Green Thumb Education Series:

"Nitrogen in the Garden"

will start momentarily.

Upcoming presentations of Green Thumb Education Series:

March 23: *Diagnosing Environmental Stress*
Linda Chalker-Scott, WSU Professor and Extension Horticulturalist
Location: Clallam County Courthouse Commissioners' Room

April 13: *Two Views, Old and New*
Bev Dawson and Marilynn Elliott, Master Gardeners
Location: Clallam County Courthouse Commissioners' Room

WSU EXTENSION
Clallam County

Nitrogen in the Garden

Green Thumb Education Series

Bob Cain, Master Gardener

March 9, 2023

For starters!

- Take a nice deep breath

Nitrogen in the air

- That breath you took contains about 75-80% nitrogen!
- Your lungs removed the oxygen and you exhaled the nitrogen back to the atmosphere.
- Nitrogen is all around you and in just about everything you see around you!
- Unfortunately, we cannot use atmospheric nitrogen efficiently and have to rely on others to make it usable.

A long time ago ....

- Early in earth's history the atmosphere was very different! Mainly nitrogen, carbon dioxide and some sulfur gases (volcanism).
- There was very little oxygen, green plants had not yet evolved and no photosynthesis.
- Most microbes and Archea were anaerobic and did not require oxygen.
- A very few species evolved to be able to process atmospheric nitrogen but this process still avoided the use of oxygen – more later!

The core of the problem

- Nitrogen exists as two nitrogen atoms connected by 3 chemical bonds.
- These bonds are very strong and make nitrogen very inert and hard to combine with other chemical elements.
- Breaking these bonds to make the nitrogen useful requires a lot of energy typically yielding ammonium species (NH4).
- Only a small fraction of organisms can achieve this.

Ubiquitous Nitrogen

- Nitrogen is integral to all life – found in all amino acids, protein, DNA and RNA and in most biomolecules.
- All living things contain carbon, oxygen, hydrogen and nitrogen as well as other elements.
- It is a major macronutrient for plants – as shown in fertilizers as N-P-K. It is needed for growth and development.

The big question

- If nitrogen is so inert, how did it get into our bodies and those of most living things?

Solving the Puzzle

- Nitrogen has been known to be critical to plant growth.
- Hellreigel and Willfarth (1886)– something in the soil (not nitrogen) was conferring a positive nitrogen like effect on certain legumes.
- When peas (legumes) were grown in sterilized soil they lost this advantage and leaves became yellow, symptoms of nitrogen deficiency appeared just as in non-legumes.
- Something in the soil was providing nitrogen to the plants.
- Biejernick (1888) isolated a bacterium *Rhizobium* from legume roots and nodules and showed it produced ammonium in the soil. In the Northwest US forests *Frankia sp* are more dominant.

Nitrogen Fixation

Plant/microorganism symbiosis can utilize atmospheric nitrogen and covert it to a usable form. This is called “Nitrogen Fixation.”

Many plants called “Legumes” can partner with some bacteria to run this process. Peas, beans, other legumes and some trees such as alders participate in this interaction.

Since the nitrogen-to-nitrogen bond is so strong it takes several enzymatic steps to accomplish this fixation and produce ammonium species which plants can use. This demands a lot of energy from the plant and bacterium.

The process is complex

- Initially the plant must attract the right microbe to the root hair surface.

- To do so it must establish the microbe is not a pathogen.

- The interaction of the two partners create a structure called a nodule which must be oxygen free. Leghemoglobin is the active oxygen scavenger – like hemoglobin turns red in contact with oxygen.

