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Large seeded broad beans for the Japanese Market

R Laurence, *et al*
Tasmanian Institute of Agricultural Research

Project Number: VG97012

VG97012

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Level 1
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Telephone: (02) 8295 2300
Fax: (02) 8295 2399
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Dr Rowland Laurence et al

Tasmanian Institute of Agricultural Research

Project Title: Large seeded broad beans for the Japanese market

Project Number: HRDC VG97012

Project Leader: Dr Rowland C N Laurence
Principal Research Fellow
Tasmanian Institute of Agricultural Research
University of Tasmania North West Centre
P O Box 447
Burnie
Tasmania 7320
Phone: 61 3 6430 4901 Fax: 61 3 6430 4959
E-mail: **Rowland.Laurence@utas.edu.au**

Technical support: Leon Hingston

Technical assistance: Elizabeth Yeomans, Patricia Saunders and Nigel Downward

This report describes the work carried by the project team between August 1997 and June 2002 (the period of HRDC/HAL project funding) to introduce and select genotypes of broad beans (*Vicia faba*) suitable for export and sale in Japan. Reference is made also to preparatory work carried out prior to August 1997. The project VG97012 was originally planned for the above five-year period. It was provided initially with three years' funding by the HRDC and two further years' funding support followed a re-application in 1999-2000.

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30 June 2002

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Media Summary

Five years work by the Tasmanian Institute of Agricultural Research and funded by Horticulture Australia Limited has selected improved types of broad bean, suitable for export to the Japanese fresh market. The Japanese market has required imports of fresh broad beans in recent years to satisfy off-season demand in November through January, when Australia can grow the crop in temperate latitudes. The market window was, however, reduced in the recent season of 2001-02.

After comparing a wide range of types from different countries and locations, large-seeded broad beans with uniform pod shape, earliness and high yield have been selected in research trials. Research has also developed recommendations on how best to sow and manage the crop to provide the best yields and the largest seeds. For example, pruning the tops off plants at a critical time during growth has been shown to improve seed size and is helpful during harvesting.

Selecting the optimum time to pick the crop has been difficult previously, as the size of the beans increases beyond the time when they are most palatable and marketable. Work in this project, however, has confirmed that a simple test can be employed to help predict the best time to pick the crop to get the highest quality.

Technical Summary

This project commenced in July 1997 with the objectives of selecting lines of broad bean (Vicia faba) suitable for fresh export to Japan and also of gaining agronomic information to support their production in Australia. The work has been managed in collaboration with a stakeholder reference group consisting of growers, export company representatives and the Tasmanian Department of Primary Industries Water and Environment. It has comprised the introduction, selection, multiplication and market appraisal of genotypes, studies of seed maturity to assist timing of harvest, the investigation of the effects of plant population and stopping (top-pruning plants during growth) and a test of mechanised harvesting using a green bean harvester available locally.

Twenty-four lines were collected locally, from the national fababean breeding program in Australia, from New Zealand and from Japan. Early selections were made by the stakeholder reference group and a New Zealand consultant on the basis of pod and seed characteristics – pod length and shape, seeds per pod and seed size. The line Jumbo, acquired by a local company, was included as a check. The genetic integrity of all selected lines was maintained by plantings under insect-proof cages (in early years) and in isolated areas (in later seasons). Re-selections were also made on the basis of marketable yield of pods and seeds. Final re-selections, from 2000-01 field trials were the lines Imported, 3FB, 1142 and the cultivar Jumbo and these genotypes were again bulked in isolation plots in 2001-02. These seed stocks are held by the Tasmanian Institute of Agricultural Research pending decisions by interested stakeholders on commercial development. Unfortunately, a deterioration in prices for the product in Japan during the last season, 2001-02, has reduced this interest. Samples of selections were sent to Japanese buyers, who advised that all samples sent were suitable for the Japanese market.

Early samples sent to Japan in 1998-99 were said to be too variable in maturity and, therefore, growth analysis of pods and seed was carried out in the two subsequent seasons in order to try to identify a time in seed development when seed size and maturity were optimized, before seeds exhibited the unattractive characteristic (to the market) of hilum darkening. Pod and seed length and fresh weight, seed dry matter and the development of hilum darkening, as a measure of seed maturity, were monitored by node in Jumbo, Imported and 1142 in 1999-2000. Jumbo and 1142 were similarly monitored in 2000-01 and main and lateral stems were also compared. Seed of marketable size was mostly restricted to the lowest nodes in the cultivar Jumbo and the line Imported but marketable seed was found up to the fourth node in the line 1142. While seed dry matter was maintained below 17 per cent during early development, the onset of hilum darkening closely followed the attainment of seed dry matter values of twenty per cent. Thus, monitoring seed dry matter content may be used to assist the prediction of optimum harvest time. Seed size increased beyond this optimal time for harvesting.

The effects of plant density on yield of stopped and un-stopped plants of the line Jumbo were investigated over two seasons. Optimum populations for maximum marketable pod yield of unstopped plants were about twelve plants per sq m, where over 50 per cent of pods were marketable. The percentage of pods, which were

marketable, was reduced at low plant density. When stopping was employed, optimal populations were found to be about fourteen plants per sq m. Small modifications may be required for other genotypes, with respect to earliness and growth habit. One method of stopping plants caused significant yield reductions but best methods returned small increases in seed size and marketable yield.

The project found little effect on yield and quality due to sowing over a relatively narrow range of treatment times and it was concluded that preferred sowing time should be targeted primarily to production locality and market window.

A practical test of mechanical harvesting of pods with a green *(Phaseolus)* bean harvester was unsuccessful and harvesting by hand is recommended until machinery currently commercially available can be suitably modified.

Introduction

Plans for the Australian vegetable industry, reviewed in 1997, reinforced the importance of identification of new overseas markets, which offer opportunities for strategic development and of the development of products, which suit these markets. Recent years have seen Tasmania expand its supply to export vegetable markets, as have other Australian production regions. Attempts to strategically develop new export markets and products have been integral in this expansion. In the 1990s, export market managers of locally-based supply companies identified the supply of large-seeded broad beans (soromame), either in pod or as a minimally prepared fresh product, as a speciality, into Japanese markets as one such opportunity.

At the time of year when Australia could supply this commodity from temperate climates in southern latitudes, prices in Japan usually were high due to low seasonal supply. This represented a market opportunity and the market window was thus well defined. While the annual harvest in Japan is about 7,000 tonnes, Tokyo markets alone sell about 2,000 tonnes per month during the major sales months of April, May and June and about 100 tonnes per month in the Australian window in November, December and January. With the assumptions that a further 50 per cent of sales could be achieved in other major Japanese markets and that 50 per cent of demand could be serviced from Australia during this market window, the market potential at that time was considered to be in the order of 225 tonnes of product at a price of approximately $10 per kg cf. This suggested a market value of about $2.2 million per annum for Australian industry. Size of the individual beans, the quality of pods and beans and maturity were of critical importance to buyers and to the viability of production for export.

Additionally, although specific market information had not been collected, industry personnel believed that a quality, fresh-prepared product might be capable of being re-positioned in the Australian market place with increased sales. Current sales of fresh broad beans in-pod in New South Wales, Victorian and Tasmanian supermarkets are in the order of 20 tonnes per month.

In 1993, Vecon Pty, a privately-owned vegetable packing and exporting company in northern Tasmania, introduced a broad bean cultivar, named Jumbo, from Japan and grew small quantities for evaluation. Little progress was made until 1996, when interest was renewed within this company (under new ownership), a second vegetable packing and exporting company, staff of the Tasmanian Department of Primary Industries, Water and Environment (DPIWE) and the recently formed Tasmanian Institute of Agricultural Research (TIAR). The work reported here was then proposed and supported by the industry.

The species *Vicia faba* exhibits a wide range in seed size and type, and is adapted to cool temperate through to mediterranean climates. It also exhibits a wide range of growth and flowering habit and yield. These factors vary both with genotype and with the level of inter-generational hybridity, which, in turn, is influenced by bee activity, temperature and humidity and causes unpredictability of pod set (Bond, 1983; Bond and Kirby, 1999).

Research on the crop has majorly concentrated on production of dry grain product for both stock feed and human consumption (Laurence, 1979). While among unimproved genotypes, large-seeded types (broad beans) are often the highest yielding, small to medium sized seed cultivars (faba beans) are used extensively in mechanised production systems. An Australian national faba bean breeding program has been established for several years in South Australia and, at the time of commencement of this project, was principally seeking improved disease resistance.

Some faba beans are grown in Tasmania for stock feed sales or as green manure and broad beans are grown currently for freezing by vegetable processors for human consumption. The latter industry employs mechanical harvesting of the green beans only. Consequently, cultivars grown for these purposes are not of the largest seed size and are regarded as too small for the Japanese fresh export market. Introduction of suitable genotypes and selection through this project were considered necessary for this Japanese export market.

While broad beans for processing have been grown in cool temperate Australia for several years, there is little reported work in areas other than viral and fungal diseases of crops for the processing sector (Williams, 1976). However, in the late 1980's, when broad beans were processed for human consumption by canning as well as freezing, the then Tasmanian Department of Agriculture collaborated with local companies to select white flowered/white hilum lines, since lines with a dark hilum or excessive seed coat pigment discolour canning fluids. The work was successful in producing two locally adapted lines.

The principal aim of the work reported here, therefore, was to select improved lines of vegetable broad beans suitable for production in southern Australia and export to the Japanese fresh market and to provide data to support recommendations on production methods for this purpose. Agronomic work in this project to assist production recommendations concentrated on investigating the effects of sowing density on yield and quality. This was considered important to ensure the optimisation of marketable product and use of seed, for which associated costs are high. Definition of maturity and the value of top-pruning plants ("stopping") were also investigated, with the aim of assisting the continuity of supply of product to maturity specification. A simple test of harvesting using a machine, which was available locally, was also completed.

This project's activities, therefore, are reported under the following headings: -

- accession, maintenance and selection of lines

- agronomic investigations
    - sowing density and "stopping"
    - sowing time
    - seed maturity and harvest timing
    - harvesting methods

and the methods used and results gained in these areas of activity, together with relevant discussion, are reported here under these titles.

Industry involvement and research collaboration

Players in the Tasmanian vegetable industry had considered the production of fresh broad beans for local and export markets prior to the inception of this project. The then fresh vegetable packer and exporter, Vecon Pty Ltd, had introduced one cultivar from Japan and grown small quantities, before shelving its interest. Two local vegetable growers, Mr. Mike Badcock and Mr. Don Badcock had also shown interest at that time, had grown the crop and tested small quantities in the Japanese market. Mr. Neil Armstrong, Managing Director of Harvest Moon Pty Ltd, another Tasmanian fresh vegetable grower, packer and exporter saw market potential in the product and was supportive of the project. The three latter persons, together with Mr. Joe Gayton of Vecon Pty Ltd and Mr. Peter Simmul of the Tasmanian Department of Primary Industry, Water and Environment were consulted regularly on the directions of this research project and consequent results were discussed. The group met formally, as a reference group, on an annual basis after seasonal outputs and also informally through each season.

Research collaboration was pursued with Dr Jeff Paull, a faba bean breeder at the University of Adelaide, to whom the author is grateful for the provision of material. Contact was also made, through Dr Paull, with Dr Larry Robertson, ICARDA, Aleppo, Syria, with respect to origin and ownership of a broad bean line (1142).

Dr John Burgmans, who had worked with Japanese cultivars of broad bean (soromame) in New Zealand, was contracted to assist in selection of lines and visited Tasmania for this purpose in December 1998. Dr Burgmans also provided four cultivars of Japanese origin to this project after this time. Dr Burgmans' report on his consultancy accompanies this report (Appendix A).

Accession, maintenance and selection of lines

Materials and Methods

With the prospect of gaining funding support for this work, contacts were made in 1996 and 1997 in order to access lines of *Vicia faba* with the desired pod and seed characteristics. Accessions were acquired (Table 1) from Dr Jeff Paull at the National Faba Bean Breeding Program at the Department of Agronomy and Farming Systems, University of Adelaide Waite Campus between 1996 and 1998. At that time this program concentrated on disease resistance in field (small-seeded) faba beans but held some genetic material of interest to this project. Lines were also acquired locally from growers and researchers and Dr J Burgmans' consultancy role resulted in four lines being acquired early in 1999.

Table 1. Broad bean accessions acquired in the project

Accession	Provider	Origin	Month acquired
517	Dr J Paull, Adelaide	Syria	September 1996
820	Dr J Paull, Adelaide	Portugal	September 1996
941	Dr J Paull, Adelaide	Cyprus	September 1996
980	Dr J Paull, Adelaide	Greece	September 1996
1036	Dr J Paull, Adelaide	Naxos	September 1996
Jumbo	Field Fresh Tasmania	Japan	June 1997
B16	DPIWE	Unknown	June 1997
890	Dr J Paull, Adelaide	ICARDA	July 1997
749	Dr J Paull, Adelaide	ICARDA	July 1997
1142	Dr J Paull, Adelaide	ICARDA	July 1997
741	Dr J Paull, Adelaide	ICARDA	July 1997
1140/3	Dr J Paull, Adelaide	ICARDA	July 1997
1065	Dr J Paull, Adelaide	ICARDA	July 1997
1093	Dr J Paull, Adelaide	ICARDA	July 1997
1141	Dr J Paull, Adelaide	ICARDA	July 1997
892	Dr J Paull, Adelaide	ICARDA	July 1997
ex Badcock	Don Badcock	Japan	October 1997
Imported	P Simmul, DPIWE	Japan	December 1997
Aquadulce	G Dean, DPIWE	Unknown	May 1998
974	G Dean, DPIWE	Unknown	May 1998
1FR	Dr J Burgmans	Japan	January 1999
2FB	Dr J Burgmans	Japan	January 1999
3FB	Dr J Burgmans	Japan	January 1999
4FB	Dr J Burgmans	Japan	January 1999

In season 1996-7, five lines, which had been received from Dr Paull in 1996, underwent preliminary screening. As *Vicia faba* flowers can be cross-pollinated by bees, genetic integrity of the lines was maintained by planting within an insect-proof

cage. The line 980 was considered worthy of further assessment but others were considered to have too small a seed size for re-selection. However, the line 517 exhibited a green seed (testa) colour and was retained for this reason.

In season 1997-98, ten further lines from Dr Paull were received and, together with line 980 and two local acquisitions (B16 and Jumbo), a total of 13 lines were planted at Forthside Vegetable Research Station, North West Tasmania in small, unreplicated plots on 11 August 1997, principally for seed multiplication. An insect-proof cage was again used. These lines were:- 980, B16, 749, 890, 1065, 1140/3, 741, 1142, 517, 892, 1141, 1093 and Jumbo. These lines were harvested in February 1998.

In season 1998-99, these accessions, together with the line, "Imported" (of Japanese origin and received after quarantine in Kingston Quarantine Centre, Hobart) and three other lines, which became available locally (ex Badcock, Accn 974 and Aquadulce), were compared in field plots at Forthside Research Station. Thus, the total number of lines sown in season 1998-99 was 17 (Table 2).

Table 2. Accessions and selections sown for evaluation in season 1998-99.

Jumbo	ex Badcock
1142	Imported
1141	1093
1140/3	892
1065	890
980	517
749	B16
741	974
Aquadulce	

These accessions were replicated twice in a randomised block design. Plots, 1.6m long by 1.2m wide, were sown by hand on 2 June 1998 after 250 kg/ha of 13.15.13 mixed fertiliser had been pre-drilled uniformly into the trial area. Seeds were placed at 150mm intervals within single rows, each 300mm apart, giving a sowing density of 22 seeds/sq m. Plots were hand-weeded, irrigated to field capacity when a evaporative deficit of 35mm had been accumulated and mancozeb was sprayed when required to control major leaf diseases.

Flowering dates were noted and pod length, seed length and seed fresh weight were determined on sub-samples of eight plants per plot at a once-over harvest, which was carried out when the hilum of a seed was first seen to darken in colour.

Re-selection of lines from these plots was undertaken on 8 December 1998 by Dr John Burgmans, a consultant from New Zealand who had previously worked with soromame for Japan, Mr. Joe Gayton, Japanese market specialist for Field Fresh Tasmania, Mr. Neil Armstrong, Managing Director of Harvest Moon Pty, Mr. Don Badcock, a grower with previous experience of the market in question, Mr. Peter Simmul from DPIWE and the Chief Investigator, Dr Rowland Laurence. Funds for Dr Burgmans' visit were successfully sought from the Tasmanian Institute of Agricultural Research (the Research Agency)'s Visiting Scientist Program.

The critical pod and seed attributes, which were suggested by buyers and used as the basis for selection were:- uniformly straight pods, a predominance of three seeds per pod and bean size as large as possible. A bean length of 30 mm or more was used as a practical guide and while regularly achieved, was not rigorously imposed.

In addition to the above comparative assessment, seed of each accession was sown in a small isolated field plot on Forthside Research Station, on the University Farm near Burnie in Northwest Tasmania or on collaborator's farms, in order to maintain the genetic integrity of these genotypes. Between 20 and 100 seeds of each line were sown depending on availability and a minimum isolation distance of 300m between plots was used to reduce potential pollinating bee activity to acceptably low levels (Bond, 1983).

