DETERMINATION OF MAJOR LIMITING NUTRIENTS AND SITE-SPECIFIC FERTILIZER RECOMMENDATION TOWARDS OPTIMIZING RICE PRODUCTION IN THE IRRIGATED PERIMETER OF THE ZIO VALLEY (TOGO) #9481

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ABSTRACT

Adoption of appropriate inorganic fertilization schemes is essential to improving fertilizer use efficiency and crop performance for precision agriculture. This study aims to contribute to the improvement of rice yields in the irrigated perimeter of the Zio Valley in Togo through appropriate inorganic fertilization. Nutrient omission trials were set up during November 2020 to March 2021 and May to September 2021, with farmers identified in the four (04) villages (Mission Tove, Ziowonou, Kovie and Assome) located in the Zio valley. Three (03) producers per village were selected on the rice-growing perimeter of the Zio valley. A complete randomized block design with five treatments was installed at each site. The treatments consist of diagnostic plots: T1(N81P110K88), T2(N0P110K88), T3(N81P0K88), T4(N81P110K0) and T5(N0P0K0). Each treatment was carried out in three repetitions. The data collected related to the yield of paddy grains and straw. Analyses were also carried out to determine the export rate of N, P and K in the grains and in the straw. The subtractive trials showed a significant difference between the plots having been fertilized and the non-fertilized plots on the yield of paddy rice. On average, the full NPK treatment gave the highest yield (4 557.82 kg/ha). It is followed by T4 (3 873.67 kg/ha) and T3 (3 493,04 kg/ha) treatments, then T2 (2 808.78 kg/ha). The lack of Nitrogen, Phosphorus and Potassium led to respective yield reductions of 60%, 29% and 17% compared to the T1 (NPK) plots. The order of nutrient limitation in the perimeter is N>P>K. Kovie and Mission Tove producers should use the N130P34K77 formula for a target yield of 4.25 t/ha. The recommended formulas for the Ziowonou and Assomé villages are respectively N96P21K82 and N81P11K26 with respective target yields of 5.7 t/ha and 4.1 t/ha.

Keywords: Irrigation, rice, nutrient, yield, fertilization formula

INTRODUCTION

In irrigated rice cultivation in West Africa, nitrogen (N) and phosphorus (P) fertilizers account for about 20% of total production costs. More generally, it is noted that the cost of fertilizers represents more than 30% of operating expenses (Donovan et al., 1999). Because of this importance, it is necessary to ensure the efficiency of the fertilizers used through a permanent adaptation of the fertilization formulas to production areas and crops. However, a single pan-territorial formula ($N_{76}P_{30}K_{30}$) has been recommended for several decades for all cereal crops in Togo. It emerged from the work of Ngbendema et al. (2017), that the application of this formula in irrigated rice cultivation only makes it possible to obtain yields of 3.5 t/ha on average with an operating account deficit of 32 000 FCFA. In this situation, rice farmers increase the amounts of fertilizers without any scientific basis in the hope of improving their yields and the profitability of their farms. This inappropriate practice results in loss of nutrients

and wastage of foreign exchange and can even lead to environmental pollution (Ezui, 2010). Thus, all actions to improve production should consider the new challenges and objectives of agricultural production, including the reduction of the environmental impacts of crops, the control of production costs and the balanced use of fertilizers (Yousaf et al., 2016), especially for crops of major importance for food security such as rice.

The production of rice in the irrigated perimeters makes it possible to improve yields thanks to the favourable growing conditions they offer and especially with the possibility of conducting at least two cycles of rice cultivation per year. This study aims to contribute to the improvement of paddy rice yields in the irrigated perimeter of the Zio valley through appropriate mineral fertilization. Specifically, the study aims to (i) identify and prioritize the major nutrients limiting rice production and (ii) propose suitable and economically viable fertilization formulas.

