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Research Article

Effect of Increasing Doses of NPK on Groundnut Development and Productivity in the Marginal Zone of Southern Chad

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Abstract
The aim of the study was to determine the optimum level of NPK fertilizer on groundnut productivity. The plant material was the Fleur 11 groundnut variety, and the fertilizer used was NPK (12-24-12). The trial was conducted in a Fisher block design with five treatments repeated four times. The treatments applied were T0 (0 kg NPK/ha), T1 (50 kg NPK/ha), T2 (75 kg NPK/ha), T3 (100 kg NPK/ha), T4 (125 kg NPK/ha). Treatment T2 (54.35±2.475) recorded the highest number of leaves per plant at 30 DAS, followed by T4 (54.3±2.1). The lowest number of leaves per plant was observed on T0 (41.6±2.5). Treatment T4 (307±8.5) recorded the highest number of leaves per plant at 60 days, followed by T1 (306.25±10.75). The lowest number of leaves per plant was obtained on T0 (218.5±18). The highest haulm yield was recorded on T3 (0.681 t/ha±0.029) followed by T1 (0.651 t/ha±0.029). The lowest yield was recorded on T0 (0.472 t/ha±0.025). The highest shell yield was obtained on T1 (2.10 t/ha±0.108) followed by T3 (1.96 t/ha±0.573). The lowest yield was recorded on T0 (1.118 t/ha±0.688). The highest weight was recorded on T1 (382.5 g±12.583) followed by T3 (350 g±17.795). The highest weight was recorded on T1 (382.5 g±12.583), followed by T3 (350 g± 17.795). The lowest weight was obtained on T0 (0.204 kg±4.112). The required dose of 50 kg NPK ha^{-1} (T1) could be recommended to growers to make peanut cultivation more profitable. However, further studies are needed to assess soil organic matter levels prior to fertilizer application, and to optimize cropping techniques likely to further improve groundnut productivity under the experimental conditions.
Keywords: Chad, *Arachis hypogea* L, Fleur 11 Variety, NPK Dose, Good Productivity.

1. Introduction

In Chad, agriculture is the main economic activity. It employs 80% of the working population and contributes an average of 40% to GDP. Production systems are mainly extensive and not very productive, and are based on family farming, practised on two (2) to five (5) ha for rainfed crops. Chad has a potential arable land area of 39 million ha, representing 30% of the national territory, of which around three (3) million ha are cultivated annually (CPP, 2016).

Chad's agricultural policy is to ensure food security for the population with low-cost, quality agricultural products on sustainable bases (Goalbaye *et al.,* 2018) and to contribute to poverty reduction in rural areas. However, agricultural production is often in deficit due, among other things, to climatic hazards and rudimentary means of production (Djirabaye and Goalbaye, 2014). Also, for several decades, Chadian agriculture has been affected by bad farming practices based on the agriculture with high consumption of external inputs system, the abusive use of synthetic chemical inputs which has proved potentially polluting for the environment (UNEP, 2022) and slash-and-burn cultivation. These practices have led to acidification and impoverishment of the soil, destruction of vegetation cover, pollution of watercourses and loss of biodiversity (CORPEN, 2006). Farmers also find it difficult to use chemical inputs properly, as they do not know the optimal doses for each crop. All these factors and their corollaries have led to a drop in yields, which in turn has created food insecurity.

In Chad, groundnuts are playing an increasingly important role in crop production systems. Indeed, it is one of the cash crops that has increased producers' income through the marketing or processing of its products (Goalbaye *et al.,* 2017). Groundnut is the sixth most important oilseed crop in the world. It is grown in over

100 countries on more than 26.4 million hectares, with an average productivity of 1.4 tonnes per hectare (FAO, 2003).

In Chad, it is the second most important cash crop after cotton. The country produced an average of 414,868 t/ha in 2003 on an average area of 444,066 ha (SCN, 2012). This production has been falling year on year due to a decline in soil fertility caused by irrational land use, water erosion and wind erosion, leading to nutrient depletion. Groundnuts are the second most widely grown crop in southern Chad after sorghum, and over 80% of the population engage in farming (FAO, 2016). Yet, in recent years, groundnut productivity has been steadily declining in most localities in the Sudanian zone of Chad, despite producers' compliance with technical itineraries (Goalbaye *et al.,* 2017).

The plant material used is the Fleur 11 groundnut variety, which is adaptable to our experimental area, southern Chad. This variety is a genetic prototype developed by research for a given environment. The Fleur 11 variety, selected in Senegal, is a 90-day Spanish variety that is productive in both water-stressed and favorable conditions, and has high membrane tolerance (Clavel *et al.,* 2007). It has already been characterized agronomically, botanically and physiologically (Clavel *et al.,* 2005): it is a pure line, bred in 1991 and introduced into Chad in 1997. This plant variety is widely cultivated in the Sahelian and Sudanian production zones in southern Chad, where the experimental site is located. The cycle from sowing to maturity (50%) is 90 days. The plant is erect; the seeds are light pink in color and weigh 53g per 100 seeds. Potential yields range from 1.5 to 2.5 t/ha. Its organoleptic and technological characteristics are as follows: oil content 50%, shelling yield 71%, intended for oil milling and confectionery. Other plant characteristics include resistance to cercosporiosis, aspergillosis, drought and low dormancy. The Fleur 11 variety is widely grown in the experimental area, in this case in the Sudanian zone in southern Chad. Indeed, groundnut is one of the cash crops that has increased producers' income through the marketing or processing of its products (Goalbaye *et al.,* 2017). Research results are available for groundnut cultivation (Sène, 1987; Konlan *et al.,* 2013; Yadeta, 2014; Seraphin *et al.,* 2015; Didagbé *et al.,* 2015; Ahounou *et al.,* 2016; Coulibaly *et al.,* 2017; Goalbaye *et al.,* 2017; Onyuka *et al.,* 2017). Several studies have been conducted on the use of fertilizers for groundnut cultivation (Gautreau, 1985; Clouvel, 1994; Goalbaye *et al.,* 2016).

