Soya bean nitrogen management and effectiveness

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Soya bean inoculants have come a long way on a global scale over the past decade, with higher quality products and increased efficiency of *Bradyrhizobium japonicum* (*B. japonicum*) products in nodulating soya beans.

In South Africa we have seen the soya bean production area grow considerably and expand to new areas throughout the country. There are very different growing conditions from the east to the west of our country, and consideration must be given to each situation that could influence the treatment of nitrogen-fixing bacteria.

Environmental impact

I would like to congratulate soya bean growers for reducing their impact on our environment and requirement for chemically based petroleum fertiliser, chemical nitrogen (N). As soya beans require high amounts of N of between 70 to 105kg/ton of yield, we will require a lot of N to produce this amount of protein.

As soya bean growers in South Africa, we will need to use around 405 287 820 litres of oil to produce around 306 000 tons of urea fertiliser for our crops (figures based on estimated N and hectares of soya bean production). By using high quality inoculants, we can reduce this dependence on oil and N, making farming more sustainable for future generations to come.

Every producer has to decide which product to use on their soya bean crop and how to manage the treatment. This article contains some basic guidelines on which to base this decision.

Registration process

Nitrogen-fixing bacteria resort under the pesticide registration process of the Department of Agriculture, Land Reform and Rural Development (DALRRD) in South Africa. All products must be registered under the aforementioned *Act 36* in order for them to be sold. The supplying company must prove the efficacy of the product over a minimum of three trials for the specific treatment of the product.

South Africa is currently one of the countries experiencing more difficulty registering *Rhizobium* products, with regulations similar to Canada, Brazil and Argentina. We have seen a number of new products come into the market that are not on specification this year and a number of which are not registered. This is cause for concern, given the magnitude of problems this may cause to the soya bean yield.

The role of *B. japonicum*

All soya bean varieties rely on *B. japonicum* for biological N fixation. The Agricultural Research Council (ARC) in South Africa isolated *B. japonicum* WB74 many years ago and this isolate has since been used as an effective means to nodulate soya bean plants. There are, however, various strains around the world which can and will fix high volumes of N, e.g. USDA 110, 442, Semia 5081 and many more.

Although all these isolates fall under the same species, they sometimes display differences in nutrient requirements, growing conditions and formulation requirements which the manufacturers or suppliers will need to understand. Product effectiveness will also have to be proven in a greenhouse and in the field in order to be registered under *Act 36* as a legume inoculant for N fixation. All the strains mentioned above have been registered in South Africa and are effective, but will have different application guidelines to be truly effective.

Active ingredient concentration

Multi-strain products can sound great to the ear as it implies a dual or triple mode of action, but in biological products, active ingredient concentration is critical to the performance of the product. At a formulation of 1-2 x 10^{10} CFU/ml, we are very close to the maximum number of

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cells that can be produced under liquid fermentation, unless you can centrifuge the product and make it a more concentrated formulation of 1-2 x 10^{11} CFU/ml.

Once a saturated solution has been achieved, the numbers of the one *B. japonicum* strain need to be reduced in order to add another to the formulation. Now, there are two or more strains of *B. japonicum* in the product, one of which will be more dominant in performing the targeted action – in this case, N fixation on soya bean. Essentially, you now have a reduced volume of the dominant strain of bacteria performing the task.

Effect of product quality

The quality of the product is a very important aspect of *B. japonicum* and will influence effectiveness in the field. Due to the slow growth rate of these micro-organisms, the final product must be contaminant-free and contain a high amount of the micro-organism. It will be easily noticeable if a *B. japonicum* product is contaminated, since this micro-organism does not produce a foul-smelling product. Any bacterial contaminant will result in a foul-smelling product and possible swelling of the bladder.

Looking back ten years, most of the products in the market were manufactured

at 1-2 x 10^9 CFU/ml with one to six months' shelf life, with 24 hours to treat and plant the product. With new technologies, however, products can be produced at 1-2 x 10^{10} CFU/ml and 18 months' shelf life, with 60 days between treatment and planting. This illustrates how products are now more stable and of higher quality with added technology to protect the bacteria on the seed. With the longer shelf life, improved seed survival and ten times more bacteria per millilitre, we have clearly come a long way over the past decade.

Nodule placement

The placement of nodules is also very important, as the amount of plant available N it can produce, is ten times more on the primary root as opposed to the secondary root structure. Be careful not to look at the number of nodules only, but rather at the positioning on the root zone. This is very important – the same amount of N can be fixed by one nodule of the same size in dry weight on the primary root, as ten nodules on the secondary root.

Various technologies such as OSMO protection, signal generation, microbial membrane protection (MMP), extracellular polysaccharide (EPS) and bacterial protectors, result in superior inoculants compared to normal *B. japonicum* products.

OSMO protection, one of the most common technologies, utilises compounds known as osmolytes to maintain the integrity of the cell under environmental pressures. This makes the bacteria hardier and increases survival during desiccation when cells are placed on the seed or in the soil. During the production process, the cells are exposed to sufficient moisture, away from UV radiation. These ideal conditions are, however, removed once the product is applied to seed or in soil.

We need to utilise the best technologies available to help bacteria overcome these stressors in order to increase effectiveness in the field. There is a fine balance between sticky/wet seed and practical planting ability of the seed, the best seed being slightly sticky/wet to increase bacterial survival. In all cases, calibration of your planter must be done using treated seed.

Influence of planting conditions

Planting conditions are extremely important as bacteria and seed require moisture to germinate and grow. This is often easier said than done with our local growing season. Producers are constantly pushing the boundary to plant or not, due to dry soil and a very hot top 5cm of soil at 40 to 50°C. When planting soya beans, the best conditions are crucial for good nodulation and plant germination.

