Improving soya bean yield in South Africa: A practical approach

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Soya beans were first used as a domesticated crop at least 2 700 years ago. This super crop originated in China and gradually made its way to the rest of the world. The first documented report of soya bean in South Africa was from a trial planted at Cedara Research Station in KwaZulu-Natal in 1903.

The first full-scale effort to promote soya bean was a trial of 400 introductions (cultivars, lines) planted in 1925. By 1943, researchers concluded that there was no suitable soya bean cultivar for local conditions. This was true to some extent as the total production of this crop was only 6 000 tons after 1945. The average yield was only 250kg/ha.

Various institutions such as the Department of Agriculture, the Oilseeds Board and the Agricultural Research Council (ARC) tried to promote soya bean production in South Africa. This was an uphill battle. The total area under soya bean and the average yield fluctuated in such a manner, that industry planning was difficult.

All this changed for the better in the new millennium. The Protein Research Foundation (PRF), with the help of various public and private institutions, has promoted soya bean to the extent where we are currently on the verge of self-sufficiency.

Photosynthesis

As maize is the dominant crop in South Africa, it will be of value to compare this crop with soya beans for at least the photosynthetic efficiency. The productivity of the crop is primarily based on its photosynthetic cycle. In the case of soya beans, a C3 plant, the first product of this process is a three carbon (compound), while maize, a C4 plant, will produce a four-carbon product. The implication of this difference is that maize is more efficient in terms of water use and can produce a more harvestable crop under the same growing conditions, thus direct comparison between these crops is not possible.

Length of growing season

Soya beans are day-length sensitive plants, but there are vast differences among cultivars. To simplify cultivar choice, the crop is classified into different maturity groups (MG). There are 13 MGs worldwide, of which only four are of practical significance in South Africa, where MG 4 to 7 are planted. MG 4 is normally planted in the cooler production areas where these cultivars are better adapted. The early cultivars need a longer period of day length to initiate flowering, while MG 7 needs shorter days to flower. Day length requirement varies even within a given maturity class.

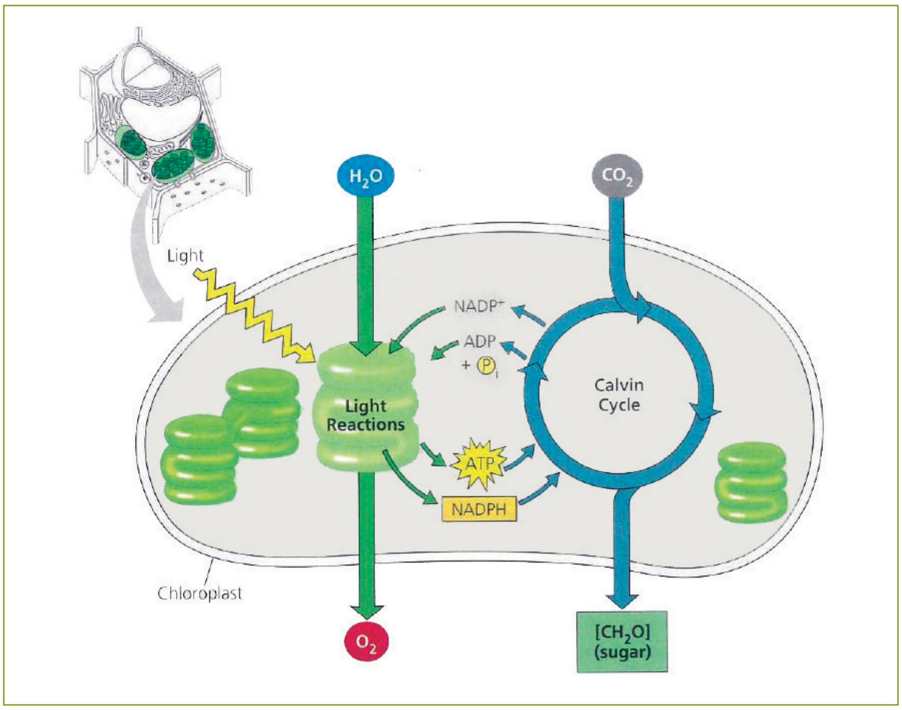
Temperature is also a confining factor. In cool areas, shorter growers generally outperformed the longer MG cultivars as they can complete their life cycle in a shorter period. A longer growing season will increase yield potential with an MG 7 type of cultivar. Yield is also determined by the seed growth rate. It is genetically difficult to increase both entities – the long, effective growing season, as well a high seed growth rate.

