Effects of mineralfertilizers and environment on productivity and nitrogen fixation of six groundnut (*Arachishypogaea* L.) genotypes

Abstract

In the Sahel, and particularly in Niger, groundnutis not only a cash crop but also a foodcrop. It alsoplays an important role in animal feed and croppingsystems. However, thislegumeisoftengrown on poorsoils, especiallythosedeficient in nitrogen and phosphorus. In addition to thissoilinfertility, thereisinsufficient and poor spatial distribution of rainfall, sometimesresulting in delayedplanting and periods of droughtduring the crop cycle. These conditions can have significantconsequences on the agro-morphological performance of groundnut, as well as on theirability to fix atmosphericnitrogen (N^2). In thiscontext, a studywascarried out in the experimentalfield of the Faculty of Sciences and Technologies of the André Salifou University and in the experimentalfield of the Practical Training Institute (IPF Kaoura) in Matameye. The aim of thisstudyis to investigate the effects of mineralfertilization and environmental conditions on the agro-morphological performance and nitrogen fixation of six groundnutgenotypes: 55-437, Samnut, RRB, Yar Aguié, White Greece and Red Greece. The treatmentapplied at eachenvironmentconsisted of threemodalities: (i) F0 treatment (unfertilized), (ii) F1 treatmentwithnitrogen and phosphorus in the form of diammonium phosphate or DAP (18-46-00) at 50 kg ha^{-1}) and (iii) F2 treatment (withnitrogen, phosphorus and potassium in the form of NPK (15-15-15) at 100 kg ha^{-1}). The experimental design usedwas a factorial design with four replications. The results of thisstudyshowedthat the NPK treatment gave the best haulm and seedyields in bothenvironments. In terms of seedyield, RRB, 55-437 and Samnutgenotypeswere the best performers in F0, F1 and F2 treatments at Matameye. In Zinder, the best performinggenotypeswereSamnut in the F0 treatment, Yar Aguié in the F1 treatment and RRB in the F2 treatment. In terms of nodulation, Matameye had an average of 139 and 163 nodules per plant for the F1 and F2 treatments, respectively, compared to 127 nodules per plant for the F0 treatment. In contrast, in Zinder, F0 and F1 treatments at the same time yielded a similar number (43 nodules per plant), while F2 treatment showed a lower number with only 37 nodules per plant.

Keywords: Groundnut, Fertilization, Environment, Matamelé, Zinder.

Introduction

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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

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Genotypes and expérimental conditions. Six groundnutgenotypeswereassessed. Three local genotypes (Yar Aguié, Greece White, and Greece Red) and threeimprovedgenotypes (55-437, Samnut and RRB) largelygrown in Zinder regionwereused in thisstudy (Figure 1).

The experimentswerecarried out at the experimentalfield of the Faculty of Sciences and Technologies of André Salifou University (Zinder) and in the experimentalfield of the Private Training Institute (Matameye). The Matameye site islocated 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 ispredominantlysandy. The climate of the studies area isclassified as Sahel-Sudanian. Rainfall patterns show considerable spatial and temporal variability, withannualrainfallrangingfrom 500 to 750 mm in Matameye and 500 to 600 mm in Zinder. Most rainfalloccursbetween June and September, with the highest cumulative rainfalloccurring in August.

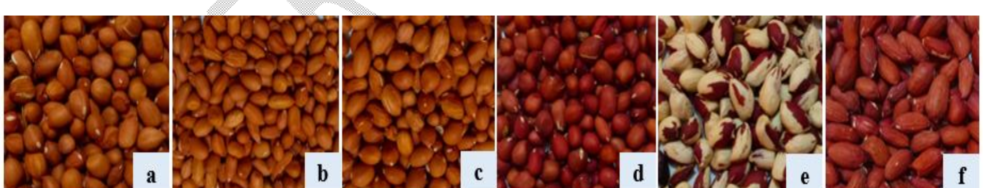

Figure 1: Seeds of six groundnut (*Arachishypogaea* L.) genotypesevaluated in thisstudy. With a = 55-437; b = Yar Aguié; c = Samnut; d = RRB; e = Greece white; d = Greecered

