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Influence of Microdose of Mineral Fertilizer and Organic Manure on the Production of Groundnuts in Southern Benin

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Authors' contributions

This work was carried out in collaboration among all authors. Authors KS, ELS and NFA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors PGT, TOYC, FGHK, JFDS and CEA managed the analyses of the study. Author ELS managed also the literature searches. Authors BAS and CEA supervised all of this study. All authors read and approved the final manuscript.

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ABSTRACT

The use of mineral fertilizers improves crop production and soil productivity. However, its access remains limited to smallholder farmers. This study aim to assess the influence of microdose of mineral fertilizer and organic manure on the production of groundnuts. Field experience was carried out using Fischer design with five treatments and five replications: T control (Without organic matter and fertilizer); T0 recommended dose of mineral fertilizer (103.77 kg/ha or 0.93 g/poquet 15 days after sowing); T1 recommended dose of mineral fertilizer and organic matter (0.5 kg/m²); T2 microdose of mineral fertilizer (0.57 g NPKSB [14-23-14-5-1] 15 days after sowing); T3 microdose of mineral fertilizer and organic matter (0.5 kg/m²). Linear mixed-effect models were used to analyze the data. The results showed that the microdose of mineral fertilizer and / or organic manure had a significant effect on yield parameters such as aboveground biomass (fresh or dry), the number of nodules and the weight of the groundnuts pods (Prob < 0.05). The treatment T2 (microdose of mineral fertilizer) increased grain yields (8.1±1.5 g/plant) compared to other treatments. Thus, the microdose of mineral fertilizer is economically more profitable than the recommended dose.

Keywords: Microdose; mineral fertilizer; organic manure; groundnut.

1. INTRODUCTION

Benin is a developing country where agriculture is the basis of the economy which represents 32.7% of the Gross Domestic Product (GDP) and provides around 70% of jobs. Like other countries in the world, it faces the challenges of increasing food production to meet the needs of an increasingly growing population. Seventy-two percent (72%) of farmers are smallholder producers with low financial capacity to cope with adverse effects of climate change [1,2]. This induces increasingly fragile and precarious production conditions and the consequences of which are, among other things, the low income of populations. Recent studies show that low soil fertility keeps people in chronic poverty [3,4]. Faced with this major constraint limiting agricultural productivity, it is necessary to work on the development of agricultural practices that sustainably increase food production and farmers' incomes while protecting and restoring the environment. To this end, a number of technological packages have been developed. Unfortunately socio-economic difficulties linked to access to mineral fertilizers, sufficient quantities of manure, compost and labor considerably limit the effective implementation of these technological packages developed by various research institutions and development projects.

To cope with these difficulties, the technique of microdose of mineral fertilizers which consists to supply small amount of mineral fertilizers in the seed hole has been developed by the institutions of Research in particular the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in partnership with the national research institutes [5,6]. It is cited as one of the methods with the potential to increase crop yields in order to optimize the efficient use of fertilizers and to increase substantial crop yields and therefore farmer income [7,8]. However, groundnuts identified as one of the main legumes cultivated in Benin, record low yields. In terms of consumption, the 4% of the value of household spending on plant and animal products is spent on buying groundnuts or their by-products. Beninese takes from groundnut 5; 8.9 and 20.5% of their calorie, protein and fat needs respectively. It is used in food, animal feed and in industry. The main objective of this study is to assess the influence of microdose of mineral fertilizer and organic manure on the production of groundnuts.

2. MATERIALS AND METHODS

2.1 Study Site

This study was carried out in the municipality of Za-Kpota limited in the North-West by the municipality of Djidja, in the North-east by the municipality of Zagnanando, in the South-west by the municipality of Bohicon, in the East by the municipality of Covè and to the South-East by the municipality of Zogbodomey (Fig. 1). The town is located between 7°12' and 7°32' north and 2°15' and 2°30' East. It covers an area of approximately 600 km^2 on which 87,076 people live (RGPH3, 2002). Located in the center of the Zou department, the town is influenced and dominated by sub-equatorial climate determined

