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# Effects of Pesticides, Temperature, Light, and Chemical Constituents of Soil on Nitrogen Fixation

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## Abstract

Nitrogen is a vital component of atmosphere and plays important roles in the biochemistry of all life forms on the earth. Various mechanisms of biological nitrogen fixation and recycling in the environment have been evolved in all known ecosystems. For example, symbiotic nitrogen fixation is the major N<sub>2</sub>-fixing mechanism in the agroecosystems. Symbiotic nitrogen fixation is dependent on the biotic factors, such as host plant genotypes and the microbial strains. However, the interaction of these biotic factors is influenced by abiotic factors, such as climate and environmental conditions. The effects of various environmental variables, such as pesticides, temperature, and light as well as acidity, alkalinity, salinity, phosphorus, and water content status of the soils on the nitrogen fixation have been discussed briefly in this chapter.

**Keywords:** nitrogen fixation, salinity, ammonification, nitrite, denitrification

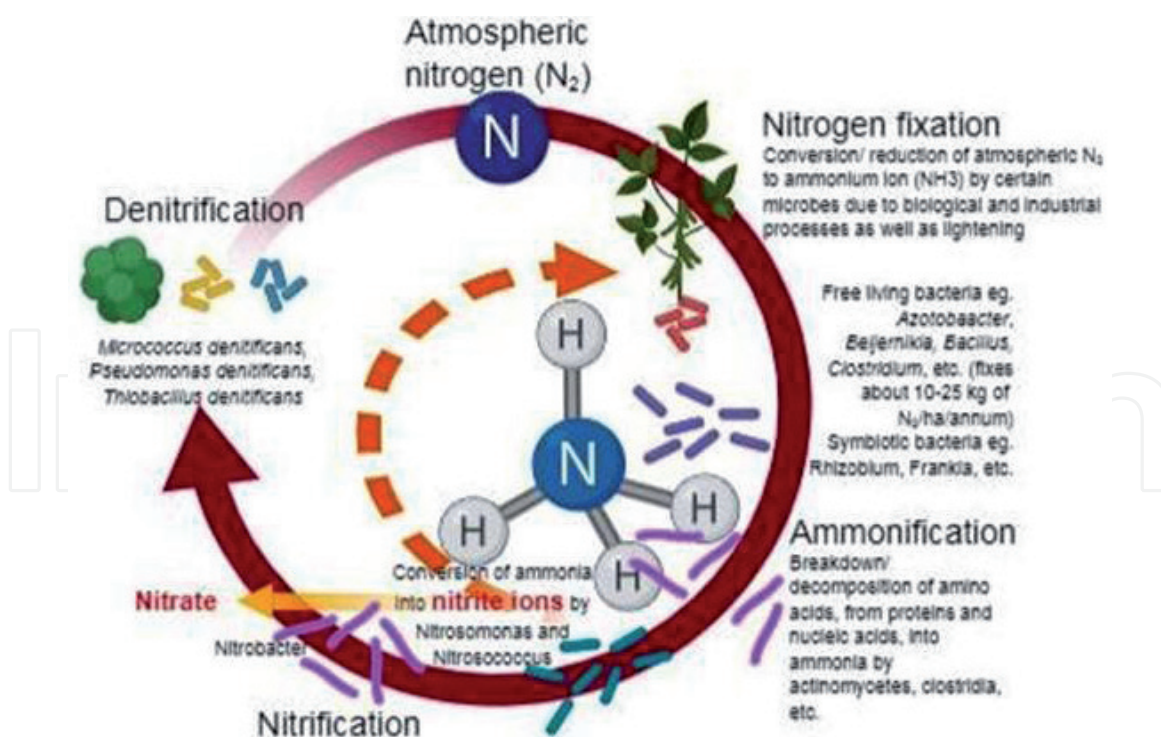
## 1. Introduction

The nutrient nitrogen is an essential element required by all life forms including the plants due to the presence in essential molecules such as proteins, amino acids, and enzymes. Although, this nutrient is in a large amount in the atmosphere, a small group of microorganisms is able to fix it becoming them available to plants.

The biological and physical processes in an ecosystem convert the nitrogen into multiple chemical forms and the phenomenon is called as nitrogen cycle. Biological nitrogen fixation accounts for about 70% of the atmospheric nitrogen. The four steps involved in a nitrogen cycle, namely nitrogen fixation, ammonification, nitrifications, and denitrification are described in **Figure 1**.

This process of nitrogen fixation is influenced by several aspects of biotic and abiotic variables. In this chapter, the effects of various factors especially the pesticide applications, temperature, and light as well as acidity, alkalinity, salinity, phosphorus, and water content status of the soils on the nitrogen fixation have been discussed briefly.