Experimental design and fertilizationtreatment. The experimental design used in thisstudywas a factorial design with four blocks (or replicates) eachconsisting of eighteensmall plots. This gives a total of 72 small plots or experimentalunits. Each plot covered an area of 7.2 m² (3 m x 2.4 m) and consisted of sevenrows of thirteenbuncheseach, with a spacing of 20 cm betweenbunches and 40 cm betweenrows. The spacingbetween blocks was 2 m, while the spacingwithineach block was 1 m between plots. The total area of eachexperimentalfieldwas 1006.4 m^2 (34 m x 29.6 m). Threefactorswerestudied in thisresearch: environment (twomodalities), mineral fertilisation treatments (threemodalities) and genotypes (six variants). Regarding the fertilisation factor, the control treatment (F0) consisted in the absence of mineral fertilisation, while the F1 treatmentconsisted 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) mineralfertilizer at a rate of 100 kg ha^{-1} (Cheik et *al*., 2019). Mineral fertiliser applications for treatments F1 and F2 were made on the fifteenthdayaftersowing (DAS). Sowingwascarried out during the first tendays of July. Twomanualploughingswerecarried out 14 and 28 daysaftersowing.

Data collection. Phenological observations wereconducted as part of the experimental process. These observations included the emergence of seedlings, the onset of flowering and the attainment of maturity. Samplesweretaken to estimate the nitrogen-fixing capacity of the genotypesevaluated, with the resultsexpressed as a function of fertiliser treatment. Samplesweretaken on the 21st, 46th and 71st daysaftersowing. The procedureconsisted of digging up the plant withitsrootsafter a raineventusing a dibble, rinsing the roots to removedebris, making the nodules clearly visible and thencountingthem. Samplesweretakenfrom the peripheral plants within the plot, which are therefore not included in the plot area considereduseful for the purposes of thisstudy. At the time of harvest, a representative plot and a yield square of fifty central plots of a total area of four m² wereharvested. The plants werethenuprooted and exposed to sunlight for twoweeks, afterwhichtheyweredriedunder cover to prevent infestation by termites and otheranimals. Following this drying process, the pods and tops wereseparated and weighed to determine the number of pods and seeds per plant. Haulmbiomass, pod and seedweights per plant and yield squares werealsocalculated. The haulmbiomass, pod and seedweightsobtainedfrom the yield squares wereextrapolated to obtain the yield of theseparameters per hectare.

Statistical data analysis. The data werethensubjected to one-way and two-wayanalysis of variance (ANOVA). One-wayanalysis of variance (ANOVA) is a statisticaltoolused to test the hypothesis of equality of meansacross multiple samples. In otherwords, itassesses the homogeneity of the means of thesesamples. This hypothesisislinked to an alternative hypothesis, H1, which states that the samplemeans are not equal, indicatingthat the samples are not homogeneous. Analysis of variance (ANOVA) allows the effect of one or more factors on the data understudy to betested by comparisonwith a control sample. Meanswerecomparedusing the Student Newman-Keuls test with a threshold of $\alpha=5\%$, abovewhich the H0 hypothesisisrejected. In thisstudy, an alpha of 0.05 isconsideredsignificant, while an alpha of 0.01 and 0.001 are consideredhighly and verysignificant, respectively. Analyses wereperformedusingGenStat 14th edition software (VSN International Ltd, HemelHempstead, UK).

Results

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, Grèceblanc 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 3). 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 (Tables 1 and 2).

Table 1. Effects of mineralfertilizers and genotypic variation on haulmbiomass (Kg ha^{-1}) and seedyield (Kg ha^{-1}) between test genotypes at Matamaye. Where G = genotype; Trt = fertilizationtreatment; GxTrt = interaction betweengenotype and fertilizationtreatment.

Matamaye	**Haulmyield(Kg ha^{-1})**			**Seedyield(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 mineralfertilizers and genotypic variation on haulmbiomassyield(Kg ha^{-1}) and seedyield(Kg ha^{-1}) between test genotypes at Zinder. Where G = genotype; Trt = fertilizationtreatment; GxTrt = interaction betweengenotype and fertilizationtreatment.

