

History of Soil Fertility and Plant Nutrition

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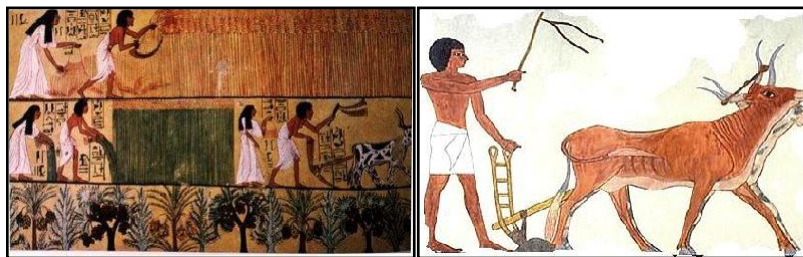
Introduction:

Actively managing soil nutrients to provide optimum plant nutrition has been a core practice of agricultural production throughout human history. For many centuries agricultural production has relied on recycling of organic residuals, such as manure and crop residues. Plant nutrition has been of great interest since time immemorial, at first among philosophers, and later among researchers. The history of environmental discoveries concerning the way plants feed is full of misconceptions and incorrect theories. Learning about the multi-generational effort to find an explanation for this process that is fundamental for agriculture shows us the tenacity and ingenuity of many outstanding personalities and scientists of that time. It also allows for general reflection which shows that present-day knowledge (which often seems obvious and simple) is the fruit of a great collective effort of science. The concept of soil fertility and its management to improve crop yields is not new perhaps it is as old as the development of agriculture by man. In ancient time also, they had knowledge of applying manures such as farm yard manure, green manure, night soil, bone, wood ashes, etc., to soil for the purpose of increasing crop yields.

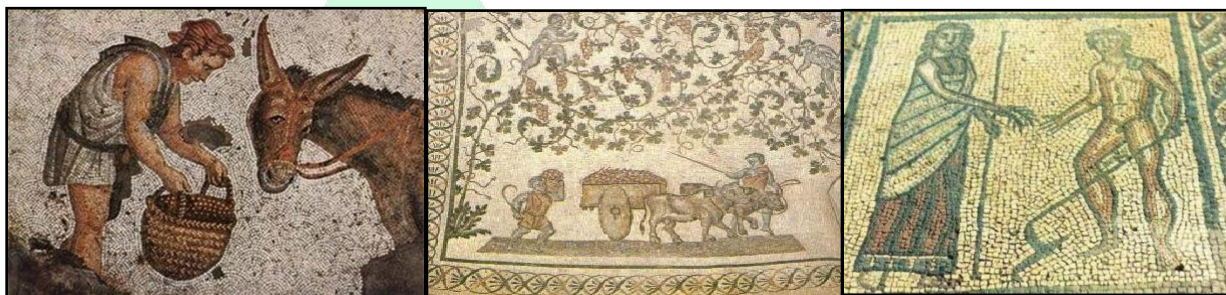
Ancient History

- ❖ Ancient Egyptian murals show lots of agricultural practices - tillage, planting, irrigation and harvesting but **no fertilization**

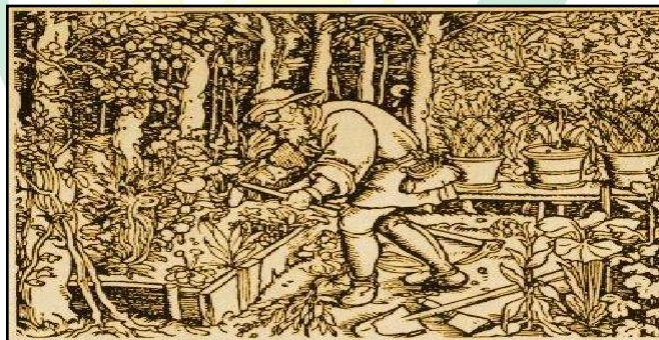




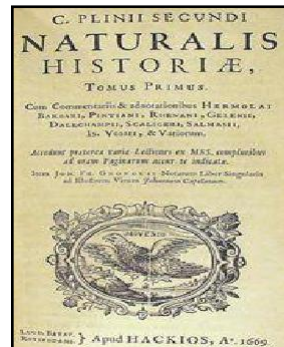
- ❖ **Roman art also reveals a lot about their agriculture.** In addition to Saturn and Ceres (Roman god and goddess of Agriculture), the Romans had a god of manure named Stercutius that was worshiped by old women and children.