One of the problems facing Chadian agriculture is maintaining soil fertility. Traditionally, soil fertility was managed by introducing a resting sole into the cropping succession, supplemented from time to time by animal organic matter. However, under demographic pressure, the extension of cultivated areas, without any increase in livestock, has led to a significant deterioration in land fertility. A change in practices is needed to maintain production, mainly through the large-scale use of chemical fertilizers. For some years now, southern Chad has been suffering from the adverse effects of climate change, particularly wind and/or water erosion, leading to soil impoverishment which, in turn, has reduced crop yields. Today, it is very difficult in agriculture to obtain good yields without the addition of fertilizers, whether chemical or organic. Most soils in southern Chad suffer from a lack of organic or mineral nutrients. Indeed, according to the FAO (2003), Chad has the lowest consumption of fertilizers at less than 10 kg per hectare per year, compared with a world average of 90 kg. Most of the fertilizer formulas once proposed by the extension services (ONDR) for groundnuts no longer take account of the current level of soil degradation. Growers also find it difficult to use chemical inputs properly, as they are unfamiliar with the optimum doses for each crop. For this reason, it is necessary to determine the optimal dose of chemical fertilizer and to use varieties adapted to the study area. It is in this context that this study entitled "Effect of increasing doses of NPK on the development and productivity of groundnut in the marginal zone of southern Chad" was initiated.

The overall objective of this study is to improve groundnut productivity in the marginal zone of southern Chad.

1.1. Specific Objectives

Specifically, this study aims to:

1) Apply the appropriate dose of NPK chemical fertilizer on impoverished soils for groundnut cultivation.
2) Determine the optimum level of NPK chemical fertilizer (12-24-12) for groundnut cultivation.

2. Materials and Methods

2.1. Presentation of the Experimental Site

2.1.1. Geographical Location

The experiment was carried out in July 2024 in Doyaba at the University of Sarh (UDS), (09'081''89°N, 18'42''947°E, altitude 360 m).

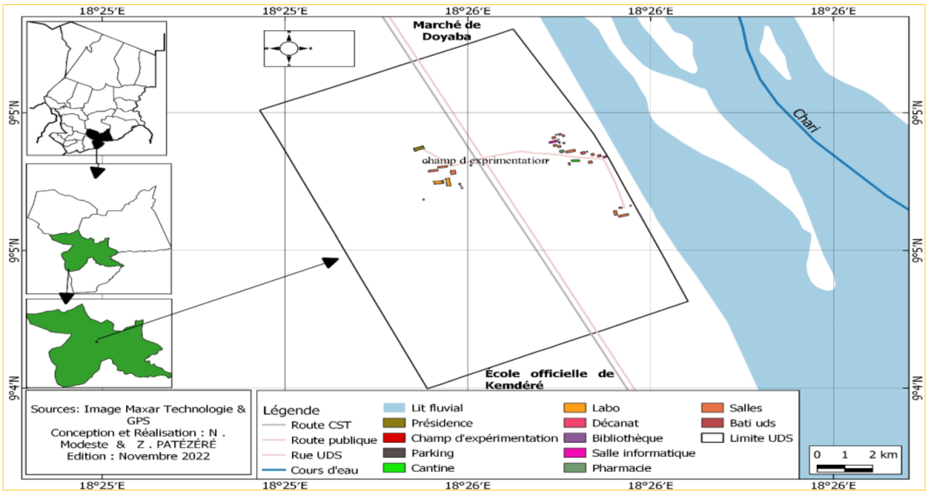

Figure 1. Location of study area.

2.1.2. Climatic Characteristics of the Study Site

Located in south-eastern Chad, Doyaba enjoys a Sudanian-type climate marked by two seasons: the dry season from November to April and the wet season from May to October. Average annual rainfall in Doyaba from 2005 to 2014 ranged from 69.21 to 27 mm. Average annual temperatures range from 26 to 28.8°C. The highest mean annual temperatures were recorded in 2005 and 2014, at 28.1°C and 28.8°C respectively. The lowest temperatures were recorded in 2006, 2007 and 2008 (CST, 2016).

2.1.3. Soil Conditions and Relief

The Doyaba site has soils that fall into the category of tropical ferruginous soils formed in hot climates from sandy-sandy or sandy-clay materials of sedimentary origin. The soils are leached ferruginous, red in color and uniformly sandy-clayey to clayey in texture, with a pH that is slightly acidic at the surface and very acidic at depth (Naïtormbaïdé, 2012). The site is impoverished by the loss of organic matter and has a degraded structure (Bationo *et al.,* 2004).

