LITERATURE REVIEW

Soybean (*Glycine max* (L.) Merrill) has two important characteristics. One is it contains rich nutrients, especially oil and protein. On average, soybean seed contains 40% protein, 21% oil, 34% carbohydrate and 4.9 % ash. Its other main desirable characteristic is that, in association with the bacteria *Rhizobium*, it has the ability to fix nitrogen from air. The amount of nitrogen fixed by soybean crop found in the field varies from 0 to 300 Kg N/ha, representing 0 to 87 % of total crop nitrogen (Harper, 1987). Soybean production has extended into many different parts of the world, where it is combined with other crops to form diverse cropping systems. In North America, soybean had previously been grown in monoculture, but recently, double-cropping systems with cereals have been developed in the USA and are now being utilized in South America (Johnson, 1987). In the tropics and subtropics, soybean is commonly grown throughout the year in sequential cropping with rice or intercropped with corn and sorghum. China, Indonesia and Thailand each grows large areas of soybean after one or two crops of rice, forming rice-soybean or rice-rice-soybean cropping systems (Guo, 1983; Pasaribu *et al.*, 1983; Shanmugasundaram *et al.*, 1980). Rice being a cereal crop, requires large amount of nitrogen to grow and produce high yield. When nitrogen fertilizer is applied to the rice crop, some is taken up by the plant, some is lost, the rest remains in the soil. The amount of nitrogen removed by rice depends on the amount and form of nitrogen involved and can be influenced by management practices. Without nitrogen application, 52-80 kg N/ha may be removed at a rice grain yield of around 3.4 t/ha (Watanabe *et al.*, 1981). Increasing fertilizer nitrogen application rates to rice increases the amount of nitrogen removed (De Datta, 1988). Normally, in the tropics, about 30% of applied nitrogen is lost from the field system (De Datta, 1986). The loss can be through several processes, including volatilization of ammonia, leaching and denitrification. After crop removal and losses, some of the applied nitrogen is left in the soil after cropping. Many authors commonly find that 20-30 % of the nitrogen fertilizer applied at the time of transplanting remains in the soil at harvest (Watanabe *et al.*, 1981) although values of up to 34% have recently been reported (De Datta *et al.*, 1988). Most residual nitrogen exists as organic or chemically bound nitrogen in the soil which can be used by the succeeding crop. Sisworo *et al* (1990) found that soybean can recover 2.8% of the fertilizer nitrogen which was applied to the first crop of rice in rice-soybean-cowpea cropping systems.

The residual nitrogen from the rice therefore may affect nitrogen fixation in the succeeding soybean crop. This effect normally occurred at the plant establishment stage, especially during the period of nodule formation (Stone *et al*, 1987). Residual nitrogen from previous crop stimulated nodule formation, increased the proportion of plant nitrogen derived from nitrogen fixation and the amount of nitrogen fixed have been found (Lamb *et al*, 1987).

Various factors such as soil mineral nutrients as well as environmental conditions affect nitrogen fixation in soybean. Mineral nutrient deficiencies can limit nitrogen fixation by the legume-*Rhizobium* symbiosis in many agricultural soils and as a result seriously depress potential yields. It can be anticipated that the constraints imposed by poor mineral nutrition on legume yield and nitrogen fixation will become more prevalent as a consequence of increased crop production following the greater use of improved, high yielding crop varieties and better management practices.

Of the mineral nutrients, combined nitrogen (soil and fertilizer nitrogen) is one of the most important factors that influence nitrogen fixation in soybean. This influence can be stimulating or depressing, depending on the level of nitrogen supplied, as shown schematically in Fig. 1.

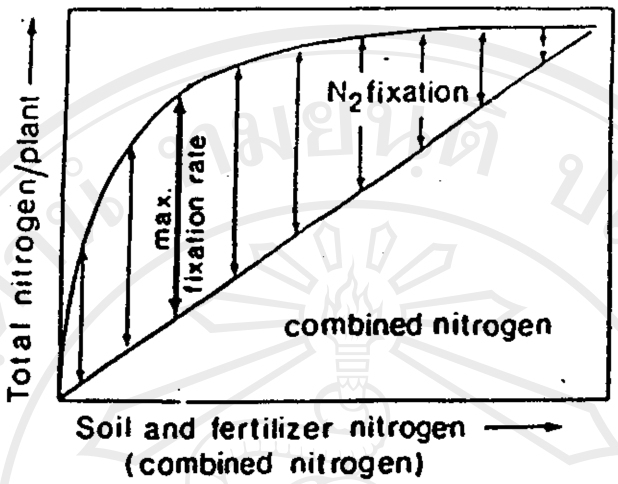

Figure 1 Simplified scheme of the relationship between nitrogen fixation and nitrogen uptake from soil and fertilizer in nodulated legumes (Marschner, 1986).

