Crop production is the process of managing plants to maximize sunlight interception, assimilation, and storage of carbohydrates that ultimately produce grain, fruits, and fiber to benefit mankind. The assimilation process can be reduced significantly by low soil fertility, insufficient plant nutrient application, pests, soil type, and weather. Producing soybeans involves managing all controllable inputs to optimize plant utilization of photosynthesis. Progressive farmers develop a greater understanding of many interactions that may influence soybean growth and yield response. Corresponding management adjustments are implemented to enhance the opportunity of soybean plants to optimize their productive potential.

**Soybean Production and Nutrient Requirements**

The national average soybean yield has steadily increased in the last 36 years. Based on USDA agricultural statistics, in 1980 the average soybean yield was 26.5 bushels per acre (bu/ac) and in 2016 the average soybean yield was 52.1 bu/ac. That is an average of 0.7 bu/ac increase per year. Tremendous advances in biotechnology, plant breeding, genetic selection, georeferenced field management zones, yield monitors, and big data have contributed to our current production level. Apparently, no single advancement will result in a huge yield response, but it will be a series of adjustments customized to a specific farm and/or field. These customized management modifications are often referred to as “fine-tuning” production plans. A focus on soil fertility and plant nutrition can provide significant benefits toward achieving maximum soybean yields. What is the maximum soybean yield potential? Many state soybean associations sponsored yield contests that revealed several producers exceeding 100 bu/ac during the 2016 growing season. This production level removes 380 lbs nitrogen (N), 84 lbs phosphorus (P), 130 lbs potassium (K), and 18 lbs sulphur (S) per acre (IPNI). These nutrient amounts are for removal in seeds at harvest. Much greater volume is required for soybeans to grow and manifest optimum potential. Nutrient uptake levels at 100 bu/ac yield include 490 lbs N, 110 lbs P, 240 lbs K, and 36 lbs S (IPNI). The crop uptake and removal rates will vary slightly by geographic regions. These nutrient requirements reveal a need to maintain soil test values in the optimum range and add nutrients based on anticipated production levels. Soybeans are legumes which have the ability to convert atmospheric nitrogen to plant-available ammonium (NH₄⁺) in a process called N fixation. Therefore, N is not a recommended addition; although, N fixation provides less than 70% of total N requirements (Salvagiotti, 2008). Soybeans utilize soil N from carryover and organic matter mineralization to compensate for the extra N needs.

**Production Factors**

Six major influential factors of soybean production include:

1. Weather has greatest impact on yield response
2. Soil fertility needs to be maintained with balanced crop nutrition
3. Variety selection to optimize genetic potential with intensive management
4. Utilize pesticides to protect yield potential
5. Enhance stand establishment with seed protectants
Haegele & Below evaluated the influence of individual production factors and they are shown in Table 1.0. Table 1.0 Influence of production factors on soybean yield.

<table>
<thead>
<tr>
<th>Soybean Yield Factor</th>
<th>Change in Yield (bu/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertility</td>
<td>4.3</td>
</tr>
<tr>
<td>Variety</td>
<td>3.2</td>
</tr>
<tr>
<td>Foliar pesticides</td>
<td>3.6</td>
</tr>
<tr>
<td>Seed treatment</td>
<td>2.6</td>
</tr>
<tr>
<td>Row width</td>
<td>2.1</td>
</tr>
</tbody>
</table>

The weather factor was omitted. Values are average of six trials in one year. (Adapted from Haegele & Below, 2013)

"Nitrogen, P, K, and S are the key nutrients for crop growth and development. Applying these nutrients can produce synergistic relationships when one factor influences the ability of plants to use the second factor (Black, 1993). Therefore, crop production and quality can be improved by fertilizer. For example, Sexton et al. (1998) reported that N and S affect the level and composition of seed storage proteins in soybean" (Kaiser & Kim, 2013).

Nitrogen can provide an early start for soybean seedlings, especially under intensive management. Nitrogen fixation begins at V-3 growth stage, so adding approximately 20-25 lbs/ac of N should be sufficient. Over application of N will reduce activity of N fixing bacteria. Research studies have indicated that N fixation was reduced when legumes were grown in sulphur deficient soils. "Symbiotic N fixation of legumes are very sensitive to S deficiency and that growth of S-deficient legumes may be limited by N supply" (Duke & Reisenauer, 1986).

Phosphorus is critical for maximizing and challenging soybean yields. Phosphorus is interactive in photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement and several other processes in plants (IPNI, 1999). Broadcast and band applications are effective. Soil test phosphorus levels should be in optimum range for your area and soil type.