Harvest index

The increase of the harvest index (ratio between seed mass and total biomass at maturity) seemed to be a method to increase yield without changing a great many other contributing yield factors. Literature indicates that the harvest index may vary between 0,35 to 0,65.

Harvest index appears to vary among cultivars within seasons. Excessive vegetative growth in the first part of a season followed by adverse conditions in the reproductive phase, will lead to a low harvest index. Breeding for a better harvest index seems to be difficult, but it may well be a future avenue to follow for higher yields.

Figure 1: The process of photosynthesis.



Water use efficiency

Water use efficiency (WUE) is a general term which can be used to compare different crops in terms of their productive use of water. For this comparison, the entire growth cycle is used. In the case of soya beans an average value of 6 to 8kg grain is produced for every millimetre of moisture used. This is rather low compared to the more than 18kg of grain/mm of moisture for maize.

This can be directly linked to the C4 photosynthetic pathway in maize, compared to the C3 cycle of soya beans. Add to this that soya beans produce a photosynthetic 'expensive' product of 40% protein and 20% oil compared to maize, with less than 10% protein and 4% oil.

Table 1: The growth of soya bean production in South Africa. (Source: The development of the Protein Research Foundation 2016, and Crop Estimates Committee reports)

Average for production seasons	Ten-year average (ha)	Ten-year production average	Ten-year yield average (ton/ha)
1991/92 to 2000/01	88 683	125 184	1,4
2001/02 to 2010/11	206 536	335 000	1,6
2011/12 to 2020/21	630 525	1 141 995	1,8

Yield potential

In older publications, the authors put the yield ceiling of soya bean at 5,5 tons per hectare. Since then, high yielding cultivars hit the market while agronomic practices improved substantially.

Yield competitions, with producers' participation, brought a new dimension to crop yields. Yield competitions were held in South Africa where 5,3 tons per hectare were realised under dryland conditions in the previous season, while a yield of more than four tons per hectare were harvested on 400ha on a farm in the North West. What is clear from this yield data is that the average yield in South Africa has the potential to substantially increase.

Practical measures to boost yield

Quite a few practical measures can be executed to increase yield countrywide. The list that follows is by no means complete, but it touches on agronomic practices that can be adjusted for higher and more stable yields. Keep in mind that the soya bean production area is diverse in terms of especially climate and soil type.

Cultivar selection

The obvious starting point for higher yields is the correct cultivar choice. The production area of soya bean is broadly divided in three regions: cool, moderate and warm. In some cases, it is divided into four areas. Each region will have a set of cultivars within a maturity group best suited for a specific region. MG is an index value for cultivar-based photoperiod needs.

The selection of the best cultivar for a specific region within the correct MG is the most crucial decision for higher yields. To underline the importance of cultivar selection, the *Soybean Cultivar Recommendations (2019/20)* was used to illustrate this point, as it showed a more or less average yield for the last ten seasons. In the cool area, the yield difference was approximately 28% between the best and worst yielding cultivars. In the moderate and warm areas, it was 27 and 45%, respectively.

Nitrogen fixation

For high yields, nitrogen (N) supply should be at an optimum throughout the growing season. The N source could be inorganic (expensive) or through N fixing, the preferred and cheaper as well as the more sustainable option.

