16. O'Connor, B.P., I.C. Logan, and G.R. Rowe. 1975. Effect of ethofumesate on barley grass and other pasture species. Proc 28th NZ Weed and Pest Control Conf:12-16.

17. Rahman, A., B.E. Manson, and B. Burney. 1978. Residual activity of ethofumesate under different soil and climatic conditions. Proc 31st NZ Weed and Pest Control Conf: 203-207.

18. Rolston, M.P., and M.D. Hare. 1986. Competitive effects of weeds on seed yields of first year grass seed crops. J. Applied Seed Prod. 4:34-36.

19. Thomas, R.G. 1980. Growth of the white clover plant relation to seed production. *In* Lancashire, J.A. ed. *Herbage Seed Production.* Grassland Research and Practice Series No 1, NZ Grasslands Ass:56-63.

Competition Between Vegetative and Reproductive Growth and its Effects on Reproductive Abortion and Pod Set in Soybean (*Glycine max* (L.) Merrill)

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ABSTRACT

Reproductive abortion is a major limitation to yield in soybean. Abortion levels in field plantings in New Zealand were over 80% for the cultivar Amsoy. The mechanisms responsible for this are unclear, but it has been suggested that abortion is either under direct hormone control or the result of intraplant competition for nutrients. The effects of intraplant competition between vegetative and reproductive growth in glasshouse-grown soybeans were studied by removing 50 or 100% of all young leaves starting from three different stages of reproductive development. Two related cultivars were used; the indeterminate Amsoy and the semi-determinate cultivar, Matara.

In both cultivars, young leaf removal (YLR) diverted assimilates to cause an increase in flowers or pods for at least a short period during development. Matara has a less plastic growth response than Amsoy and did not respond well to treatment. However, in Amsoy, 50% YLR starting at growth stage R3 (Fehr and Caviness' scale) increased both flower and pod numbers per plant by 44%, the increase in pod set being mainly concentrated on the middle part of the main stem. YLR did not change the proportion of combined reproductive abortion in either variety (79% in Matara, 82% in Amsoy). Losses of reproductive units occurred at all stages during development, but most dramatically during the flowering stage. The results obtained have been fitted into a model constructed to describe nutrient flows into reproductive components. This approach confirms that these data cannot be fully explained on the basis of assimilate partitioning alone.

Additional index words: Leaf removal

INTRODUCTION

Reproductive abortion is an important factor to be considered in yield improvement in soybean (*Glycine max* (L.) Merrill) and other legume crops. Reproductive abortion in soybeans has been reported to vary from 32 to 83% of yield potential (Van Schaik and Probst, 1958a; 1958b). At present, the mechanisms responsible for high reproductive abortion are unclear. A number of hypotheses have been proposed to explain this effect, i.e. nutrient deficiencies (Wiebold et al., 1981), hormonal control (Huff and Dybing, 1980) and vascular constrictions (Gates et al., 1983).

Weibold et al. (1981) have suggested that under normal conditions, a localized decrease in photosynthesis can cause an increase in abortion in adjacent reproductive units because of a reduction in available carbohydrate. Antos and Wiebold (1984) showed that high abortion rates in the lower one-third of the canopy were associated with low concentrations of total soluble sugar and starch in the stem and petioles. However, Heitholt et al. (1986) reported that concentrations of carbohydrates did not change in fully open flowers even though the percentages of reproductive abortion were altered by source-sink manipulations. Moreover, reproductive abortion occurred mainly at the flowering stage when photosynthetic rate was relatively high, and during the first days after flower opening. Flowers are small sinks relative to the size of the whole plant as indicated by a slow absolute dry matter accumulation rate (<5 mg flower^{-1} day^{-1}) (Heitholt, et al., 1986). Therefore, it seems that while flower abortion may not be limited by the available supply of photoassimilate present during flower growth, the hormonally controlled maintenance of sink strength of flowers may be crucially important.

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In a previous field trial, it was found that the percentage of reproductive abortion within a cultivar was surprisingly consistent throughout the wide range of plant densities studied (6 to 61 plants m^{-2}), (Chanprasert, unpublished data). This consistency in abortion rate has also been found in highly productive growing conditions by Morandi et al. (1988) when they used light breaks at night to increase source capacity and thus yield potential.

The results of such field studies suggest that competition for assimilates plays an important role in regulating soybean yield and soybean yield components. Interplant and intraplant competition are probable causes of high abortion rates in higher and lower density plants, respectively. Whereas in high density plants leaf growth stopped before peak flowering, new leaves were progressively produced during flowering and early pod development in plants grown at medium and low densities. These young leaves serve as strong sinks for assimilates from roots and older leaves and compete intensely with reproductive sites (Thrower, 1962). The higher reproductive abortion percentage found in the field for the indeterminate cultivar Amsoy (82%) compared to 65% for the semi-determinate Matara (Chanprasert, unpublished data) was probably attributable to its more plastic growth habit which resulted in increased intraplant competition between reproductive and vegetative structures during the flowering period.

Although, there are reports showing that removal of competitive sinks (such as the plant apex) enhances reproductive growth and increases pod set in soybean (Amuti, 1983) and in *Phaseolus vulgaris* (Bennie and Clifford, 1980), there appear to be no reports on the effect of young leaf removal (YLR) in relation to changes in yield and yield components in soybean. Accordingly, the objectives of this experiment were to study and compare these effects in an indeterminate and a semi-determinate cultivar of soybean (Amsoy and Matara, respectively) with special emphasis on the impact of reproductive abortion in reducing yield potential.

MATERIALS AND METHODS

Plant Culture

Seeds of Amsoy and Matara were sown in the glasshouse at the Seed Technology Centre, Massey University, Palmerston North, New Zealand, (40°S, 170°E, on 13 August 1986, using 15 cm diameter pots containing a mixture of peat, pumice and sand. This sterile mixture contained balanced proportions of fertilizer and slow release trace elements, plus Terrazole soil fungicide. Emerging seedlings were thinned to one plant per pot. A set of (daylight) fluorescent lamps producing a light intensity of 80-100 μE m^{-2} sec^{-1} (Photosynthetically Active Radiant) at the top of mature plants was used as supplementary lighting for 13.5 hours day^{-1}. The glasshouse was adjusted to control temperature between 20 C and 30 C and an attempt was made to keep the relative humidity above 70% during flowering and pod development. One hundred ml of Hoagland's nutrient solution was applied every alternate day to each pot from the first flowering until maturity (pod yellowing). A spray treatment of Malathion (maldison: 0.2% w/v solution) was given 40 days after planting (DAP) and 'Attack' (pirimiphos-methyl plus permethrin: 0.1% v/v solution) was used three times at 10 day intervals to control two spotted mite.

