

Optimization of Mineral Fertilization of Cotton (*Gossypium hirsutum* L.) under Late Sowing Conditions in the Countries of the Regional Program for Integrated Cotton Production in Africa (PR-PICA)

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Abstract— Late sowing of cotton is an increasing constraint in West and Central African countries due to irregular rainfall, which reduces the length of the growing cycle and limits the effectiveness of mineral fertilization. This study aimed to determine the most efficient and cost-effective mineral fertilization strategy for cotton cultivation under late-sowing conditions in the countries of the Regional Integrated Cotton Production Program in Africa (PR-PICA). Trials were conducted during the 2023 and 2024 cropping seasons at ten experimental sites in Benin, Burkina Faso, Mali, and Senegal using a randomized complete block design with four replications. Four treatments were compared including a control with no fertilization (0% FMR), the recommended dose (100% FMR: 200 kg ha⁻¹ of NPKSB + 50 kg ha⁻¹ of urea), 75%, and 50% of this dose. Agro-morphological parameters, yield components, seed cotton yield, and the benefit/cost ratio were evaluated. The results show that application of mineral fertilization significantly improves plant growth, the number of bolls per hectare, and seed cotton yield compared to the unfertilized control. However, no significant difference was observed between doses of 100%, 75%, and 50% of the recommended mineral fertilizer for seed cotton yield. Country and year effects were significant for most of the variables studied, reflecting the influence of soil and climate conditions on crop performance. The economic analysis indicates that 50% of the recommended mineral fertilizer dose offers the best economic efficiency by reducing the fertilization costs with no significant effect on seed cotton yield. These results show that under late sowing conditions, applying 50% of the recommended mineral fertilizer is an agronomically effective and economically advantageous strategy. This mineral fertilization dose represents a relevant option to improve the profitability of cotton cultivation while limiting input costs under late sowing conditions in PR-PICA member countries.

Keywords— Cotton, late sowing, mineral fertilization, yield, economic profitability, PR-PICA.

I. INTRODUCTION

Cotton (*Gossypium hirsutum* L.) cultivation is one of the main drivers of agricultural and economic development in the member countries of the Regional Integrated Cotton Production Program in Africa (PR-PICA), namely Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Mali, Senegal, Chad, and Togo. This sector represents a vital source of income for millions of producers, contributes to the supply of textile industries, and makes a significant contribution to these countries' export earnings (FAO, 2022; Renaudin, 2010). However, the sustainability of cotton production is currently facing several major constraints, including the progressive decline in soil fertility and the increasing effects of climate variability, resulting in an irregular rainy season, more erratic rainfall distribution, and an increased frequency of droughts (PR-PICA, 2024; Traoré et al., 2021; Ndour et al., 2018).

The most significant consequence of this climate variability is the increased frequency of late sowing of cotton. In rainfed cotton production systems, the delayed onset of rainfall forces farmers to postpone sowing, thus reducing the effective duration of the crop cycle. This shortening of the cycle exposes the sensitive flowering, fruiting, and boll-filling phases to less favorable water availability and high temperatures at the end of the season, which generally leads to reduced vegetative growth, boll production, and seed cotton yield (Amonmidé et al., 2020; Sêkloka et al., 2015).

In the cotton-growing areas of the PR-PICA region, the lixisols generally have low nutrient reserves, making mineral fertilization essential to maintain crop productivity. Current recommendations are based on the application of 200 kg ha⁻¹ of NPKSB fertilizer supplemented by 50 kg ha⁻¹ of urea (PR-PICA, 2024). However, these recommendations were developed under normal sowing conditions, and their relevance in late-sowing situations remains insufficiently documented. Indeed, when the growing cycle is shortened, the cotton plant's capacity to absorb and utilize nutrients, particularly nitrogen and potassium, can be limited, which is likely to reduce the agronomic and economic efficiency of fertilization (Sêkloka et al., 2015).

