Borage production

for oil and
gamma-linolenic acid

A report for the Rural Industries Research and Development Corporation

by Rowland Laurence

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Researcher Contact Details
Dr Rowland Laurence
Tasmanian Institute of Agricultural Research
PO Box 447/3523
Burnie Tasmania 7320

Phone: 03 6430 4901
Fax: 03 6430 4999
Email: Rowland.Laurence@utas.edu.au

In submitting this report, the researcher has agreed to RIRDC publishing this material in its edited form.

RIRDC Contact Details
Rural Industries Research and Development Corporation
Level 1, AMA House
42 Macquarie Street
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone: 02 6272 4539
Fax: 02 6272 5877
Email: rirdc@rirdc.gov.au.
Website: http://www.rirdc.gov.au

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Foreword

Borage oil contains a high level of gamma-linolenic acid, a human dietary supplement, for which there is strengthening international market demand. Borage is being grown increasingly for this extract, in comparison to the more traditional source, evening primrose. There is no significant commercial production of borage in Australia at present but commercial yields of seed elsewhere, in New Zealand, Canada and in the UK, where about half of world production occurs, are low due to the lack of improved commercial varieties and production practices.

This project has sought to investigate and recommend agronomic practices for borage when grown under local climatic conditions in order that future yields and profitability in Australia may allow supportive growers and processors to gain a competitive advantage in an expanding world market. This report provides information and recommendations on sowing time, plant population and harvest timing, which will be critically important facets of any future commercial borage production. Consideration is given also to other production practices.

This project was funded in major part from RIRDC Core Funds, which are provided by the Australian Government. The project was also funded in minor part by financial and in-kind contribution from the Natural Plant Extracts Coop. Soc. Ltd in Tasmania.

This report, a new addition to RIRDC’s diverse range of over 1000 research publications, forms part of its Emerging New Industries (Essential Oils and Plant Extracts) R&D program, which aims to support the growth of a profitable and sustainable essential oils and natural plant extracts industry in Australia.

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Simon Hearn
Managing Director
Rural Industries Research and Development Corporation
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7. The Tasmanian-based plant extracts company, Botanical Resources Australia, for discussion and assistance with commercial windrowing operations and the provision of windrowing machinery.
8. Dr Peter Lapinskas, consultant, for helpful discussion.

About the author

Dr Rowland Laurence, currently leads the Vegetable Research Group of the Tasmanian Institute of Agricultural Research (TIAR), having previously managed the Tasmanian Government’s research and extension effort on vegetables and field crops. TIAR is a joint venture between the University of Tasmania’s School of Agricultural Science and the Tasmanian Government’s Department of Primary Industries, Water and Environment. Having worked on the agronomy and nutrition of a range of tropical and temperate horticultural crops, Dr Laurence now leads research projects in the areas of new crops, horticultural agronomy and sustainable farming systems.
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<th>Description</th>
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<tbody>
<tr>
<td>BRA</td>
<td>Botanical Resources Australia</td>
</tr>
<tr>
<td>FSANZ</td>
<td>Food Standards Australia New Zealand</td>
</tr>
<tr>
<td>GLA</td>
<td>Gamma-linolenic acid</td>
</tr>
<tr>
<td>NPE</td>
<td>Natural Plant Extracts Cooperative Society Ltd.</td>
</tr>
<tr>
<td>PUFA</td>
<td>Polyunsaturated fatty acid</td>
</tr>
<tr>
<td>TIAR</td>
<td>Tasmanian Institute of Agricultural Research</td>
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Executive Summary

Borage (Borago officinalis L) is an herbaceous annual. It is a native of the Mediterranean region but now is cultivated around the world for its seed oil. This oil has a high proportion of gamma-linolenic acid, a polyunsaturated fatty acid used as a nutriceutical and dietary supplement. The market for this and other such products has grown strongly worldwide in recent years and this is predicted to continue. While evening primrose oil still enjoys the major share of demand for such oils, borage oil has a higher percentage of gamma-linolenic acid in its oil than does evening primrose, and is beginning to replace the former oil directly.

Borage has been considered previously as a crop for south-eastern Australia, with a RIRDC supported, development project between 1994-96 finding that borage was a more promising alternative than evening primrose. The author has also carried out genotypic improvement work on borage since 1998. With commitment shown to borage development both by a cooperative of Tasmanian growers and a downstream processor, a proposal to the RIRDC to carry out agronomic investigations on borage in 1999-2000 was successful. This work began in September 2000, with the objective of providing local information on key agronomic practices and recommendations for the production of borage.

This work has investigated the effects of sowing time, sowing rate and harvest timing on borage seed yield through field trials and large area observation of commercial harvesting techniques. While crop rotation, stale seed bed preparation, good crop germination and early vigour were the targeted means of weed control, one observation of herbicide application to post-emergent borage was carried out also.

Three field experiments investigating time of sowing effects were carried out in the consecutive seasons 1999-2002. Over this period, earlier sowing times were employed to counter the large reductions in seed yield, which were found to occur due to delayed sowings. The collective results of the three experiments showed that sowing the crop in early August was most conducive to high seed yield and that no yield benefit was apparent from sowing this line of borage in July. However, yields of dry borage seed were reduced by more than one-third when sowing was delayed by about one month and longer delays induced commensurate reductions.

The borage plant sheds its seed quickly upon maturity and the timing of windrowing, the initial harvest operation, was also found to be critical, this being consistent with other published work. Delaying harvest for a period of one week resulted in seed yield reductions of around fifty per cent and similar yield reductions occurred after a four-day delay. It was concluded that windrowing should be completed within one or two days of the loss from the plant of the first mature seed.

These experiments, therefore, have provided strong evidence of the critical importance of early sowing and exact harvest timing from the point of view of the crop’s profitability.

Observation and experimentation on the effects of sowing rate and row spacing were carried out in the consecutive seasons 2000-03 in large field plots, with the additional objective of making observations on the mechanical handling of the crop and demonstration. In the first and third of these seasons’ field operations, weather conditions resulted in the poor preparation of a stale seedbed for weed control and later than optimal sowing times. Under these conditions, increasing sowing rate improved the ability of the crop to compete with weeds and improved seed yields. In the second of these three seasons, 2001-02, improved seedbed preparation, the application of a pre-emergent desiccant herbicide and mechanical brush weeding allowed the crop to compete well with annual weeds. Results of this replicated experiment showed that field germination was marginally improved by decreasing the distance between the rows (i.e. increasing the distance between plants in the row) but this did not translate into significantly improved seed yields. Yields improved with increasing sowing rates. This experiment indicated that a sowing rate of 16 kg/ha may be worthwhile if seed germinability is poor. However, if high field germination can be
achieved, a sowing rate of 8 kg/ha may be sufficient. Given the prospective cost of seed, sowing more than 16 kg/ha of borage seed is unlikely to be worthwhile. While treatment yields were similar to commercial yields reported elsewhere, significant quantities of mature seed were found on the ground after the windrowing operation, which was considered timely. This suggested, therefore, that the windrower used was too harsh to return maximum seed yields. The use of a ‘softer’ windrowing machine, using a Draper belt mechanism, in reducing seed losses in the following season’s work was encouraging in reducing such losses. Other modifications to windrower cutter bar mechanisms may further limit seed losses by reducing sideways movement of the plant at the cutter bar and thence seed loss from shattering. A bulky windrow also may improve the retention of seed dislodged.

