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Evaluation of novel, high yielding pea lines - stage 1

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Project Number: VG03046

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FINAL REPORT

Evaluation of Novel, High Yielding Pea Lines Stage 1

Project Number: VG03046

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Purpose of report

This report describes the work carried out for the period of HAL project funding, which was conducted to examine the potential of several new pea lines to increase yield or decrease sowing density compared with current commercial standards.

Contributors

The project team would like to thank:

1. Horticulture Australia Limited for financial support;
2. The Tasmanian Institute of Agricultural Research for additional administrative and financial support and physical resources;
3. Mr Leon Hingston for technical support; and
4. Mr David Goulden, Crop and Food Research New Zealand, for agreeing to undertake initial breeding of S2-271 into a processing pea variety.

Report Date: February 2004

Disclaimer

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Media Summary

A new series of pea lines was developed in a French breeding program in the 1990's. These lines differ from current processing pea lines as they consistently produce multiple branches from the plant base, each of which produces pods that mature at a similar rate to those on the main stem. The increased yield or decreased planting density that is possible due to the multiple stems makes these lines worthy of further investigation. This project has major significance to the processing pea industry as it has the potential to develop pea lines that have superior yields to current commercial lines.

The lines were originally sent to Australia for experimental greenhouse studies, so no field agronomic data was available at the project's commencement. In this project, we evaluated these pea lines under Tasmanian conditions to observe plant growth habit. As these lines have not been bred for Australian conditions, the trial results have been interpreted only as having the 'potential' for improving current commercial pea lines.

One of the tested lines grew very well under Tasmania conditions with up to three main stems yielding multiple pods produced per plant. This is in contrast to the industry standard Small Sieve Freezer (SSF) which produces only one stem per plant. Predicted yield for this novel line was less than SSF due to fewer seeds produced per pod: however, the number of seeds can be easily increased by breeding this novel line with a larger-podded variety such as SSF. After showing these lines to representatives from the pea industry, we were able to obtain the services of a pea breeder to introduce the multiple stem character into current commercial lines to produce a higher yielding pea line.

The observation that one of the novel lines performed as previously observed in greenhouse studies was a major success of the project. We were able to demonstrate that at least one of our new lines was able to produce multiple main stems and with the appropriate breeding to be performed in the coming years, we will be able to trial new pea varieties with increased yields.

Technical Summary

A new series of pea lines was developed at Institut National de la Recherche Agronomique, France, in the 1990's, after screening populations of peas for altered phenotypes. These new lines differ from other pea lines as they consistently produce multiple branches from the base of the plant. Each of these branches or additional stems produces pods that mature at a similar rate to those on the main stem, thus increasing yield per plant. The increased yield that is possible due to the multiple stems produced at the plant base makes these lines worthy of further investigation.

These lines were originally sent to Australia from Dr Catherine Rameau, Institut National de la Recherche Agronomique, for experimental greenhouse studies, so no field agronomic data existed at the start of the project. Therefore, the issue investigated in this project was to evaluate the novel pea lines under Tasmanian conditions and observe whether we could obtain the high yields predicted by preliminary greenhouse studies in France and Australia.

Two pea lines were compared against the commercial standard variety Small Sieve Freezer (SSF). One novel line (S2-271) grew very well under Tasmania conditions with up to three main stems produced per plant. This is in contrast to SSF, which produced only one stem per plant. As each stem of S2-271 produced several pods, the total number of pods produced per plant was twice as many as produced by SSF. Predicted yield for S2-271 was less than SSF as S2-271 plants produced half as many peas per pod as SSF plants. With conventional breeding however, we can increase the number of seeds per pod in S2-271 by crossing it with a large-podded variety, such as SSF.

After showing these lines to representatives from the pea industry, we were able to obtain the services of Mr David Goulden, a pea breeder New Zealand Crop and Food Research, to breed our most promising pea line with current commercial lines in an effort to produce higher yielding peas.