In season 1999-2000, seed of the re-selected lines (Jumbo, Imported, B16 and 1142, *see below*), together with four additional lines (1FR, 2FB, 3FB and 4FB) was multiplied in isolated field plots as described above for the previous year. These plots were sown at Forthside Research Station and the University Farm, Burnie, between 2 July and 16 July 1999. These multiplications provided 23 kg of Jumbo seed, 5 kg of Imported, 3 kg of B16, and 20 kg of 1142, while plots of the four additional lines above returned seed quantities ranging between 0.2 kg (1FR) and 2 kg.

In season 2000-01, these accessions, with the exception of 1FR (of which insufficient seed was available), were again compared in a replicated field trial of randomised block design at Forthside Research Station. Three replicates of plots 5m long and 1.2 m wide, and consisting of four rows of seeds, were planted by hand on 10 July 2000 to an overall density of 15 seeds/sq m. 250 kg/ha of 13.15.13 mixed fertiliser was again pre-drilled uniformly into the trial area and plots hand-weeded and irrigated to field capacity when an evaporative deficit of 35mm had been accumulated. Mancozeb was sprayed when required to control major leaf diseases. Pods were picked by hand from net plots of 4 m long by 2 rows wide when seed samples showed first signs of hilum darkening. Five harvests were made between 4 December and 14 December 2000. The fresh weights of all pods and marketable pods (as judged by previous criteria) were recorded and the fresh weights and lengths of seed from sub-samples of 30 pods were also recorded for each plot. Analyses of variance were carried out on these data.

Seed of the above eight accessions was also sown in separate isolation plots for multiplication as previously described.

In season 2001-02, the final season for work on this project, activity with regard to development of accessions, was restricted to further bulking of those lines re-selected by the industry reference group at their meeting of 23 May 2001. These were Imported, 3FB, 1142 and Jumbo. These were thence planted in isolation plots at the University Farm in Burnie in June 2001.

Tests of market acceptance

The cultivar Jumbo, as earlier described, was introduced by Vecon Pty and a small area was grown in seasons 1997-98 and 1998-99 by this company, with support from

staff of the Tasmanian Department of Primary Industries, Water and Environment. Small box samples were sent to Japanese buyers by the company and, with the exception of a problem with incorrect maturity, referred to elsewhere in this report, were judged to be acceptable to the market. The line 3FB was said by Dr Burgmans, who provided it to the project, to be a cultivar of Japanese origin and was therefore assumed to be acceptable in that marketplace. Lack of quantity of this product also limited testing during the time of this project. The lines 1142 and Imported, however, were tested in the marketplace by sending small box samples from isolation plots grown in 2001-02 to Japan. Samples of whole pods (4kg approx.), selected according to the "marketable" criteria previously described, were picked on 9 January 2002 and sent by airfreight via JM Segall and Company Limited, Sydney to Tomei Fruits Company Limited, Tokyo, for appraisal. Advice was received on 21 February 2002 (Appendix B) that both lines were suitable for the Japanese market.

This advice (Appendix 2) also indicated that prices of the product in Japan had collapsed during the targeted window in November 2001, confirming information provided by Field Fresh Tasmania.

Results

Season 1998-99

The measured parameters of accessions compared in the 1998-99 field trial are summarised in Table 3.

All lines grew well during the 1998-99 season. Flowering of the earliest accession, 1093, commenced on 8 September and that of the latest accession on 27 September. Mild infections of lines with botrytis and ascochyta were evident during later growth, with least infection on the line Imported. Infection of all lines with bean rust also occurred and, although being reduced by fungicide application, became severe towards maturity.

The group re-selected Jumbo, Imported, B16 and 1142 on the characteristics previously listed. Less agreement was reached on the importance in the market place of other attributes, such as seed colour and shape. These re-selections were in agreement with the data in Table 3, except with regard to the line 1065, which exhibited a large number of misshapen pods but was otherwise seen as a suitable genotype.

Season 2000-01

The measured parameters for accessions compared in the 2000-01 field trial are summarised in Table 4.

The industry reference group considered these data at their meeting of 23 May 2001 and agreed that the accessions Imported, 3FB, 1142 and Jumbo (already in use in small commercial plantings) were worthy of further bulking of seed for commercial trials.

Table 3. Flowering dates, mean pod lengths, seeds per pod, seed lengths and seed fresh weights of accessions compared in 1998-99 field trial.

Accession	Days to first flower	Days to 50% flower	Mean pod length (mm)	Mean no. seeds per pod	Mean seed length (mm)	Mean seed fresh weight (g)
Jumbo	108	118	175	3.0	28.3	4.13
1142	104	108	174	2.8	34.5	5.41
1141	104	108	150	2.1	31.8	5.00
1140/3	100	106	165	2.8	27.7	3.36
1065	104	108	156	3.0	30.4	3.87
980	106	110	143	2.4	31.1	4.05
749	104	108	123	2.0	30.0	4.12
741	108	111	235	4.3	27.1	2.67
Aquadulce	115	118	168	4.8	24.5	2.45
ex Badcock	108	111	198	5.3	28.6	1.14
Imported	108	118	175	3.2	28.5	4.08
1093	98	106	146	2.8	26.4	2.82
892	104	108	150	4.0	21.6	1.75
890	106	110	223	3.8	28.7	3.63
517	106	110	150	2.9	25.2	3.09
B16	108	118	165	2.8	30.0	4.77
Accn 974	117	121	110	2.9	20.9	1.70
P sig	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01
lsd for level	6.1	6.3	64.7	1.59	3.32	1.38

Table 4. Total fresh weight of pods, fresh weight of marketable pods, mean number of seeds per pod, mean seed length and fresh weight of seed from marketable pods of accessions compared in the 2000-01 field trial.

Accession	Total pod fresh weight (t/ha)	Marketable pod fresh weight (t/ha)	Mean no. of seeds per pod	Mean seed length from marketable pods (mm)	Seed fresh weight from marketable pods (t/ha)
Imported	36.4	21.1	3.48	28.5	7.3
2FB	32.5	17.8	3.31	29.0	5.6
3FB	33.3	20.2	3.24	29.5	6.5
4FB	29.7	5.9	3.02	31.6	2.2
B16	31.5	17.2	3.36	28.6	5.5
1142	42.8	19.8	3.32	34.2	8.6
Jumbo	33.7	20.0	3.45	28.9	6.6
P sig	<0.01	<0.01	ns	<0.01	<0.01
lsd for level	6.65	3.78		1.30	1.52

Discussion

The wide range in values of the parameters measured is consistent with the great variation in plant habit expressed by the species *Vicia faba*. While many lines, including those thought to originate in Japan (e.g. Jumbo, Imported and 3FB), were similar in terms of habit, earliness and pod characteristics, the line 1142 (probably of Middle eastern origin) exhibited a more determinate growth habit, a larger seed size and greater earliness to flowering and maturity. These characteristics, in combination with the line's high yield and acceptability to Japanese buyers, indicate that this project has been successful in improving these market place quality parameters. The results of this aspect of the work confirm that total pod yields, mean seed number per pod and mean seed length (size) are heritable characteristics. However, the straightness and overall uniformity of pod shape may well have both genotypic and phenotypic influences. As the high proportion of misshapen pods in line 1065 in comparison to other genotypes led to its rejection in this project, some genetic influence on this parameter is suggested. However, it is also possible that poor weather, and thence pollination conditions, may result in misshapen and blemished pods.

Ownership of selected lines

Milestones attached to the extension of the project in 1999-2000 intended that commercialization of selected lines would be investigated through defining their ownership and negotiating a commercialization process, such as a 'closed loop', with interested industry stakeholders. Preliminary investigation of ownership was pursued for 1142. This line was found to be held in trust by ICARDA (Appendix C). Dr Paull indicated that, with this arrangement, no difficulty would exist with public release of this ICARDA derived germplasm but that ownership of the unmodified line would be restricted. Commercial production could progress through some form of 'closed loop' process and would not as such be restricted.

The issue of a prospective commercialization process was discussed with industry stakeholders. While the four selections appealed to these stakeholders, the reference group (of which major prospective stakeholders were part) saw no value in pursuing the issue until sufficient stakeholders' market testing of selected lines had been completed. The collapse of prices in the 2001-02 season, referred to above, has resulted in a loss of industry interest in any commercialization process at the time of writing this report.

Agronomic investigations

1. Sowing density and "stopping"

An investigation into the effects of sowing density on yield and quality was considered important to ensure the optimization of marketable product and use of seed, as costs associated with these large seeds are high. One field experiment was carried out to investigate the effect of sowing rate/plant density on yield and quality of unstopped plants in 1999-2000.

After discussions with the industry reference group in June 2000 led to the consideration that the practice of stopping plants might assist harvesting, seed size and might also be combined commercially with sequential sowings, an experiment investigating the effects of stopping was carried out in the following season (2000-01). A further field experiment attempted to verify the findings of these two trials in the following year (2001-02) and also investigated possible interaction between the treatments.

Materials and Methods

The effect plant density on pod and seed yield and quality parameters (1999-2000).

The cultivar Jumbo was sown by hand in a field experiment at Forthside Research Station, Northwest Tasmania on 2 July 1999, following pasture. The krasnozem soil had a topsoil (0-10 cm) pH value of 6.3 and 300 kg/ha of 13:14:13 mixed fertiliser with trace elements were pre-drilled prior to sowing. Five density treatments (2, 4, 9, 15 and 30 seeds/sq m) were compared using three replicates of a randomized block design. Plots were 10m long by four seed rows wide and single seeds were placed orthogonally to provide equidistant spacing between plants both within and between rows (709mm, 500mm, 333mm, 258mm and 185mm respectively for the above density treatments). Weeds were controlled with a pre-emergent contact herbicide, followed by hand weeding and applications of mancozeb were made when required for control of major leaf disease. The trial was irrigated when required to replace a 35mm soil moisture deficit. Dates of first flower were noted and plants in buffer rows were monitored for pod and seed maturity. A first harvest of full-sized pods (using a subjective assessment) was made at the first sign of seed hilum darkening (10 December 1999) and a second harvest of remaining pods was completed one week later (17 December 1999). Actual plant numbers were recorded. Pods were separated into marketable (straight, three-seeded and blemish-free) and un-marketable. Seed from marketable pods was separated into marketable and un-marketable seeds, based on seed length being greater or less than 30mm (chosen subjectively as a guide to market place acceptability, while acknowledging the probable influence of supply and demand on this value). The actual lengths of seeds above 30mm were also recorded.

The effect of stopping (top-pruning) plants on pod and seed yield and quality parameters (2000-01).

Three stopping treatments were applied to two cultivars, Jumbo and 1142, in a factorially designed field trial, which was sown at Forthside Research Station on 10 July 2000. These lines were selected for the trial as they appeared to be most promising at that time and and adequate seed reserves were available. Sowing was carried out by hand into a krasnozem soil of pH 6.5 after pre-drilling 500kg/ha of 7:12:9:6 mixed fertiliser into double rows, 50mm apart with a Fiona drill, with the seed subsequently placed in single rows 30mm apart, between the fertiliser rows. Seeds were sown to a population density of 15/sqm. Plots were each 5m long and 1.2m wide and were weeded, irrigated and sprayed for disease as were trials previously described. The three stopping treatments were (1) nil, (2) removal of plant growing apices when six nodes on main stems bore fully-opened flowers and (3) removal of plant apices when first growth of fertilised pods was visible on the two lowest, pod-bearing nodes. Plant height in both cultivars was approximately 1m at this time and 100-150mm of apical growth was removed with horizontal sweeps of a hand-held, mechanical hedge trimmer, with the intention of reflecting an operation with could be commercially reproduced with tractor-driven equipment. Removal of plant growing apices when six nodes on main stems bore fully-opened flowers (Treatment 2) was carried out 105 days after sowing for line 1142 and 116 days after sowing for cultivar Jumbo. Removal of plant apices when first growth of fertilised pods was visible (Treatment 3) was carried out 116 and 125 days after sowing respectively for the two cultivars. Sequential hand-harvesting began on 29 November 2000 for line 1142 and eight days later for cultivar Jumbo, when first hilum darkening was seen to occur. The total fresh weight of pods, fresh weight of marketable pods, the mean seed number per marketable pod, the fresh weight of seeds from sub-samples of 30 marketable pods and the mean length of seed from these sub-samples of marketable pods were recorded and analyses of variance carried out on these data.

The effect of plant density and stopping plants on pod and seed yield and quality parameters (2001-02).

The industry reference group maintained an interest in the practical application of stopping plants in a commercial operation and, as the sowing density/plant population experiment carried out in 1999-2000 only investigated the effects of treatments on unstopped plants, it was considered that the effects of treatments on stopped plants should also be investigated.

A field trial was carried out, therefore, to compare the effects of those sowing density treatments used in the previous experiment on the pod and seed yield and quality parameters of stopped and unstopped plants of the cultivar Jumbo. Stopping at the six flowering nodes stage was employed only. The experiment thus consisted of five sowing density treatments (2, 4, 9, 15 and 30 seeds/sq m) in main plots and two stopping treatments (nil and top pruning at the six flowering nodes stage) as sub plots in a split plot, randomised block design with three replicates. The trial was planted by hand at Forthside Research Station on 18 June 2001. Gross plots consisted of four single plant rows, each 400mm apart and 10m long (main plots). Mixed fertiliser (7:12:9:6) was mechanically applied before planting in two bands, adjacent to the seed positions, at 566 kg/ha before planting. Weed and disease control and irrigation

were similar to previously described trials, as was the application of the single stopping treatment. Net sub-plots of two rows, each 4m long were harvested when dry matter (80°C to constant weight (24h)) of seed samples reached 20 per cent, this determinant being used as a result of maturity assessment work carried out in seasons 1999-00 and 2000-01(see below). The first of four sequential harvests began on 4 December 2001 and these were completed on 14 December 2001. Plant densities at harvest, the total fresh yield and number of pods, the fresh yield and number of marketable pods, the total fresh yield and number of seeds and the fresh yield and number of marketable seeds were recorded per net plot and analyses of variance carried out on these data. Marketable pods were taken to be those over 150mm in length, which were uniformly straight and predominantly three-seeded. Marketable seed was considered to be that which was blemish-free and over 32mm in length.

Results

The effect plant density on yield and quality of unstopped plants (1999-2000).

Seed germination was high and plant densities achieved were close to those intended in all but the highest density treatment where plant competition was severe. Plants of all treatments exhibited first flowers on 21 September 1999, 81 days after planting. This was considerably less than the same cultivar, Jumbo, planted one month earlier in the previous season. The effects of treatments on pod and seed yield and quality parameters are shown in Tables 5 and 6 respectively.

Table 5. The influence of sowing density on pod yield and quality of cultivar Jumbo 1998-99.

Seed density / sq m	Plant density / sq m	Total pod number / sq m	Total pod yield (t/ha)	Marketable pod number / sq m	Marketable pod yield (t/ha)
2	1.93	26.3	8.2	4.5	1.90
4	3.67	31.4	9.3	5.9	2.52
9	8.31	72.1	27.5	18.4	9.55
15	13.44	71.1	26.3	15.9	8.09
30	25.46	128.2	46.0	23.0	12.21
F.prob	<0.001	<0.001	<0.001	<0.01	<0.01
lsd 0.01				12.9	6.59
lsd 0.001	2.62	60.9	24.4	-	-

Table 6. The influence of sowing density on seed yield parameters of cultivar Jumbo 1998-99.

Nominal plant density / sq m	Actual plant density / sq m	Number of mark'ble seed / sq m	Yield of mark'ble seed (t/ha)	Mean length of mark'ble seed (mm)	Number of unm'ble seed / sq m	Yield of unm'ble seed (t/ha)
2	1.93	4.7	0.26	33.0	66.9	2.03
4	3.67	6.7	0.36	31.8	80.0	2.17
9	8.31	59.8	3.60	33.9	145.6	4.05
15	13.44	58.0	3.48	34.0	155.3	3.85
30	25.46	87.2	5.26	34.0	301.8	7.44
F.prob	<0.001	<0.01	<0.01	ns	<0.001	<0.001
lsd 0.01		48.5	3.06			
lsd0.001	2.62				151.8	4.05

Plants in low density treatments tillered profusely, resulting in many small unmarketable pods. The highest plant density treatment (30 seeds/sq m) returned the highest total and marketable pod numbers and yields but increases above 9 and 15 seeds/sq m were not significant at the levels shown.

Similar effects were found with regard to total and marketable yields and numbers of seed. Low density treatments produced few marketable seeds and the highest plant density treatment returned highest numbers and yields of marketable seeds. However, increases above the 9 and 15 seeds/sq m treatments again were not statistically significant at the levels shown. The data indicated that sowing densities which result in plant populations of about 12 plants /sq m are optimal when orthogonal spacing of seed is used. Higher sowing rates are likely to incur high sowing costs.

Nominal increases in the mean length of marketable seeds with increasing plant density were statistically insignificant. The numbers and yields of unmarketable seeds were high in all treatments, which probably reflected the rigorous imposition of the nominated 32mm seed length value for distinction between these categories. While this was necessary for a numerical evaluation of marketability, the distinction imposed may have been excessively severe from a market standpoint.

The effect of stopping (top-pruning) plants on pod and seed yield and quality parameters (2000-01).