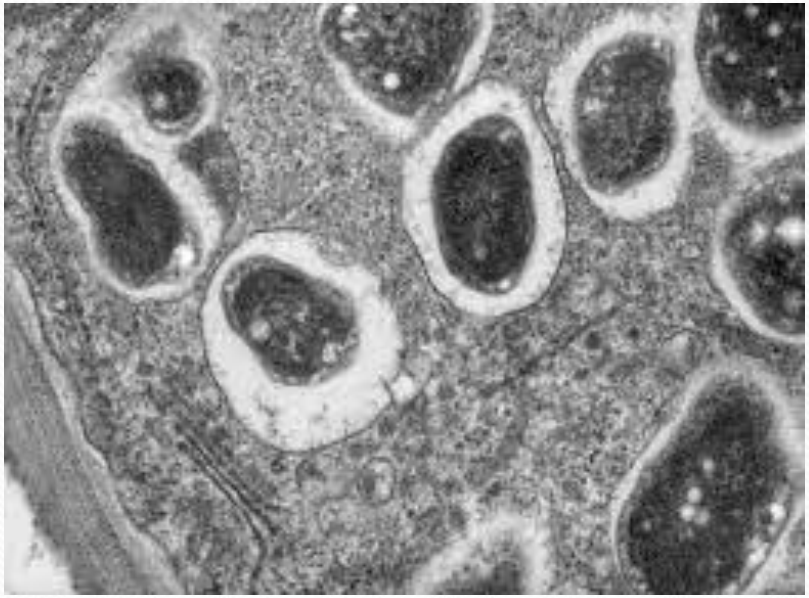
- The microbe creates usable nitrogen for the plant to produce nitrogen containing bio-molecules – chlorophyll, amino acids, genetic material, etc. The microbe gets carbohydrate and other molecules from the plant photosynthetic processes.

- The process can be turned on or off depending on the supply of usable nitrogen in the plant root zone.

