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Nodulation, Growth, Yield, and Yield Traits of Soybean as Influenced by Inorganic Fertilization in Ethiopia: A Review

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Abstract

Soybean is a legume crop that can be used as an important source of protein for farmers who lack access to resources and cannot purchase animal products; it can also be used as an oil crop, an animal feed, chicken meal, and to increase soil fertility. In contrast to the global average, the country's soybean productivity is incredibly poor. Thus, the aim of this review was to assess how inorganic fertilization affected soybean nodulation, growth, yield, and yield characteristics. According to a number of research findings, the use of various inorganic fertilizer rates generally has a considerable impact on various growth, yield, and yield-related components of soybeans. In accordance with this, the review showed that growth, yield, and yield parameters of soybean increased with increasing rates of inorganic fertilizer. Moreover, as found from this review, the findings showed that the highest yield of soybean ranged between 1960.2 kg ha-1 and 3642 kg ha-1, which was recorded in plots that were treated with high nutrients; however, the lowest grain yield of soybean ranged from 1014 kg ha-1 to 1935kg ha-1 in plots that received no nutrients. Fortunately, the maximum yield (3642 kg ha-1) observed in this review was still very low when compared to other countries; for example, the average farm yield in Russia ranged from approximately 1480 kg ha-1 to 3940 kg ha-1 for the typical farm in west central Indiana. As a result, this showed that a significant research study was required to enhance soybean production and productivity by understanding what is truly affecting soybean yield in Ethiopia.

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Growth, yield, nodulation, fertilizer, animal feed, chicken meal.

Introduction

Due to its nutritional value, versatility, and greater adaptability to various cropping systems, soybean was first introduced to Ethiopia in the 1950s (Belay, 1987). It is a crop that can be crucial for Ethiopian farmers who lack resources and cannot get animal products as a source of protein. Additionally, it has the potential to be utilized as an oil crop, animal feed, chicken meal, to improve soil fertility, and most crucially, as a source of revenue for the nation in the form of foreign exchange (NSRL, 2007). It is now a crop that may be found in several agro-ecological areas of Ethiopia. According to CSA (2020), a total of 125,623 tons of soybeans are produced on 54,543 hectares of land; nevertheless, the average productivity in the country is 2.30 t ha^{-1}, which is lower than the global average productivity (2.79 t ha^{-1}) (FAOSTAT, 2019).

According to Hailemariam and Tesfaye (2018), the main causes of Ethiopia's low soybean productivity were low varietal stability, a limited genetic base of cultivars, insect pests and diseases, multi-nutrient deficiencies, low fertilization, limited access to improved soybean seed, and poor agronomic practices.

According to Tarekegne and Tanner (2001), the effective use of mineral fertilizers in infertile soil is a fast and effective way to increase crop production. In agreement with this finding, Jasemi *et al.,* (2014) reported that vegetative growth and biological yield are highly dependent on chemical fertilizer consumption and that the application of the fertilizers increased biological yield. It is consistent with the findings of Devi *et al.,* (2012), who reported that higher phosphorus and boron fertilizer application rates resulted in more primary branches per plant. The results of Xiang *et al.,* (2012), who discovered that the increase in soybean pod production is caused by an increase in the application of blended macro- and micronutrient fertilizer from 0 to 112.5 kg ha^{-1}. According to Wondimu *et al.,* (2016), the major effects of soybean varieties and nitrogen fertilizer rates had a substantial impact on the grain yield of soybeans. The results of the study is consistent with the research findings of Malik *et al.,* (2006), who showed that the application of blended NPS fertilizer had an important effect on the harvest index of soybeans. However, different kinds, amounts of rainfall, types of soil, and management techniques affect how soybeans react to the use of mineral fertilizer. Therefore, the purpose of this research was to investigate how inorganic fertilization in Ethiopia affected soybean nodulation, growth, yield, and yield characteristics.

