Effects of mineral fertilizers and environment on productivity and nitrogen fixation of six groundnut (*Arachis hypogaea* L.) genotypes

Abstract

In the Sahel, groundnuts play a major role in human and animal nutrition, as well as in cropping systems. However, this crop is often grown on nitrogen- and phosphorus-poor soils, accompanied by pockets of drought during the cycle. This can have negative effects on its agronomic performance and ability to fix atmospheric nitrogen. The aim of this study was to examine the effects of mineral fertilization and environmental conditions on the agronomic performance and nitrogen fixation of six groundnut genotypes. The experiments were carried out in the experimental field of the Faculty of Science and Technology of the André Salifou University and in the experimental site of the Institut Pratique de Formation in Matameye. The treatment applied in each locality comprised three modalities: F0 (unfertilized), F1 (with Di-Ammonium Phosphate input), and F2 (with NPK input). A factorial design with four replications was used. The results obtained show that F2 gave the best yields of tops and seeds in both localities. Nodulation was higher in Matamaye than Zinder, irrespective the treatment. The results showed significant interactions between sites, fertilization treatments and genotypes for the parameters studied. The results show that good fertilization improves peanut productivity and nitrogen fixation capacity.

Keywords: Groundnut, Fertilization, Environment, Interaction, Matamaye, Zinder.

Introduction

Groundnuts (*Arachis hypogaea* L.) are a significant contributor to the Nigerien economy, with particularly high production in the Maradi and Zinder regions. These regions remain the major groundnut production basins in Niger, accounting for more than 87% of national production (Andres et *al.*, 2023). Groundnut cultivation is a significant source of income for Nigerien farmers, who frequently sell their harvest in local markets or in neighboring countries (Andres et *al.*, 2023). Furthermore, this species is a staple source of protein and oil for local populations, often consumed in the form of a peanut paste or sauce to accompany traditional Nigerien dishes (Reddy et *al.*, 2003; Ntare, 2006; Hamidou et *al.*, 2018). Bricas et *al.* (2009) found that the average consumption of shelled groundnuts was 4 kg per person per year in urban areas, 3 kg per person per year in secondary cities, and 1 kg per person per year in rural areas. In addition to its economic and food role, groundnut production is often practiced in rotational systems, where the crop is planted after another harvest to maximize benefits related to soil fertility and cultural practices (Devi et *al.*, 2009). Hamidou et al. (2018) reported that groundnut can fix up to 100 kg ha-1 of N_2, demonstrating its significant potential for enhancing soil fertility. As a legume, groundnut forms symbioses with nitrogen-fixing bacteria, allowing it to produce its own source of nitrogen while improving soil fertility, structure, and quality. Additionally, it fosters more sustainable agricultural production. In this context, groundnut cultivation represents a viable alternative for increasing the productivity of food crops such as millet and sorghum, which can be grown in association or in rotation. Additionally, it can ensure the sustainability of the production system by improving the physicochemical properties of the soil.

However, despite the importance of this species, the yield in Niger remains low. In 2021, for instance, 1,019,567 hectares of groundnuts were cultivated, with an estimated production of 518,784 tons, resulting in an average yield of just 509 kg ha^{-1}. This figure is significantly below the global average yield for the same period, which is estimated at 1.7 t ha^{-1} (FAOSTAT, 2024). The primary factors contributing to this low yield are drought and infertile soils, which are mainly deficient in nitrogen and phosphorus. As several authors have noted (Vance, 2001; Twomlow, 2004; Hamidou et *al*., 2018), these two types of constraints can have a significant negative impact on productivity and atmospheric nitrogen fixation in legumes.

To improve groundnut production in Niger and enhance the sustainability of the production system, it is essential to develop high-yielding genotypes that are adapted to the different agroecological zones. These genotypes must also be efficient in N_2 nitrogen fixation and accompanied by reasoned mineral fertilization. Several studies have shown that mineral fertilization is an effective method for increasing crop production on poor soils (Venkateswarlu et *al*., 1990; Dakora and Keya, 1997; Neera, 2007). The hypothesis of this work is that there is a significant interaction between environmental, fertilization treatments, and genotypes. This would enable us to recommend the most suitable genotype(s) for each environment, in terms of both yield and symbiotic N_2 fixation.

The objective of this study was to evaluate the impact of environmental factors and mineral fertilization on agronomic parameters and symbiotic N_2 fixation in six groundnut genotypes. Additionally, we aimed to examine the interaction between these factors and genotypes.

Material and methods

Genotypes, study sites and expérimental conditions : Six groundnut genotypes were assessed. Three local genotypes (Yar Aguié, Greece White, and Greece Red) and three improved genotypes (55-437, Samnut and RRB) largely grown in Zinder region were used in this study (Figure 1).

The experiments were carried out at the experimental field of the Faculty of Sciences and Technologies of André Salifou University (Zinder) and in the experimental field of the Private

Training Institute (Matameye). The second site is located at 13°42'51" N latitude and 8°49'47" E longitude, 85 km southeast of the city of Zinder. The soil texture of the experimental stations is predominantly sandy. The climate of the studies area is classified as Sahel-Sudanian. Rainfall patterns show considerable spatial and temporal variability, with annual rainfall ranging from 500 to 750 mm in Matameye and 500 to 600 mm in Zinder. Most rainfall occurs between June and September, with the highest cumulative rainfall occurring in August.

