The Importance of Nodulation in Green Pea Production

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Nitrogen Fixation

$N_2 \rightarrow \text{Ammonia} \rightarrow \text{Proteins, etc}$

Nitrogenase
- Iron Protein
- Molybdenum Iron Protein

Energy (ATP & electrons)
Infective...

- Infectiveness is the ability of a rhizobial strain to form nodules with a particular legume.
- Effectiveness is the ability of those nodules to fix nitrogen.
Effective Nodules

- Fix N ($N_2$ to protein)
- Have leghemoglobin*
- Have high rates of fixation
- Withstand stress
- Active during the life of the plant
Nodule Initiation

- Attachment to root (minutes)
- Increase in numbers (hours)
- Root hair curling (5 hours)
- Infection Thread (3 days)
- Peribacteroid membrane
- Penetration of root cortex
Nodule Type

- **Indeterminate:** elongated with a meristematic region and increase in length as they grow (peas)
- **Determinate:** round, no pronounced meristematic region (soybean)
Nodule Regions

- Meristematic (active growth)
- Infection (plant cells infected)
- Active (bacteroids, $N_2$ fixation & leghaemoglobin)
- Senescence (lysis, degradation)
Nodules
Leghaemoglobin
Bacteroids In Soybean Nodule
Rhizobium

- Bacteria
- Living Organisms*
- Form Symbiosis with Legumes
- Specific for Legume
- Fix Nitrogen
- Not altruistic
Legume Specificity

- Nodulation species and strain specific.
- Each rhizobial strain is likely to nodulate only specific legumes (cross-inoculation group).
Rhizobial Species

Sinorhizobium: *S. meliloti* is very restrictive in nodulation preference, alfalfa, sweet clover.

Rhizobium: *R. leguminosarum* nodulates pea, lentils and beans.

Bradyrhzizobium: *B. japonicum* nodulates soybeans.
Bacterial Requirements

- Food (photosynthetic)
- Oxygen
- Water
- Suitable environment
- Temperature
- pH
- Inorganic nutrients
Mineral Nutrition

- Calcium – low Ca inhibits nodulation
- Phosphorus (energy)
- Iron, Sulfur & Molybdenum*
- Minor elements (Co, Ni)
- Nitrogen*

Excess – inhibits nodulation
Deficiency – inhibits root growth
Soil Environment

- Acid (pH)
- Temperature
- Moisture
- Nitrogen
- Salinity
- Alkalinity
Soil Acidity (pH)

- Survival of Rhizobia
- Growth of Rhizobia
- Root infection
- Nodule Initiation
- Symbiotic efficiency
- Nutrition of the host legume
Effect on Nodulation

- pH optimum species specific
- Peas – pH 7 - 8
- Heavy Metals (Al & Mg)
- Other factors (root hairs, mucigel, calcium, etc.)
Nodulated plants grown at less than optimum pH levels are less productive.

Alfalfa grown at pH 7.0 to 7.3 fixed twice as much N as plants grown at 4.9 to 5.2.
Moisture

- Generally not a problem for Rhizobia
- Too much can cause anoxia*
- Too little will disrupt nodulation
- Loss of nodules
Rhizobia are mesophiles
Do not grow below 50°F (10°C) or above 100°F (37°C)
Elevated temperature may disrupt nodulation
Optimum temperature ca. 77°F (25°C)
Salinity

Effects greater on host
Rhizobia tolerant of salt
Peas not considered salt tolerant
Other Factors

- **Pathogens**
- **Light**
- **Soil Structure (gas exchange)**
- **Oxygen** (leghemoglobin)
- **Carbon Dioxide**
Inoculation I

- Correct strain of rhizobia must be present in sufficient numbers with the appropriate legume.

- New Fields

- Old fields out of production

- If there is a doubt

Rhizobia can live for 125 years
Inoculation II

- Granular - in furrow
- Frozen – irrigation, broadcast, etc.
- Liquid
- Powdered Peat
- Clay
Inoculation III*

- Use appropriate inoculum
- Check the “sell by” date
- Check the container
- Store properly
Inoculation IV

❄ Shotgun Approach (USA)

❄ Specific strain for specific cultivar (Australia)
Compatibility

- Insecticides are more toxic than fungicides, which are more toxic than herbicides
- Keep exposure time as short as possible
- Liquid interfaces speed up any detrimental activity
Thank You!

- Rhizobia are alive!
- Plants must be healthy
- Thermodynamics
  The power of energy in transit