Young leaf removal

Commencing at different times, all or half the emerging young leaves were removed every two days (by cutting the petioles) throughout the remainder of the growth period. Every alternate young leaf was cut off in the 50% removal treatment. These operations were started at three different stages of reproductive development, following Fehr and Caviness' (1977) scale. Thus, in all, there were seven treatments as listed in Table 1 which indicates the treatment notation. Data for Amsoy and Matara were analyzed separately using a completely randomized design with 5 replicate plants per treatment.

Table 1. Young leaf removal (YLR) treatments applied to pot grown soybeans, cvs. Matara and Amsoy.

Treatment	% leaves removed	Growth stage at which removal started[1]
Control	0	-
R1-50	50	R1
R1-100	100	R1
R3-50	50	R3
R3-100	100	R3
R5-50	50	R5
R5-100	100	R5

[1] Growth stage at which leaf removal started: R1 = "beginning bloom" stage (one open flower at any node on the main stem); R3 = "beginning pod" (one pod 5 mm long at one of the four uppermost nodes on the main stem with a fully developed leaf); R5 = "beginning seed" (seed 3 mm long in a pod at one of the four uppermost nodes on the main stem with a fully developed leaf)

Measurements

Starting from first flowering, flowers (both flower buds and flowers with corolla exerted) of each cultivar were counted and identified by placing acrylic paint on the calyx. Flowers were divided into two groups: early flowers (developing before the 'full pod' stage; R4 on the Fehr and Caviness Scale) and late flowers (developing subsequently). Counting, marking and observations were done on alternate days where possible and at not more than 5 day intervals. Developing pods from early flowers which were longer than 2 cm were counted and marked by placing acrylic paint at the tip of each pod. These were classified as 'early pods' while 'late pods' were those developing from subsequent flowers. During reproductive development until seed maturity, numbers of abscising young (0.5 - 2.0 cm) and large pods (>2.0 cm) were recorded every alternate day. All these activities were performed for each node of each plant. Reproductive structures occurring on branches were recorded for the node at which the branch originated.

The Matara plants were harvested on 1 December 1986 (109 DAP) and Amsoy on 14 December (122 DAP). Numbers of early and late pods per plant were determined at each node. Numbers of seeds per pod and average seed weight (mg seed^{-1}) calculated at 10% seed moisture content were determined for whole plants. Separation of pods, seeds per pod and seed weight into early and late categories was done only for the Amsoy cultivar.

RESULTS

Effect of YLR on leaf numbers

The two cultivars responded differently to YLR in terms of total numbers of leaves produced per plant (Table 2). In Matara, there were no significant differences between treatments whereas in Amsoy, 100% YLR at growth stage R1 and R3 increased the numbers of young leaves initiated by 31 and 28%, respectively.

YLR had no effect on node number per plant (average nodes per plant were 11.8 and 13.7 for Matara and Amsoy, respectively, data not shown).

Table 2. Effect of YLR on the total number of leaves produced per plant in Matara and Amsoy soybeans.

	Total leaves plant^{-1}	
Treatment	Matara	Amsoy
Control	19.8	21.6
R1-50	18.6	20.8
R1-100	24.0	28.2
R3-50	20.2	23.8
R3-100	19.8	27.6
R5-50	20.2	24.0
R5-100	24.6	25.2
LSD 0.05	NS	5.0
CV (%)	23.5	15.7

Effect of YLR on reproductive development, yield and yield components

Only Amsoy showed a response to YLR by increasing total flowers numbers per plant (Table 3). This significant increase of 44% over the control occurred in the R3-50 treatment and was attributable to changes in late flower production (data not shown).

Table 3. Effect of YLR on total flower and final pod number per plant and seed yield in Matara and Amsoy soybeans.

	Flowers		Pods		Seed yield (g plant^{-1})	
Treatment	Matara	Amsoy	Matara	Amsoy	Matara	Amsoy
Control	84	89	18.8	15.6	6.2	4.7
R1-50	64	101	14.2	16.6	5.5	5.2
R1-100	80	69	11.4	13.4	3.9	4.9
R3-50	72	129	15.0	22.4	5.0	6.6
R3-100	66	76	11.4	13.0	4.5	4.9
R5-50	71	94	15.0	19.4	5.7	6.9
R5-100	85	117	18.4	17.6	6.3	5.6
LSD 0.10	NS	29.1	4.8	5.4	1.24	NS
LSD 0.05	NS	35.0	-	-	1.49	NS
CV (%)	31.2	28.0	30.1	29.5	21.7	38.0

