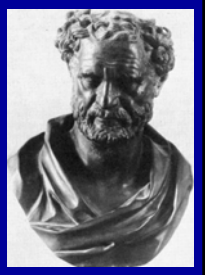
Lecture 31
Agricultural Scientific Revolution: Chemical

Crop Nutrition

Antiquity
Democritus of Abdera (ca 460–360 BCE)

Mother earth when fructified by rain gives birth to crops for the nourishment of man and beast
But that which come from earth must return to earth and that which came from air to air
Death however, does not destroy matter but only breaks up the union of its elements which are then recombined into other forms



Aristotle (384–322 BCE)

Four elements: earth, water, fire, and air
Aristotle assumed plants assimilated organic matter from the roots based on the fact that organic matter, particularly manure and plant residues, benefited plant growth
Beginning of Humus Theory of plant nutrition

Tsi, Chinese writer (1100 BCE)

They (green manure) are broadcast in the fifth or sixth month and plowed under in the seventh or eighth month…Their fertilizing value is as good as silkworm excrement and well-rotted farm manure

Pliny (23–79 CE)

It is universally agreed by all writers that there is nothing more beneficial than to turn up a crop of lupines, before they have podded, either with the plough or the fork, or else to cut them and bury them in heaps at the roots of trees and vines

Bernard Palissy (1510–1589)

Proposed concept that manuring was to replace substances lost by crop removal

Manure is carried to the field for the purpose of restoring to the latter a part of what had been removed… Proceeding thus you will restore to the soil the same substances that have been removed by previous crops and which following crops will regain to their advantage

Jan Baptista van Helmont (1577–1644)

Infamous experiment with willow
- **Attributed plant growth to water!!!**

Planted a willow in soil
- **After 5 years, willow gained 169 pounds and soil lost 2 ounces**

John Woodward (1665–1728)

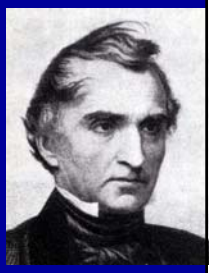
Demonstrated that spearmint grew better in water containing soil that rainwater alone

17th Century Chemists

- Johan Glauber (1604–1655)
- Gabriel Plattes 1600–1655)
- Analyzed salts such as woodashes, limestone, and saltpeter (potassium nitrate) on plant growth
- In Thirty Year War due to lack of manure invented chemical fertilizer called “philospher dung” or “fattening salt”
- Despite these observation the belief that humus (organic matter) was the “food of plants” was upheld well into the 19th century
  Humus Theory supported by renowned chemists:
  Theodore de Saussaure (1767–1845)
  Sir Humphrey Davy (1778–1829)

- The burning question in the early 19th century was whether the ashes produced by plants were constituents produced by plants or must be absorbed and what was their role
- A prize was offered to solve the problem of the source and function of inorganic elements in plant ash
- Prize awarded to A.F. Wiegmann and L. Polstroff based on experiments using synthetic soil vs. sand alone: origin of plant ash was soil

Justin von Liebig (1803–1873)



- Dominant figure in plant nutrition
  Proves that humus *per se* not absorbed by plants
- Demonstrated that carbon was supplied by air and not by humus
- He incorrectly believed C was absorbed by roots
- Liebig assumed N was absorbed from the air (not from humus) but this was insufficient for agriculture
- Was unaware of N fixation by bacteria
- Realized that animal manures were an important source of N

Contribution of Plant Nutrition in the 20th Century

- The concept of essential element
  - C H O from air and water
  - N P K Ca macro elements
  - S Fe B Mg Mn Cl Ni Cu Zn micro elements
- The contribution of air as a source of carbon via CO_2 and nitrogen indirectly through N-fixing micro-organisms
- The creation of inorganic fertilizers
- The importance of trace elements
- The respective role of nitrate and ammonia nitrogen in plant nutrition

- The concept of cation exchange and soil fertility
- The classification of soils and its relation to plant nutrition
- The importance of soil tilth, pH
- The problems of nutrient balance
- Use of foliar application
- Soil testing and leaf analysis
- The production of nitrogen from the Huber process and the development of the fertilizer industry

Pest Control

Search for chemicals have ancient tradition (Compounds used before 1850)

