YIELD OF MAIZE (*Zea mays* L.) VARIETIES AS AFFECTED BY NEEM OIL COATED UREA APPLICATION IN SOUTHERN BENIN

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Abstract

Maize is one of the most important cereals grown and consumed in Benin Republic. In maize cultivation, huge amount of nitrogen is used contributing to soil and environment pollution. Despite such huge level of applied nitrogen, maize grain yield is still below 2 ton/ha. The aim of this study was to make available to the maize grain's farmers, an eco-friendly practice based on the use of Neem Oil Coated Urea (NOCU) for a high maize grain yield in Benin. An experiment was carried out from April 2023 to August 2023 using a split plot with four blocks design. The treatments consisted on the combination of four varieties (V1: DMR ESR-W, V2: EVDT 97 STR W, V3: 2000 SYN EE-W and V4: ABONTEM) and five levels of fertilization (T0: the control, T1: Urea only, T2: NOCU at 1%, T3: NOCU at 3% and T4: NOCU at 6%). Yield data were collected. Results showed that with the application of the NOCU at the rate of 3% *(200 Kg/ha of NPK and 75 Kg/ha of urea + 3ml of neem oil)*, V1 and V4 showed the highest maize grain yield (3.82 ton/ha) and (4.71 ton/ha) respectively. With the application of the NOCU rate at 6% *(200 Kg/ha of NPK and (75 Kg/ha of urea + 6ml of neem oil)*, V2 and V3 showed the highest maize grain yield (5 ton/ha) and (4.07 ton/ha) respectively. These results suggest that the NOCU at 3% *(200 Kg/ha of NPK and (75 Kg/ha of urea + 3ml of neem oil)* and 6% *(200 Kg/ha of NPK and (75 Kg/ha of urea + 6ml of neem oil)* can be used for the maize production in Benin. Further studies should be conducted to depict the post-harvest behavior of produced maize from NOCU.

1-Introduction

In Benin Republic, maize contributes to 6.54% to the Gross Domestic Product (GDP) and is listed among the crop being promoted in four Agricultural Development Territorial Agency (ATDA) (6, 5, 4, 3 and 2) out of the seven ATDAs established by Benin government. Maize production provides employment for communities in rural area and improves the farmer's livelihood (Saïdou et al., 2018). Among the West African countries, maize production volume is low in countries such as Benin Republic, Côte d'Ivoire and Togo compared to that of Nigeria and Burkina Faso (FAOSTAT, 2020). At the same time, the yearly per capita consumption of maize is high in Benin Republic (87 kg), followed by Togo (70 kg) and Ghana (45 kg) (Badu-Apraku & Fakorede, 2017). The actual maize grain yield is between 0.8 ton and 1.2 ton/ha which is far below the potential yield of 3 to 4t/ha. According to the DSA (2021) the maize grain yields in Benin during 2017, 2018, 2019, 2020 production season were respectively 1.29 ton/ha, 1.32 ton/ha, 1.07 ton/ha, 1.27 ton/ha. This reported low yield is caused, by the soil degradation due to the increasing of the fertilizers amount, by the soil fertility degradation, and by the climate change effect (low annual rainfall, high temperature) (Tovihoudji et al., 2022). Taking into account the importance of maize and huge consumption by the population with the poor grain yield, it is urgent to develop strategies to increase maize yield.

Attempts have been made by Saïdou et al. (2018) who recommended the use of N-P-K rates at 80 Kg N /ha, 30 Kg P /ha and 25 Kg K /ha and 80 Kg N/ha, 15 Kg P/ha and 40 Kg K/ha (for Acrisols) and 80.5 Kg N/ha, 22.5 Kg P/ha, 20 Kg K/ha (for Ferric and Plintic Luvisols) in intensive maize grains production system in the Southern and Center parts of Benin. According to Tovihoudji et al. (2022), the combination of microdose and drought tolerant varieties (especially 35 kg/ha of N and 8 kg/ha of P applied to TZE Y Pop STR QPM maize varieties), was suggested in the current context of declining soil fertility and climatic variability. In the context of increasing prices of fertilizers (Ali & Azaroual, 2022), of climate change, soil fertility declines along with consumers tendency to consume safe and quality product, there is an urgent need to develop eco-friendly practices (agro-ecological practices) respecting consumers attributes and farmers health.

Many researches have been conducted to develop agro ecological practices in maize production. Tovihoudji and al. (2019) found that microdose fertilization alone increased maize grain yields up to 1.145 ton/ha compared to the unfertilized land (1.096 ton/ha) in northern Benin. The same authors also reported that combining microdose fertilization with farmyard manure increased yields from 1.834 to 4.475 ton/ha with microdose + farm yard manure compared by 0.420 to 1.687 ton/ha. Akplo et al. (2019) found that the highest growth rate (2.38 cm/day), leaf area (65.70 cm²), collar diameter (1.39 cm), grain yield (4.148 ton DM/ha), straw yield (5.077 ton DM/ha) and harvested index (40%) were obtained with the combination of plowing and mulch. Amogou et al. (2021) showed that the inoculation of maize of seeds with *Pseudomonas syringae* + 50% NPK + urea led to an increase of yield by 30.64 to 32.25%. All these technologies, although proven by research, are not accessible to farmers. Therefore, there is a need to develop and rethink other agronomic practices promoting the reduction of urea while increasing maize grain yield and with high potential to be adopted by maize grains farmers.

In India, Gudge et al. (2019) found that the application of Neem Oil Coated Urea (NOCU) increased the cob length, the cob width, the numbers of cobs per hectare and 1000 seed weight in maize plants compared with simple urea application (uncoated urea). Ashraf et al. (2019) found that the application of NOCU delayed the nitrification up to 30 days and increased the plant available N pool compared to uncoated urea. The apparent N recovery ranged from 61-84% between coated urea treatments than ordinary urea. The relative growth rate increased by 11-89% and 30-70% in all natural nitrification inhibitors coated urea. Fagodiya et al. (2019) found that the NO_2-N emission decreased by 16% in NOCU with higher maize grain yield as compared to the uncoated urea application. The same authors also reported that the greenhouse gas intensity was reduced by 6% in NOCU. So far, no scientific report has been found dealing with NOCU in maize production in Benin Republic. Therefore, this study aims at developing eco-friendly practices based on NOCU application in maize production in Benin. Specific objectives were to (i) evaluate the effect of the NOCU on the different maize varieties yield and physiological parameters and (ii) determine the economical rate of NOCU giving a relatively high grain yield.

2-Materials and methods

2.1. Experimental sites and maize varieties used

The experiment was conducted from April 2023 to August 2023in the southern Benin (Guinean zone phytogeographical zone) at Zè municipality. The climate is characterized by a tropical type with a bimodal rainfall with two rainy seasons (March to July and September to October) and two dry seasons: (August and November to February). Geographically, the site was located in latitude of 6°36' 36"N and longitude of 2°13' 46"E. The variation of the annual rainfall in southern Benin is between 1200 mm and 1300 mm (Adigoun et al., 2022). The average annual temperature is around 25 °C and the maximum is 34.5 °C.

Four maize varieties were used, three local varieties and one hybrid. The local varieties are those that are well appreciated by the farmers and mostly produced in southern Benin. These varieties are: DMR ESR-W, EVDT 97 STR W and 2000 SYN EE-W (Adigoun et al., 2022).

2.2.Experimental design and treatments

In each experimental site a Split-plot design with two factors was used. The first factor was the ''**Variety**'' with 4 modalities: ***V1****: DMR ESR-W;* ***V2****: EVDT 97 STR W;* ***V3****: 2000 SYN EE-W;* ***V4****: ABONTEM,* The second factor was the "**Rate of NOCU**": For maize cultivation in the Republic of Benin, the NPK 10-20-20 fertilizer is applied at 200 Kg/ha 21 days after sowing (DAS) and urea is applied at 100Kg/ha between 30 and 45 DAS depending on the varieties (Salami et al. 2020). According to Ashraf et al. (2019), 100g of granular urea is coated with 1mL of neem oil. To prepare the NOCU, 75% of the dose of 100 Kg/ha of urea (2.4g per plant) was mixed with the neem oil at the rate of 1ml/100g of urea. The NOCU was applied at different doses; 1%, 3% and 6%. The NOCU at 1% was prepared by a mixture of 100g of granular urea and 1ml of neem oil. The NOCU at 3% was prepared by a mixture of 100g of granular urea and 3ml of neem oil and the NOCU at 6% was prepared by a mixture of 100g of granular urea and 6ml of neem oil. Based on these data, five modalities were identified: (i) *The control (T0: 0 Kg/ha of NPK and 0 Kg/ha of urea);* (ii) *Urea (T1: 200 Kg/ha of NPK and 100 Kg/ha of PU);* (iii) *NOCU at 1% (T2: 200 Kg/ha of NPK and NOCU at 1% (75 Kg/ha PU + 1ml of neem oil));* (iv)

NOCU at 3% (T3: 200 Kg/ha of NPK and NOCU at 3% (75 Kg/ha PU + 3ml of neem oil) and (v) NOCU at 6% (T4:200 Kg/ha of NPK and NOCU at 6% (75 Kg/ha PU + 6ml of neem oil).
The experiment, was composed by four replications (4 blocks) with 20 experimental units (5 × 4 from treatments combination with a total of 80 experimental units per experiment) per block. The plots size was 3 m × 5.5 m (16.5 m^2) and contained 24 maize plants. The block size was 132 m × 4 m (528 m^2). The maize seeds were sown at the density of 62,500 plants/hectare (0.80 m × 0.40 m) with 2 seeds per hole.

