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Original Research Article

Update of Mineral Fertilization Recommendations for Maize (*Zea mays* L.) in the Savannah Region of Togo

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Abstract: The recommendations specific site of the nutrients in maize cultivation are necessary in the region of Savannah in Togo in the current context of the variability of the endogenous fertility of soils. To this end, based on the results of subtractive trials whose treatments were: the absolute control - $N_0P_0K_0$ (T_1), $N_0P_{60}K_{70}$ (T_2), $N_{120}P_0K_{70}$ (T_3), $N_{120}P_{60}K_0$ (T_4) and $N_{120}P_{60}K_{70}$ (T_5) kg ha^{-1} coupled with the maize variety Ikenne, conducted in the prefectures of the Savannah region, target yields were determined taking into account the potential yield of the Ikenne variety. Fertilization formulas to obtain the difference between the target yields and those measured on the zero N, zero P and zero K treatments were calculated. The results revealed that the gradient of priority nutrient requirement for maize was N > P > K in the prefectures. In Tandjouaré, grain yields of 3, 3.5, 4, and 4.5 Mg ha^{-1} were obtained with the fertilizer formulas $N_{92}P_0K_0$, $N_{112}P_{10}K_0$, $N_{132}P_{18}K_{16}$ and $N_{152}P_{26}K_{29}$ kg ha^{-1}, respectively, with corresponding value/cost ratios of 16, 13, 11, and 10. In Tône, achieving grain yields of 2.5, 3, 3.5, 4, and 4.5 Mg ha^{-1} is subject to the fertilizer formulas $N_{79}P_{24}K_0$, $N_{99}P_{32}K_{16}$, $N_{119}P_{41}K_{30}$, $N_{139}P_{49}K_{43}$ and $N_{159}P_{57}K_{56}$ kg ha^{-1}, respectively, with corresponding value/cost ratios of 9, 8, 12, 7, and 6. In Oti, achieving grain yields of 3, 3.5, 4, and 4.5 Mg ha^{-1} is subject to the fertilizer formulas $N_{66}P_7K_0$, $N_{86}P_{16}K_9$, $N_{106}P_{24}K_{22}$ and $N_{126}P_{32}K_{36}$ kg ha^{-1}, respectively, with corresponding value/cost ratios of 19, 14, 11, and 10. In Kpendjal, obtaining grain yields of 2.5, 3, 3.5, 4 and 4.5 Mg ha^{-1} is subject to fertilizer formulas $N_{70}P_{16}K_5$, $N_{90}P_{24}K_{18}$, $N_{110}P_{33}K_{31}$, $N_{130}P_{41}K_{45}$ et $N_{150}P_{49}K_{58}$ kg ha^{-1}, respectively, with corresponding value/cost ratios of 11, 9, 8, 7 and 7.

Keywords: Maize, fertilizer formula recommendation, subtractive trials, Savannah Region of Togo, value/cost ratios.

INTRODUCTION

In Togo, low crop yields are often explained by unfavorable rainfall conditions, the natural nutrient poverty of soils, diseases and the low use of external inputs (Kanda *et al.*, 2014). Agriculture is one of the country's most important sectors in terms of economic growth. It contributes around 40% of GDP (Gross Domestic Product). A variety of crops are grown, with corn predominating. Despite its high yield potential, maize cultivation is characterized by low productivity, linked to declining soil fertility and poor rainfall distribution during cropping seasons (Amouzou *et al.*, 2013). Similarly, the application of fertilizer doses popularized during the Green Revolution continues to be adopted in the country's different agro-ecological zones, without taking into account soil degradation and crop nutrient requirements (Detchinli *et al.*, 2017). Maize cultivation is nutrient-demanding, and therefore requires adapted N-P-K fertilizer formulas, specifically to improve productivity and economic profitability. To this end, the community-based approach, which aims at the effective participation of end-users in the exercise of determining fertilizer doses proves indispensable.

The aim of the present study is to develop appropriate fertilization formulas for specific target yields, while strictly respecting the environment and the soil's endogenous nutrient reserves.

METHODOLOGY

Fertilization formulas

Based on the average yields obtained under each treatment in the subtractive trials in each prefecture, target yields were determined, taking into account the

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potential yield of the Ikenne variety. The fertilization formulas needed to achieve these target yields were then calculated.

The dose of each element was calculated using the following formula developed by IFDC in 2012:

$$\textbf{Fertilizer dose} = \frac{\textbf{Targeted yield} - \textbf{Zero yield}}{\textbf{IE} * \textbf{RR}}$$

IE: Internal Efficiency
RR: Recovery Rate
EI data from Janssen *et al.*, (1990) were used in the study. Which are: EI (N): 50 kg Grains/kg absorbed N, EI (P): 400 kg Grains/kg absorbed P and EI (K): 75 kg Grains/kg absorbed K.
The IFDC, 1997 were used for the recovery rate. For clay soils, the recovery rate (RR) is: RR(N)= 0.5, RR(P)= 0.1, RR(K)= 0.5.

Economic Analysis

The analysis of the economic efficiency of different fertilizer doses had been carried out with the aim of estimating the economic impact of different productivity levels according to different treatments applied to the plots. According to studies by Njoroge *et al.*, (2018) the economic efficiency of fertilizer use is one of the key factors determining treatment adoption and therefore the amount of fertilizer used. This involves, among other things, estimating the gross revenue per hectare based on the targeted yield of crops according to their current market value and determining the contribution of each individual treatment to the crop's gross revenue. CVR indicates the value of additional yield produced per unit of money invested in fertilizers, as shown by the following equation:
CVR = (additional maize product due to fertilizer use (kg ha^{-1}) × grain price (F CFA kg^{-1})) / (amount of fertilizer applied × cost of fertilizer (F CFA kg^{-1})) (Njoroge *et al.*, 2018).