In summary, we were able to demonstrate that at least one of our new lines was able to produce multiple main stems with additional pods as predicted by greenhouse studies. We have also secured the services of a well-respected pea breeder, who will introduce this multiple stem trait into Tasmanian commercial varieties. With the appropriate breeding and selection to be performed over the coming years, we will be able to trial a new pea variety that will potentially out yield existing commercial varieties.

Introduction

The Tasmanian pea industry is dominated by the production of green peas for processing. The main cultivar (variety) grown is Small Sieve Freezer (SSF), and the seed companies Syngenta Seeds and Seminis Seeds, and New Zealand Crop and Food Research annually send new varieties to Tasmania for evaluation under Tasmanian conditions. Representatives from the two major Tasmanian processing companies Simplot and McCain Foods view the new lines and order seed to be grown in their commercial program the following year. Characteristics such as disease tolerance/resistance, number of productive pods per plant and per node, consistent maturation and yield are important observations made in these trials. With a continual requirement for the pea processing industry to improve both yield and quality, cultivar evaluation is an important component assisting this process.

In addition to the annual Tasmanian variety trials, several other pea-breeding programs are conducted around the world. One program that Suzanne Morris, the Project Leader, had previous exposure to was conducted at Institut National de la Recherche Agronomique, France, in the 1990's. Suzanne identified several lines with altered shoot characteristics as having the potential to increase yields in Tasmanian commercial varieties. These new lines differ from other pea lines as they consistently produce multiple branches from the base of the plant (Murfet and Rameau, 2000; Rameau et al., 2002; Morris et al., 2003; Murfet, 2003). Each of these branches or additional stems produce pods that mature at a similar rate to those on the main stem, thus increasing yield per plant. The increased yield that is possible due to the multiple stems produced at the plant base and subsequent increase in pod number makes these lines worthy of further investigation.

In the initial application, we proposed that the project be undertaken in two stages. We suggested that at the completion of Stage 1, the project be reassessed and seed companies approached for financial support to progress the project to Stage 2, introduction of the novel lines into Tasmanian processing pea varieties. Recommendations for continuation of the project into Stage 2 are discussed later. Hereafter, the report describes the objectives and results of Stage 1 of the project.

These lines were originally sent to Australia from Dr Catherine Rameau, Institut National de la Recherche Agronomique, for experimental greenhouse studies, so no field agronomic data existed at the start of the project. Therefore, the first aim of this project was to evaluate the novel pea lines under Tasmanian conditions and observe whether we could obtain the high yields predicted by preliminary greenhouse studies in France and Australia.

As the seed was sourced from France, the novel lines have not been bred for Australian conditions. Therefore, to assess the ability of this multiple stem trait to increase yields in Tasmanian varieties, these novel lines must be introduced into suitable commercial pea lines. The second aim of this project was therefore to obtain support from a seed company or pea breeder to breed the multiple stem trait into Tasmanian commercial lines. This project has major significance to the pea industry, both in Tasmania and Nationally, as it has the potential to develop pea lines that have superior yields to current commercial lines.

Materials and Methods

Trial Details

As previously mentioned, this project is to be conducted in two Stages. The current Stage aimed to grow the novel pea lines under Tasmanian conditions and identify any useful characteristics that could be introduced into commercial lines using traditional breeding methods. The pea lines S2-271 and M3T-475 were tested against the current commercial standard Small Sieve Freezer (SSF). The lines S2-271 (ex cv. Solara) and M3T-475 (ex cv. Térèse) were originally sourced from Institut National de la Recherche Agronomique, France.

To generate the quantity of seed required for the field trial, seed was first multiplied in the Tasmanian Institute of Agricultural Research (TIAR; Burnie) greenhouse under an extended photoperiod of 18 h. Seeds were sown in a bark/peat/sand potting mix containing a slow release fertilizer as a nutrient source. Additional seed was also sourced from The University of Queensland.