The high total pod yield of line 1142, when compared with cultivar Jumbo, was again evident in this experiment but was not reflected in the yield of marketable pods. The difference in seed size between the two genotypes was also re-affirmed.

Both stopping treatments reduced total and marketable pod yield (Tables 7 and 8) but the six-flowering node stopping treatment was less severe than the alternative

treatment tested. The yield of marketable pods and of seed from these marketable pods reflected the same treatment effect. Differences between these treatments in the number of seeds per pod showed the same trend also but were not large enough to reach statistical significance.

Table 7. The effects of stopping treatments on pod and seed yield and quality parameters of cultivar Jumbo and line 1142 in season 2000-01.

Treatment	Total pod fresh weight (t/ha)	Marketable pod fresh weight (t/ha)	Mean number of seed / marketable pod	Seed from marketable pods (t/ha)	Mean length of seeds from marketable pods (mm)
Cultivar					
Jumbo	30.18	16.54	3.37	5.35	30.75
1142	33.59	13.84	3.30	6.03	32.54
F prob	<0.01	<0.05	ns	ns	<0.001
lsd for level	3.34	2.33			1.03
Stopping					
Nil	38.01	18.53	3.46	6.72	31.20
Two pods	24.85	11.52	3.24	4.54	31.80
Six fl. nodes	32.78	15.53	3.30	5.79	31.94
F.prob	<0.001	<0.01	ns	<0.05	<0.05
lsd for level	5.92	4.05		1.42	0.61
Interaction	see Table 8	ns	ns	ns	ns

Table 8. Values of total pod fresh weight (t/ha) for the cultivar Jumbo and the line 1142 after different stopping treatments.

	Stopping treatment		
Cultivar	Nil	Two pods	Six fl. nodes
Jumbo	34.00	25.13	31.39
1142	42.02	24.58	34.16
	F prob <0.05	**lsd for level** 4.07	

Both stopping treatments increased the mean length of the seeds in marketable pods. A differential effect of stopping treatments between the two cultivars was only found in total pod weight, where Jumbo was more affected than 1142 by the earlier applied stopping treatment (six flowering nodes). This effect is consistent with the earlier maturity of 1142, found in other experiments.

The effect of plant density and stopping treatments on pod and seed yield and quality parameters (2001-02).

Twenty-eight days after sowing, plant emergence in all plots was above 98 per cent of the target densities. First flowers opened in lowest treatment density plots on 25 September 2001, 98 days from sowing, followed by first flowers in highest density treatments one or two days later. Plant densities at harvest and other yield data are shown in Tables 9 - 14.

While total and marketable pod numbers and yields increased to maximum values at plant populations of about 12 plants /sq m, which were similar to those found in the previous experiment two years before, interactive effects of the two treatments on these parameters were found. In the case of total pod yield, this interaction reached statistical significance (Table 10) and showed that the maximum total pod yield per hectare of stopped plants was greater than that of unstopped plants but that this maximum occurred at a higher plant population than that required when plants were not stopped.

The number of marketable pods was reduced significantly by the stopping treatment but the yield of marketable pods was not significantly changed. These results, in addition to the numerical, but not statistically significant, increase in total pod number returned by the stopping treatment, are consistent with earlier experimental results in indicating that stopped plants provide fewer, but larger, pods (and seeds) than unstopped plants.

Table 9. The influence of sowing density and stopping on harvested plant density and pod yield parameters of the cultivar Jumbo in 2001-02.

Seed density / sq m	Plant density / sq m	Total pod number / sq m	Total pod Yield (t/ha)	Marketable pod number / sq m	Marketable pod yield (t/ha)
2	1.88	37.70	16.67	14.59	7.35
4	4.06	42.20	17.89	14.07	7.01
9	8.98	61.30	26.82	23.44	12.00
15	15.05	65.90	28.78	24.69	12.15
30	28.13	56.55	22.78	13.96	6.61
F.prob	<0.001	<0.05	ns	<0.05	<0.01
lsd for level	10.50	23.73		7.12	4.97
Stopping					
Nil	11.52	50.74	21.60	19.98	9.69
Six fl. nodes	11.72	54.72	23.57	16.32	8.36
F.prob	ns	ns	ns	<0.05	ns
lsd for level				3.26	
Interaction	ns	ns	see Table 10	ns	ns

Table 10. Values of total pod fresh yield (t/ha) for the five seed densities after two stopping treatments.

	Stopping treatment	
Seed density	Nil	Six fl. nodes
2	18.21	15.12
4	19.32	16.46
9	25.15	28.49
15	26.45	31.10
30	18.85	26.69
F prob <0.05	**lsd for level** 9.89	

The interactive effect between plant density and stopping treatment was statistically insignificant when marketable pod number and yield were considered. However, the statistically significant effect with regard to total pod yield described above suggests that marketable pod yields of stopped plants similar to those of unstopped plants may be achieved by increased plant density. In this experiment, the nominally highest marketable pod yield of unstopped plants (12.85 t/ha) was achieved with a seed density of nine seeds/sq m, while the next highest seed density treatment (15 seeds/sq m) was required to return the nominally highest marketable pod yield of stopped plants (12.13 t/ha).

Table 11. The influence of sowing density and stopping on seed yield parameters of the cultivar Jumbo in 2001-02.

Seed density / sq m	**Total seed number / sq m**	**Total seed yield (t/ha)**	**Marketable seed number / sq m**	**Marketable seed yield (t/ha)**
2	113.70	4.49	29.45	1.71
4	128.35	4.60	21.10	1.24
9	189.25	7.31	45.10	2.62
15	207.15	7.86	44.00	2.54
30	167.55	6.15	26.90	1.58
F.prob	<0.05	<0.05	<0.05	<0.05
lsd for level	69.90	2.62	15.20	0.91
Stopping				
Nil	154.06	5.97	19.46	1.12
Six fl. nodes	168.34	6.19	47.16	2.75
F.prob	ns	ns	<0.001	<0.001
lsd for level			7.36	0.45
Interaction	see Table 12	ns	see Table 13	see Table 14

Total seed numbers and total seed yields increased to maxima at a seed density of 15 seeds/sq m. Whilst nominal increases in these parameters were found to be due to the stopping treatment, these did not reach statistical significance (P<0.05). However, the interactive effect between seed density and stopping treatment was statistically significant (P<0.05) in the case of total seed number (Table 12). This again demonstrated that a higher total seed number was returned by stopped plants but at higher seed densities than those at which the maximum seed number occurred in unstopped plants.

Table 12. Values of total seed number /sq m for the five seed densities after two stopping treatments.

	Stopping treatment	
Seed density	Nil	Six fl. nodes
2	121.6	105.8
4	139.8	116.9
9	180.2	198.3
15	192.1	222.2
30	136.6	198.5
F prob <0.05	**lsd for level**	73.36

The numbers and yields of marketable seeds were low compared with previous experiments as, in this experiment, 32mm was taken as a minimum length for marketable seed. However, interactive effects similar to those described above were evident in these measured parameters and were highly statistically significant (P<0.001, Tables 13 and 14). These data support the earlier experiment's (2000-01) finding that stopping plants at the six-flowering node stage of growth produce higher numbers and yields of marketable seed but that an increased sowing density/plant population (from 12 up to 15 plants/sq m) was required to maximise these increases.

Table 13. Values of marketable seed number/sq m for the five seed densities after two stopping treatments.

	Stopping treatment	
Seed density	Nil	Six fl. nodes
2	22.90	36.00
4	13.00	29.20
9	24.80	65.40
15	21.80	66.20
30	14.80	39.00
F prob <0.05	**lsd for level**	17.82

Table 14. Values of marketable seed yield (t/ha) for the five seed densities (seeds/sq m) after two stopping treatments.

	Stopping treatment	
Seed density	Nil	Six fl. nodes
2	1.33	2.09
4	0.76	1.71
9	1.43	3.80
15	1.23	3.84
30	0.85	2.30
F prob <0.05	**lsd for level**	1.07

Discussion

These experiments have shown that the establishment of 10 –12 plants /sq m is likely to be adequate for optimum yields of both pods and seed of soromame from unstopped plants, if seed costs are also considered, although maximum yields result from higher sowing rates. Seed costs are likely to be high for such large seeded genotypes and may justify lower sowing rates. However, profuse tillering at low densities and consequent high numbers of small, unmarketable pods must be avoided. While only Jumbo was used in the experiments to determine optimal sowing density, it is likely that a small modification of this recommended seeding rate will be required for genotypes with different growth habit or maturation. For example, the more determinate habit and earlier maturation of the line 1142 may suggest the use of a slightly higher sowing rate.

The experiments have also shown that, while stopping plants can have detrimental yield effects, these effects can be minimal or insignificant (2001-02 season experimental result) if the procedure is well timed. Confirmatory work on this aspect would be worthwhile, given other reports of the effects of seasonal conditions on the determination of growth, on pod set and their likely interactive effects on stopping procedures (Lindner, 1989; Miccolis and Bianco, 1993). In addition, positive benefits can be gained in relation to numbers of marketable seed returned and, perhaps, yield if sowing rates are increased (from 12 to 14 viable seeds /sq m, for example, in the case of the cultivar Jumbo). Mean seed length may also be slightly but significantly improved by correct application of the stopping treatment. At similar plant densities of 15 plants/sq m, total pod yields were nominally slightly reduced in season 2000-01 by stopping plants at the six flowering node stage but were slightly improved in the following year's experiment by this treatment. As stopping plants can lead to easier harvesting by hand, and may facilitate machine harvesting (although a trial described later in this report was not successful) the practice is recommended.

2. Sowing time

The industry reference group considered that some information should be gained on the effects of sowing time on yield and the timing of the harvest period. At first, this was considered relevant to targeting the beginning of the Japanese market window in late November and, later, also to the ability of Australian growers to provide continuity of supply using the 'once-over' harvesting of stopped plants. With these objectives, a field experiment was carried out in the 2000-01 season to investigate the effect of a delayed sowing date on unstopped plants of the lines Jumbo and 1142. In 2001-02, two sowing times of stopped plants of the cultivar Jumbo were used in a simple test of a local mechanical harvester on stopped plants (described later in this report). While the mechanised harvesting attempt was unsuccessful, hand-harvested sub-plots were taken for further information on the time of sowing effect.

Materials and Methods

The effect of delayed sowing on unstopped plants of the lines Jumbo and 1142 (season 2000-01)

Seed of the lines Jumbo and 1142 was sown by hand at two times (on 10 July 2000 and on 31 July 2000) in a field trial of factorial design at Forthside Research Station. Three replicates of plots 5m long and 1.2 m wide were planted to an overall density of 15 seeds/sq m. 250 kg/ha of 13.15.13 mixed fertiliser was drilled before sowing and plots were hand-weeded and irrigated to field capacity when an evaporative deficit of 35mm had been accumulated. Mancozeb was sprayed when required to control major leaf diseases. First pods were picked by hand from net plots of 4 m long by 2 rows wide when seed samples showed first signs of hilum darkening. Sequential harvests were made between 4–24 December 2000, with pods assessed subjectively for length over 170mm. The fresh weights of all pods and marketable pods (as judged by previous criteria) were recorded and the fresh weights and lengths of seed from sub-samples of 30 pods from each plot were also recorded. Analyses of variance were carried out on these data.

The effect of delayed sowing on the yield of stopped plants of the cultivar Jumbo (2001-02).

Seed of the cultivar Jumbo was sown on 18 June and 9 July 2001 by hand into single rows, each 800mm apart, at Forthside Research Station. This configuration was used to accommodate the test of a mechanical harvester as later described. Seeds were sown at an overall density of 8 per sq m after 544 kg/ha of 7:12:9:6 mixed fertiliser had been placed in three adjacent bands. One plot only, 36m long by 6.4m wide was sown at each of the above times and weed and disease control and irrigation were carried out as in field trials previously described. Plants were stopped at the 'six-flowering node stage', when six nodes on main stems bore fully-opened flowers, which occurred on 15 October 2001 for the first-sown plot and 23 October 2001 for the second. Two sub-plots, each of 2 rows by 5m long (equivalent to an area of 4 sq m) of each sowing time treatment, were hand harvested on 11 December 2001 and 17 December 2001 respectively, when seed dry matter reached a level of 20 per cent. The

test of a mechanical harvester (see below) was also carried out at this time and total and marketable pod yields and marketable seed yields were recorded. As these data were acquired only from duplicate sample areas within single, unreplicated treatment plots, analysis of variance was not carried out.

Results

The effect of delayed sowing on unstopped plants of the lines Jumbo and 1142 (season 2000-01)

The results of this experiment showed that delayed sowing tended to return increased total pod yields of both cultivars but the difference in these means over both cultivars did not approach statistical significance. Similarly, there was little effect on marketable pod yields, mean seed length or on the seed fresh weight from marketable pods (Table 15). When the results with the cultivar Jumbo are considered alone, however, the increased total pod yield with delayed sowing was close to statistical significance (P=0.05). The experimental data again demonstrated the difference in mean seed length between the two lines (P<0.001). The trend towards an interactive effect of delayed sowing on the mean seed size of the two cultivars, again, was nearly statistically significant (P=0.05).

Table 15. Total fresh weight of pods, fresh weight of marketable pods, mean number of seeds per pod, mean seed length and fresh weight of seed from marketable pods of the accessions 1142 and Jumbo sown at two times in the 2000-01 field trial.

Accession	**1142**		**Jumbo**		**F prob**	**lsd for level**
Sowing time	10 Jul	31 Jul	10 Jul	31 Jul		
Total pod fresh weight (t/ha)	42.8	44.0	33.7	44.9	ns	
Marketable pod fresh wt (t/ha)	19.8	21.8	20.0	22.8	ns	
Mean no. of seeds per pod	3.32	3.31	3.45	3.30	ns	
Mean seed length from marketable pods (mm)	34.18	32.71	28.91	30.03	Cv means only	
	Cv mean 33.45		Cv mean 29.47		P<0.001	1.69
Seed fresh weight from marketable pods (t/ha)	8.59	9.17	6.59	7.69	ns	

The effect of delayed sowing on the yield of stopped plants of the cultivar Jumbo (2001-02).

As noted above, analysis of variance was not carried out and data are presented as means of duplicate readings only (Table 16).

While delayed sowing tended to return an increased total pod yield of unstopped plants of cultivar Jumbo in 2000-01 and the trend was evident through other measured

parameters of the cultivar Jumbo, little effect was seen in the mean yield values returned from stopped plants in 2001-02.

Table 16. Days to first flower and harvest, mean total pod yields, marketable pod yields and marketable seed yields of duplicate sample areas from two plots of stopped plants, cultivar Jumbo, sown at two times in season 2001-02.

Sowing date	Days to first flower	Days to harvest	Total pod yield (t/ha)	Marketable pod yield (t/ha)	Marketable seed yield (t/ha)
18 June	97	176	38.96	11.05	4.89
9 July	94	161	36.97	12.47	3.65

Discussion

While a wide range of sowing time was not investigated in this work, the results gained show consistently that there is no detrimental effect of delaying sowing to the yields of unstopped plants within the times considered. While results from 2000-01 suggest there may indeed be some positive influence of delayed sowing on total yields of pods, the meaned values gained from the stopped plants used in the test conducted in 2001-02 do not support this conclusion. This latter result suggests that sowing delay may have a small negative effect on yield of stopped plants, this effect should be further investigated and a small increase in sowing density may be required for later crops.

The application of these results to a commercial practice of "once-over" harvest of sequentially sown crops of stopped plants suggests that crop yield projections will not need to be adjusted significantly for changes made in sowing time.

Seed maturity and harvest timing

In addition to work carried out in the current project, a local company, in collaboration with the Tasmanian Department of Primary Industries, Water and Environment, grew a plot of the cultivar Jumbo in season 1998-99 and sent pod samples to Japanese buyers for assessment. While buyers' responses deemed pod and bean size and shape to be acceptable, maturity was unacceptable, with a first trial consignment being immature and the second over-mature. A better understanding of this aspect of quality, was considered to be important to future success of the enterprise. Therefore, the industry reference group agreed to the conduct of pre-harvest growth analysis in seasons 1999-2000 and 2000-01 in order to attempt better definition and prediction of optimal seed maturity and harvest timing. The latter was defined as a point in bean development immediately prior to hilum darkening, such that maximum bean size is attained without the detraction of the change in hilum colour. The objective of this work was to better define changes in pod and seed maturity with time and with the position at which pods are borne on the plant, and to investigate whether changes in seed dry matter content could adequately be used as a predictor of optimal seed maturity. Both seasons' work was carried out on unstopped plants.

Materials and Methods

Season 1999-2000

In season 1999-2000, seed of the three lines, 1142, Jumbo and Imported was sown in single, unreplicated plots, each 10m long by 2.7m wide, 2 July 1999 at Forthside Research Station. Seed was sown to a density of nine seeds per sq m in orthogonal pattern (seeds and rows were both spaced 0.33m apart) after pre-drilling 300kg/ha of 13:14:13 mixed fertiliser and trace elements with a Fiona drill. Weed and disease control and irrigation were carried out as described in previous sections of this report.