Faced with this situation, farmers sometimes adopt empirical strategies such as reducing fertilizer doses or even completely eliminating urea application during very late sowing of cotton (Amonmidé et al., 2020). Although these practices aim to limit production costs, they are still based on few validated experimental references at the regional level. In a context where farm profitability is becoming a major issue, it appears necessary to determine the fertilization doses that reconcile agronomic performance and economic efficiency under late sowing conditions.

We hypothesized that under late sowing conditions, a reduction in the recommended mineral fertilization dose would maintain a yield level comparable to that obtained with the full dose, while improving the economic profitability of the crop. The objective of this study is therefore to evaluate the effects of different mineral fertilization doses on growth, yield components, seed cotton yield, and the economic profitability of cotton under late sowing conditions in several PR-PICA member countries.

II. MATERIALS AND METHODS

2.1 Study Sites

The experiments were conducted during the 2023 and 2024 cropping seasons in four member countries of the Regional Integrated Cotton Production Program in Africa (PR-PICA): Benin, Burkina Faso, Mali, and Senegal. The trials were established at research stations representative of the main cotton-producing areas in each country to cover a diversity of soil and climate conditions.

In Benin, trials were conducted at the Permanent Experimental Centers (CPEs) of Angaradébou (3°1'00"E, 11°19'50"N) and Okpara (9°20'49"E, 2°41'3"N), belonging to the Cotton and Fiber Agricultural Research Center (CRA-CF) of the National Institute of Agricultural Research of Benin (INRAB). These two sites represent the northern and north-central zones of the Beninese cotton basin, respectively, and concentrate a significant portion of national production of seed cotton.

In Burkina Faso, experiments were conducted at the Farako-Bâ (N 11°05' and W 04°19'), Houndé (N 11°32' and W 03°26'), and Kouaré (N 11°58'4 and E 00°18') stations. The soils at these sites are lixisols characterized by low organic matter content, low nitrogen and phosphorus reserves, limited cation exchange capacity, and a slightly to moderately acidic reaction. Rainfall recorded during the 2023 growing season varied across the sites, reflecting significant climatic variability.

In Mali, trials were conducted at Farako/Finkolo (-5°48'W, 11°21'N) and N'Tarla (12.6193°N, -5.689°W) research stations, both part of the Sikasso Regional Agricultural Research Center. The soils, with a sandy-loam texture, have a high sand content,

low nutrient retention capacity, and moderate acidity. Rainfall totals recorded over the two years of experimentation indicate contrasting water conditions between growing seasons.

In Senegal, the study was carried out in three Multi-Local Experimental Units (AMEX) in the Senegalese cotton-growing region:

- AMEX of Koussanar (Tambacounda Region): located in the northern/dry zone of the cotton-growing basin, approximately 7 km from the town of Koussanar. The soil is primarily of a slightly leached tropical ferruginous type. The climate is Sudano-Sahelian, characterized by an average annual rainfall of between 600 and 800 mm.
- AMEX of Kolda (Kolda Region): located in the middle zone of the cotton-growing basin, near the border with the Vélingara department. The soils there are tropical ferruginous (moderately to heavily leached). The climate is Sudanian, with annual rainfall generally varying between 800 and 1,000 mm.
- AMEX of Kédougou (Kédougou Region): located in the southern/humid zone of the cotton basin. The soils are predominantly ferrallitic and gravelly. The climate is of the Sudanian-Guinean type, characterized by high annual rainfall between 1,000 and 1,300 mm.

2.2 Experimental Setup

The trials were conducted using a randomized complete block design (blocks of Fisher) with four treatments and four replications. Each elementary plot consisted of six 10-m-long rows spaced 0.80 m apart, corresponding to an area of 48 m². After eliminating edge effects, observations and harvests were carried out on a usable plot composed of the four central 8-m-long rows, for a total area of 25.6 m². The total area of one trial was 768 m², excluding access paths.