Zinder	Haulmyield(Kg ha^{-1})			Seedyield(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	

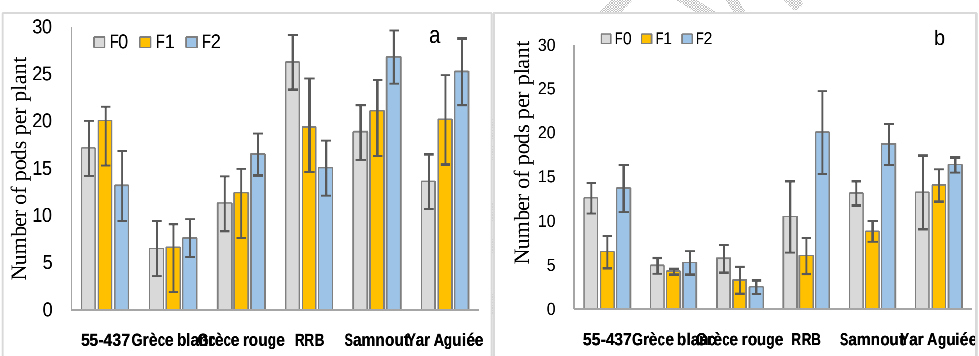

Figure 2: Number of pods per plant at harvest for groundnutgenotypesunder control treatmentwith no fertilizer (F0), treatmentwithfertilizer in the form of DAP (F1) and treatmentwithfertilizer in the form of NPK (F2) in Matamaye (a) and Zinder (b).

Genotypic variation and the effect of mineralfertilization on the number of nodules per plant. Among the genotypesevaluated, Greece white and reddid not have enough plants and were not affected. Figure 3 shows the evolution of the number of nodules as a function of fertilizationtreatment at Matameye and Zinder. Observation of this figure shows that nodulation isgreater in Matameyethan Zinder, whatever the fertilizationtreatment. It shouldbenotedthat at Matameye, the F2 treatmentwas more conducive to nodulation than the F1 treatment. At genotypiclevel, a significant interaction wasfoundbetweengenotypes and fertilizationtreatments in bothlocalities. 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 significantdifferencebetweengenotypes at F0 and F1 treatments. However, under F2treatment, ANOVA showedthatYar Aguié followed by RRBformed more nodules. In Zinder (Table 4), ANOVA showed no significantgenotypic variation at the 21stDASunder F1 treatment. 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, itwasonly at the F2 levelthat ANOVA revealedsignificantgenotypic variation. 55-437 and Samnutwere the best, whileRRB came last.

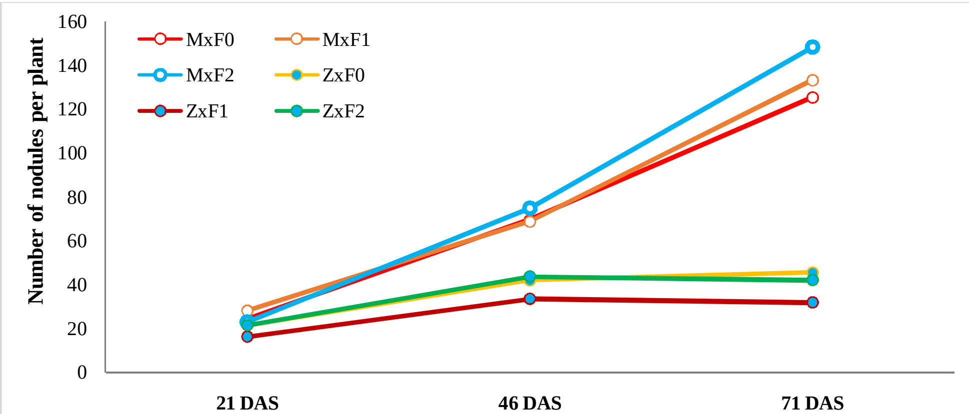

Figure 3: Evolution of the number of nodules per plant under the threefertilizationtreatments at Matameye. With DAS =daysaftersowing; F0 = control treatment; F1 = DAP treatment; F2 = NPK treatment; MxF0 = number of nodules under F0 treatment at Matameye; MxF1 = number of nodules under F1 treatment at Matameye; MxF2 = number of nodules undertreatment F2 in Matameye; ZxF0 = number of nodules undertreatment F0 in Zinder; ZxF1 = number of nodules undertreatment F1 in Zinder; ZxF2 = number of nodules undertreatment F2 in Zinder