- ❖ A number of **Roman authors** (e.g., Cato, Columella, Pliny the Elder) wrote detailed textbooks on agriculture that described the use of animal manures, green manures and about improvement of soil productivity.

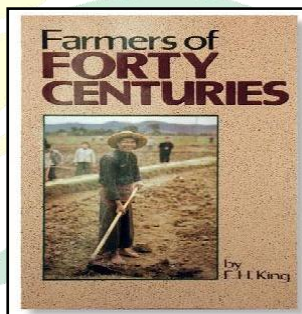
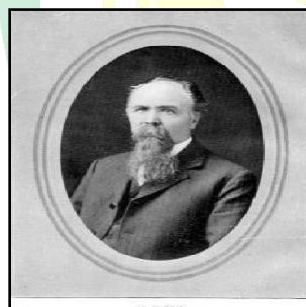


- ❖ Pliny the Elder (AD 23-79) classified animal manures with respect to their advantages and disadvantages of most animal manures and recommended the use of green manures. *"It is universally agreed by all writers that there is nothing more beneficial than to turn up a crop of lupines, before they have 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."*

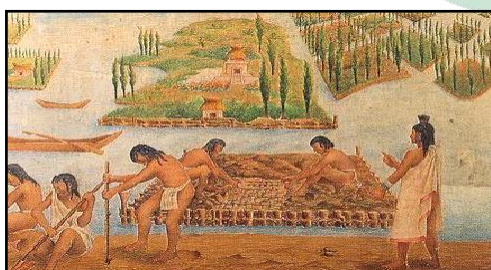


The earliest records of soil improvement using green manures are from the Chou dynasty (~1000 BC) in China. Later (500 BC), Tsi gave the following advice- *“Green manures are planted in the 5th or 6th month, and plowed under in the 7th or 8th month... Their fertilizing value is as good as silkworm excrement and well-rotted farm manure”*

- ❖ FH King (1911) stated in his book “Farmers of Forty centuries” that *“We desired to learn how it is possible, after twenty and perhaps thirty or even forty centuries, for their soils to be made to produce sufficiently for the maintenance of such dense populations”*.



- ❖ Chinampas agriculture in Central America was done where there were real floating gardens which made it possible to create areas for cultivation in the shallow parts of the lakes.



Middle Ages:

In 1240, Roman agricultural literature was summarized by Crescentius

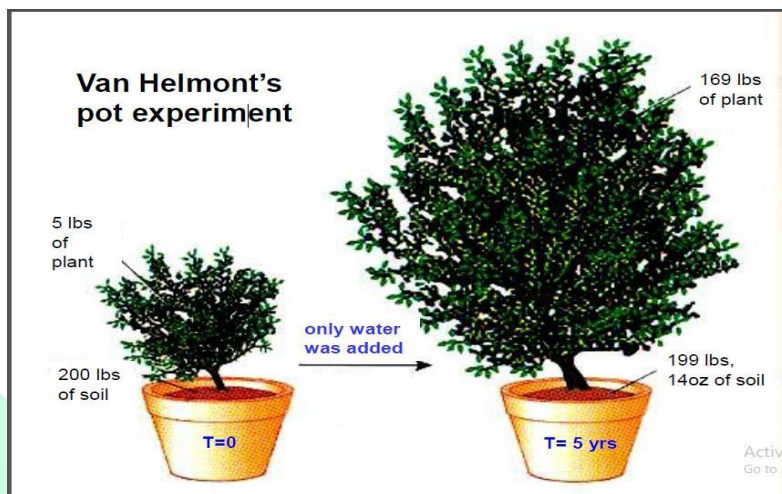


- ❖ Bernard Palissy (1510-1589) Ceramicist and hydraulic engineer wrote: “Manure is carried to the field for the purpose of restoring to the latter a part of what had been removed... Proceeding thus you will restore to the soil the same substances that have been removed by previous crops and which following crops will regain to their advantage”.

