. J. 1977. Growth and grain yield of **Lupinus albus,** cv. Ultra, at different plant populations. New Zealand Journal of Agricultural Research (In the press).

Herbert, S. J. and Dougherty, C. T. 1978. Influence of irrigation, and foliar feeding of N, P, K, S, during seed-filling in two lupin species. New Zealand Journal of Experimental Agriculture. (In the press).

Herbert, S.J. and Hill, G.D. 1978a. Plant density and irrigation studies on lupins. I. Growth analysis of **Lupinus angustifolius** cv. WAU11B. New Zealand Journal of Agricultural Research (In the press).

Herbert, S. J. and Hill, G. D. 1978b. Plant density and irrigation studies on lupins. II. Components of seed yield of **Lupinus angustifolius** cv. WAU11B. New Zealand Journal of Agricultural Research. (In the press).

Hicks, D. R. and Pendleton, J. W. 1969. Effect of floral bud removal on performance of soybeans. Crop Science **9:** 435-7.

Perry, M. W. 1975. Field environment studies on Lupins. II. The effects of time of planting on dry matter partition and yield components of **Lupinus angustifolius** L. Australian Journal of Agricultural Research **26:** 809-18.

Phillips, I. D. J. 1975. Apical dominance. Annual Review of Plant Physiology **26:** 341-67.

Smith, R. H. and Bass, M. H. 1972. Relationship of artificial pod removal to soybean yields. Journal of Economic Entomology **65:** 606-8.

Thomas, G. D. Ignoffo, C. M., Biever, K. D. and Smith, D. B. 1974. Influence of defoliation and depodding on yield of soybeans. Journal of Economic Entomology **67:** 683-5.

Withers, N. J. 1975. A spacing and defoliation study with Unicrop lupins. Proceedings Agronomoy Society of New Zealand **5:** 13-6.