The pea lines were sown using an Oyjord seed drill at Forthside Research Station (FRS), Northwest Tasmania, on 5th September 2003, following oats. The krasnozem soil had a topsoil (0-10 cm) pH value of 6.8 and 105 kg/ha triple superphosphate was predrilled prior to sowing. Two density treatments (100 and 75 seeds/m^2) were compared using two replicates in a randomized block design. Plots were 3.5 m long by 4 rows at 150 mm row spacing. Weeds were controlled by hand weeding and the trial was irrigated when required to replace the 35 mm soil moisture deficit. Germination counts were conducted on 15th October 2003 to determine plant density (Table 1). Agronomic assessments were conducted on 7th January 2004 (slightly over-mature plants), with number of pods and peas per pod, first and total number of productive nodes, presence of single or double pods and number of stems observed. Other observations also included incidence of mildew and collar rot diseases.

Table 1 – List of pea lines, and seed and plant density for field trial.

Treatment	Pea line	Seed density/m^2	Plant density/m^2
A	S2-271	100	77
B	S2-271	75	56
C	M3T-475	100	82
D	M3T-475	75	62
E	SSF	100	110
F	SSF	75	85

Results

Plant density varied from the theoretical sowing density due to poor seed germination (Table 1). To obtain enough seed of S2-271 and M3T-475 for the trial, seed of various ages (typically one to six years old) was sourced from Plant Physiology Laboratory, The University of Queensland, after being introduced from France for genetic and physiology studies. To avoid poor germination rates in future trials, fresh seed should be planted wherever possible.

The first noticeable difference between the novel lines and SSF is that they are 'afila' (having tendrils in place of leaflets) (Plates 1-3). The benefit of this characteristic is that the plants are able to remain upright for a longer period. The second noticeable difference is that S2-271 and M3T-475 have a significantly shorter vine compared with SSF (Table 2). This shorter stature, together with the afila leaves, makes these lines more resistant to lodging.

Node to first flower was similar among the lines, however M3T-475 flowered approximately two nodes later than S2-271 and SSF. The slightly later flowering node of M3T-475 plants did not affect the total productive nodes however, as each SSF and M3T-475 plant produced at least five productive nodes. S2-271 produced up to 12 productive nodes per plant and this increase in nodes compared with SSF is reflected in the large number of pods produced per S2-271 plant. Despite the large number of pods set on S2-271 plants, both S2-271 and M3T-475 plants only produced approximately 3 seeds per pod: this is half as many as SSF plants. S2-271 and SSF both consistently produced several double pods per plant, whereas this trait was rarely seen in M3T-475 plants.

The most interesting trait observed in S2-271 plants was their ability to produce multiple stems, typically three per plant (Plate 3). The multiple stems are produced early in seedling development and grow from the cotyledonary node or lower nodes on the main stem (Rameau et al., 2002). These stems flower and set seed at a similar rate to those on the main stem and it is these additional stems that significantly increase the number of productive nodes and pods per plant. M3T-475 plants also produced multiple stems but this branching phenotype was not as dominant as observed in S2-271 plants.

The predicted yield for SSF plants was higher than typical commercial yields, as plants were over-mature at the time of assessment. Despite being over-mature, plants from all lines were of a similar age which allowed for accurate comparisons among plant varieties. SSF plants at either density had far greater predicted yields than plants from the other lines: this is despite S2-271 plants having a greater number of pods produced per plant. M3T-475 plants yielded the lowest of the three varieties assessed.

Disease incidence was also observed in the field plants. No collar rot was observed in plants from any variety (data not shown). SSF and M3T-475 had a low incidence of downy mildew, whereas S2-271 had a low incidence of both downy and powdery mildew (data not shown). These diseases are potentially devastating for a commercial pea crop so the branching trait should be bred into a line that is tolerant or resistant to downy and powdery mildew.

Plants were grown at two different densities to assess the impact of plant competition on growth, particularly in those lines with multiple stems. However no differences in agronomic characters were observed when treatments A and B, treatments C and D, and treatments E and F were compared.

