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Time of N Application on the Nutritional Quality of Soybean Seeds

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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 soybean 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 the nutritional quality (crude protein and oil content) of soybean seeds. It was a split plot experiment with four replications with treatments arranged in a Randomized Complete Block Design. The three soybean cultivars 'Gyidie', 'Tondana', and 'Nangbaar' 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, at two weeks after flowering, and at three weeks after flowering) served as the sub-plot factor. Before planting, a germination test was performed, and all cultural activities were timely performed. The results indicated that N fertilizer treatment at three weeks after flowering increased crude protein content of the seed. It was also observed that, the oil content increases did not follow any special order.

Keywords: Soybean; Nitrogen Fixation; Rhizobia; Protein and Seed oil

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. The prevailing weather conditions from seed formation up to the time of ripening and harvest determine the quality of seeds produced by the soybean plant. Reduced rainfall leads to the production of low quality seeds. According to [4], the causal factors may act in either an additive or a synergistic manner and may be of physiological, pathological or mechanical origin. By way of anatomy and morphology, soybean seeds have features that make them more susceptible to damage factors than other plant species. Daily relative humidity among these factors play a major role during the physiological, commercial maturity and pre-harvesting stages of soybean growth and development causing a decrease in seed quality due to the constant exposure to hydration and dehydration processes to balance with the environment [5,6]. This characteristic is caused by highly permeable seed tegument [7]. Soybean seed quality during storage relates directly to its previous history. The seed quality may increase, preserve or decrease by exposure to the various factors [8].

Soybean seeds at the raw state contain many anti-nutritional factors (protease trypsin inhibitors, lipase inhibitors, hemagglutins and goitrogens) which must be deactivated by adequate heat treatment before its addition to both animal and human diets. According to [9], these anti-nutritional factors (ANFs) may cause unfavourable physiological effects and may reduce weight gain in animals [10]. Soybean is noted for its high nutritional value, health benefits and nutraceutical importance and according to [11], the use of soybean in animal production is very communal due to its nutritional and functional possessions majorly as meat extenders in animals which can be obtained from variety of vegetable meals, crops, crop residues, fodder and concentrate fed either in raw or treated form. As part of the vegetables fed to animals, soybean and its products are cheap but the richest source of protein that completes all the protein requirements of animals in the animal production industry. By 2050 human population is estimated to hit 9 billion and as part of their nutritional requirements, will exert pressure on the animal production industry [12]. To overcome the eminent food scarcity, it has become necessary for scientists to look for new ways of generating varieties of animal feed and breeding highly productive animals. Human consumption of animal products (meat, milk and egg), fruits and vegetables provides the basic nutrients together with the phytochemicals that reduce the risk of chronic diseases and promote good health. Soybean directly through soya foods or indirectly through animal feed contribute significantly to human health. Human consumption of soy products have through many studies proven to have many health benefits especially cancer related ailments which include: prostate cancer [13], breast cancer among Asian women who use soy products in their Asian diets [14], improvement in bone health of women under menopause [15]. Soybean production in the United States of America initially was targeted for oil production. The protein source which contains all the essential amino acids primarily was used to supplement those of cereals for animal feeds to promote good health and performance especially in young livestock. The use of soybean meal for animals expanded to Europe and Africa through importations.

The objective of this study was to determine the effect of time of nitrogen supply on total nitrogen, crude protein and oil content of soybean seed.

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 with treatments arranged in a Randomized Complete Block Design (RCBD). The main plot factor was soybean and the varieties were; 'Gyidie', 'Tondana' and 'Nangbarri'. 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.

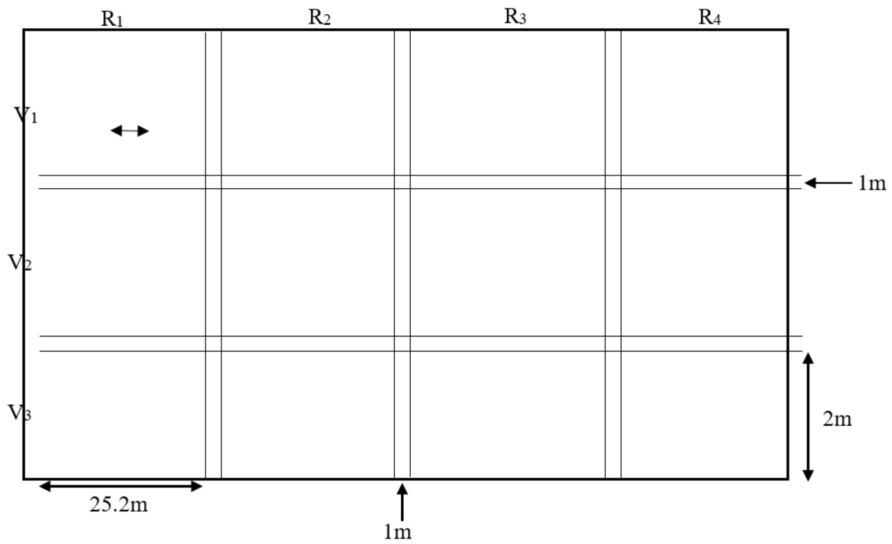

Figure 1

After planting operations

Weeds were controlled on three occasions by hoeing. Plots were generally free of pest and disease attack, so no control measures were adopted. At maturity, plants from the two central rows of each plot were harvested and seeds were extracted. Seeds from each plot were dried and weighed. Sample seeds from each plot were ground for protein and oil analysis.