Results and Discussion

Results

Development of Fertilization Formulas

Based on the results of the subtractive trials, the fertilization formulas developed to obtain the difference between the targeted yields and those measured on the zero N, zero P and zero K treatments, as well as their value-cost ratios, are presented in Table 1 below:

Table 1: Fertilization formulas and their value/cost ratios

Prefecture	Targeted yield	Fertilization formula	CRV
Tandjouaré	3	$N_{92}P_0K_0$	16
	3.5	$N_{112}P_{10}K_0$	13
	4	$N_{132}P_{18}K_{16}$	11
	4.5	$N_{152}P_{26}K_{29}$	10
Tône	2.5	$N_{79}P_{24}K_0$	9
	3	$N_{99}P_{32}K_{16}$	8
	3.5	$N_{119}P_{41}K_{30}$	12
	4	$N_{139}P_{49}K_{43}$	7
	4.5	$N_{159}P_{57}K_{56}$	6
Oti	3	$N_{66}P_7K_0$	19
	3.5	$N_{86}P_{16}K_9$	14
	4	$N_{106}P_{24}K_{22}$	11
	4.5	$N_{126}P_{32}K_{36}$	10
Kpendjal	2.5	$N_{70}P_{16}K_5$	11
	3	$N_{90}P_{24}K_{18}$	9
	3.5	$N_{110}P_{33}K_{31}$	8
	4	$N_{130}P_{41}K_{45}$	7
	4.5	$N_{150}P_{49}K_{58}$	7

In general, nutrient doses evolved in line with target yields in all four prefectures. N doses are higher than P and K doses. RVCs have followed almost the same rhythm in the different prefectures.

Discussion

Development of Fertilization Formulas

The fertilization formulas developed to obtain the targeted yields and those measured on the zero N, zero P and zero K treatments were the subject of debate. The mineral fertilization formulas thus obtained present fertilizer doses in excess of current recommendations and demonstrate the need for each prefecture to have its own fertilization formula. These results confirm the studies by Igue *et al.*, (2013), Blanchard *et al.*, (2014), Detchinli *et al.*, (2017), Amouzou *et al.* (2018), Lare and Sogbedji (2020) on the need to update fertilization formulas in Sub-Saharan Africa.

The mineral fertilization formulas developed for the same targeted yields in the different prefectures vary from one prefecture to another, confirming the heterogeneity of soils in the region. Results also varied from one prefecture to another when it came to obtaining 80% of the potential yield of the Ikenné variety, i.e. 4 Mg ha^{-1}. The results thus obtained for the target yield of 4 Mg ha^{-1} in the four prefectures contradict those of ITRA (2021) in the same prefectures, which relied instead on the physico-chemical characteristics of the soils to develop fertilization formulas, stipulating that for a target yield of 4 Mg ha^{-1}, a $N_{97}P_{16}K_{30}$ mineral fertilization formula is required for the four prefectures. However, it has been shown that soils in Togo's Savannah region are heterogeneous from one prefecture to another, and even from one plot to another (Lare *et al.,* 2022). Our results corroborate those of Badiane (2021), who states that fertilization formulas developed on the basis of soil analysis have limitations compared to fertilization formulas developed on the basis of subtractive tests (Case du Nutrient Expert). Fertilizer recommendations based on soil analysis have certain limitations: they are labor-intensive, time-consuming and show poor correlations between endogenous nutrient supply and soil analysis values (Dobermann *et al.,* 2003). Different ranges of fertilizer formulas have been developed to enable each grower to produce according to his or her budget. In sub-Saharan Africa, the lack of financial resources and information sometimes forces growers to use fertilizer doses that do not meet crop needs, or even lower than current recommendations, which have become obsolete, thus contributing to the degradation of arable soils. The basis of this technology is to make the farmer the guarantor of his production, whatever his financial means or area of operation. According to studies by Amadou *et al.,* (2020), farmers' low financial mobilization capacity is one of the main constraints to agricultural production. On the other hand, these formulas have been developed to identify the most cost-effective formulas that correspond well to crop response.

The nutrient doses obtained, especially nitrogen, for the targeted yield panoplies corroborate the work of Ziadi *et al.,* (2006), Mustapha (2012), Njoroge *et al.,* (2019), for whom nitrogen fertilization plays an essential role in plant growth and crop yield, and that it contributes to increasing agricultural production while having an impact on the quality of harvested products. For Batamoussi *et al.,* (2014), nitrogen is the main element limiting cereal crop yields. The poverty of agricultural land has made the use of fertilizers, especially mineral ones, indispensable to production (Sanou *et al.,* 2018).

Profitability of Fertilization Formulas

The Cost-Value Ratios (CVRs) calculated on the basis of the fertilization formulas developed having been greater than 2, the threshold value set by the FAO in 2005, theoretically indicates that the fertilization formulas developed are profitable. For the Tandjouaré, Oti and Kpendjal prefectures, the lower the target yield, the higher the RVC. On the other hand, in the Tône prefecture, the best RVC is obtained for a target yield of 3.5 Mg ha^{-1}.

CONCLUSION

Crop fertilization at economical doses is one of the solutions for increasing crop productivity. Following the objective of developing site-specific mineral fertilization formulas for the prefectures of Tandjouaré, Oti, Kpendjal and Tône for maize cultivation, the results showed different amplitudes. The mineral fertilization formulas thus developed varied from one prefecture to another, and were all economically profitable with CVRs above threshold 2. However, a real-life validation study is essential to confirm or invalidate their performance.

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