2.2. Plant Material

The plant material consists of the groundnut variety Fleur 11, with a 90-day cycle. The average yield obtained from this variety in improved cultivation is 1.5 to 2.5 t/ha (ONDR, 2001). The level of intensification is improved (ploughing, weeding, fertilizing).

2.3. Fertilizers

The fertilizer used is the chemical fertilizer NPK (12-24-12), which are nutrients designed to provide plants with supplementary nutrition, with the aim of improving their growth, and increasing their yield and the organoleptic qualities of the seeds.

2.4. Methods

2.4.1. Experimental Setup

The trial was conducted using a five-treatment Fisher block design (T0, T1, T2, T3 and T4) with four replicates. NPK doses (0, 50, 75, 100 and 125 kg ha^{-1}) correspond respectively to treatments T0, T1, T2, T3 and T4. Only one factor is studied: the optimal level of NPK.

2.4.2. Cultivation Methods

The experimental plots were ploughed to a depth of 15-20 cm. The plots were then harrowed to prepare the seedbed. Sowing took place on July 15, 2024, after a useful rainfall of at least 20 mm. To avoid any limiting factors, seeds were treated with a mixture of insecticide and fungicide thioral (thiram and heptachlor). Sowing is carried out on one (1) seed, placed at a depth of around 5 cm. A spacing of 40 cm x 20 cm was chosen. A first weeding was carried out on the 12th day after emergence and a second weeding 14 days after the first. Five (5) treatments (T0, T1, T2, T3 and T4) corresponding to doses (0, 50, 75, 100 and 125 kg ha^{-1} of NPK) were applied during sowing, and buried in the furrows 10 cm from the sowing line. No phytosanitary treatments were applied. The dimensions of the elementary plot are 8 m long and 5 m wide, i.e. 40 m^2, with each block having a surface area of 200 m^2, giving a total surface area of 800 m^2 for the trial as a whole. A 50 cm border will be chosen for the passage, a 50 cm space between the elementary plots and a 1 m space between the blocks. The previous crop is cassava.

Figure 2. Delimitation of test plot.

Figure 3. Seed treatment.

Figure 4. Fertilizer application.

2.4.3. Phenological Observations
The dates of 25%, 50% and 100% of emergence and flowering and of the crop cycle were determined.

2.4.4. Calculated, Measured or Recorded Parameters
Agronomic parameters were measured or recorded: number of leaves per plant, hull yield, haulm yield, 1000-seed weight and number of pods per plant.

2.4.5. Statistical Analysis
Data entry and graphical representation of the agronomic parameters measured were carried out using Excel (2007). Data were analyzed using SPSS software (Statistical Package for Social Sciences version 20.0). The means of the various parameters were separated by the Student-Newman-Keuls (NSK) multiple rank test.

3. Results and Discussion
3.1. Results
3.1.1. Phenological Observations
At 4 days after sowing (DAS), emergence was at 25% on all elementary plots. At 5 days after sowing, emergence was at 50% and at 6 days after sowing, emergence was at 100% on all elementary plots (Table 1). At 25 days after sowing, flowering was observed at 25%, at 29 days after sowing flowering was at 50% on all elementary plots and at 34 days after sowing flowering was at 90%. Harvesting took place on the 92nd day after sowing.

Table 1. Phenological observations (in days).

	Germination				Flowering			Harvest
Time (days)	0	4	5	6	25	29	34	92
Percentage (%)	0	25	50	100	25	50	90	100

3.1.2. Number of Leaves per Plant at 30 DAS
The number of leaves per plant at 30 DAS is shown in Figure 5. Treatment T2 (54.35±2.475) recorded the highest number of leaves per plant, followed by T4 (54.3±2.1) and T1 (50.65±2.85). The lowest number of leaves per plant was observed on treatments T0 (41.6±2.5) and T3 (45.3±1.15). Statistical analysis revealed that there was no significant difference between treatments with regard to the number of leaves per plant at 30 DAS at the 5% threshold ($F=2.018$; $P< 0.001$).