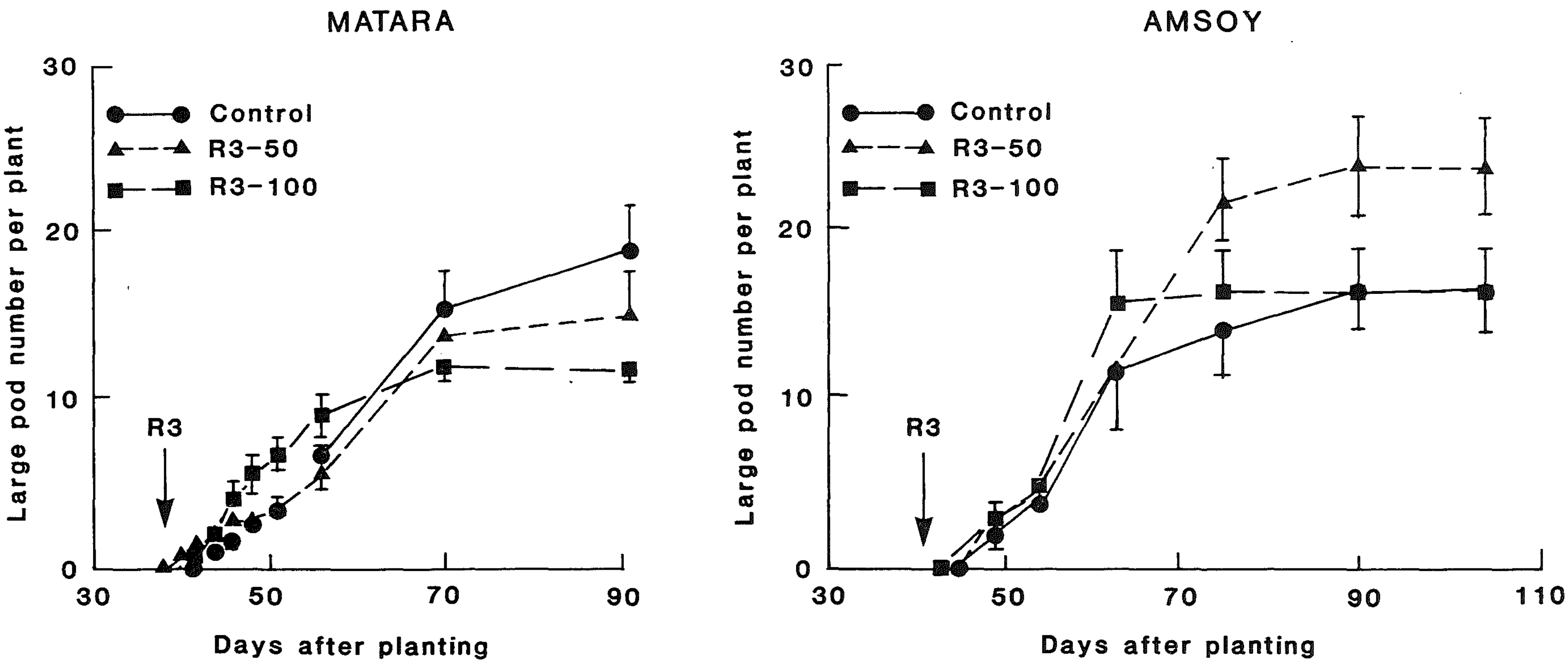

Figure 1. Effect of YLR starting at growth stage R3 on cumulative large pod production in Matara and Amsoy soybeans. Vertical bars represent SE of means.

The production of mature pods in response to YLR differed between cultivars. In Matara, YLR had a generally deleterious effect on mature pod number. Treatments R1-100 and R3-100 in particular, showed a significant decrease. In Amsoy, in parallel with the change in flower numbers, treatment R3-50 increased mature pod number by 44% over the control due to late pod production, but no significant effects were found due to other treatments. Seeds per pod and seed weights did not change as a result of the treatments (average numbers of seeds per pod were 2.1 in both cultivars and average seed weight was 179 and 156 mg seed^{-1} for Matara and Amsoy, respectively). As might be expected, there were thus significant correlations between pod numbers and seed yields (r = 0.932** for Matara and r = 0.866* for Amsoy). Seed yields of Matara plants in treatments R1-100 and R3-100 were therefore significantly decreased. Although R3-50 was a promising treatment for Amsoy, variation between plants was high and no significant increase in overall seed yield was found (Table 3).

Timing and position of pod production

Although YLR depressed final large pod numbers (>2 cm long) per plant in Matara, there was an indication that plants responded to 100% YLR by increasing the number of large pods produced per day over a short period of about 10 days during 46 to 56 DAP (Fig. 2). As source strength was exhausted during later stages of pod growth, the number of large pods declined to levels below the control.

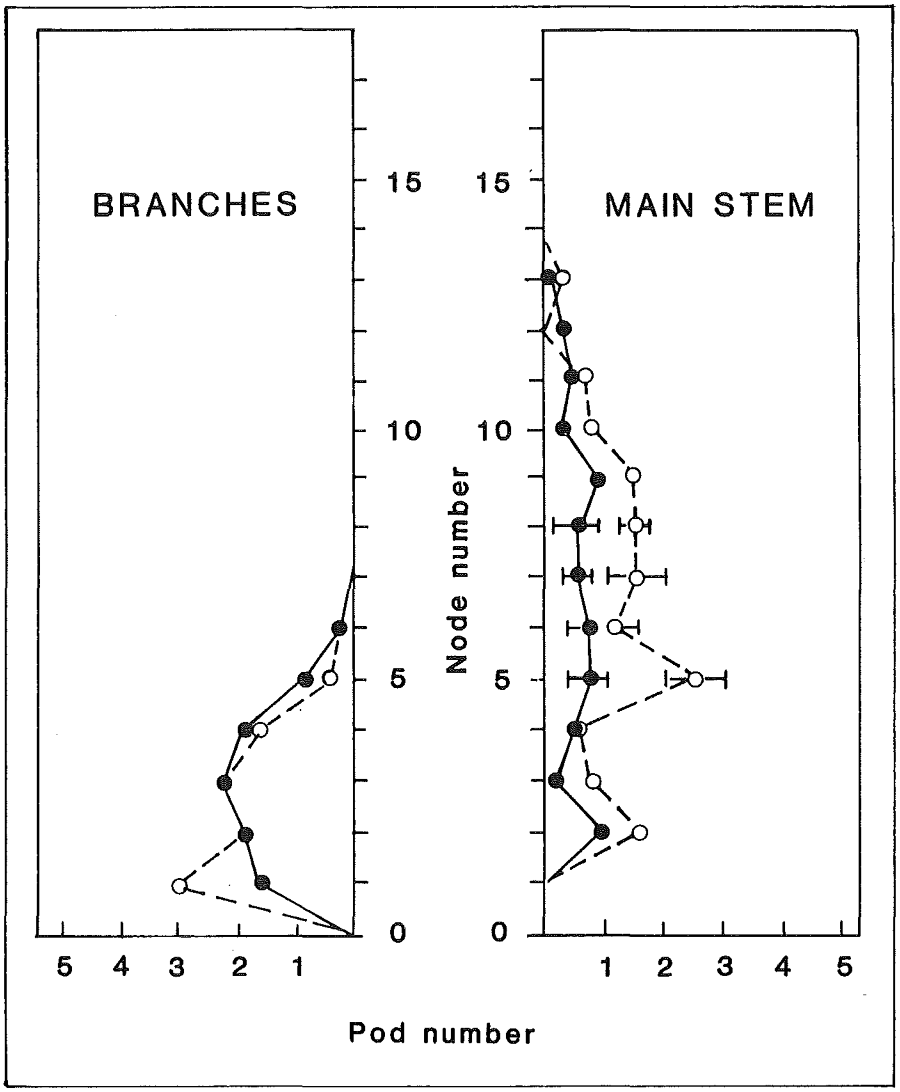

Figure 2. Mature pod production at each node on Amsoy plants, comparing plants given treatment R3-50 with untreated controls. Horizontal bars represent SE of means.

