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Effect of Urea Application on Leaf Senescence and Grain Yield of Soybean

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Abstract

Soybeans through a symbiotic relationship can fix atmospheric N_2 with localized rhizobia, however the amount of N_2 fixed is typically insufficient to meet its nitrogen needs due to the presence of an ineffective native rhizobia population. Three varieties of soybean were used in a field experiment in 2022 at the Plantation Crops Section of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, to study how nitrogen fertilizer application affected grain yield and leaf senescence. It was a split plot experiment with four replications and treatments arranged in a Randomized Complete Block Design. The three soybean cultivars 'Gyidie', 'Tondana', and 'Nangbarri' served as the main plot factor, and the N sources (control, 45 kg N/ha at one week prior to flowering, at flowering, at one week after flowering, two weeks after flowering, and three weeks after flowering) served as the sub-plot factor. Before planting, a germination test was performed to determine the percentage viability of seeds and all cultural activities were carried out timely. The findings indicated that N fertilizer applications, particularly those made three weeks after blooming decreased the rate of leaf yellowing and leaf drop during grain filling. Again, grain yield generally increased following the N fertilizer treatment but was more pronounced for the applications made at flowering and one week after flowering.

Keywords: Senescence; Grain Yield; Blooming; Soybean

Introduction

Soybean [*Glycine max* (L.) Merr.] is a member of the (legume) family, *Fabaceae*. It is an annual herbaceous plant [1] and on the global scale, it is an economically important leguminous crop. Smallholder farmers identify soybean as a "wonder crop" that provides numerous economic, nutritional and health benefits. It has a grain content of 40% protein, 20% oil and all essential amino acids, including methionine, cysteine and lysine, and hence could eradicate malnutrition among low-income earners. According to [2,3] the crop can be grown in a variety of locations with minimal farming inputs.

One-third of total above ground dry weight is partitioned over a variety of cultivars to develop seeds, with the remainder dispersed throughout leaf (22%) stem (22%) petiole (10%) and pod (14%) tissues [4]. It is unclear how contemporary soybean varieties and agronomic management approaches have affected dry matter accumulation and partitioning in increasingly intensive agricultural production systems. The average soybean grain yield in Ghana is 1.5 Mt/ha, however, the attainable grain production under rain-fed circumstances is projected to be 2.5 Mt/ha (40 percent higher than the national average) as reported by [5].

[6] reported that, low levels of soybean grain yield in Ghana could be mainly ascribed to inadequate technological inclusion in the production systems, such as soil nutrient management practices that could increase productivity. Because of their symbiotic relationship with soil rhizobia, many legumes undergo biological nitrogen fixation (BNF). Other rhizobia, notably *Bradyrhizobium japonicum*, can form relationships with soybeans, as in other legumes [7].

According to [8], soybeans can fix between 50 and 80 percent of the nitrogen they require, but most cultivars are unable to fix all the nitrogen required for seed growth and development. Symbiotic N_2 fixation bacteria such as *Bradyrhizobium japonicum* have been discovered to be limited in the soils of Ghana since the soybean plant is not native to Ghana [9]. *Bradyrhizobium* is frequently missing in soils with no production history of soybean, therefore for N fixation to be efficient, successful nodule formation may require a fully described *Bradyrhizobium* species [10]. In soybeans, nitrogen from nodules and fertilizers serves as the most essential factor to guarantee a satisfactory growth rate of the source (photosynthetic organs) as well as flower bud growth during the vegetative stage. In fact, the yield at the pod filling stage is influenced by how nitrogen is effectively transferred from the vegetative parts to reproductive organs as reported by [11]. The removal of N from the actively growing portions increases the rate of leaf drop, limiting the leaf canopy's photosynthetic potential by shortening the seed filling period, this results in a lower yield as was reported in a study conducted by [12].