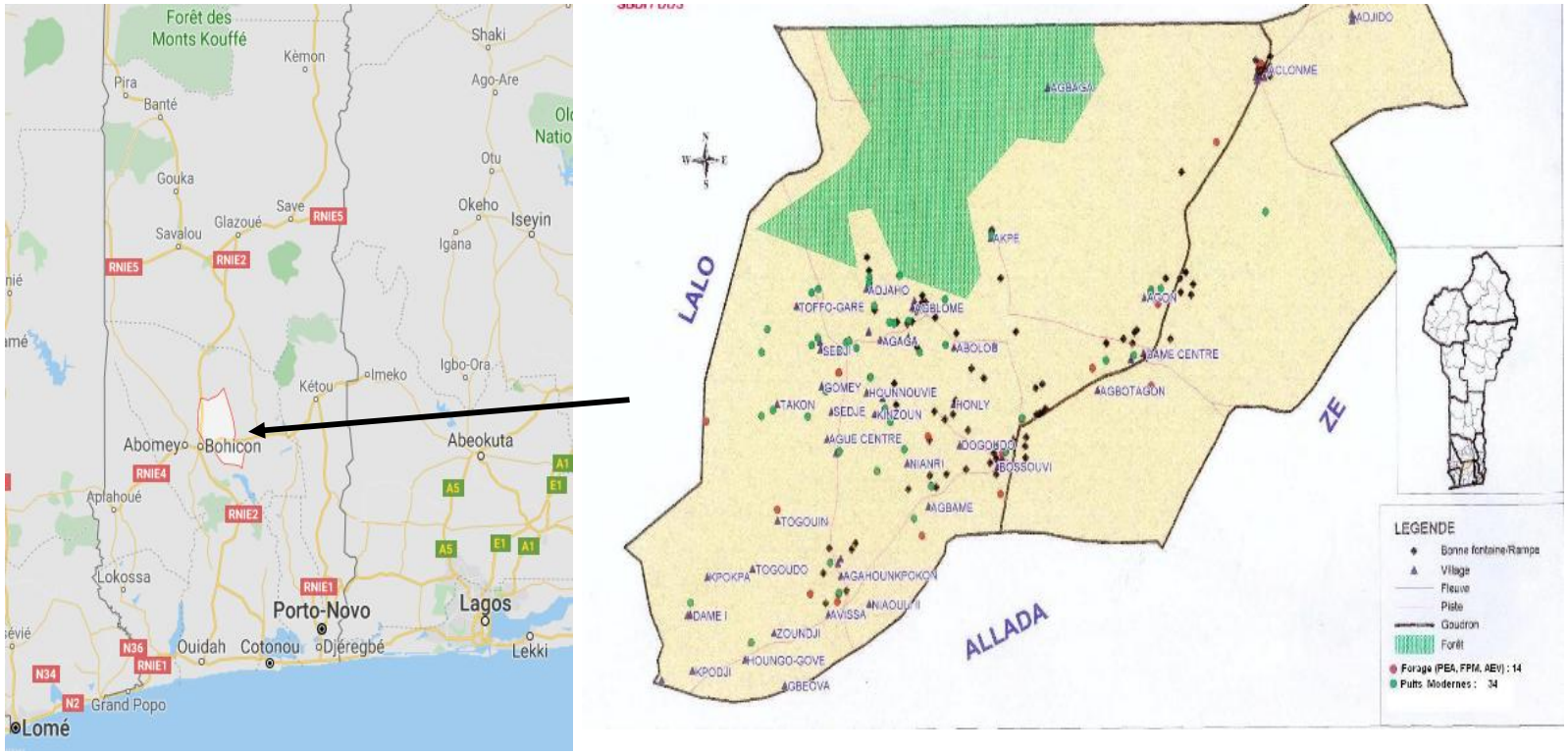

Fig. 1. Geographical location of the municipality of Za-Kpota
(www.Googlemap.com)

Table 1. Doses of applied fertilizers

	Fertilizer	Dose (kg / ha)	Nutrient rate (kg / ha)	Amount of fertilizer per 9 m² (g)	Amount of fertilizer per crop line (g)
Recommended dose	Urea	30.43	14.0 (N)	27.4	5.5
	TSP	50.00	23.0 (P_2O_5)	45	9
	KCl	23.33	14.0 (K_2O)	21.00	4.20
Microdose	Urea	18.91	8.7 (N)	17.02	3.4
	TSP	30.43	14.0 (P_2O_5)	27.39	5.5
	KCl	14.5	8.7 (K_2O)	13.05	2. 6

two dry seasons and two rainy seasons. Three types of soil are encountered in the municipality of Za-Kpota. These are: ferralitic soils commonly called “terres de barre”, poor in organic matter and minerals because of their long use, tropical ferruginous soils, but less poor, very shallow due to concrete outcrops and hydromorphic soils still rich and suitable for agricultural production which are encountered in depressions and shallows.