Table 2 – Agronomic characters assessed from peas growing in FRS field trial.

Code	Vine length (cm)	Node to first flower	Total productive nodes	No. double pods	Total no. pods	No. peas per pod*	No. stems per plant	Predicted yield (kg/ha)
A	43.3 ± 1.2^{b}	12.0 ± 0.3^{b}	11.4 ± 1.1^{a}	4.0 ± 0.7^{a}	15.4 ± 1.6^{a}	3.2 ± 0.1^{b}	3.0 ± 0.1^{a}	13,860
B	39.2 ± 1.2^{b}	12.5 ± 0.3^{b}	12.0 ± 0.7^{a}	3.2 ± 0.5^{a}	15.3 ± 1.1^{a}	3.0 ± 0.1^{b}	3.1 ± 0.2^{a}	10,080
C	40.4 ± 1.2^{b}	14.3 ± 0.3^{a}	5.0 ± 0.5^{b}	0.6 ± 0.2^{b}	5.6 ± 0.6^{b}	3.5 ± 0.3^{b}	1.7 ± 0.1^{b}	7,872
D	41.3 ± 1.0^{b}	14.9 ± 0.3^{a}	7.1 ± 0.6^{b}	0.9 ± 0.3^{b}	7.9 ± 0.7^{b}	3.7 ± 0.1^{b}	1.9 ± 0.1^{b}	7,936
E	74.0 ± 1.7^{a}	12.6 ± 0.2^{b}	5.1 ± 0.8^{b}	2.8 ± 0.5^{a}	7.9 ± 1.2^{b}	6.0 ± 0.2^{a}	1.1 ± 0.1^{c}	21,120
F	74.3 ± 1.6^{a}	12.7 ± 0.2^{b}	5.5 ± 0.5^{b}	3.5 ± 0.3^{a}	8.8 ± 0.8^{b}	5.8 ± 0.3^{a}	1.1 ± 0.1^{c}	18,360

Data shown are mean ± SE. Values within a column, having the same letter are not significantly different at the P = 0.05 level. Means were calculated from 15 plants per replicate sowing.
* number of peas per pod was calculated from 40 pods per replicate sowing.

Plate 1 – Suzanne Morris with greenhouse peas.

Plate 2 – Field trial at FRS.

Plate 3 – Pea with multiple stems.

Discussion

The first aim of this project was to evaluate the novel pea lines under Tasmanian conditions and observe whether we can obtain the high yields predicted by preliminary greenhouse studies in France and Australia. This trial has shown that one line, S2-271, has the potential to improve yield of current commercial lines as it produces at least three main stems per plant. As each of these stems produce multiple pods, the number of pods of a similar maturity at harvest time is increased. The increase in pods caused by these multiple stems is advantageous as the ability of these pods to reach maturity at a similar time is important for harvesting of the mature crop.

From the commencement of the project, we highlighted that the trial results could only be interpreted only as having the ‘potential’ for improving current commercial pea lines, as the lines tested were not bred for Australian conditions. We have shown the potential for improving current lines by demonstrating that S2-271 can produce multiple stems and double the number of productive nodes compared with SSF. If we could introduce the multiple stem phenotype into a commercial line such as SSF that produces large pods, then we have the capacity to massively increase the yield per plant. In this trial, we planted each line at two different densities to assess the impact of plant competition on the growth of the plants with multiple stems. It was thought that the increase in stem number caused too much resource competition and thus weaker plants. One way of overcoming this weaker growth habit is to reduce the sowing density and allow each plant (and stem) to obtain the adequate resources to reach their full growth potential. We tested this theory in the current trial by sowing all the varieties at two densities but did not observe any density on predicted yields (Table 2). However, the possibility of sowing the seeds at a lower density should be followed up when the multiple stem trait is introduced into commercial pea variety.

The second aim of this project was to obtain support from a seed company or pea breeder to introduce the multiple stem trait into processing lines. We have also achieved this objective by obtaining the services of a pea breeder from New Zealand Crop and Food Research to carry out introduction of this multi-stem trait into Tasmanian commercial varieties.