2.3 Treatments Studied

In this experiment, four levels of mineral fertilization were compared:

- T1: control without fertilization (0% of the recommended mineral fertilizer);
- T2: 100% of the recommended mineral fertilizer (200 kg ha⁻¹ of NPKSB + 50 kg ha⁻¹ of urea);
- T3: 75% of the recommended mineral fertilizer;
- T4: 50% of the recommended mineral fertilizer.

Cotton fertilizer 14N-18P-18K+6S+1B was applied 10 days after emergence, while urea 46% N was applied between 20 to 30 days after emergence, these application periods being specific to late sowing.

2.4 General Cotton Crop Management

The cotton cultivation operations were carried out according to the technical guidelines recommended in each country. Soil preparation was performed by mechanical plowing or animal traction, depending on the site. Sowing of cotton was carried out at a rate of three to five seeds per hill, followed by thinning to two plants per hill before the fifteenth day after emergence. Weed control was carried out according to the practices recommended in each country. With regard to the phytosanitary protection of cotton plants against pests and diseases, the first two treatments (30 and 44 days after emergence) were carried out using alternative products to pyrethroids, and the others using binary products against caterpillars and sucking pests, in compliance with current recommendations.

2.5 Measured Variables and Economic Analysis

The observations focused on the main growth and agronomic parameters of cotton, including plant height at harvest, plant density, number of bolls per plant, average weight of boll (AWB), and seed cotton yield. Yields were determined from harvests carried out on usable plots according to the harmonized PR-PICA procedures.

The profitability of different fertilization strategies was evaluated using the partial budget method, considering only the costs and revenues associated with the treatments. The calculated indicators included gross revenue, net profit, gross margin, and

the benefit/cost ratio (BCR), obtained by dividing profits by production costs. The following formula was therefore used: $BCR = \text{present value of benefits} / \text{present value of costs}$. A BCR value greater than 1 indicates that the strategy is economically viable. Fertilizer and seed cotton prices for each country were used for these economic calculations.

2.6 Statistical Analyses

The data were subjected to analysis of variance (ANOVA) using R software (version 4.0.1) after verifying the model's application conditions (normality of the distribution). When the effect of the treatments was significant at the 5% level, the means were separated using Duncan's test.

III. RESULTS

3.1 Effects of Mineral Fertilization Doses on Cotton Growth Parameters

Mineral fertilization had no significant effect on plant density at harvest ($p = 0.77$), indicating that the different fertilizer doses applied did not influence stand maintenance under late sowing conditions (Table 1). However, plant density differed significantly between countries ($p < 0.001$) and the growing seasons ($p < 0.001$). The highest densities of cotton plants were observed in Mali and Senegal, while Benin recorded the lowest values. Similarly, the 2024 growing season had a higher average density than that of 2023. The significant interaction between countries and years reflects a variation in stand maintenance conditions depending on the study environments.

TABLE 1
COTTON PLANT DENSITY PER HECTARE UNDER LATE SOWING CONDITIONS IN FOUR COUNTRIES OF THE REGIONAL PROGRAM FOR INTEGRATED COTTON PRODUCTION IN AFRICA (PR-PICA)

Factors	Level	Number of plants/ha	p-value	Coefficient of variation (CV%)
Treatments	T1	46705 a	0.77	1.98
	T2	48293 a		
	T3	46088 a		
	T4	46974 a		
Countries	Mali	51854 a	2.2e-16 ***	14.8
	Burkina Faso	47853 b		
	Benin	36911 c		
	Senegal	51441 a		
Years	2023	44724 b	0.00235 **	6.89
	2024	49306 a		
Countries x Years			0.0011 **	
Overall Average		47015		

Legend: T1: no mineral fertilizer application; T2: application of 100% of the recommended mineral fertilizer, FMR (200 kg/ha of NPK+S+B and 50 kg/ha of urea), T3 = application of 75% of the FMR, T4: application of 50% of the FMR; CV: coefficient of variation; significant differences ($P < 0.05$) between treatments are indicated by stars and letters indicate homogeneous groups.