To ensure an adequate supply of N to the crop, inoculation of the bacteria should be successful. This entails several steps. The handling of inoculants prior to application as well as during soil application is important, as is the purchasing of the best inoculants with the right bacterial density and ingredients. Currently, most of the inoculants used in South Africa are WB 74, which may be replaced in future by the more promising *Bradyrhizobium japonicum* bacteria.

Biological N fixation, when successfully executed, will not only supply adequate N in an organic form, but will also prohibit N from leaching into the soil. Take note that the nodules on the primary root are much more productive in terms of N produced, than the same number of nodules on the secondary roots. According to some sources, the primary root nodules will be up to ten times more productive than nodules on the secondary roots. The continuous supply of N through fixation also auto-regulates the plant's vegetative growth. Inorganic N fertilisation applied at the beginning of the season resulted in excessive vegetative growth.

Soil acidity

Liming acid soils are important to improve nodulation and thus N fixation. Low pH is normally associated with high soil acid saturation. These levels should preferably not be above 20% for high soya bean yields. For adequate nodulation, water pH should be above six. Liming of acid soils decreases the toxic levels of aluminium and manganese, while enhancing the uptake of phosphorus, calcium and especially molybdenum, which is crucial for N fixation.

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Liming as a standard practice in South Africa became more important as soils became more acid due to the acidic fertilisers applied. In most cultivated soils in South Africa a decline in the pH can be seen, with the potential to substantially decrease soya bean yield.

General soil fertility

To achieve optimum yields, it is important to maintain soil fertility at a level that will enable the soya bean to produce the highest economic yield for a specific environment. Phosphorus (P) plays a significant role in essential metabolic processes, such as energy transfer, leaf area expansion and N fixation.

In South Africa, soils vary in their P status. To rectify soil P, several aspects should be taken into consideration, such as pH and the ratio of other elements. In general, a P level of 20mg/kg^{-1} P (Bray 1) will be sufficient for optimum soya bean yield. Soya beans remove at least 8kg P per ton of grain. Thus, the practice to plant soya bean without fertiliser will inevitably lead to yield suppression.

Potassium (K) will seldom be a yield-limiting element if K values are above 100mg^{-1}/kg. K is related to, among others, tissue strength and the regulation of stomata. Soya bean will remove more than 20kg of K for every ton of grain.

Soya bean fertiliser guidelines for calcium (Ca) and magnesium (Mg) are still vague. Sulphur (S) requirements for one ton grain produced are almost on par with P, where 6kg S per ton of grain are removed. This element may well be in short supply in a wide area, especially as more fertilisers with high purity are used.

A shortage of micronutrients will inevitably decrease yield, even though minute amounts are needed. Molybdenum (Mo) is especially vital in the process of N fixation. The need for this micro-element is accentuated when retained seed is planted, which will not necessarily have adequate Mo in the seed. In the latter case, Mo application is vital.

Weed control

The first five to six weeks after planting is a period during which soya beans are especially vulnerable for weed competition. Weeds will deplete soil moisture and nutrients, as well as excrete allelopathic chemicals which will hamper soya bean growth and, ultimately, yield.

Timely weed control with a variety of herbicides, including pre-emergence herbicides together with new cultivars that will be able to accommodate a larger spectrum of herbicides, will have a profoundly positive effect on soya bean yield.

Plant population and row width

Plant population is a hotly debated subject. In most cases, the plant population is higher than needed, but it seldom causes problems, provided that intra-row spacing is not closer than 5cm.

The dominant crop in South Africa is maize (2 755 400ha), as opposed to soya bean (827 100ha). Most cultural practices are thus tailored for maize. The result of this is that most of the soya bean is planted in 76cm rows or wider. Although narrow rows have the potential to increase yield, the changeover may not be economically feasible. There is also the belief that narrow rows will enhance the severity of diseases.