Prior to the anticipated optimum maturity time, ten plants of each cultivar were selected at random from these plots and destructively harvested. Data was recorded on the number and fresh weight of pods at each node (numbered from the first pod-bearing node) and the number and fresh weight of seeds at each node (numbered from the first pod-bearing node). The mean length of the seeds at each node was calculated and a determination made of their dry matter content (80°C to constant weight (24h)). In addition, the proportion of seeds at each node showing a darkened hilum was recorded at final harvest. Five such destructive harvests were carried out at, approximately, weekly intervals, with the first occurring on 12 November 1999 (133 days after planting) and the last on 10 December 1999 (161 days after planting). Regression analyses were carried out on key parameters.

Season 2000-01

The two cultivars 1142 and Jumbo only were selected for pod and seed maturity investigations in 2000-01, as results elsewhere described in this report and gained in the previous year's growth analysis reflected variation between these lines in earliness. The line Imported, however, provided results very similar to those of Jumbo in the previous year's study and thus further investigation of this line's

development and maturity was not considered worthwhile. After consideration of the previous year's maturity study results, it was considered that a greater frequency of harvests and segregation of the data recorded from main and lateral stems would provide more precise information on which to base prediction.

Seed of the line 1142 and cultivar Jumbo was sown in single, unreplicated plots, each 36m long by 3.6m wide, 10 July 2000 at Forthside Research Station. Seed was sown to a density of fifteen seeds per sq m in single rows, each 0.3m apart. Mixed fertiliser (7:12:9) was banded to either side and below the seed row at 500 kg/ha with a Fiona drill. Weed and disease control and irrigation were again carried out as described in other sections of this report.

Ten plants of each genotype again were selected at random from these plots and sequentially and destructively harvested. These harvests were again begun prior to the anticipated optimum maturity time but were made more frequently than in the previous experiment. Seven harvests of line 1142 were made between 27 November and 18 December 2000. Eight harvests of cultivar Jumbo were made between 27 November and 21 December 2000. Main stems were separated from lateral stems and the number and fresh weight of pods at each node (numbered from the first pod-bearing node) and the length and fresh weight of individual seeds at each node (numbered from the first pod-bearing node) were recorded. The mean length of the seeds at each node was calculated and a determination made of their dry matter content (80°C to constant weight (24h)). In addition, the proportion of seeds at each node showing a darkened hilum was recorded. Linear and exponential regression analyses were carried out on key parameters.

Results

While linear relationships were found to adequately describe the plotted parameters in some cases, exponential regressions generally provided 'best fit' curves for the data, with high values for R^2, particularly in season 1999-2000. The data, therefore, are shown as exponential relationships in the following figures.

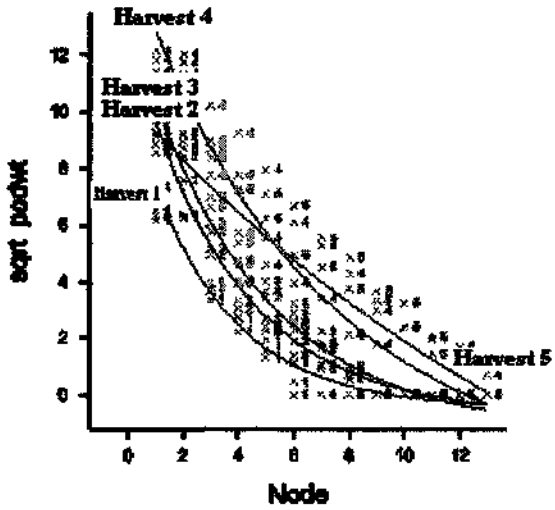
Season 1999-2000

Figures 1a-1c show the relationship between total pod yield (square root transformation) and node position at differing harvest times of the lines 1142 and Imported and the cultivar Jumbo.

The analyses confirm that the lowest nodes contribute most to yield and their relative contribution is maintained through the harvest period.

Inspection of the regression constants for line 1142, in comparison to the line Imported and the cultivar Jumbo, support the other aspects of this report indicating a more determinate growth habit of line 1142, higher nodes contributing relatively less to yield over the sequential harvest times.

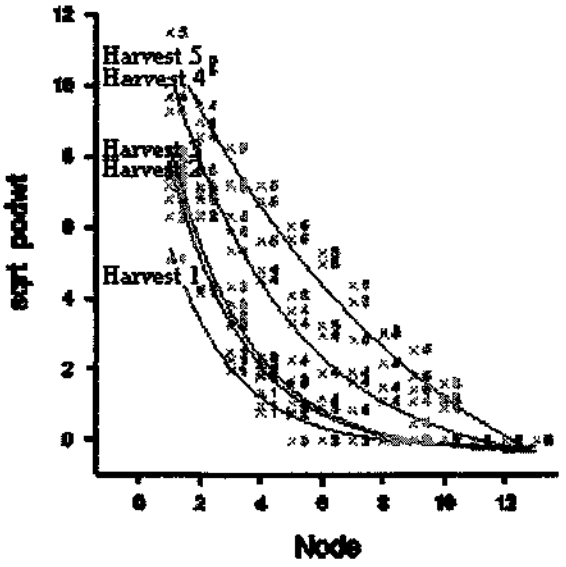
Figure 1a – Exponential fitted curves and descriptive equations of values for total pod yield (g/sq m, square root transformation) per node regressed against node (numbered from first pod-bearing node) for each harvest time of line 1142 in season 1999-2000.



$R^2 = 0.914$

Harvest 1: sqrt podwt = -0.493±0.388 + 10.94±1.01 x 0.7199 ± 0.044^{Node}
Harvest 2: sqrt podwt = -0.725±0.490 + 13.591±0.852 x 0.7607 ± 0.0326^{Node}
Harvest 3: sqrt podwt = -1.286±0.632 + 14.653±0.750 x 0.7947 ± 0.0288^{Node}
Harvest 4: sqrt podwt = -2.89±1.28 + 18.264±0.948 x 0.8596 ± 0.023^{Node}
Harvest 5: sqrt podwt = -10.6±9.96 + 20.95±9.48 x 0.9494 ± 0.0332^{Node}

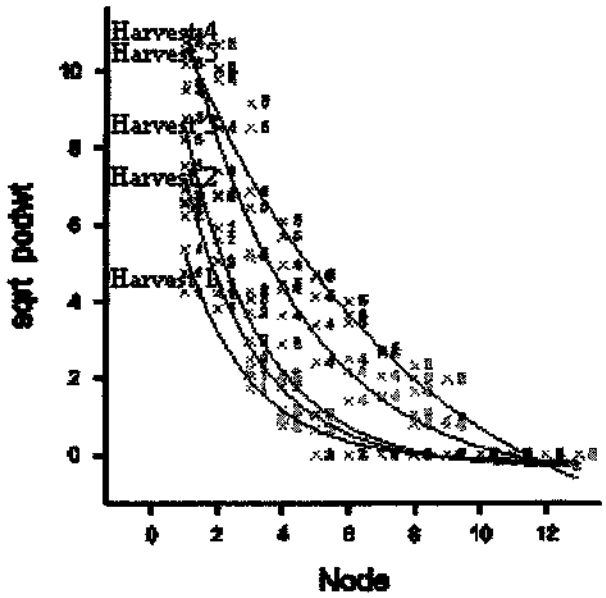
Figure 1b – Exponential fitted curves and descriptive equations of values for total pod yield (g/sq m, square root transformation) per node regressed against node (numbered from first pod-bearing node) for each harvest time of line Imported in season 1999-2000.



$R^2 = 0.959$

Harvest 1: sqrt podwt = $-0.219 \pm 0.168 + 8.884 \pm 0.831 \times 0.6345 \pm 0.0402^{Node}$
Harvest 2: sqrt podwt = $-0.366 \pm 0.187 + 12.184 \pm 0.724 \times 0.6705 \pm 0.0265^{Node}$
Harvest 3: sqrt podwt = $-0.423 \pm 0.192 + 12.774 \pm 0.693 \times 0.6817 \pm 0.0245^{Node}$
Harvest 4: sqrt podwt = $-0.891 \pm 0.331 + 14.425 \pm 0.467 \times 0.7796 \pm 0.0176^{Node}$
Harvest 5: sqrt podwt = $-4.20 \pm 1.31 + 17.06 \pm 1.01 \times 0.8917 \pm 0.0165^{Node}$

Figure 1c – Exponential fitted curves and descriptive equations of values for total pod yield (g/sq m, square root transformation) per node regressed against node (numbered from first pod-bearing node) for each harvest time of cultivar Jumbo in season 1999-2000.

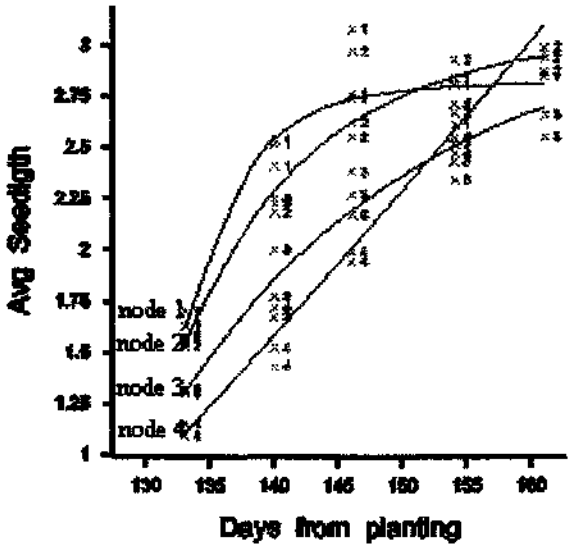


$R^2 = 0.948$

Harvest 1: sqrt podwt = -0.203±0.186 + 8.650±0.957 x $0.6288±0.0.473^{Node}$
Harvest 2: sqrt podwt = -0.305±0.194 + 11.633±0.901 x $0.6466±0.0336^{Node}$
Harvest 3: sqrt podwt = -0.399±0.205 + 13.335±0.841 x $0.6627±0.0279^{Node}$
Harvest 4: sqrt podwt = -0.772±0.317 + 15.682±0.579 x $0.7561±0.0.190^{Node}$
Harvest 5: sqrt podwt = -3.244±0.977 + 15.978±0.730 x $0.8691±0.0178^{Node}$

Figures 2a-2c show the relationship between mean length of all seeds at a node position and the number of days from planting of the lines 1142 and Imported and the cultivar Jumbo. Marketable and unmarketable seeds were present in the sample resulting in mean values less than the size limit for marketable seed previously discussed. Differences in mean values for each genotype suggested that nodes 1, 2 and 3 and, possibly, 4 were likely to contribute to marketable yield of line in 1142 whereas only nodes 1and 2 were likely to contribute in the line Imported and cultivar Jumbo. Maximum seed length at node 1 in line 1142 reached a maximum about two weeks earlier than for the other two genotypes. *Hilum darkening* appeared before these mean seed lengths reached their maxima, although considerable variation was present between individual seeds.

Figure 2a – Exponential fitted curves and descriptive equations of values for the mean length (cm) of all seeds at a node (numbered from first pod-bearing node) regressed against the number of days from planting for the line 1142 in season 1999-2000.



$R^2 = 0.946$

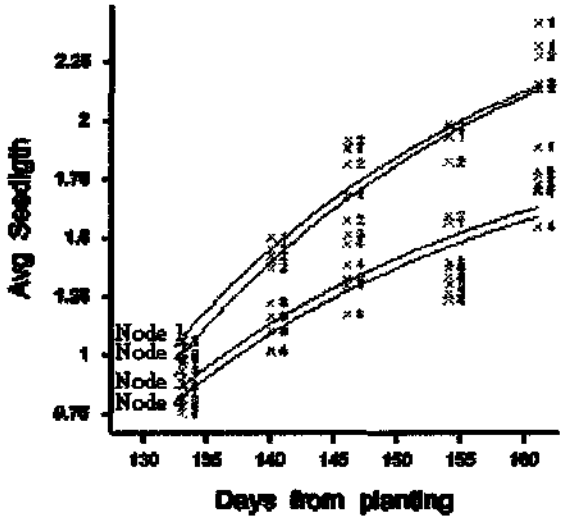
Node 1: Mean seed length = $2.8112 \pm 0.579 - 2.71 \times 10^{12} \pm 1.86 \times 10^{13} \times 0.8074 \pm 0.0471^{\text{Days from planting}}$

Node 2: Mean seed length = $3.033 \pm 0.120 - 750359 \pm 2150842 \times 0.906 \pm 0.0199^{\text{Days from planting}}$

Node 3: Mean seed length = $3.127 \pm 0.345 - 1675 \pm 3796 \times 0.950 \pm 0.0174^{\text{Days from planting}}$

Node 4: Mean seed length = $-21 \pm 159 + 14 \pm 147 \times 1.0031 \pm 0.0220^{\text{Days from planting}}$

Figure 2b – Exponential fitted curves and descriptive equations of values for the mean length (cm) of all seeds at a node (numbered from first pod-bearing node) regressed against the number of days from planting for the line Imported in season 1999-2000.

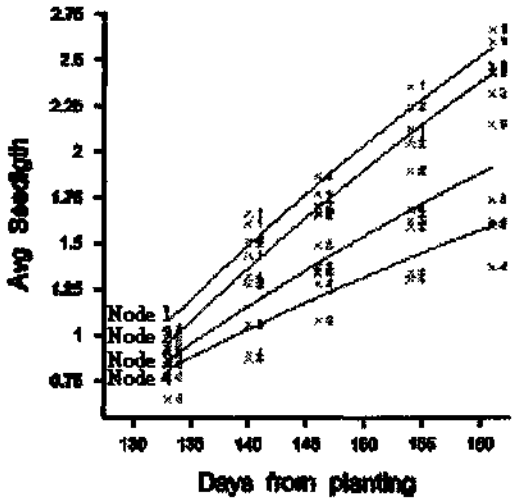


$R^2 = 0.874$

Node 1: Mean seed length = $2.762-196.0 \times 0.9649 \pm 0.106^{\text{Days from planting}}$
Node 2: Mean seed length = $2.775-206.2 \times 0.9649 \pm 0.106^{\text{Days from planting}}$
Node 3: Mean seed length = $2.066-139.7 \times 0.9649 \pm 0.106^{\text{Days from planting}}$
Node 4: Mean seed length = $2.028-140.7 \times 0.9649 \pm 0.106^{\text{Days from planting}}$

(NB. Values lacking standard errors are fixed linear descriptors determined by the model when R values in the fitted curve A+B*R**X are invariate).

Figure 2c – Exponential fitted curves and descriptive equations of values for the mean length (cm) of all seeds at a node (numbered from first pod-bearing node) regressed against the number of days from planting for the cultivar Jumbo in season 1999-2000.



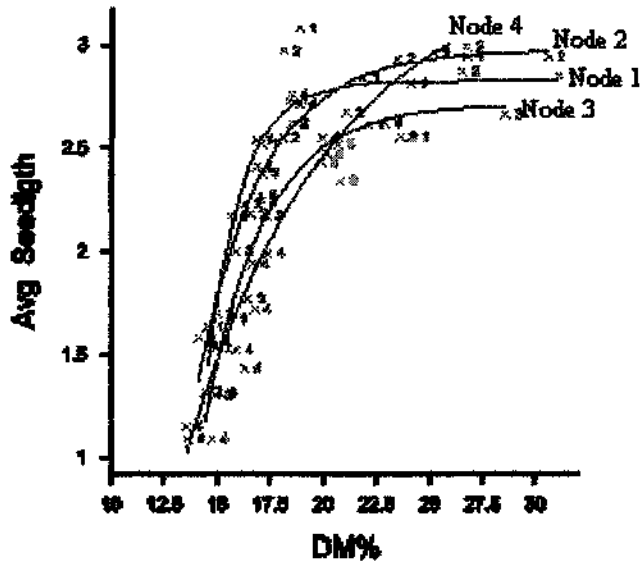
$R^2 = 0.919$

Node 1: Mean seed length = $6.449-25.30 \times 0.98842 \pm 0.00797^{\text{Days from planting}}$
Node 2: Mean seed length = $6.244-24.89 \times 0.98842 \pm 0.00797^{\text{Days from planting}}$
Node 3: Mean seed length = $4.650-17.82 \times 0.98842 \pm 0.00797^{\text{Days from planting}}$
Node 4: Mean seed length = $3.636-13.29 \times 0.98842 \pm 0.00797^{\text{Days from planting}}$

(NB. Values lacking standard errors are fixed linear descriptors determined by the model when R values in the fitted curve A+B*R**X are invariate).

Figures 3a-3c show the relationship between mean length of all seeds at a node position and their mean dry matter, for each of the first four nodes of the lines 1142 and Imported and the cultivar Jumbo. Mean seed lengths in all genotypes reached maxima when dry matter values were between 23-25 per cent. The incidence of dark hilum at final harvest was greater than 50 per cent at nodes 1 and 2 of Jumbo and 1142 but was less than 50per cent at the nodes 1and 2 of the line Imported.