In Amsoy, the tendency for a short-lived increase in large pods produced was not as clear in R3-100 as in Matara, while all other treatments except R3-50 followed the same pattern as the control (data not shown). However, in the case of R3-50, the increase in large pods produced from after 60 DAP was dramatic and persisted until the end of the experiment.

The 44% increase in mature pod set caused by R3-50 occurred in the middle part of the plants, particularly at nodes 5 to 8 (Fig. 2). Increased pod set on branches was relatively unimportant (<10%) compared to the 83% increase in pod numbers borne on the main stem.

Reproductive abortion

In control plants, for every 100 flowers, 32.1 produced young pods in Matara and 29.0 in Amsoy. Of these young pods, 22.7 and 18.0 developed into large pods, respectively (Fig. 3). Eventually, large pods reached the mature pod stage with very little abortion (0.2 and 0.0, respectively, for the two cultivars). When the percentages of total abortion were calculated, Matara and Amsoy plants had 77.5% and 82.0% combined abortion, respectively. Figure 3 emphasizes the importance of abortion at the flower stage which did not differ significantly between treatments (data not shown).

In Matara, large pod abortion was significantly increased by 100% YLR, although the contribution to combined abortion was negligible (Table 4). In the Amsoy cultivar, YLR treatment R1-100, where plants bear the smallest number of mature leaves during the later stages of reproductive development, showed a significantly lower percentage of young pod abortion than the control (Table 4). At the later stage, however, large pod abortion was greater in treatments R3-50 and R3-100. Again, however, abortion of young and large pods was only a small component of combined abortion, and both in cultivars there were no significant effects of YLR on combined reproductive abortion.

DISCUSSION

Intraplant competition between vegetative and reproductive growth

Plant responses to YLR differed between the two cultivars. The semi-determinate Matara showed only negative effects while the indeterminate Amsoy showed improvements in pod set and yield potential. Responses of both cultivars depended on the time and intensity of YLR.

Full leaf removal (100% YLR) at stages R1 and R3 caused a significant reduction of seed yield in Matara, but not in Amsoy. Yield loss as a result of mature leaf removal during reproductive development, causing a shortage in assimilate supply during late stages in soybean, is common (Johnston and Pendleton, 1968; Mesa and Fehr, 1984; Bhattacharjee and Ghude, 1985). Determinate soybean cultivars have been shown to be more affected in this respect than indeterminate soybeans (Fehr et al., 1981). This may be due to the ability of indeterminate soybeans to form new leaves during the reproductive phase (Table 2).

In both cultivars seed yield was significantly correlated with numbers of pods per plant, confirming the well established view that this is the most important component of yield in soybean (Dominquez and Hume, 1978). Pod growth and development has been reported to rely mainly on the corresponding subtending leaf (Blomquist and Kurst, 1971; Stephenson and Wilson, 1977a). Therefore, the increased pod set on nodes 5-8 in Amsoy with R3-50 treatments (Fig. 2) reflects not only reduced intraplant competition but the continued efficiency for photosynthesis of leaves at these nodes during pod development and maturation. Stephenson and Wilson (1977b) reported that, between pre-flowering and early pod development in soybean, assimilate was stored in stems and transferred to pods during later development, a finding also noted for faba bean (*Vicia faba*) by Ismail and Sagar (1981). Removal of some young leaf material probably reduces the competition for this temporary store of assimilates, allowing more to be available for additional pod set. Leaves borne in the middle of the plant are in the best position for light interception in treated plants and are therefore more likely to maintain the photosynthate supply required by additional pods until maturity.

These results suggest that a high degree of intraplant competition exists in Amsoy plants during the early stages of reproductive development and a partial reduction of competitive sinks causes a re-direction of photoassimilates in favor of flower initiation and pod set. This idea is supported by evidence from other sources. Heitholt and Egli (1985) found that floral removal in soybean during the early reproductive phase increased leaf number, although these new leaves were quite small and did not result in a significant change in leaf area. Conversely, Gehriger and Keller (1980) studied the distribution of ^{14}C-labeled assimilates into flowers and young pods in faba bean and revealed that topping which reduced the level of intraplant competition and increased pod set, increased the incorporation of label into young flowers.

Full (100%) YLR at growth stages R1 and R3 did not significantly change flower number and pod number per plant in Amsoy. In fact, plants given these treatments reinitiated more young leaves resulting in significantly more leaves produced per plant (Table 1). This agrees

