Early-season nitrogen fertiliser management of soya bean: Feeding for yield

By Stephano Haarhoff, Yara Africa Fertilizer, and Pieter Swanepoel, AgriSciences Faculty, Stellenbosch University

Fertilising soya bean has been a challenging component of sustainable soya bean production across farming systems in South Africa. Much research has been conducted over the decades exploring soya bean yield response to applied fertilisers, but many questions remain.

The decision-making process regarding soya bean nutrition for producers is further complicated by inconsistent growth conditions early in the growing season. For example, soil conditions at the time of planting or crop establishment, can limit soil microbial activity and thus potentially hinder nitrogen fixation and early vegetative growth. This can be more prevalent across the hot and dry western production regions such as the Free State and North West, while high loads of crop residues alongside cooler conditions in the eastern production regions may lead to a shortage in nitrogen supply before nodulation is completed.

Understanding soya bean fertiliser dynamics is therefore critical to promote maximum yields by enabling plants to fully utilise available resources, such as sunlight and soil water.

Early-season nitrogen fertiliser

Soya bean utilises nitrogen originating from two nitrogen sources, i.e. biological nitrogen fixation originating from the relationship between soil-living bacteria, rhizobia (*Bradyrhizobium japonicum*), and soya bean; and inorganic nitrogen available from the soil. This symbiotic relationship between soya bean and the bacteria involves the release of ammonia to the plant by the bacteria in exchange for organic compounds provided by the soya bean plant.

The bacteria live in small growths on the roots called nodules (*Photograph 1*). It is within these nodules that nitrogen, which was otherwise unavailable for use by the plant, is transformed to a plant-available nitrogen form. This process is called nitrogen fixation. Indeed, this relationship promotes nitrogen enrichment of the soil, and increases plant growth and development while it reduces the need for inorganic nitrogen from soil or fertilisers.

Drivers of nitrogen fixation

It is generally believed that 50 to 60% of soya bean nitrogen demand is addressed by bacterial fixation. However, these values are highly variable among farms and are therefore challenging to incorporate into soya bean fertiliser programmes. Nitrogen fixation is primarily driven by climate conditions, soil tillage practice, soil water status, and temperature and inoculation strategy. Interestingly, soya bean will generally not be a host to naturalised soil rhizobia as is the case with other warm-season legumes such as cowpea and mung bean.

Before nodules are formed (ten to 14 days after emergence), soya bean nitrogen demands must be met by the soil inorganic nitrogen pool and seed reserves. If low soil nitrogen levels are present, poor nitrogen uptake may lead to restricted growth and development, ultimately resulting in yield penalties. An application of up to 40kg of N/ha^{-1} at the V1 development stage, may increase aboveground leafy growth and yield in the more arid production regions of South Africa (Botha *et al*., 1997).

This positive effect is attributed to the easily accessible source of nitrogen for plant uptake before effective nodulation has taken place. In higher yielding regions, such as KwaZulu-Natal and Mpumalanga, an early-season nitrogen fertiliser application (25 to 40kg of N/ha^{-1}) can be done to address nitrogen needs due to the shorter growing season and more favourable growth conditions. Nitrogen fixation alone may be insufficient during accelerated early season growth.

Potential trade-offs

Several potential trade-offs associated with an early-season nitrogen fertiliser application exist. Firstly, high soil inorganic nitrogen levels may prevent or limit nodules from forming, ultimately restricting nitrogen fixation and supply later in the growing season when conditions are favourable for crop growth.

In addition, urea-based nitrogen applications may hasten crop residue breakdown if broadcasted, which is a crucial consideration when soya bean forms part of no-till or conservation agricultural systems. The loss of soil cover could lead to higher soil temperatures, as well as increased soil water losses by evaporation and runoff during high rainfall events. This effect may be more prevalent in the subsequent maize or soya bean rotation sequence as residue levels are low following soya bean.

Also, in farming systems where soil water is the most limiting factor for crop production, low soil water levels following planting may restrict nitrogen uptake, omitting the benefits offered by early season nitrogen-fertiliser applications.