Planting date

In South Africa, more than 90% of soya bean is produced under dryland conditions. The distribution of rainfall, however, is erratic. Under normal circumstances, producers start planting maize first. If this practice changes it will have a substantial impact on soya bean yield. To illustrate this point, a trial was conducted at Schweizer-Reneke where 30 cultivars were planted 26 days apart, starting November 11. The maturity groups varied between 4,7 (short growers) to 7,1 (long growers). The average yield drop for the late planting was 39%. Yields for individual cultivars drop as much as 57%. These results underline the benefits of a longer growing season and a smart cultivar choice.

In normal seasons, long fallow periods will enable a producer to plant earlier as water is stored for early season growth. Soil properties, however, should be conducive to moisture storage. Early planting is then possible with only limited rainfall in the early season.

Crop rotation

In most of the traditional soya bean production areas, a two- to three-year crop rotation cycle with maize, the dominant crop, is practiced. What is of concern is a practice of continuous soya beans (year-on-year) planted without or with limited fertiliser applications. This will inevitably result in poor yields.

Certified seed

It is generally accepted that 80% of soya beans planted in South Africa is from retained seed. This may have negative yield implications. To handle, store and treat seed at farm level poses its own challenges which, if not done properly, will adversely affect the yield potential of a cultivar.

Harvesting

Harvesting at the right time and at a moisture percentage which will ensure minimum shattering is vital for maximum yield. The availability of combine harvesters, especially in non-traditional soya bean production areas, may lead to substantial yield losses, if harvesting had to be postponed.

In conclusion

This paper covered a few possibilities that may be considered practical to increase soya bean yield countrywide using available cultivars. This is by no means a complete list, nor does it deal with the many possibilities that breeding of new cultivars can offer.

It is difficult to quantify the major production inputs. The result was based on literature reviews and practical experience. The numbers will give rise to a debate which may help to bring about more clarity to enhance soya bean yields. The demarcation of percentage increases in yield is rather conservative. In a great many cases, it is possible to enhance the yields even further.

- The right cultivar selection offers the best possibility to increase yield countrywide. There are, however, some challenges. Almost 80% of the crop is planted from farm-kept seed, thus changing cultivars is not that easy – potential for yield increases: 10%.
- N fixation through successful inoculation is still a long way from perfect. Problems may occur during storage, handling and application of inoculants. Nitrogen deficiency symptoms with yellowed leaves were clearly visible during the previous production season – potential for yield increase*: 6% (**The use of inorganic fertiliser was not considered, except for a possible starter N application of up to 15kg/ha. The cost of inorganic N fertiliser is in most cases too high for profitable soya bean production*).
- Soil acidity is a major concern in most production areas. The pH of soils in the eastern production areas are below or close to pH 6 (water), which is considered optimum for soya bean production and N fixation – potential yield increases through soil acidity correction: 4%.
- Soil fertility as a combination of the elements discussed will have a profound effect on yield if corrections are made. It will be easy to rectify the problem, but in most cases it is expensive – potential yield for yield increase: 4%.
- Weed control may offer the best opportunity to rectify the current problems. On most farms, the equipment is already available for timely control of weeds using the appropriate herbicide – potential for yield increase: 5%.
- Plant population and especially row width will make a difference. Due to the high cost of planters, changing to narrow rows will be slow, thus the impact will be limited – potential for yield increase: 2%.
- Earlier planting date with the right cultivar will have a profound effect on yield – potential for yield increase*: 3% (**The yield potential can be much higher, but late rain may prohibit early planting*).
- Crop rotation, certified seed and harvesting vary between seasons. The potential can be high, but on a countrywide scale the impact is limited – potential for yield increase: 3%.

Considering the aforementioned potential for yield increases and if all the production practises materialised in an average year, then 2,5 tons/ha is possible countrywide. In a record season such as the previous one, it is possible to produce more than three tons/ha countrywide.

The challenge for all soya bean producers is to optimise their production practices by taking practical steps to enhance their yields.

This article has been shortened for publication in *Oilseeds Focus*. For more information, contact the Protein Research Foundation at 011 803 2579 or 011 803 1894, or send an email to pns@proteinresearch.net.