- Alum (aluminium sulphates)
- Antimony
- Arsencial compounds
- Bittern calcium and aluminum salts
- Calcium carbonate (Chalk)
- Copper sulfate
- Cobalt
- Gas lime (hydrated lime)
- Sodium sulphate
- Iron and Iron salts
- Lime
- Mercury
- Niter (saltpeter = KNO_3)
- Nitric acid
- Nitrum (sodium carbonate)
- Potash
- Quick lime (calcium oxide)
- Salt of Ammon (ammonium chloride, prepared from camel's urine)
- Salt (sodium chloride)
- Sulfur
- Sulfuric acid
- Verdigris (Copper acetate)
- Water

- Copper Sulphate plus Lime: First example of successful pest control
- Alexis Millardet, mycology professor, University of Bordeaux, notices that grape vines sprayed with mixture of copper sulphate (blue stone or blue vitrol) plus lime to prevent pilfering (the blue color looked poisonous) were relatively free of downy mildew caused by the fungus *Plasmopara viticola*
- It was found that active ingredient was both copper and sulfur
- The lime was necessary to "safen" the mixture by changing pH
- The mixture of copper sulfate plus lime is now known as Bordeaux mixture

Insecticides

- The development of insecticides in the early 20th century included a number of truly dangerous materials including arsenicals (stomach poisons) and mercuric compounds
- DDT
- Development of pesticides received a major boost with the discovery that DDT could control mosquitoes at very low concentrations
- The use of DDT in WWII is credited with saving many lives by control of the malaria vector
- However, DDT was shown to have serious environmental consequences due to the fact that the material was stable and would accumulate in the food chain
- DDT affected the fertility of birds though a reduction in egg shell thickness

Rachel Carson (1907–1964)

- The case against DDT was made by Rachel Carson, a marine biologist and author, in her famous book *Silent Spring* (1962)
- The book dramatically changed public perceptions about the use of pesticides and led to the outlawing of DDT

1929

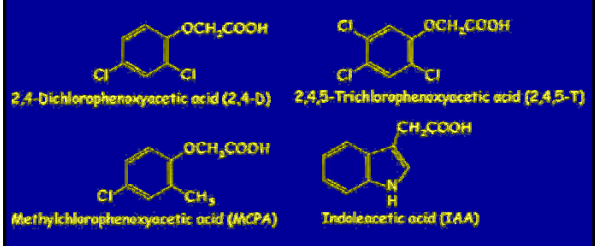
1981

Growth Regulation

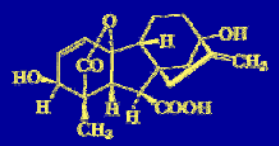
- Regulation of plant growth one of main contribution of 20th century science
- Charles Darwin and son Francis in a famous experiment with a light source, oat seedlings and razor blade proved that the tip of the seedling (coleoptiles) was responsive to light
- Julius Sachs 1880 assumes presence of root forming, flower forming substances that move in the plant

- Hormone Concept developed from animal physiology: Substance produced in one part of the organism and transferred to another to influence a specific physiological process
- Fritz Went, 1929, demonstrates that the substance from the excised tip of the oat coleoptile causing curvature, could be absorbed by agar and would cause a reaction when placed on a 2nd decapitated oat seedling
- Fritz Went and Kenneth V. Thimann, 1937, demonstrates that the hormone concept was applicable to plants
- Plant hormone termed "phytohormone"
- Active substance from the tip shown to be IAA (indoleacetic acid), also known as auxin

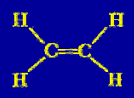
Structures of Auxin-like Herbicides Compared with that of Indoleacetic Acid



Other Growth Regulators



Gibberellic acid



Ethylene

Abscisic acid

Kinetin

Growth Regulators Have a Profound Affect in Horticulture

- Rooting (synthetic auxins)
- Growth promotion and retardation
- Abscission and thinning
- Fruit setting
- Fruit ripening
- Induction of flowering
- Herbicides
  - 2,4-D, a chemical similar to auxin
    - Killed broad leaved plants but not grasses (selectivity) at low concentration
    - Still widely used; led to chemical herbicide revolution in agriculture

Organic Movement: Backlash of the Chemical Revolution

- Assumption is that inorganic fertilizer is harmful
- Importance of organic matter, humus, and earthworms
- Anti pesticide (but use some supposed natural ones)
- Ecological and Spiritual approach to agriculture

Sir Albert Howard (1873–1947)

- Early advocate of organic agriculture
- Worked in India
- Concept of "healthy soils"
- Importance of biologic and physical factors in soils; composting
- Unscientific attacks marred scientific reputation but is a hero to organic movement.

Rodale Press and Organic Gardening Magazine

J.I. Rodale (1898–1971)

Robert Rodale (1930–1990)