Nitrogen fertiliser source

Nitrogen fertiliser source is another consideration when choosing the appropriate fertiliser strategy for soya bean. Local research showed that nitrate sources were better utilised by soya bean compared with urea or ammonia sources. In the soya bean production systems of the United States, an increased soya bean yield was found in cases where nitrate-N levels were below 50kg/ha^{-1} in the top 90cm or below 90kg/ha^{-1} in the top 60cm of the soil profile.

The symbiotic relationship between soya bean and rhizobia for optimal nitrogen supply following optimal nodulation.

Shallow soya bean roots are vital for nitrogen, phosphorus, and potassium uptake under no-tillage practices.

High crop residue loads under no-tillage may inhibit the required nitrogen supply to soya bean plants early in the growing season.

Soil layers restricting soya bean root growth should be addressed to avoid yield losses.

Limiting high nitrate levels in the immediate soil region surrounding nodules is extremely challenging, as deeper placement (>10cm) is only achievable prior to planting during seedbed preparation in conventional tillage systems.

Future outlook and considerations

Several agronomic management factors should be considered when deciding on the optimal nitrogen fertiliser strategy. A systems approach should be followed where all contributing factors such as the previous crop, tillage system, soil fertility status, and crop residue, are considered to achieve sustainable soya bean yields:

Soil fertility status: Depletion of soil nutrients (phosphorus, potassium, and micronutrients) due to long-term monoculture or inadequate fertiliser strategies, restrict soya bean yields in the short term. Across maize-soya bean or maize-maize-soya bean crop rotation sequences, large amounts of nutrients are removed annually from fields and should be replaced by the application of fertiliser, cattle manure, and/or chicken litter. Soil layers deeper in the profile are easily depleted by long-term maize monoculture, especially under no-tillage characterised by no soil disturbance.

Stratification of these nutrients in the upper 15cm of the soil profile has been identified in soya bean production systems and may be problematic if insufficient root development takes place (*Photograph 2*). Soil pH status should not inhibit the availability of nutrients (especially micronutrients molybdenum and iron) or microbial activity, and should be addressed by the timeliness application of lime. Gypsum can also be considered to ameliorate certain soil chemical problems.

Crop residue levels: Maize residues dominate maize-soya bean cropping systems and are primarily utilised as livestock feed during the winter months or left on the surface if no livestock is present in the farming system (*Photograph 3*). Due to the high C:N ratio of maize residues, the amount of nitrogen present in these residues is insufficient to meet the needs for rapid decomposition by soil microbes. As a result, microbes compete with developing soya bean plants for available soil nitrogen.

Where high loads of crop residues are present, alongside optimal growth conditions, the insufficient nitrogen supply should be addressed by band placement or broadcasting of a starter nitrogen fertiliser at planting. This approach may be vital where conventional systems are converted to no-till systems to promote economically sustainable yields.

Soil tillage: Soya beans are highly sensitive to compacted soil layers (*Photograph 4*). Soil layers restricting soya bean root growth due to compaction, should be addressed accordingly. A once-off tillage action may be needed where the soil-water-plant interactions are severely limited, which ultimately affects the symbiotic relationship between soya bean and nitrogen supply via nitrogen fixation or fertiliser applications.

Soil compaction can be either a biological problem caused by a lack of actively growing plant roots throughout the soil profile, or the use of farm machinery and uncontrolled traffic on soils. The sustainable use of alternative crop rotation sequences by incorporating cover crops into these maize-soya bean dominated systems, can potentially serve as a tool to combat these concerns over the long term. However, more research is required to demonstrate the effects of cover crop roots on soil physical quality and compaction in South African production systems.

Tools to address nitrogen needs

Although early-season nitrogen fertiliser can be utilised as a tool to address soya bean nitrogen requirements early in the growing season, there is a need to explore whether nitrogen fertiliser can reduce nitrogen limitations without compromising the biological fixation capacity of soya bean plants.

Quantifying these effects across a wide range of soil types and climate regimes, may reveal additional tools for farmers to further improve their soya bean productivity using current resources. Inconsistent rainfall patterns and high daily temperatures highlight the need for such approaches.

For additional information, references, or discussion, send an email to Dr Stephano Haarhoff at stephano.haarhoff@yara.com or Dr Pieter Swanepoel at pieterswanepoel@sun.ac.za.