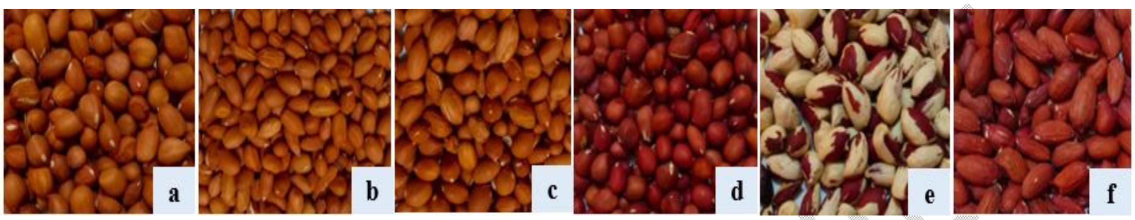

Figure 1: Seeds of six groundnut (*Arachis hypogaea* L.) genotypes evaluated in this study. With a = 55-437; b = Yar Aguié; c = Samnut; d = RRB; e = Greece white; d = Greece red

Experimental design and fertilization treatment. The experimental design used in this study was a factorial design with four blocks (or replicates) each consisting of eighteen small plots. This gives a total of 72 small plots or experimental units. Each plot covered an area of 7.2 m² (3 m x 2.4 m) and consisted of seven rows of thirteen bunches each, with a spacing of 20 cm between bunches and 40 cm between rows. The spacing between blocks was 2 m, while the spacing within each block was 1 m between plots. The total area of each experimental field was 1006.4 m^2 (34 m x 29.6 m). Three factors were studied in this research: environment (two modalities), mineral fertilisation treatments (three modalities) and genotypes (six variants). Regarding the fertilisation factor, the control treatment (F0) consisted in the absence of mineral fertilisation, while the F1 treatment consisted in the application of the mineral fertiliser diammonium phosphate (DAP) at a rate of 50 g ha^{-1}. The F2 treatment, on the other hand, involved the incorporation of NPK (15-15-15) mineral fertilizer at a rate of 100 kg ha^{-1} (Cheik et *al.*, 2019). Mineral fertiliser applications for treatments F1 and F2 were made on the fifteenth day after sowing (DAS). Sowing was carried out during the first ten days of July. Two manual ploughings were carried out 14 and 28 days after sowing.

Data collection. Phenological observations were conducted as part of the experimental process. These observations included the emergence of seedlings, the onset of flowering and the attainment of maturity. Samples were taken to estimate the nitrogen-fixing capacity of the genotypes evaluated, with the results expressed as a function of fertiliser treatment. Samples were taken on the 21st, 46th and 71st days after sowing. The procedure consisted of digging up the plant with its roots after a rain event using a dibble, rinsing the roots to remove debris, making the nodules clearly visible and then counting them. Samples were taken from the peripheral plants within the plot, which are therefore not included in the plot area considered useful for the purposes of this study. At the time of harvest, a representative plot and a yield square of fifty central plots of a total area of four m² were harvested. The plants were then uprooted and exposed to sunlight for two weeks, after which they were dried under cover to prevent infestation by termites and other animals. Following this drying process, the pods and tops were separated and weighed to determine the number of pods and seeds per plant. Haulm biomass, pod and seed weights per plant and yield squares were also calculated. The haulm biomass, pod and seed weights obtained from the yield squares were extrapolated to obtain the yield of these parameters per hectare.

Statistical data analysis. The data were then subjected to one-way and two-way analysis of variance (ANOVA). One-way analysis of variance (ANOVA) is a statistical tool used to test the hypothesis of equality of means across multiple samples. In other words, it assesses the homogeneity of the means of these samples. This hypothesis is linked to an alternative hypothesis, H1, which states that the sample means are not equal, indicating that the samples are not homogeneous. Analysis of variance (ANOVA) allows the effect of one or more factors on the data under study to be tested by comparison with a control sample. Means were compared using the Student Newman-Keuls test with a threshold of $\alpha=5\%$, above which the H0 hypothesis is rejected. In this study, an alpha of 0.05 is considered significant, while an alpha of 0.01 and 0.001 are considered highly and very significant, respectively. Analyses were performed using GenStat 14th edition software (VSN International Ltd, Hemel Hempstead, UK).