Nitrogen fertilizer applied throughout the reproductive phase (R1 to R5) has proven in various experiments to boost the ability and periods of inorganic nitrogen utilization. To prevent premature senescence and boost seed production, nitrogen fertilization of soybean plants during the peak of seed demand may be beneficial [13,14]. N_2 fixation and nitrate absorption from the soil are the two ways that soybeans obtain their nitrogen. A soybean crop's ability to fix N_2 in the environment varies significantly. According to [15,16], typical levels range from 100 to 175 kg of nitrogen per hectare and meet roughly half of the crop's needs. N_2 fixation accounted for 40–50% of total N crop assimilation in field trials conducted in the Pampas, Argentina [17,18]. For years, this partial contribution of N_2 fixation to meet soybean N demands has fuelled soybean nitrogen fertilizer application research. In general, nitrogen fertilization of soybeans at the time of sowing did not result in higher seed yield [19-21]. Only when soybean was grown on acid soils with low organic matter levels, as reported by [22], or when it was subjected to drought, as reported by [23-25] had constant yield responses to nitrogen fertilizer been reported. This unresponsiveness of nitrogen supplied at planting is due to the well-known counter effect of high levels of soil nitrate on the formation of nodules as well as the activities of nitrogenase in nodules that have already developed [26].

The objective of this study was to determine the effect of nitrogen application on leaf senescence and grain yield of soybean.

Materials and Methods

Experimental Site

The study was carried out at the Plantation Crops Section of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi. The site is located on latitude 06^0 41' and longitude 01^0 33' West. The location is in the semi-deciduous forest, and the annual rainfall is in two seasons (major and minor), with an average of 1203.8 mm for the main season from April-July. In the minor season, the average is 504.25 mm but the rainfall experienced during the experiment from September-December was 309 mm. The field experiences an annual temperature range of 20 - 32 °C and humidity averaging between 75 and 79 percent.

Site Preparation

The vegetation was slashed using cutlass and later ploughed and harrowed using a tractor. Plots were laid out 5 x 2m with a total plot size of 20 x 36m with one-metre alley between plots and 2m between replications.

Experimental Design, Planting and Treatments

Planting was done in the minor season (11th September 2021). The experimental design used was Split--plot arranged in a Randomized Complete Block Design (RCBD) with the three soybean varieties; 'Gyidie', 'Tondana' and 'Nangbarri' serving as the main plot treatments in the experiment. The N fertilizer (45 kg N/ha applied at one week before flowering, at flowering, one week after flowering, two weeks after flowering, three weeks after flowering, and the control) served as sub-plot treatments. The N source (urea) was applied 5 cm by the side of each plant and buried.

Leaf Senescence

Senescing leaves for each plot was determined after flowering at an interval of 15 days (15, 30 and 45 days after flowering). This parameter was obtained by tagging three (3) plants in a row for each plot. Plastic mesh was used to surround the tagged plants to prevent other senesced leaves from adding up. Sampling was done by manually picking and counting sensced leaves from the tagged plants. The average for each treatment was calculated for the sampling dates.

Grain Yield

An area of 120 x 60cm was harvested for each plot, sun dried, threshed and winnowed. The grains were dried in an oven at 60 °C for 72 hours. The dry weights were obtained and converted to kilograms per hectare.

Results and Discussion

Leaf Senescence

Table 1 shows the number of leaves that senesced from the three varieties and the effect of time N application on leaf senescence. Varietal effects were not significant (P>0.05) at all the sampling occasions. At 15 days after flowering, application of fertilizer at flowering resulted in the least number of senesced leaves, which was significantly lower than only the control treatment effect. At 30 DAF, N application at 3 WAF resulted in the least number of senesced leaves, and this was significantly lower than all other treatment effects. The control treatment effect was lower than all treatments, except the application one week before flowering and at flowering. The results at 45 DAF were similar to at 30 DAF, where N application at 3 WAF resulted in significantly lower number of senesced leaves than all other treatments. Additionally, the control treatment effect was similar to that of application at one week before flowering (1 WBF) and at flowering only.