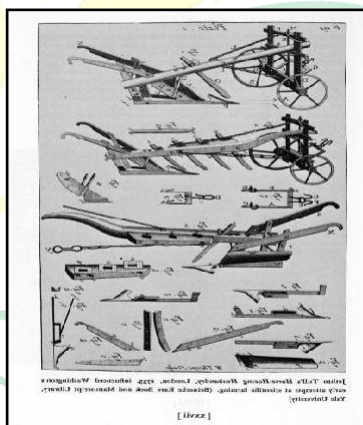
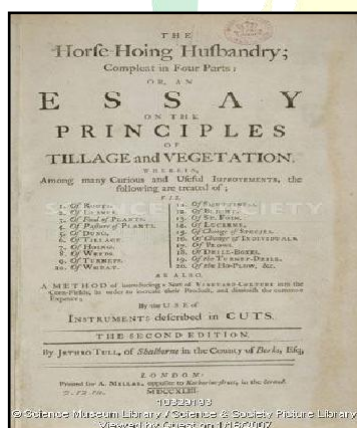


Early modern period, 16th-19th century

- ❖ Van Helmont’s (1577-1644) Willow tree experiment was another milestone in the history of Plant nutrition. He has explained about the Principle of Vegetation and what do plants eat?



- ❖ Van Helmont also performed experiments that involved combusting charcoal and reported that 62 lbs of charcoal produced, 1 lb of ash. He wrote that the other 61 lbs consisted of the "spirit of the wood," which he called "gas".
- ❖ Jethro Tull (1731) invented the grain drill and many complementary technologies that resulted in large increases in grain yields during the 18th century.



- ❖ **Tull's theory of plant nutrition:** "All sorts of dung and compost contain some matter, which, when mixed with the soil, ferments therein; and by such ferment dissolves, crumbles, and divides the earth very much. This is the chief, and almost only use of dung. *The value of dung is not to nourish, but to dissolve, i.e., divide the terrestrial matter, which affords nourishment to the mouths of vegetable roots.*"

❖ **The humus theory:**

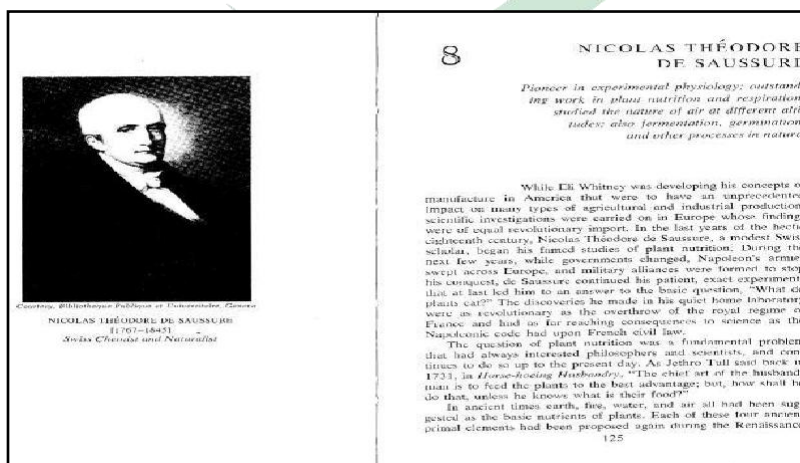
- Similar to animals, plants must feed upon organic substances that are similar to them in composition.
- Soil organic matter aka humus, is the chief nutrient for plants and the primary source of soil fertility.
- Roots absorb humus and transform it into plant substance, by combining it with water.



❖ Nicolas-Théodore De Saussure (1804), Swiss chemist and plant physiologist in the early 1800s, rejected most of the *principle of vegetation* concepts of his predecessors and arrived at many ground breaking conclusions:

- ❖ Soil, not air, supplies plants with N
- ❖ Roots are active and selective absorbers of water and salts
- ❖ Plants only absorb CO₂ and release O₂ when exposed to sunlight
- ❖ All plant tissues including seeds and roots consume O₂ and give off CO₂