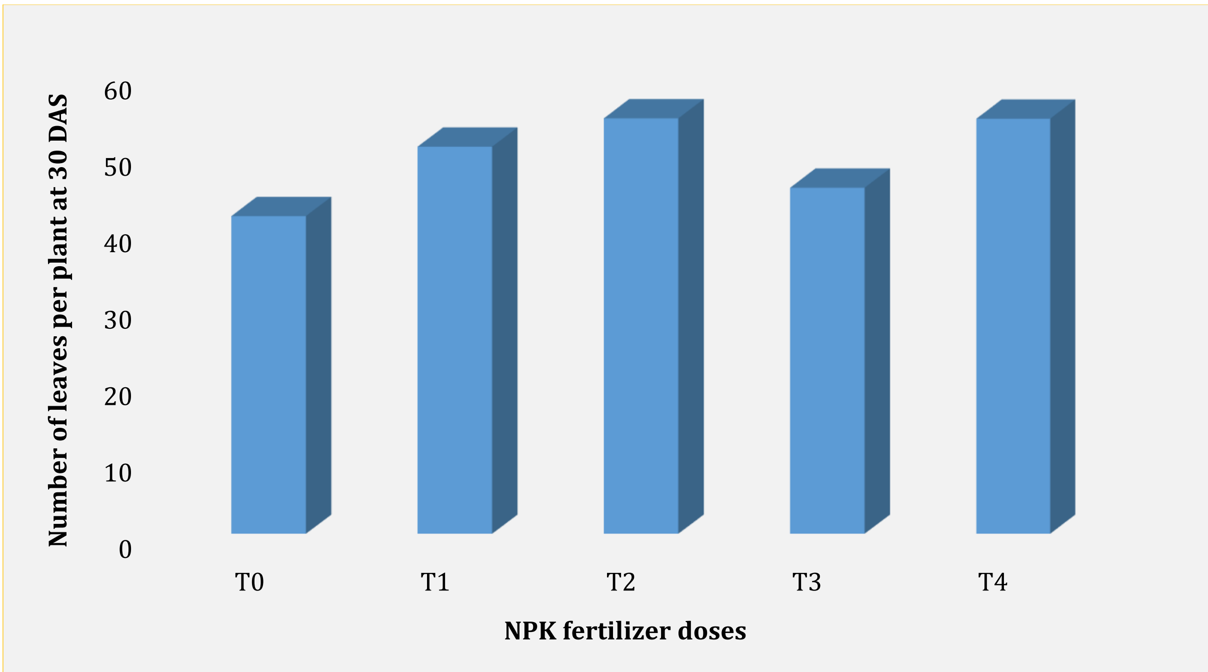

Figure 5. Number of leaves per plant at 30 DAS.

3.1.3. Number of Leaves per Plant at 45 DAS

The number of leaves per plant at 45 days after harvest is shown in Figure 6. Treatment T2 (120.75±9.125) had the highest number of leaves per plant at 45 days after planting, followed by T1 (116.25±10.875). The lowest number of leaves per plant was noted in treatments T0 (107.25±8.25), T3 (108±7.5) and T4 (109±3.00). Analysis of variance showed that there was no significant difference between treatments in terms of number of leaves per plant at 45 days before harvest at the 5% threshold (F=0.245; P= 0.086).

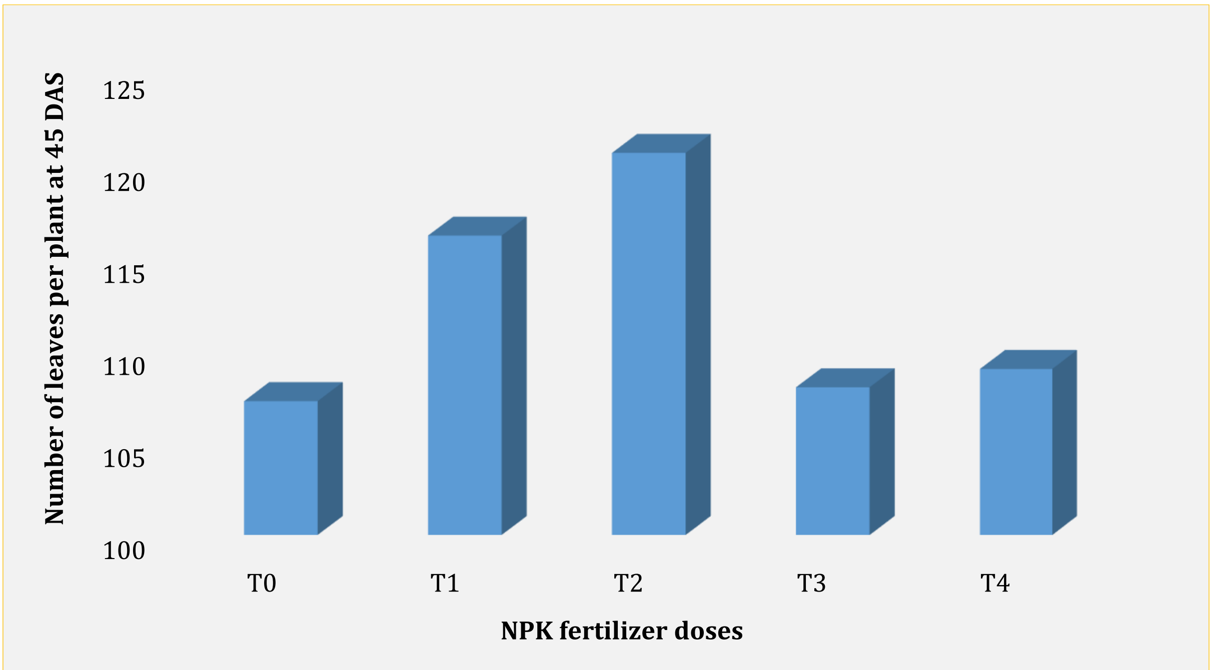

Figure 6. Number of leaves per plant at 45 DAS.

3.1.4. Number of Leaves at 60 DAS

The number of leaves per plant at 60 days after harvest is shown in Figure 7. Treatment T4 (307±8.5) recorded the highest number of leaves per plant at 60 DAS, followed by T1 (306.25±10.75) and T2 (285.25±7.75). The lowest number of leaves per plant was obtained in treatments T0 (218.5±18) and T3 (271.75±6.875). Analysis of variance revealed that there was a significant difference between treatments in the number of leaves per plant at 60 days at the 5% threshold (F=4.010; P= 0.094).

