Vol. 3 Issue-3, November 2022 (e-ISSN: 2582-8223)

Insect as a Source of Nitrogen to the Plants

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ARTICLE ID: 19

Introduction

Nitrogen is one of the macronutrient which acts as a primary nutrient for plants and is required in large amount for plant metabolism and growth. It exists in numerous forms in soil which can be converted from inorganic to organic forms and vice versa. In soil it is available in organic forms as animal waste, manures, residue etc., they all go through the decomposition process and were made available to the plants. Inorganic forms (NH_4^+ and NO_3^-) involve symbiotic bacteria which converts nitrogen into the usable form so that plants can absorb. It has several processes such as Nitrogen fixation, Nitrification, Assimilation, Ammonification and Denitrification. The nitrogen cycle is a biological process through which nitrogen is converted to ammonium and nitrates ions by the atmosphere to soil to the organism and again into the ecosystem. Despite of all these methods by which nitrogen is converted to available form that can be used by plants, it is still a limiting factor especially for many plants. The reason for nitrogen deficit in soil are; N mobility i.e. leaching of nitrogen through soil erosion or poor farming practices, nitrogen immobilization, biological processes such as denitrification and microbial competition which remove and limit soil nitrogen levels. Insects, despite of its potential damaging effect, can be an essential nitrogen source for plants and it should not be overlooked. When viewed on a per plant basis, insects potentially become increasingly important as a source of nitrogen. Here we will we discuss how insects acts as a source of nitrogen reservoir for plants.

Insect as source of nitrogen reservoir

Insect damage causes a potential nitrogen loss to plants. But insects contain approximately 10% nitrogen by weight (Fagan *et al*., 2002). There is approximately 15g of insect nitrogen below ground and approximately 100–200 g of insect-bound nitrogen above ground in a square hectare of temperate ecosystem soil (Van, 1989). This amount is not insignificant, compared to microbial fixed nitrogen in the soil whereby microbes can fix approximately 100 g of nitrogen per hectare per year (Kummerow *et al*., 1978). Insects also have the potential to promote the fixation of atmospheric N through interactions with free-livingand endosymbiosis prokaryotes, thus resulting in an input of N to the system.

Possibilities of transfer of insect nitrogen to plants:

This below ground loss of nitrogen can however partially be counter balanced through the incorporation of insect-derived nitrogen back into plants. It can be accomplished through the following activity (Behie *et al*., 2013)

a. Direct ingestion of insects (carnivorous plants)
b. Indirect transfer of insect-derived nitrogen through bacterial or fungal ammonification and nitrification or through the association of symbiotic mycorrhizal fungi
c. Direct transfer of insect-derived nitrogen through a partnership with endophytic insect pathogenic fungi.

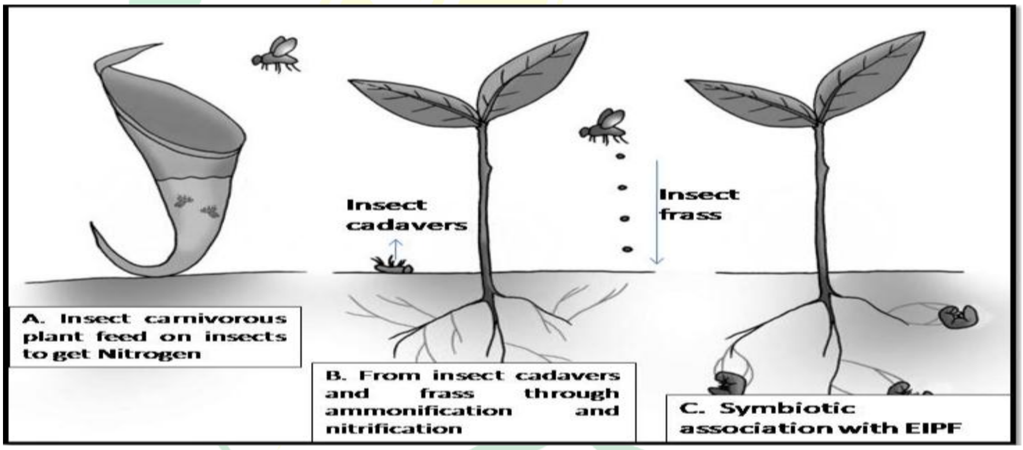

Fig. 1. Different adaptation through which plant can derive nitrogen from insects

A. Direct ingestion of insects (carnivorous plants):

The carnivorous plants derive N by directly feeding on insects. There are about 600 known species of carnivorous plants mostly found in nutrient poor soil (Brewer, 2001) that speaks to the enormous potential of insects as a source of nitrogen. They have the ability to trap and digest insects. They are able to obtain between 10-80% of their total N from insects (Ellison *et al*., 2001). These carnivorous plants use sophisticated traps and lures in order to capture insect prey, such as visual clues (attractive colours & UV guides) and chemical clues (nectar guides, volatile compound sex: sarracenin, phenol etc.).