The South African environment is far more arid compared to the rest of the world. Take the three biggest soya bean growing regions in the world. In winter, the United States (US) has snow of 0,5 to 1,5m deep, and high organic matter. They need the soil to dry out before planting. Brazil has a high rainfall figure and high humidity, similar to the east coastal region of KwaZulu-Natal, with a fair amount of organic matter but low pH soils.

Argentina generally receives a few hundred millimeters of rainfall in winter with high organic matter ranging from 2 to 5%. They can normally plant winter wheat with great yields under dryland conditions but moving west, this changes to more arid conditions with organic matter from 0,5 to 2% and reduced moisture.

All these major regions are generally at sea level whereas South African conditions are at 5 000 to 6 000ft above sea level. A more suitable comparison is the western region of Argentina. South African producers face challenging conditions of low organic matter of 0,25 to 0,75%, low soil pH (KCl) 4 or pH (H_2O) 5, and a dry starting point. Of course producers can enjoy good yields, but they must be mindful of these conditions under which soya beans are produced in South Africa.

Aspects to consider during treatment

When treating biological products to your seed via seed treatment or through in-furrow application, temperature and sunlight must be taken into account. *B. japonicum* must be stored at a maximum of 25°C ambient temperature and away from sunlight.

Operations must be managed strictly. For example, when undertaking a seed treatment, take only the seed you will use for the morning planting and return to the store more frequently to collect fresh treated seed that is stored carefully and responsibly in your shed. Managing the treatment and treated seed on farms, is very important for great results.

The physical treatment of seed is vital to a good start, and every seed must be treated with the same amount of *B. japonicum* as the next. Ensure that the treatment machine is clean and free of any chemicals that will influence the bacterial treatment. Seed treatment machines must be calibrated at least daily. Calibrating the seed treatment machine when moving from one variety to the next is also very important, as seed size will influence the flow rate of the seed through the machine. If this is not done, the product's results could vary.

Treatment methods

There are three types of treatment methods, namely slurry mixture, wet sequential, and dry sequential. When using a slurry mixture, all products must be added into one container. These include *Rhizobium*, biologicals, chemicals, nutrients, and/or water. You will need to treat and plant as soon as possible, as this method poses a massive risk for bacterial survival.

The most economical method is wet sequential treatment, which entails creating wet layers of treatment: first liquid chemical treatment, then *Rhizobium* and thirdly, drying powder or DS/WP fungicide. This method can be achieved in a seed treatment machine using various applicators on the machine. The best method is to allow each treatment to dry between each application. This is often not feasible and is very impractical, but from a treatment point of view, this is by the far the best way.

Molybdenum and cobalt

Molybdenum and cobalt are vital to the functioning of the nitrogenase enzyme which acts as a catalyst to N fixation in soya bean and legume plants. Without molybdenum and cobalt, the N fixation process will be limited. Certified seed producers will apply three to four applications of molybdenum in the production cycle of the seed to increase the molybdenum in the seed.

Various journals show that a soya bean seed can contain more than 1 000 times molybdenum within the seed, if applied during the production cycle rather than a seed treatment on the seed. Molybdenum and cobalt can be applied as a seed treatment or foliar

application in the growing season, and will help your nitrogenase activity.

There are some warnings, as both are salts which will dry out bacteria on the seed when treating them together with a *Rhizobium*. Be sure when applying molybdenum and cobalt to the seed treatment, to plant within 4 to 6 hours after seed treatment. Use a very high quality *Rhizobium* inoculant with OSMO protection technology to increase survival of the bacteria, as this will be crucial to nodulation.

Use of fertilisers

Fertilisers are important to soya bean yield, but managing the type and placement is very important. Too much N is highly problematic. Around 10kg/ha is more than sufficient for planting. Any more than this will hamper nodulation and delay the process.

Placement needs to be a minimum of 50mm below and 50mm on either side of the seed to prevent moisture and salt burn. Far too many growers are being advised to use maize fertiliser blends for their soya beans, when they really need to use P, K, S, Ca, Mg and micro-elements to increase soya bean yield. However, this needs to be specially created for your soya bean crop.

The R1 growth stage is when growers and agronomists need to evaluate the nodulation process and assess its success. If not, action is needed. Apply high volumes of N fertiliser of 100 to 200kg/ha of N, which would be around 100 to 450kg of urea or 200 to 700kg of LAN, depending on the conditions and soil type. Talk to your local agronomist for final details of this application. Between 70 and 105kg of N is needed per ton of soya beans. This is much more than maize which requires around 15kg/ton of N.

In-furrow or seed treatment?

I have run many trials statistically and commercially in side-by-side trials, and both methods of application of *Rhizobium* are effective. It really depends on how growers manage their farm operations. If you are comfortable with either method, choose the best one for you.

In-furrow treatment yields slightly, but not significantly more secondary nodulation and can in some cases seem more effective. Once harvested, though, you generally don't see any significant yield advantage due to the placement and efficacy of the nodules on the secondary root structure. Many growers treat the seed and apply the product in-furrow to cover any treatment mistakes. This works well to ensure effective results.

As we are increasingly planting in sandy soils in the western region, nematode pressure and control are vital to good soya bean production but also influence *Rhizobium* nodulation, N fixation and the ability to have space on the root structure. Contact your chemical agent for registered options available.

Soya bean inoculants are very important to your farming operation, as they provide high amounts of N to your soya bean crop. Its impact can range from 200 to 1 500kg of yield per hectare. Depending on the soil, region and yield of your planted crop, it could equate to as much as 40% of your crop yield. Be sure to get the treatment correct via seed treatment or in-furrow applications.

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