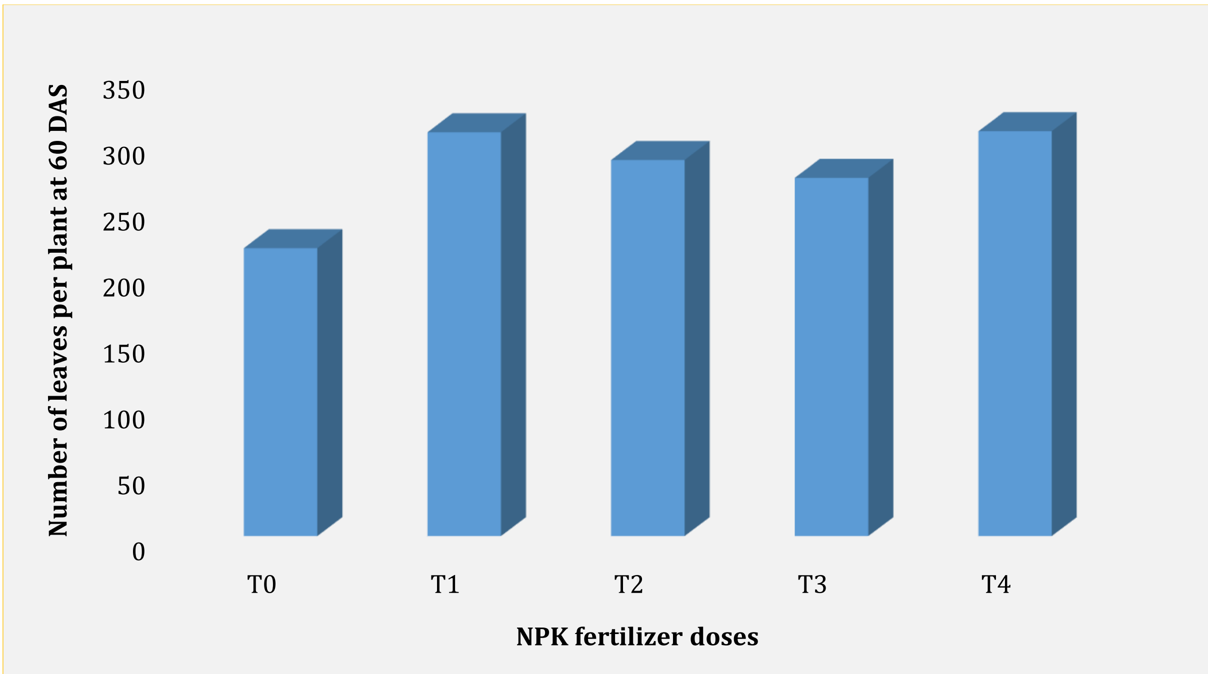

Figure 7. Number of leaves per plant at 60 DAS.

3.1.5. Fodder Yield

The haulm yield is shown in Figure 8. The highest yield was recorded on treatment T3 (0.681 t/ha±0.029), followed by T1 (0.651 t/ha±0.029) and T2 (0.613 t/ha±0.068). Low yields were observed in treatments T4 (0.508 t/ha±0.045) and T0 (0.472 t/ha±0.025). Analysis of variance revealed highly significant differences between treatments in haulm yield at the 1% level ($F=9.075$; $P=0.064$). However, treatments T1, T2 and T3 were statistically equal, as shown in Table 3.