Table 3: Evolution of the number of nodules per plant under the threefertilizationtreatmentsunderMatameye conditions. With DAS = daysaftersowing; F0 = control 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 threefertilizationtreatments at Zinder conditions. With DAS = daysaftersowing; F0 = control 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 parametersstudied. At harvest, resultsshowed a positive correlationbetweenhaulmbiomass production and seedweight per plant at Matameyeonly (r = 21%). Figures 4, 5 and 6illustrate the complexrelationshipsbetweenhaulmbiomass, seedweight and number of pods per plant in relation to the number of nodules formed per plant at 70 daysaftersowing (DAS). At Matamaye, the data showed positive and significantcorrelationsbetween the number of nodules formed per plant at 71st DAS and seedweights per plant (r = 43%), as well as with the number of pods per plant (r = 50%). However, the correlationwithabove-groundbiomasswasweak (r = 8%), indicatingthatalthough nodule formation isbeneficial for seed and pod production, its impact on total biomassislimited. In Zinder, on the other hand, results show positive correlationsbetween the number of nodules formed at 71st JAS and above-groundbiomass production at harvest (r = 19%), seedweight per plant (r = 25%) and number of pods per plant (r = 14%). Thesecorrelations, although all positive, remainweak, whichcouldsuggestthatotherenvironmental or agronomicfactors influence biomass and yields more significantly at this site.

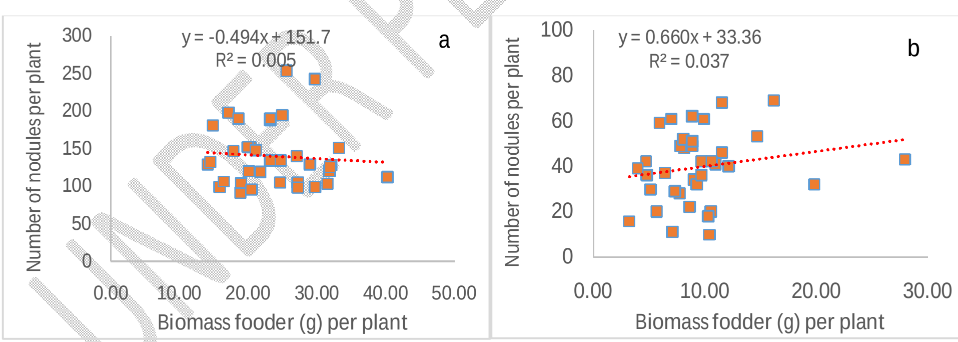

Figure 4: Correlationbetweenbiomassproduced and number of nodules per plant in Matamaye (b) and Zinder (b)

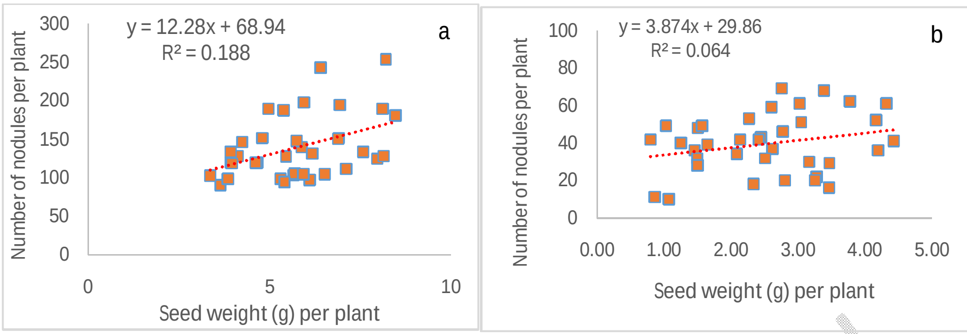

Figure 5: Correlation between seed weight and number of nodules per plant in Matamaye (b) and Zinder (b)

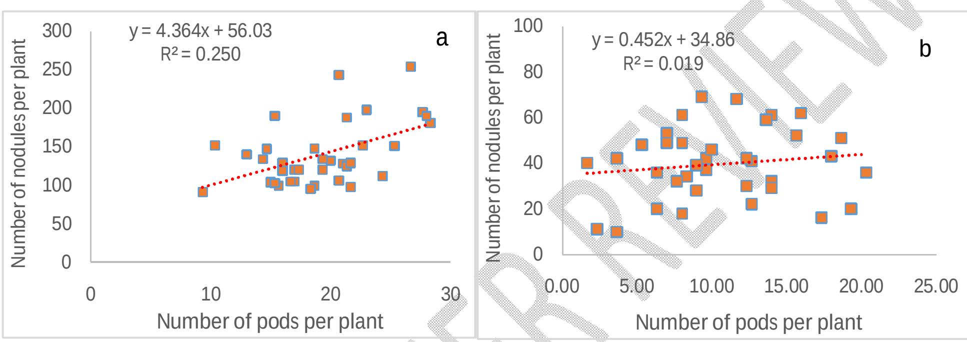

Figure 6: Correlation between the number of pods and the number of nodules per plant in Matamaye (b) and Zinder (b).