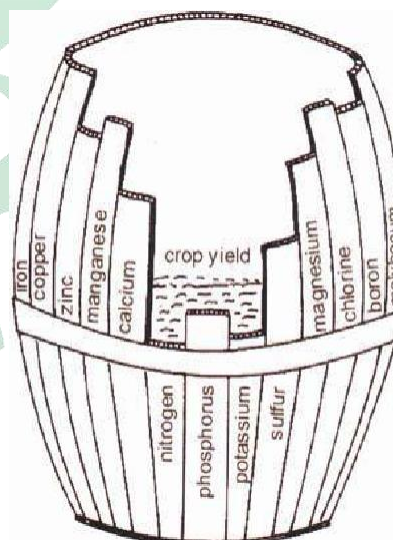
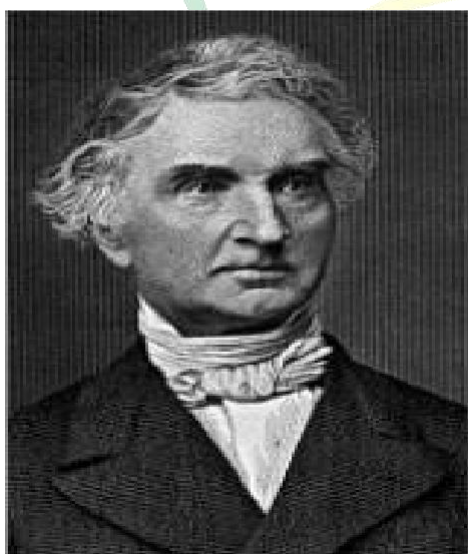
“He did not fully reject the Humus Theory”



- ❖ Carl Sprengel (1838) rejected the humus theory and gave the conclusion as “The conclusion should have been reached long ago that humus is not such an important substance as we have been led to believe, and that the current doctrine of humus is exceedingly full of contradictions.”



- ❖ Justus von Liebig (1840) was a pioneering German chemist who wrote and lectured extensively about the mineral nutrition of plants. As the first professor to use the laboratory method of teaching chemistry, he is regarded as one of the greatest chemistry educators of all time. He was held in such high esteem that, only few dared to question his pronouncements about mineral nutrition. Liebig did not actually introduce the **Law of the Minimum** but deserves credit for popularizing the concept.



- ❖ Liebig believed that the ash generated when a crop is burned contained the optimal blend of nutrients for fertilizing the crop and recommended a “check book” approach to fertilization
- ❖ Some of Liebig’s theories were not supported by experimental evidence but few were willing to publicly question them: *‘Agricultural crops receive quite sufficient nitrogen from the atmosphere’*
- ❖ Lawes and Gilbert (1843) founded the first agricultural experiment station in Rothamsted and conducted Broadbalk experiment which is continuous growing of wheat for more than 160 years. This is the oldest agricultural field experiment in the world.



- ❖ JB Lawes opened one of the first fertilizer factories in Europe and needed to convince farmers that they should use his fertilizers.

J.B. LAWE'S PATENT MANURES, composed of Super Phosphate of Lime, Phosphate of Ammonia, Silicate of Potass, &c., are now for sale at his Factory, Deptford-creek, London, price 4s. 6d. per bushel. These substances can be had separately; the Super Phosphate of Lime alone is recommended for fixing the Ammonia of Dung-heaps, Cesspools, Gas Liquor; &c. Price 4s. 6d. per bushel

From: *The Chronicle*, July 1, 1843 page 442

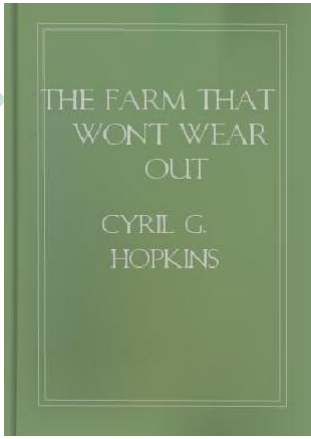
- ❖ Broadbalk demonstrated the value of N and P fertilizer and stated that manure was not necessary to produce high crop yields. However, the plots receiving both manure and fertilizer often produced the highest yields.
- ❖ The Broadbalk archive currently contains over 200,000 bottles of hay, grain and soil