Technology Transfer

The most appropriate method of technology transfer in relation to this project was through regular contact with pea industry representatives and press releases to the general community (see list below). In addition to contact with the local industry persons, seed and breeding company representatives were personally invited to view the field trial, which was followed by a discussion on the usefulness of these new lines to the processing industry. These discussions proved fruitful as we were able to obtain the services of Mr David Goulden, a pea breeder from New Zealand Crop and Food Research, to breed our most promising line with a commercial line in an effort to produce a higher yielding pea variety. The Project Leader will keep in contact with Mr Goulden over the course of the breeding and will relay any useful information to pea industry representatives at the appropriate times.

The Project Leader has also made presentations to growers and industry personnel on several occasions throughout the year at the Department of Primary Industries, Water and Environment Forthside Research Station Open Day and at the Annual Presentation Day of the Tasmanian Potato and Vegetable Agricultural Research and Advisory Committees. These presentations were given verbally at the site of fieldwork or during the day's proceedings, and supported by publication of work summaries in abstract booklets (Appendices A and B).

To inform industry persons who were not present at these information days, the Project Leader also sent out a brief summary of the project and the work performed to date (Appendix C). The Project Leader also presented a brief synopsis of the project at a scientific conference to highlight to other researchers the potential of commercializing scientific investigations (Appendix D).

Industry Reports and Seminars, and Magazine Articles

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Morris, SE, ‘New peas being tested’, *The Advocate*, 17 December (2003).

Morris, SE, ‘Pea research update’, ABC Rural - Merian Ellis, Northern Tasmania, 17 December (2003).

Conference Publication

Morris, SE, Beveridge, CA, Murfet, IC, Rameau, C, ‘Highlighting the commercial potential of *RMS6* and *RMS7*’, *Combined Conference Abstracts ComBio2003 Conference*, Melbourne, Australia, 108 (2003).

Recommendations

This report discusses results from Stage 1 of the project. The outcomes listed at the commencement of the project were to (1) assess the performance of these new pea lines under Tasmanian conditions, and (2) report the potential for future development of pea lines to a commercial partner.

We assessed the performance of two novel lines under Tasmanian conditions and observed that one line (S2-271) grew exceptionally well, producing up to three main stems yielding multiple pods per plant. This line however did not yield as highly as the commercial standard due to a reduced number of seeds produced per pod. Therefore we recommend that this line be selected for further breeding with commercial green pea varieties that produce larger pods.

Our second outcome was to attract a commercial partner to fund the breeding of S2-271 with a commercial green pea variety. After discussions with industry representatives during the course of the trial, we were able to obtain the services of Mr David Goulden, New Zealand Crop and Food Research, to commence the breeding. It is recommended that this project now proceed to Stage 2, to allow new varieties to be produced that have the capacity to increase yields for pea growers and processors without increased the planting area, and to strengthen the Australian pea industry by providing our industry with a competitive advantage over other pea producing countries. A further application will be submitted to HAL to seek funding for Stage 2 of the project.

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Appendices

Appendix A: Morris, SE, Project abstract published by the Department of Primary Industries, Water and Environment in support of the Forthside Research Station Open Day (2003).

Appendix B: Morris, SE, Project abstract published by the Tasmanian Potato and Vegetable Agricultural Research and Advisory Committees in support of their Annual Presentation Day (2003).

Appendix C: Morris, SE, 'Pea Research Update', *Newsletter for limited circulation throughout pea industry*, Tasmanian Institute of Agricultural Research & Horticulture Australia Ltd, Burnie, Tasmania (2003).

Appendix D: Morris, SE, Beveridge, CA, Murfet, IC, Rameau, C, 'Highlighting the commercial potential of *RMS6* and *RMS7*', *Combined Conference Abstracts ComBio2003 Conference*, Melbourne, Australia, 108 (2003).