Discussion

This study, carried out in Matamaye and Zinder to assess the effects of the environment and mineralfertilization on the productivity and symbiotic fixation of peanutgenotypes in the Zinder region, will not onlyimprovepeanutproductivity, but alsoenhancesoilquality by addingorganicmatter and increasingmicrobialbiodiversity. The resultsobtainedshowedthat the use of mineralfertilizersincreasedhaulmyields by 30-70%. Theseresults are in line withthosefound by Hamidou et *al.* (2018) according to which the addition of Urea, DAP and TSP can increasehaulm and podweights by 70-80%. Otherresearchers have alsoreportedsignificantimprovementsfrommineralfertilization (Singh et *al.*, 2011;Bargaz, 2012). This improvementvariedfrom one environment to another. Increases due to DAP (F1) and NPK (F2) inputs wererespectively 19% and 36% in Matamaye and 48% and 127% in Zinder. This shows the importance of mineralfertilization in improvingcropproductivity. With regard to seedyield, the resultsshowedthat the effects of fertilizersvariedfrom one environment to another. In Matamaye, the use of F1 and F2 resulted in yieldincreases of 17% and 30% respectively. In Zinder, on the other hand, F1 and F2 reducedyields by 21% and 9% respectively. The drop in seedyieldrecorded in Zinder couldbe due to a terminal droughtthataffected plants at the flowering and pod-filling stages. This couldbeexplained by the factthat in Zinder, F1 and F2 inputs favoredvegetativegrowth (leaves and stems) to the detriment of pod formation, and the droughtrecordedduring the criticalpod-filling stage. Severalauthors have reported the depressiveeffect of terminal drought on ray yield (Halilou et *al.*, 2015;Bacharou et *al.*, 2019; Beggi et *al.*, 2015).

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Our resultsrevealedsignificantdifferencesbetweenthesegenotypes for seedyield. Significantenvironmental and mineralfertilizationeffectswerealsoobserved. Sites werecharacterized by greater variation in yield. According to Yan et *al.* (2000), the measuredyield of eachgenotype in each test environmentis a mixture of the effects of environment (E), genotype (G) and the interaction betweengenotype and environment (G x E). According to the sameauthor, environmentexplains in most cases the greatest variation in yield (up to 80% or more), whilegenotype and G x E interaction contributeless. Moreover, the genotypiceffect and the G x E interaction must beconsideredsimultaneouslywhenselectinggenotypes. This iswhy Yan et *al.* (2000) deliberately put the twotogether and calledthem GGE instead of separatingthem. GGE thenrefers to the effect of genotype (G) and that of genotype x environment interaction (GE), which are the two best sources of variation in genotypeevaluation (Yan et *al.*, 2001). The significant interactions betweengenotype, fertilizationtreatment and environmentindicatethatgenotypesrespondeddifferently to changes in eachenvironmental component. Variation in the amount and distribution of rainfall in space and time, in relation to the level of soilfertility in essential mineralelements, mayexplain the significantenvironmentaldifferences and the differentgenotypicresponsesrecordedbetweenlocalities. Theseresults are in line withthosefound by Harou (2019), whofound interactions betweengenotype and fertilization, genotype and environment and thengenotype, fertilization and environment. For example, at Zinder, the incidence of water deficitduring the pod-fillingperiodwould have had a depressiveeffect on seedyield, particularly in plants in treatments F1 and F2. In Matamaye, on the other hand, therewas no such stress.

