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Nitrogen Yielding Plants: The Pioneers of Agriculture with a Multipurpose

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Abstract: Out of the basic elements of nitrogen, phosphorus and potassium (N, P, K), nitrogen is the most unavailable for soil. Though it is the most abundant gas in the atmosphere, yet the form in which it is utilized by the soil and plants for their vital functions is not readily available. Growing of leguminous plants like alfalfa, beans, clovers, nuts, etc in a way benefits the plants and soil by yielding nitrogen in the compound form. The biological nitrogen fixation can be used as an efficient way to equip the soil with nitrogen which takes place with the help of root knot nodule bacteria. Leguminous plants fix atmospheric nitrogen by working symbiotically with special bacteria, rhizobia, which live in the root nodules. Rhizobia infect root hairs of the leguminous plants and produce the nodules. This will not only help the poor farmers but also the soil to get rid of chemical fertilizers. In this paper some plants which yield nitrogen in the soil are discussed.

Key words: Agriculture · Nitrogen yield · Bacteria · Leguminous crops

INTRODUCTION

Nitrogen is one of the most abundant gases of the earth's atmosphere and is one of the prime constituents of basic fertilizers (N,P,K). The gaseous form of this element cannot be used directly by the plants. As a result, it is often a limiting factor in agricultural production, especially for those crops that take up large amounts of nitrogen. Adequate nitrogen soil content is necessary for healthy plants and their growth and reproduction. More importantly, plants use nitrogen for photosynthesis [1]. While native plants are better adapted to their surroundings and often times less affected by nitrogen deficiency, in plants such as vegetable crops, supplemental nitrogen may be required.

Good crops depend on an adequate supply of nitrogen. Most nitrogen is naturally present in the soil as organic content. However, nitrogen loss due to erosion, runoff and leaching of nitrate can also cause nitrogen deficiency in plants. Some of the most common symptoms of nitrogen deficiency in plants include the yellowing and dropping of leaves and poor growth. Delaying of flowering and fruiting may also be there. As organic matter decomposes, nitrogen is slowly converted to ammonium, which is absorbed by plant roots. Excess ammonium is turned into nitrate, which plants also use to produce protein. However, unused nitrates remain in the groundwater, resulting in leaching of the soil. There are several ways to add nitrogen to soil. Supplemental nitrogen is usually provided by using organic or chemical fertilizers. Plants obtain nitrogen through ammonium and nitrate.

Nitrogen Fixation: Nitrogen fixation refers to the conversion of atmospheric nitrogen to ammonia and then to nitrogen containing organic compounds that becomes available to all forms of life. Nitrogen can be fixed by non-biological processes, such as lightning or the Haber-Bosch process used to produce fertilizer products such as urea [2]. However, biological fixation is the most common process for nitrogen fixation. Globally, an estimated 193 x 106 tons of nitrogen is fixed through biological fixation each year (Table 1).

Building up levels of organic matter in the soil is another way of raising soil nitrogen. This can be achieved by using organic fertilizer in the form of compost or manure. Another sustainable way is growing legumes for supplement soil nitrogen. Although organic fertilizer must be broken down in order to release ammonium and nitrate, which is much slower, using organic fertilizer to add nitrogen to soil is safer for the environment. The presence of the nitrogen on extreme ends like too much or too little can be just as harmful to plants as too little. Too much nitrogen can result in plant burning, which causes them to shrivel and die. It can also cause excess nitrate to leach into groundwater. Nitrogen is used by the plant to produce leafy growth and formation of stems and branches. Plants most in need of nitrogen include grasses

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Table 1: Various sources of nitrogen fixation

S. No.	Source of N fixation	Nitrogen fixed (10^6 tons per year)
1	Land	153
2	Legume	39
3	Non-legume	10
4	Others	104
5	Sea	40
6	Total biological	193
7	Lightning	9
8	Industry	85
9	Total non-biological	94

Table 2: List of a Few *Rhizobium* species and their corresponding hosts

	Rhizobium species	Host plants
1	*Bradyrhizobium japanicum*	*Glycine max* (soybean)
2	*Rhizobium fredii*	*Glycine max* (soybean)
3	*R. phaseoli*	*Phaseolus vulgaris* (common bean)
4	*R. meliloti*	*Medicago sativa* (alfalfa)
5	"Cowpea rhizobia" group or *Rhizobium* sp.	*Vigna unguiculata* (cowpea),
6	*R. trifolii*	*Trifolium* sp. (clovers)
7	*R. Ieguminosarum*	*Pisum sativum* (peas)

and leafy vegetables such as cabbage and spinach. Basically, the more leaf a plant produces, the higher its nitrogen requirement.

Nitrogen Through Fertilizers: Most chemical fertilizers will contain three elements essential for growth of the plant, Nitrogen (N) Phosphorus (P) and Potassium (K). These elements help in boosting the plant growth and provide resistance from many deficiency diseases. But, many a times, these chemical fertilizers are not feasible to the economically downtrodden farmers, for whom the nitrogen (N) is often the most limiting element for cereal grain production.