This chapter has addressed each environmental variable and discussed the effect of each one on the nitrogen fixation process and brings information related to it, for



**Figure 1.**  
The nitrogen cycle.

example, regarding the use of pesticides in an indiscriminate way. Usually, when the pesticides are used in the recommended dose, it does not harm the soil microbiota, but when the pesticides are overused, it may affect the physiological and growth characteristics of both rhizobia and legume plants. They also inhibit more or less the symbiotic nitrogen fixation by blocking biochemical communication and dialogues between the legumes and rhizobial symbionts.

## 2. Effects of pesticides on nitrogen fixation

In the current scenario of modern agriculture, agrochemicals play a key role in improving plant protection and production of food crops. Chemical pesticides are extensively used against a range of pests infesting agricultural crops worldwide. Due to the indiscriminate use of pesticides, the issue of the impact of these chemicals on the environment and soil has gained attention. Only about 0.1% of the total applied pesticides reach the target site/organism, while the remaining bulk contaminates the soil environment [1]. Consequently, sizable amounts of pesticides reach soil directly and indirectly, which affects the composition of soil microflora [2].

One of the most important and potentially limiting factors to biological nitrogen fixation is the use of chemical pesticides. Recommended doses of pesticides, in general, do not have any harmful effect on nitrogen fixation.

At higher doses, various chemical pesticides affect the physiological and growth characteristics of both rhizobia and legume plants. They also inhibit more or less the symbiotic nitrogen fixation by blocking biochemical communication and dialogues between the legumes and rhizobial symbionts [3].

Herbicides applied to leguminous crops constitute a potential hazard to the establishment and performance of the  $N_2$ -fixing root nodules. Soil and foliar application of herbicide at the recommended rates altered the morphology of root hairs and reduced nodule numbers and nitrogenase activity [4]. Some rhizobium strains also shown resistance towards herbicides when isolated and grown in laboratory media.

Legume seeds are inoculated with specific rhizobium to increase yield and at the same time they are also treated with fungicides to disinfect and guard it against seed and soil-borne pathogens. It is imperative to know the effect of seed disinfectants on the efficacy of rhizobia. Earlier studies show fungicidal seed treatment is safe as far as nitrogen fixation by rhizobium in symbiosis with legumes is concerned. Contradictory, Osman et al. reported a very strong negative effect of the dose of the thiram on *Rhizobium meliloti* [5].

### 3. Effects of temperature and light on nitrogen fixation

Temperature has a significant influence on survival and persistence of N-fixing microbes in soils [6]. Elevated temperatures may delay nodule initiation and development, and interfere with nodule structure and functioning in temperate legumes. Whereas in tropical legumes, competitive ability and N fixation efficiency of legume symbionts are mainly affected. Similarly, low temperatures reduce nodule formation and nitrogen fixation in temperate legumes.

In the extreme environment ( $-40$  to  $-68^{\circ}\text{C}$ ) of the high arctic, native legumes can nodulate and fix nitrogen at rates comparable to those observed with legumes in temperate climates [7]. This indicates that both the plants and their rhizobia have successfully adapted to arctic conditions.

At constant temperature ( $20^{\circ}\text{C}$ ) under long photoperiod (14 hours), plants may not show a significant decrease in N fixation in terms of fixation per plant or per unit nodule mass [8]. However, under a short photoperiod (6 hours) at the same temperature, plants show a significant decrease in N fixation. Under short photoperiod, plants compensate for reduced photosynthesis by maintaining only half the root nodule mass and N fixation activity as that of long photoperiod. However, similar rates of  $\text{N}_2$  fixation per unit mass of nodule may be observed in some plants under both the long and short photoperiods. This is because the shoot reserves for sustaining nitrogenase activity may compensate for reduced N fixation ability of plants.

### 4. Effects of acidity, alkalinity, and salinity on nitrogen fixation

A major problem associated with many acidic soils is metal toxicity. Highly acidic soils ( $\text{pH} < 4.0$ ) frequently have low levels of phosphorus, calcium, and molybdenum and high levels of aluminium and manganese which are often toxic for both plants and symbiotic N-fixing bacteria [7]. Nodulation by this N-fixing bacteria is more affected than the normal growth of the host-plants in such conditions. It is a well-known fact that most leguminous plants grow less favourably in acidic conditions than in neutral or slightly alkaline conditions [9]. This is mainly due to a reduced nitrogen fixation as may be concluded from the improved growth at low pH upon the addition of combined nitrogen.