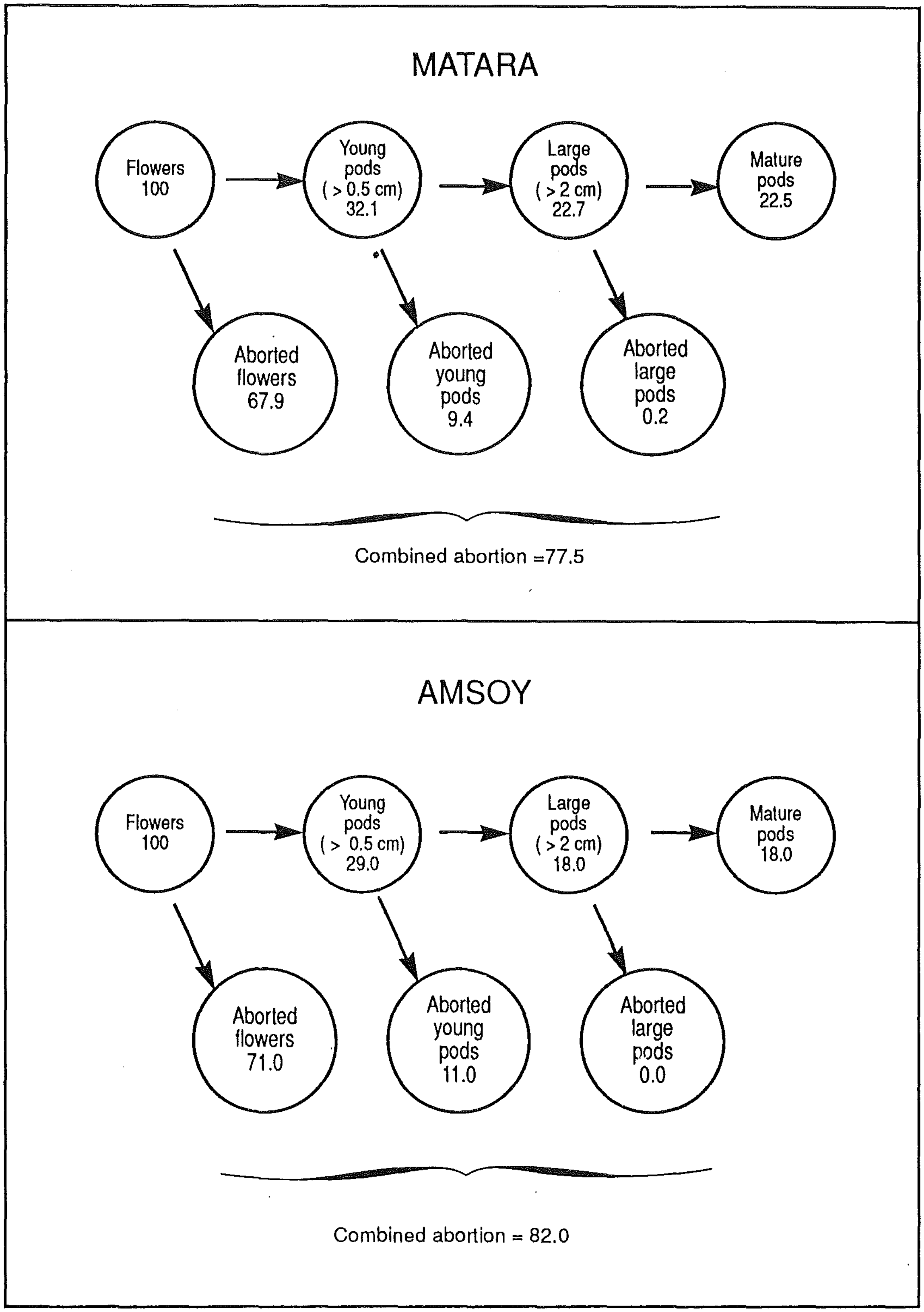

Figure 3. Pod set and abortion in untreated plants. The diagrams show the fate of each 100 flowers of cv. Matara and Amsoy.

with results found in lupin (Pate and Farrington, 1981) and tomato (Ho, 1984) which have shown that during flowering, the flower is a minor sink for assimilates compared with the root, main stem and developing lateral shoots.

It is interesting that plant responses to 50% YLR at growth stage R1 differed from those at R3. R1-50 did not significantly increase flower number per pod set (Table 3). This suggests that the reproductive sink was limiting at this stage of development in Amsoy. Because of this, extra assimilate made available by YLR at later stages could only go to increase the seed weight in early setting pods.

YLR at the late flowering period (R5) appears to be too late to stimulate flower production since the pattern of cumulative flower production per plant was not altered (data not shown) and total flower numbers were not significantly increased. In both cultivars, flower production activity was low at this stage.

In Amsoy, although R3-50 significantly increased late pod set after 74 DAP (Fig. 1) and thus mature pod number by 44%, seed yield per plant was not significantly different from the control (Table 3). An increase in pod numbers per plant without an increase in seed yield is a common observation in soybean research (Burton and Curley, 1966; Boize, 1982; Nooden and Nooden, 1985). However, in most of these cases, yield compensation was due to a reduction in seed weight which was not found in the present study. Certainly it can be concluded that R3-50 is a promising treatment in increasing pod number per plant and possibly seed yield in Amsoy.

The other key result from this study is the high level of combined abortion which remains a surprisingly constant proportion of reproductive potential despite plant manipulation. It is evident from this experiment and studies by Van Schaik and Probst (1958b) and Wiebold et al. (1981) that flower abortion is far more important than pod abortion (Fig. 3). This unchanged and high rate of flower abortion again implies that there may be a severe level of intraplant competition during the flowering period in soybean.

A model for explaining assimilate flows

The large increase in late pod set in Amsoy resulting from R3-50 treatment contrasts greatly with the limited effects of the R1-50 and R3-100 treatments. The data suggest that YLR causes high concentrations of assimilates to accumulate in conductive tissue, but restrictions exist on their utilization by reproductive growth.

In order to characterize these limitations more carefully and thereby test the hypothesis that nutrient deficiency directly limits pod set, a descriptive flow model was developed (Figure 4). Assimilate from the resource tank of photosynthetically active leaves flows into new leaves then into reproductive growth. Young leaves are placed nearer to the source than reproductive growth outlets because they are reported to be stronger sinks than flowers or pods during this period (Pate and Farrington, 1981; Ho, 1984). The amount of assimilate flow depends on the number of exporting photosynthetically active leaves which is a function of time and, in this study, YLR treatment. In plants where young leaves are removed, additional new leaves can be initiated and assimilates will be diverted to support their development. Possibly accumulated assimilate may even 'drive' the expansion of otherwise dormant leaf buds. At the reproductive site, assimilates can flow from the top compartment (flowers) to the other two significant components of seed yield (pods and seeds). Seed numbers per pod did not change significantly in this study and are not included.

The model is used to explain and summarize the data for the Amsoy cultivar, allowing the source-sink relationships between exporting leaves and reproductive sinks to be presented on a comparative basis for all six YLR treatments and the control. At the source level, photosynthetically active leaves are important for the growth of reproductive structures, but this evaluation clearly demonstrates that the timing of removal of competing vegetative sinks greatly affects the response obtained. Using Figure 5, the effects of YLR at each stage will be discussed in turn.

1) When YLR was commenced at R1, 50% leaf removal increases flow of assimilate into early seed weight but does not significantly affect any other growth statistic. Those data strongly suggest that plants are sink limited at this time. Despite a very high floral abortion rate, this is not reduced by the increased assimilate availability caused by removal of competing vegetative growth, and the only route for spare assimilate is into heavier early seed weight. Complete YLR (R1-100) does not reinforce this outcome; now there is a shift to new leaf initiation and reproductive components do not change, compared to controls. This suggests that a change in hormonal balance occurs within the plant to facilitate compensatory vegetative growth. Results for the R1-100 treatment also support the idea that plants are pre-programmed at this time to produce a certain number of early flowers and pods.

