## Variation in yield of faba bean across southern Australia following rhizobial inoculation

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### Abstract

Introduction of relatively new legumes such as faba beans (*Vicia faba*) into newly developing agro-ecosystems tends to focus initially on selection of those species and cultivars that have the ability to tolerate edaphic constraints. Field trials were established at 9 sites across the cropping regions of SE Australia to evaluate the effects of the soil environment on the ability of rhizobia to form nodules on faba beans. Grain yield and root nodulation of faba bean varied across a range of soil types in 1999, 2000 and 2001 (Victoria, southern NSW and Tasmania). Grain yields increased up to 0.97 t/ha in response to rhizobial inoculation at the Rutherglen site and 2.48 t/ha at Cressy in northern Tasmania. Our results highlighted the need for rhizobial inoculation when new pulse legumes were grown in different soil environments.

### Keywords

Pulse legumes, nodulation, grain production

### Introduction

The Australian continent constitutes a wide spectrum of climatic conditions and soil environments in which to maintain a viable agricultural industry. Soil types in the pulse growing regions of southeastern Australia vary from highly alkaline ($pH_{Ca}$ 7-9) in NW Victoria and much of South Australia, neutral acidic soils ($pH_{Ca}$ 5-7) of the Wimmera, central and southern Victoria to highly acidic soils ($pH_{Ca}$ 3.5-5.5) of NE Victoria, SW Victoria, southern NSW and much of Tasmania. This wide variation in soil type has serious implications for *Rhizobium* survival, effective nodulation and the need for re-inoculation of following pulse crops.

Inherent soil factors together with a previous paddock history of legumes can influence the legume-*Rhizobium* symbiotic relationship. The growth and survival of *Rhizobium* spp in soil environments can be affected by a combination of factors including acidity (and toxicity of Al), salinity, alkalinity (including high concentrations of Ca and B), soil temperature, moisture, fertility (including nutrient deficiencies), and soil structure. The correct soil pH is crucial for the survival of *Rhizobium* spp, and in adverse soil pH environments, strains of rhizobia differ markedly in their ability to infect the host plant (1).

The capacity of a rhizobial inoculant to colonise soils in sufficient quantity to provide effective nodulation is highly dependent on the soil type. Thus, a thorough understanding of the background populations will enable recommendations to be made regarding the need for re-inoculation of pulse legumes.

In this paper we report the effects of the soil type and environment on the ability of rhizobia to form nodules and the variation in rhizobial inoculation when faba beans were introduced into a range of different soil environments.

### Methods

Field experiments were conducted over the 1999/00, 2000/01 and 2001/02 seasons at 9 sites across the cropping regions of SE Australia at Rutherglen, NE Victoria; Penshurst and Hamilton, SW Victoria; Horsham, Wimmera CW Victoria; Walpeup, Mallee NW Victoria; Brocklesby, southern NSW and Cressy, northern Tasmania. Site characteristics are summarised for each site in Table 1.

**Table 1. Location, soil classification, soil pH and level of background rhizobial populations for *Vicia faba* cultivars across 9 locations in the pulse growing regions of south eastern Australia**

| Site location & year | Soil classification | Soil $pH_{Ca}$ | Background rhizobial populations | Faba bean cultivar |
|---|---|---|---|---|
| Rutherglen 1999 | Yellow sodosol | $pH_{Ca}$ 4.7 | Moderate | Ascot |
| Rutherglen 2000 | Yellow sodosol | $pH_{Ca}$ 4.7 | Moderate | Fiord |
| Rutherglen 2001 | Yellow sodosol | $pH_{Ca}$ 4.7 | Low | Fiesta VF |
| Penshurst 1999 | Clay loam | $pH_{Ca}$ 4.9 | Low | Ascot, Fiesta VF, Manafest |
| Hamilton 2001 | Volcanic acids | $pH_{Ca}$ 4.5 | Low | Fiesta VF, Fiord, Manafest, 1*A56/1[A] Aquadulce, Ascot |
| Horsham 1999 | Friable grey clay | $pH_{Ca}$ 8.0 | High | Ascot, Fiesta |
| Walpeup 1999 | Sandy clay loam | $pH_{Ca}$ 6.0 | High | Fiord |
| Cressy, Tas 2001 | Grey sodosol | $PH_{Ca}$ 4.7 | Low | Fiesta |
| Brocklesby 2001 | Sandy clay loam | $pH_{Ca}$ 5.6 | Low | Fiesta |

[A] 1*A56/1 = Icarus*Ascot56/1

At each site, *Vicia faba* cultivars were sown as three replicates in a randomised complete block design with rhizobial and nil inoculum treatments applied at the recommended rate. Site establishment and inoculation treatment details were similar to those methods outlined in (2). Preparation, sowing and maintenance of each site were carried out as required throughout the growing season. Annual grasses and broadleaf weeds were controlled using the appropriate herbicides according to label recommendations.