In a field observation of the effects on borage of the application of several post-emergence herbicides, Afalon®, Alicide®, Ramrod® and Stomp330® produced no visual symptoms or reduction in plant growth and these herbicides, therefore, may be worth further investigation in order to provide a chemical weed control option when required in growing borage.

The information and experience gained with the borage crop through this project have been extremely valuable in determining important field operational factors, without which successful borage production locally would have been unlikely. While this report concludes the current project, other work on aspects of genetic improvement of borage is still in progress and collaboration between a Sydney-based company and a grower member of this project’s stakeholder group has resulted in about eight hectares of borage being sown commercially in the current season, 2003-04. A local oil extraction facility, suitable for use with borage is also available. This crop, if successful, will provide sufficient borage seed to test the market potential of the local product. Speaking at a growers’ field day in October 2003 in Tasmania, the principal of the interested company indicated that, grower contracts could follow within two years.
Introduction

Background and literature review

Borage (Borago officinalis L) is an herbaceous annual growing to around one metre in height. It is native to southern Europe, northern Africa and Asia Minor but is also now cultivated around the world. One of three species of Borago, it is the only representative of the Boraginaceae which is currently grown for economic benefit, although other genera in the family contain some well-known weed species, such as Patterson’s curse/ Salvation Jane (Echium plantagineum). Borage has also been grown traditionally as a source of food for bees and as an ornamental. Its leaves, petioles and flowers have a pleasant and distinctive taste and have been used in cooking and salads (Osborne, 1999) as well as in traditional medicine for the treatment of swelling and inflammation, coughs and other respiratory complaints (Coon, 1963, Prakash, 1990).

Borage is grown commercially for its seed oil which, with its high proportion of the polyunsaturated fatty acid (PUFA), gamma-linolenic acid (GLA), targets the market for nutriceuticals and dietary supplements. This market has grown strongly worldwide in recent years and its growth is predicted to continue at a rate of more than ten per cent for the next five years. This demand follows increasing evidence that the quality of fats, as well as the quantity, in the human diet is important in terms of health, with unsaturated fats appearing to have a role in preventing atherosclerosis. PUFAs are not synthesised by the human body and must be acquired from specific foodstuffs. They are important precursors of physiologically active compounds, such as prostaglandins, thromboxanes and leukotrienes. Relevant PUFAs can be divided into two types – 18:2n-6 (omega-6) fatty acids and 18:3n-3 (omega-3) fatty acids, with the important omega-6 PUFAs, linoleic acid, gamma-linolenic acid and arachidonic acid found chiefly in vegetable oils and the important omega-3 PUFAs, alpha-linolenic acid, eicosapentaenoic acid and docosahexaenoic acid, found chiefly in fresh leafy vegetables and in certain fish oils (Meyer et al., 1999).

In borage, these values are offset by the presence of erucic acid and toxic pyrrolizidine alkaloids, although these are present at sufficiently low level to absent in practice the potential poisonous properties of the plant (Larsen et al., 1984, De Smet, 1991).

Borage has been of interest as a potential source of industrially useful oils for over forty years (Kleiman et al 1964) and grown commercially for its seed oil for more than twenty years in England (Anon., 1985, Long, 1985) and North America (Beaubaire and Simon, 1986, 1987; Janick et al., 1989). However, evening primrose (Oenothera sp.) is still the most established source of GLA, although borage is becoming a preferred source due to its high seed oil content (around 34 per cent) and the high proportion of GLA (around 23 per cent) in this oil (Whipkey et al., 1988). While evening primrose still enjoys the major share of demand, borage oil is beginning to directly replace the former oil. As some marketed products need GLA levels higher than those usually found in evening primrose oil, the use of borage oil is at present relative to both the quantity and quality of evening primrose oil in the marketplace. Other plant sources, such as blackcurrant are also used for the production of GLA (Simon, 1988).

Borage is now also grown in other countries, such as New Zealand and world production is estimated to be over 3,500 hectares, about half of which is grown in eastern England. The resulting global production of borage oil, in the order of 350 tonnes, is probably about one fifth or one quarter of evening primrose oil production.

Simon (1988) reported genetic variation in total fatty acids and GLA content among several lines but no variation in the desirable trait of reduced seed shattering/seed retention. Galway and Shirlin (1990) evaluated several hundred lines and concluded that yield, GLA content and erucic acid content were heritable characteristics but that the heritability of oil content was not demonstrated. GLA was negatively correlated with oil content but positively correlated with erucic acid content. Blue-flowered lines were higher in GLA content than white-flowered genotypes. Princen and Rossi (1996), working in Argentina,
also found this result, as did the author of this report in other project work. A dwarf line with poor agronomic characteristics but with a tendency towards seed retention has been found in UK and gained Plant Variety Rights in New Zealand in 2000 (Lapinskas, personal communication). Lines generated by mutation after treatment with ethyl methyl sulphonate are also claimed to have more seed-retention properties and their use in breeding programs has been suggested (De Haro Bailon et al., 1998).

Time of sowing investigations in Alberta, Canada recommended early sowing for maximum yield while nitrogen fertiliser application had little effect on yield and tended to decrease harvest index (El-Hafid et al., 2002). However, in Egypt, sequential foliar application of urea improved seed production but lowered seed oil content (Refaat et al., 2000). Suchorska and Osinska (1997) also found early sowing (April) in Poland to result in the highest seed yields.

Simpson (1993a) described the development and life cycle of borage and devised a code using eight reference stages based on those used for rape, except for inflorescence development, which is cymose in borage in contrast to the racemose development of the rape inflorescence. Simpson (1993b) also found that swathing (windrowing) of the crop at harvest resulted in higher yields than those after desiccation with diquat or glyphosate. Optimum swathing was estimated to be when the youngest flowers of apical cymes with shed or mature seeds were the first to the third from the base of the cyme, although assessment was particularly difficult in plots with low plant densities.

Attempts to control weeds in borage crops with herbicides have generally met with limited success. Stobart and Simpson (1999), after assessing eleven herbicides and combinations, concluded that only pre-emergence propachlor had a potential for safe use in borage and that none of the treatments used completely controlled the site’s weed flora, dominated by Chenopodium album, Galium aparine and Polygonum spp. Mechanical weed control methods have met with some success, depending on weed flora composition. Vester and Rasmussen (1989) found that a multiple row brush hoe gave more effective control of annual weeds in borage than did a conventional hoe, although effectiveness against Elymus repens was poor. However, Reddiex et al. (2001) compared three mechanical weed control implements in borage grown organically in New Zealand and found that tyne-weeded plots reduced weed dry matter significantly without affecting crop dry matter or yield.

**Borage investigations in Australia**

Borage has been considered previously as a crop for south-eastern Australia. In the early 1990s, the then Department of Agriculture in Tasmania made trial sowings, together with evening primrose and other ‘new’ crops but interest waned due to market down-turn (Hart, personal communication). A development project focusing on evening primrose was carried out with RIRDC support between 1994-96 (Douglas and Barrett, 1997) but this work found borage to be a more promising alternative than the former crop. For evening primrose, seed yields were estimated to be 150-250 kg per hectare, oil contents between 14-18 per cent and GLA contents between 9.8-10.4 per cent and these were considered to be unprofitable at that time. However, borage seed yields were estimated to be up to 2.05 tonnes per hectare, with oil contents of 25-33 per cent and GLA contents between 23.8-24.8 per cent. While such yield estimates indicated high profitability, they are well in excess of other published figures and also higher than those found in the investigations described in the current report.