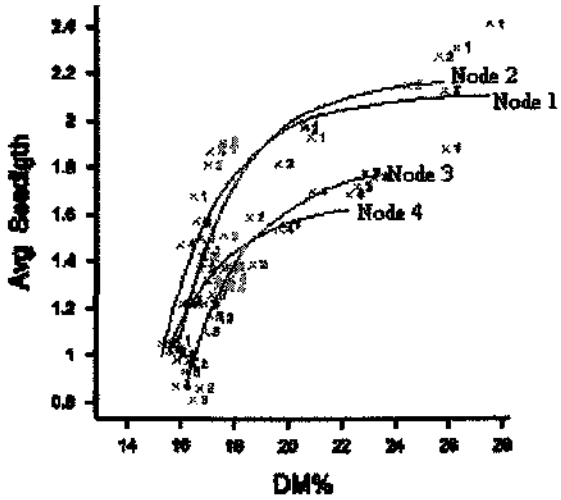
Figure 3a – Exponential fitted curves and descriptive equations of values of the mean length (cm) of all seeds at a node (numbered from first pod-bearing node) regressed against the mean seed dry matter (%) for the line 1142 in season 1999-2000.



$R^2 = 0.876$

Node 1: Mean seed length = 2.8219±0.0844-12971±36664x $0.533±0.103^{\text{Dry Matter}}$
Node 2: Mean seed length = 2.972±0.118-167.0±198x $0.7189±0.0599^{\text{Dry Matter}}$
Node 3: Mean seed length = 2.708±0.128-286±425x $0.6957±0.0715^{\text{Dry Matter}}$
Node 4: Mean seed length = 3.412±0.800-16.5±13.2 x $0.8669±0.0695^{\text{Dry Matter}}$

Figure 3b – Exponential fitted curves and descriptive equations of values of the mean length (cm) of all seeds at a node (numbered from first pod-bearing node) regressed against the mean seed dry matter (%) for the line Imported in season 1999-2000.

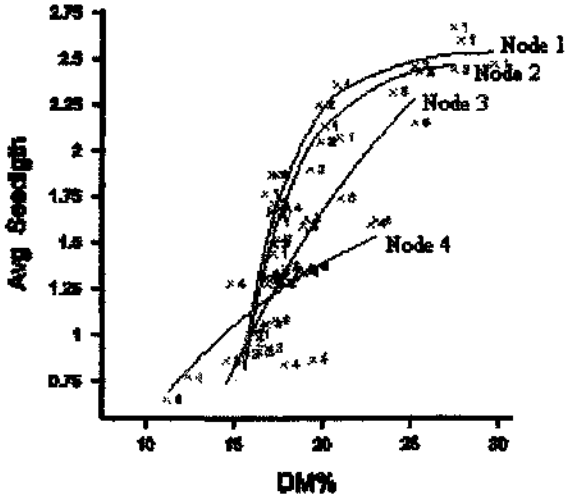


$R^2 = 0.813$

Node 1: Mean seed length = 2.110-958.7x $0.06429 \pm 0.0491^{\text{Dry Matter}}$
Node 2: Mean seed length = 2.176-1291x $0.06429 \pm 0.0491^{\text{Dry Matter}}$
Node 3: Mean seed length = 1.810-1207x $0.06429 \pm 0.0491^{\text{Dry Matter}}$
Node 4: Mean seed length = 1.656-613.5x $0.06429 \pm 0.0491^{\text{Dry Matter}}$

(NB. Values lacking standard errors are fixed linear descriptors determined by the model when R values in the fitted curve A+B*R**X are invariate).

Figure 3c – Exponential fitted curves and descriptive equations of values of the mean length (cm) of all seeds at a node (numbered from first pod-bearing node) regressed against the mean seed dry matter (%) for the cultivar Jumbo in season 1999-2000.



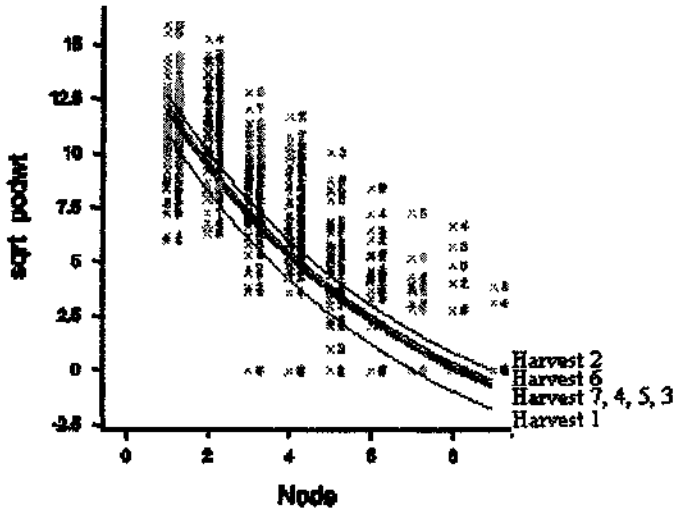
$R^2 = 0.871$

Node 1: Mean seed length = 2.542±0.114-627±945x $0.06840 \pm 0.0650^{\text{Dry Matter}}$
Node 2: Mean seed length = 2.493±0.137-381±458x $0.07098 \pm 0.0596^{\text{Dry Matter}}$
Node 3: Mean seed length = 3.67±2.24-8.21±3.60x $0.0932 \pm 0.0724^{\text{Dry Matter}}$
Node 4: Mean seed length = 2.04±1.18-3.45±1.790x $0.920 \pm 0.104^{\text{Dry Matter}}$

Season 2000-01

Figures 4a and 4b show the relationship between total pod yield (square root transformation) and node position at differing harvest times of the line 1142 and the cultivar Jumbo. More variation was contained within the data compared with that from the previous year, Rsq values were lower than in the previous year and the differences between yields at successive harvest times were less measurable. Best fit regression lines at different harvest times were very similar or identical and this lack of displacement reflected the little change in total yield of sampled plants over the harvest period. Lowest nodes, however, again contributed most to yield, but change in the relative contribution of nodes to yield over sequential harvests was not apparent.

Figure 4a – Exponential fitted curves and descriptive equations of values for total pod yield (g/sq m, square root transformation) per node regressed against node (numbered from first pod-bearing node) for each harvest time of line 1142 in season 2000- 01.

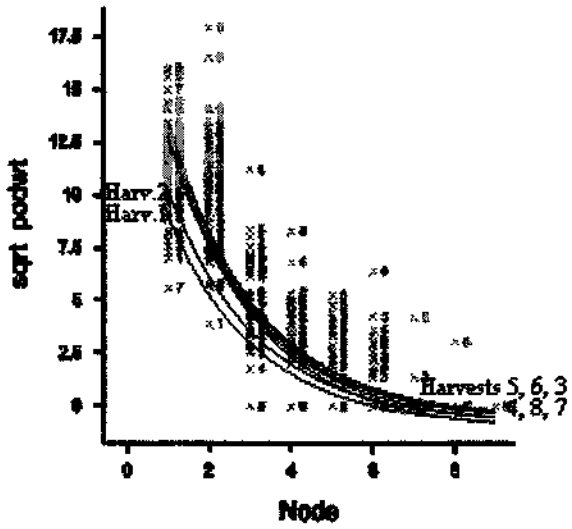


$R^2 = 0.730$

Harvest 1: sqrt podwt = $-6.698+20.61 \times 0.8525 \pm 0.0127^{Node}$
Harvest 2: sqrt podwt = $-4.907+20.61 \times 0.8525 \pm 0.0127^{Node}$
Harvest 3: sqrt podwt = $-5.713+20.61 \times 0.8525 \pm 0.0127^{Node}$
Harvest 4: sqrt podwt = $-5.597+20.61 \times 0.8525 \pm 0.0127^{Node}$
Harvest 5: sqrt podwt = $-5.612+20.61 \times 0.8525 \pm 0.0127^{Node}$
Harvest 6: sqrt podwt = $-5.373+20.61 \times 0.8525 \pm 0.0127^{Node}$
Harvest 7: sqrt podwt = $-5.539+20.61 \times 0.8525 \pm 0.0127^{Node}$

(NB. Values lacking standard errors are fixed linear descriptors determined by the model when R values in the fitted curve A+B*R**X are invariate).

Figure 4b – Exponential fitted curves and descriptive equations of values for total pod yield (g/sq m, square root transformation) per node regressed against node (numbered from first pod-bearing node) for each harvest time of cultivar Jumbo in season 2000- 01.



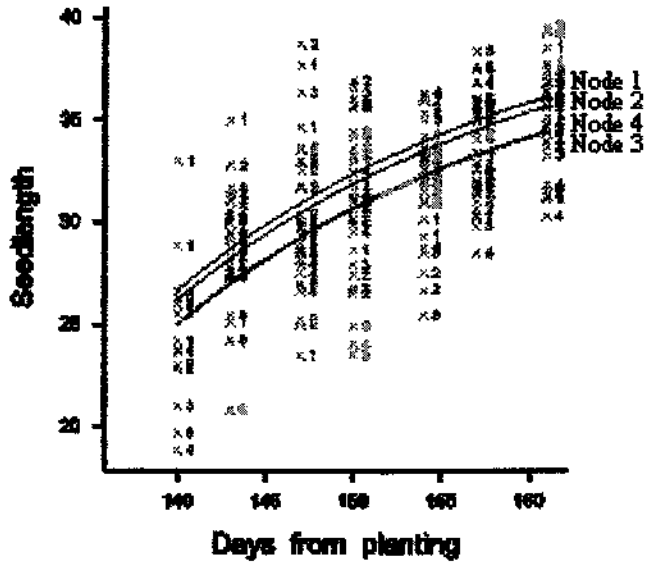
$R^2 = 0.799$

Harvest 1: sqrt podwt = -0.9974 +15.66 x 0.63149±0.00969^{Node}
Harvest 2: sqrt podwt = -0.8137 +17.39 x 0.63149±0.00969^{Node}
Harvest 3: sqrt podwt = -1.1500 +21.88 x 0.63149±0.00969^{Node}
Harvest 4: sqrt podwt = -0.8689 +21.38 x 0.63149±0.00969^{Node}
Harvest 5: sqrt podwt = -0.5783 +22.18 x 0.63149±0.00969^{Node}
Harvest 6: sqrt podwt = -0.6345 +22.09 x 0.63149±0.00969^{Node}
Harvest 7: sqrt podwt = -0.6904 +21.18 x 0.63149±0.00969^{Node}
Harvest 8: sqrt podwt = -0.5424 +21.14 x 0.63149±0.00969^{Node}

(NB. Values lacking standard errors are fixed linear descriptors determined by the model when R values in the fitted curve A+B*R**X are invariate).

Figures 5a and 5b show the relationship between mean length of all seeds at a node position and the number of days from planting of the line 1142 and the cultivar Jumbo. The relationships determined for these data were also less precise than those obtained in 1999-2000. For line 1142, nodes 1-4 again provided seed of marketable size and seed length increased beyond 160 days. Again for line 1142, dark hilum was observed on seeds from nodes 1 and 2 only (2 plants of 10) at Harvest 3 (147 days from planting) and thence over nodes 1-4, on 8 plants of 10, at Harvest 4 (150 days from planting). This confirmed that hilum darkening began before mean seed length reached a maximum. For cultivar Jumbo nodes 1 and 2 only provided seed of marketable size and seed length increased beyond 160 days. Hilum darkening was observed at nodes 1 and 2 on 3 out of 10 plants at Harvest 4 (150 days from planting) and at nodes 1 -3 on 8 out of 10 plants at the following harvest.

Figure 5a – Exponential fitted curves and descriptive equations of values for the mean length (mm) of all seeds at a node (numbered from first pod-bearing node) regressed against the number of days from planting for the line 1142 in season 2000-01.

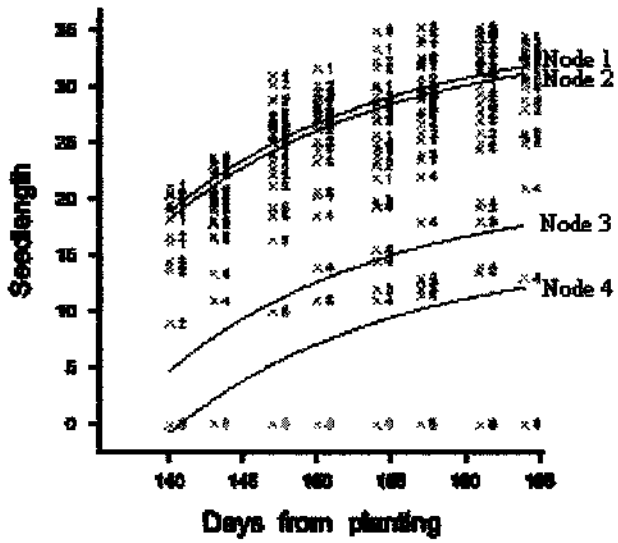


$R^2 = 0.496$

Node 1: Mean seed length = $41.31-14450 \times 0.9519 \pm 0.0186^{\text{Days from planting}}$
Node 2: Mean seed length = $40.83-14450 \times 0.9519 \pm 0.0186^{\text{Days from planting}}$
Node 3: Mean seed length = $39.58-14450 \times 0.9519 \pm 0.0186^{\text{Days from planting}}$
Node 4: Mean seed length = $39.65-14450 \times 0.9519 \pm 0.0186^{\text{Days from planting}}$

(NB. Values lacking standard errors are fixed linear descriptors determined by the model when R values in the fitted curve A+B*R**X are invariate).

Figure 5b – Exponential fitted curves and descriptive equations of values for the mean length (mm) of all seeds at a node (numbered from first pod-bearing node) regressed against the number of days from planting for the cultivar Jumbo in season 2000-01.



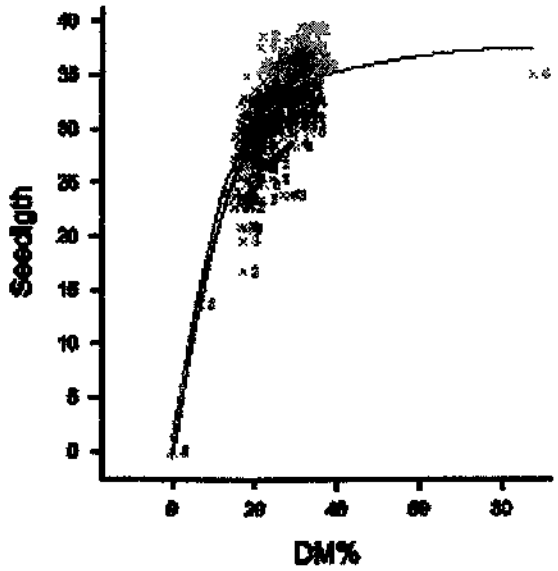
$R^2 = 0.560$

Node 1: Mean seed length = 34.93-215227 x 0.9344±0.0242$^{\text{Days from planting}}$
Node 2: Mean seed length = 34.27-215227 x 0.9344±0.0242$^{\text{Days from planting}}$
Node 3: Mean seed length = 20.81-215227 x 0.9344±0.0242$^{\text{Days from planting}}$
Node 4: Mean seed length = 15.28-215227 x 0.9344±0.0242$^{\text{Days from planting}}$

(NB. Values lacking standard errors are fixed linear descriptors determined by the model when R values in the fitted curve A+B*R**X are invariate).

Figures 6a and 6b show the relationship between mean length of all seeds at a node position and their mean dry matter, for each of the first four nodes of the line 1142 and the cultivar Jumbo. Seed size continued to increase until dry matter percentage reached 30 per cent and above, in contrast to the previous season. In line 1142 regressions for nodes 1-4 were very similar, with all nodes able to contribute to marketable yield. Hilum darkening started on nodes 1 and 2 at 147 days after sowing, when mean seed length was 31.1mm. Mean seed dry matter at this time was 20 per cent. In the cultivar Jumbo, hilum darkening was first seen on nodes 1 and 2 of three out of 10 plants at Harvest 4, 150 days after planting. Mean seed lengths at nodes 1 and 2 were then 26.5mm and 26mm respectively. Thus these nodes only were likely to provide seed of good marketable size. Mean dry matters of seeds at this time at nodes 1 and 2 were again close to 20 per cent.

Figure 6a – Exponential fitted curves and descriptive equations of values of the mean length (mm) of all seeds at a node (numbered from first pod-bearing node) regressed against the mean seed dry matter (%) for the line 1142 in season 2000-01.

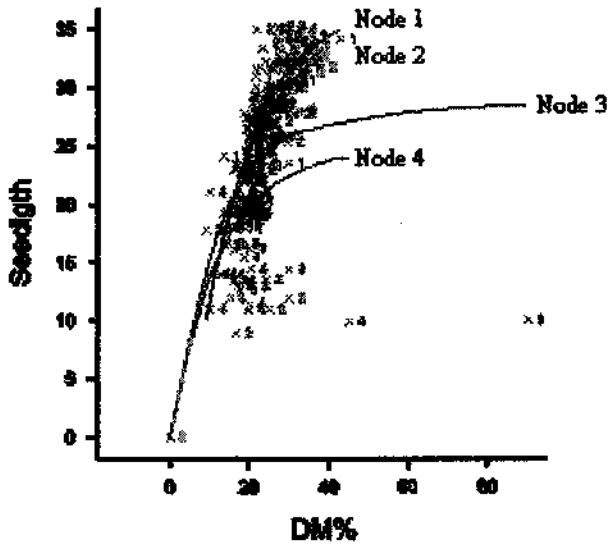


$R^2 = 0.902$

Node 1: Mean seed length = 38.78-37.58x $0.92579 \pm 0.00335^{\text{Dry Matter}}$
Node 2: Mean seed length = 38.28-37.58x $0.92579 \pm 0.00335^{\text{Dry Matter}}$
Node 3: Mean seed length = 37.09-37.58x $0.92579 \pm 0.00335^{\text{Dry Matter}}$
Node 4: Mean seed length = 37.54-37.58x $0.92579 \pm 0.00335^{\text{Dry Matter}}$

(NB. Values lacking standard errors are fixed linear descriptors determined by the model when R values in the fitted curve A+B*R**X are invariate).