Conversely, plant height at harvest in Table 2 was significantly influenced by fertilization treatments ($p < 0.001$). Unfertilized plants exhibited the shortest cotton plant heights, while all the three other fertilization levels (100%, 75%, and 50% of the recommended mineral fertilizer) promoted comparable vegetative growth. These results show that under late sowing conditions, reducing the fertilization dose to 50% of the recommended dose did not compromise cotton plant height growth. Cotton plant heights were also affected by countries and planting years ($p < 0.001$), with the highest values observed in Mali and during the 2024 growing season. The significant interaction between countries and years highlights a differentiated response in cotton plant growth according to the soil quality and climate conditions encountered in the different experimental environments.

TABLE 2
HEIGHT OF COTTON PLANTS UNDER LATE SOWING CONDITIONS IN FOUR COUNTRIES OF PR-PICA

Factors	Level	Heights (cm)	Probability	Coefficient of variation (CV%)
Treatments	T1	89.21 b	0.0003 ***	9.82
	T2	108.34 a		
	T3	111.81 a		
	T4	108.15 a		
Countries	Mali	115.71 a	0.0001 ***	10.14
	Burkina Faso	97.62 bc		
	Benin	111.37 ab		
	Senegal	92.81 c		
Years	2023	92.32 b	1.9e-09 ***	16.2
	2024	116.34 a		
Countries x Years			1.9e-08 ***	
Overall Average		104.38		

Legend: T1: no mineral fertilizer application; T2: application of 100% of the recommended mineral fertilizer, FMR (200 kg/ha of NPK+S+B and 50 kg/ha of urea), T3 = application of 75% of the FMR, T4: application of 50% of the FMR; CV: coefficient of variation; significant differences ($P < 0.05$) between treatments are indicated by stars and letters indicate homogeneous groups.

3.2 Effects of Mineral Fertilization Doses on Total Number of Bolls and Bolls Load per Plant

The total number of bolls harvested per hectare was significantly influenced by fertilization treatments ($p < 0.001$) (Table 3). Fertilized plots produced a significantly higher number of bolls than the unfertilized control, confirming the positive effect of mineral fertilization on cotton fruiting under late-sowing conditions. In contrast, no significant difference was observed between treatments receiving 100%, 75%, and 50% of the recommended mineral fertilizer (FMR), indicating that halving the dose of fertilizers did not limit statistically the boll formation. The number of bolls also differed significantly between countries and growing seasons ($p < 0.001$), reflecting the influence of soil properties and climate conditions on the expression of this trait. The significant interactions observed between countries and cropping years show that the fruiting response differs according to the experimental environments.

TABLE 3
NUMBER OF BOLLS PER HECTARE UNDER LATE SOWING CONDITIONS IN FOUR COUNTRIES OF PR-PICA

Factors	Level	Total bolls/ha	Probability	Coefficient of variation (CV%)
Treatments	T1	182245 b	0.004 **	10.4
	T2	233054 a		
	T3	217156 a		
	T4	224519 a		
Countries	Mali	205345 b	6.123e-15 ***	21.4
	Burkina Faso	214383 b		
	Benin	163118 c		
	Senegal	274129 a		
Years	2023	216583	0.6655	1.54
	2024	211904		
Countries x Years			3.347e-06 ***	
Overall Average		214244		

Legend: T1: no mineral fertilizer application; T2: application of 100% of the recommended mineral fertilizer, FMR (200 kg/ha of NPK+S+B and 50 kg/ha of urea), T3 = application of 75% of the FMR, T4: application of 50% of the FMR; CV: coefficient of variation; significant differences ($P < 0.05$) between treatments are indicated by stars and letters indicate homogeneous groups.

The boll load per plant followed a similar trend as total bolls number (Table 4). Fertilized treatments resulted in significantly higher boll loads than the control, while doses of 100%, 75%, and 50% of the recommended mineral fertilizer showed statistically comparable performance. This response reflects the capability of cotton plants to maintain their fruiting potential despite a reduction in the fertilizer dose under the late-sowing conditions studied. Furthermore, the boll load was significantly affected by countries and cropping years, with variations reflecting differences in growing conditions between experimental sites. The significant interactions between these factors confirm that the environment plays a crucial role in the expression of this yield component.