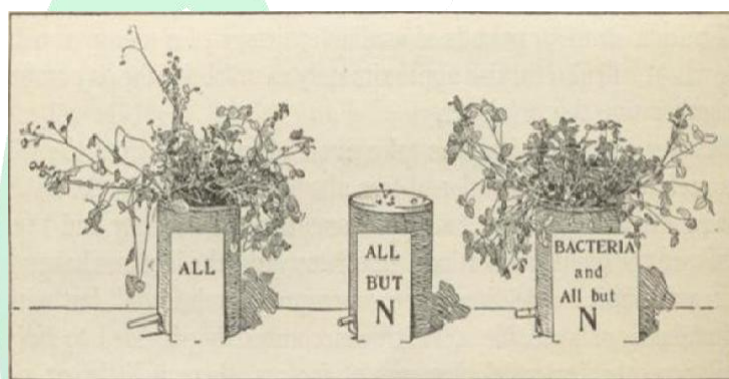
- ❖ Hopkins and Pettit (1876) started Morrow Plots at the University of Illinois which is the oldest agronomic experiment in the U.S.



Cyril Hopkins (right), head of the University of Illinois Department of Agronomy, and James H. Pettit (left), assistant in Soil Analysis at the Agriculture Experiment Station, collect soil samples from the Morrow Plots



- ❖ Hopkins in his book stated that *“The farmer should be as familiar with the names of the ten essential elements of plant food as he is with the names of his ten nearest neighbors”*.
- ❖ He also stated that *“it is not the land itself that constitutes the farmer's wealth, but it is in the constituents of the soil, which serve for the nutrition of plants, that this wealth truly consists.”*
- ❖ The book written by Cyril Hopkins *“Soil Fertility and Permanent Agriculture”* in 1910 mentioned that *“Legumes can fix their own Nitrogen if they have the appropriate bacteria”*.



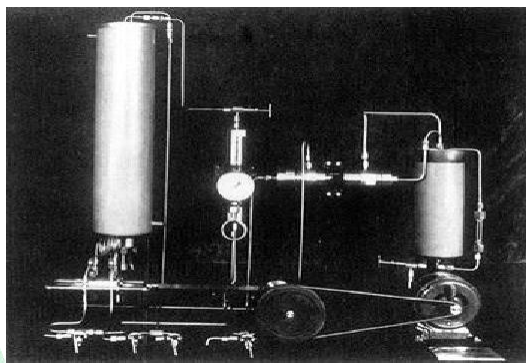
**Rhizobia bacteria first
Isolated in mid 1880s**

- ❖ 19th century farmers had limited opportunities to purchase nutrients. Some used guano imported from South America. Large yield responses were reported for a wide range of crops after applications of guano. Guano is a concentrated source of N (~ 12 %) and P₂O₅ (~ 12 %), with much higher analyses than most organic fertilizers.



Present day 20th Century:

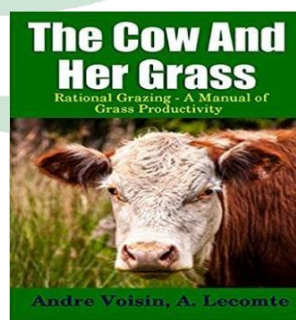
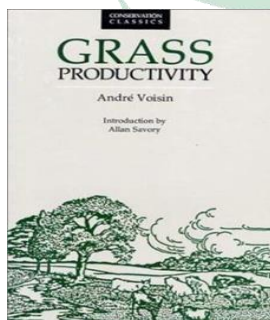
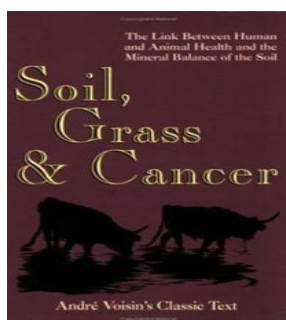
- ❖ Fritz Haber designed a Laboratory apparatus for producing NH_3 from H_2 and N_2 . The catalytic process took place in the large cylinder.



- ❖ The amazing effectiveness of the ‘*chemicalization*’ of agricultural production and utilization of the achievements of the *Green Revolution* in the 1980s gave the technological capacity to feed the earth's population
- ❖ Large-scale research on the effect of fertilization on the content of minerals and main organic substances (protein, amino acids, vitamins, hormones, enzymes and the like) was launched. That research led **Andre Voisin (1903-1964)**, a French researcher, to the discovery of two new fertilizer laws in the 1960s. These laws are known as the *Law of the Maximum* and *Law of the priority of biological quality*.

