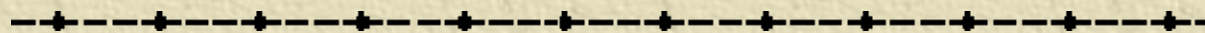




The Importance of Nodulation in Green Pea Production



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Nitrogen Fixation*

 $\text{N}_2 \rightarrow \text{Ammonia} \rightarrow \text{Proteins, etc}$

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, N₂ fixation & leghaemoglobin)**
 - ✦ **Senescence (lysis, degradation)**

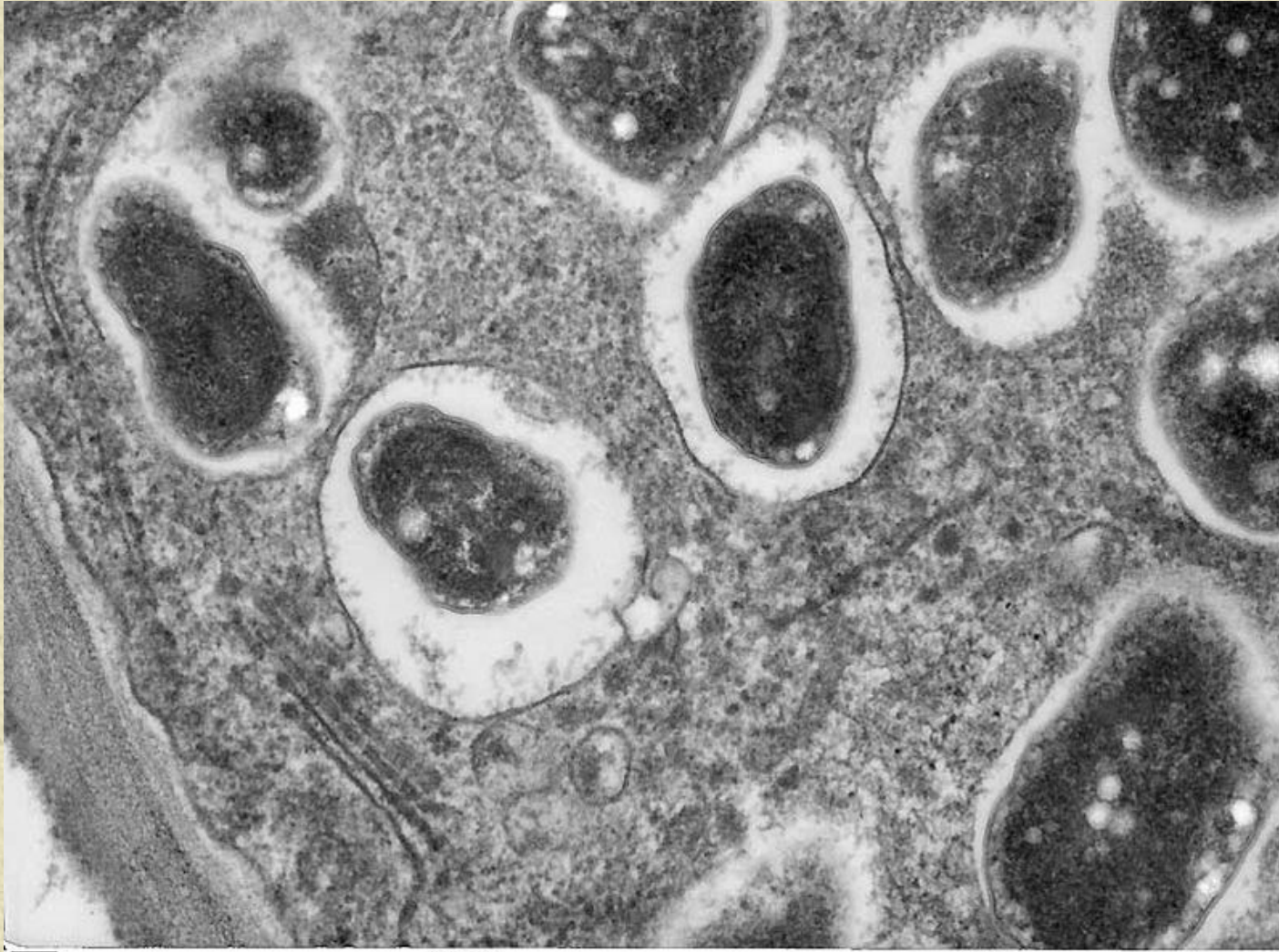
Nodules



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.
- ✦ **Bradyrhizobium:** *B. japonicum* nodulates soybeans.

Bacterial Requirements

✦ **Food (photosynthate)**

✦ **Oxygen**

✦ **Water**

✦ **Suitable environment**

Temperature

pH

Inorganic nutrients

Mineral Nutrition

✦ Calcium – low Ca inhibits nodulation

✦ Phosphorus (energy)

✦ Iron, Sulfur & Molybdenum*

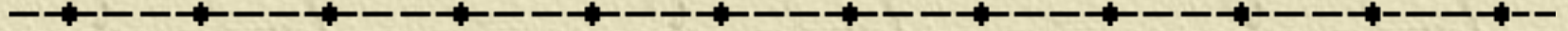
✦ Minor elements (Co, Ni)

✦ 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.)

Effect on Legume

- ✦ 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**

Temperature

- ✦ **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**

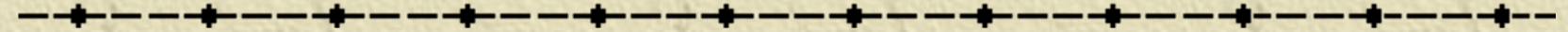
✱ **If there is a doubt**





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)**

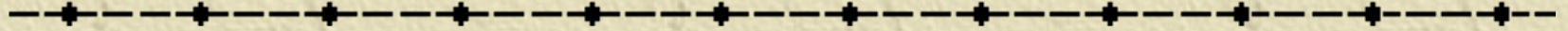
✱ **Specific strain for specific cultivar (Australia)**






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