MATERIALS AND METHODS

For the identification of the major limiting nutrients and the recommendation of fertilization formulas, Nutrient omission trials were set up during November 2020 to March 2021 and May to September 2021, with producers identified in the four (04) villages (Mission Tove, Ziowonou, Kovie and Assome) located in the Zio valley. Three (03) producers per village were selected on the rice-growing perimeter of the Zio valley. A complete randomized block design with five treatments was installed at each site. The treatments consist of diagnostic plots: T1($N_{81}P_{110}K_{88}$), T2($N_0P_{110}K_{88}$), T3($N_{81}P_0K_{88}$), T4($N_{81}P_{110}K_0$) and T5($N_0P_0K_0$). Each treatment was carried out in three repetitions. The data collected related to the yield of paddy grains and straw. Analyses were also carried out to determine the export rate of N, P and K in the grains and in the straw. The application of urea is conducted in three stages, i.e., 50% at 15 days after transplanting (DAR), 25% at 30 DAR and 25% at 45 DAR. As for the TSP and KCl the whole quantity is brought 7 DAR. The paddy rice harvest has been done at 118 DAR for the first season and 122 for the second season.

The order of limiting the needs of rice plants in N, P and K nutrients is determined according to the methodology of Mawussi et al. (2015). Statistical analysis of the grain and straw yield data for the different treatments was conducted using the SPPS V26 software through an analysis of the variance of the data and discrimination of the means according to the Student Newman Keuls test at the threshold of 5 %. Major nutrient requirements were estimated based on three factors: yield gap, nutrient internal efficiency (IE) and recovery rate (TR) following the formula (a) below (Dogbe et al., 2015). The yield gap was calculated as the difference between the target yield (NPK) and the yield from the zero N, zero P, or zero K omission plots. For EI and TR, reference values were used. Thus, in this paper, we have adopted EI of 53 kg grain produced for any kg N absorbed, 34.8 kg grain produced/kg of K absorbed, and 294 kg grain produced/kg of P absorbed (Sahrawat, 2000). Regarding the recovery rate, we adopted the average recovery fractions of N, P and K of 30%, 15%, and 30% respectively (Dobermann and Fairhust, 2000; Dogbe et al., 2015). Two economic parameters were used to assess the profitability of the different recommended options: the value cost ratio (VCR) and the marginal revenue rate (MRT).

RESULTS AND DISCUSSION

Determination of the order of limitation of nutrients N, P and K

The average yields of paddy rice and straw obtained in each village of the irrigated perimeter over the two cropping cycles are given in Table 1.

Table 1. Effect of mineral fertilizers on paddy rice and straw yield in the four villages.

		Ziowonou	Kovié	Mission Tové	Assomé	Moyenne
Paddy grain yield (t/ha)	T1	5.76±0.2 a	4.27±0.9 a	4.10±0.8 a	4.15±0.1 a	4.56 ±0.9 a
	T2	4.18±0.6 c	2.19±0.7 cd	1.99±0.9 c	2.86±0.2 b	2.81±1.1 c
	T3	4.78±0.3 b	2.78±0.9 bc	2.72±0.3 bc	3.67±0.1 a	3.49±1.1 bc
	T4	4.84±0.4 b	3.46±0.8 ab	3.30±0.7 ab	3.87±0.1 a	3.87±0.8 b
	T5	2.88±0.7 d	1.26±0.4 d	1.59 ±0.3 c	1.79±0.2 c	1.88±0.8 d
Straw yield (t/ha)	T1	5.70±0.4 a	4.35±0.3 a	4.07±1.1 a	4.21±0.2 a	4.62±0.8 a
	T2	2.98±0.1 b	2.66±0.1 b	2.18±0.8 c	2.48±0.1 d	2.58±0.4 c
	T3	3.01±0.4 b	3.98±0.7 a	3.57±0.4 b	3.15±0.8 c	3.45±0.2 b
	T4	3.13±0.2 b	4.29±0.4 a	4.09±0.6 a	3.82±0.5 b	3.83±0.4 b
	T5	1.08±1.0 c	1.84±0.8 c	1.61±0.3 d	1.27±0.7 e	1.47±0.6 d