In 1997, the Sydney-based company, Willala Agricultural Pty., expressed interest in the development of borage production and the Tasmanian Institute of Agricultural Research began work in 1998 to acquire and select suitable lines. This work continues at the present time with breeding of selected material.

After the first acquisition of seed lines associated with the above project work, which occurred in October 1998, four observation plots, each 30 sq m in area, were sown by the author and the project team at the Forthside Research Station in North-west Tasmania in November 1998. After incorporation of mixed fertilizer (13-14-13, broadcast at 500 kg/ha), three lines (ex Dans, USA; ex Bioriginal, Canada and ex
Scotia, UK) were sown in late November 1998 at 16 kg/ha and at 8 kg/ha. The plots were irrigated, weeded by hand and top-dressed with nitrogen fertiliser six weeks after emergence. In February 1999, dried seed yields were estimated from samples harvested by hand from areas of five sq m per plot and 250 g samples of cleaned seed were analysed for total oil content and GLA. Dried seed yields varied between 400-500 kg per ha, which were good compared with published yield data. Seed oil yields varied between 27.0 and 31.2 per cent, which were low compared with published figures, and GLA levels in oil varied between 23.3 and 25.6 per cent, which were similar to, or a slight improvement on, most published levels.

A proposal to carry out agronomic investigations on borage was made to the RIRDC in 1998-99 but was unsuccessful. However, with the commitment shown by the above company and further support pledged by a cooperative of Tasmanian growers, Natural Plant Extracts Cooperative Society Ltd. (NPE), a similar proposal in 1999-2000 was successful and resulted in the work reported here, beginning in September 2000. Borage is also one of several oilseeds investigated in the RIRDC Project UWA-47A, begun in 1998-99.

**Industry and research collaboration**

An industry reference group, comprising Bernard Brain, Chris Read and Rob Marshall of NPE, Michael Hart of the Tasmanian Department of Primary Industries, Water and Environment, together with TIAR researchers, was inaugurated at the start of this project in order to maintain stakeholder involvement and ensure industry-relevant outputs. An example of communication occurring around the meetings of this reference group is provided as Appendix A.

Several Australian and overseas industry contacts were made during this research, particularly in the initial acquisition of material in conjunction with the concurrent genotypic improvement project. While some have lapsed, with the realisation of the potential for Australian market competition, others remain. Dr Peter Lapinskas, previously leader of borage research for Scotia Pharmaceuticals, UK and now a consultant, has provided support and technical information and Dr Rosemary Cole, previously of Horticulture Research International, UK has provided comment on the European market situation.

The Tasmanian-based, plant extracts company, Botanical Resources Australia has collaborated in discussions on commercial windrowing and harvesting operations and has provided windrowing machinery for testing in borage plots. Discussions on prospects for borage oil in local markets were held with the Melbourne-based Clover Corporation.
Objectives and approach of the project

Objectives

The RIRDC sub-program, Essential Oils and Plant Extracts aims to support the growth of a profitable and sustainable essential oils and natural plant extracts industry in Australia, through strategies which, in part, develop genotypes and provide agronomic systems for products with prospects of commercial viability.

The objective of work reported here has been to provide local information on key agronomic practices for the production of borage and, with reference to relevant overseas information, provide recommendations for the commercial production of borage in south-eastern Australia.

The poor seed retention associated with borage required that optimal harvest time and harvest methods be derived for local conditions and that optimal sowing time, plant population and weed control methods defined. While other husbandry practices, such as fertiliser and water requirements are important, they were considered to be beyond the scope of the work reported here.

Approach

Seed was collected from the lines sown in November 1998 in the initial observations briefly described above. Seed of one of these lines found thereafter to be in largest quantity was used for all subsequent agronomic investigations described in this report. This line of seed was supplied by Dr Peter Lapinskas, who indicated it was a landrace used by him in his work with Scotia Pharmaceuticals, UK, which was later replaced with improved material. The line was included in genotype screening trials carried out by the author in other project work and was found usually to rank in the second quartile of genotypes tested with regard to seed yield. In 2002, Dr Lapinskas indicated to the author that Scotia Pharmaceuticals’ work in this area had ceased and that no ownership claims on this line were known to him or, indeed, likely to be made.

The approach taken in this work, therefore, was to investigate the effects of sowing time, sowing rate and harvest timing on borage seed yield through replicated field trials. In the first years of the project work, restrictions on the quantity of seed available necessitated using small plots and hand harvesting. In the latter seasons, larger plot sizes were able to be employed and commercial harvest techniques investigated. Most investigations of sowing date and harvest timing were carried out using small plot experiments, while sowing rate and mechanical harvesting observations were carried out on plant material grown in large plots. While crop rotation, stale seed beds, good crop germination and early vigour were considered to be the reasonably reliable means of weed control in large plots, one simple observation of the effects of herbicide application to post-emergent borage was carried out in 2001-02.

In chronological summary, therefore, the following experiments were carried as part of this project:

In 1999-2000, a field trial was carried out investigating the effects of variation in sowing time and harvest timing.

In 2000-01, this work was repeated. In addition, a first attempt was made to sow, windrow and harvest large plots mechanically. Two sowing rates were used.

In 2001-02, sowing rates were compared again in large plots and spacing between rows was also varied in an attempt to observe the effects on mechanical weed control. Time of sowing investigations were finalized with a small plot experiment and a simple observation of herbicide applications to borage was carried out.

In 2002-03, a commercial grower was enlisted to grow a large area demonstration.
The project work, together with the acknowledgement of the funding and in-kind support provided by the RIRDC and NPE, has been publicised at formal seminar presentations, grower and industry field days, in the local rural and daily press, in State Department of Primary industries, Water and Environment topical newsletters (see Appendix B), in radio interviews and in the Tasmanian Institute of Agricultural Research Annual Report.
Timing of sowing and harvest studies

1999-2000

Method
A field experiment investigating the effects of variation in sowing time and harvest timing was sown by hand at the University/TAFE Farm near Burnie in North-west Tasmania. Plots were 5m long and 1.6m wide (four rows) and there were six replications of each treatment in the randomized block design. Compound fertiliser (11:13:19) at 500 kg/ha was broadcast and incorporated before sowing borage seed at a rate of 16 kg/ha. Plots were fully irrigated on a schedule based on an estimated deficit of 40 mm and weeded by hand. Three sowing times were compared: 8 September 1999, 18 October 1999 and 8 December 1999. Dates of emergence and when fifty per cent of plants in a plot had commenced flowering (visual estimate) were recorded. Plots sown on the 18 October 1999 were duplicated to allow the comparison of two harvest times. The first of these was carried out when the first two or three mature seeds were found upon a 0.5 sq m sheet placed beneath the plants. The maturity was taken to reflect the optimum time prescribed by Simpson (1993). The second harvest treatment was carried out seven days later. Plants were dried and threshed and the seed re-cleaned and weighed. Analysis of variance was performed on the data.

The line used above was sown also on 24 September 1999 in a comparison of several genotypes carried out adjacent to the above field trial. To limit laboratory costs, oil and GLA contents determined for this line grown in the latter trial were taken as representative of those in the former field trial.