2) When the flow of assimilates was manipulated at R3, 50% YLR increased the flow to late reproductive yield components, significantly increasing the total number of flowers and late pod set. This indicates that, during this stage, source-limitation plays a role in controlling seed yield because reducing vegetative sink competition increases pod set. However, 100% YLR at R3 caused additional new leaf initiation without increasing output to the reproductive containers (except the third compart-

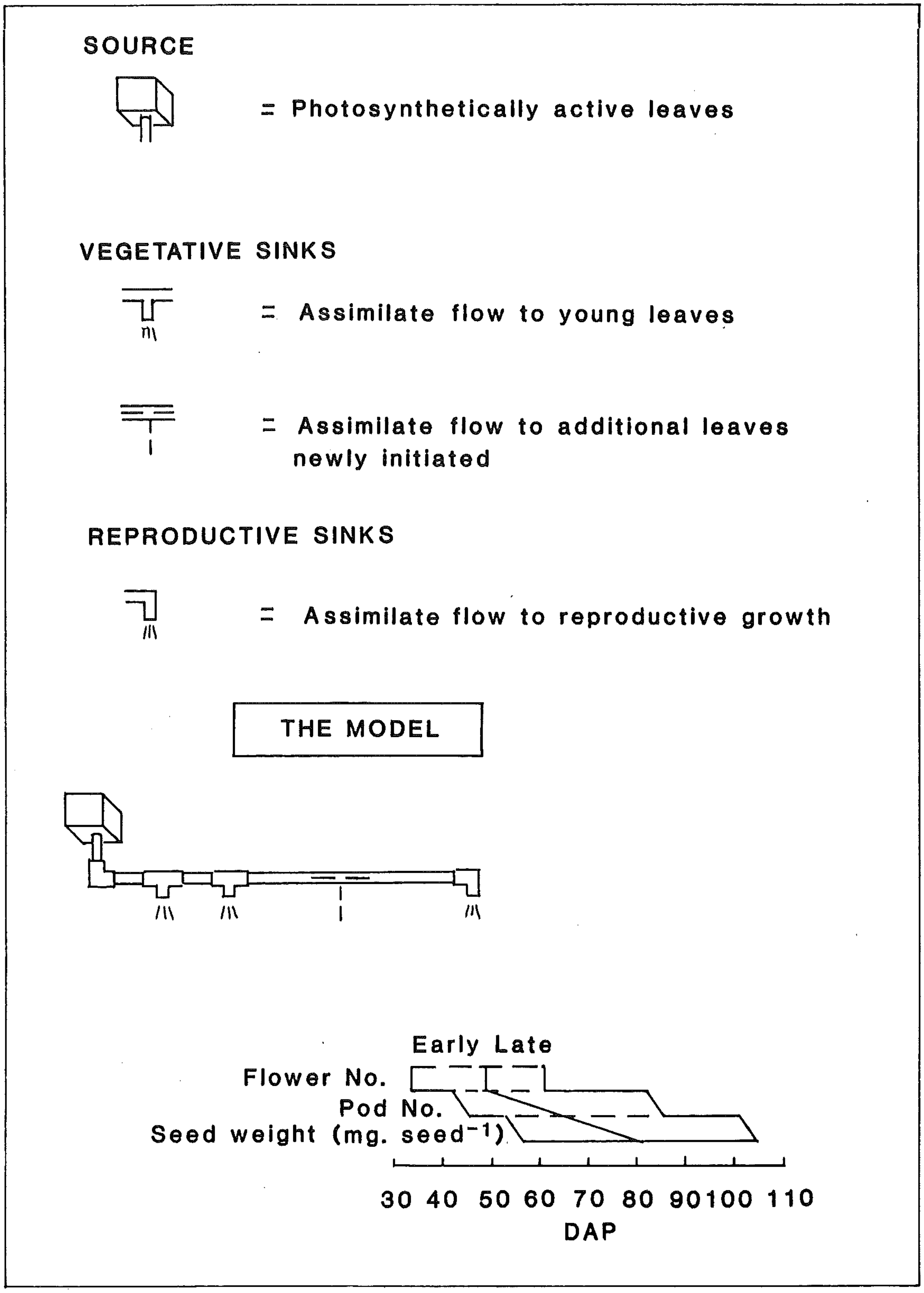

Figure 4. An assimilate flow model for reproductive growth in soybean. Competing vegetative sinks comprise young leaves and additional newly initiated leaves which arise as a consequence of YLR treatments. The reproductive sink consists of six sections representing the early and late components of yield. Seed numbers per pod did not vary with treatment and have been omitted from the model. Sections are constructed according to the timings of flowering, pod formation and seed development in the early and late groups.