Results and Discussion :

Genotypic variation and the effect of mineral fertilizers on yield components. Statistical analysis of the haulm biomass and seed yield data showed a significant interaction ($P<0.001$) between environment, genotypes and fertilization treatments (GxExTrt). The interaction indicates that the performance of a genotype can vary from one environment to another and, within the same environment, from one fertilizer treatment to another, as shown by the results in Tables 2 and 3. For haulm production at Matamaye, the best genotypes in treatment F0 were RRB and 55-437, while Samnut and 55-437 showed the best haulm values in treatments F1 and F2, respectively (Table 1). As for seed production, the results show that RRB and Samnut had the highest yields in treatments F0 and F2 respectively, while the ANOVA showed no significant difference between the ecotypes in treatment F1. In Zinder, the best genotypes for haulm production in treatments F0, F1 and F2 were 55-47, Grèce blanc and RRB. For seed production, however, the best genotypes were 55-437 in F0, Yar Aguié and Samnut in F1 and RRB in F2 (Table 2). The results show that these genotypes, which gave higher yields under each condition, were among the best genotypes in terms of number of pods per plant (Figures 1 a and b). Overall, the F1 and F2 treatments helped to improve both haulm and seed yields at both locations. The F1 and F2 treatments improved haulm yield by 19% and 36%, respectively, over the F0 control at Matameye and by 48% and 56% at Zinder. For seed yield, F1 increased yield by 17% and F2 by 30% over the F0 control at Matameye, but the two treatments reduced seed yield by 21% and 9% respectively.

Table 1. Effects of mineral fertilizers and genotypic variation on haulm biomass (Kg ha^{-1}) and seed yield (Kg ha^{-1}) between test genotypes at Matamaye. Where F0 = control treatment; F1 = DAP treatment; F2 = NPK treatment.

Matamaye	**Haulmyield (Kg ha^{-1})**			**Seed yield (Kg ha^{-1})**		
	F0	**F1**	**F2**	**F0**	**F1**	**F2**
55-437	2110±345^{ab}	2726±978^{a}	2853±298^{a}	211±61^{ab}	251±47^{a}	188±45^{c}
Grèce blanc	1384±416^{c}	735±131^{d}	1570±231^{b}	237±07^{ab}	240±11^{a}	243±08^{b}
Grèce rouge	569±126^{d}	1595±499^{c}	1564±335^{b}	167±39^{b}	179±37^{a}	292±48^{ab}
RRB	2427±529^{a}	1689±206^{c}	1765±293^{b}	280±78^{a}	227±58^{a}	154±18^{c}
Samnut	1659±690^{bc}	2646±752^{ab}	3067±452^{a}	161±59^{b}	195±59^{a}	314±45^{a}
Yar Aguié	1272±189^{c}	1845±163^{ab}	1985±491^{b}	53±21^{c}	203±23^{a}	251±16^{b}
Moyenne	1570±720	1873±847	2134±695	185±86	216±46	240±64
G (F Prob)		<0,001			0,006	
Trt (F Prob)		<0,001			<0,001	
GxTrt (F Prob)		<0,001			<0,001	

Table 2. Effects of mineral fertilizers and genotypic variation on haulm biomassyield (Kg ha^{-1}) and seed yield (Kg ha^{-1}) between test genotypes at Zinder. Where F0 = control treatment; F1 = DAP treatment; F2 = NPK treatment.

Zinder	**Haulmyield (Kg ha^{-1})**			**Seed yield (Kg ha^{-1})**		
	F0	**F1**	**F2**	**F0**	**F1**	**F2**
55-437	1507±392^{a}	1469±276^{a}	1430±236^{a}	323±82^{a}	167±21^{b}	123±33^{b}
Grèce blanc	999±209^{b}	1310±413^{a}	1173±491^{a}	71±16^{c}	89±36^{c}	68±05^{b}
Grèce rouge	1057±151^{b}	1818±265^{a}	1574±425^{a}	75±18^{c}	71±09^{c}	60±19^{b}
RRB	683±162^{bc}	1301±460^{a}	1779±480^{a}	210±26^{b}	104±44^{c}	314±93^{a}
Samnut	854±68^{bc}	1400±399^{a}	1692±259^{a}	276±77^{ab}	231±61^{a}	272±85^{a}
Yar Aguié	537±74^{c}	1063±167^{a}	1151±157^{a}	249±25^{ab}	289±35^{a}	264±47^{a}
Moyenne	939±365	1394±384^{a}	1467±406	201±107	159±87	183±117
G (F Prob)		<0,001			<0,001	
Trt (F Prob)		<0,001			0,016	
GxTrt (F Prob)		0,033			<0,001	

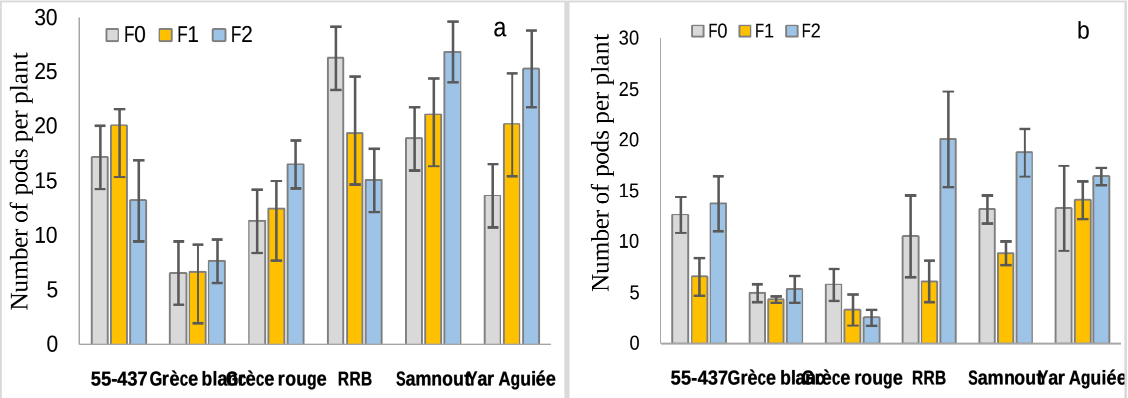

Figure 2: Number of pods per plant at harvest for groundnut genotypes under control treatment with no fertilizer (F0), treatment with fertilizer in the form of DAP (F1) and treatment with fertilizer in the form of NPK (F2) in Matamaye (a) and Zinder (b).

Genotypic variation and the effect of mineral fertilization on the number of nodules per plant. Among the genotypes evaluated, Greece white and red did not have enough plants and were not affected. Figure 3 shows the evolution of the number of nodules as a function of fertilization treatment at Matameye and Zinder. Observation of this figure shows that nodulation is greater in Matameye than Zinder, whatever the fertilization treatment. It should be noted that at Matameye, the F2 treatment was more conducive to nodulation than the F1 treatment. At genotypic level, a significant interaction was found between genotypes and fertilization treatments in both localities. At Matameye (Table 3), the results show that at 21stDAS, genotypes 55-437 and Samnut at F0, Samnut and Yar Aguié at F1 and RRB at F2 formed more nodules. At 71st DAS, the ANOVA showed no significant difference between genotypes at F0 and F1 treatments. However, under F2 treatment, ANOVA showed that Yar Aguié followed by RRB formed more nodules. In Zinder (Table 4), it was only under F1 treatment level that the ANOVA showed significant genotypic variation. The results show that the Yar Aguiée (19 nodules) and 55-437 (18 nodules) formed more nodules and are statistically distinct toRRB (9 nodules). At 71stDAS, however, it was only at the F2 level that ANOVA revealed significant genotypic variation. 55-437 and Samnut were the best, while RRB came last.

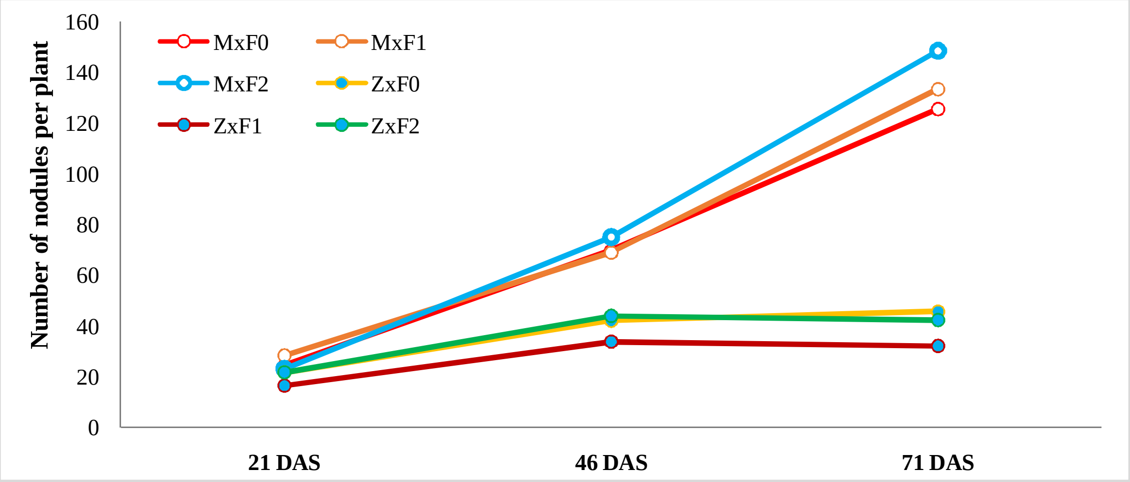

Figure 3: Evolution of the number of nodules per plant under the three fertilization treatments at Matameye. With DAS = days after sowing; F0 = control treatment; F1 = DAP treatment; F2 = NPK treatment; MxF0 = number of nodules under F0 treatment at Matameye; MxF1 = number of nodules under F1 treatment at Matameye; MxF2 = number of nodules under treatment F2 in Matameye; ZxF0 = number of nodules under treatment F0 in Zinder; ZxF1 = number of nodules under treatment F1 in Zinder; ZxF2 = number of nodules under treatment F2 in Zinder

Table 3: Evolution of the number of nodules per plant under the three fertilization treatments under Matameye conditions. With DAS = days after sowing; F0 = Unfertilised treatment; F1 = DAP treatment; F2 = NPK treatment

Matameye	**21 DAS**			**46 DAS**			**71 DAS**		
	F0	**F1**	**F2**	**F0**	**F1**	**F2**	**F0**	**F1**	**F2**
55-437	35±05^{a}	22±09^{a}	20±05^{a}	68±7^{b}	51±12^{c}	58±07^{a}	124±22^{a}	106±11^{a}	121±09^{c}
RRB	15±10^{b}	26±08^{a}	31±15^{a}	67±13^{b}	80±15^{ab}	99±33^{a}	117±29^{a}	174±60^{a}	186±14^{b}
Samnut	29±10^{ab}	28±08^{a}	21±03^{a}	57±16^{b}	58±09^{ac}	67±14^{a}	111±16^{a}	140±12^{a}	120±24^{c}
Yar Aguié	17±04^{b}	28±13^{a}	18±07^{a}	116±32^{a}	81±12^{a}	74±35^{a}	156±25^{a}	135±13^{a}	227±45^{a}
Moyenne	24±11	26±09	22±09	77±30	68±17	75±28	127±28^{a}	139±38	163±53
G (F Prob)		0,527			<0,001			<0,001	
Trt (F Prob)		0,456			0,331			0,001	
GxTrt (F Prob)		0,012			0,015			<0,001	

Table 4: Evolution of the number of nodules per plant under the three fertilization treatments at Zinder conditions. With DAS = days after sowing; F0 = Unfertilised treatment; F1 = DAP treatment; F2 = NPK treatment

Zinder	**21 DAS**			**46 DAS**			**71 DAS**		
	F0	**F1**	**F2**	**F0**	**F1**	**F2**	**F0**	**F1**	**F2**
55-437	23±03^{a}	18±02^{a}	14±08^{a}	44±16^{a}	46±13^{a}	40±12^{a}	47±05^{a}	43±03^{a}	48±11^{a}
Rouge de l'INRAN	26±03^{a}	9±01^{b}	22±11^{a}	47±18^{a}	32±08^{a}	54±06^{a}	59±05^{a}	22±15^{a}	29±11^{b}
Samnut	11±02^{a}	13±02^{ab}	23±09^{a}	37±10^{a}	39±16^{a}	44±20^{a}	50±22^{a}	33±10^{a}	52±17^{a}
Yar Aguié	15±05^{a}	19±04^{a}	23±09^{a}	40±07^{a}	38±14^{a}	48±05^{a}	43±20^{a}	43±14^{a}	37±13^{ab}
Moyenne	18±07	15±04	20±09	42±13	39±13	46±12	50±15	35±14	41±15
G (F Prob)		0,452			0,845			0,141	
Trt (F Prob)		0,074			0,267			0,015	
GxTrt (F Prob)		0,122			0,534			0,122	

Relationship between certain parameters studied. At harvest, results showed a positive correlation between haulm biomass production and seed weight per plant at Matameye only (r = 21%). Figures 4, 5 and 6 illustrate the complex relationships between haulm biomass, seed weight and number of pods per plant in relation to the number of nodules formed per plant at 70 days after sowing (DAS). At Matamaye, the data showed positive and significant correlations between the number of nodules formed per plant at 71st DAS and seed weights per plant (r = 43%), as well as with the number of pods per plant (r = 50%). However, the correlation with above-ground biomass was weak (r = 8%), indicating that although nodule formation is beneficial for seed and pod production, its impact on total biomass is limited. In Zinder, on the other hand, results show positive correlations between the number of nodules formed at 71st JAS and above-ground biomass production at harvest (r = 19%), seed weight per plant (r = 25%) and number of pods per plant (r = 14%). These correlations, although all positive, remain weak, which could suggest that other environmental or agronomic factors influence biomass and yields more significantly at this site.

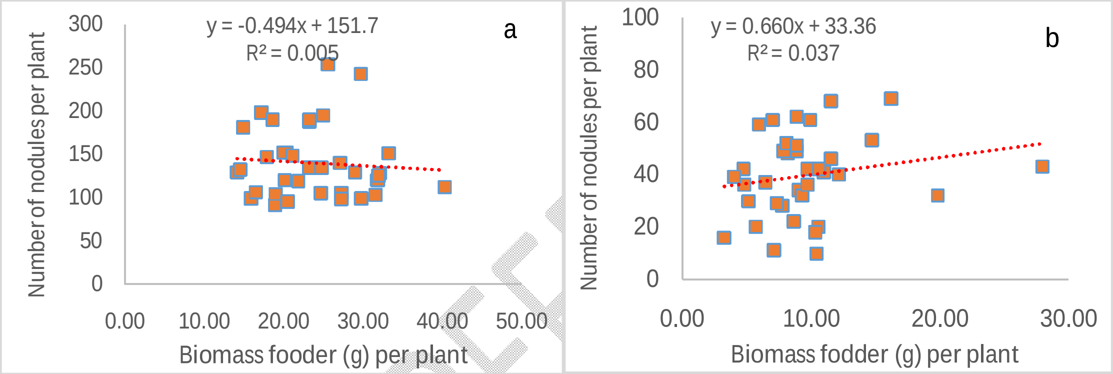

Figure 4: Correlation between biomass produced and number of nodules per plant in Matamaye (b) and Zinder (b)

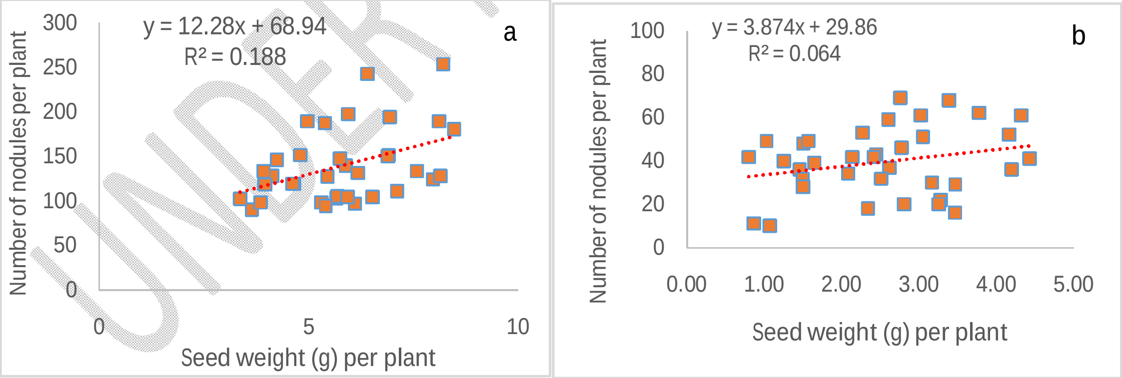

Figure 5: Correlation between seed weight and number of nodules per plant in Matamaye (b) and Zinder (b)

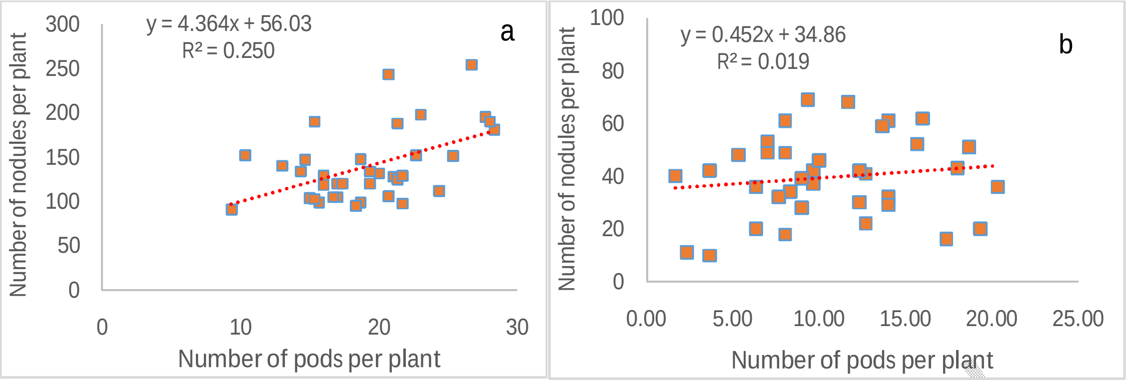

Figure 6: Correlation between the number of pods and the number of nodules per plant in Matamaye (b) and Zinder (b).

Discussion

The results obtained showed that the use of mineral fertilizers increased haulm yields by 30-70%. These results are in line with those found by Hamidou et *al*. (2018) according to which the addition of Urea, DAP and TSP can increase haulm and pod weights by 70-80%. Other researchers have also reported significant improvements from mineral fertilization (Singh et *al*., 2011; Bargaz, 2012). This improvement varied from one environment to another. Increases due to DAP (F1) and NPK (F2) inputs were respectively 19% and 36% in Matamaye and 48% and 127% in Zinder. This shows the importance of mineral fertilization in improving crop productivity. With regard to seed yield, the results showed that the effects of fertilizers varied from one environment to another. In Matamaye, the use of F1 and F2 resulted in yield increases of 17% and 30% respectively. In Zinder, on the other hand, F1 and F2 reduced yields by 21% and 9% respectively. The drop in seed yield recorded in Zinder could be due to a terminal drought that affected plants at the flowering and pod-filling stages. This could be explained by the fact that in Zinder, F1 and F2 inputs favored vegetative growth (leaves and stems) to the detriment of pod formation, and the drought recorded during the critical pod-filling stage. Several authors have reported the depressive effect of terminal drought on ray yield (Halilou et *al*., 2015; Bacharou et *al*., 2019; Beggi et *al*., 2015).

Our results revealed significant differences between these genotypes for seed yield. Significant environmental and mineral fertilization effects were also observed. Sites were characterized by greater variation in yield. According to Yan et *al*. (2000), the measured yield of each genotype in each test environment is a mixture of the effects of environment (E), genotype (G) and the interaction between genotype and environment (G x E). According to the same author, environment explains in most cases the greatest variation in yield (up to 80% or more), while genotype and G x E interaction contribute less. Moreover, the genotypic effect and the G x E interaction must be considered simultaneously when selecting genotypes. This is why Yan et *al*. (2000) deliberately put the two together and called them GGE instead of separating them. GGE then refers to the effect of genotype (G) and that of genotype x environment interaction (GE), which are the two best sources of variation in genotype evaluation (Yan et *al*., 2001). The significant interactions between genotype, fertilization treatment and environment indicate that genotypes responded differently to changes in each environmental component. Variation in the amount and distribution of rainfall in space and time, in relation to the level of soil fertility in essential mineral elements, may explain the significant environmental differences and the different genotypic responses recorded between localities. These results are in line with those found by Harou (2019), who found interactions between genotype and fertilization, genotype and environment and then genotype, fertilization and environment. For example, at Zinder, the incidence of water deficit during the pod-filling period would have had a depressive effect on seed yield, particularly in plants in treatments F1 and F2. In Matamaye, on the other hand, there was no such stress.

At Matamaye, all the genotypes tested responded positively to F1 and F2 fertilization, with the exception of RRB, which produced more seeds under F0 conditions. The response varied from one genotype to another, and the most affected by F1 and F2 were Yar Aguié (with seed yield increases of 283% and 374% respectively) and then Samnut (21% and 95% respectively). These results are in agreement with those found by Sebahutu (1988), according to whom cowpea seed yield increases can go up to over 500% following the application of NPK fertilizer (50-50-50). Similarly, Harou (2019) found yield increases of up to 287% following the application of phosphorus to cowpea. These results show that the addition of mineral fertilizers (F1 and F2) can significantly contribute to improving peanut seed yield in Matamaye. In Zinder, on the other hand, the response varied from one genotype to another. F1 and F2 improved haulm production in all six genotypes evaluated. F1 improved seed yields of Grèce blanc and Yar Aguié by 25% and 17% respectively, and caused a 48% and 50% reduction in 55-437 and RRB. As for F2, a yield increase of 50% was recorded in RRB and 7% in Yar Aguié. The addition of F2 negatively affected the seed yield of 55-437 and Grèce rouge, reducing it by 60% and 20% respectively. This can be explained by the fact that the F2 treatment triggered significant vegetative development in these varieties, which, exposed to drought, were unable to form sufficient pods and seeds. Several studies have shown that drought when it occurs during the critical stage, flowering, pod formation and filling, can negatively affect crop productivity (Halilou et *al.*, 2015; Harou et *al.*, 2019). Our find Results revealed that genotype performance varied from site to site. Thus under F0 treatment, RRB and Grèce blanc were respectively the best genotypes in terms of seed yield in Matamaye, while in Zinder, it was genotypes 55-437, Samnut and Yar Aguié that expressed good performance. In F1 conditions, 55-437 and Grèce blanc were the best in Matamaye, while in Zinder, Yar Aguié were the best genotypes in terms of seed yield. The results of this study indicated that in F2 conditions, Samnut and Grèce rouge performed better in Matamaye; RRB, Samnut and Yar Aguié in Zinder. The extension of these genotypes according to their environment will make peanut production more profitable in the Zinder region.

The results of this study showed a positive correlation between haulm biomass production and seed weight per plant, but this correlation was only significant at Matamaye (r = 21%). This suggests that significant haulm development in the Matamaye locality may contribute to increased seed weight. In Matamaye, the data show positive and significant correlations between the number of nodules formed per plant at 71st DAS and seed weights per plant (r = 43%) as well as with the number of pods per plant (r = 50%), but a weak correlation with above-ground biomass (r = 8%), indicating that although nodule formation is beneficial for seed and pod production, its impact on total biomass is limited. These results underline the importance of symbiotic fixation not only in improving productivity, but also in improving soil fertility and structure. These results confirm those found by Hamidou et al. (2018), who showed that a cereal crop grown in rotation with groundnut or cowpea increased biomass production.

Conclusion

The results of this study showed that the use of mineral fertilizers significantly improves productivity and atmospheric nitrogen fixation in peanuts, whatever the environment. This work also revealed that the effects of mineral fertilization practices and environmental conditions can interact in complex ways, directly affecting yield. For example, DAP (F1) and NPK (F2) inputs had different effects at different sites. At Matamaye, the results show a significant positive response, while at Zinder, where drought conditions were reported, the same inputs failed to produce the expected benefits on seed yield. This contrast highlights the need to adapt fertilization and crop management strategies to local production conditions, in terms of both soil and climatic conditions. An integrated approach that takes into account environmental factors, cropping practices and genetic characteristics will significantly improve groundnut productivity in the Zinder region, as well as that of cereals grown in association or in rotation. These results should also serve as a basis for training and practical recommendations for farmers, enabling them to improve their production while promoting the sustainability of their farms.

Disclaimer (Artificial intelligence)

Option 1:

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.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

References

1. Andres, L., Acosta-Alba, I., Ganda, Seydou, S., Habonimana, B., Kotyza, P., & Sitou, L. (2023). Analysis of the peanut value chain in the Republic of Niger. Report for the European Union, DG-INTPA. Value Chain Analysis for Development Project (VCA4D CTR 2017/392-416), 135 pp + annexes
2. Bricas, N., Thirion, M. C., & Zoungrana, B. (2009). Production and consumption basins of food crops in West and Central Africa. Interim Report, CIRAD, AFD, CILSS, IFAD.
3. Dakora, F.D. & Keya, S.O. (1997). Contribution of legume nitrogen fixation to sustainable agriculture in Sub-Saharan Africa. Soil Biol. Biochemi., 29, 809-817.
4. Devi, M. J., Sinclair, T. R., Vadez, V., & Krishnamurthy, L. (2009). Peanut genotypic variation in transpiration efficiency and decreased transpiration during progressive soil drying. Field Crops Research, 114(2), 280-285.
5. FAOSTAT, 2024. Food and Agricultural Organization of the United Nations (FAO) Statistics, Statistics Division. http://www.fao.org/faostat/fr/#data/QC/visualize/
6. Hamidou, F., Harou, A., Achirou, B. F., Halilou, O., & Bakasso, Y. (2018). Nitrogen fixation in peanut and cowpea under drought conditions for improved productivity in the Sahel. Tropicultura, 36(1).
7. Neera, G. (2007). Symbiotic nitrogen fixation in vegetable nodules: process and signaling. See you again. Agron. Sust. Dev., 27, 59-68.
8. Ntare, B.R. (2006). Arachis hypogaea L. In: PROTA 1: Cereals and Cereals and dried vegetables, Brink, M., Belay G (eds); pp – 21 - 27. PROTA, Wageningen, Netherlands, 327p

9. Twomlow, S. J. (2004). Increasing the role of vegetables in smallholder farming systems—the future challenge. Symbiotic nitrogen fixation: prospects for application in tropical agroecosystems. Science Publishers, NH, USA, 29-46.
10. Vance, C. P. (2001). Symbiotic nitrogen fixation and phosphorus acquisition. Plant nutrition in a word of declining renewable resources, plant physio., 127, 390-397.
11. Venkateswarlu, B., Saharan, N., & Maheswari, M (1990). Nodulation and N2 (C2H2) fixation in cowpea and groundnut during water stress and recovery, Fiel Crops Res., 25, 223-232.
12. Cheik, A. B., Tchokanaka, A., Ousmane, S., & Souley, M. L. (2019). Technical-economic sheet for peanut cultivation. Zinder Regional Chamber of Agriculture, Version 1 - February 2019, 3p
13. Halilou, O., Hamidou, F., Taya, B. K., Mahamane, S., & Vadez, V. (2015). Water use, transpiration efficiency and yield in cowpea (Vigna unguiculata) and peanut (Arachis hypogaea) across water regimes. Crop and Pasture Science, 66(7), 715-728.
14. Bacharou Falke, A., Hamidou, F., Halilou, O., & Harou, A. (2019). Assessment of groundnut elite lines under drought conditions and selection of tolerance associated traits. Advances in Agriculture, 2019(1), 3034278.
15. Yan, W., Cornelius, P. L., Crossa, J., & Hunt, L. A. (2001). Two types of GGE biplots for analyzing multi-environment data. Crop Sci. 40:656-663.
16. Yan, W., Hunt, L.A., Sheng, Q., & Szlavnics, Z. (2000). Cultivar evaluation and mega-environments investigation based on GGE biplot. Crop Sci. 40:597605.
17. HAROU, A. (2019). Agrophysiological responses of cowpea [Vigna unguiculata (L.) Walp.] under water deficit and phosphate fertilization conditions in Niger. Single PhD Thesis, Faculty of Science and Technology, Abdou Moumouni University of Niamey, 144p.
18. Beggi, F., Falalou, H., Buerkert, A., & Vadez, V. (2015). Tolerant pearl millet (Pennisetum glaucum (L.) R. Br.) varieties to low soil P have higher transpiration efficiency and lower flowering delay than sensitive ones. Plant and Soil, 389(1-2), 89-108.
19. Bargaz, A. (2012). Agrophysiological and biochemical characterization of bean (Phaseolus vulgaris) Rhizobia symbioses efficient for symbiotic nitrogen fixation under phosphorus deficit. Kadi Ayyad University, Marrakech, 46p.
20. Singh, A., Baoule, A. L., Ahmed, H. G., Dikko, A. U., Aliyu, U., Sokoto, M. B., Alhassan, J., Musa, M., & Haliru, B. (2011). Influence of phosphorus on the performance of cowpea (Vigna unguiculata (L) Walp.) varieties in the Sudan savanna of Nigeria. Agricultural Sciences, 2(03), 313.
21. Sebahutu, A. (1988). Results of research on bean fertilization in Rwanda. In: Proceedings of the 4th Regional Seminar on bean improvement in the Great Lakes Region, 21-25 November 1988. Bukavu (Zaire). CIAT African Workshop Series, No.9. pp. 81-89.
22. Yan, W., Hunt, L. A., Sheng, Q., & Szlavnics, Z. (2000). Cultivar evaluation and mega□environment investigation based on the GGE biplot. Crop science, 40(3), 597–605.
23. Harou, A., Hamidou, F., Halilou, O., Bacharou, F. A., & Bakasso, Y. (2019). Physiological Response of Cowpea [Vigna Unguiculata (L.) Walp.] Genotypes to Water Deficit Under Lysimeter Conditions and Agronomic Performance in the Field.