Individual plants were collected 10-12 weeks after sowing for scoring of nodulation and for plant dry matter measurements. Plant roots were scored for nodulation on a 0-5 scale, based on the nodule number, size, position, distribution and pigmentation of effective nodules on the crown and lateral roots (modification of (3)). Grain (seed) yield was determined by mechanical harvesting of the entire plot.

## Results and discussion

Rhizobial inoculation is an important factor when introducing legumes into farmer paddocks. When an uninoculated legume is sown into soil containing a large population of effective rhizobia bacteria, an abundance of effective nodules can be formed and rhizobial inoculation of the seed is unnecessary. Alternatively when no nodules are formed and little background soil rhizobia remain, inoculation of the introduced legume is necessary (4). Site characteristics and background rhizobial populations (Table 1) showed that there was considerable variation in the presence (or survival) of root-nodule bacteria at individual sites within a location or between rhizobial species (Table 2). On some soil types rhizobial strains were present that are capable of infecting the host legume and forming nodules, but at others rhizobia were not present in the soil and no nodules are formed (Table 2).

Historically, acid soils are devoid of *Rhizobium leguminosarum* bv *vicea* populations and for effective nodulation into such a paddock without a prior history of *Vicia faba*, rhizobia must be introduced to the soil at the time of sowing. Background rhizobial populations were low on the acidic soils at Penshurst, Brocklesby and Cressy as shown by the low nodulation data obtained for the nil rhizobial treatment (Table 2). In contrast, when faba beans were grown in the more alkaline soils at Walpeup and Horsham, effective nodulation of the nil rhizobia treatments occurred (Table 2). On alkaline soils and acidic soils with a background history of *Rhizobium leguminosarum* bv *vicea* populations abundant effective nodules were formed indicating the presence in the soil of a large population of effective root nodule bacteria.

**Table 2. Nodulation (nodule score per plant) responses for *Vicia faba* following inoculation with *Rhizobium leguminosarum* bv *vicea* strains SU303, WSM1274 and WSM1455 in different edaphic environments across SE Australia (scale 0-5).**

| Site location | Nodule score for inoculated rhizobial strains | | | | LSD |
|---|---|---|---|---|---|
| & year | Nil | SU303 | WSM1274 | WSM1455 | (P<0.05) |
| Rutherglen 99 | 3.38 | 3.85 | 3.02 | 3.69 | n.s. |
| Rutherglen 00 | 2.60 | 2.93 | 2.81 | NT[1] | n.s. |
| Rutherglen 01 | 1.29 | 3.74 | 3.68 | 2.60 | 0.61 |
| Penshurst 99 | | | | | |
| - Ascot | 0.15 | 0.80 | 0.62 | 1.02 | |
| - Fiesta VF | 0.08 | 0.58 | 0.69 | 0.92 | |
| - Manafest | 0.07 | 1.10 | 0.83 | 0.90 | 0.53[*] |

| | | | | | |
|---|---|---|---|---|---|
| Hamilton 01 | | | | | |
| - Ascot | 4.42 | 4.76 | 4.62 | 4.74 | |
| - Fiesta VF | 4.71 | 4.76 | 4.62 | 4.74 | |
| - Manafest | 4.79 | 4.91 | 4.70 | 4.72 | |
| - Aquadulce | 4.41 | 4.73 | 4.79 | 4.79 | |
| - Fiord | 4.46 | 4.41 | 4.25 | 4.75 | |
| - 1*A56/1 | 4.27 | 4.44 | 4.52 | 4.53 | 0.56* |
| Horsham 99 | | | | | |
| - Ascot | 2.91 | 3.47 | 3.28 | 2.78 | |
| - Fiesta VF | 3.53 | 3.76 | 3.84 | 3.13 | 0.98* |
| Walpeup 99 | 1.30 | NT | 1.80 | 1.60 | n.s. |
| Cressy 01 | 0.17 | 1.65 | 0.81 | 0.61 | 0.36 |
| Brocklesby 01 | 0.48 | 3.60 | 3.27 | 3.83 | 1.45 |

NT not tested, * Cultivar x rhizobia strain interaction

Nodulation responses to faba bean inoculation were obtained at the Rutherglen (01), Penshurst, Cressy and Brocklesby sites with some sites also highlighting differences between individual rhizobial strains. At the Cressy site, inoculation with strain SU303 resulted in a significantly greater nodulation than that obtained using strains WSM1274 and WSM1455.