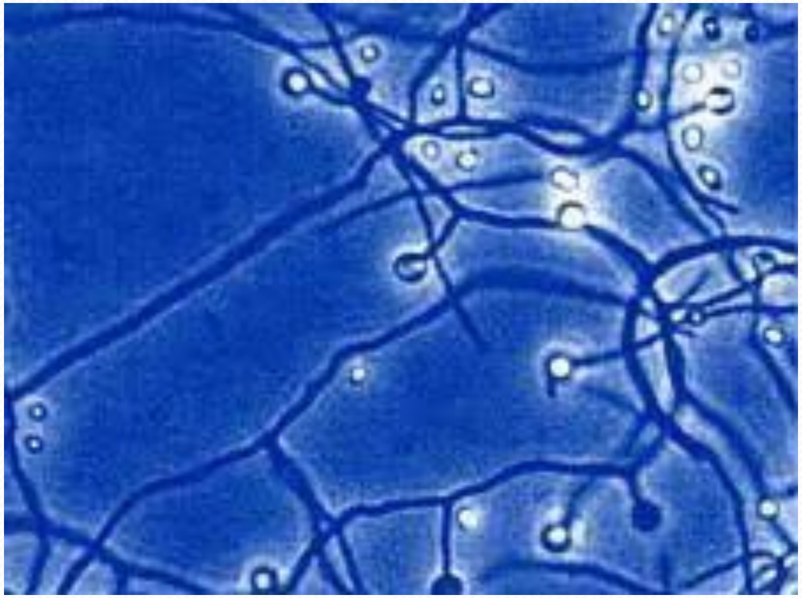
One of the many beneficial microbes

*Rhizobium leguminosarum b*acteria

More Common Nitrogen Fixers

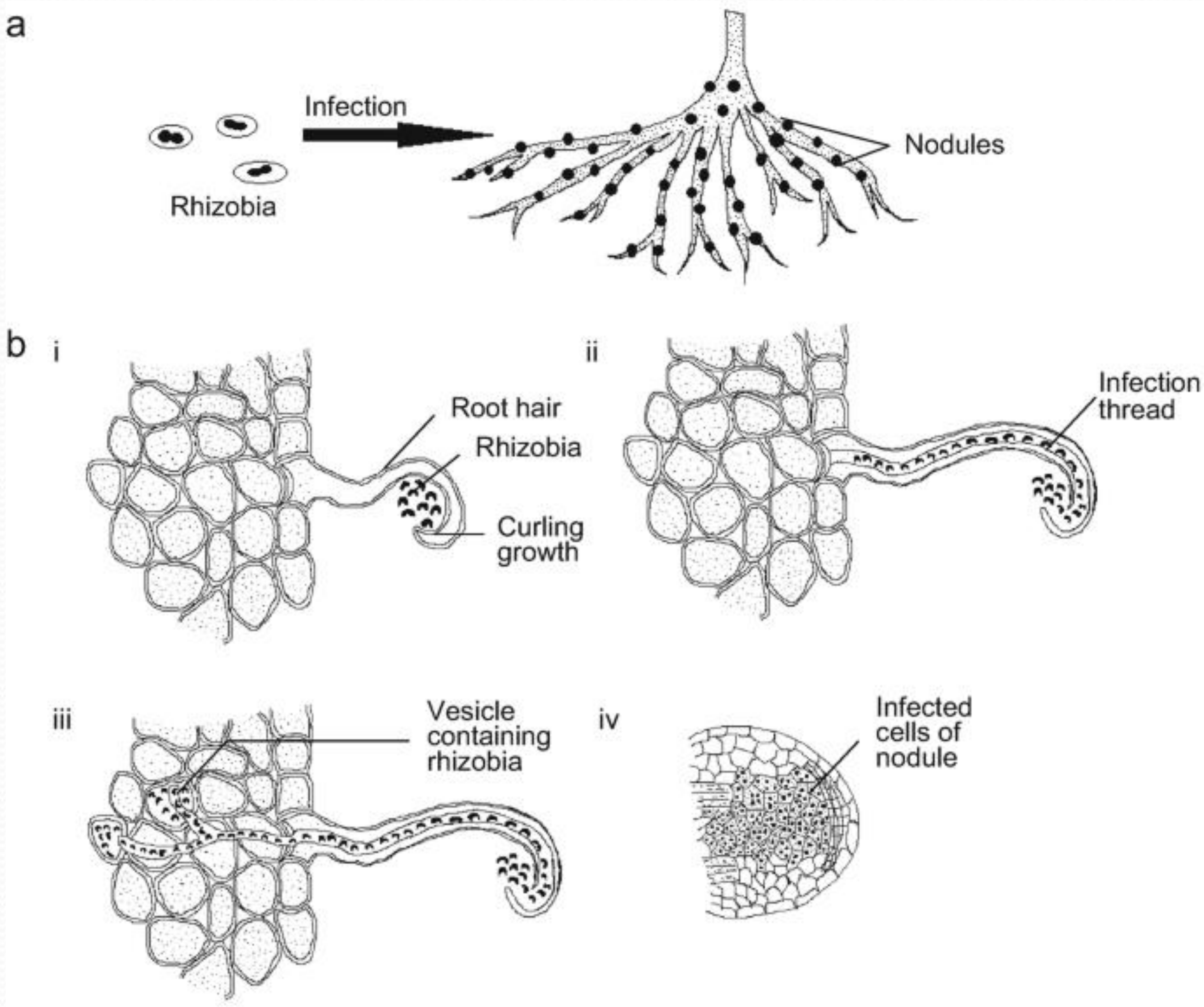


Bradyrhizobium sp.- a nitrogen fixer, commonly added to inoculants.



Frankia sp – a nitrogen fixing filamentous *Acinetobacter.*

Nodulation



a
Infection
Rhizobia
Nodules
b
i
Root hair
Rhizobia
Curling growth
ii
Infection thread
iii
Vesicle containing rhizobia
iv
Infected cells of nodule

How it looks in the field

Note the nodules attached to the runner bean roots!

More than just peas and beans

Nitrogen in the soil

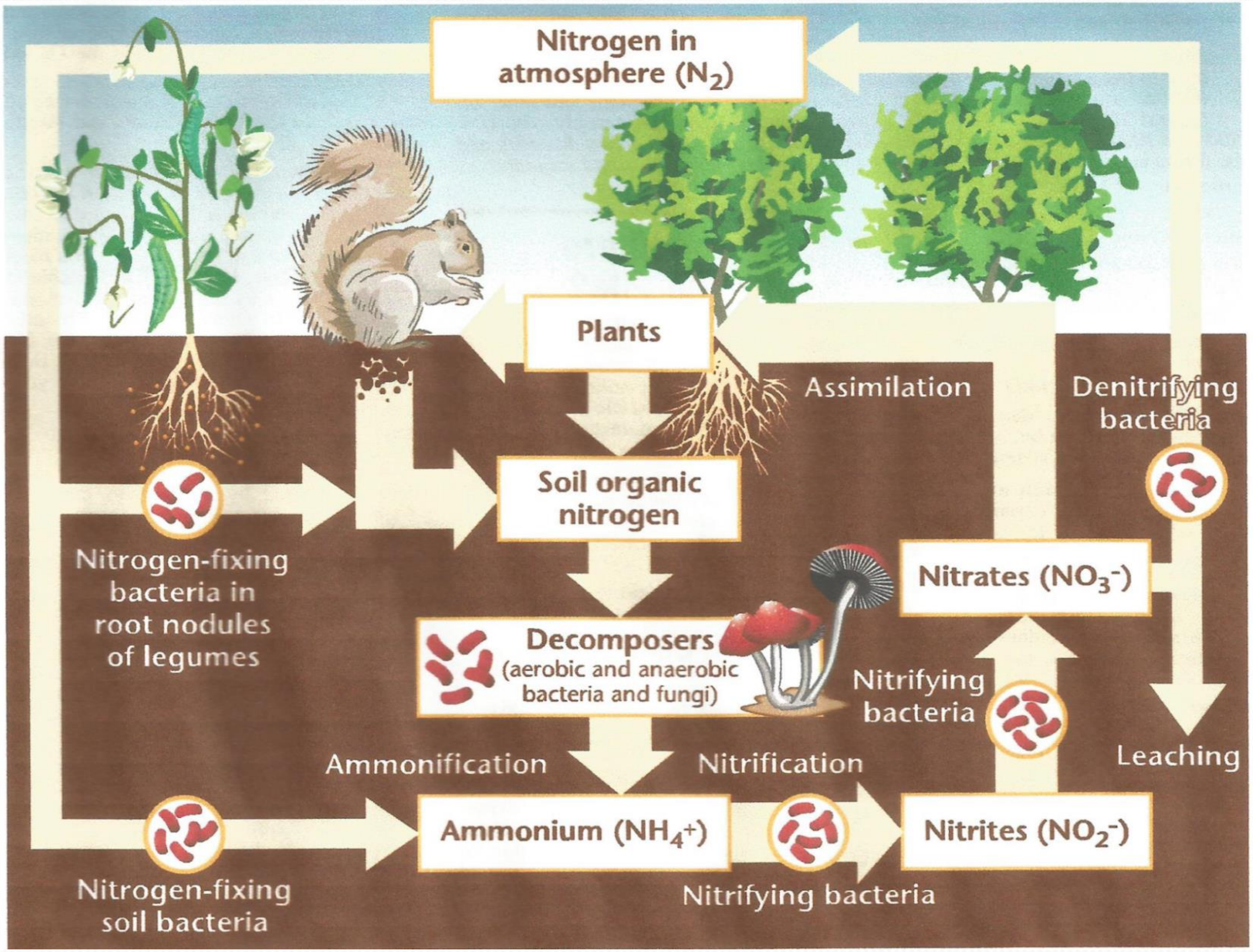
- Atmospheric Nitrogen (N_2) – 80% of soil atmosphere. Not available to plants except N- fixing legumes

- Organic Soil Nitrogen (N) – found in humus, lignin, proteins and amino acids from decomposition. Can be converted to ammonium by soil microbes.

- Ammonium ions (NH_4) - inorganic and very water soluble. Can be used directly by plants and can be converted to nitrate by soil microbes.

- Nitrate (NO_3) - inorganic and very water soluble. Can be used directly by plants and can be leached away or converted to nitrogen gas in wet soils by microbes.

Nitrogen Cycling in Nature



Adding Inoculants

While most soils will contain nitrogen fixing bacteria some may need a refresher or top up. Both commercial products and those for home use are available.

Home-use products contain *Bradyrhizobium japonicum* and other species as well as several defined species of *Rhizobium leguminosarum.*

Commercial products contain the same species as well as others such as *Azobacter*. Some may have been modified to promote higher level of nodulation and fixation.

Some examples

Home use product.

Commercial product for peanuts

Historical context

The benefits of growing legumes as part of a planned cycle was know in Roman times and probably much further back in history.

Planting legumes is a common feature indigenous cultures, such as the Three Sisters System – Corn, Beans, Squash.

Up until the late 19th century the main nitrogen input for agriculture in Europe was still animal manure or some legumes. However, about this time it was realized that as the population increased, following industrialization, there would not be enough to support the yields needed for that population.

More History

To keep crop yields in line with population growth a new source of available nitrogen was needed. In conjunction with this, at the turn of the 20th century war in Europe seemed inevitable. Nitrogen would be needed for explosives and the natural sources of nitrate from sea bird guano were seriously depleted.

Synthetic Nitrogen Capture

- The Haber Process, later refined into the Haber-Bosch is an artificial nitrogen fixation process and is the main manufacturing method of producing ammonia today.