2.2 Experiment Design and Data Collection

The field experiment was installed in 2019 during the rainy season with local variety of groundnuts (*Arachis hypogaea*) of spanish group. The experimental was carried out in Fischer design with five treatments and five replications. The elementary plots had a dimension of 3 m x 3 m (9 m²). The treatments were T control (without organic matter, without mineral fertilizer), T0 recommended dose of mineral fertilizer (103.77 kg / ha or 0.93 g / poquet 15 days after sowing); T1: recommended dose of mineral fertilizer and organic matter (0.5 kg / m²); T2: microdose of mineral fertilizer (0.57 g of NPKSB (14-23-14-5-1) / poquet 15 days after sowing); T3: microdose of mineral fertilizer and organic matter (0.5 kg / m²). The organic manure was brought during plowing to an amount of 4.5 kg per experimental unit; the recommended dose was brought per poquet at a quantity of 93.4 g per experimental unit. The microdose consisted in bringing a small quantity (0.57 g) of mineral fertilizer 15 days after sowing in a bucket made at most 10 cm from the groundnut plant while taking care not to injure the roots. The rates of mineral fertilizer applied are summarized in Table 1. The soil texture of the site was sandy loam. The organic carbon and total nitrogen contents were 0.39 and 0.032% respectively. Soil pH was 5.99. The contents of exchangeable potassium and assimilable phosphorus were 0.13 Cmol/kg and 4 mg/kg respectively.

Burial of organic matter (rabbit droppings) was done during ploughing for experimental units requiring organic matter. Sowing was carried out in poquets with a spacing of 15 cm between poquets and 60 cm between rows, i.e. a density of 101,000 plants per hectare. Growth data (height and number of leaves) were collected on 10 groundnut plants selected at random by the diagonal method. Yield data was collected at plant maturity. Biomass, kernel and shell yields were estimated after drying under study until constant weights were obtained.

2.3 Data Analysis

The General Linear Mixed Effects Model (lme function from the nlme library) was used to analyze continuous variables such as plant height and yield parameters. The mixed-effect generalized linear model (glmer function from the lmertest library) with the Poisson family was used to analyze count data (leaf count and nodule count). In the different analyses, microdoses of fertilizer and organic matter were considered as fixed factors and producers as random factor. All statistical analysis were carried out in R Software (version 3.5.3). Graphs were made using the ggplot2 package in R.

3. RESULTS

3.1 Effect of Microdose Mineral Fertilizer and/or Organic Manure on Groundnut Growth Parameters

The analysis of the influence of microdose mineral fertilizer and/or organic manure on groundnut growth parameters (Table 2) showed that the treatments had a significant effect on both parameters (leaf height and number of leaves).

The evolution of growth parameters as a function of time (Fig. 2) showed that the leaf count initially increased and peaked at 60 days and then decreased. The trends were the same regardless of the treatment, but the simultaneous application of the recommended dose and organic matter proved to be more effective, followed by T3, T2 and T0 treatment in last position. The influence of treatment on height was similar to that noted for leaf count with the only difference being that the height did not decrease during the 75 days of collection.

Table 2. Results of the analysis of the influence of treatment on growth parameters

Factors	Height			Number of sheets	
	DF	chisq	prob	chisq	prob
Time	4	888.54	$< 10^{-3}$	4733.988	$< 10^{-3}$
Treatment	3	131.55	$< 10^{-3}$	301.492	$< 10^{-3}$
Time Treatment	12	35.8	$3.5 < 10^{-4}$	41.153	$< 10^{-3}$
$ICC_{production}$ (%)	-	43.63	-	8.69	-

ICCs: Interclass coefficients

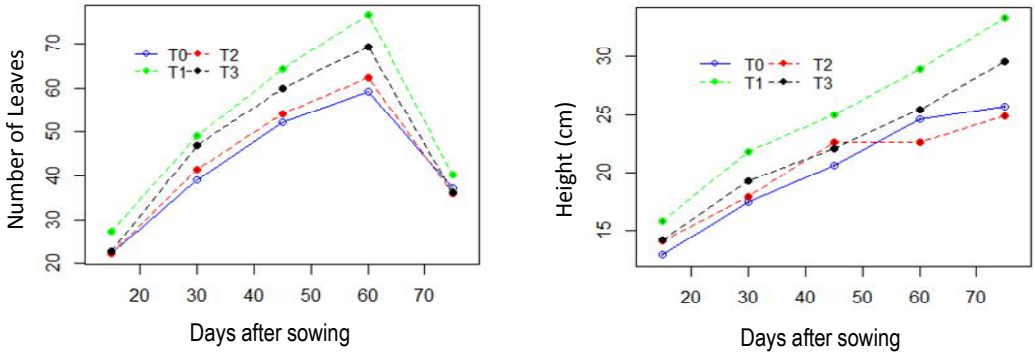

Fig. 2. Effect of microdose of mineral fertilizer and / or organic manure on groundnut growth parameters