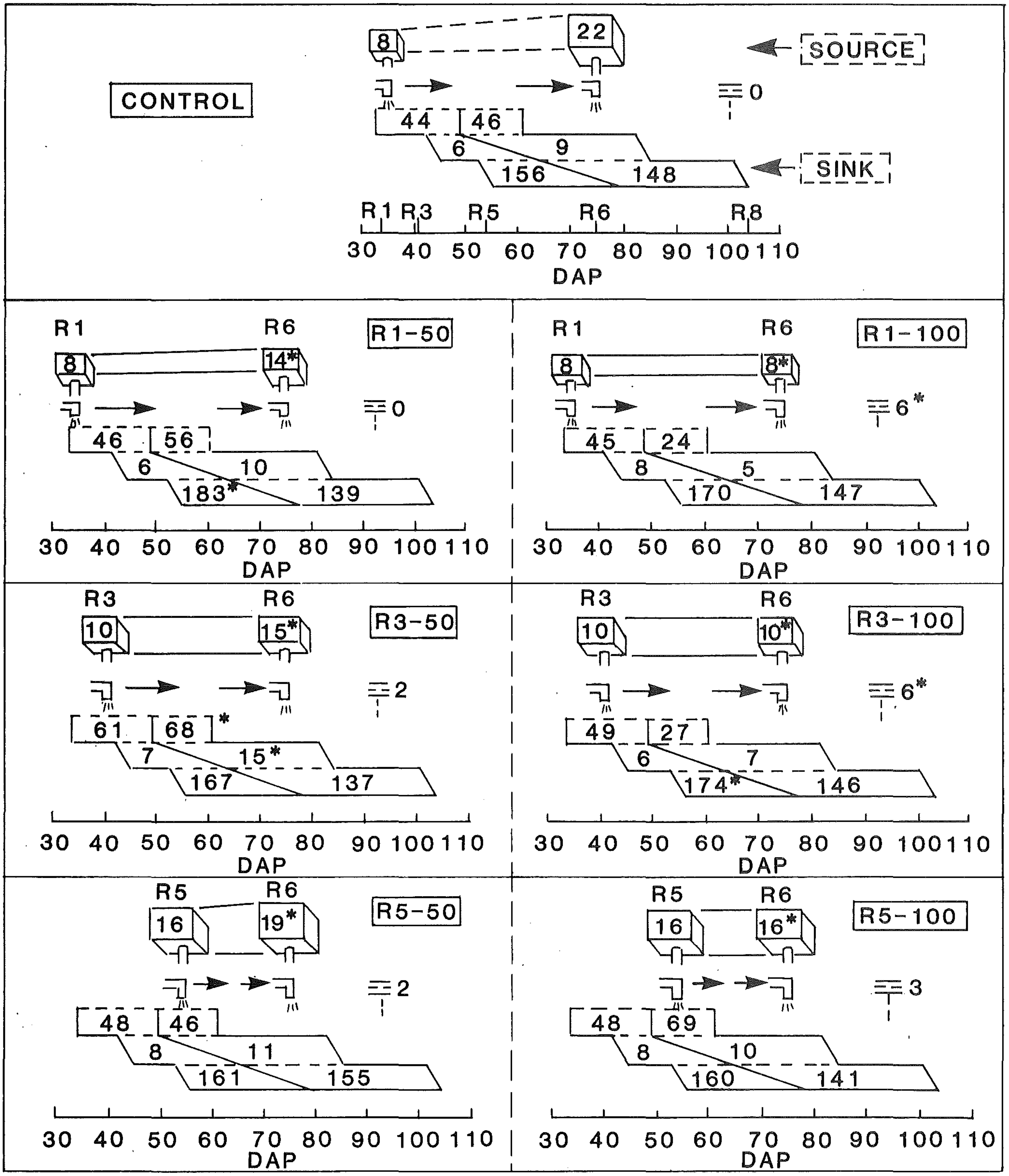

Figure 5. The model used to compare the effects of the YLR treatments on reproductive development in Amsoy. Values for flower and pod numbers per plant and mean seed weights are shown in the appropriate boxes (see Figure 4). Values asterisked are significantly different from the untreated control (P<0.10).

ment of the early group: early seed weight). This suggests that the high new leaf initiation stimulated by severe YLR rapidly increased sink competition with the later reproductive units.

3) Treatments at R5 are too late to induce any significant changes in reproductive growth; sink activity is once again limiting.

In the present study, the imposition of YLR was based on the idea of competitive sink reduction. The expectation that YLR could reduce intraplant competition was correct, but use of the model shows that many events can be only partly reconciled with a hypothesis of direct control via nutrient availability. Not only have sink limitations been identified in sections (1) and (3) above, but the consistency of combined reproductive abortion in both Amsoy and Matara suggests that high reproductive abortion in soybean may have been pre-programmed in these plants. It would seem an easy option for plants to decrease their abortion rates and thereby increase sink activity, but data (Table 4) shows that this does not happen. The conclusion from the model is that another level of control, most probably hormonal, must be superimposed on nutrient availability.

In soybean, hormonal balances in the whole plant system rather than changes in any single hormone probably control reproductive abortion. There is evidence that auxins (Huff and Dybing, 1980), gibberellins (Birnberg and Brenner, 1987), cytokinins (Crosby et al., 1981; Carlson et al., 1987; Dyer et al., 1987) and ethylene (Urwiler and Stutte, 1986) may all be involved in reproductive abortion in soybean, whereas ABA seems to be the least significant hormone in this respect (Huff and Dybing, 1980; Yarrow et al., 1988). The effects of gibberellins and auxins produced by vegetative sinks seem to be detrimental to reproductive growth in soybean. This is supported by evidence that exogenous treatment of soybean leaves with gibberellins cause lower pod set (Birnberg and Brenner, 1987) and exogenous applica-

Table 4. Effect of YLR on young pod, large pod and combined abortion for Matara and Amsoy soybeans (values expressed as percentages of total flower numbers).

	Abortion (%)				
Treatment	Young pod		Large pod		Combined
Matara					
Control	9.4		0.2	(0.020)[1]	77.5
R1-50	10.8		0.6	(0.049)	77.4
R1-100	13.4		1.8	(0.131)	86.4
R3-50	15.3		0.0	(0.000)	77.6
R3-100	9.8		1.2	(0.095)	79.9
R5-50	6.8		0.3	(0.025)	78.5
R5-100	7.2		1.1	(0.094)	77.1
LSD 0.10	NS			(0.062)	NS
LSD 0.05	NS			(0.074)	NS
CV (%)	27.8		103.3		6.6
Amsoy					
Control	11.0	(0.308)	0.0	(0.000)	82.0
R1-50	3.3	(0.178)	0.5	(0.043)	82.3
R1-100	1.5	(0.074)	0.6	(0.048)	80.4
R3-50	13.3	(0.351)	1.9	(0.121)	82.3
R3-100	6.4	(0.211)	2.3	(0.119)	81.5
R5-50	5.0	(0.208)	0.2	(0.022)	78.3
R5-100	13.7	(0.335)	0.0	(0.000)	84.5
LSD 0.10		(0.164)		(0.068)	NS
LSD 0.05		-		(0.081)	NS
CV (%)	64.1		124.8		7.3

[1] Values in parentheses are arcsin $\sqrt{\ }$ transformed values

tions of auxin-transport inhibitors such as TIBA and morphactin can increase pod set (Nooden and Nooden, 1985), possibly through the diversion of photoassimilates between leaf growth and reproductive growth.

The increase in pod set by YLR beginning at growth stage R3 in Amsoy in the present study may thus be the result of reduced endogenous levels of gibberellins and/or auxins and raised cytokinins during subsequent development. A further study on changes in these hormone levels in treated and untreated Amsoy would be most interesting. Comparisons using the less plastic cultivar, Matara, where YLR at growth stage R3 was ineffective might prove a valuable reference. Results from this research may be helpful in understanding hormonal control in soybean reproductive development and also in supporting further applied research on the use of various techniques of plant manipulation for soybean production.