At Matamaye, all the genotypestestedrespondedpositively to F1 and F2 fertilization, with the exception of RRB, whichproduced more seedsunder F0 conditions. The responsevariedfrom one genotype to another, and the mostaffected by F1 and F2 wereYar Aguié (withseedyieldincreases of 283% and 374% respectively) and thenSamnut (21% and 95% respectively). Theseresults are in agreement withthosefound by Sebahutu (1988), according to whomcowpeaseedyieldincreases can go up to over 500% following the application of NPK fertilizer (50-50-50). Similarly, Harou (2019) foundyieldincreases of up to 287% following the application of phosphorus to cowpea. Theseresults show that the addition of mineralfertilizers (F1 and F2) can significantlycontribute to improvingpeanutseedyield in Matamaye. In Zinder, on the other hand, the responsevariedfrom one genotype to another. F1 and F2 improvedhaulm production in all six genotypesevaluated. F1 improvedseedyields of Grèce blanc and Yar Aguié by 25% and 17% respectively, and caused a 48% and 50% reductionin 55-437 and RRB. As for F2, a yieldincrease of 50% wasrecorded in RRB and 7% in Yar Aguié. The addition of F2 negativelyaffected the seedyield of 55-437 and Grèce rouge, reducingit by 60% and 20% respectively. This can beexplained by the factthat the F2 treatmenttriggeredsignificantvegetativedevelopment in thesevarieties, which, exposed to drought, wereunable to formsufficientpods and seeds. Severalstudies have shownthatdroughtwhenitoccursduring the critical stage, flowering, pod formation and filling, can negatively affect cropproductivity (Halilou et *al.*, 2015;Harou et *al.*, 2019). Our findResultsrevealedthatgenotype performance variedfrom site to site. Thusunder F0 treatment, RRB and Grèce blanc wererespectively the best genotypes in terms of seedyield in Matamaye, while in Zinder, itwasgenotypes 55-437, Samnut and Yar Aguié thatexpressed 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 seedyield. The results of thisstudyindicatedthat in F2 conditions, Samnut and Grèce rouge performedbetter in Matamaye; RRB, Samnut and Yar Aguié in Zinder. The extension of thesegenotypesaccording to theirenvironmentwillmakepeanut production more profitable in the Zinder region.

The results of thisstudyalsoshowed a positive correlationbetweenhaulmbiomass production and seedweight per plant, but thiscorrelationwasonlysignificant at Matamaye (r = 21%). This suggeststhatsignificanthaulmdevelopment in the Matamayelocalitymaycontribute to increasedseedweight. In Matamaye, the data show positive and significantcorrelationsbetween the number of nodules formed per plant at 71st DAS and seedweights per plant (r = 43%) as well as with the number of pods per plant (r = 50%), but a weakcorrelationwithabove-groundbiomass (r = 8%), indicatingthatalthough nodule formation isbeneficial for seed and pod production, its impact on total biomassislimited. Theseresultsunderline the importance of symbiotic fixation not only in improvingproductivity, but also in improvingsoilfertility and structure. Theseresultsconfirmthosefound by Hamidou et al. (2018), whoshowedthat a cerealcropgrown in rotation withgroundnut or cowpeaincreasedbiomass production.

Conclusion

The interaction betweengenotype and environment has shownsignificant impacts on seedyield, highlighting the importance of understandingthesedynamics to optimizepeanut cultivation. Our findings show thatgeneticvariabilitybetweengenotypesis crucial, as somemaybebetteradapted to specificsoil and climate conditions. Varietalselectioncouldpotentiallyincreasecropresistance to situations of environmental stress, such as soilpoverty and drought. The analysisalsorevealedthat the effects of mineralfertilization practices and environmental conditions can interact in complexways, directlyaffectingyield. For example, DAP (F1) and NPK (F2) inputs haddifferentiatedeffects at different locations. In Matamaye, the results show a significant positive response, while in Zinder, wheredrought conditions werereported, the same inputs failed to produce the expectedbenefits on seedyield. This contrast highlights the need to adaptfertilization and crop management strategies to local soil and climatic conditions.

The results of thisstudythus highlight the importance of an integratedapproachthattakesintoaccountenvironmentalfactors, cropping practices and geneticcharacteristics. Improvingpeanutproductivity in the Zinder regioncannotbeachievedeffectivelywithoutongoingassessment of the interactions betweentheseelements. In addition, furtherresearchisneeded to identifysustainable and resilient management practices thatwilloptimizeyields and preservesoilquality in the long term. The knowledgeacquiredhereshouldalso serve as a basis for training and practicalrecommendations for farmers, enablingthem to improve production whilepromoting the sustainability of theirfarms.

Comment [A5]: Conclution short and clearanswering the researche objectives

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Comment [A6]:

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