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Failure of navy beans to respond to inoculation with Rhizobium

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Summary

Three field experiments were conducted at four sites to select a suitable strain of *Rhizobium* and to gauge the response of navy beans to inoculation with *Rhizobium* and to ammonium nitrate. Of the seven plantings, only two had satisfactory nodulation despite the presence of effective naturalized rhizobia at all sites. Where nodulation was poor, there were no growth responses to ammonium nitrate. Soil moisture and nitrate levels seem to be implicated in the nodulation failure.

Under nitrogen limiting condition with adequate moisture growth differences occurred between *Rhizobium* strain treatments. There was a significant correlation between dry weight of tops at 6 weeks and grain yield at maturity justifying the use of early vegetative growth as a criterion of final grain yields in *Rhizobium* strain trials. Although fast and slow growing strains were tested, no single strain was outstanding in performance.

1. Introduction

In the navy bean (*Phaseolus vulgaris* L.) growing areas of Queensland at Kingaroy, Lockyer and Inglewood, the nitrogen nutrition of the crop is satisfied by nitrogenous fertilizers used at a rate of 20 to 50 kg N ha^{-1} depending on soil type and cropping history (Gallagher 1970). Inoculation of seed with cultures of *Rhizobium* is not commonly practised, but should be considered as a method of economizing on fertilizer usage. The experiments reported here sought to gauge the field responses to inoculation and compare yields with those from N fertilizers.

2. Materials and methods

Initial glasshouse tests screened 67 strains of *Rhizobium* of local and overseas origin for effective nodulation of navy beans in Leonard jars in the contained vermiculite-sand-charcoal mixture with Jensen's seedling solution of which six were selected for field testing. Attributes and origin of each strain are listed in table 1. Strains representing a range of N fixing efficiency were selected for the purposes of comparison to the standard commercial strain CC511. In each experiment, seeds were inoculated with peat based inoculants (3 g peat culture per kg seed) using a 20% gum arabic sticker. The sowing was made into a moist seedbed at 25 to 40 mm depth at the rate of 30 kg seed ha^{-1}. The row spacing was 0.8 m with guard rows in which nodulation was assessed. Field nodulation was assessed in 20 plants dug from each plot at approximately 6 to 8 weeks after planting. At the same time, dry weights of the plant tops were taken. The crops were finally left to mature and grain yields taken from the datum rows.

In the first experiment, strains were field tested at four sites, namely, Indooroopilly (infertile schist pH 7.8), Ormiston (krasnozem pH 5.9), Gatton (black soil pH 7.8) and Kingaroy (red clay–loam pH 6.3). Initial soil nitrate levels (0 to 15 cm) at these sites were 7, 8, 34, 25 ppm nitrate nitrogen (NO_3–N) respectively with low ammonium levels < 4 ppm (NH_4–N) at all sites. Test cultures of the inoculum strains were prepared on irradiated peat to a minimum standard of 10^8 rhizobia g^{-1} peat. Inoculated seeds of Kerman and Gallaroy cultivars were sown at each site except Indooroopilly (Gallaroy only) in September 1974. N fertilizer controls (125 kg ha^{-1} urea) and uninoculated controls were included. The design was eight treatments x four replications in randomized blocks with 6 m rows. All sites were irrigated.

Table 1. Symbiotic rating of six strains of *R. phaseoli* on Gallaroy navy beans

Strain	Host	Origin	Growth rates*	Dry wt. † top (g)	N%
QA 1061	*P. vulgaris* ..	Dalveen, Q. ..	S	3.2	2.1
QA 1063	*P. vulgaris* ..	Kingaroy, Q. ..	F	3.0	2.6
CC 511	*P. vulgaris* ..	Commercial Inoculant Strain	F	2.9	2.5
CB 1281	*P. vulgaris* ..	Beerwah, Q. ..	F	2.3	2.1
QA 1062	*P. vulgaris* ..	Inglewood, Q. ..	S	2.1	2.3
CB1964	*P. coccineus* ..	Cuernavaca, Mexico	F	1.4	2.7
Uninoculated control	..	..	..	0.9	1.8
N control	..	..	..	3.4	2.7
L.S.D. P=0.05 ..	..	..	..	0.4	..
P=0.01 ..	..	..	..	0.5	..

* F=fast growing; S=slow growing.

† =Glasshouse Leonard jar trial.

The second and third experiments gauged the responses of beans cv. Kerman to inoculation with a commercial peat inoculant (CC511) and to N fertilizer as ammonium nitrate and in combination at the rate of 0, 20, 40 kg N ha^{-1} at two selected sites in the South Burnett region. Site 1 at Taabinga was an infertile red-brown clay loam forest soil pH 5.9 with high clay content. Site 2 was a fertile red clay loam scrub soil (pH 6.3) at Crawford. Site 1 received amendments of phosphorus, potassium and trace elements whereas site 2 received only phosphorus. The levels of soil nitrate at planting (0 to 15 cm) were low, being 5 ppm and 9 ppm (NO_3–N) respectively, with low ammonium levels of 4 ppm (NH_4–N) at both sites. Both trials were conducted as rain-grown crops. The planting dates were 26 January 1973 and 6 January 1975. The design was six treatments x four replications in randomized blocks with two 20 m datum rows separated by two similar guard rows.