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REFERENCES

1. Amuti, K. 1983. Effect of removal of flower buds, open flowers, young pods and shoot apex on growth and pod set in soybean. J. Exp. Bot. 34:719-725.
2. Antos, M., and W.J. Wiebold. 1984. Abscission, total soluble sugars, and starch profiles within a soybean canopy. Agron. J. 76:715-719.
3. Bennie, R.C., and P.E. Clifford. 1980. Effects of some defoliation and decapitation treatments on the productivity of french beans. Ann. Bot. 46:811-813.
4. Bhattacharjee, N.S., and D.B. Ghude. 1985. Effect of artificial and natural defoliation on the yield of soybean. Indian J. Agric. Sci. 55:427-429.
5. Birnberg, P.R., and M.L. Brenner. 1987. Effect of gibberellic acid on pod set in soybean. Plant Growth Regulation. 5:195-206.
6. Blomquist, R., and C. Kurst. 1971. Translocation pattern of soybeans as affected by growth substances and maturity. Crop Sci. 11:390-393.
7. Boize, L.M. 1982. The influence of auxin antagonists on pod and seed number and yield of soybean (*Glycine max* Merrill). pp. 213-219 *In* J.S. McLaren (ed) Chemical manipulation of crop growth and development. Butterworth Scientific, London.
8. Burton, J.C., and R.L. Curley. 1966. Influence of triiodobenzoic acid on growth, nodulation and yields of inoculated soybeans. Agron. J. 58:406-408.
9. Carlson, D.R., D.J. Dyer, C.D. Cotterman, and R.C. Durley. 1987. The physiological basis for cytokinin induced increases in pod set in IX93-100 soybeans. Pl. Physiol. 84:233-239.
10. Crosby, K.E., L.H. Aung, and G.R. Buss. 1981. Influence of 6-benzylaminopurine on fruit-set and seed development in two soybean, *Glycine max* (L.) Merr. genotypes. Pl. Physiol. 68:985-988.
11. Dominguez, C., and D.J. Hume. 1978. Flowering, abortion, and yield of early-maturing soybeans at three densities. Agron. J. 70:801-805.
12. Dyer, D.J., D.R. Carlson, C.D. Cotterman, J.A. Sikorski, and S.L. Ditson. 1987. Soybean pod set enhancement with synthetic cytokinin analogs. Pl. Physiol. 84:240-243.
13. Fehr, W.R., and C.E. Caviness. 1977. Stages of soybean development. Iowa Agric. Exp. Sta. Spec. Rep. No. 80.
14. Fehr, W.R., B.K. Lawrence, and T.A. Thompson. 1981. Critical stages of development for defoliation of soybean. Crop Sci. 21:259-262.
15. Gates, P., M.L. Smith, G. White, and D. Boulter. 1983. Reproductive physiology and yield stability in *Vicia faba* L. pp. 43-54. *In* D.G. Jones and D.R. Davies (eds.) Temperate Legumes: Physiology, Genetics and Nodulation. Pitman Advanced Publishing, Boston.
16. Gehriger, W., and E.R. Keller. 1980. Influence of topping of faba beans (*Vicia faba* L.) on their growth and on the supply of the flowers with ^{14}C. Fabis. 2:33.
17. Heitholt, J.J., and D.B. Egli. 1985. Influence of deflowering on dry matter production of soybeans. Field Crops Res. 12:163-173.
18. Heitholt, J.J., D.B. Egli, and J.E. Leggett. 1986. Characteristics of reproductive abortion in soybean. Crop Sci. 26:589-595.
19. Heitholt, J.J., D.B. Egli, J.E. Leggett, and C.T. Mackown. 1986. Role of assimilate and carbon-14 photosynthate partitioning in soybean reproductive abortion. Crop Sci. 26:999-1004.
20. Ho, L.C. 1984. Partitioning of assimilates in fruiting tomato plants. Plant Growth Regulators 2:277-285.
21. Huff, A., and C.D. Dybing. 1980. Factors affecting shedding of flowers in soybean (*Glycine max* (L.) Merrill). J. Exp. Bot. 31:751-762.
22. Ismail, A.M.A., and G.R. Sagar. 1981. The influence of leaf age, leaf position and sinks on the rate of export and partition of ^{14}C on different stages of development following assimilation of $^{14}CO_2$ by a single leaf of *Vicia Faba* L. J. of Hort. Sci. 56:55-63.
23. Johnston, T.J., and J.W. Pendleton. 1968. Contribution of leaves at different canopy levels to seed production of upright and lodged soybeans (*Glycine max* (L.) Merrill). Crop Sci. 8:291-292.

24. Mesa, D.P., and W.R. Fehr. 1984. Plot type and treatment method for assessment of soybean response to defoliation. Crop Sci. 24:847-850.

25. Morandi, E.N., L.M. Casano, and L.M. Reggiardo. 1988. Post-flowering photoperiodic effect on reproductive efficiency and seed growth in soybean. Field Crops Res. 18:227-241.

26. Nooden, L.D., and S.M. Nooden. 1985. Effects of morphactin and other auxin transport inhibitors on soybean senescence and pod development. Pl. Physiol. 78:263-266.

27. Pate, J.S., and P. Farrington. 1981. Fruit set in *Lupinus angustifolius* cv. Unicorp II. Assimilate flow during flowering and early fruiting. Aust. J. of Pl. Physiol. 8:307-318.

28. Stephenson, R.A., and G.L. Wilson. 1977a. Patterns of assimilate distribution in soybeans at maturity. I. The influence of reproductive development stage and leaf position. Aust J. of Agric Res. 28:203-209.

29. Stephenson, R.A., and G.L. Wilson. 1977b. Patterns of assimilate distribution in soybeans at maturity. II. The time course of changes in ^{14}C distribution in pods and stem sections. Aust. J. of Agric. Res. 28:395-400.

30. Thrower, S.L. 1962. Translocation of labelled assimilates in the soybeans. II. The pattern of translocation in intact and defoliated plants. Aust. J. of Biol. Sci. 15:629-649.

31. Urwiler, M.J., and C.A. Stutte. 1986. Influence of ethephon on soybean reproductive development. Crop. Sci. 26:976-979.

32. Van Schaik, P.H., and A.H. Probst. 1958a. The inheritance of inflorescence type, peduncle length, flowers per node and percent flower shedding in soybeans. Agron. J. 50:98-102.

33. Van Schaik, P.H., and A.H. Probst. 1958b. Effect of some environmental factors on flower production and reproductive efficiency in soybeans. Agron. J. 50:192-197.

34. Wiebold, W.J., D.A. Ashley, and H.R. Boerma. 1981. Reproductive abscission levels and patterns for eleven determinate soybean cultivars. Agron. J. 73:43-46.

35. Yarrow, G.L., W.A. Brun, and M.L. Brenner. 1988. Effect of shading individual soybean reproductive structures on their abscisic acid content, metabolism, and partitioning. Plant Physiol. 86:71-75.