Legumes: in House Nitrogen Production for Plants: Plants in the bean family, legumes, have nodules on their roots where symbiotic bacteria live that fix nitrogen from the air for use by the plant. They are unique among crop plants in their ability to satisfy their large demand for nitrogen either through absorption and assimilation of inorganic nitrogen from the soil solution or by symbiotic fixation of atmospheric nitrogen. The presence of nitrate in the soil is desirable because it is required by plants for growth and development. However, nitrate is highly mobile and easily moves with water. The results of a heavy rain can move nitrates downward in the soil, below the root zone of plants. With crops that require a lot of nitrogen over a period of time, like cabbages, adding nitrogen incrementally through the growth period is the most efficient application method. It has long been recognized [3,4] that interactions are possible between the processes of absorption, assimilation and translocation of NO_3; N_2 fixation; and assimilation and translocation of the product NH_3.The reduction and assimilation of NO_3-in higher plants occurs in both above and below ground organs and the extent to which these parts participate in its assimilation depends on the plant species, the level of NO_3, and the environmental conditions to which the plant is expose [5]. Similarly, white sweet clover produces about 2.5 tons/acre dry matter and about 63 lb of nitrogen (N) per ton of dry matter (NRCS). To optimize N fixation, the soil should have adequate phosphorus, sulfur and micronutrients, especially iron and molybdenum, suitable pH and good aeration.

Of the total nitrogen required by legumes, generally about half is nitrogen fixed from the atmosphere, with the remainder being taken up from residual nitrate in the soil [6]. It is usually noticed that where legumes are grown, outside applications of manure or fertilizer nitrogen are not needed. Different legumes also vary in the amount of total nitrogen they can fix. Listed below in the table are common legumes used in agriculture and the total amounts of nitrogen they fix during a growing season. (Table 3).

Biological Nitrogen Fixation (BNF): It is the process where the atmospheric nitrogen (N=N) is reduced to ammonia in the presence of an enzyme nitrogenase which is a biological catalyst found naturally only in certain microorganisms such as the symbiotic *Rhizobium* and *Frankia,* or the free-living *Azospirillum* and *Azotobacter.* Biological nitrogen fixation is brought about by free-living soil microorganisms and by symbiotic associations of microorganisms with higher plants. In this paper we will mainly discuss about the legume-*Rhizobium* symbiosis. Leguminous plants fix atmospheric nitrogen by working symbiotically with special bacteria, rhizobia, which live in the root nodules. Rhizobia infect root hairs of the leguminous plants and produce the nodules. The nodules become the home for bacteria where they obtain energy from the host plant and take free nitrogen from the soil air and process it into combined nitrogen [7]. In return, the plant receives the fixed N from nodules and produces food and forage protein.

The biochemical mechanism of N_2 fixation can be written in simplified form as follows: nitrogenase

nitrogenase
N2----------------→ NH3-------------->----------Amino Acid----------→ proteins
+ATP, +H+, low oxygen tension

Table 3: Some Common Nitrogen Yielding Plants

S.NO.	Botanical name	Common nitrogen yielding crops	Family
1	*Medicago sativa*	Alfalfa	Fabaceae
2	*Pisum sativum*	Field peas	Fabaceae
3	*Trifolium pratense*	Red clover	Fabaceae
4	*Glycine max*	Soybeans	Fabaceae
5	*Melilotus officinalis*	Sweet clover	Fabaceae
6	*Lablab purpureus*	Hyacinth bean	Fabaceae
7	*Melilotus alba*	White sweetclover	Fabaceae
8	*Vigna _ubterranean*	Bambara groundnut	Fabaceae
9	*Arachis hypogaea*	Groundnut	Fabaceae
10	*Vigna unguiculata*	Cowpea	Fabaceae
11	*Mucuna pruriens*	Velvet bean	Fabaceae
12	*Phaseolus vulgaris*	Common bean,	Fabaceae
13	*Vicia villosa*	Hairy vetch	Fabaceae
14	*Vigna radiata*	Mung bean	Fabaceae
15	*Cajanus cajun*	Pigeon pea	Fabaceae
16	*Vicia faba*	Broad bean	Fabaceae
17	*Sesbania rostrata*	Sesbania sp.	Fabaceae
18	*Cicer arietinum*	Chickpea (garbanzo)	Fabaceae
18	*Trifolium incarnatum*	Crimson clover	Fabaceae
20	*Vigna angularis*	Adzuki bean	Fabaceae
21	*Trifoliumhybridum*	Alsike clover / true clover	Fabaceae
22	*Trifolium alexandrinum*	Berseem clover	Fabaceae
23	*Lotus corniculatus*	Birdsfoot trefoil	Fabaceae
24	*Mastigocladus laminosus*	Blue-green alga	Nostocophycideae
25	*Carya illinoinensis*	Pecan	Juglandaceae
26	*Aspirillum*	Free living bacteria	Rhizobiaceae
27	*Klebsiella*	Free living bacteria	Rhizobiaceae
28	*Azotobacter*	Free living bacteria	Rhizobiaceae
29	*Clostridium*	Free living bacteria	Rhizobiaceae
30	*Azospirillum*	Free living bacteria	Rhizobiaceae