Growth parameters of soybean as affected by inorganic fertilizer

Plant height (cm)

Increased plant height was linked to increased plant population and increased plant nutrients, as shown by many studies. Habtamu *et al.,* (2018) report that the smallest value (38.81 cm) was obtained at 23/23 kg NP ha^{-1}, while the maximum plant heights (52.55 cm) were reported at 69/69 kg NP ha^{-1}. According to this study, 0/0 kg NP ha^{-1} decreased by 35.4% when compared to 69/69 kg NP ha^{-1}.It also accords with the research findings of Deresa *et al.,* (2018), who observed that common bean (*Phaseolus vulgaris* L.) plants gradually grew taller with increasing rates of blended NPS fertilizer (0–150 kg ha^{-1}). This result aligned with that of Okubay *et al.,* (2014), who asserted that the lowest plant height was noted from the use of nil nitrogen fertilizer and the highest plant height was recorded from the application of 69 kg N ha^{-1} (112.33 cm for soybeans).In the study by Agegn *et al.,* (2022), applying a dose of 200 kg ha^{-1} NPSZnB resulted in the tallest plants (63.37 cm), while the shortest plants (48.23 cm) were grown in the absence of NPSZnB fertilizer. Due to the increased availability of phosphorus, sulfur, and nitrogen in the soil, blended NPSZnB fertilizer rates increased, leading to maximum vegetative plant development.

Number of nodules

According to a study by Getachew Gebrehana and Abeble Dagnaw (2020), applying nitrogen at a rate of 18 kg per hectare (ha) boosted nodule number and dry weight by 98.3 and 115.0%, respectively, over an unfertilized control and by 61.0 and 58.0% above the highest nitrogen rate (54 kg per hectare). According to Teshome (2017), the study revealed that the interaction of 80 kg ha-1 K_2O with 4.6 t ha^{-1} lime application produced the most nodules per plant (69.7), which was statistically comparable to the interaction of 40 kg ha^{-1} K_2O with 4.6 t ha^{-1} lime applications at the Gishe site. This result is consistent with the findings of Tirfessa *et al.,* (2022), who discovered that the total number of nodules per plant increased by 183% after the application of 100 kg ha^{-1} of NPSB, whereas the minimum total (18.97) was recorded from the control.

Yield, and yield components of soybean as affected by inorganic fertilizer

Yield (kg ha^{-1})

Tarekegn and Kibret (2017) undertook a field study in order to figure out the impact of Bradyrhizobium inoculation and nitrogen and phosphate fertilizer treatment on nodulation, yield, and yield characteristics of soybean at Pawe in Ethiopia. There are two levels of Bradyrhizobium, three levels of phosphorus (0, 23, and 46 kg ha^{-1}), and three levels of nitrogen (0, 11.5, and 23 kg ha^{-1}). According to their research findings, the highest amount of grain produced was reported when the three elements interacted. As a consequence, the interaction of 11.5 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} with *B. japonicum* inoculation produced the highest grain yield (3115.88 kg ha^{-1}), while the lowest grain yield (1730.42 kg ha^{-1}) was obtained from the treatment that received no fertilizer (control). Similar research was conducted at Sodo Zuria Woreda by Dela *et al.,* (2023) to determine the effects of blended (NPSB) fertilizer rates and Rhizobium strain on common bean production and yield attributes as well as farmer income. Treatments included two types of

Rhizobium strains (HB-A15 and HB-429 (*Rhizobia etli*)), five different rates of blended NPSB fertilizer (0, 50, 100, 150, and 200 kg ha^{-1}), and control (without inoculation). They found that the interaction impact of blended NPSB fertilizer and the Rhizobia strain on grain yield was significant (P< 0.05). The highest grain yield (3017.7 kg ha^{-1}) was obtained following Rhizobium etli inoculation with an application of 150 kg ha^{-1} blended NPSB, while the lowest grain yield (1496.3 kg ha^{-1}) was obtained following the control. This indicates that the soil fertility issue, which is a direct contributor to low production in the study location, can be resolved by the application of both the novel Rhizobia strain and inorganic NPSB. In two places, the Assosa and Begi districts of western Ethiopia, field trials were carried out during the 2016–17 and 2017–18 cropping seasons, according to Zerihun Getachew Gebrehana and Abeble Dagnaw (2020). With six nitrogen fertilizer rates (0, 9, 18, 27, 36, and 54 kg ha^{-1}), as well as two levels of inoculation (inoculated and un-inoculated), the highest soybean seed yield was attained in 2016–17 and 2017–18, respectively, when nitrogen inoculation was applied at 18 and 27 kg ha^{-1} across all locations. As combined with N at 18 kg ha^{-1}, inoculation boosted grain yield in 2016–17 and 2017–18 by 75.0 and 76.8%, respectively, as compared to control plants.