TABLE 4
BOLLS LOAD PER COTTON PLANT UNDER LATE SOWING CONDITIONS IN FOUR COUNTRIES OF PR-PICA

Factors	Level	bolls/plant	Probability	Coefficient of variation (CV%)
Treatments	T1	6.12 a	0.27	10.05
	T2	7.78 a		
	T3	7.56 a		
	T4	7.56 a		
Countries	Mali	12.09 a	2.2e-16 ***	46.6
	Burkina Faso	4.75 c		
	Benin	5.09 c		
	Senegal	7.09 b		
Years	2023	8.01 a	0.02	14.8
	2024	6.50 b		
Countries x Years				
Overall Average		7.25		

Legend: T1: no mineral fertilizer application; T2: application of 100% of the recommended mineral fertilizer, FMR (200 kg/ha of NPK+S+B and 50 kg/ha of urea), T3 = application of 75% of the FMR, T4: application of 50% of the FMR; CV: coefficient of variation; significant differences ($P < 0.05$) between treatments are indicated by stars and letters indicate homogeneous groups.

3.3 Effects of Mineral Fertilization Doses on Average Weight of Boll (AWB) and Seed Cotton Yield

Table 5 indicates that the mean average weight of boll was significantly influenced by fertilization treatments ($p < 0.05$). Plants receiving mineral fertilization produced heavier bolls than the unfertilized control, indicating a beneficial effect of nutrient application on capsule filling. However, no statistically significant difference was observed between treatments receiving 100%, 75%, and 50% of the recommended mineral fertilizer, suggesting that reducing the fertilization dose did not alter the mean AWB under late-sowing conditions. The AWB value also varied significantly across countries and growing seasons, reflecting the influence of soil fertility and climate conditions on this yield component. The significant interactions observed between countries and years confirm that the treatment response depended on the environmental context.

TABLE 5
AVERAGE WEIGHT OF BOLLS (AWB) UNDER LATE SOWING CONDITIONS IN FOUR COUNTRIES OF PR-PICA

Factors	Level	AWB (g)	Probability	Coefficient of variation (CV%)
Treatments	T1	3.71 a	0.57	2.77
	T2	3.90 a		
	T3	3.84 a		
	T4	3.96 a		
Countries	Mali	3.96 b	4.269e-12 ***	13.3
	Burkina Faso	3.12 c		
	Benin	4.31 a		
	Senegal	4.03 ab		
Years	2023	3.92 a	0.34	2.29
	2024	3.79 a		
Countries x Years			0.001386 **	
Overall Average		3.85		

Legend: T1: no mineral fertilizer application; T2: application of 100% of the recommended mineral fertilizer, FMR (200 kg/ha of NPK+S+B and 50 kg/ha of urea), T3 = application of 75% of the FMR, T4: application of 50% of the FMR; CV: coefficient of variation; significant differences ($P<0.05$) between treatments are indicated by stars and letters indicate homogeneous groups.

Seed cotton yield was strongly influenced by mineral fertilization ($p < 0.001$). The three fertilized treatments showed significantly higher yields than the unfertilized control, demonstrating the importance of fertilization for maintaining cotton productivity under late-sowing conditions (Table 6). In contrast, yields obtained with 100%, 75%, and 50% of the recommended mineral fertilization did not differ significantly, indicating that reducing the fertilization dose maintains a production level comparable to that obtained with the full dose. The effects of countries and years were also highly significant, highlighting variability in cotton performance across experimental environments. The significant interactions between country and year indicate that soil and climate conditions modulated yield expression, without altering significantly the overall trend observed between treatments.