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- **Active traps:** these plants trap their prey by moving rapidly. Ex: venus fly trap, water wheel etc. Snap traps of the Venus flytrap and waterwheel plant are hinged leaves that snap shut when trigger hairs are touched.
- **Semi-active traps:** these plants primarily rely on sticky surface exudates to ensure their prey. Ex: sundew plant, butterworts etc. Flypaper traps of sundews and butterworts are leaves covered in stalked glands that exude sticky mucilage.
- **Passive traps:** these plants lie in deadly and wait for their small victims, which are attracted by enticing scents, colors & nectar. Ex: pitcher plants. Pitfall traps of pitcher plants are leaves folded into deep, slippery pools filled with digestive enzymes.

After catching the prey they digest it by secreting enzymes (proteases, peptidases, phosphatases, esterase, ribonucleases, chitinases) and absorb nutrients from the digested prey. In addition to these glands, it also produces free radicals to aid in the degradation of prey. Insects are enzymatically digested and insect-derived nutrients are metabolized. Insects remain, however, a critical source of nitrogen for all carnivorous plants.

B. **Indirect transfer of insect derived nitrogen through bacterial or fungal ammonification and nitrification or through symbiotic mycorrhizal fungi:**

Plants can derive nitrogen indirectly through insect cadavers/insect frass through bacterial or fungal ammonification and nitrification or transfer of this nitrogen to the plants through symbiotic mycorrhizal fungi.

- **Insect cadavers**, the dead decaying insects in soil act as a large reservoir of organic nitrogen. It breakdown very fast compared to other organic material and is readily available to plants. Insect frass, the byproduct of insect production is regarded as an efficient organic fertilizer or soil amendment. Insect frass contain large amount of organic nitrogen in the form of uric acid which is again converted to inorganic forms such as ammonia and nitrates (Frost *et al.*, 2007) and provide adequate nutrient to allow plant growth in a substrate of low fertility soil. It also increases the soil microbial biomass which speeds up the decomposition of natural leaf litter and insect cadavers which release high amount of inorganic nitrogen into the soil. It has been observed that, in certain forest ecosystems, insect cadavers and frass deposition can represent up to 70% of the nitrogen returning to the soil when insect populations are large because of insect cadavers and frass deposition (Hollinger, 1986).

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- **Role of ammonifying and nitrifying bacteria-** The ammonifying bacteria such as *Bacillus*, *Pseudomonas* and *Streptomyces* converts organic nitrogen of insect cadaver and insect frass in to ammonia after which Nitrifying bacteria, such as *Nitrobacter* and *Nitrosomonas* convert ammonia in to nitrate.
- **Role of mychorrhizal fungi-** Mycorrhizae form symbiotic relationship between plant and fungi. Its major role is to enhance nutrient (mostly N) and water uptake by the plant from soil. It provides nutrients by effectively increasing the surface area of the plant roots and by mobilizing nitrogen. In return the plant provides plant-synthesized carbohydrates (mainly in the form of monosaccharide) to the fungus. These fungi also play a key role in the decomposition of insect cadavers and release of organic nitrogen. Some mycorrhiza fungi transfer nitrogen from insect cadavers to their plant host. For example, the ectomycorrhizal basidiomycete, *Laccaria bicolor*, was found to harvest nitrogen bound in insect cadavers and subsequently furnish plant roots with this scavenged nitrogen (Klironomos, 2001).

C. Direct transfer of insect derived nitrogen through a partnership with endophytic insect pathogenic fungi :

- Insect-derived nitrogen is directly transferred to plants through a partnership with entophytic insect and pathogenic fungi (EIPF). Endophytic fungi are a class of plant symbionts that form intercellular root associations with the plants and transfer the nutrients to plants from decaying organic matter. E.g., *Heteroconium chaetospira*, a dark septate endophyte, was able to transfer nitrogen to the roots of cabbage plants which is derived from decaying organic matter (Usuki *et al*., 2007).
- Also EIPF is able to acquire nitrogen from the insects it infects and transfers the insect-derived nitrogen to plants through endophytic association. *Metarhizium* and *Beauveria* are examples of insect pathogenic fungi that have recently been discovered to have endophytic capabilities (Sasan *et al*., 2012). It parasitizes and kills a soil-born insect, then transfer the insect-derived nitrogen to plants via fungal mycelia and endophytic association.

Conclusion

Nitrogen is one of the most essential nutrients. If plants don't have access to nitrogen, they'll be unable to make proteins, amino acids, and DNA, which is why a nitrogen deficiency causes stunted growth. Insects represent a nitrogen reservoir which we should not overlook. Plant can gain nitrogen from insects by three different adaptations. First specialized adaptation is by carnivorous plants in low nitrogen habitats. Insect carnivorous plants (such as pitcher plants and sundews) obtain their substantial amounts of nitrogen from the insects by directly capturing and feeding on them. Secondly, plant can obtain nitrogen from insect cadavers and frass through the activity of ammonifyg and nitrifying bacteria. Numerous plants also form associations with mycorrhizal fungi that can provide soluble nitrogen from the soil. Finally, a specialized group of endophytic, insect-pathogenic fungi (EIPF) provide host plants with insect-derived nitrogen. These soil-inhabiting fungi form symbiotic relationship with certain plant species. They can infect a wide range of insect hosts and also form endophytic associations in which they transfer insect-derived nitrogen to the plant. Hence, insects potentially become increasingly important as a source of nitrogen.

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