In various studies, soybean grain yield increased steadily as the rate of applied nitrogen was raised to the ideal level, and the grain yields observed as a result of each subsequent rate of nitrogen varied from one another. Oljirra and Temesgen (2019) conducted a field experiment in Bako Agricultural Research Center during the 2018 main cropping season to examine the effect of NPS rates on yield and yield components of soybean varieties including Dhidhessa, Ethio-Yugoslavia, and Wello, as well as five rates of NPS (0, 50, 100, 150, and 200 kg ha^{-1}). This was done in order to find economically viable blended NPS rates that increase productivity. The most significant impacts of the NPS fertilizer rate consequently had a substantial (P< 0.05) impact on the seed yield, as determined by the analysis of variance. The use of a 100 kg ha^{-1} NPS fertilizer rate resulted in the largest seed yield (2763 kg ha^{-1}), whereas the application of no fertilizer rate produced the lowest seed yield (1935 kg ha^{-1}). The highest seed yield may have been achieved due to effective assimilation partitioning of photosynthesis from source to sink in the post-flowering stage, which was caused by increased levels of sulfur, its availability along with major nutrients, and higher uptake of the crop. Moreover, Agegn *et al.*, (2022) carried out a field experiment in the 2020–2021 cropping season in Guangua district, Northwestern Ethiopia, to determine the effect of blended NPSZnB fertilizer rates on seed yield and quality of soybean varieties. Five levels of blended NPSZnB fertilizer (0, 50, 100, 150, and 200 kg ha^{-1}) and three soybean varieties (Pawe-01, Pawe-02, and Pawe-03). Likewise, they found that different rates of blended NPSZnB fertilizer, varieties, and the interaction effect of NPSZnB rates and varieties significantly affected soybean grain yield. The Pawe-03 variety produced the highest grain yield of soybean (2876.98 kg ha^{-1}) when 100 kg ha^{-1} of NPSZnB fertilizer was used during planting, but the Pawe-01 variety produced the lowest grain yield of soybean (1030.16 kg ha^{-1}) when no fertilizer was applied. Their research results further showed that application of the ideal blended fertilizer rate rapidly enhanced the grain yield of soybeans, but when we applied more than the optimum amount, the yield dropped.

According to a paper from a study by Habtamu *et al.*, (2018), the research study was conducted to evaluate the reaction of soybean to plant population and nitrogen and phosphorus fertilizer during the 2015–2016 cropping season in Kersa woreda in Jimma zone, southwest Ethiopia. There are four levels of plant population and nitrogen and phosphorus fertilization (23/23, 23/46, 46/46, and 69/69 kg/ha, respectively). Accordingly, their findings disclosed that statistical analysis of the data displayed significant variation among plant population and nitrogen and phosphorus fertilizer at p <0.01 as well as significant differences between the interaction between plant population and NP fertilizer at p <0.05. While the least grain yield (1106.3 kg ha^{-1}) was obtained at 23/23 kg NP ha1 and 166,667 plants/ha, the maximum grain yield (1960.2 kg ha^{-1}) was recorded with a combination of 23/46 kg NP ha^{-1} and 400000 plants/ha. The net crop absorption rate and the quantity of plants gathered in $unit^{-1}$ areas may be the causes of the higher grain production.

According to various studies, applying lime to acid soils is advantageous in instances where nutrients in the soil are rendered unavailable due to a very low pH or extreme acidity. Teshome (2017), for example, conducted an experiment during the 2016 main cropping season at three sites (Gishe, Laften, and Ago) to assess the impact of potassium fertilization and liming on soybean growth, grain yield, and quality. As two factors, five amounts of potassium fertilizer (0, 20, 40, 60, and 80 kg ha^{-1}) and two levels of lime (0 and 4.6 t ha^{-1}) were used. The combined analysis of variance revealed that the combination of potassium fertilizer and soil liming over sites significantly influenced the mean grain yield of soybean (P <0.001). At Gishe, 60 kg ha^{-1} K2O with 4.6 t ha^{-1} lime produced the highest grain yield (3642 kg ha^{-1}), whereas the control treatment at the Ago site produced the lowest yield (1014 kg ha^{-1}). This finding suggests that applying potassium fertilizer and liming the soil have more advantages for soybean yield (259.17%) than the control.