Seed nitrogen (N)

The seeds were ground in a miller at the laboratory, and nitrogen concentration was then assessed by the Kjeldahl's N digestion and distillation method.

The nitrogen content of the sample was calculated by the formula:

$$N\left(gkg^{-1}\right) = \frac{(mlHC1 - mlblank) \times Normality \times 14.01}{Weightofsample\,(g) \times 10}$$

Percentage crude protein content

The crude protein percentage for each treatment was calculated by multiplying the nitrogen content of the seed by a constant (6.25), representing the proportion of amino acids contained by soybean, to produce the crude protein content.

Content of crude fat

The Soxhlet extraction method was used to determine the crude fat content, which was computed using the following formula:

$$(Weightoffat/WeightofSample) \times 100 = crudefat\,(\%ofdrymatter)$$

Results and Discussion

Seed N, crude protein, and crude fat content

Table 4.11 shows the results of seed nitrogen, crude protein and crude fat content of treatments. Varietal differences for total seed N, crude protein and crude fat were significant (P<0.05). The 'Gyidie' variety produced the greatest seed N and crude protein. Crude fat was greatest in the 'Tondana' variety. For N application periods, application at 3 weeks after flowering produced the greatest seed N content, which was significantly higher than all other treatment effects. The control treatment effect was significantly lower than all other treatments (P<0.05). Crude protein content was greatest in the 3 weeks after flowering application, and this showed significant difference from all other application times.

For crude fat content, the one week before flowering application effect was the greatest, but this was significantly higher than the control treatment effect only. All other treatment differences were not significant.

Table 1: Effect of variety and N application time on soybean seed N, crude protein and crude fat content

	Seed N Content (%)	Crude protein (%)	Crude fat (%)
Variety			
Gyidie	5.18	32.52	11.57
Tondaua	4.90	30.94	14.49
Nangbarri	4.70	29.62	12.45
LSD (5%)	**0.15**	**0.71**	**0.17**
Time of N Application			
1 WBF	4.69	29.49	13.64
At flowering	4.94	30.85	12.06
1 WAF	4.89	30.78	13.62
2 WAF	5.17	32.39	12.99
3 WAF	6.01	38.30	13.33
Control	3.87	24.34	11.36
CV (%)	**6.69**	**6.60**	**15.19**
LSD (5%)	**0.31**	**1.94**	**1.85**

A meta-analysis conducted in 2009 found an average increase in protein concentration of +0.7% with N fertilization before flowering, and of +11% with applications during flowering and pod setting relative to the unfertilized control (Rotundo and Westgate, 2009). N fertilizer application at the various stages of growth and development had impact on the N concentration and crude protein content of the seed compared with the control plots that recorded least values of 3.87% and 24.34 % respectively. Generally, the seed N concentration for the various treatments was low compared with what have been reported in other studies. The average values recorded for seed N for this study was 4.93 % which translated into given low levels of protein with an average of 31.02 % for the treatments. This could be due to the initial low levels of soil N and poor nodulation recorded. The increase in crude protein content of the seed as compared with the control following the N application is similar to what was reported by Pareek and Shahtawat (1998) that there was a significant increase in protein content with application of 60 kg N /ha.

The application of N fertilizer at different stages of growth in this study significantly impacted on the oil content of the seed conforming to what have been reported in other studies. Jayapaul and Ganesaraja (1990) observed that there was a significant increase in oil and protein content with application of 40 kg N/ha. Vara *et al.* (1994) also reported similar results. Kumawat *et al*. (2000) reported that crude protein content of the seed increased with increase N levels from 20-80 kg/ha, whereas oil content decreased with increasing levels of nitrogen. Yadav and Chandel (2010) in their studies reported significant increase in oil content with N application of 40 kg ha^{-1} as basal and 40 kg ha^{-1} at 60 DAS. Further application of 20 kg ha^{-1} at 75 DAS produced 24.4% increase in protein content of the seed over the control. Niranjan *et al.* (2015) did similar work by applying 20 kg N ha^{-1} as basal dose + 20 kg N ha^{-1} as a top-dressing during pod filling and observed seed protein content of 38% which is similar to present results where 45 kg N ha^{-1} applied at 3 WAF resulted in 38% seed protein content. Morshed *et al.* (2008), Rathod *et al.* (2006), Jyothi *et al.* (2013) and Maryam *et al.* (2013) all reported similar findings in their studies that N fertilizer application at different rates at different stages of growth increased the protein content of the seed.

Conclusion

The findings of this study indicate that, applying nitrogen fertilizer at three weeks after flowering enhanced the protein content of soybean seed. Additionally, nitrogen and the oil content of the seed were also enhanced.

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