Potassium demand is greatest during early reproductive growth stages. It is not a part of the chemical structure of plants, but it is critical in functionality of many growth regulators that control growth and development (IPNI, 1998).

"Sulfur is an essential building block in chlorophyll development and protein synthesis. Sulfur is required by the rhizobia bacteria in legumes for nitrogen fixation. In general, crops remove about as much sulfur as they do phosphorus" (Oldham, 2017).

Seed Analysis

Traditional methods of diagnosing plant nutrient deficiencies should be employed. Another approach to enhancing soybean production is evaluating seed quality. "Relative soybean–seed yield was better correlated with sulfur concentration in seeds than that in the uppermost mature leaves at flowering" (Hitsuda et al., 2008). Nutritional stress can be expressed in the foliage and seeds; therefore, seeds may be utilized as S assessment tool. Results may be incorporated into the following year’s crop nutrient management plans (Hitsuda et al., 2008). "There are variations depending on the sulfur nutritional status of the plants until the full pod stage, it appears that sulfur supply until the full-seed stage controls soybean yield" (Hitsuda et al., 2008). While analyzing seed nutritional status, the seed quality can be evaluated by determining the protein. Soybean protein can be influenced by variety, available S, available N, and growing conditions. Nitrogen and S are components of amino acids and directly influence protein synthesis. A soybean co-product, soybean meal, is a primary protein supplement for livestock feed. Soybean meal that contains higher than average protein content provides a higher value product to the feed industry.
TIGER-SUL Research

Achieving major yield advantages in soybean production has been very challenging. The national average production has only increased 0.70 bu/ac/year. The need exists to “fine tune” soybean production practices to maximize yield potential. TIGER-SUL Products’ research efforts strive to demonstrate the importance of including sulphur and micronutrients with phosphorus and potassium to balance a crop nutrient management program. Figure 1.0 reveals significant yield advantage when sulphur and manganese were included in the soil fertility program. TIGER XP had somewhat lower yield as it is a newer product and was not included in all trials in this data set.

A yield response of 3.2 bu/ac x $9.40/bu soybeans = $30.08/ac gross return less the cost of 33 lbs/ac of TIGER 90CR x $0.35/lb = $11.55/ac cost of TIGER 90CR. Therefore, $30.08 – $11.55 = $18.53 net return/ac.

A yield response of 6.3 bu/ac x $9.40/bu soybeans = $59.22/ac gross return less the cost of 46 lbs/ac of TIGER Mn x $0.56/lb = $25.76/ac cost of TIGER Mn. Therefore, $59.22 – $25.76 = $33.46 net return/ac. Granted, the value of soybeans and the cost of TIGER Products may vary by specific locations.

Figure 1.0  Soybean yield in response to Tiger sulphur and micronutrient products.

To further investigate soybean seed quality, TIGER-SUL Products began a research trial at one location to evaluate the influence of sulphur and manganese on seed quality. There were no statistical differences in sulphur or manganese on soybean seed protein content (Figure 2.0). This is from very limited data but shows potential need for further research. “Sulfur fertilization significantly increased grain protein concentration at two of three locations” in a Minnesota trial (Kaiser & Kim, 2013). A 2-3 percent increase in seed protein can significantly increase the protein content of soybean meal.

Figure 2.0  Soybean seed protein as influenced by Tiger sulphur and manganese application.

Values are average of 4 years, 15 trials, 5 states (Ohio, Illinois, Iowa, Mississippi, Tennessee).

Values are average of two years at one location.
Multiple researchers agree that seed S concentration correlated to yield response and support that finding with tissue analyses conducted at V-5 and R-2 growth stages. This new nutrient management tool to further evaluate S requirements for soybeans should be employed to challenge yield goals and supplement those nutrient needs with TIGER-SUL Products. As producers strive to achieve 100, 125, or 150 bu/ac soybean yields, Dr. Daniel Davidson with Illinois Soybean Association suggests that the following questions be answered with a “yes”; if not, then soil fertility may be an obstacle to achieving your high soybean yield goals:

a) Do you soil test at least every 4 years?
b) Are you collecting plant tissue samples to monitor for micronutrients and hidden hunger?
c) Do you apply P and K every year on your soybeans?
d) Do you apply sulphur?
e) Are you applying enough fertilizer to replace removal by record yields?
f) Have you applied micronutrients - manganese, zinc, boron?
g) Do you maintain soil pH level between 6.3 – 6.8?
h) Do you have a specific soybean nutrient management program?

References: