Optimizing *Rhizobium spp.* Application for Maximizing Peanut Yield in the Sudanian Climate of Chad

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ABSTRACT

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| Peanut is one of the cash crops in Chad. The impoverishment of agricultural soils in recent years has contributed to its decline in production. The objective of this study is to improve peanut production by introducing microbial biofertilizer (*Rhizobium spp.*). More specifically, it is to determine the optimal dose of *Rhizobium spp.* on peanut crops. The experiment was conducted at the experimental site of the University of Sarh (Chad). The peanut variety Fleur 11 with a 90 day cycle was grown in a Fisher block design with six treatments and 4 replicates. Treatments T0, T1R, T2R, T3R, T4R, T5E represent respectively the negative control without *Rhizobium spp.* and without fertilizer, the dose of *Rhizobium spp.* 3.12 g/ 1 kg of seed, 6.24 g/ 1 kg of seed, 9.36 g/ 1 kg of seed, 12.48 g/1 kg of seed and the 2nd positivecontrol with mineral fertilizer (20-10-10). Treatment T5E (41.825±1.456) recorded the highest number of leaves at 30 DAS followed by T0 (31.475±2.652). T3R (90.725 ±3.397) obtained the highest number of leaves at 45 DAS followed by T5E (79.85±5.424). T3R (112±2.497) recorded the highest number of leaves at 60 DAS followed by T5E (101.05 ±3.426). T3R (3.503 kg/20 m2 ±0.338) recorded the highest shell yield followed by T5E (3.238 kg/20 m2 ±0.577). T3R (515 g ±8.793) recorded the highest 1000 seed weight followed by T5E (509.75 g ±9.322). The introduction *of Rhizobium spp.,* at a dose of 9.36 g per 1kg of peanut seed, resulted in better performance in terms of good vegetative development and pod yield. However microbial biofertilizers (*Rhizobuim spp.*) have a late action compared to other fertilizers. Therefore a good fertilization with *Rhizobium spp.* on peanut crops could be preceded by organic fertilization during ploughing to ensure a good start to the vegetative cycle. In this case, further studies are necessary to confirm the results obtained under the same experimental conditions and also to determine the quantity of organic fertilizer to be applied during ploughing. |

***Keywords:*** *Rhizobium spp., dose, Peanut, productivity, Sarh, Chad.*

1. INTRODUCTION

The FAO has estimated that 750 million people are seriously food insecure, i.e. almost one person in ten worldwide. Two billion people do not have regular access to safe, nutritious and adequate food (FAO, 2020). Food security and the fight against poverty have become major concerns for most countries in the world (WFP, 2023).

Africa faces the multiple challenges of climate variability, one of the factors exacerbating poverty and food insecurity. This climatic variability is felt at a local level through fluctuations in the period and duration of rainfall that are difficult to control, sudden and unpredictable floods, variations in annual rainfall, drought, soil degradation, and so on. These factors have contributed to a decline in agricultural productivity. This downward trend in agricultural production means that Africa cannot guarantee food security for its people, even though it still has potentially arable land.

Faced with these multiple problems, Africa needs to find specific, sustainable and adaptable solutions to increase agricultural production in order to meet the population's food needs. One of these solutions is crop diversification. Crop diversity and the use of farming techniques are key factors in sustainably boosting agricultural productivity and ensuring food security. To meet the growing demand of the world's population by 2050, estimated at around 9 billion people, and the expected changes in diet, global agricultural production will need to increase by 60% over the same period (FAO, 2019). This explains why population growth far outstrips agricultural production. The major challenge for agricultural research is therefore to help increase crop yields and soil productivity, while safeguarding the environment. To solve this problem, tropical farmers will have to increase their production and productivity. But in many countries it will be very difficult to increase the area under cultivation. As a result, increased production will have to come from higher productivity and intensification of current cropping systems (Goalbaye, 2014). One of the major challenges facing agriculture in African countries is food self-sufficiency (Boyé *et al*, 2016).

Chad's agricultural policy is to ensure food security for the population with low-cost, high-quality agricultural products on a sustainable basis, and to promote increased productivity for small-scale producers (Goalbaye *et al*, 2018). However, low crop yields due to soil impoverishment in recent years have forced farmers to use chemical fertilizers, thereby damaging the environment.

Moreover, chemical fertilizers imported from the West are generally expensive and not accessible to most growers (Bado, 2002 ; Goalbaye *et al*, 2016). As a result, an alternative use of non-polluting microbial biofertilizer (*Rhizobium spp.*) is possible to improve agricultural productivity. The work of Gomong et *al (2017)* on the inoculation of legumes with *Rhizobium spp.* on impoverished soils has shown the need to use *Rhizobium spp.* in legume crops without giving the optimum doses in order to make the crops profitable.

Several studies have shown the importance of using organic or microbial biofertilizers to improve crop yields (Goalbaye *et al, 2024* ; Goalbaye *et al*, 2016 ; Kasango *et al*, 2013 ; Useni *et al*, 2013 ; Kaho et al, 2011 ; Mulaji, 2011 ; N’dienor 2006 ; Ndayegamiye et al, 2005). However, research should focus more on developing appropriate cultivation techniques to increase crop yields (Taffoua et al, 2008). Peanuts are one of Chad's cash crops, which improve farmers' incomes by being marketed and used in various culinary dishes. Despite this, in recent years peanut productivity has been declining in certain localities in the Sudanian zone of Chad (Touroumgaye et al, 2017). One of the main causes of this decline in agricultural production is believed to be the loss of soil fertility (Touroumgaye et al, 2018). The general objective of this study is to improve Peanut production on impoverished soils.

2. material and methods

**2.1 Experimental site**

The experiment was carried out from June to September 2024 at the experimental site of the University of Sarh (Chad). The study site is located in the Province of Moyen Chari, where the climate is Sudanian (average rainfall: 1100 mm/year; temperature: 24 - 38°C). The soils are ferruginous, leached and red in colour, with a uniformly sandy-clay to clay texture and a pH that is slightly acid at the surface and very acid at depth (Naïtormbaïdé, 2012).

**2.2 Material**

The plant material consists of *Rhizobium* bacteria and the Fleur 11 Peanut variety with a 90-day cycle. The average yield under improved cultivation is 3 t/ha.

**2.3 Methods**

**2.3.1 Experimental design**

The trial was conducted using a Fisher block design. It consisted of a single factor, the fertilizer dose, with six treatments (T0, T1R, T2R, T3R, T4R, T5E) with 4 replicates. Treatments T0, T1R, T2R, T3R, T4R, T5E represent respectively the negative control without *Rhizobium spp.* and without fertilizer, the dose of *Rhizobium spp.* 3.12 g/ 1kg of seed, 6.24 g/ 1Kg of seed, 9.36 g/ 1kg of seed, 12.48 g/1K g of seed and the 2nd positive control with mineral fertilizer (20-10-10). The size of the elementary plots is 5m\*4 m = 20 m2, the size of the elementary plots per block is 120 m2: the aisle between the blocks is 1.5m, the aisle between the elementary plots is 30 cm, and the total surface area of the experiment is 120 m2 \*4= 480 m2.

**2.3.2 Cultural Operations**

The individual plots were ploughed to a depth of 15-20 cm. They were then harrowed to prepare the seedbed. *Rhizobium spp.* from different treatments T0, T1R, T2R, T3R and T4R were mixed with milk powder in equivalent doses and diluted in 0.125 l of water before being mixed with the seeds. This is to ensure that the *Rhizobium spp.* adhere well to the seeds.

Sowing is carried out after a useful rainfall of at least 20 mm. Sowing is carried out on one seed, placed at a depth of around 5 cm with a spacing of 30 cm x 25 cm. NPK fertilizer (20-10-10) at the equivalent rate of 50kg/ha is applied 5 cm from the T5E top dressing. A first weeding was carried out 12th days after sowing (DAS) and a second weeding 22th day after sowing.

**2.3.2 Measured or recorded parameters**

The agronomic parameters were based on phenological observations (50% date of emergence, 50% date of flowering and the crop cycle) and measurements of the number of leaves per plant at 30, 45 and 60 days, number of pods per plant, shell yield and 1000-seed weight. The number of leaves and pods was determined by hand counting. The weight of 1000 seeds was weighed using an electronic precision balance for the different treatments in all the replications.

Grain yield per plant was calculated using the Garfius formula: W = XYZ (Garfius, 1964).

Where X: is the number bolls per plant; Y: average number of seeds per boll; Z: average seed weight.

**2.3.3 Statistical analysis**

The data collected were analyzed using SPSS software (Statistical Package for Social Sciences version 20.0). The means of the different parameters were separated using the Student-Newman-Keuls multiple arrangement test.

3. results and discussion

**3.1 Number of leaves at 30 DAS**

The results for the number of leaves at 30 days after sowing (DAS) are shown in Figure 1. Treatment T5E (41.825 ± 1.456) recorded the highest number of leaves at 30 days after sowing, followed by treatments T0 (31.475 ± 2.652), T4R (30.35 ± 2.675) and T1R (30.3 ± 1.989). Treatments T3R (29.35 ± 2.042) and T2R (30.125 ± 0.771) had the lowest number of leaves at 30 DAS. The analysis of variance (ANOVA) of the treatment means showed that there were highly significant differences in the number of leaves at 30 DAS at the 1% level (F=20.574; P< 0.01).

**Fig. 1. Number of leaves at 30 DAS**

The results of the number of leaves at 30 days showed that only treatment T5E (41.825), the positive control, recorded a significantly higher number of leaves than treatment T0 (31.475), the negative control, and the four treatments T1R (30.3), T2R (30.125), T3R (29.35) and T4R (30.35) inoculated with *Rhizobium spp.* This could be explained by the fact that the soil in which the trial was planted was impoverished. Furthermore, the nodules that formed three weeks after sowing and which normally become functional five weeks after sowing have not yet fixed atmospheric nitrogen and only the T5E treatment, the positive control, benefited from the mineral fertilizer applied at sowing (IFDC/C4CP., 2016).

**3.2 Number of leaves at 45 DAS**

The results for the number of leaves at 45 days are shown in Figure 2. Treatment T3R (90.725 ±3.397) had the highest number of leaves at 45 days, followed by treatments T5E (79.85 ± 5.424), T4R (74.7 ±2.340), T2R (73.325 ±2.486) and T1R (69.625 ±0.613). Treatment T0 (60.2 ±2.804) had the lowest number of leaves. The analysis of variance (ANOVA) of the treatment averages revealed that there were significant differences in the number of leaves 45 days after harvest at the 5% threshold (F=2.907; P < 0.05).

Leaf number results at 45 days showed that treatment T3R (90.725) had the highest leaf number, followed by treatments T5E (79.85) and T4R (74.7). The increase in the number of leaves is thought to reflect the functionality of the nodules that fix atmospheric N2 (Zahran., 2001 ; Wang et al., 2017)

**Fig. 2. Number of leaves at 45 DAS**

**3.3 Number of leaves at 60 DAS**

The result of leaf number at 60 DAS is reported in Figure 3. Treatment T3R (112 ±2.497) recorded the highest leaf number at 60 DAS followed by treatments T5E (101.05 ±3.426), T1R (96.55 ±4.132), T4R (89.9 ±4.334) and T2R (88 ±2.503). Treatment T0 (64 ±2.511) noted the low leaf number. Analysis of variance (ANOVA) of the treatment means revealed that there are highly significant differences in leaf number at 60 DAS at the 1% level (F=26.46 ; P < 0.01).

**Fig. 3. Number of leaves at 60 DAS**

In terms of the number of leaves at 60 days, the T3R treatment (112) recorded the highest number of leaves, followed by T5E (101.05) and T1R (96.55). These results are in line with those of Guei (2020) who did similar work on voandzou. The author reported that the inoculated plants all had higher leaf numbers than the control but similar overall to the fertilized plants.

**3.4 Shell yield kg/20 m2**

The shell yield result of different treatments is reported in Figure 4. The T3R treatment (3.503 kg/20 m 2 ±0.338) recorded the highest shell yield followed by T5E treatments (3.238 kg/20 m 2 ±0.577) and T4R (2.93 kg/20 m 2 ±0.607). Low shell yields are observed on T1R treatments (2.876 kg/20 m 2 ±0.693), T2R (2.551 kg/20 m 2 ±0.314) and T0 (2.536 kg/20m 2 ±0.308). Analysis of variance of the treatment means revealed that there were highly significant differences in shell yield at the 1% level (F=5.078; P<0.01).