Biomass yield (kg/ha)

In a study conducted by Dame and Tasisa (2019), the greatest level of above-ground dry biomass yield (8718 kg ha^{-1}) was observed at the rate of 200 kg ha^{-1} blended NPS fertilizer application, whereas the smallest biomass yield (6910 kg ha^{-1}) was obtained with nil NPS fertilizer being applied. This result is consistent with the findings of Teshome (2017), who discovered that the interaction of 60 kg ha^{-1} K_2O with 4.6 t ha^{-1} lime applications at Gishe produced the highest biomass yield (10,508 kg ha^{-1}) and was statistically insignificant with 60 and 20 kg ha^{-1} K_2O without lime at Laften and 80 kg ha^{-1} K_2O with 4.6 t ha^{-1} lime applications at Gishe. At the Ago site, the application of 40 kg ha1 of K_2O without lime resulted in the lowest biomass output (371 kg ha^{-1}).Similar to this finding of Habtamu *et al.*, (2018), who showed that maximum biomass yield (5491.7 kg ha^{-1}) was recorded at the combination of 23/46 kg NP ha^{-1} and plant population (400,000), while minimum value (3075 kg ha^{-1}) was obtained at 23/23 kg NP ha^{-1} and plant population (166,667).

Number of pods per plant

According to Teshome's research from 2017, the Gishe Farm treatment of 60 kg ha^{-1} K_2O with 4.6 t ha^{-1} lime applications produced the largest number of pods per plant (82.73), whereas the Ago site's control treatments produced the lowest value (19.80). The number of soybean pods per plant increased (51.14) with the increase in phosphorous and other micronutrient fertilizer rates, as reported in an additional study by Khanam *et al.,* (2016). The result reported here is consistent with the research of Oljirra and Temesgen (2019), who found that the unfertilized treatments had the lowest number of pods per plant (32.0) and the highest number of pods per plant (40.9) at an NPS rate of 100 kg ha^{-1}. In agreement with this, Agegn *et al.,* (2022) suggested that variety Pawe-03 produced the highest number of pods per plant (39.67), whereas variety Pawe-01 produced the lowest number of pods per plant (22.33) when variety Pawe-01 was planted with no blended fertilizer application. This could be as a result of the combination of macronutrients (N, P, and S) and micronutrients (boron and zinc), which are crucial for the commencement and production of pods in legume plants. The application of 80–120 kg P_2O_5 ha^{-1} of soybean produced a comparable outcome, increasing the quantity of pods produced per plant (Bashour and Sayegh, 2007).

Hundred seed weight (g)

According to Tamiru *et al.*, (2012), the Brady rhizobium strain inoculation resulted in a noticeably higher weight for soybean 1000-seeds. In their statistical analysis of the data, Habtamu *et al.*, (2018) found that the relationship between plant population and NP fertilizer as well as the interaction between plant population and NP fertilizer were significant at P 0.05. The heaviest documented hundred seed weights (21.3g) were at an arrangement of 46/46 kg NP $ha^{-1}$and 200,000 plants, while the smallest ever measured hundred seed weights (18.50g) were at 23/23 kg NP ha^{-1} and 400,000 plants. Similar to this final result, Girma *et al.*, (2014) noted a notable increase in haricot bean thousand seed weights at the rate of 40 kg ha^{-1} NPS applied with fertilizer. This study's findings are comparable to those of Agegn *et al.,* (2022), who found that the hundred seed weight was significantly (P <0.0001) altered by soybean varieties, blended NPSZnB fertilizer rates, and the interaction of varieties with NPSZnB rates. The planting of variety Pawe-02 with the application of 100 kg ha^{-1} NPSZnB resulted in the greatest hundred seed weight (12.3 g), whereas variety Pawe-03 with the treatment of 200 kg ha^{-1} NPSZnB fertilizer produced the lightest hundred seed weight (7.33 g).

According to a number of research findings, the use of various inorganic fertilizer rates generally has a considerable impact on various growth, yield, and yield-related components of soybeans. In accordance with this, the review showed that growth, yield, and yield parameters of soybean increased with increasing rates of inorganic fertilizer. Moreover, as found from this review, the findings showed that the highest yield of soybean ranged between 1960.2 kg ha^{-1} and 3642 kg ha^{-1}, which was recorded in plots that were treated with high nutrients; however, the lowest grain yield of soybean ranged from 1014 kg ha^{-1} to 1935kg ha^{-1} in plots that received no nutrients.

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