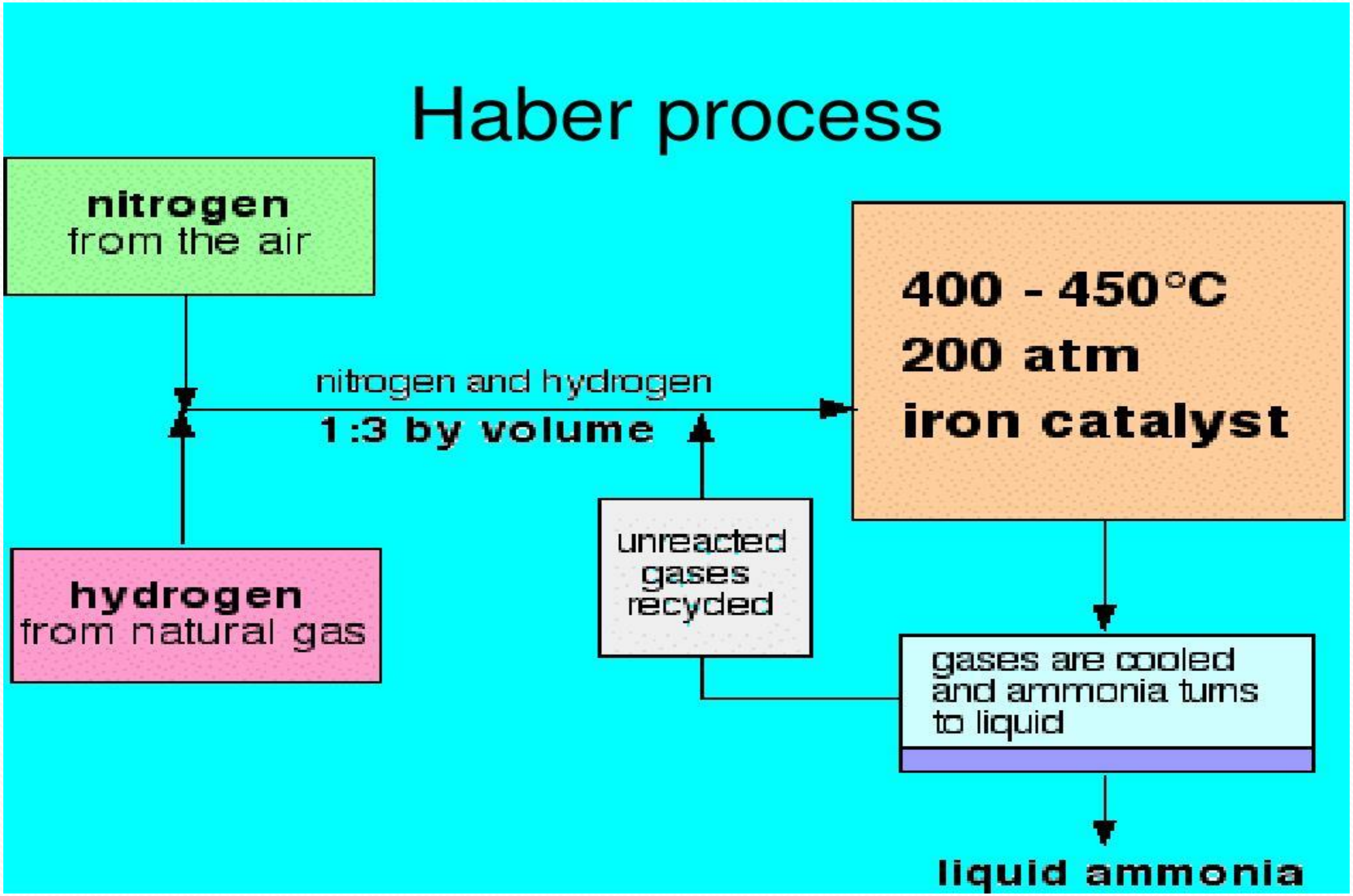
- The process converts atmospheric nitrogen to ammonia by reacting it with hydrogen and a metal catalyst under high temperature and pressure.

- Prior to this invention, the production of ammonia had proved very difficult and impractical.

- During World War 1, Germany needed this process to produce explosives since the importation of Chilean saltpeter (Guano) had been blockaded by the Allied forces.

- Due to the use of the process to provide raw materials for explosives many scientists objected to Haber receiving the Nobel Prize in 1918.

Synthetic Nitrogen Capture



Synthetic Nitrogen Fertilizers Advantages and Issues

- Provides quick release nitrogen inputs which are very water soluble. Relatively short-term effect.

- Production requires a lot of energy and often extreme conditions of high pressure and temperature.

- Easy to oversupply this kind of fertilizer which can get into groundwater, streams and lakes.

- Groundwater contamination can lead to wells being too high in nitrate with associated toxicity.

- Nitrate in run off can cause algae blooms (Lake Anderson) and lead to oxygen depletion in aquatic environments.