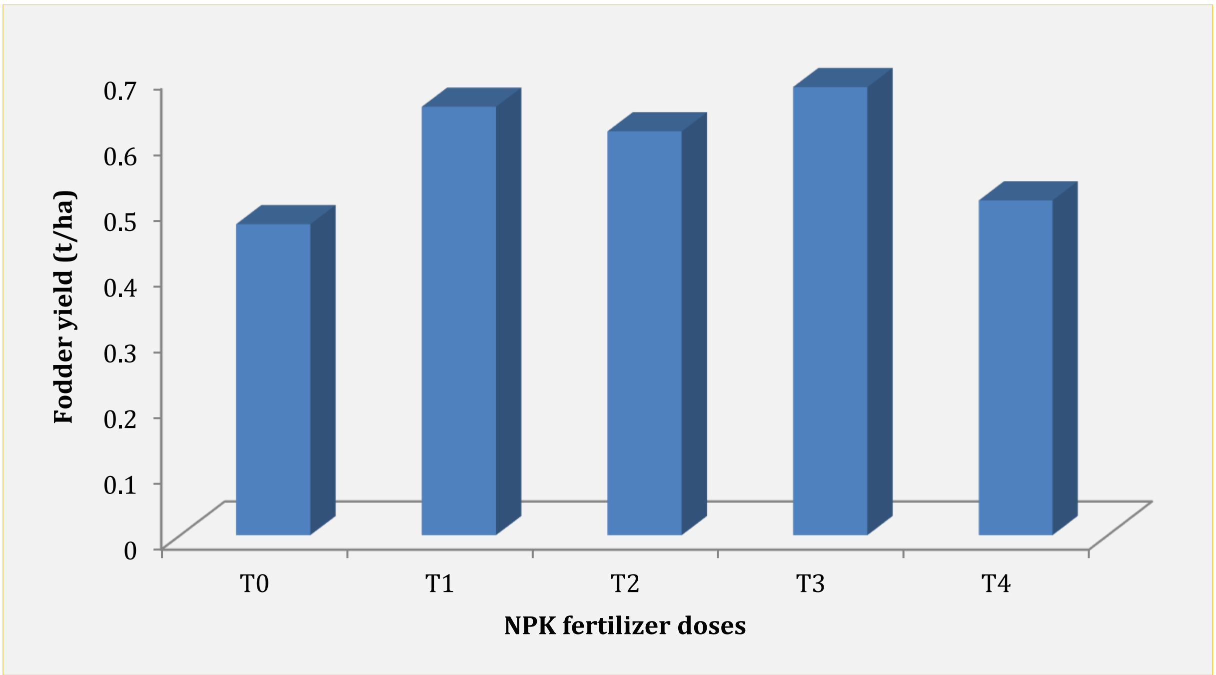

Figure 8. Fodder yield.

3.1.6. Hull Yield

Hull yields are shown in Figure 9. The highest yield was obtained on treatment T1 (2.10 t/ha±0.108), followed by T3 (1.96 t/ha±0.573) and T2 (1.623 t/ha±0.227). Low yields were recorded for treatments T0 (1.118 t/ha±0.688) and T4 (1.212 t/ha±0.047). Analysis of variance revealed that there was a highly significant difference between treatments in terms of shell yield at the 1% level ($F=33.00$; $P=0.004$). However, treatments T1, T2 and T3 were statistically equal.

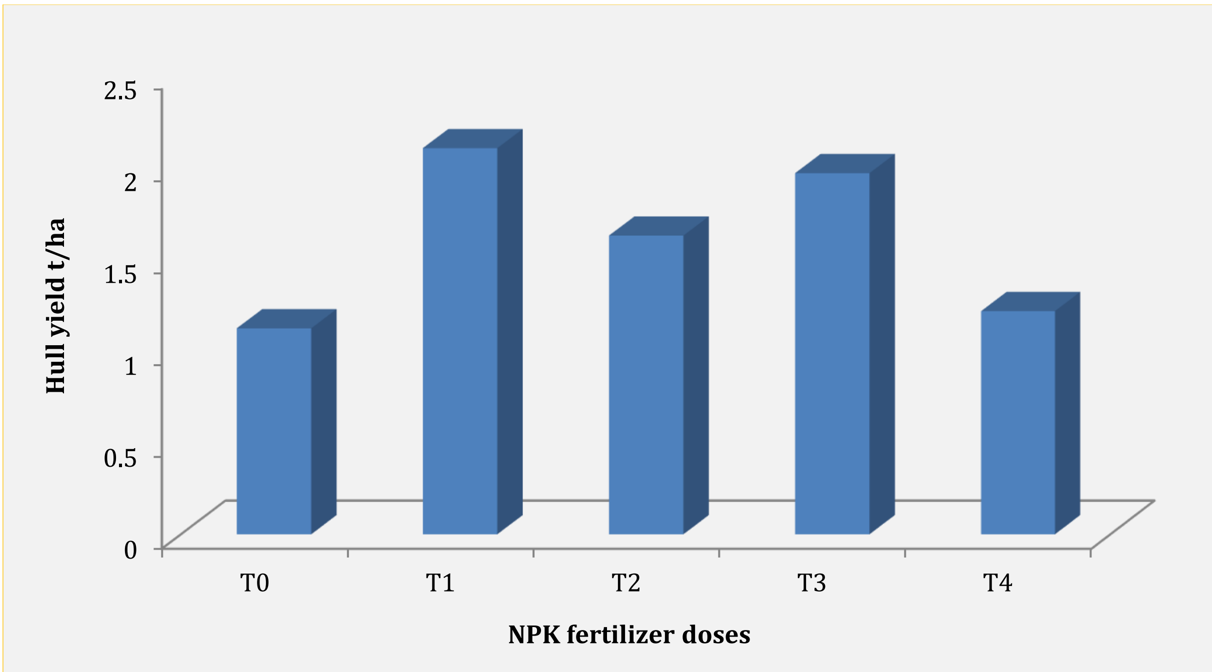

Figure 9. Hull yield.

3.1.7. Number of Pods per Plant

The number of pods per plant is shown in Figure 10. The highest number is observed on treatment T1 (40.5± 1.290), followed by T3 (39.75±1.707) and T2 (39.00±6.218). The lowest number of pods per plant was recorded on treatments T0 (22.00±0.816) and T4 (28.75±0.957S). Statistical analysis of variance showed that there was a highly significant difference between treatments in terms of number of pods per plant at the 1% threshold (F=30.547; P=0.034). Treatments T1 and T3 were statistically equal. Similarly, treatments T2 and T4 are statically equal (Table 3).