The results of the subtractive tests showed that the absence of one of the three major nutrients leads to a significant drop in rice yield in the four villages of the irrigated perimeter of the Zio valley. On average, T1($N_{81}P_{110}K_{88}$) gave the best output as well for the paddy rice as for the straw is respectively 4,56 t/ha and 4,62 t/ha. The lack of nitrogen in T2 led to a strong decrease in yield. Thus, over the two seasons, the average yield of paddy rice recorded on the plots having received T1($N_{81}P_{110}K_{88}$) was higher than those obtained under T2 ($N_0P_{110}K_{88}$), T3 ($N_{81}P_0K_{88}$) and T4 ($N_{81}P_{110}K_0$) respectively by 60, 29 and 17%. As for rice straw yield, the yield increase rates of T1 compared to T2, T3 and T4 were 79%, 34% and 20% respectively. Thus, the yield of paddy rice in the irrigated perimeter of Zio is more limited by nitrogen. The order of nutrient limitation is therefore: N>P>K. Nitrogen is found to be the most limiting for yield, while yield reductions caused by the absence of phosphorus or potassium seem statistically similar. Nitrogen indeed plays a vital role in grain production (Wanyama et al., 2015). Several other studies have also shown that Nitrogen and Phosphorus are the two main nutrients limiting the yield of rice production in West Africa due to poor soil organic matter (Dogbe et al., 2015).

Nutrient recommendations

Additional export needs and specific fertilization recommendations for producers in villages located in the Zio Valley irrigated perimeter are presented in Table 5. Nutrient needs varied from one village to another. For nitrogen, the need is higher in Mission Tové (21.01 kg/ha) and Kovié (21.43 kg/ha) than in Ziowonou (15.44 kg/ha) and Assomé (13.03 kg/ha). The P requirement per village follows the same hierarchy as that of nitrogen with a higher requirement in Mission Tové (7.37 kg/ha) and a lower requirement in Assomé (2.36 kg/ha). As regards the K requirement, it is almost identical in Ziowonou, Mission Tové and Kovié at around 1.4 kg/ha whereas it is 0.4 kg/ha in Assomé. The soils of Assome therefore appear to be the least poor.

The amounts of nutrients in the recommended formulas are economically sustainable and will significantly improve rice yields. IFDC, (2014) found that farmers began to opt for fertilizer use when the RVC is two (2) or more. Compared to the current recommendation, the quantities will increase from 76 to 110 fertilizer units per ha for nitrogen and from 30 to 66 units per ha for potassium. For phosphorus, there is a slight decrease from 30 to 24 fertilizing units.

Table 2. Yield gap and village-specific recommendation.

	Treatment	Yield gap (kg/ha)	Nutrient recommendation (kg/ha)			RVC	MRT (%)
			N	P_2O_5	K_2O		
Ziowonou	T4($N_{81}P_{110}K_0$)	858.93			82.27		
	T3 ($N_{81}P_0K_{88}$)	917.27		20.80		2.98	165
	T2($N_0P_{110}K_{88}$)	1523.22	95.8				
	T5 ($N_0P_0K_0$)	2818.46					
Kovié	T4($N_{81}P_{110}K_0$)	805.4			77.15		
	T3 ($N_{81}P_0K_{88}$)	1487.3		33.73		2.52	1 25
	T2($N_0P_{110}K_{88}$)	2073.01	130.38				
	T5 ($N_0P_0K_0$)	3012.7					
Mission Tové	T4($N_{81}P_{110}K_0$)	797.73			76.41		
	T3 ($N_{81}P_0K_{88}$)	1379.11		31.27		2.12	108
	T2($N_0P_{110}K_{88}$)	2114.09	132.96				
	T5 ($N_0P_0K_0$)	2508.7					
Assome	T4($N_{81}P_{110}K_0$)	274.55			26.30		
	T3 ($N_{81}P_0K_{88}$)	475.48		10.78		4.19	263
	T2($N_0P_{110}K_{88}$)	1285.87	80.87				
	T5 ($N_0P_0K_0$)	2352.48					

CONCLUSION

This study has made it possible to highlight the importance of the major nutrients N, P and K in improving the yield of paddy rice in the irrigated perimeter of the Zio valley. It also made it possible to identify the edaphic diversity and the nutritional needs of the rice plots on the perimeter of Zio and to confirm the need to adapt the fertilization formulas for each production zone. Nitrogen is revealed as the major nutritive element limiting rice production in the irrigated perimeter of the Zio valley. However, due to the poor soils of the perimeter, phosphorus and potassium also proved to be limiting.

The results of the soil studies, combined with those of the subtractive tests conducted during two cropping cycles between 2020 and 2022, make it possible to propose three economically viable fertilization formulas with realistic target yields. Thus, the producers of Kovié and Mission Tové will use the $N_{130}P_{34}K_{77}$. The formulas recommended for Ziowonou and Assomé villages are respectively $N_{96}P_{21}K_{82}$ and $N_{81}P_{11}K_{26}$.

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