Too much nitrogen in runoff

Synthetic Nitrogen Fertilizers Advantages and Issues

- In synthetic fertilizer mixes nutrients are shown as % N-P-K look at the first number (N) such as 10-10-10 (10% nitrogen). The label will often state the source of the nitrogen.

- The strongest garden fertilizer with a high nitrogen content is urea (~45% nitrogen by weight).

- Most synthetic nitrogen fertilizers are very water soluble and are applied several times a year since they become depleted very quickly by downward migration away from the root zone.

- They should be regarded as short-term quick fixes.

Synthetic Nitrogen Fertilizers

Source	%N	%P	%K
Urea	46	0	0
Ammonium sulfate	21	0	0
Diammonium phosphate	18	46	0
Sulfur coated urea (SCU)	35	0	0

Urea readily converts to ammonium.
Ammonium sulfate is useful or acid loving plants.
Diammonium phosphate provides N and P.
SCU is a slow release fertilizer for N.

Organic Nitrogen Fertilizers Advantages and Issues

- Provides slow release nitrogen inputs which are very water soluble. Relatively long term effect since microbial breakdown is required to release available nitrogen.

- Production requires less energy and in many cases the sources would otherwise be regarded as waste, such as feather meal and blood meal.

- Application is often required prior to the crop being planted so that some breakdown occurs before planting.

- Groundwater contamination and associated toxicity is very much reduced.

- Many fertilizer mixes may still have some manure component but many are manure free and are complex mixtures of many products.

Organic Nitrogen Fertilizers Examples

- Ensure the product is approved as organic by OMRI or other agencies.

Source	%N	%P	%K
Blood meal	15	1	1
Feather meal	12	0	0
Fish meal	10	4	0
Bat guano	10	3	1
Cotton seed meal	7	2	1
Fish emulsion	5	1	1
Composted chicken manure	5	3	2
Bone meal	4	24	0
Alfalfa	2	0.5	2

Simple Methods to Input Organic Nitrogen – Cover Cropping

Soil Builder ® cover crop – peas, oats, rye, fava beans

Incorporation of Cover Crops

Cover crop can be dug in to start decomposition.

Alternatively, some people leave the crop residue and plant directly into it as it decomposes.

Benefits of Cover Cropping

- Reduces use of synthetic fertilizer and avoids leaching and groundwater contamination.

- Grasses provide organic matter while the legumes fix nitrogen to reduce fertilizer usage.

- Leaving the cover crop residue in the soils will help control weeds by using no-till methods.

- Some legumes can produce significant amounts of nitrogen fixing and reduce fertilizer usage, e.g. Clover -125-150 lbs/acre, Beans – 14010 lbs/acre, Peas – 120 lbs/acre and Alfalfa – 10 lbs/acre.
125 lb/acre = 4oz urea or 12oz blood meal for an average raised bed.

- Minimizes soil erosion and compaction during the wet season.

Conclusions

- Nitrogen is essential for good plant growth.

- However it must be applied carefully to avoid pollution.

- Cover cropping or application of organic fertilizers mitigates these effects for the most part.

Key Resources

- Tales from the Underground by David W. Wolfe, Basic Books Ltd.

- Revealing how bacteria and grasses fix nitrogen – https://cas.wsu.edu/2018/08/30/revealing-how-bacteria-grasses-fix-nitrogen/

- Cover Crops for Home Gardens, OSU Extension Publications, FS304 (Free download)

- Soil Fertility in Organic Systems: A Guide for Gardeners and Small Acreage Farmers, Pacific Northwest Publication (PNW) 646 (Free download)

- Cover Crops for Home Gardens West of the Cascades, WSU Publications, FS1111E and. EB1824 are also free downloads.

- Many publications from WSU Center for Sustaining Agriculture and Natural Resources. (CSANR) at https://csanr.wsu.edu/

More Resources

- A Home Gardener's Guide to Soils and Fertilizers, WSU Publication EM 063E (Free download)

- Fertilizing with Manure, WSU Publication PNW0533 (Free download)

- Fertilizing Your Garden, OSU Publication EC 1503 (Free download) (A good guide for fertilizer application calculations.)

- Secrets to Great Soil, (Storey's Gardening Skills Illustrated) by Elizabeth P. Stell, pp 116-117. (Covers methods of adding nitrogen organically and conventionally and cover cropping.)

- WSU Master Gardener Curriculum – Fertilizers