Figure 6b – Exponential fitted curves and descriptive equations of values of the mean length (mm) of all seeds at a node (numbered from first pod-bearing node) regressed against the mean seed dry matter (%) for the cultivar Jumbo in season 2000-01.



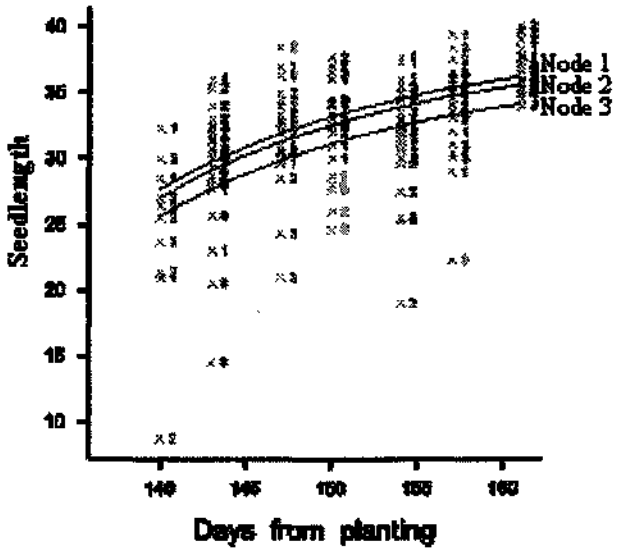
$R^2 = 0.902$

Node 1: Mean seed length = $36.85-60.10 \times 0.92232 \pm 0.00624^{\text{Dry Matter}}$
Node 2: Mean seed length = $34.88-52.28 \times 0.92232 \pm 0.00624^{\text{Dry Matter}}$
Node 3: Mean seed length = $28.41-28.44 \times 0.92232 \pm 0.00624^{\text{Dry Matter}}$
Node 4: Mean seed length = $24.67-24.69 \times 0.92232 \pm 0.00624^{\text{Dry Matter}}$

(NB. Values lacking standard errors are fixed linear descriptors determined by the model when R values in the fitted curve A+B*R**X are invariate).

Figures 7a and 7b show the regressed relationships between mean seed length at each of nodes 1-3 only and days from planting for main stems and lateral stems respectively of the line 1142. Figures 8a and 8b show these relationships for the cultivar Jumbo. Seed length on lateral stems lagged that of seed length on main stems but by the time dark hilum was first evident, little difference between seed length at respective nodes remained between main and lateral stems. Similar trends were evident in mean pod weight but regressions accounted for less variation in the data than was the case with mean seed length and therefore representative figures are not shown.

Figure 7a – Exponential fitted curves and descriptive equations of values for the mean length (mm) of all seeds at each of nodes 1–3 (numbered from first pod-bearing node) on main stems of the line 1142, regressed against the days from planting in season 2000-01.

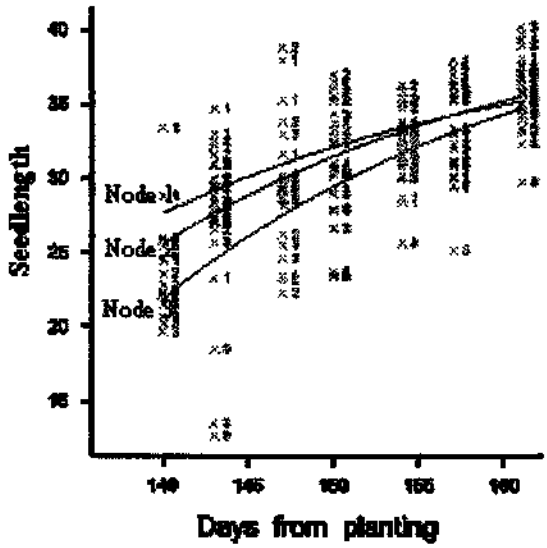


$R^2 = 0.317$

Node 1: Mean seed length = $38.92-137070 \times 0.9350 \pm 0.0512^{\text{Days from planting}}$
Node 2: Mean seed length = $38.29-137070 \times 0.9350 \pm 0.0512^{\text{Days from planting}}$
Node 3: Mean seed length = $36.88-137070 \times 0.9350 \pm 0.0512^{\text{Days from planting}}$

(NB. Values lacking standard errors are fixed linear descriptors determined by the model when R values in the fitted curve A+B*R**X are invariate).

Figure 7b – Exponential fitted curves and descriptive equations of values for the mean length (mm) of all seeds at each of nodes 1--3 (numbered from first pod-bearing node) on lateral stems of the line 1142, regressed against the days from planting in season 2000-01.

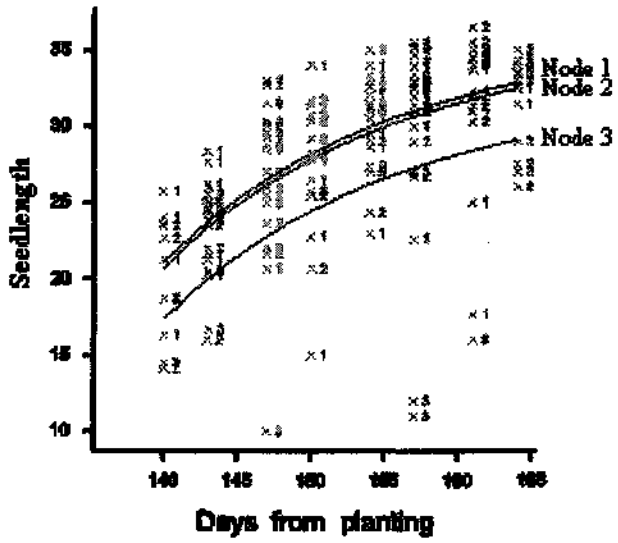


$R^2 = 0.490$

Node 1: Mean seed length = $40.01-7166 \times 0.9556 \pm 0.0205^{\text{Days from planting}}$
Node 2: Mean seed length = $41.77-9351 \times 0.9556 \pm 0.0205^{\text{Days from planting}}$
Node 3: Mean seed length = $42.80-12115 \times 0.9556 \pm 0.0205^{\text{Days from planting}}$

(NB. Values lacking standard errors are fixed linear descriptors determined by the model when R values in the fitted curve A+B*R**X are invariate).

Figure 8a – Exponential fitted curves and descriptive equations of values for the mean length (mm) of all seeds at each of nodes 1--3 (numbered from first pod-bearing node) on main stems of the cultivar Jumbo, regressed against the days from planting in season 2000-01.

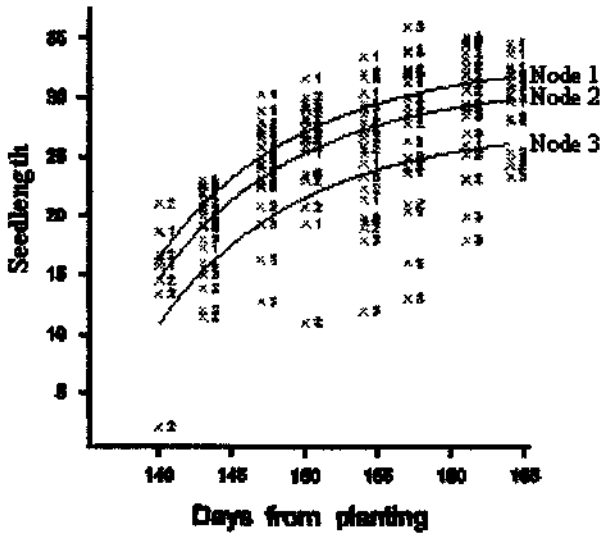


$R^2 = 0.386$

Node 1: Mean seed length = $35.94-130173 \times 0.9372 \pm 0.0227^{\text{Days from planting}}$
Node 2: Mean seed length = $35.58-130173 \times 0.9372 \pm 0.0227^{\text{Days from planting}}$
Node 3: Mean seed length = $32.21-130173 \times 0.9372 \pm 0.0227^{\text{Days from planting}}$

(NB. Values lacking standard errors are fixed linear descriptors determined by the model when R values in the fitted curve A+B*R**X are invariate).

Figure 8b – Exponential fitted curves and descriptive equations of values for the mean length (mm) of all seeds at each of nodes 1–3 (numbered from first pod-bearing node) on lateral stems of the cultivar Jumbo, regressed against the days from planting in season 2000-01.



$R^2 = 0.548$

Node 1: Mean seed length = $33.09-32777211 \times 0.9017 \pm 0.0160^{\text{Days from planting}}$
Node 2: Mean seed length = $31.25-32777211 \times 0.9017 \pm 0.0160^{\text{Days from planting}}$
Node 3: Mean seed length = $27.47-32777211 \times 0.9017 \pm 0.0160^{\text{Days from planting}}$

(NB. Values lacking standard errors are fixed linear descriptors determined by the model when R values in the fitted curve A+B*R**X are invariate).

Discussion

The regressed data over two years shows, as expected, that the lowest nodes contributed the greatest part of total pod yield through both pod number and seed size. Reducing mean seed length (size) with increasing node number thus determined the number of nodes, which were likely to contribute to a total commercial yield of marketable seed and, with the cultivar Jumbo these nodes were probably restricted to nodes 1 and 2. With respect to the line 1142, however, nodes 1-4 inclusive were able to contribute to a total commercial yield of marketable seed due to larger seed size. The relative contribution of differently positioned nodes to total yield also appeared to vary between the two genotypes, with 1142 reflecting a more determinate habit than Jumbo. While these experiments were carried out on unstopped plants, this genetic variation in growth and yield distribution may mean some reappraisal of the best stopping time to be employed on each the genotypes.

Regression equations, although statistically significant, explained only the minority of variation in relation to the differing contributions to mean pod weight and seed length found at comparable nodes of main and lateral stems (Figures 7a, 7b, 8a and 8b). However, these regressions indicated that differences in the values of these parameters at the time of optimum harvest were small and unlikely to contribute to large variation in the maturity of samples of marketed product.

The onset of hilum darkening, a property visually detracting from the appearance of the marketed product, was not recorded in the first year's collection of data save for a note that the incidence at final harvest was greater than 50 per cent at nodes 1 and 2 of cultivar Jumbo and of line 1142 but less than 50 per cent at nodes 1 and 2 of the line Imported. Records in 2000-01 indicated that hilum darkening first occurred soon after the dry matter values of seed taken from nodes 1 and 2 reached 20 per cent. This occurrence was consistent and may be used as a predictor of harvest timing. Furthermore, the darkening of seed hila progressed rapidly, making the accurate prediction of correct harvest maturity important to the achievement of optimum market quality. Hilum darkening occurred before maximum seed size was achieved and maximum seed size was not achieved until seed dry matter values were around 30 per cent or more.

Corroborative data was also taken from plots of stopped plants sown to investigate time of sowing effects and mechanical harvesting in season 2001-02. This data confirmed the value of this predictor.

Harvesting methods

While the mechanical harvesting of dry, small-seeded *Vicia faba* cultivars, fababeans, and of smaller-seeded broad bean cultivars (such as the cultivar *Coles Dwarf*) used for fresh, frozen product sales, is commercially routine, attempts to mechanically harvest the pods of cultivars with large seed has not been successfully recorded. The agronomic investigations earlier described indicated that sequential production of stopped plants would be commercially feasible. Therefore, the industry reference group agreed, at its meeting in May 2001, that once-over, mechanical harvesting of fresh pods, followed by hand-shelling of seed, might provide a cost advantage to the local industry in this market sector. As a mechanical harvester designed for use with green (*Phaseolus*) beans was available locally from Harvest Moon Pty, a test of this machine for harvesting stopped plants of the cultivar Jumbo was completed in 2001-02.

Materials and Methods

Plots used in this investigation were those used also for an unreplicated comparison of sowing time effects in 2001-02 described above. Seed of the cultivar Jumbo was sown in single plots only, 36m long by 6.4m wide, on both 18 June and 9 July 2001, by hand into single rows, each 800mm apart, at Forthside Research Station. This configuration was used to accommodate the test of the mechanical harvester. Plants were stopped at the 'six-flowering node stage', when six nodes on main stems bore fully-opened flowers. This and other plot husbandry practices are described in the previous section of this report. The mechanical harvester was employed on the earlier sown plot on 11 December 2001, when seed dry matter reached a level of 20 per cent. Two sub-plots, each of 2 rows by 5m long (equivalent to an area of 4 sq m) were hand harvested for comparison. Total and marketable (straight, three-seeded pods) pod yields and marketable seed yields were recorded from duplicate sub-plots and means calculated. The proportions of intact but unmarketable (misshapen and non-three-seeded) pods, broken pods and trash yields were also noted. Analysis of variance was not carried out. After the poor result of the attempt to harvest the earlier sown plot with this machine, a second attempt on the later sown plot was abandoned.

Results

The results of the mechanical and hand harvesting of the early sown plot of stopped Jumbo plants are shown in Table 17. Yields of marketable product from machine-harvested samples were very low. The machine was therefore agreed to be unsuited to this purpose and further tests abandoned.

Table 17. Total and marketable pod and seed yields and their components returned from mechanical and hand harvested sub-plots of stopped plants of cultivar Jumbo in 2001-02.

	Machine harvested sample	Hand harvested sample
Total pod yield (t/ha)	11.01	38.96
Marketable pod yield (t/ha)	0.50	11.05
Intact, unmarketable pod yield (t/ha)	1.94	26.53
Unmarketable (broken) pods (t/ha)	7.19	Nil
Trash yield (t/ha)	1.38	Nil
Marketable seed yield (t/ha)	0.89	4.89

Discussion

The green bean harvester used in the test was not suited to stripping the pods off the stopped broad bean plants. The stripping mechanism of this machine rotated around a horizontal axis and pressed the vertical broad bean stems towards the ground without stripping the pods. The broad bean pods were also attached to stems with a strength, which prevented their removal by the harvesting mechanism, without considerable damage. It was apparent that a mechanism, which maintained the stems in their vertical habit, whilst forcing the pods down, against the natural angle at which they were borne on the stem, might have proven to be more successful. It was considered that two contra-rotating, helical stripping mechanisms, turning on vertical axes, might fulfil such a requirement.

Technology Transfer

The preferred mechanism for technology transfer in relation to this project has been through the initial and regular involvement of a group of industry stakeholders, who represented companies interested in producing and supplying the product to Japanese markets. As described earlier (see Industry Involvement and Research Collaboration), formal annual meetings were held between project staff and this group (the Industry Reference Group) to review findings and agree on work for the following season, in addition to informal contact during each year. These meetings were held in May or June of each year and followed the format of presentation of a background and of the previous year's results by the Chief Investigator, followed by a discussion on priorities and plans for further work.

The final season's reporting to stakeholders (Appendix D) was carried out against a background of collapsed prices in Japan of the product in the Australian export window due to unusually high local production. Whilst interest in the potential of the product remains within the stakeholder group, further commercial testing of the improved lines is unlikely until Japanese prices improve. Seed of the improved lines is currently in storage with the Tasmanian Institute of Agricultural Research.

The Chief Investigator made presentations to growers and industry personnel on the annual occasions of presentations of current project results, held under the auspices of the Tasmanian Vegetable and Potato Research and Advisory Committees. These committees have a role in assisting the collaboration among Tasmanian and other research providers, and ensuring that project work meets industry priorities and that projects report regularly to industry on results. An example of the related summary publication (for 2002) is attached as Appendix E.

The projects results were also featured at Annual Research Presentation Days held by the Tasmanian Institute of Agricultural Research. The most recent of these was held in June 2002 and attracted over 200 attendees. The work has also been reported annually in the Annual Report of this organization.

Field days, conducted at Forthside Research Station in North West Tasmania have also featured the project's work annually with verbal presentation by the Chief Investigator at the sites of field work and supported by publication of work summaries.

While the above occasions have publicised the project's work and Horticulture Australia's support, commercial development by industry has been most important. In related work, one commercial company, supported by the Tasmanian Department of Primary Industry, Water and Environment, sent approximately 250 kg of pods of the line Jumbo as samples to the Japanese market in December 2000. These were well received and maturity was said to be acceptable. Prices received were about 30 per cent above the calculated cost of production. Product was also sent to Japan in December 2001 but shipments were discontinued after prices deteriorated.

Recommendations

The following recommendations are drawn from the preceding results and discussion:

Accession, maintenance and selection of lines

That the bulked seed of the selected lines be made available to the stakeholders and others who wish to pursue production and sales of fresh market broad beans in the targeted markets. While the cultivar Jumbo has been used to date by one stakeholder, the line 1142 should be considered for commercial development, as its larger seed size may provide an advantage over other genotypes. Commercial development of this genotype should be within the accepted arrangements made with ICARDA (Appendix C).