The nodulation response due to inoculation was perpetuated through to harvest, as shown by the grain yield responses to inoculation at the Rutherglen (01), Penshurst, Hamilton, Cressy and Brocklesby sites. With the expansion of pulse crops into more marginal areas, faba beans are emerging as a promising crop in SW Victoria, NE Victoria in drier years and northern Tasmania with yields between 1.78 and 6.27 t/ha. Growing season rainfall (GSR) impacted significantly on grain yield. At the Rutherglen site (00), grain yield (Table 3) and plant DM measurements (data not shown) were reduced by wet conditions compared to the grain yields obtained in years 1999 and 2001. GSR in 2000 was higher and soils remained saturated for longer which contributed to lower grain yields.

Soil pH, paddock history, disease control and rainfall all contributed to successful crops and grain yields. The presence of background rhizobia was not always sufficient in itself to ensure optimal $N_2$-fixing capacity in the host legume as the capability of strains to fix N within naturalised populations can vary considerably. It was difficult to introduce superior strains (by inoculation) when there was a high background population of indigenous and well-adapted rhizobia, and the number of nodules occupied by the inoculant strain may actually decline in the years following the initial inoculation (5, 2).

**Table 3. Grain yield (t/ha) responses for *Vicia faba* after inoculation with *Rhizobium leguminosarum* bv *vicea* strains SU303, WSM1274 and WSM1455 in different edaphic environments across SE Australia.**

| Site location | Grain yield (t/ha) for rhizobial strains | | | | LSD |
|---|---|---|---|---|---|
| | Nil | SU303 | WSM1274 | WSM1455 | (P<0.05) |
| Rutherglen 99 | 4.36 | 4.12 | 3.71 | 4.07 | n.s. |
| Rutherglen 00 | 0.98 | 1.13 | 1.15 | 1.13 | n.s. |
| Rutherglen 01 | 5.34 | 6.27 | 6.31 | 6.20 | 0.37 |
| Penshurst 99 | | | | | |
| - Ascot | 1.78 | 2.93 | 2.62 | 2.86 | |
| - Fiesta VF | 2.74 | 3.81 | 3.21 | 3.29 | |
| - Manafest | 3.15 | 4.55 | 2.94 | 4.73 | 1.00* |
| Hamilton 01 | | | | | |
| - Ascot | 1.31 | 1.25 | 1.29 | 1.08 | |
| - Fiesta VF | 1.56 | 1.25 | 1.24 | 1.39 | |
| - Manafest | 1.41 | 1.66 | 1.53 | 1.92 | |
| - Aquadulce | 1.35 | 1.72 | 1.71 | 1.72 | |
| - Fiord | 1.13 | 1.02 | 1.20 | 1.12 | |
| - 1*A56/1 | 2.05 | 2.28 | 2.24 | 2.18 | 0.41* |
| Horsham 99 | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| - Ascot | 2.78 | 2.96 | 2.70 | 2.85 | |
| - Fiesta VF | 3.21 | 3.01 | 2.94 | 3.05 | ns* |
| Walpeup 99 | 1.02 | NT | 1.05 | 1.02 | n.s. |
| Cressy 01 | 3.68 | 6.16 | 5.33 | 5.43 | 1.02 |
| Brocklesby 01 | 1.67 | 2.62 | 2.50 | 2.30 | 0.74 |

* Cultivar x rhizobia strain interaction

## Conclusion

Field assessment of *Vicia faba* across a range of edaphic environments has shown clear differences in the survival of *Rhizobium* strains effective in promoting grain yield (Table 2 and 3). However, we also need to understand the implications of these responses for re-inoculation when subsequently re-sowing into a paddock with a previous history of legumes. If there is sufficient effective rhizobia, is there a need to re-inoculate?

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