T = control (without organic matter, without mineral fertilizer); T0 = recommended dose of mineral fertilizer (103.77 kg / ha or 0.93 g / poquet 15 days after sowing); T1 = recommended dose of mineral fertilizer plus organic matter; T2 = microdose of mineral fertilizer (0.57 g of NPKSB *(14-23-14-5-1) 15 days after sowing); T3 = microdose of mineral fertilizer plus organic matter*

Table 3. Results of the influence of treatment on yield parameters

Yield parameters	Treatment			
	DF	chisq	prob	$ICC_{producer}$ (%)
Fresh aboveground biomass (g / plant)	4	28.081	$< 10^{-3}$	31.98
Dry biomass (g / plant)	4	12.631	0.013	17.31
Root biomass (g / plant)	4	3.039	0.551	36.81
Number of nodules per plant	4	121.560	$< 10^{-3}$	20.25
Pod weight (g / plant)	4	27.913	$< 10^{-3}$	32.50
Seed weight (g / plant)	4	18.194	0.001	31.34

ICCs: Interclass coefficients

3.2 Effect of Microdose of Mineral Fertilizer and/or Organic Manure on Groundnut Yield Parameters

The results of the model estimation (Table 3) indicated that the application of microdose mineral fertilizer and/or organic manure had a significant effect on yield parameters such as aerial biomass (fresh or dry), nodule number and groundnut pod weight (Prob <0.05). The random effect of growers was not negligible as the Interclass Coefficients (ICCs) were all greater than 17%.

The combination of microdose and organic matter (T3) resulted in higher yields of fresh aerial biomass (46.6 ± 5.5 g/plant; Fig. 3). On the other hand, application of the recommended

dose (T0) was more effective followed by T2 for dry biomass yield (2.3 ± 0.9.and 2.2 ± 0.7 g/plant, respectively). For nodule count, pod weight and grain weight, microdose application (T2) was more effective followed by the recommended dose plus organic matter (T1).

4. DISCUSSION

It appears from our work that the treatments carried out had a significant effect on the number of leaves and height. The T1 and T3 treatments had a positive impact on the above-ground biomass; this could be explained by the contribution of organic manure. The significant yield increases observed with the application of the microdose fertilizer technique show that they induce a positive effect on the production of the groundnut crop. Grain yields were high using this technique compared to the T control and the recommended T0 rate. Similar results were obtained by Aune et al. [9], Sogodogo et al. [7]