Results and Discussion
Dates of emergence, 50 per cent first flower and harvest for the four treatments are shown in Table 1. Seedlings emerged from Treatment 1 after 14 days, from Treatment 2 after 10 days and from Treatment 3 after 9 days. Times between emergence and flowering were commensurately accelerated but little difference was found between the periods between flowering and harvest for the different sowing times. This suggests that seed ripening may be more dependent on climatic factors than other growth phases.

Table 1. Dates of emergence, initiation of flowering and harvest, together with clean seed yields returned from treatments in the time of sowing and harvest timing experiment, 1999-2000.

<table>
<thead>
<tr>
<th>Treat</th>
<th>Plant time</th>
<th>Emergence</th>
<th>Flowering</th>
<th>Harvest</th>
<th>Seed yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8 Sept 1999</td>
<td>22 Sept 1999</td>
<td>29 Nov 1999</td>
<td>10 Jan 2000</td>
<td>650.5</td>
</tr>
<tr>
<td>2a</td>
<td>18 Oct 1999</td>
<td>28 Oct 1999</td>
<td>18 Dec 1999</td>
<td>31 Jan 2000</td>
<td>446.0</td>
</tr>
</tbody>
</table>

Least significant difference between any two treatments (P=0.05) = 129.6 kg/ha

Large reductions in seed yield occurred and were due to delayed sowing time. However, seed yields from both Treatment 1 and Treatment 2a compared favourably with published values of experimental and commercial borage yields. The values suggested that earlier sowing dates should also be compared in further experiments.

The very critical nature of harvest timing was shown by the seven day delay between Treatments 2a and 2b resulting in a yield reduction of 44 per cent. The trial site was reasonably exposed, windy conditions
were frequent and it was observed that such weather, even for short periods of time, resulted in significant seed loss.

2000-2001

Method
A similar experiment was carried out in the following season. The same line of borage was sown at a rate of 16 kg/ha in field plots 5m long and 1.6m wide (four rows) at the Forthside Research Station near Devonport in Tasmania. Three replications of each treatment were sown and four sowing times and two harvest timings were compared in a split-plot design. This further investigation of harvest timing was considered worthwhile in order to establish whether a harvest intermediate to those used in the previous year’s experiment might return improved yields. While a first harvest treatment (Harvest 1) was carried out at the initiation of seed shedding, as defined in the previous season, a second harvest treatment (Harvest 2) was carried out four days after the first.

Compound fertiliser (7:12:19) at 500 kg/ha was again broadcast and incorporated before sowing and plots were again fully irrigated and hand-weeded when required. In addition, Fusilade® was applied to all plots on 16 October 2000 at 2 mL/L by knapsack sprayer to assist in controlling weed grasses. Urea (50 kg/ha N) was applied to each time of planting treatment at the initiation of elongation of the primary stem. Sowing treatments (main plots) were begun earlier than in the previous season with the first being 4 August 2000, the second, 24 August 2000 and the third was carried out on 15 September 2000.

As in the previous season, harvests were carried out by hand and completed as early in the day as possible. Plants were dried and threshed and the seed re-cleaned and weighed. Analysis of variance was performed on the data.

Results and Discussion
Emergence was delayed with early sowing but seed yields were improved (Tables 2 and 3). Emergence of the earliest sowing took 16 days compared with the 11 days required for borage sown in early October.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Seed yield (kg/ha)</th>
</tr>
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<tbody>
<tr>
<td>Sown 4/8/00</td>
<td>367.2</td>
</tr>
<tr>
<td>Sown 24/8/00</td>
<td>315.7</td>
</tr>
<tr>
<td>Sown 15/9/00</td>
<td>198.2</td>
</tr>
<tr>
<td>Sown 4/10/00</td>
<td>135.3</td>
</tr>
</tbody>
</table>

Least significant difference between any two treatments (P = 0.01) = 67.86 kg/ha
Table 3. Dates of sowing, emergence, flowering and harvest, together with resultant mean dry seed yields of borage treatments (interactions) in the 2000-01 field trial.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Emergence</th>
<th>Flowering</th>
<th>Seed yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sown 4/8/00</td>
<td>20/8/00</td>
<td>3/11/00</td>
<td>482.3</td>
</tr>
<tr>
<td>Sown 4/8/00</td>
<td>20/8/00</td>
<td>3/11/00</td>
<td>252.0</td>
</tr>
<tr>
<td>Sown 24/8/00</td>
<td>8/9/00</td>
<td>14/11/00</td>
<td>401.7</td>
</tr>
<tr>
<td>Sown 24/8/00</td>
<td>8/9/00</td>
<td>14/11/00</td>
<td>229.7</td>
</tr>
<tr>
<td>Sown 15/9/00</td>
<td>2/10/00</td>
<td>27/11/00</td>
<td>223.3</td>
</tr>
<tr>
<td>Sown 15/9/00</td>
<td>2/10/00</td>
<td>27/11/00</td>
<td>173.0</td>
</tr>
<tr>
<td>Sown 4/10/00</td>
<td>15/10/00</td>
<td>15/12/00</td>
<td>123.3</td>
</tr>
<tr>
<td>Sown 4/10/00</td>
<td>15/10/00</td>
<td>15/12/00</td>
<td>147.3</td>
</tr>
</tbody>
</table>

Least significant difference between any two treatments (P = 0.01) = 95.97 kg/ha

The experiment has shown again that delayed sowing is very detrimental to yield of borage in Tasmania, with very significant (P < 0.01) reductions in yields across sowing times. Delaying harvest for a period of four days, compared with the seven-day delay employed in the previous year’s experiment, again resulted in very large seed yield reductions (P < 0.01). Sowing time effects and harvest timing effects, however, were found to significantly (P < 0.01) interact, with harvest timing delays in late sowing treatments resulting in less seed losses than did harvest delays employed with early sowings. While this interactive effect may be of interest in, perhaps, reflecting changes over sowing times in plant habit and/or the components of seed yield, this experiment reinforces the critical importance of early sowing and exact harvest timing from the point of view of the crop’s profitability.

This experiment, while illustrating these effects well, failed to identify an optimum time for sowing borage, with respect to seed yield, and, therefore, the need for a further experiment was indicated.

2001-2002

Method
The same line of borage again was sown at a rate of 16 kg/ha in field plots 5m long and 1.6m wide (four rows) at the Forthside Research and Demonstration Station near Devonport in Tasmania. Plots were sown at five times in 2001, the earliest of these being one month earlier than the earliest treatment sown in the previous year. Sowing dates of the five treatments were 4 July, 25 July, 15 August, 5 September and 26 September. Three replications of these five treatments were used in a randomized block design. Changes in harvest timing were not included in this season’s experiment as previous results showed conclusively that timely harvests were essential to maximise seed yields. Mixed fertilizer (500 kg/ha of 11.12.19) was pre-drilled before sowing and plots were top-dressed with 50 kg/ha of nitrogen as ammonium nitrate at the initiation of flowering. Plots again were fully irrigated and weeds controlled with a pre-emergence application of a desiccant herbicide, a post emergent application of Fusilade® and subsequent hand weeding. Net plot areas were harvested once by hand, plants dried and seed threshed, cleaned and weighed. Analysis of variance was performed on the data.

Results and Discussion
The results of this experiment are shown in Table 4. Treatment mean seed yields again reflected large reductions with delayed sowing. Individual plot values were variable and with a subsequent, high coefficient of variation (29.0%) for the trial, these treatment differences were not statistically significantly different (P=0.05). However, treatment means were consistent with the data from previous experiments,
showing that early August sowing was most conducive to high seed yield. No yield benefit was apparent from sowing this line of borage in July.