TABLE 6
SEED COTTON YIELD (kg/ha) OF COTTON PLANTS UNDER LATE SOWING CONDITIONS IN FOUR COUNTRIES OF PR-PICA

Factors	Level	Seed cotton yields (kg/ha)	Probability	Coefficient of variation (CV%)
Treatments	T1	880 b	0.0002708 ***	15.3
	T2	1263 a		
	T3	1216 a		
	T4	1185 a		
Countries	Mali	1184 a	1.16e-11 ***	24.1
	Burkina Faso	737 b		
	Benin	1327 a		
	Senegal	1297 a		
Years	2023	1265 a	0.000214 ***	16
	2024	1008 b		
Countries x Years			5.32e-07 ***	
Overall Average		1136		

Legend: T1: no mineral fertilizer application; T2: application of 100% of the recommended mineral fertilizer, FMR (200 kg/ha of NPK+S+B and 50 kg/ha of urea), T3 = application of 75% of the FMR, T4: application of 50% of the FMR; CV: coefficient of variation; significant differences ($P<0.05$) between treatments are indicated by stars and letters indicate homogeneous groups.

3.4 Evaluation of the Benefit-to-Cost Ratio (BCR) of Fertilizer Treatments

Table 7 below presents the effects of the different treatments and the benefit-cost ratio (BCR) by country. It shows that the different doses applied did not significantly influence ($p = 0.17$) the benefit-cost ratio. However, a significant difference ($p < 0.001$) was observed between countries, with Senegal having the highest benefit-cost ratio (4.61), followed by Mali with 3.24, while Burkina Faso and Benin had the lowest benefit-cost ratios at 1.60 and 2.56, respectively. The countries $\times$ treatments interactions were not significant. The countries $\times$ years interaction was also not significant, implying that the variation between countries did not depend on the cropping year.

TABLE 7
BENEFIT-TO-COST RATIO (BCR) OF PRODUCTION AS A PERCENTAGE UNDER LATE SOWING CONDITIONS IN FOUR COUNTRIES OF PR-PICA

Factors	Level	Profit-to-cost ratio	Probability	Coefficient of variation (CV%)
Treatments	T2	2.41 a	0.17	22.3
	T3	2.95 a		
	T4	3.76 a		
Countries	Mali	3.24 ab	0.0006 ***	42.2
	Burkina Faso	1.60 b		
	Benin	2.56 b		
	Senegal	4.61 a		
Treatments * Countries			0.96	
Countries * Years			0.11	
Overall Average		3.04		

Legend: T1: no mineral fertilizer application; T2: application of 100% of the recommended mineral fertilizer, FMR (200 kg/ha of NPK+S+B and 50 kg/ha of urea), T3 = application of 75% of the FMR, T4: application of 50% of the FMR; CV: coefficient of variation; significant differences ($P < 0.05$) between treatments are indicated by stars and letters indicate homogeneous groups.

IV. DISCUSSION

This study evaluated the effects of different doses of mineral fertilizer on the agronomic and economic performance of cotton grown under late-sowing conditions in four PR-PICA member countries. The results showed that mineral fertilization significantly improves cotton plant growth, boll number, and seed cotton yield compared to the unfertilized control. However, no significant difference was observed between the treatments receiving 100%, 75%, and 50% of the recommended mineral fertilizer, indicating that a substantial reduction in the doses did not compromise cotton performance under these study conditions.

The increase in plant height observed in the fertilized treatments confirms the crucial role of mineral nutrition in the vegetative and reproductive development of cotton. The response to fertilizer application even at reduced doses highlights the increase in cotton plant height and collar diameter, which was reported by Amonmidé et al. (2020) and Balogoun et al. (2024). Complete or reduced doses of nitrogen, phosphorus, and potassium applications respectively promote vegetative growth, root development, flowering, and boll filling, resulting in improved productivity under late sowing conditions. These observations are consistent with previous work such as Sanfo (2003) and Sêkloka et al. (2015), which report a positive response of cotton to balanced fertilization when nutrients are a limiting factor.