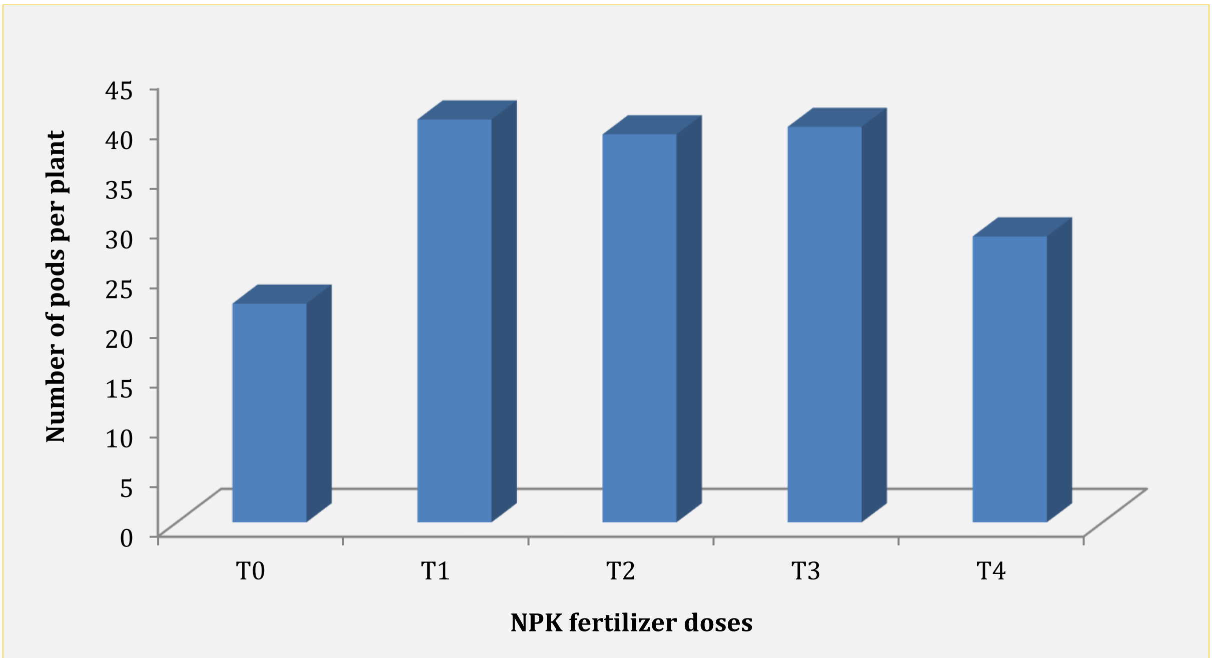

Figure 10. Number of pods per plant.

3.1.8. 1000-Seed Weight

The weight of 1000 seeds is shown in Figure 11. The highest weight was recorded in treatment T1 (382.5 g± 12.583), followed by T3 (350 g±17.795) and T2 (268.25 g±10.750). The lowest weights were obtained in treatments T0 (204.75 g±4.112) and T4 (210 g±9.128). Statistical analysis of variance showed that there was a highly significant difference between treatments in terms of 1000-seed weight at the 1% threshold (F =216.76; P < 0.001). However, treatments T4 and T0 were statistically equal (Table 3).

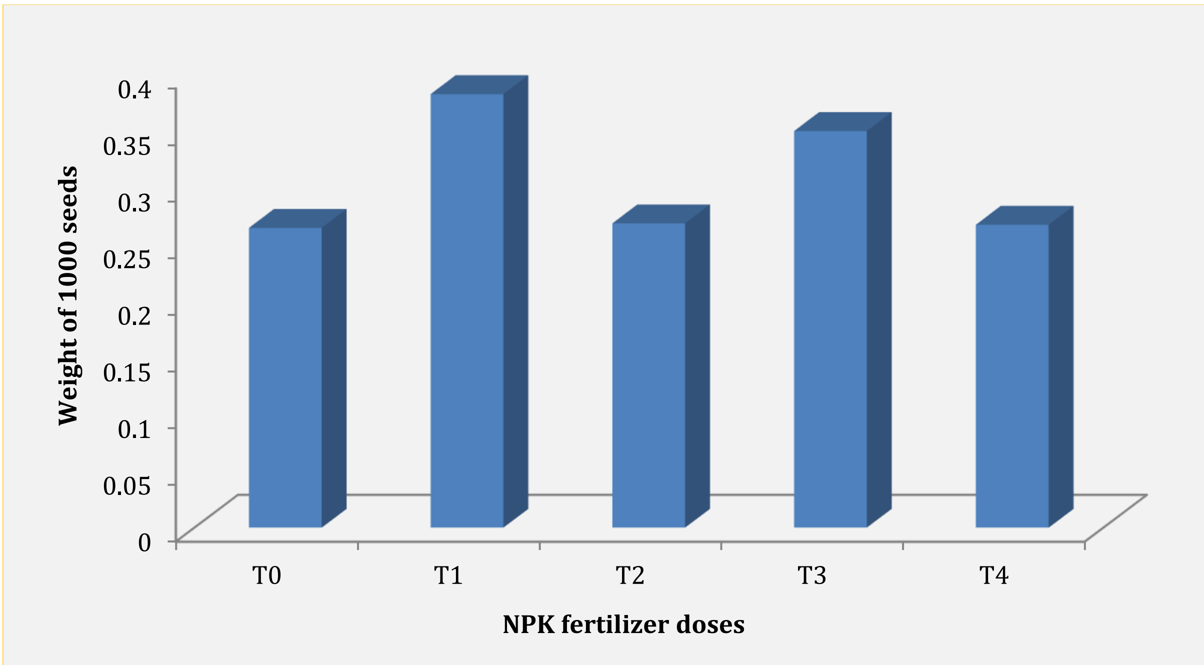

Figure 11. Weight of 1000 seeds.