Table 4. Dates of sowing, emergence, flowering and harvest, together with resultant dry seed yields of borage treatments in the 2001-02 field trial.

<table>
<thead>
<tr>
<th>Sowing date</th>
<th>Emergence date</th>
<th>Flowering date</th>
<th>Harvest date</th>
<th>Seed yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/7/01</td>
<td>25/7/01</td>
<td>17/10/01</td>
<td>29/11/01</td>
<td>361.4</td>
</tr>
<tr>
<td>25/7/01</td>
<td>14/8/01</td>
<td>9/11/01</td>
<td>14/12/01</td>
<td>474.7</td>
</tr>
<tr>
<td>15/8/01</td>
<td>1/9/01</td>
<td>20/11/01</td>
<td>31/12/01</td>
<td>496.5</td>
</tr>
<tr>
<td>5/9/01</td>
<td>20/9/01</td>
<td>29/11/01</td>
<td>4/1/02</td>
<td>264.7</td>
</tr>
<tr>
<td>26/9/01</td>
<td>9/10/01</td>
<td>7/12/01</td>
<td>14/1/02</td>
<td>131.8</td>
</tr>
</tbody>
</table>

Treatment means not statistically significant at P=0.05 level.

The results of the three years’ field trials shown that seed yields of borage are greatly lessened by sowing the crop after August and, as July sowings were shown to have no positive benefit on seed yields, early August is likely to be the best target date for this field operation.
Sowing rate and spacing

Sowing rates used in 1999-2000, for the first observational plots of borage grown in relation to the work reported here, were eight and 16 kg/ha. The lower of these rates was that indicated by the literature and personal communication with overseas growers and the latter rate was used to ensure reasonable plant stands with seed lines having a relatively poor germination rate (around 50 per cent). In subsequent seasons, seed collected from the previous year’s agronomic experiments was re-cleaned and the highest grades (based on seed size and colour) used for comparisons of sowing rate and spacing. These latter seed lots generally achieved germination rates of between 75 – 90 percent in laboratory tests. Consequently, sowing rates used in the work reported here were determined and reported in terms of gross weight of seed sown per ha. This was considered to be adequate, given the alternate objective of easily demonstrating the work to interested growers and the large plots generally used in this work. Large plots were also employed in this work to make observations on the mechanical handling of the crop. The seed line used in this work again was that employed in the experiments described in Chapter 3, although contamination with other genotypes may have gradually become an issue over seasons, given the out-crossing nature of reproduction in borage. The objectives of comparing sowing rates in this work were to determine whether increasing sowing rate above eight kg/ha would be profitable in terms of increased seed yield. As few herbicides are registered currently for use in borage and borage production without, or with low, chemical pesticide inputs may be desirable in the marketplace, improving crop competitive ability through increasing sowing rate may be economically worthwhile.

Plots were grown in each of the three seasons (2000-03).

2000-2001

Method

Three plots, each 150 sq m in area were sown on 17 October 2000 into a krasnozem soil at the University Farm, Burnie in Tasmania, with the dual objectives, as noted above, of observing the effectiveness of locally available commercial machinery for sowing, windrowing and harvesting borage and of comparing three sowing rates. Individual plots were sown at rates of 8, 16 and 32 kg of seed per ha (treatments were not replicated) with an Accord pneumatic seed drill. A mixed fertilizer (7:12:9) was pre-drilled at the rate of 400 kg/ha. Preparation of a stale seedbed from a previous pasture phase, as a weed control measure, was attempted but weather conditions allowed one cultivation only to occur after ploughing and prior to the October sowing date indicated. No herbicides or fungicides were applied to the plots, which were irrigated by one, median pass of a travelling-gun, hard-hose irrigator when evaporative deficits reached 50mm. Plots were windrowed using a Hesston self-propelled machine, supplied and operated by the Tasmanian pyrethrum producing company, Botanical Resources Australia, on 28 January 2001. Harvesting of windrows was completed on 8 February 2001 using a Class cereal combine-harvester with a 2.4m front and tyned pick-up reel, modified for plot work with a small bag collection facility. Seed was re-cleaned and weighed.

Results and Discussion

The plots germinated well but weed growth quickly provided severe competition for the crop, presumably due to the failure to ensure an effective, stale seedbed. The plot with the highest sowing rate (32 kg/ha) competed with this weed growth reasonably effectively compared with those, which had been sown at lower rates. Windrowing was carried out some four days later than the observed, optimum date, due to the limits on the machine’s availability and some seed was present on the soil surface before windrowing. While the machine produced an effective windrow, with the cut plant material well supported and exposed on uncut stalks, the standard sickle-bar cutting mechanism was seen to result in seed loss to ground before the cutting front, presumably through vibration and disturbance of standing borage plants prior to cutting.
While the Claas harvester was not able to provide a clean seed sample, little loss of seed was seen to occur from the pick-up mechanism or from the rear of the machine. Recleaned, dry seed yields from the three plots are shown in Table 5.

**Table 5. Yields of large plots sown at three rates and mechanically harvested, 2000-01.**

<table>
<thead>
<tr>
<th>Sowing density (kg/ha)</th>
<th>Seed yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>39.7</td>
</tr>
<tr>
<td>16</td>
<td>67.2</td>
</tr>
<tr>
<td>32</td>
<td>144.0</td>
</tr>
</tbody>
</table>

The poor preparation of a stale seedbed for weed control and lack of (in hindsight) a seedling desiccant herbicide application prior to emergence of the borage, together with late sowing and windrowing resulted in poor seed yields from the three plots. The ability of the crop to compete with weeds, however, indicated that improved timeliness of the above operations could produce good results.

**2001-2002**

After the previous year’s observations, the need to obtain further information on seeding rates and mechanical operations was recognized, as was the requirement for replicated data on the topic.

**Method**

A field trial was carried out, therefore, in season 2001-02 on an area of 0.55 ha of krasnozem soil at Forthside Research and Demonstration Station, near Devonport in North West Tasmania. The area had grown an oat crop for green manure in the previous season and a stale seedbed was prepared from July 2001. Three rates of sowing (8, 16 and 32 kg/ha) again were compared, together with two inter-row spacings in an attempt to find whether a more orthogonal distribution of seed would improve the crop’s competitive ability. The plots were sown on 28 August 2001 with an Oyjord coned plot-seeder and 125 and 250 mm inter-row distances were used as treatments. Mixed fertilizer (11:13:19) was pre-drilled at a rate of 400 kg/ha before sowing. Plots were each 3.0 m wide and 82.0 m long and were sown contiguously. Each of the six treatments was replicated four times in this factorial design. A desiccant herbicide was applied immediately prior to germination. Germination counts were made in three, one sq m, randomly selected quadrats in each plot. A mechanical brush weeder was passed though the trial when plants were in the early rosette stage and some poppy re-growth plants were removed by hand in October 2001. While preparations for irrigation were made, the trial was not irrigated due to regular rainfall during the growing season. Fifty kg/ha of urea were applied to all plots at the beginning of stem elongation.

Plots were windrowed on 6 December 2001, again using a Hesston self-propelled machine, supplied and operated by the Tasmanian pyrethrum producing company, Botanical Resources Australia. Wet weather continued after windrowing and, therefore, interim yield data were collected on 24 December 2001 from 10 m lengths of windrow in each plot (equivalent to 24 sq m surface area) after artificial drying and passing plots through a stationary thresher. A further set of identical samples was taken on 18 January as it was feared that persistent wet weather would destroy the trial. The remaining windrows eventually dried and were harvested with a Claas grain harvester in February 2002. Weight of dry seed was recorded and analyses of variance carried out.