2.3.Collected data and data analysis

Yield data was collected at harvesting. Data were analyzed with R.4.3.1 software (2023) using ANOVA model. The hierarchization of the means were obtained using "Student-Newman-Keuls" (SNK), and boxplot function was used to make the boxplot.

3- Results and discussion

Results showed main effects of varieties and Treatments (NOCU) (Table 1). Regarding the varieties, similar yields were obtained for V1 and V3 and V2 and V4 (Figure 1). All treatments with NOCU have high yield compared to the farmer's practice. Although the interaction between variety and treatment was not significant, results indicated that:

- For the variety V2, the highest maize grain yield (5 ton/ha) was obtained on the plots which received the treatment T4 and the lowest (4,03 ton/ha) was obtained on the plots which did not receive any treatment.
- For the variety V3, the highest maize grain yield (4,07 ton/ha) was obtained on the plots which receive the treatment T4 and the lowest (1,99 ton/ha) on the plot which did not receive any treatment.
- For the variety V4, the highest maize grain yield (4,71 ton/ha) was obtained on the plots which receive the treatment T3 and the lowest (2,76 ton/ha) on the plants which did not receive any treatment.

Table 1. P-value of the effect of NOCU application on the maize grain yield

Factors	**Grain yield**
Variety (V)	0.000***
Treatment NOCU (T)	0.002**
V*T	0.675

: Statistically significant at $0.01 > P \geq 0.001$; *: Statistically significant at $P < 0.001$