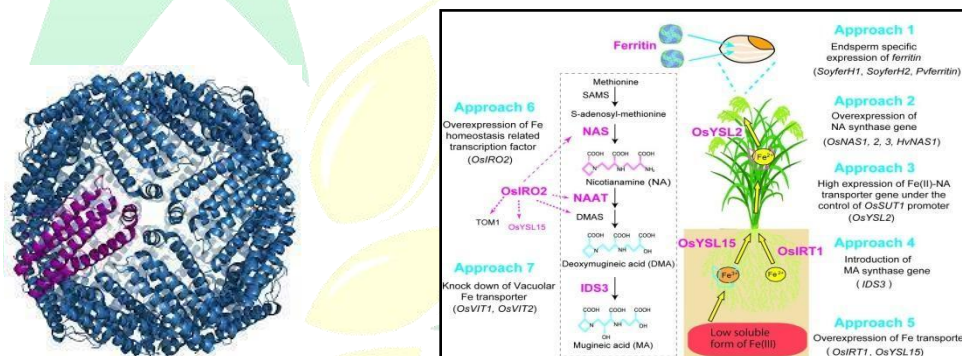
Law of maximum: “An excessive amount of available substance in soil limits the effectiveness of other substances and in consequence leads to a decrease in yields”

Law of the priority of Biological Quality: “The main goal of fertilizer use should be to improve the biological quality which is of higher importance than the amount of yield”



Modern times, the 21st century:

- ❖ In modern times, agriculture is an example of incredible symbiosis and cooperation in the area of practical application of scientific research in the field of agricultural chemistry and chemical technology, biology, physiology of mineral nutrition and other related sciences.
- ❖ Chemical innovations in plant nutrition include various strategies used separately or in combination. For example, genetic engineering is used to improve the uptake of macro and micronutrients by plants. One of the greatest successes in this area was the expression of ferritin - a protein that stores iron in a bioavailable form. Recombinant soybean ferritin was added to many grains, and pea ferritin was expressed in rice.



Milestones in the History of Plant Nutrition:

Year	Scientist	Issues
1600	Van Helmont	What can be used as food for plant growth
1772	Priestly	Plants release oxygen from leaves into the atmosphere
1804	De Saussure	Apart from CO ₂ , water also takes part in photosynthesis
1806	Thaer	First agricultural academy in Moglin (Germany)
After 1800	Thaer	The humus theory for plant nutrition
1834	Boussingault	The role of nitrogen in plant nutrition
1841	Liebig	Theory of mineral plant nutrition
1842	Sprengel, Liebig	Theory of minimum in agricultural chemistry; Liebig's Law of the Minimum
1842	Lawes	Patent: a way to obtain single superphosphate
1848	Lawes	First superphosphate factory in Liverpool
1886	Hellriegel and Wilfarth	Discovery of the phenomenon of nitrogen fixation by rhizobia
1911	Haber and Bosch	Synthesis of ammonia
1970	Borlaug	Green Revolution, technological capacity to feed the world
1994	Robert	Precision Agriculture
After 2000	Various Scientists	Innovative fertilizers

Conclusion:

There are many cases, often forgotten, perceptions that predate present-day concepts that are accepted as essential for sound management of natural resources such as that of sustainability. The great progress in plant nutrition, which has been observed in recent years, is a result of the achievements in, among other things, sciences such as chemistry, chemical technology, physics, biology, physiology of mineral nutrition, and in the use of modern



analytical techniques and using precise research equipment. New, innovative research methods have revolutionized the possibilities of measurement of plant nutrition processes, from which proper conclusions can be drawn, thus eliminating the errors. The development of studies on mineral plant nutrition results, among other things, from the necessity to increase food production whose goal is to feed approximately 9 billion people by the half of this century. It is an obligation to the society, and it must be met by, among others, farmers, biologists and chemists. One should agree with the opinion of **Arnold Fink**, an outstanding German agricultural chemist, that “Scientific theories and hypotheses can be used in agriculture as long as they find confirmation when confronted with nature”.

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