**Results and Discussion**

Field germination was mediocre. The three sowing rates applied reflected the placement of about 45, 90 and 180 seeds into one sq m of soil area and mean germinations from these sowing rate treatments were only 21.8, 47.9 and 84.5 plants/sq m respectively (Table 6). Analysis of germination data showed that, in
addition to sowing rate effects, increasing the number of rows sown (i.e. increasing the distance between plants in the row) improved germination significantly (P<0.001) and that the interaction between sowing rate and inter-row spacing was also significant (P<0.01).

**Table 6. Mean values of field germination of borage sown at three rates and two inter-row distances in 2001-02 field trial.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean germination (plants/sq m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sowing rate (kg/ha)</td>
<td>Inter-row spacing (mm)</td>
</tr>
<tr>
<td>8</td>
<td>125</td>
</tr>
<tr>
<td>8</td>
<td>250</td>
</tr>
<tr>
<td>16</td>
<td>125</td>
</tr>
<tr>
<td>16</td>
<td>250</td>
</tr>
<tr>
<td>32</td>
<td>125</td>
</tr>
<tr>
<td>32</td>
<td>250</td>
</tr>
</tbody>
</table>

Lsd between any two means (P=0.01) = 5.3

The crop grew well and, with the assistance of the mechanical brush weeding, smothered most weeds. While an understorey of annual weed species was present at the time of windrowing these interfered very little with growth or the (eventual) harvesting from the dry windrow.

Table 7 shows the yields obtained from samples of windrowed plots on 24 December 2001. At this time plots were semi-dry and the samples were further dried artificially.

**Table 7. The effect of three sowing rates and two row spacings on borage seed yields obtained from dried windrow samples on 24 December 2001.**

<table>
<thead>
<tr>
<th>Sowing rates (kg/ha)</th>
<th>Mean seed yield (kg/ha)</th>
<th>Row spacings (mm)</th>
<th>Mean seed yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>211.7</td>
<td>125</td>
<td>287.0</td>
</tr>
<tr>
<td>16</td>
<td>290.5</td>
<td>250</td>
<td>270.2</td>
</tr>
<tr>
<td>32</td>
<td>333.7</td>
<td></td>
<td>Not sig.(P=0.05)</td>
</tr>
</tbody>
</table>

Lsd (P=0.001) 25.3

Yields improved with increasing sowing rates, with the sowing rate treatment means being significantly different (P<0.001). The improved germination in narrow rows illustrated in Table 6 did not translate into significantly improved seed yields. These yields represent those, which may have been mechanically harvested from the windrow given better seasonal drying conditions. While they are similar to commercial yields reported elsewhere, significant quantities of mature seed were found on the ground beneath the windrow after the windrowing operation. This suggested that the windrower used was too harsh to return maximum seed yields. The windrower incorporated an auger feed mechanism, which may have been conducive to seed shattering. Modifications, such as a “double cut knife system” or Draper front with conveyor systems may well have improved the yields retrieved.

This experiment indicated that a sowing rate of 16 kg/ha may be worthwhile if seed germinability is similar to that found in the trial. However, if high field germination can be achieved, a sowing rate of 8 kg/ha may be sufficient. Given prospective seed costs of, for example, $10 per kg and product perhaps valued at $5 per kg, sowing more than 16 kg/ha borage seed is unlikely to be worthwhile.
Wet weather conditions persisted through January and further samples were taken from the windrow on 18 January 2002. Table 8 shows the yields obtained from these samples.

Table 8. The effect of three sowing rates and two row spacings on borage seed yields obtained from dried windrow samples on 18 January 2002.

<table>
<thead>
<tr>
<th>Sowing rates (kg/ha)</th>
<th>Mean seed yield (kg/ha)</th>
<th>Row spacings (mm)</th>
<th>Mean seed yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>117.0</td>
<td>125</td>
<td>177.3</td>
</tr>
<tr>
<td>16</td>
<td>194.8</td>
<td>250</td>
<td>185.4</td>
</tr>
<tr>
<td>32</td>
<td>232.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lsd (P=0.001) == 45.9

While seed losses were sustained from the windrows due to the unusually prolonged wet conditions experienced through January and early February 2002, the windrows remained substantially intact and Table 8 shows that the majority of seed stayed in the undisturbed windrow and was eventually harvested.

2002-2003

The seed quantity gained from the previous year’s experiment described above allowed the transfer of this work to a larger demonstration in 2002-03. Therefore, following discussions with the industry reference group, an agreement was reached with another grower member of the project stakeholder, NPE, to sow an area of about one hectare. This again included a simple comparison of sowing rates.

Method

An area of sandy loam over clay on a commercial property near Cressy in Northern Tasmania was selected for this work. An attempt to prepare a stale seedbed for weed control was made by the grower but weather conditions limited this to two cultivations. An area of approximately 1.2 ha was sown on 25 October 2002 with a Fiona seed drill, after fertilizer (300kg/ha 8:4:10) had been broadcast prior to the previous cultivation. The area was sub-divided in eight plots, to which four replicates each of two sowing rate treatments (9 and 16 kg/ha) were ascribed. All plots were 9m wide but varied in length as determined by available area. One inter-row spacing of 225mm was employed.

A desiccant herbicide was applied immediately prior to germination but no other weed control was employed. Irrigation was managed by grower, who also windrowed the area between 22 and 24 January 2003. For seed yield measurement, plants from 9 sq m areas within each plot were harvested by hand on 21 January, four days after first seeds were found to be shed. These samples were dried, threshed, re-cleaned and weighed. Lengths of windrow equivalent to 21 sq m areas were also collected from each plot area on 11 February 2003, for an additional estimate of seed yield after threshing and re-cleaning the samples. In selecting plot areas for these hand-harvest estimates, a decision was made not to make such selections randomly but to utilize areas where the crop had overcome weed growth to a reasonable extent. This was done in the interests of gaining both information on the crops potential in the conditions experienced and data related to seeding rate treatments. Analysis of variance was performed on the data.

Harvesting was completed on 7 March 2003 with the Class, 2.4m front, harvester previously used.

Results and Discussion

Germination was poor and variable, due to an uneven seedbed, which exacerbated uneven moisture distribution. With the poor early competition of the crop against weed growth, areas of fat-hen
(Chenopodium) and wild turnip (Raphanus) proliferated. Growth of individual borage plants varied to the extent that selection of a time for windrowing was difficult and a compromise was made in accepting some seed shedding from earliest plants to allow later plants to contribute to yield.

Table 9. The effect of two sowing rates on borage seed yields obtained from a pre-windrow sample harvest and a windrow sample harvest in Cressy demonstration plots 2002-03.

<table>
<thead>
<tr>
<th>Sowing rate treatment (kg/ha)</th>
<th>Pre-windrow sample harvest (kg/ha)</th>
<th>Windrow sample harvest (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>282.5</td>
<td>222.7</td>
</tr>
<tr>
<td>9</td>
<td>183.0</td>
<td>122.9</td>
</tr>
<tr>
<td>Mean</td>
<td>232.75</td>
<td>172.80</td>
</tr>
<tr>
<td>Significance level (P)</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>Lsd at above level of P</td>
<td>97.90</td>
<td>57.16</td>
</tr>
</tbody>
</table>

Results show that the higher of the two sowing rates again improved borage yield. Germination levels in the field, however, were poor, due largely to seedbed quality. Generally, only one-third to one-quarter of seed sown resulted in established plants. As concluded from the previous year’s experiment, this again suggests that the lower sowing rate may have been adequate if the field germination had been high.