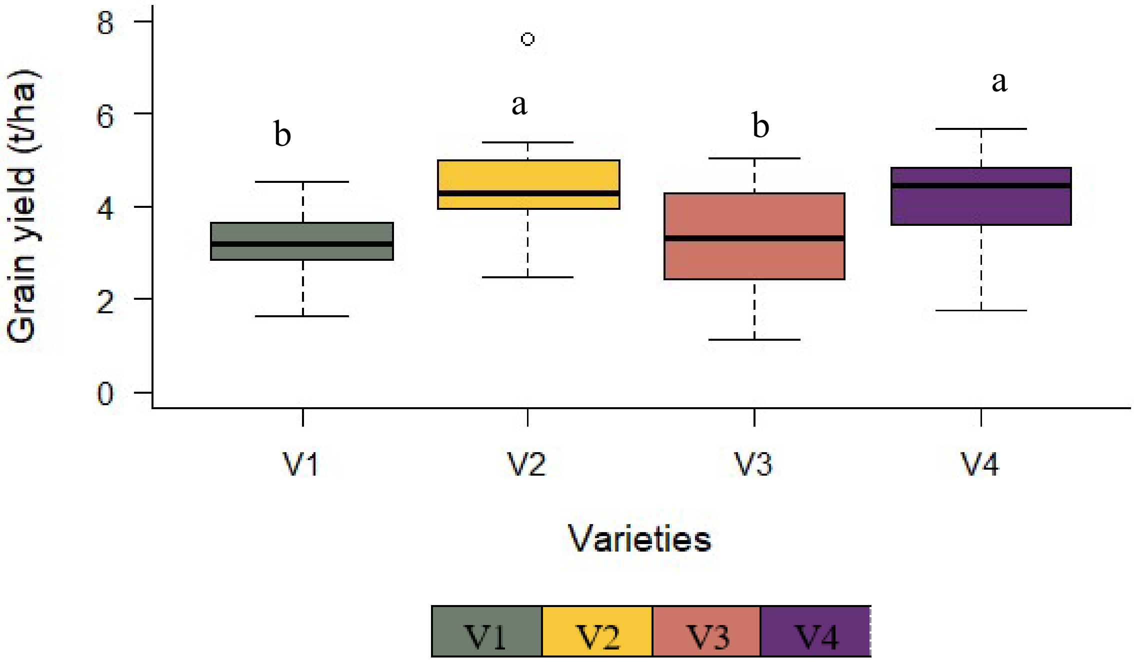

Figure 1. Effect of NOCU application on maize grain yield per variety

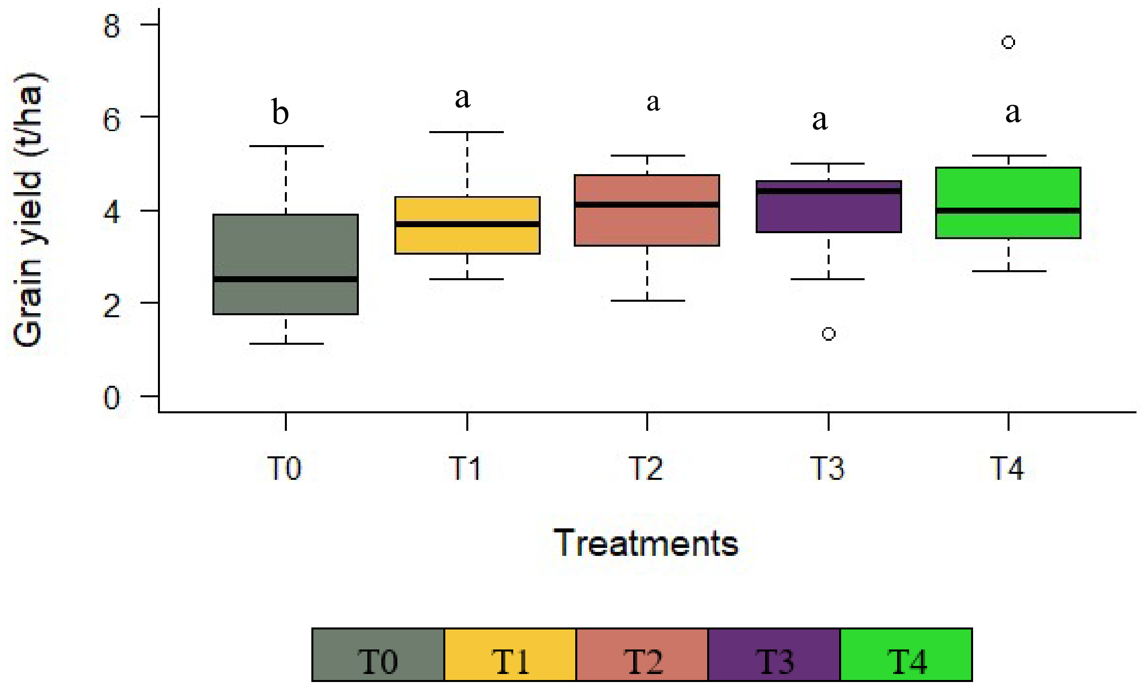

Figure2. Effect of NOCU application on maize grain yield

These previous results can be explained by the fact that the NOCU at 3% and 6% allow the nitrification inhibition for a long period of time (Ali et al., 2020). This nitrification inhibition increases the nitrogen content in the soil and in the plant by the decreasing of the NH_4^+ losses. The maize grain yield is increased because the nitrogen availability increases the stem girth which lead to the better nutrient and water uptake by the plants (Ashraf et al., 2019; Nasar et al., 2021). It is also due by the increasing of the ear length and diameter which increase the number of grains rows and the numbers of grains per row (Mu & Chen, 2021). In fact, the maize grain dry weight is influenced by the main component of the grain which is the starch (Liu et al., 2021). Physiologically, the maize grain formation is closely related with the starch synthesis in the grain by the starch enzymes. The starch synthesis enzymes such as ADP-glucose pyrophosphorylase (AGPase) ($C_{16}H_{25}N_5O_{15}P_2$), granule bound starch synthetase (GBSS), soluble starch synthase (SSS) and starch branching enzyme (SBE) have an crucial role in starch accumulation and grain weight (Liu et al., 2021). According to the same authors, when the nitrogen supply is high it has a strong positive effect on this starch enzymes activities which increase the starch synthesis and by this way the grain weight.

4- Conclusion

Maize grain yield in Benin can be increased by improving the nitrogen use efficiency of the plants. To allow this it is essential to avoid the ammonium losses in the soil by the coating of the nitrogen fertilizer with the natural nitrification inhibitors such as neem oil. The NOCU application increased the maize leaves chlorophyll content, the maize leaves area index, the maize plants height and stem girth. The different maize varieties used showed different trends after the application of the treatment. The aim of this study which is to find an eco-friendly practice to enhance the maize grain yield in Benin by the reducing of the urea amount is reached. In this study we used 75% of the recommended dose and obtained good results. We suggest to conduct a second trial to be sure about the results obtained

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