Herbicides, reduced nodulation and N-fixation in soya beans – the case for atrazine herbicide

By Prof Charlie Reinhardt

Nitrogen (N) is an immensely important element for the survival and productivity of all forms of life on earth. Due to the critical role of N in agricultural productivity, the N-fixing bacteria (rhizobia), which have a unique symbiotic (mutually beneficial) relationship with legume plants, have attained special positions in the field of agriculture as plant growth promoters.

When legume-rhizobia interaction is healthy and active, as measured by good nodulation on the root system, application of additional nitrogen is not necessary. Nodules that are actively fixing atmospheric nitrogen are coloured pink or red inside.

Soil bacteria in the *Rhizobium* group invade the roots of legume plants and form nodules on roots to fix atmospheric nitrogen into ammonia, which enters directly into the root system of host plants. This unique interaction and process allow the plants to grow in the absence of additional N sources.

Nodules on soya bean roots. Soil bacteria in the Rhizobium group invade the roots of legume plants and form nodules on roots to fix atmospheric nitrogen into ammonia.

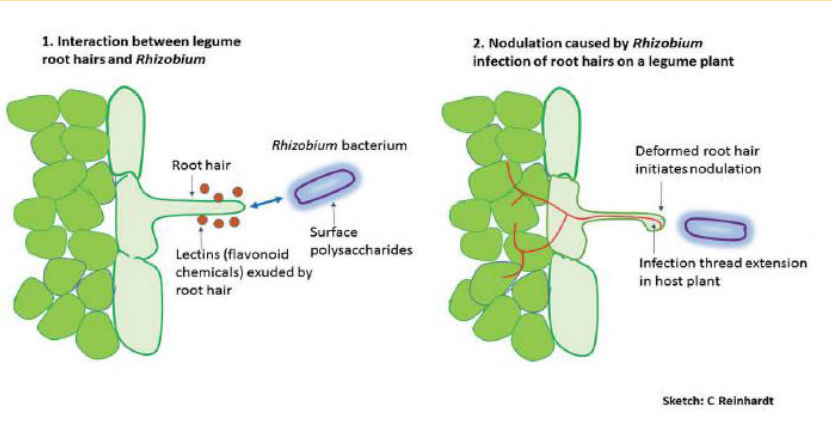
Symbiotic relationship

Soya bean plants have the ability to form a symbiotic relationship with specific *Bradyrhizobium* races (e.g. *Bradyrhizobium japonicum*) that cause the formation of nodules (small swellings) on the root system and is the location for N-fixation.

Because both soya bean and *Bradyrhizobium* species are not indigenous to South Africa, the standard practice is to ensure that soya bean-specific rhizobia are available in the immediate vicinity of the developing soya bean seedling, and explains why inoculation is advised with each planting of the crop (Botha *et al.*, 2004). Certain factors can reduce the formation of nodules, and, hence, the ability of legume plants to acquire N (ammonium) through fixation of N present as a gas in the atmosphere. Factors that are well known for limiting nodulation and N-fixation include:

- Elevated levels of nitrogen in the soil.
- Very wet conditions early in the season or extremely dry soil conditions.
- Fungi causing root disease or iron deficiency chlorosis (IDC) may negatively influence nodulation.
- Host plants that are under severe stress from physical (abiotic) and/or biological (biotic) factors.
- Limited nodulation may occur in fields in which soya beans are grown for the first time (various abiotic and biotic factors can be involved).

Figure 1: *Rhizobium* infection of legume root hairs.



Abiotic plant stressors

Herbicides represent one type of abiotic plant stressors, which can, according to certain international scientific literature sources, under specific conditions, inhibit rhizobia and cause poor nodulation and N-fixation in a variety of legume crops.

Atrazine is one such herbicide. Based on information emanating from time to time from certain quarters in South Africa, this herbicide is associated with poor rhizobia nodulation on soya bean. Information such as this perhaps could have originated from, for example, a year 2000-study report on soya bean production in South Africa, which has as one of its recommendations the following statement: "Atrazine had a negative effect on the functioning of *Rhizobium*" (translated from Afrikaans).

The risk with such an unqualified statement is that it might be used out of context. If the full findings of the particular study are scrutinised, it would reveal that the effect of atrazine on *Rhizobium* was not direct but indirect, through atrazine first having injured the atrazine-sensitive soya bean plant.

Atrazine is a selective herbicide that kills mainly broadleaf (dicotyledonous) weeds in crops belonging to the grass family, e.g. maize and sugarcane. Its toxic action in atrazine-sensitive plants is highly specific in that it inhibits the light reaction of the photosynthesis process. This life process does not occur in *Rhizobium* bacteria. Therefore, they should be immune from direct damage by atrazine.

The same argument applies to other herbicides in the s-triazine group, e.g. terbuthylazine. Research by Cardina *et al.* (1986) revealed that atrazine inhibited photosynthesis of the inherently atrazine-sensitive legume host plant to such an extent that insufficient energy-rich photosynthate (carbohydrates) reached the nodules, with a consequent reduction in N-fixation.

Harmful dosages

Similar results were reported by Shankar *et al.* (2012) for the herbicides atrazine, 2,4-D and glyphosate. *Rhizobium* nodulation was affected negatively only at herbicides dosages that were harmful to the host plant.

Van Rensburg and Strijdom (1984) basically came to the same conclusion after assessment of the toxicity of thirteen herbicides registered in South Africa against *Rhizobium* strains used in legume inoculants for lucerne, clover, soya beans, groundnuts and lupins.

In this *in vitro* (laboratory) study, the authors highlighted the non-toxic effects observed for atrazine, and stated: "The lack of toxicity of atrazine to rhizobia implied that its application to maize, following a legume crop, would not adversely affect the *Rhizobium* population present in the soil." At present, I am not aware of any research done locally or internationally since 1984 that contradicts this finding.

Unlikely in the field

Other possible sources of disinformation on herbicides being directly responsible for reduced N-fixation could be fuelled by findings from various international laboratory (*in vitro*) studies making use of impractical herbicide concentrations, i.e. much higher concentrations than those recommended for field use.

Several international studies have concluded that the negative effects of various herbicides on rhizobia and N-fixation, which are observed under laboratory conditions, are unlikely to occur in the field, provided the directions for herbicide use are closely followed (Kunelius, 1974; Duke *et al.*, 2012).

Contradiction in expert opinions and scientific research findings will continue to present obstacles on the way to get to the 'real truth'; in fact, this reality is common to all spheres of scientific endeavour. This then begs the question: How real is the supposed threat of herbicides having a negative effect on N-fixation, and what are the origins and reliability of such information?

The overwhelming evidence provided by scientific literature points to atrazine, at least, not posing risks for direct inhibition of *Rhizobium* bacteria and N-fixation, in particular when this herbicide is correctly and responsibly used. Any other factor that would sensitise the crop to herbicides could adversely affect *Rhizobium* bacteria and N-fixation indirectly (secondary effect) through the primary effect of weakening of the host plant.

References available from the author at email dr.charlie.reinhardt@gmail.com.

Strategies for management of herbicide-resistant weeds are well documented and frequently communicated on the South African Herbicide Resistance Initiative (SAHRI) website: *www.up.ac.za/sahri*. Prof Reinhardt is project leader at SAHRI, which is based in the Department of Plant Production and Soil Science, University of Pretoria (UP), dean of Villa Academy, extraordinary professor of weed science, UP, and extraordinary professor at the Department of Agronomy, Stellenbosch University (SU). References are available from the author on 083 442 3427 or email: dr.charlie.reinhardt@gmail.com.