Sowing density and "stopping"

That plants should be "stopped" (top-pruned) when six nodes bear fully-opened flowers in order to maximize the size and yield of marketable seeds, given the understanding that modification of this recommendation may be required in relation to genotype.

When plants are stopped, the cultivar Jumbo (and the lines of similar habit and maturity, Imported and 3FB) should be sown to provide a population of fourteen plants per sq m and the line 1142 should be sown to provide a population of fifteen plants per sq m. When stopping is not employed, the cultivar Jumbo (and the lines of similar habit and maturity, Imported and 3FB) should be sown to provide a population of twelve plants per sq m and the line 1142 should be sown to provide a population of thirteen plants per sq m. Rows should be configured for harvesting and to allow adequate pollination activity by bees. At least 30 cm between rows is suggested.

Sowing time

While the project found little effect on yield and quality due to sowing over the relatively narrow range of treatment times, preferred sowing time should be targeted primarily to production locality and market window.

Seed maturity and harvest timing

The project has found that optimum harvest time is related to the dry matter content of seeds borne at the lowest pod-bearing nodes (Nodes 1 and 2 in this report) and that, while seed size continues to increase beyond this point, hilum darkening occurs rapidly thereafter. It is recommended, therefore, that harvesting begin when seeds from Nodes 1 and 2 have a dry matter content of 19-20 per cent.

Harvesting methods

Harvesting by hand is recommended until improvements on currently available commercial machinery are found.

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Appendices

Appendix A. 'Soramame research cooperation with Tasmania'. A report by Dr. John Burgmans on his Tasmanian Institute of Agricultural Research Scholarship – funded visit in December 1998.

Appendix B. Advice received on 21 February 2002, from Tomei Fruits Company Limited, Tokyo via JM Segall and Company Limited, Sydney, regarding the appraisal of the market suitability of the lines 1142 and Imported.

Appendix C. ICARDA Material Transfer Agreement relating to conditions of use of line 1142, received from Dr J Paull, 25 November 1999.

Appendix D. Summary used for final season's report to stakeholders (May, 2002).

Appendix E. Project abstract published by the Tasmanian Potato and Vegetable Agricultural Research and Advisory Comittees in support of their Annual Presentation Day.

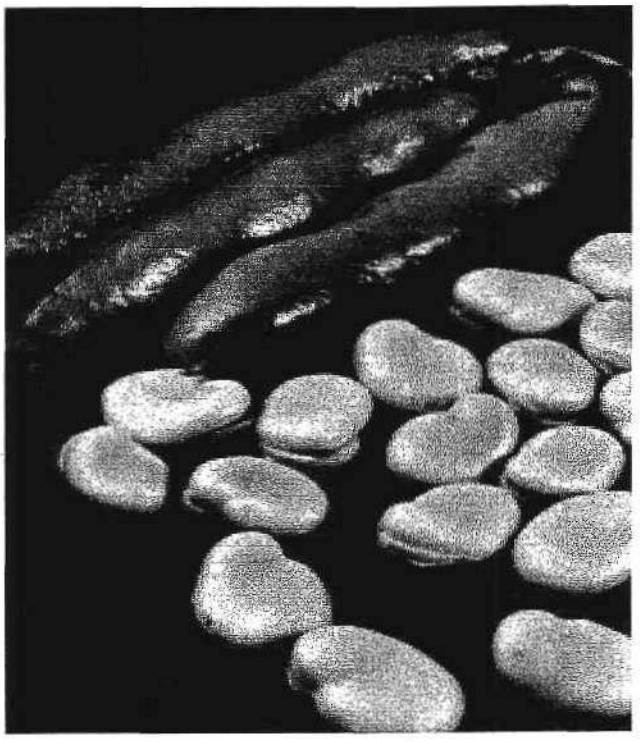
APPENDIX A

Soramame research cooperation with Tasmania

prepared for:
Rowland C N Laurence
Tasmanian Institute of Agricultural Research
P.O.Box 447, Burnie, Tasmania

prepared by:
John Burgmans
Future Resources
176 Avondale Road, Napier
New Zealand

10 January, 1999



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John Burgmans
Future Resources
176 Avondale Road, Napier
New Zealand

Summary
The main purpose of the visit was to discuss soramame research experience in New Zealand but other, so-called new vegetables, were also discussed. Some of these crops were celeriac, burdock and daikon. Some good selections of soramame have been made and it is suggested that further selections are made next season. Also it is recommended to investigate methods of improving the quality of the beans by carrying out time-of-sowing and nutrition trials. Based on our past experience, the crop requires a high nutrition level. The virus infection levels should be closely watched as once established could decimate the crop. Again, we would recommend investigating the use of oil sprays perhaps combined with insecticide applications.

Investigate new ways of linking into a new market, by either looking at varying process methods or at different options for organically grown crops or by attracting an active Japanese partner in the project. Some potential exist for the promotion of celeriac and daikon either for export or for local use.

We would be happy to assist for a season in improving the soramame and other crops in Tasmania or by assisting in introducing Japanese contacts.

Introduction
As a recipient of a **TIAR** Visiting Research Scholarship I was able to visit the University's School of Agricultural Science at Hobart and the Stoney Rise Government Centre, (**DPIWE**), Devonport and Tasmanian Institute of Agricultural Research at Burnie. First contact with the Tasmanian soramame research project was made in May 1998 when I was invited to submit four lines of soramame varieties which had been used with success for some years in New Zealand while introducing the crop to the New Zealand growers and processors. These lines are presently grown in quarantine at Hobart.

Brief talks on soramame research experience in New Zealand were given in the morning of Monday 7 December at the School of Agricultural Science and a press, radio and televison interview in the afternoon together with the Minister of Agriculture, Mr David Llewellyn.

The next day a visit was arranged for at the Tasmanian Institute of Agricultural Research at Burnie and a brief talk was given to staff of Stoney Rise Government Centre at Devonport.

Background information
Soramame, or Japanese broad bean, is similar to the broad bean (***Vicia faba***), that most older people either love or hate so well, but this bean is sweeter, larger and plant growth is more vigorous. It is popular in Japan and has a good potential for Tasmania for domestic and export markets. Soramame is harvested in New Zealand between October and early December, which is a very good time to market this product in Japan because prices peak at between $13 and $20/kg of fresh product at that time. The off-season market for fresh product is estimated to be more than $30 million per annum. Frozen products may fetch up to $5/kg. Although this seems a low price, this market provides another outlet for produce.

An opportunity exists for Tasmania to grow this crop and market it in Japan during November and December when local supply is low. Japan produces about 18,000 tonnes of

soramame each year, and it can be used fresh, frozen, dehydrated or freeze-dried. High prices can be obtained from August to November (peaking at about 1000 yen/kg). Later in the season, between December and March, prices drop to 500 yen/kg, and then to about 400 yen/kg between April and July. It is likely that processed products will become more attractive in the future. Other potentially new markets are Singapore and Indonesia. The more typical Chinese diet consumed in Taiwan and Hong Kong does not include soramame.

A limiting factor in the development of this crop in New Zealand has been the restrictions on the importation of seed into New Zealand because of infection by the ***Bean Common Mosaic Virus*** which stunts plants and reduces crop quality. It often occurs around seedling stage and other viruses, such as ***Bean Yellow Mosaic Virus***, ***Bean Top Yellow Virus*** can also cause problems, often closer to flowering time. Some other viruses recorded in the crop are ***Soybean Dwarf Virus*** and ***Beet Western Yellow Virus***. The viruses are either seed or insect borne and seed import is restricted because of this (seed borne) virus infection. The symptoms of ***BCMV*** occur quite quickly after seedling emergence and plants should be removed from the field and burned if possible.

Another restriction is the lack of knowledge required to produce large beans suitable for Japanese markets. Generally, soramame crops grown in New Zealand have had high yields and pods are 10-15 cm with three beans per pod. Although most cultivars have green beans, a new type with red colour, (Hatu Hime), has been evaluated. Red beans may offer a new niche market for fresh or processed product and can also be dehydrated for use in condiments.

Impressions on visit and discussions

Agronomy

Of the many selections of soramame which had been grown in Tasmanian trials this season only four appeared suitable because of the larger bean size and good colour. A very well known variety in Japan is Ryosai and many selections exist of this variety. It is possible that it was also present among the other selections, but under a different name. It is included with the four varieties which were send in May 1998.

From the varieties selected, Jumbo would be a good standard, but I suspect that some other selections also came from Jumbo. The other cultivars were too small in bean size to be acceptable for the Japanese market.

Good varieties in both appearance and taste were Jumbo, Don Baddock, Imported line, 517 and B16.

The four submitted lines were Hatu Hime, (Red beans), Ryosai, Kakegawa, (also called Jumbo) and Kouchi Issun. Unfortunately I was not able to view these but they should serve as a suitable comparison for future trial work. I suggest to carry on with your four selections and hopefully ending up with two or three good selections.

Diseases
Although your quarantine regulations may restrict the bulk seed importation it is a very wise precaution. The large number of virus infections that can occur are best minimised as much as possible. It may be possible to restrict the virus infection by applying either insecticides as a seed dressing or at a later stage or to use oil sprays. The film of oil on the foliage may inactivate the viruses which are spread by the aphids. We have done some work with oil sprays on capsicums and I could make some suggestions as to what product to use. Therefore anticipate the disease problems, prevent the virus spread by culling out infected seedlings and investigate the use of protective sprays.

Yield increase
Most of your selected lines still had too small a bean size. It is a common conception that large beans may be over-mature. This is not so and it would be best to cooperate with an exporter who knows exactly what size the beans should be and try to increase the size and quality of the beans in trials planned for next season. Aim to sow over a longer period than what has been done so far. In New Zealand the ideal sowing period is from early March to July and earlier sowings may increase bean size. Harvest maturity should be investigated, either use a dry matter content of the beans or use tenderometer readings, of around 120-140 as a guide. The dry matter content method has been used in our trials and usually ranged from 20% to 28%. The actual window of harvest is about two weeks, after which the beans get too tough. Again there is a need to cooperate closely with the industry in order to get the exact specifications.

Some very good results were obtained last season in New Zealand with the use of BioPhos and fish oil products. (See attached). These methods would also lead to a more wider use of organic products.

Marketing
The discussions with the industry people present at the meetings were encouraging but more should be done to develop these contacts. Widen out on the methods of processing, although your aim may be to export fresh, try to get a processor interested in either freezing, freeze drying or dehydration. Other possibilities that could be explored are bottling or use in salads as a fresh product. Try to find out what process facilities there are available in Tasmania. This would also mean that a promotion action should be carried out to make the crop more acceptable to local people. (Radio or Television?).You also have many ethnic, (Japanese) tourist facilities in Tasmania which offers other outlets for the produce that cannot otherwise be exported. Develop the overseas market concept, apart from Japan, there could be new markets in Singapore, Indonesia or interstate? If possible, invite the overseas contacts to your research establishments, get them to taste the new products and get their opinion on a personal level first hand, rather than relying on the local industry. Perhaps entice them to become an active partner in the project, either by contributing financially or by committing themselves in a marketing sense. These methods have at times been adopted successfully, all or in part, in New Zealand with the introduction of new crops. All too often we have a blinkered view of what the traditional markets may or may not want, it may be rewarding to look side-ways for new developments.

A new development could be in the way of considering a product for the organic market in Japan, which is presently on the increase with higher prices than that for conventionally grown crops. Japanese awareness for healthier products is rapidly growing.

New Crops

Some discussions centered on other new vegetables, and some of the ones which could be suitable for a new market, are celeriac, daikon or burdock. The latter crop may require a substantial input and cooperation from a Japanese firm but the other two are easier to grow and market. Both celeriac and daikon can be used as fresh product in salads or dehydrated. Can be exported to Japan or used interstate. This may require some funding for growing a new crop with a variety trial and to promote some local interest among the public and supermarkets.

Conclusion and recommendations

Some good selections of soramame have been made and I suggest that these selections are confirmed next season, also investigate methods of improving the quality of the beans by adopting time-of-sowing trials and nutrition trials. Based on New Zealand experience the crop requires a high nutrition level and I would therefore recommend to investigate the use of BioPhos and fish oil as one of the means achieving this. The virus infection levels should be closely watched as once established could decimate the crop. I would recommend, **firstly**, to investigate the use of oil sprays perhaps combined with insecticide applications.

Secondly, investigate new ways of linking into a new market, by either looking at varying process methods or by looking at the options for organically grown crops. **Thirdly**, if at all possible explore ways of attracting an overseas (Japanese) partner linked into the project, if not financially then at least in a supportive way.

I would be happy to assist for a season in improving the soramame crop or indeed with any other "new" crop in Tasmania.

Acknowledgment

I was grateful for having had the opportunity of traveling to Tasmania and receiving the ***Visiting Research Scholarship of TIAR****. The visit hopefully opens the way of cooperating more closely with the development of new crops such as soramame in Tasmania. I am also grateful for the assistance I received from the many people from TIAR and DPIWE, to mention a few, Wendy Dwyer-Kimber, Rowland Laurance, Peter Simmul and Elizabeth Yeomans.*

New crops description

Burdock
Long roots, up to 1 metre long. Mostly used for fresh market but also processed when roots can be shorter. Presently grown in China, Taiwan, Thailand, Australia and exported to Japan. There may be a market for the Japanese winter. New potential is for burdock powder as condiment, but produce can be frozen, canned or used in sauce. A need for very light soils and it is a difficult crop to harvest.

Celeriac
European celery type of root, which is used in soups, in salads and dehydrated. It is a crop that may grow well in Tasmania and could also have a good potential in local salad bars in supermarkets and find a ready market in the restaurant trade.

Daikon
Long radish roots, can be processed, salted or dehydrated. Is mostly sold as a fresh crop. Shipping costs of fresh produce may be too expensive, therefore concentrate on processing.

New products

Chitin:
A water soluble product derived from crayfish shells, which can be used to either treat the seed or as a foliar product. Reputedly encourages plant growth and may have an anti-bacterial and anti-fungal effect. It can also be applied to the soil and the beneficial effect of that may improve over the years.

Poman:
This is a soybean derived product and the properties are claimed to be similar to that of Chitin. It can either applied to the soil or as a foliar application.

Fish oil product:
An Orange Roughy product mixed with Trychoderma, foliar applications increases yields and quality and possibly the oil component may kill small insects and could therefore be useful in the minimisation of virus carrying aphids. Seed treatment of sweet corn has produced stronger plant growth. A soil application combined with BioPhos, a rock phosphate product may even have better results.

BioPhos
BioPhos is made from reactive rock phosphate. Selected soil bacteria are cultured and added to it. As a result of inoculation and multiplication of these bacteria the rock phosphate is converted to a form that is available to fungi and plants. BioPhos is only 23% water soluble so it is resistant to leaching. BioPhos uses the bacteria and fungi to make the phosphate available and retain it in this form until required by the plant. BioPhos contains 13% phosphorous, 2% sulphur and 32% calcium. The fungi may be capable of releasing 10% nitrogen, 5% phosphorous and 3% potassium.