**Fig. 4. Shell yield kg/20 m2**

In terms of shell yield, treatment T3R (3.503 kg/20m2) obtained the highest yield, followed by treatments T5E (3.238 kg/20m2), T4R (2.93 kg/20m2) and T1R (2.876 kg/20m2). These results are in line with those reported by several authors (Guei, 2020; Okogun and Sanginga, 2003; Tefera et al., 2009; Tefera et al., 2010) who have worked on the inoculation of voandzou with *Rhizobium spp*. These authors observed the high yields of plants inoculated with *Rhizobium spp.* and fertilized with chemical fertilizer.

**3.5 weight of 1000 seeds in grams (g)**

The result of weight of 1000 seeds of different treatments is shown in Figure 5. The T3R treatment (515 g ±8.793) recorded the highest 1000 seed weight followed by T5E treatments (509.75 g ± 9.322) and T2R (504.25 g ± 4.193). The low weights of 1000 seeds are noted on the T1R treatments (502 g ±2.449), T4R (501.5 g ±1.914) and T0 (501.5 g ±1.914). Analysis of variance of treatment means revealed that there were highly significant differences in seed weight at the 1% level (F=7.315; P < 0.01).

**Fig. 5. Weight of 1000 seeds in grams (g)**

In terms of 1000-seed weight, treatment T3R (515 g) recorded the highest 1000-seed weight, followed by treatments T5E (509.75 g) and T2R (504.25 g).These results concur with the findings of Guei (2020) on the inoculation of voandzou with *Rhizobium spp*. The author recorded the high seed weight of plants inoculated with *Rhizobium spp.* and fertilized with chemical fertilizer. Inoculation of cultivated legume species with *Rhizobium spp.* improves the growth and productivity of these plants (Guei, 2020; Ahemad and Kibret, 2014; Gopalakrishnan *et al,* 2015; Gomong *et al*., 2017).

Table 1 shows the different results. Values in the same column followed by the same letter are not significantly different at the 1% or 5% threshold according to the Student Newman and Keuls test.

**Table 1. Number of leaves per plant at 30 DAS, 45 DAS and 60 DAS, Shell yield (kg/20m2) and weight of 1000 seeds (g)**

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| **Treatments** | **Number of leaves per plant at 30 days** | **Number of leaves per plant at 45 days** | **Number of leaves per plant at 60 days** | **Shell yield (kg/20m2 )** | **Weight of 1000 seeds (g)** |
| **T0** | 31,475±2,652 a | 60.2 ± 2.804 bc | 64 ± 2.511 bc | 2.536 ± 0.308 b | 501.5 ± 1.914 b |
| **T1R** | 30.3 ± 1.989 a | 69.625 ± 0.613 bc | 96.55 ± 4.132 bc | 2.876 ± 0.693 b | 502 ± 2.449 b |
| **T2R** | 30.125 ± 0.771 a | 73.325 ±2,486 bc | 88 ± 2.503 bc  | 2.551 ± 0.314 b | 504.25 ± 4.193 b |
| **T3R** | 29.35± 2.042 a | 90.725 ±3.397 ab | 112 ± 2.497 ab | 2.93 ± 0.607 b | 504.25 ± 4.193 b |
| **T4R** | 30.35±2.675 a | 74.7 ±2.34 bc | 89.9 ±4.334 bc | 2.93±0.607b | 501.5 ±1.91 b |
| **T5E** | 41.825 ± 1,456 b | 79.85 ± 5.424 abc | 101.05 ± 3.426 abc | 3.238 ± 0.577 ab | 509.75 ± 9.322 a |

4. Conclusion

The T3R treatment corresponding to the dose of 9.36 g of *Rhizobium spp.* per 1kg of peanut seed gave better performance in terms of good vegetative development and pod yield. It would help farmers to reduce the cost of chemical fertilizers, while preserving the environment. This dose of *Rhizobium spp.* could be recommended to farmers in the Sudanian zone so that they can improve peanut cultivation. The results obtained revealed that microbial biofertilizers (*Rhizobium spp.*) have a delayed action compared with other fertilizers, whether chemical or organic. In fact, the nodules form three weeks after sowing and become functional five weeks after sowing. For this reason, a good fertilization with *Rhizobium spp.* on the peanut crop could be preceded by organic fertilization during ploughing to ensure a good vegetative start. However, further studies are needed to confirm the results obtained under the same experimental conditions and also to determine the quantity of organic fertilizer to be applied during ploughing.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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