Influence of Potassium on Nitrogen Fixation

Nitrogen fixation by trees, shrubs, grasses, and legumes varies widely in economic importance to farmers. The most important involves plants belonging to the family *Leguminosae* and the bacteria genus *Rhizobium*. Crops included within this group are the pea, bean, soybean, alfalfa, clover, cowpea, and lentil. Each crop performs best when provided with its specific strain of *Rhizobium* bacteria through the process of seed inoculation in the top soil or residual from previous crops. The bacteria then enter the seedling by infecting root hair cells and forming a nodule of enlarged plant cells filled with thousands of bacteria. These bacteria derive nutrition from the plant and generate ammonium (NH_4^+) from atmospheric N by a process catalyzed by the enzyme *Nitrogenase*. Conditions favoring N fixation by *Rhizobium* bacteria are similar to those necessary for good growth, vigor and dry matter production of the host plant.

Adequate potassium (K) fertility is important for the symbiotic relationship that enables bacteria to fix nitrogen (N) from the air for use by legumes.

The amount of N generated by a legume varies with the crop species, soil and crop growth conditions, and crop management practices. As the total amount of N fixed by bacteria increases, their need for an energy source to reduce N_2 to NH_4^+ also increases. This energy source is the sugar produced during photosynthesis. Any disruption in the photosynthesis process will also disrupt the N fixation process. The essential role of K in photosynthesis makes K a vital contributor to effective N fixation by legumes.

TABLE 1. Estimated N fixed by selected legumes grown under conditions of optimum production.

	N fixed, lb/A	
	Average yield	**High yield**
Alfalfa	120	350
Clovers	75	250
Soybeans	60	240
Peas, Vetch	50	180

Table 1 provides an estimate of the range in amount of N fixed by several legumes. The total amount of N fixed will usually increase with yield level. Any growth factor, such as K, which is necessary for optimum legume production, would also influence the amount of N fixed.

The N fixation process is influenced by and dependent upon K for very distinct reasons.

- Potassium is the predominant cation in the plant like calcium (Ca) is in the soil. Its high chemical activity and the presence of a water film around the K ion give it special properties. It acts to neutralize organic acid formed during carbohydrate metabolism, to maintain hydration of cellular structures such as membranes and to serve as a cofactor to help enzymes improve the movement of sugars across membranes within the plant.
- Potassium activates more than 60 enzyme systems even though it is not a part of any enzyme structure. The enzyme *Nitrogenase*, for example, is vital for N fixation.
- Potassium is essential for photosynthesis. Carbohydrates generated by photosynthesis provide the energy needed by bacteria in nodules to fix atmospheric N. Potassium allows for photosynthesis to operate at peak capacity for a longer period of time. Basically, it controls the opening and closing of leaf stomates which control the movement of carbon dioxide into the plant and water out into the air. When K is in short supply, photosynthesis and water use efficiency decline. At

TABLE 2. Effect of K on soybean yield, nodulation and protein production.

K_2O rate, lb/A	Yield, bu/A	Nodules number/plant	Nodules weight, g/cu. ft	Seed protein, lb/A
0	26	59	10	662
120	55	114	26	1,289

the same time, the rate of plant respiration remains high, resulting in the excessive consumption of carbohydrates that should be available for root growth and N fixation.

- Potassium contributes to good root growth and has been shown to improve the number and size of nodules on roots. As shown in **Table 2**, the application of K to responsive soils can increase both nodule size and number. This results in improved nodule activity and conversion of atmospheric N into organic forms of N.
- Potassium allows carbohydrates produced in leaves to get to the root system for use by nodules. One function of K is to serve as a cofactor that is required for the action of the enzyme needed to transport carbohydrates across cell membranes and into the phloem. Once in the phloem, these sugars can move quickly into the root system to stimulate growth of new root hairs as well as nodule development and function.

Photo source: Runk/Schoenberger from Grant Heilman.

Potassium in balance with other nutrients encourages N fixation by bacteria in nodules on roots of soybeans and other legumes.

A highly fertile soil is essential for optimum N fixation. During the first few days after germination, seedlings must rely upon energy from the seed for initial growth. Then, nutrients absorbed by an immature and developing root system plus photosynthesis occurring in a limited leaf area are expected to nourish the plant for the next 10 days to two weeks or until nodulation occurs and the N fixing process begins.

The legume's inability to fix much N during the first two weeks of growth is one reason growers follow the practice of applying 25 to 30 lb of N at planting. This is especially important for stimulating rapid growth of soybeans planted immediately after the harvest of a small grain crop.

Phosphorus (P) and K speed the process of seedling use of N which allows for the earliest possible development of an effective nodulation system.

In summary, the primary importance of K to N fixation by legumes is to assure rapid seedling development, earliest date of N generation by nodules, and then the formation and delivery of carbohydrates required for optimum nodule performance. BC