The above mechanism indicates that N_2-fixing systems can thrive in soils poor in elementary nitrogen and they are a source of proteins and also they provide nitrogen for soil fertility. Adenosine Tri Phosphate (ATP) is the source of energy necessary for the fragmentation and reduction of N_2 into ammonia. In rhizobia, ATP results from oxidative degradation of sugars and related molecules. These sugars are manufactured by the host-plant during photosynthesis and transferred to the nodules. In general, for each gram of N_2 fixed by *Rhizobium,* the plant fixes 1-20 grams carbon (C) through photosynthesis. It is usually accepted that N_2 fixing systems require more Phosphorus (P) than non-N_2-fixing systems. Phosphorus is needed for plant growth, nodule formation and development and ATP synthesis, each process being vital for nitrogen fixation.

Nitrogenase is an oxygen sensitive enzyme. The low oxygen tension condition is realized through compartmentation in cyanobacteria (heterocyst in *Anabaena azollae*), active respiration (in *Azotobacter*) and synthesis of leghemoglobin (in *Rhizobium* legume). Leghemoglobin is a macromolecule synthesized by symbiotic partners, the rhizobia and the host plant. *Rhizobium* synthesizes the heme portion and the plant the globine. Like human hemoglobin, leghemoglobin fixes O_2. It is responsible for the red or brown color of active (i.e., N_2-fixing) nodules. Non-N_2-fixing nodules have white nodule content or a green content when the globine has degenerated.

Effectiveness of the Legumes in Yielding Nitrogen: There are approximately 1,300 leguminous plant species in the world. Of these, nearly 10% have been examined for nodulation, 87% of which were nodulated. It was observed that not all legumes are infected by rhizobia. *Gliricidia sepium* and *Vigna unguiculata* (cowpea) nodulate freely but nodules have never been found on roots of *Cassia siamea*. A *Rhizobium* that nodulates cowpea may not nodulate *Leucaena* and vice versa. Leguminous species mutually susceptible to nodulation by a particular group of bacteria constitute a cross-inoculation group. Therefore it can be seen the mechanisms of recognition between the micro-symbiont and the host-plant is good enough to explain specificity. Table 1 gives a short list of rhizobia and their hosts to illustrate the grouping of rhizobia. Similarly not all symbioses fix N_2 with equal effectiveness. This means that a given legume cultivar nodulated by different strains of the same species of *Rhizobium* would fix different amounts of nitrogen. From the biochemical reactions of biological nitrogen fixation, it is evident that N_2 fixing systems contribute to the quality and quantity of agricultural production.

How Biological Nitrogen Fixation Takes Place in Legumes: The bacteria, which are mostly free-living in the soil in the native range of a particular legume, infect the root hairs of the plant and form small root structures called *nodules*. The association is symbiotic because the energy is provided by the plant to feed the bacteria and fuel the nitrogen fixation process. In return, the plant receives nitrogen for growth. Out of many strains of rhizobia, some will infect many hosts, while certain hosts will accept many different strains of rhizobia. In conventional cropping systems it is estimated that 50-800 kg of nitrogen per hectare per year are accumulated by nitrogen fixing plants, depending on species, soil and climate, *Rhizobium* efficiency and management [8]. Nodulating bacteria from the family Rhizobiaceae are common in the semi-arid tropics around the world. The opinion that nitrogen fixation by the root nodule bacteria, *Rhizobium*, is restricted to a specific symbiotic association with specific legumes has recently been challenged. Trinick[9] showed that nodules formed on the non-legume *Trema canabina* by a strain of *Rhizobium* which nodulated *Vigna unguiculata* (cowpea), possess nitrogenase activity and fix atmospheric nitrogen. Soybean tissue cultures inoculated with *R. japonicum*, or with cowpea strains of *rhizobia*, also possess apparently functional nitrogenase as determined by the acetylene reduction assay. Biological N_2 fixed represents nitrogen gain and determines inorganic nitrogen fertilizer savings in agricultural systems. Legumes can fix more than 250 kg N ha^{-1}. However, the amounts of N_2 fixed can vary considerably in time and space

DISCUSSION

Since nitrogen is commonly the most limiting plant nutrient and also the most expensive element as a mineral fertilizer, biological nitrogen fixation (BNF) holds great promise for smallholder and economically not so sound farmers. Biological nitrogen fixation is accomplished by certain microorganisms and plant-microbe interactions. Legumes are nitrogen-fixing systems that have long been used for biological nitrogen fixation in agriculture. Biologically fixed nitrogen can be estimated by using various techniques like the acetylene reduction assay method, xylem exudate analysis, or by other methods. A number of edaphic, climatic and biotic factors inhibit N_2 fixation. The amount of biologically fixed nitrogen can be enhanced by different methods, including inoculation with proven strains, screening for improved microbial and host-plant materials and introduction of improved cultural practices through biological nitrogen fixation more nitrogen can be yielded so that the hazards of the chemical fertilizers can be reduced.

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