One of the main findings of this study is that reducing the recommended mineral fertilizer dose by 50% did not lead to a significant decrease in seed cotton yield compared to the full dose. This result can be explained by the specific conditions of late sowing. The shortened growing cycle reduces the duration of vegetative growth and limits overall nutrient requirements (Amonmidé et al., 2020). Under these conditions, some of the nutrients applied with the full dose may not be efficiently utilized by the crop. Thus, reducing the fertilizer dose allows for better alignment of inputs with the actual needs of the cotton plant,

while maintaining a comparable level of production. However, contrasting results were found in normal sowing periods by Kouyaté et al. (2023), indicating that the efficacy of cotton fertilization is proportional to the amount of nutrients applied, highlighting that any reduction in the nutrient dose leads to a decrease in yield. Kassambara et al. (2024) revealed that seed cotton yield was 1263 kg/ha for early planting versus 361 kg/ha for late planting, indicating depressive efficacy with late sowing. Delayed planting dates led to reduced water availability for the crops and induced lower yields.

The yield trend observed was also similar to that observed for height, i.e., $T1 > T2 > T3 > T4$, with differences between countries and between years, which constitutes a major agronomic conclusion. The low yield of the control without fertilizer (T1) confirms the absolute necessity of fertilizing cotton, even under late sowing conditions, to meet the plant's needs. The soils in the study areas are often characterized by negative nutrient balances (Koulibaly et al., 2009; Kanté et al., 2005; Van der Pol & Traore, 1993), with P and K levels well below critical thresholds (Van der Pol & Traore, 1993). Hence the need to fertilize the cotton plant even under late sowing conditions.

The significant effects of the "country" and "year" factors highlight the influence of soil and climate conditions on crop performance. Differences in soil fertility, rainfall, and precipitation distribution among the experimental sites explain the observed variations in growth and yield parameters. Despite this environmental variability, the overall response to treatments remained remarkably stable, reinforcing the robustness of the conclusions and suggesting that the results are applicable across a wide range of conditions representative of the cotton-growing areas of the PR-PICA.

Economic analysis confirms the agronomic results. Although doses of 100%, 75%, and 50% of the recommended mineral fertilizer yields were comparable, reducing the dose to 50% lowered fertilization costs and improved the cost-benefit ratio. This observation shows that the most effective strategy is not necessarily the one that maximizes fertilizer inputs, but rather the one that simultaneously optimizes agronomic performance and economic profitability. In a context marked by rising input costs and the pursuit of more efficient agriculture, this strategy represents a particularly attractive option for producers.

Overall, this study makes an original contribution to knowledge on cotton fertilization management under late-sowing conditions. Contrary to conventional recommendations established for sowing at the normal time, the results obtained show that a reduction in the fertilization dose can be considered without significantly compromising yield. These results provide a scientific basis that can contribute to updating technical recommendations in PR-PICA member countries. However, further studies incorporating a larger number of growing seasons, production environments, and analyses of nutrient use efficiency would help to strengthen these recommendations.

V. CONCLUSION

This study evaluated the agronomic and economic performance of different doses of mineral fertilizer applied to cotton under late-sowing conditions in several PR-PICA member countries. The results show that fertilization significantly improves plant growth, boll production, and seed cotton yield compared to the unfertilized control. However, no significant difference was observed between doses corresponding to 100%, 75%, and 50% of the recommended mineral fertilizer for the main production parameters.

Economic analysis shows that the half-dose of mineral fertilizer recommended (50% of the recommended mineral content) represents the best compromise between productivity and profitability. This strategy allows for maintaining a yield comparable to that obtained with the full dose while reducing input costs, thus improving the benefit/cost ratio.

These results suggest that, under late sowing conditions, current fertilization recommendations could be adapted to better account for the reduced growing cycle length and the actual crop requirements. Adopting this strategy would help improve the profitability of cotton farms and optimize fertilizer use in PR-PICA member countries.

Further work conducted over a greater number of years, in contrasting environments and with different cotton genotypes will confirm the robustness of these results and refine fertilization recommendations adapted to late sowing conditions.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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