While this large area sowing was primarily intended to assess and demonstrate the potential of borage as an alternative crop, the exercise illustrated some of the pitfalls in introducing the crop into a commercial enterprise. The change in soil type at this location, compared with those used previously, indicated the high level of attention which is required in seedbed preparation for good establishment. To this end, rolling the paddock after sowing to ensure good contact between soil and seed in order may be worthwhile. Seed yields obtained were also restricted by the late sowing date. However, the successful use of a ‘softer’ windrowing machine, using a Draper belt mechanism, in reducing seed losses in this operation was encouraging.
Observations on weed control

Borage investigations in the current project quickly demonstrated that the crop has an ability to compete well with annual weed species if sown early and established well. The usefulness of preparing a stale seedbed, while not demonstrated well in the current work, is likely to enhance the crop’s early establishment. As the successful use of a brush-weeder in the 2001-02 season shows, the potential for use of mechanical weeding equipment offers some surety for those growers who are able to acquire the correct implement, but the operation must be carefully controlled. As failure of these techniques impacts greatly on borage seed yields, the need for a ‘last resort’ chemical herbicidal remedy was considered important. Indications were provided to the author by overseas collaborators that programs of chemical weed control in borage are being developed but specific information was not given. Therefore, in 2001-02 an initial observation was carried out to investigate the effects of some widely-used, commercial herbicides on borage plants as part of the current project. Herbicides active against annual broad-leaved weed species were targeted. While weedy grasses are unlikely to compete strongly with borage, the herbicide fluazifop (Fusilade®) may be used for the control of grass weeds in culinary herbs, including borage (NRA, now FSANZ, cited in Infopest, Queensland DPI, September, 2000).

Method
This observation was carried out at Forthside Research and Demonstration Station, near Devonport in North West Tasmania in season 2001-02. Borage was sown at a rate of 16 kg/ha in field plots 5m long and 1.6m wide (four rows) on 5 September 2001 and mixed fertilizer (500 kg/ha of 11.12.19) was pre-drilled before sowing. The following herbicides were applied on 11 and 12 October 2001 over the borage plants, which were completing the rosette stage: Afalon® (500g/kg linuron) at a rate of 1.5 kg/ha, Allicide® (600g/l chloropropham) at a rate of 4 l/ha, Command 480® (480g/l clomazone) at a rate of 1 l/ha, Gesatop 500® (500 g/l simazine) at a rate 1 l/ha, MCPA 500 ® (500 g/l 2-methyl-4-chlorophenoxyacetic acid) at a rate of 11/ha, Ramrod ® (480 g/l propachlor) at a rate of 9 l/ha and Stomp 330® (330 g/l pendimethalin) at a rate of 2l/ha. Control plants were sprayed with water only. Visual effects on borage plants were noted.

Results and Discussion
MCPA 500® interrupted normal plant growth and twisting and wilting of borage plants was visible fourteen days after application. Symptoms became more severe over the following fourteen days but plants did not die off completely.

Command 480® and Gesatop 500® both produced leaf margin necrosis after fourteen days and a general yellowing off of plants after a further two weeks.

Application of Afalon®, Allicide®, Ramrod® and Stomp330® produced no visual symptoms or reduction in plant growth over the 40 day, post-spraying observation period. The application of these herbicides, therefore, may be worth further investigation in order to provide a chemical weed control option when required in growing borage.
Conclusions, implications and ongoing work

This project has attempted to meet the stated objectives of providing local information on sowing time, sowing rate and weed control towards the recommendation of important practices for commercial borage crop husbandry.

Conclusions

Time of sowing and harvest
The work has shown conclusively that delaying sowing time beyond mid-August in northern Tasmania is very detrimental to seed yields of borage, with one month’s delay capable of reducing yields by at least one-third and two month’s delay potentially reducing yields by more than half. July sowing provided no yield benefit in comparison to August sowing in this present work. The desirability of reducing weed competition through preparation of a stale seedbed means, therefore, that such preparation should begin by early June, given the slow germination of weeds under winter temperatures in Tasmania.

Confirmation of the critical nature of the timing of the windrowing operation has been gained in this work. With the inherent inability of the borage plant to retain mature seeds and little genetic variability evident in this attribute, this field operation must be planned and performed within a day of the predicted optimum time. In practical terms, this optimum time is one to two days after the first seed is lost from the plant (Simpson, 1993b). The windrowing operation itself must be as ‘gentle’ as possible to limit seed loss and the Draper belt mechanism was felt to provide a better result than a windrower incorporating an auger feed acting upon the cut plant material. In addition, ‘double-cut’ knife mechanisms, such as ‘four-finger’ guards or fingerless knives sometimes used on rice, navy bean and soybean harvesters may be worthy of trial in borage windrowing. These modifications to cutter bar mechanisms may limit seed losses by reducing sideways movement of the plant at the cutter bar and thence seed loss from shattering at the cutter bar. A bulky windrow also may improve the retention of seed dislodged and this also reflects the importance of timely sowing and strong vegetative growth before the commencement of flowering.

Sowing rate and spacing
The studies reported here which were carried out on sowing rate and spacing of borage were also used as a platform for observation of mechanised sowing and harvesting operations and, in retrospect, this limited the quality of the data on sowing rate and spacing, which was acquired. Poor weed control and some late sowing times in these studies probably impacted on the effects of sowing rate and spacing by exacerbating them.

These studies found that seed yields were improved by high sowing rates and these increases varied up to levels equivalent to twice the yield returned from a low sowing rate (8kg/ha). However, the most reliable data obtained (from 2001-02) indicated that yield improvements were in the order of one-third when sowing rate was increased from 8 to 16 kg/ha and by a further 14 per cent when a sowing rate of 32 kg/ha was used. Field germination in this study (around 45-50 per cent of seed sown) was considerably lower than laboratory tests. This suggests that a lower sowing rate (8 to 16 kg/ha) may be adequate if an improvement in field germination is obtained. As mentioned earlier, rolling the seedbed after sowing may assist this cause. While a reduction in inter-row spacing returned a statistically significant improvement in field germination in this trial, the nominal increase in seed yield, which resulted, was not statistically significant.
Given prospective seed costs of, for example, $10 per kg and product perhaps valued at $5 per kg, sowing more than 16 kg/ha borage seed is unlikely to be worthwhile. An important message to prospective growers, therefore, is that, while high sowing rate and narrow row spacing are likely to reinforce the positive effects of timely sowing on weed control through enhanced crop competitiveness, timely sowing and good weed control are, themselves, most important contributors to profitability.

**Observations on weed control and other agronomic practices**

While markets do not at the present time generally specify borage production without pesticides, such quality or indeed organically produced borage may command premium prices in the future.

Reducing weed seed burdens in paddocks to be sown with borage, through selection of a crop rotation and preparation of a stale seedbed will, therefore, be important methods of weed control. These can be assisted by mechanized weeding operations with brush or tyned weeding implements.