Nitrogen fertilizer applications made at the different stages of growth and development supported the soybean plant by reducing the number of leaves that dropped from the plant because of re-mobilization of N from the leaves. The varieties showed no major variation across the treatments. At 15 days after flowering, the N application made one week after flowering recorded the least number of leaf drop compared with the control and all the other treatments (Table 1). The treatment effect at 3 weeks after flowering resulted in the least number of senesced leaves at 30 DAF and 45 DAF, which were significant from the control and all other treatment effects. These findings confirm what was reported by [27] that, adding N fertilizer at bloom and pod stages could significantly prolong the functional period of leaves and improve photosynthetic capacity. Similarly, [28] reported a small effect of N addition on leaf senescence on the duration of seed-filling period. [29] also observed that when soybean photosynthesis was increased during the seed-filling period, seed growth and N accumulation increased but did not accelerate leaf senescence.

Table 1: Effect of variety and N application times on leaf senescence

	20 DAF	35 DAF	50 DAF
Variety			
Gyidie	11.32	12.62	15.57
Tondaua	11.68	12.64	15.47
Nangbarri	11.79	12.76	15.63
LSD (5%)	**NS**	**NS**	**NS**
Time of N Application			
1 WBF	11.17	13.33	16.37
At flowering	11.14	13.11	16.15
1 WAF	11.55	12.30	15.17
2 WAF	11.75	12.16	14.81
3 WAF	11.67	11.28	13.85
Control	12.31	13.86	16.99
CV (%)	**7.28**	**3.92**	**3.99**
LSD (5%)	**0.68**	**0.41**	**0.51**

Grain Yield

Table 2 shows differences in grain yield among the varieties were not significant (P>0.05). For periods of N application, application at one week after flowering resulted in the greatest grain yield (776.28 kg/ha), and was significantly greater than all other treatment effects, except that of 2 weeks after flowering.

Table 2: Effect of variety and time of N application on seed yield

Variety	Grain Yield (kg/ha)
Gyidie	661.33
Tondana	688.25
Nangbarri	664.86
LSD (5%)	**NS**
Time of N Application	
1 WBF	629.06
At Flowering	607.20
1 WAF	776.28
2 WAF	738.25
3 WAF	642.58

Control	652.20
CV (%)	**12.04**
LSD (5%)	**96.76**

The results indicated significant difference in total grain yield across the various treatments with the treatment 1 WAF recording the highest grain yield (776.28 kg/ha). This may be that the N-fertilizer application made one week after flowering made available adequate amount of N to coincide with the peak demand for nitrogen by the soybean plant for maximum grain filling. These findings confirm the study carried out by La Menza *et al.* (2019) with high rates of N fertilization (540-870 kg N ha^{-1}) split into several applications between V2 to R5 stages and found an average of 11% (0.46 Mg ha^{-1}) increase in yield and 15 mg g^{-1} increase in seed protein concentration. A study conducted in Kansas by [33] showed that N fertilizer application at R3 stage of 56 kg N ha^{-1} increased soybean yield by 9% and when applying large amount of 670 kg N ha^{-1} in three split applications of 223 kg N ha^{-1} at three different times during the growing season (planting, R1 and R3 stages). These confirm the fact that a smaller application of N fertilizer either at or near pod setting to meet all the N demands of soybean when BNF is lower is important for maximum yield. Other studies found an increase in seed number with N fertilizer applications before or during the period of pod setting [25,31,32]. These reports support the yield recorded for the 1 WAF plots of this study.

Conclusion

The findings of this study showed a significant delay in leaf senescence in terms of yellowing and drop at the reproductive stage following N fertilizer application, especially the applications made two and three weeks after flowering. Grain yields were also enhanced by the application of N fertilizer, especially for the treatments applied at flowering and one week at flowering.

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