The fourth experiment investigated the effects of placing lime on nodulation and yields of inoculated and fertilized beans cv. Kerman at Taabinga. Lime was applied either by broadcasting 4 weeks before planting, as a seed pellet, or as a side band at time of planting. In addition superphosphate with trace elements and nitrogen as ammonium nitrate (where applicable) were banded in the same way. The planting date was 5 February, 1974. The design was 13 treatments x three replications in randomized blocks. Nodulation was assessed at 8 weeks and grain yields taken at maturity (table 3).

Despite favourable soil moisture at planting with prompt emergence in all rain-grown experiments, beans suffered periodic moisture stress soon after emergence in experiment 2 and at flowering and early pod filling stages in experiments 3 and 4.

3. Results

Nodulation was variable with only three plantings having plants with 20 or more nodules. Uninoculated controls nodulated at all sites. In the first experiment, nodulation was prolific at Indooroopilly and Ormiston where mean nodule numbers for all treatments were 98.4 and 262.2 nodules per plant respectively but poor at Gatton and Kingaroy (1.6 and 4.5 nodules per plant respectively). This improved with time up to 10 weeks at Kingaroy but not at Gatton.

The cultivar Kerman nodulated consistently better than Gallaroy at both these latter sites but because of the moderately high N status of these soils, there were no growth or yield differences between strains of rhizobia. At Ormiston and Indooroopilly, strain differences occurred which showed up in leaf colour, plant size and grain yields. The early dry matter yields (6 weeks) were correlated to final grain yields for both cultivars (figure 1). For Kerman and Gallaroy the correlation coefficients were $r = 0.89$ and 0.92 respectively at Ormiston and $r = 0.94$ Gallaroy at Indooroopilly. All the coefficients were significant at $P = 0.01$. In all cases, the highest yields were from the N fertilizer control plots and the lowest from uninoculated controls. The top performing strains in grain yields were QA1061 on Kerman and CB1281 and CC511 on Gallaroy depending on the site.

In sharp contrast, nodulation in rain-grown crops was consistently low (tables 2 and 3). Neither inoculation nor lime application increased nodule numbers. However, ammonium nitrate suppressed this scant nodulation in two instances. No significant yield responses to any of the treatments (inoculum, lime or N fertilizer) were obtained at any site or season.