During the first few weeks of symbiotic development, combined nitrogen is essential for plant growth, which in turn can influence nodule growth. Therefore, in soil with very low levels of combined nitrogen, nitrogen deficiency can depress plant growth and development, and subsequently limit photosynthesis which in turn may limit nodule growth and nitrogen fixation. Thus from this very low level, nitrogen fixing legumes can respond to increasing levels of mineral nitrogen, to an optimum level, after which nitrogen will be inhibited with further increase in combined nitrogen (Marschner, 1986).

When the level of nitrogen increases, nodulation is inhibited and nitrogenase activity of established nodules declines. Direct effects of combined nitrogen on nitrogen fixation may possibly be induced by the action of nitrate reductase on nitrate and the synthesis and accumulation of nitrite (NO_2^-), leading to accumulation of nitrite in the nodule leading to a decline in the nitrogenase activity. There may also be indirect effect on nitrogen fixation through the carbohydrate supply from the phloem of shoot. When nitrogen is supplied to the plant in the form of either nitrate or ammonium, and a considerable proportion of carbohydrate is required for amino acid and protein synthesis, a correspondingly lower proportion of carbohydrate is available to the nitrogen fixation

Therefore, the highest nitrogenase activity (nitrogen fixation rate) is obtained when combined nitrogen either from soil or from fertilizer is available in amounts that are sufficient for vigorous plant growth during the period of soybean plant establishment, but not too high to depress the nodule formation, growth and nitrogen fixation.

Quantitative assessment of the role of nitrogen fixation on cropping systems depends on the measurement of the proportions originating from soil and from atmospheric nitrogen (Bergersen *et al.*, 1985). On the other hand, the amount of nitrogen removed in the harvested seed of grain legume can be very high. Therefore, in order that the potential contribution of fixed nitrogen from grain legume to cropping systems can be assessed it is essential the input of nitrogen from fixation is balanced against the amount removed in the harvested grains. There has been increasing use of xylem-solute methods for evaluation of nitrogen fixation both in field and in glasshouse.

The sap, ascending in the xylem from the roots of soybean to the growing parts of the shoot, carries nitrogen containing compounds originating

(a) from the root nodules as assimilation products of nitrogen fixation (Pate *et al.*, 1980) and
(b) from inorganic soil nitrogen (mainly NO_3^-) taken up by the roots.

Samples of this sap can be obtained as "bleeding sap" produced from the root stump of decapitated plants by root pressure, or as smaller samples obtained from stems by vacuum extraction (Herridge, 1984). Analysis of these samples, taken at various times during plant development, provides information about the relative dependence of the plant on soil nitrogen and on nitrogen fixed in the nodules (Pate *et al.*, 1980;

Herridge, 1982). The quantitative difference in xylem nitrogen sap composition between nitrogen-fixing plants and non-nitrogen-fixing plants which are fully dependent upon soil nitrogen, has been used to develop an assay system based on analysis of xylem sap to assess the extent to which plants depend on nitrogen-fixation or mineral-nitrogen (Peoples *et al.,* 1989).

Nitrate or ammonium ions are the two most important forms of nitrogen taken up by root from the soil. Sap derived from soil mineral nitrogen will be transported in the xylem as free nitrate or as organic products of nitrate reduction (mainly the amino acid asparagine) in the root. Soybean along with many tropical legumes have been reported to transport its fixed nitrogen from nodules in the form of the ureides (allantoin and allantoic acid) (Hansen *et al.,* 1987; Pate, 1976; Herridge, 1984). In these ureide-exporters, a relatively low proportion of total plant nitrate reductase activity is present in the roots (Wallace, 1986), so that much of the absorbed nitrate is passed to the shoot still as free unreduced nitrate. As a consequence, the composition of the xylem sap from field grown nodulated plants deriving their nitrogen from both sources will contain not only ureide but also nitrate and amino acids.

Quantitative relationships between the proportion of ureide nitrogen to the total sap nitrogen in the xylem and degree of dependence on symbiotic nitrogen fixation have been established (Herridge, 1982). This method of ureide analyses will be used to quantify nitrogen fixation in soybean grown after rice.