Highly alkaline soils ( $\text{pH} > 8.0$ ) tend to be high in sodium chloride, bicarbonate, and borate, and are often associated with high salinity which reduces symbiotic nitrogen fixation [4]. However, the symbiotic N-fixing rhizobia, showing significantly higher salt tolerance, have been isolated from alkaline soils [10]. This suggests that the possession of high salt tolerance trait might be of some evolutionary significance for the survival of rhizobia in alkaline soils. Phosphate solubilising, alkaline tolerant rhizobia have also been isolated from wild legumes grown in dune systems of the southwest coast of India [11]. The stress tolerance traits of these rhizobia are of potential value in strain improvement of symbiotic bacteria for efficient N-fixing ability.



Soil salinity, which extremely increases in the protected cultivation, may occur when there are irregular irrigation schedules, inadequate drainage systems, wrong fertiliser applications, etc. [12]. The specific sensitivity of leguminous crops, where the N fixation is predominated by symbiotic bacteria, to soil salinity is well documented for initiation, development, and function of nodules [13]. An increase in salinity decreases the nodule permeability in these crops. This decrease is associated with a contraction of nodule inner-cortex cells and an increase in abscisic acid content of the nodule [14]. This phenomenon may lead to less survival of the symbiotic N-fixing bacteria associated with these crops. Even if the bacteria are survived, they may be less viable with decreased N-fixing ability. However, survival of the viable *Rhizobium* sp. under extreme conditions of salinity has been reported recently in root nodules of *Sesbania aculeata* [10].

5. Effects of phosphorus (P) status of soil on nitrogen fixation

Phosphorus deficiency in soils affects nodule functioning; however, it does not inhibit the other aspects of plant growth and metabolism. There exists an interaction between the plant’s growth and N fixation in response to increasing P supply [15]. This interaction may be positive, zero, or negative. A negative interaction suggests a greater need for P by N<sub>2</sub>-fixing plants; a zero interaction indicates that the plants have the same P requirement for growth and N fixation, while a positive interaction indicates that higher P supply may be inhibitory to N<sub>2</sub> fixation (Figure 2).

Legume tissues do not appear to have higher P content than those of other plants. Therefore a positive interaction exists between legume’s growth and N fixation in response to P supply (Figure 2). For example, in both soybean and lucerne (alfalfa), nodules from plants grown under P deficiency may have a higher concentration of P than those grown with sufficient P and may fix more N<sub>2</sub> per unit of P [16].

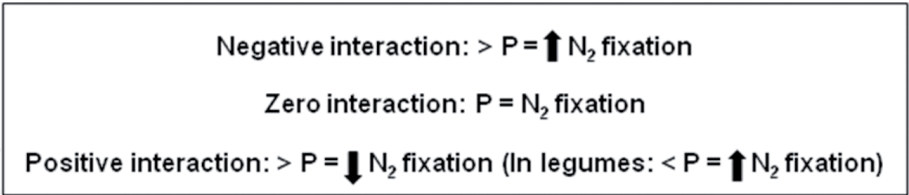


Figure 2.  
Effects of phosphorus (P) status of soil on nitrogen fixation.

6. Effects of soil water availability on nitrogen fixation

Water influences the growth of soil micro-organisms through processes of diffusion, mass flow, and nutrient concentration [17]. Soil water retention is related to soil pore space, and soils containing larger pores and pore spaces retain less water. Thus, soil aggregates having smaller internal pore spaces offers more favourable environments for the growth of N-fixing microbes.

There is a high degree of correlation between soil water content and N-fixing activity [16]. Maximum N fixation occurs at about field capacity of soil and above this, the N-fixing activity may be reduced due to water logging. Slow natural drying of soil over a 6 week period may result in a progressive reduction of N-fixing activity, which can be restored by irrigation. This indicates that soil water availability is

the major environmental factor affecting nitrogen fixation. It is plausible that water stress directly affects nodule activity. This effect may further be aggravated by reduced supplies of photosynthate due to wilted plant leaves [18].

## **7. Conclusion**

Environmental variables such as pesticides, temperature, and light as well as acidity, alkalinity, salinity, phosphorus, and water content status of the soils have a significant impact on nitrogen fixation. Despite many decades of progress and the acquisition of ample information, the physiological and molecular bases of the effects of these environmental variables on the symbiotic and non-symbiotic  $N_2$  fixation systems remains largely unknown and empirical in nature. Although understanding these processes was originally thought to be straightforward and tractable, we now have learned that the flavonoid nod-gene inducers are specific for a particular  $N_2$  fixation system [19]. Needless to say that, the production of these inducers is influenced by environmental variables. Therefore, more work needs to be done to understand the underlying molecular bases for tolerance to environmental variables in both  $N_2$  fixation systems. Further, the genomics and proteomics tools need to be combined with traditional plant breeding and microbial selection studies in order to rapidly define and utilise their genetic loci involved in tolerance to environmental stresses.

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