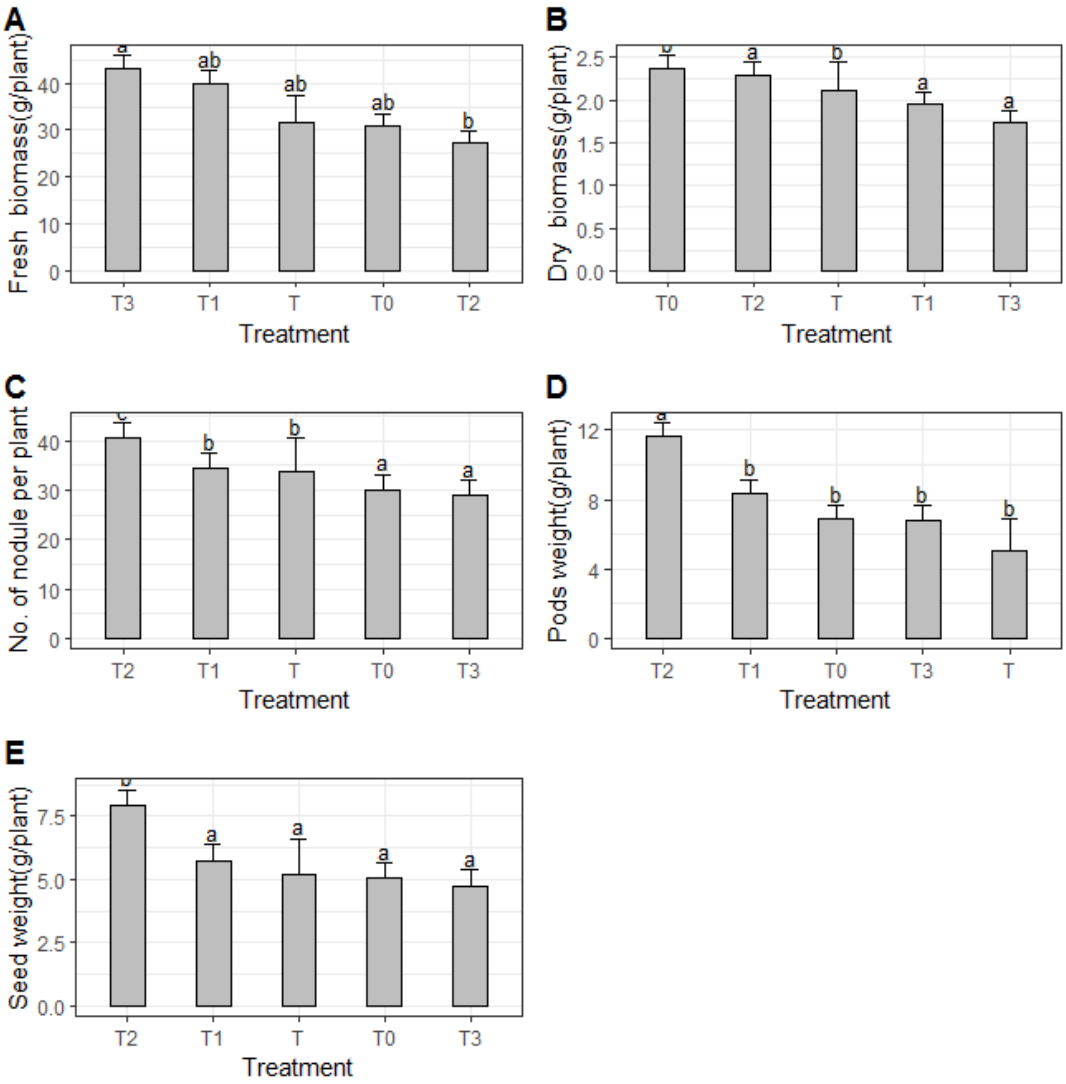

Fig. 3. Effect of microdose of mineral fertilizer and/ or organic manure on groundnut yield parameters

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and Tovihoudji et al. [8], on demonstration tests of the microdose technique in a farming environment in Mali and Benin. According to these authors, the application of mineral fertilizer to the pots resulted in a higher grain yield of millet, sorghum or maize compared to the control without fertilizer.

The observed increase in yields is due to the improvement of the nutritional status of the soil by the different fertilizer inputs. Ouattara [10] showed that most soils with natural poverty respond positively to different fertility improvement practices. This improvement resulted in good plant nutrition and hence increased yields. Regarding microdose, its performance is reported to be related to the high concentration of nodules, which results in increased nutrients in the root systems, improving accessibility and efficiency of use and reducing losses [11]. The performance of microdosing can also be explained by the fact that the location of fertilizers in the surface horizon colonized by the roots of the plants leads to their proliferation and growth; this allows the plants to better capture nutrients and water. These results are in line with those obtained by Agbé [12], Taonda et al. [13] and Saba [14].

From an economic point of view, the interesting results obtained with microdosing are due to the fact that this technology reduces the amount of fertilizer and therefore the cost of production. These results are in line with those obtained previously, showing that microdosing favoured an increase in producers' income [1,9,13,15]. The fertilizer micro-dosing technique may be accessible to poor producers with low incomes because of the reduced investment cost in fertilizer [16]. Under harsh climatic conditions, the economic loss could be lower with the micro-dosing technique, compared to the usual fertilization practice based on higher fertilizer doses. This has been demonstrated by the studies of Bielders and Gérard [17] in Niger.

5. CONCLUSION

This study showed that microdose technique of mineral fertilizer and organic manure compared to the producers practice on groundnut (*Arachis hypogaea* L.) cultivation significantly increases yields. The highest seed yields were obtained with mineral fertilizer applied in microdose compared to yields from the recommended dose. In view of the high yields obtained by the use of the microdose fertilizer technique in groundnut production, it appears that the cultivation system based on this technique contributes to the improvement of food security and income of producers in our regions. However, constraints on access to mineral fertilizer limit the large-scale adoption of the technique by producers. Efforts must be made to reduce the cost of mineral manure so that producers can afford it.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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