Chemical, post-emergent, weed control options presently are restricted (as far as has been ascertained) to Fusilade® for grass weed control. However, the initial observation carried out in this project, suggests that some herbicidal products currently used locally on other crops are worthy of further testing on borage.

**Implications and ongoing work**

The information and experience gained with the borage crop through this project have been extremely valuable in determining important field operational factors, without which successful borage production locally would have been unlikely.

Other work by the author on aspects of genetic improvement of borage is still in progress, in collaboration with the Sydney-based company Willala Pty Ltd. In 2003, the principal in this company was introduced to the NPE grower member, with whom farm-based plots were studied in 2002-03 and a local cold-press extraction plant, suitable for expressing a crude oil extract, was viewed. An agreement has been reached between the above to produce and extract seed from about eight hectares of borage in the current season, 2003-04. This crop was sown on 21 October 2003. If successful, it will provide sufficient product to test the market potential of the local product. Speaking at a growers’ field day in October 2003 in Tasmania, the principal of Willala indicated that, if this testing was successful, grower contracts could follow within two years.

A broadly-based project on alternative grain crops - principally grain legumes but including minor investigations on alternative oilseeds, including borage - has recently been successful in attracting funding support from the Grains Research and Development Corporation. This project, involving cooperation with the Tasmanian section of the grower-driven research group, Southern Farming Systems, is lead by Mr. Geoff Dean of the Tasmanian Institute of Agricultural Research. It hopes to pursue irrigation practices and weed control.
Recommendations

The following broad recommendations regarding borage-growing methods are made, both from the outputs of the current project and from relevant overseas literature:

A uniform, non-compacted, stale seedbed should be prepared well in advance of sowing, which should take place, in Tasmania, in early to mid-August. Sowing should attempt to establish about 35-40 plants per sq m in rows less than 200mm apart. This will equate to a sowing rate of about ten kg/ha if a field germination of 70 per cent can be achieved.

While fertilizer use should be guided by soil tests, only moderate amounts of macronutrients are likely to be required. About 200 kg/ha of a medium analysis mixed fertilizer is a suggested application, with a single, moderate nitrogen top-dressing in the early rosette growth stage. Later nitrogen topdressings may lodge in the rosette and burn the growing point.

A pre-emergent desiccant herbicide should be applied to improve weed control. Post-emergent chemical control of grass weeds and/or mechanical inter-row cultivation should be employed if necessary.

For best yields, irrigation should be used to supplement rainfall when required.

Few disease or insect pests have been found locally to date. However, if insecticides are used at or close to flowering, toxicity to bees and other pollinators should be avoided. The crop is extremely attractive to bees.

The crop should be monitored closely for maturity as the green seed increases in size and turns brown and then black. Black seed is quickly shed and windrowing must be carried out between two and four days after the first seeds are lost from the plant. Any modification to windrowing machinery, which lessens impact forces on the plant at the cutter bar or during its passage through the windrower, is likely to improve the harvested yield.
Bibliography


Appendices

Appendix A. - Note to NPE on progress, for NPE meeting, July 2002.

Appendix B - A recent (December 2003) topical article on the project published in “Tas Regions”, a periodical for growers published by the DPIWE, Tasmania.
Appendix A. - Note to NPE on progress, for NPE meeting, July 2002.

Jo McLaughlan
Natural plant Extracts Coop Soc Ltd
Fax 6327 2475

19 July 2002

For attn: Chris Read

Dear Chris,

Thank you for your phone call today, regarding the telephone meeting of NPE members next Tuesday evening.

I attach the project’s previous annual progress report to RIRDC of November 2000 (another is due November 2002) and a “Research in Progress” report to RIRDC of April 2002. Our main effort on the project last season, as described, was a ‘commercial’ trial on Forthside Research Station, which covered an area of approximately 0.6 ha. Three seeding rates and two row spacings were used to seek effective weed control after preparing a stale seed bed and employing a pre-emergent burn-off spray. The practice worked well with the crop smothering most weeds, particularly the highest seeding rate. No other chemical application was made but some regrowth poppy weeds had to be hand pulled.

The plots were windrowed in early December 2001. Samples from the windrow were taken on 24 December and again on 18 January as we feared that persistent wet weather would destroy the trial. The windrows were eventually dried and harvested with the DPIWE Claas header in February 2002.

<table>
<thead>
<tr>
<th>Seeding rate (kg/ha)</th>
<th>8</th>
<th>16</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row spacing (mm)</td>
<td>125</td>
<td>250</td>
<td>125</td>
</tr>
<tr>
<td>Yield of clean seed (kg/ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windrow sample 24 Dec</td>
<td>225</td>
<td>197.70</td>
<td>292.80</td>
</tr>
<tr>
<td>Windrow sample 18 Jan</td>
<td>110.9</td>
<td>123.10</td>
<td>197.30</td>
</tr>
</tbody>
</table>

While around 300kg/ha is similar to reported yields and it was pleasing to see how seed stayed in the undisturbed windrow through the unseasonally wet weather, we have done better in other plots (c 500kg/ha). I believe the windrower we use (Hesston) knocks seed onto the ground from the green plants and a more gentle windrowing procedure is needed.

While the genetic improvement work with Willala Agricultural has finished its first term of four years, it is likely that this will continue on a reduced scale. I have discussed recently with Duncan Reid, the company’s principal, the need to offer a price to a grower for a commercial test and he suggested his coming to Tasmania for a meeting with NPE. Is this worth pursuing?

The RIRDC/NPE borage agronomy project is due for completion in August 2003. I would appreciate NPE feedback on the direction for the final season’s work due to start shortly and we could discuss this at NPE’s convenience.

Regards,

Rowland Laurence.
Appendix B. - A recent (December 2003) topical article on the project published in “Tas Regions”, a periodical for growers published by the DPIWE, Tasmania.

Borage Borage Borage

Borage, a traditionally-used annual herb, yields a seed oil rich in poly-unsaturated fatty acids, and which, in particular contains a high level of gamma-linolenic acid.

This fatty acid, often referred to as GLA, is a human dietary supplement for which there is an increasing international market demand. Borage is increasingly being grown for this extract, in preference to the conventional source, the seed of the herb evening primrose that yields comparatively less GLA.

There is presently no commercial production of borage in Australia. Around half the world production occurs in New Zealand, Canada and the UK, however yields are low due to the lack of improved commercial varieties and production practices.

A TIAR project, supported by the Rural Industries Research and Development Corporation and the Natural Plant Extracts Cooperative Soc. Ltd, has sought to investigate and recommend agronomic practices for borage when grown under local climatic conditions.

Other ongoing work by TIAR is selecting improved genotypes with respect to the yield of oil and GLA and the characteristic of seed retention, as the borage plant rapidly sheds its seed on maturity and this limits commercially-harvested yields.

The completed agronomic work has provided information and recommendations on sowing time, plant population and harvest timing, which are critically important factors of any future commercial borage production.

An August sowing time has generally produced the highest yields and sowing rates of around ten kg per hectare have been adequate. Few herbicides are registered for use in borage, but the plant competes well with weeds provided good crop germination is achieved and weed populations are reduced through preparatory cultivations.

Discussions between the above industry stakeholders have recently resulted in the prospect of an expanded sowing of about five hectares in 2003-04, with the possibility of using a local press for expression the seed oil. This development should allow good judgements to be made on the crop’s commercial prospects in Tasmania.

For further details contact Dr Rowland Laurence, TIAR, on 64 304901 or Rowland.Laurence@utas.edu.au.