Table 2. Number of leaves per plant at 30 JAS, 45 JAS and 60 JAS.

Treatments	Number of leaves per plant at 30 days	Number of leaves per plant at 45 JAS	Number of leaves per plant at 60 days
T0	41.6±2.5[a]	107.25±8.25[a]	218.5±18[a]
T1	50.65±2.85[a]	116.25±10.875[a]	306.25±10.75[b]
T2	54.35±2.475[a]	120.75±9.125[a]	285.25±7.75[b]
T3	45.3±1.15[a]	108±7.5[a]	271.75±6.875[a]
T4	54.3±2.1[a]	109±3.00[a]	307±8.5[b]
Values in the same column followed by the same letter are not significantly different at the 5% threshold according to the Student Newman and Keuls test.			

Table 3. Yields of hulls, tops, number of pods per plant and weight of 1000 seeds.

Treatments	Fodder yield t/ha	Hull yield t/ha	Number of pods per plant	Weight of 1000 seeds in gr
T0	0.472±0.025[a]	1.118±0.688[a]	22±0.816[a]	204.75±4.112[a]
T1	0.651±0.29[c]	2.1±0.108[b]	40.5±1.290[c]	382.5±12.583[d]
T2	0.613±0.068[b]	1.623±0.227[b]	39±6.218[c]	268.25±10.750[b]
T3	0.681±0.029[c]	1.96±0.573[b]	39.75±1.707[c]	350±17.795[c]
T4	0.508±0.045[a]	1.212±0.047[a]	28.75±0.957[b]	210±9.128[a]
Values in the same column followed by the same letter are not significantly different at the 5% threshold according to the Student Newman and Keuls test.				

4. Discussion

The number of leaves per plant at 30 and 45 days after sowing (DAS) is statistically the same for all treatments. Indeed, at this stage, the vegetative development of the peanut is almost uniform in all the elementary plots of the experiment. At 60 days old, the number of leaves per plant differs from one treatment to another. Treatments T3, T1 and T2 show greater vegetative development than treatments T0 and T4. This could be explained by the use of mineral fertilizer. Similar results were reported by Goalbaye *et al.,* (2016), who observed good vegetative development in peanuts at certain stages of development, depending on the doses of mineral and organic fertilizer.

Analysis of the results showed high haulm yields in treatments T1, T2 and T3 compared with the control T0 and T4, which received the highest dose of fertilizer. These results could be explained by the fact that groundnuts respond better to low doses of fertilizer. Similar results were reported by Goalbaye *et al.,* (2016), who obtained high haulm yields compared with the unfertilized control. Similarly, these results concur with the findings of Deblay (2006), Yannick *et al.,* (2013) and Lucien *et al.,* (2013), who obtained low biomass on the maize crop with unfertilized control soils.

Analysis of the shell yield results showed that treatments T1, T2 and T3 were statically equal to and superior to the control T0 and T4, which received the high dose of fertilizer. These results show that peanuts respond better to low doses of fertilizer. These results are in line with those obtained by Goalbaye *et al.,* (2016), who carried out similar work on the effect of organic and mineral fertilization on the groundnut crop. The 1000-seed weight of treatments T1 and T3 is higher than the control (T0) and treatment T4, which received the highest dose of fertilizer. The 1000-seed weight of treatments T1 and T3 although high is lower than the 1000-seed weight of the technical data sheet of national catalog of plant species and varieties in Chad (2015).

5. Conclusion

The aim of the present study is to contribute to the improvement of agricultural productivity for the groundnut crop. The aim of this work was to determine the optimal level of NPK fertilizer on the productivity of groundnut Fleur 11.

The results of this study showed that treatments T1, T2 and T4, corresponding respectively to doses of 50 kg NPK/ha, 75 kg NPK ha-1 and 125 kg NPK/ha, produced good groundnut vegetative development. Good haulm and hull yields and the highest seed weight were recorded in treatments T3 and T1 with the lowest dose of NPK fertilizer. Thus, the required dose of 50 kg NPK ha^{-1} could be recommended to growers to make peanut cultivation more profitable. This recommended low NPK fertilizer dose would be economical, enabling growers to increase their production per unit area while maintaining soil fertility in the long term and improving their standard of living.

Declarations

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Author Contributions: TG: Definition of intellectual content, implementation of study protocol, review manuscript; IA: Design of study, statistical analysis and interpretation, literature survey, data collection, data analysis, manuscript preparation, editing, and manuscript revision; AAC: Concept, design, literature survey, prepared first draft of manuscript, data collection, data analysis, manuscript preparation and submission of article; EW: Concept, literature survey, manuscript revision; JB: Concept, design, literature survey, manuscript preparation, manuscript review.

Conflict of Interest: The authors declare no conflict of interest in this research work.

Consent to Publish: The authors agree to publish the paper in International Journal of Recent Innovations in Academic Research.

Data Availability Statement: The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

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