Appendix A

GREEN PEA NOVEL VARIETIES PROJECT

Funding: Horticulture Australia Ltd.

We are currently evaluating novel pea varieties that may out yield existing processing varieties.

These plants consistently send out multiple branches (tillers) from the plant base, with pods maturing at a similar rate to those on the main stem: hence the possible yield increase. The increased yield or decreased planting density that is possible due to the multiple stems produced at the plant base makes these lines worthy of further investigation.

These lines were originally sent to Australia for experimental greenhouse studies, so no field agronomic currently exists. The trials planned for this project, which is supported by the vegetable grower levy and Horticulture Australia Ltd, will be the first attempt to grow these varieties in Tasmania.

This project has major significance to the Australian pea industry as it has the potential to develop pea lines that have superior yields to current commercial lines.

Contact: Dr Suzanne Morris, TIAR, Ph: 6430 4503

Appendix B

EVALUATION OF NOVEL, HIGH YIELDING PEA LINES - STAGE 1

Suzanne Morris
Tasmanian Institute of Agricultural Research

Project Investigators
Suzanne Morris, Rowland Laurence, Phil Brown, Christine Beveridge (UQ)

Background
A new series of pea lines was developed at Institut National de la Recherche Agronomique, France, in the 1990's, after screening populations of peas for altered phenotypes. These new lines differ from other pea lines as they consistently produce multiple branches from the base of the plant. Each of these branches or secondary stems produces pods that mature at a similar rate to those on the main stem, thus increasing yield per plant. The increased yield that is possible due to the multiple stems produced at the plant base makes these lines worthy of further investigation.

Objectives
- Evaluate these novel pea lines under Tasmanian conditions. Assessments will be made by representatives from seed companies, pea breeders and the general pea industry.

Work undertaken to date
Early plantings of these new varieties will be sown in late August 2003 at the Forthside Research Station in conjunction with the pea varietal trials conducted by Leon Hingston.

Technology transfer activities and plans
The project outline has been communicated to the Australian pea industry, in particular Tasmanian and Victorian growers, through general articles published in 'Tasmanian Country', 'Good Fruit and Vegetables' and the 'Victorian Vege-link newsletter'. Further technology transfer activities are planned to disseminate our results to the pea industry.

Funding
Horticulture Australia Ltd

Commencement and Completion Date
1 July 2003 – 30 June 2004

Project collaborators
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Appendix C

Appendix D

HIGHLIGHTING THE COMMERCIAL POTENTIAL OF *RMS6* AND *RMS7*

Morris S.E.[1,2], Beveridge C.A.[2], Murfet I.C.[3], Rameau C.[4]

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The pea *ramosus* (*rms*) mutants offer an excellent opportunity to explore the physiological control of branching. Mutants *rms1* through *rms5* display increased branching at the basal and aerial nodes [1], whereas *rms6* and *rms7* only produce laterals at the basal nodes [2-4]. In addition to these physiological studies, the *rms* mutants, particularly *rms6* and *rms7*, also offer the Australian pea industry with valuable tools for reinventing the local market. The most striking feature of the *rms6* phenotype is that laterals at the cotyledonary node of intact *rms6* plants tend to grow out and form secondary stems [2, 3]. In contrast, buds at the cotyledonary node of *rms7* plants remain mostly dormant. Despite the inconsistency for *rms7* to produce laterals from the cotyledonary node, both *rms6* and *rms7* plants produce multiple branches from the plant base (nodes 1 to 3) [4]. The reduced indeterminacy of the main stem in *rms6* and *rms7* plants may prove agronomically valuable to the Australian pea industry. The potential for increased yields or reduced sowing rates in the field due to this multiple stem phenotype has encouraged Horticulture Australia Pty Ltd to fund a one year project to allow the pea industry to assess whether these characteristics would be useful in commercial pea lines. Presented here is a brief physiological description of *rms6* and *rms7*, including some of the key features that make these mutations agronomically desirable.

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