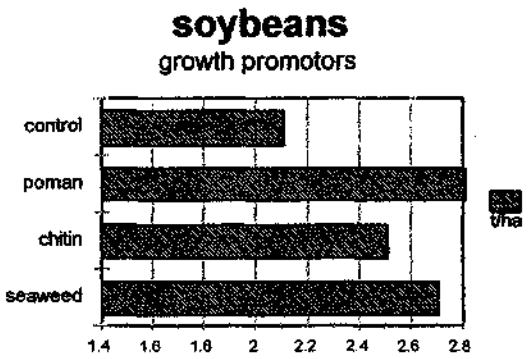


Figure 2

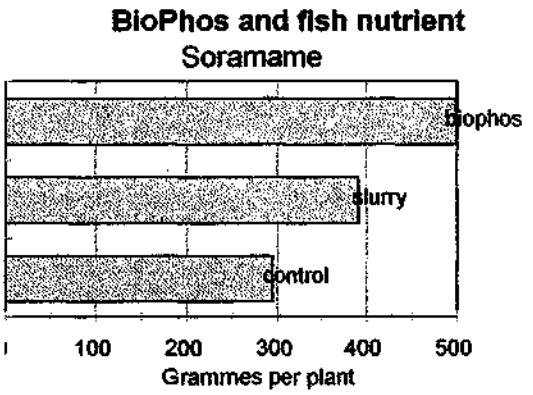
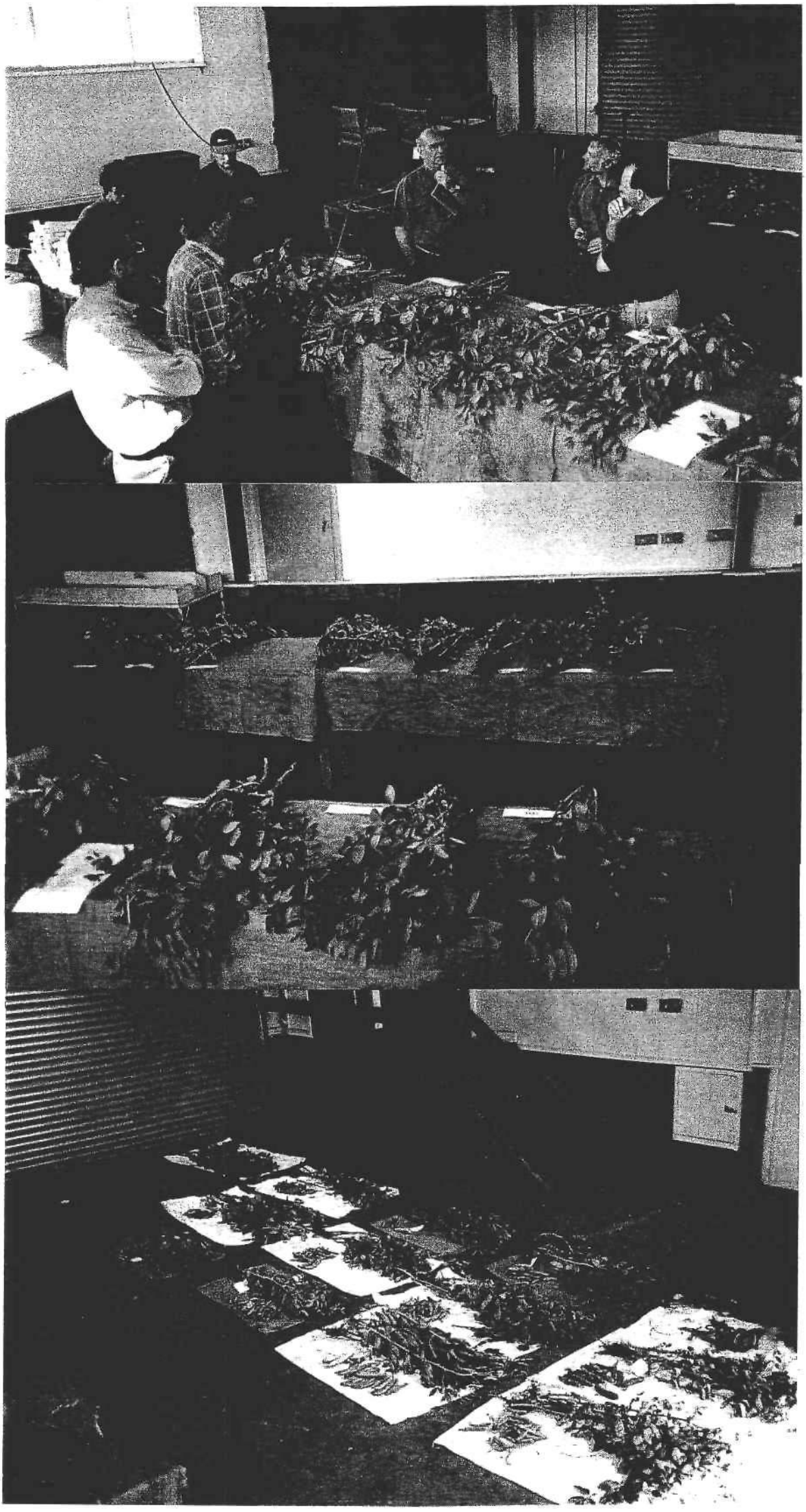


Figure 3

Illustrations

Figure 1	Cover photograph; Ryosai, a well known variety in Japan.
Figure 2	Growth promoters on soybeans
Figure 3	BioPhos on soramame
Photographs on page 9	Selection of broad bean varieties at Burnie



APPENDIX B

To: <Rowland.Laurence@utas.edu.au>
Subject: FEED BACK ON BROAD BEAN SAMPLES SENT 10 JAN 2002
Date: Thu, 21 Feb 2002 09:49:14 +1100
X-Mailer: Microsoft Outlook Express 4.72.3155.0

Dear Rowland,

Mr. Izutani from Tomei fruits advised us that both samples we sent him were suitable for the Japanese market. (He could not advise which was more suitable.)

I would like to comment that due to the market conditions in Japan this season, it would not have been financially viable to ship broad beans.

Best regards
Michael Segall

APPENDIX C

THE UNIVERSITY OF ADELAIDE

DEPARTMENT OF PLANT SCIENCE, WAITE CAMPUS
GLEN OSMOND, SOUTH AUSTRALIA 5064

Jeff Paull Phone: (08) 8303 6564 Fax: (08) 8303 7119
Email: jpaull@waite.adelaide.edu.au

To: **Roland Laurence** **Fax Number: 03 6430 4959**

From: **Jeff Paull**

Pages : **3** **Date: 25 Nov 1999**

Rowland,

This is the latest copy of the MTA that comes with seed from ICARDA.

517 and 1142 are held in trust.

Regards

Jeff

June 20, 1999

THE INTERNATIONAL CENTER FOR AGRICULTURAL RESEARCH IN THE DRY AREAS (ICARDA)

MATERIAL TRANSFER AGREEMENT (MTA)

The material described in the attached list is being furnished by the International Center for Agricultural Research in the Dry Areas (ICARDA) under the following conditions:

(A) For materials held in trust by ICARDA

ICARDA is making the germplasm described in the attached list available as part of its policy of maximizing the utilization of genetic material for research. The material was either developed by ICARDA; or it was acquired prior to the entry into force of the Convention on Biological Diversity; or if it was acquired after the entering into force of the Convention on Biological Diversity, it was obtained with the understanding that it could be made freely available for any agricultural research or breeding purposes.

The material is held in trust under the terms of an agreement between ICARDA and FAO, and the recipient has no rights to obtain Intellectual property Rights (IPR) on the germplasm or related information.

The recipient may reproduce the seed and use the material for agricultural research and breeding purposes and may distribute it to other parties provided that recipient is also willing to accept the conditions of this agreement.

The recipient, therefore, hereby agrees not to claim ownership over the material to be received, nor to seek IPR over that germplasm or related information. He/She further agrees to ensure that any subsequent person or institution to whom he/she may make samples of the germplasm available, is bound by the same provision.

ICARDA makes no warranties as to the safety or title of the material, nor as to the accuracy or correctness of any passport or other data provided with the material. Neither does it make any

warranties as to the quality, viability, or purity (genetic or mechanical) of the germplasm being furnished. The phytosanitary condition of the germplasm is warranted only as described in the attached phytosanitary certificate. The recipient assumes full responsibility for complying with the recipient nation's quarantine/biosafety regulations and rules as to import or release of genetic material.

Upon request, ICARDA will provide information that may be available in addition to whatever is furnished with the seed. Recipients are requested to furnish ICARDA performance data collected during evaluations.

The material is supplied expressly conditional on acceptance of the term of this agreement. The recipient's retention of the material constitutes such acceptance.

(B) **For materials not covered under the FAO/ICARDA agreement**

The recipient is not to seek or obtain any form of IPR without written permission of ICARDA. In such cases ICARDA and the recipient will negotiate the terms and conditions to be applied to any such IPR. In such negotiations ICARDA will seek to act in the best interests of developing countries.

Upon request, ICARDA will provide information that may be available in addition to whatever is furnished with the seed. Recipients are requested to furnish ICARDA performance data collected during evaluations.

The material is supplied expressly conditional on acceptance of the term of this agreement. The recipient's retention of the material constitutes such acceptance.

Large seeded broad beans for the Japanese market - HAL Project VG 97012

Project summary prepared for meeting of stakeholders, May 2002.

Background

The initial, three-year project commenced in July 1997 with the objectives of selecting lines of broad bean (*Vicia faba*) suitable for export to Japan and gaining agronomic information to support their production in Australia. In 2000, two years' further funding was provided by HAL to allow bulking of re-selections and further agronomic investigation. The work has been managed in collaboration with a stakeholder group consisting of Mike Badcock, Don Badcock, Field Fresh Tasmania, Harvest Moon and DPIWE and has comprised:

1. the introduction, selection, isolation and market appraisal of genotypes
2. a study of seed maturity to assist timing of harvest
3. the investigation of the effects of plant population and "stopping"
4. a test of machine harvesting

The project is due for completion at the end of May 2002.

Summary of findings

1. Introduction, selection, isolation and market appraisal of genotypes

Twenty-one lines were collected locally, from the national fababean program in Australia, from New Zealand and from Japan. Early evaluation, by the stakeholder group and a New Zealand consultant, was made on the basis of pod and seed characteristics – pod length, seeds per pod, seed size and seed fresh weight. The line Jumbo, being used commercially by Field Fresh, was included as a check. From 2000-01 field trial results (Table 1) the lines Imported, 3FB, 1142 and Jumbo were the best re-selected genotypes. These were bulked last year.

Table 1. Cultivar selection data 2000-01 (two sowing times for Jumbo and 1142)

Cv (sown 10/7)	Total pod wt t/ha	Marketable pod wt t/ha	Seed from marketable pods t/ha	Mean seed length from marketable pods mm
Imported	36.4	21.1	7.3	28.5
517	33.8	8.5	4.3	27.1
2FB	32.5	17.8	5.6	29.0
3FB	33.3	20.2	6.5	29.5
4FB	29.7	5.9	2.2	31.6
B16	31.5	17.2	5.5	28.6
1142	42.8	19.8	8.6	34.2
Jumbo	33.7	20.0	6.6	28.9
Cv (sown 31/7)				
1142 T2	44.0	21.8	9.2	32.7
Jumbo T2	44.9	22.8	7.7	30.0
P sig., lsd	0.01, 6.65	0.01, 3.78	0.01, 1.52	0.01, 1.30

The following quantities of these selections are now available:

Cultivar	First grade (kg)	Damaged (kg)	Total (kg)
Imported	35.5	5.5	41.0
3FB	0.4	0.0	0.4
1142	334.9	13.2	348.1
Jumbo	165.4	83.4	248.8

A response to HAL regarding the ownership of these lines has been deferred pending stakeholders' decisions on their future interest in them.

Samples of Imported and 1142 were sent to the Japanese market in January via JM Segall and Co. Mr. Izutani from Tomei fruits advised that both samples we sent him were suitable for the Japanese market. He could not advise which was more suitable.

2. Seed maturity

Jumbo samples sent to Japan in 1998-99 were said to be too variable in maturity. Therefore, growth analysis of pods and seed was carried out in the two subsequent seasons using plants, which were not "stopped", in order to try to identify a point in seed development where seed size was optimised before hilum darkening. Pod and seed length and fresh weight, seed dry matter and the development of hilum darkening, as a measure of seed maturity, were monitored by node in Jumbo, Imported and 1142 in 1999-2000. Jumbo and 1142 were similarly monitored in 2000-01 and main and lateral stems were also compared.

Seed maturity, as expected, was delayed at higher nodes and on lateral branches. Seed of marketable size (assumed to be >33mm long) was mostly restricted to the lowest two or three nodes in Jumbo and Imported, while 1142, with an inherently larger seed, was less restricted. While seed dry matter was maintained around 17-18 per cent through early development, the attainment of near maximum seed size generally coincided with seed dry matter values of twenty per cent. Hilum darkening began soon after seed dry matter values passed this level. Thus, monitoring seed dry matter content offers a way of assisting the prediction of optimum harvest time in the field.

3. The effects of plant population and "stopping"

The effects of plant density on yield of "un-stopped" plants of the line Jumbo were investigated in 1999-2000. It was found that, while total fresh pod yields rose to over 40 t/ha with high plant populations, applying the stringent criteria for marketable pods reduced yields to less than one-third of this figure. Best fresh seed yields (from marketable pods only) reached the equivalent of about 5 t/ha. Optimum populations for maximum marketable pod yield were 10-12 plants per sq m, where slightly above 50 per cent of pods were marketable. The percentage of pods, which were marketable, was reduced at low plant density.

In 2000-01, an experiment compared two times of "stopping" plants (1. when two pods were set and 2. when seven nodes had achieved full flower) with "unstopped" plants of Jumbo and 1142, as a possible aid to both increasing bean size and the effectiveness of sequential planting and harvesting.

Table 2. Effect of "stopping" on pod and seed yields of Jumbo and 1142

	Total pod wt t/ha	**Marketable pod wt t/ha**	**Seed from marketable pods t/ha**	**Mean seed length from marketable pods mm**
Cultivar				
Jumbo	30.18	16.54	5.35	30.75
1142	33.59	13.84	6.03	32.54
P sig	0.01	0.05		0.001
lsd 0.05	2.350	2.329		0.499
"Stopping"				
Nil	38.01	18.53	6.72	31.20
At 2 pods	24.85	11.52	4.54	31.80
At 7 fl nodes	32.78	15.53	5.79	31.94
P sig	0.001	0.001	0.025	0.05
lsd 0.05	3.450	2.852	1.419	0.612

While both "stopping" treatments reduced yield (Table 2), the 'seven node' treatment was less severe. Both stopping treatments increased seed size in Jumbo (by around four per cent) but had less effect on seed size in 1142.

The effects of plant density and "stopping" were again investigated in 2001-02 using Jumbo only.

Table 3. The effects of planting density and "stopping" on pod and seed yields of the cultivar Jumbo.

	Total pod yield t/ha	**Marketable pod yield t/ha**	**Total seed yield t/ha**	**Marketable seed yield t/ha**
Plant dens/sq m				
2	16.66	7.34	4.49	1.71
4	17.89	7.01	4.60	1.23
9	26.82	12.00	7.30	2.61
15	28.77	12.14	7.85	2.53
30	22.77	6.61	6.14	1.57
Sig		0.099	0.057	0.029
lsd 0.05		23.73	2.623	0.911
"Stopping"				
Nil	21.59	9.68	5.97	1.12
7 fl nodes	23.57	8.35	6.18	2.74
Sig				<0.001
lsd 0.05				0.447

In this trial (Table 3), optimal plant density was again 10-12 / sq m for both total and marketable pods and seed (all seed greater than 33mm in length). The yields of marketable seed appear low in the table as mean seed length in the cultivar Jumbo is less than 33mm. The "stopping" treatment employed had no significant effect on the total pod yield overall but tended to result in lower yields at low density and higher yields at high density. Small, overall, marketable pod yield reductions due to "stopping" were not statistically significant. While total seed yields showed a similar trend, the yield of marketable seeds was greatly improved by "stopping" plants. Monitoring of seed dry matter before the harvest of this trial again confirmed that a value of 20 per cent dry matter is a good indicator of optimal harvest time.

4. A test of machine harvesting

Two areas of Jumbo were planted in single rows 0.8m apart on 18 June and 9 July 2001 to attempt a mechanised harvest of pods from the stopped plants with a green (Phaseolus bean) harvester. The machine was ineffective, as indicated by the following (Table 4) comparison with hand-harvested sub-plots.

Table 4. Pod and seed yields from "stopped" Jumbo plants using mechanical and hand-harvesting.

		Total pod yield t/ha	Marketable pod yld t/ha	Marketable seed yld t/ha
First planting	Machine	11.00	0.50	0.89
First planting	Hand harvest	38.96	11.05	4.89
Second planting	Machine	abandoned	abandoned	abandoned
Second planting	Hand harvest	36.97	12.47	3.65

The orientation and position of the harvester's stripping mechanism was unsuited to the habit and height of the broad bean plant. It was considered that vertical orientation of a (helical) mechanism would be more effective. Harvesting the whole plant mechanically and semi-automated stripping of pods in the shed has been suggested as another option.

Rowland Laurence 22 May 2002.

APPENDIX E

Large-seeded broad beans for the Japanese market

Rowland Laurence

Tasmanian Institute of Agricultural Research

Project Investigators:
Dr Rowland Laurence, Leon Hingston, Elizabeth Yeomans, Patricia Saunders, Nigel Downward, Peter Simmul, DPIWE

Background:
This project has sought to assist the development of a new, fresh vegetable export industry based on the off-season supply of broad bean pods and/or podded beans to Japanese markets, through the introduction, selection and agronomic study of suitable genotypes in Tasmania. This moderate, but readily met, market opportunity has been identified by local export companies, for supply between November to January, when *soramame* prices have been high in Japan. In 2001-02, the final year of the project, market prices have dropped below a level required for export viability.

Objectives:
To access and select improved genotypes for production and market requirements by evaluating them for marketable traits, such as uniform, large beans and for productivity under local conditions. To test market samples and advise agronomy.

Work Undertaken and Result to Date:
The project has compared a range of introductions, including those grown in Japan, and carried out investigations into sowing rate and time and the maturity of marketable seed. The project has also maintained the purity of lines in isolation. Four lines have been selected for seed bulking for commercial testing. Samples have been accepted by Japanese buyers. Trial results have also provided information on the effect of "stopping" plant top-growth by pruning, together with data on the relationship between seed size and maturity characteristics, which is important for timely harvesting. The effectiveness of a mechanical harvester was investigated with results indicating that new machinery and harvesting methods would need to be developed if this approach is to be successful. The project's final report has recently been completed.

Technology Transfer Activities and Plans:
Interested export companies and growers have been part of a reference group through the project and are in positions to further develop production when market conditions improve.

Funding (amounts and sources):
HRDC Vegetable Levy - $112,340 over five years to June 2002.

Commencement and Completion Date:
July 1997 - June 2000. Now extended to June 2002.

Project Collaborators:
Field Fresh, Tasmania; Harvest Moon; Don Badcock; Michael Badcock; Peter Simmul, DPIWE.

Contact Details:
Dr Rowland Laurence, TIAR, University of Tasmania, GPO Box 447, Burnie, 7320. Ph: (03) 6430 4901 Fax: (03) 6430 4959. Email: Rowland.Laurence@utas.edu.au