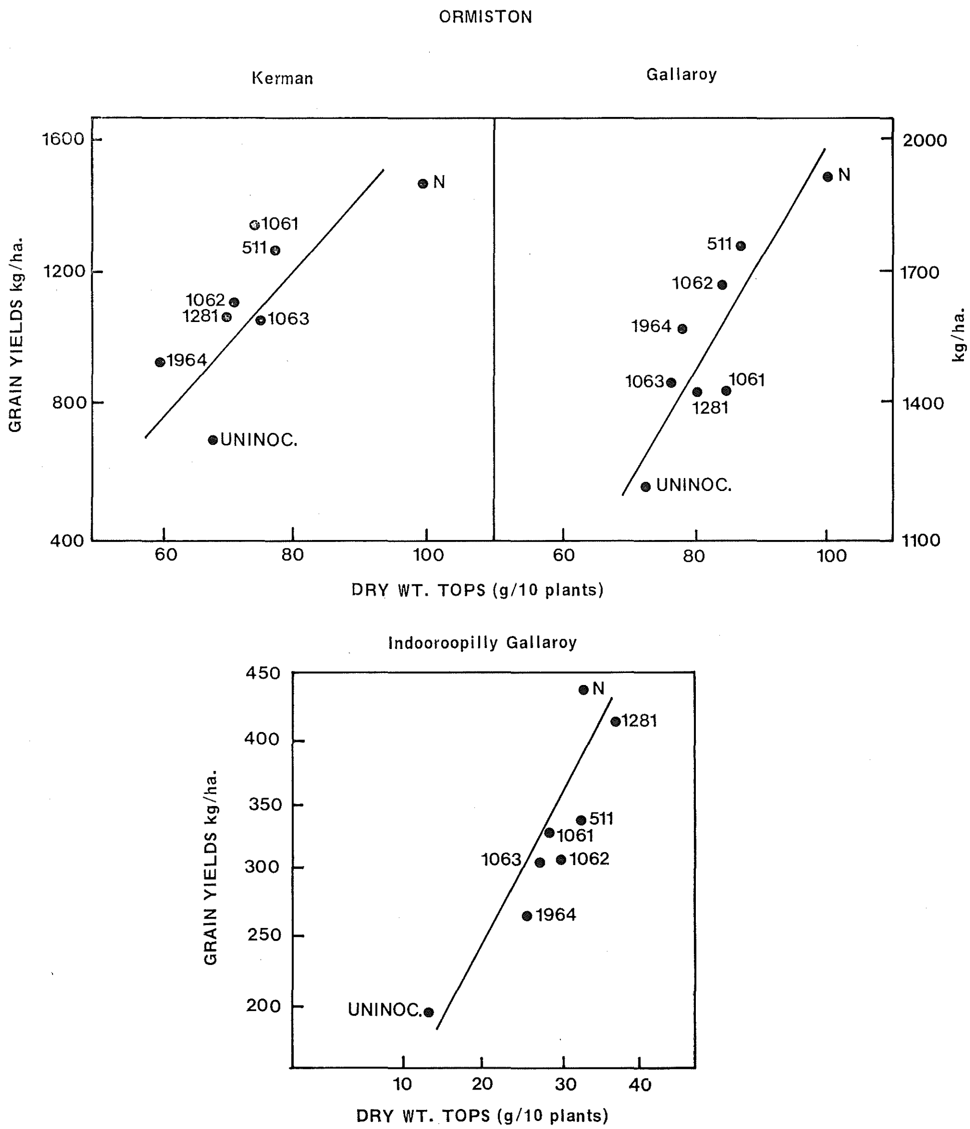

Figure 1 Relationship between dry weights of tops and grain yields in navy beans.

Table 2. Responses of navy beans to inoculation with *Rhizobium* and ammonium nitrate application

—	Taabinga		Crawford	
	Yield of clean grain kg/ha	Nodules/plant (8 weeks)	Yield of clean grain kg/ha	Nodules/plant (8 weeks)
Uninoculated	311.2	0.6	1362.1	3.0
Inoculated	309.2	0.2	1436.5	1.4
Uninoculated + 20 kg/ha N	307.2	0.4	1497.3	2.9
Inoculated + 20 kg/ha N	313.5	0.2	1628.3	4.2
Uninoculated + 40 kg/ha N	303.5	0.2	1514.5	1.8
Inoculated + 40 kg/ha N	311.7	0.1	1540.4	0.8
	NS*	..	NS*	..

* Non-significant differences.

Table 3. Responses of navy beans to inoculation, ammonium nitrate and various lime treatments at Taabinga

—	Yield clean grain kg/ha	Nodules/plant (8 weeks)
Uninoculated	734.4	13.8
Inoculated	840.3	18.9
Uninoc. 100 kg/ha lime banded	713.5	23.3
Inoc. 100 kg/ha lime banded	692.7	19.11
Uninoc. 200 kg/ha lime banded	650.7	12.2
Inoc. 200 kg/ha lime banded	749.7	23.6
Uninoc. 400 kg/ha lime banded	806.9	17.7
Inoc. 400 kg/ha lime banded	656.6	20.6
Uninoc. Lime Broadcast	815.5	14.2
Inoc. Lime Broadcast	838.7	17.3
Uninoc. Lime Broadcast 30 kg/ha N	800.7	6.3
Inoc. Lime Broadcast 30 kg/ha N	778.7	11.7
Inoc. lime pelleted	833.6	13.5
	NS*	NS*

* Non-significant differences.

4. Discussion

The nodulation in field plantings recorded in these studies was generally poor. Of the seven plantings made, only two could be classed as having satisfactory nodulation. All sites carried some effective rhizobia so the presence of effective rhizobia was not the main determining factor in achieving nodulation.

Since the crops did not respond to N fertilizer application while poorly nodulated, it must be assumed that nitrogen was not the main limiting factor. Soil moisture could be a more critical factor in determining nodulation and yields. Rain-grown crops which suffered moisture stress invariably failed to nodulate and produced low grain yields about average or below average for crops in Queensland. In contrast, irrigated crops produced prolific nodulation and higher yields. In the exceptional instances of poor nodulation under favourable moisture conditions at Gatton and Kingaroy, soil nitrates probably inhibited nodulation.

Where favourable nodulation occurred under irrigation, *Rhizobium* strain differences were apparent. No single strain emerged as the top performer although both fast and slow growing rhizobia were represented. However, the growth differences provided an opportunity to examine correlations between vegetative growth and grain production. Since most nodulation trials are rarely taken through to grain yields, it is important to establish whether the usual criterion of early dry matter production bears any relationship to final grain yield. In the three cases examined, there was a significant correlation between dry weight tops (6 weeks) and final grain yields in both cultivars of navy beans, vindicating the use of the simpler criterion in *Rhizobium* strain trials.

Ormiston was by far the best nodulating and grain producing site of those tested. However, the best yields under nodulation at this site still fell short of those from N fertilizer by as much as 20% in Gallaroy. This opens the question of whether nodulation is of value in a short term crop of 12 to 14 weeks' maturity. Observations made periodically in these trials further indicate that nodulation is often slow to appear, limited in development and of doubtful activity as judged by nodule colour. Such erratic field responses to inoculation make it futile to recommend inoculation of navy bean seed until more is known about the factors favouring field nodulation. Swaby and Noonan (1946) reported similar problems with nodulation in canning beans in N.S.W. This contrasts sharply with experiences with soybean (Diatloff 1970) where, once a suitable strain was selected, nodulation in commercial plantings was consistently good on a range of soils and cultivars.

5. Acknowledgements

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