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RESEARCH ARTICLE

EFFECTS OF MINERAL FERTILIZATION AND *MUCUNA PRURIENS* ON PEST PRESSURE AND YIELD IN COTTON CROPS (*GOSSYPIMUM SPP.*) IN SOUTH-CENTRAL BENIN

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Abstract

Cotton (*Gossypium spp.*) occupies a prominent place in the Beninese economy, but pest pressure management remains one of the major constraints of the sector. This study aims to evaluate the comparative effect of mineral fertilization alone (FR) and its combination with *Mucuna pruriens* residues (FRME) on pest diversity and cotton yield in South-Central Benin. The experiment was conducted using a randomized complete Fisher block design with two treatments and four replications. Results showed that pest species richness was identical (8 species), but the Shannon diversity index was lower under FRME (1.10) than under FR (1.6), indicating a less balanced community. Abundance analysis revealed a generalized suppressive effect of FRME, reducing the total number of pests by 22.3%. Furthermore, statistically significant differences were observed for several key pests: *Anomis flava* and *Amrasca biguttula* (foliage-feeding pests), as well as *Cryptophlebia leucotreta*, *Helicoverpa armigera*, and *Dysdercus völkerei* (fruit organ pests) had their populations significantly reduced under FRME. Finally, the FRME treatment generated a statistically significant yield gain of 194.5 kg/ha ($p = 0.0462$) compared to the FR control. This study demonstrates that the incorporation of *Mucuna pruriens* can simultaneously reduce the abundance of several important pests and increase yield, thus offering a promising strategy for more sustainable cotton production. The integration of *Mucuna pruriens* into the cotton fertilization system in Benin could have a significant impact on sustainable production policies, promoting not only a reduction in pests but also improved yields, thereby strengthening the economic viability of this essential crop for the country.

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Introduction:

Cotton (*Gossypium spp.*) constitutes one of the main export crops in West Africa, cultivated primarily for its fiber used in the textile industry (Kpadé **et al.**, 2019). In Benin, this crop has strategic economic importance, representing 40% of foreign exchange earnings, 12 to 13% of the national Gross Domestic Product (GDP), and approximately 60% of the industrial fabric, while providing income to more than one-third of the population (INSAE, 2020). Despite progress made in recent years with national production of 728,000 tons in 2021 (MAEP, 2021), the Beninese cotton sector faces major technical challenges, particularly pest pressure management, which constitutes a determining factor for obtaining high yields and quality fiber. Fertilization plays a crucial role in quantitative and qualitative yield improvement. The action of fertilization on plant health is a lever in pest management that deserves particular attention (Raynal **et al.**, 2014), especially as it promotes plant health and strengthens their resistance against bioaggressors (Badji **et al.**, 2020).

The intensification of phytosanitary control, with the emergence of new pests such as *Amrasca biguttula* (jassids), leads to an increase in the number of treatments (cost of 7,000 to 8,000 FCFA/ha per additional treatment), generating considerable financial and environmental impacts. This situation encourages revisiting cultural practices and exploring alternative strategies, particularly the use of organic amendments to optimize pest control (Raynal **et al.**, 2014). Understanding the interactions between fertilization practices and the agricultural ecosystem, where nutrients, soil, and pests interact dynamically, suggests the existence of a link between the type of fertilization used and pest pressure. This study aims to evaluate the comparative effect of conventional mineral fertilization and its combination with *Mucuna pruriens* residues on: (i) the diversity and abundance of cotton pests, and (ii) seed cotton yield under the pedoclimatic conditions of South-Central Benin.

Material and Methods:

Study area:

The experiment was conducted in the village of Gobaix, Djidja Municipality, located in the South-Central zone of Benin (**Figure 1**). This municipality constitutes the main cotton production zone of the region, encompassing the Departments of Collines, Zou, Couffo, Mono, and Plateau. The Municipality of Djidja is bounded to the south by the Municipalities of Abomey, Agbangnizoun, Bohicon, and Za-Kpota, to the west by the Department of Couffo (Municipality of Aplahoué) and the Republic of Togo, to the east by the Municipality of Covè, and to the north by the Department of Collines (Municipalities of Dassa and Savalou) (DGCS-ODD, 2019).

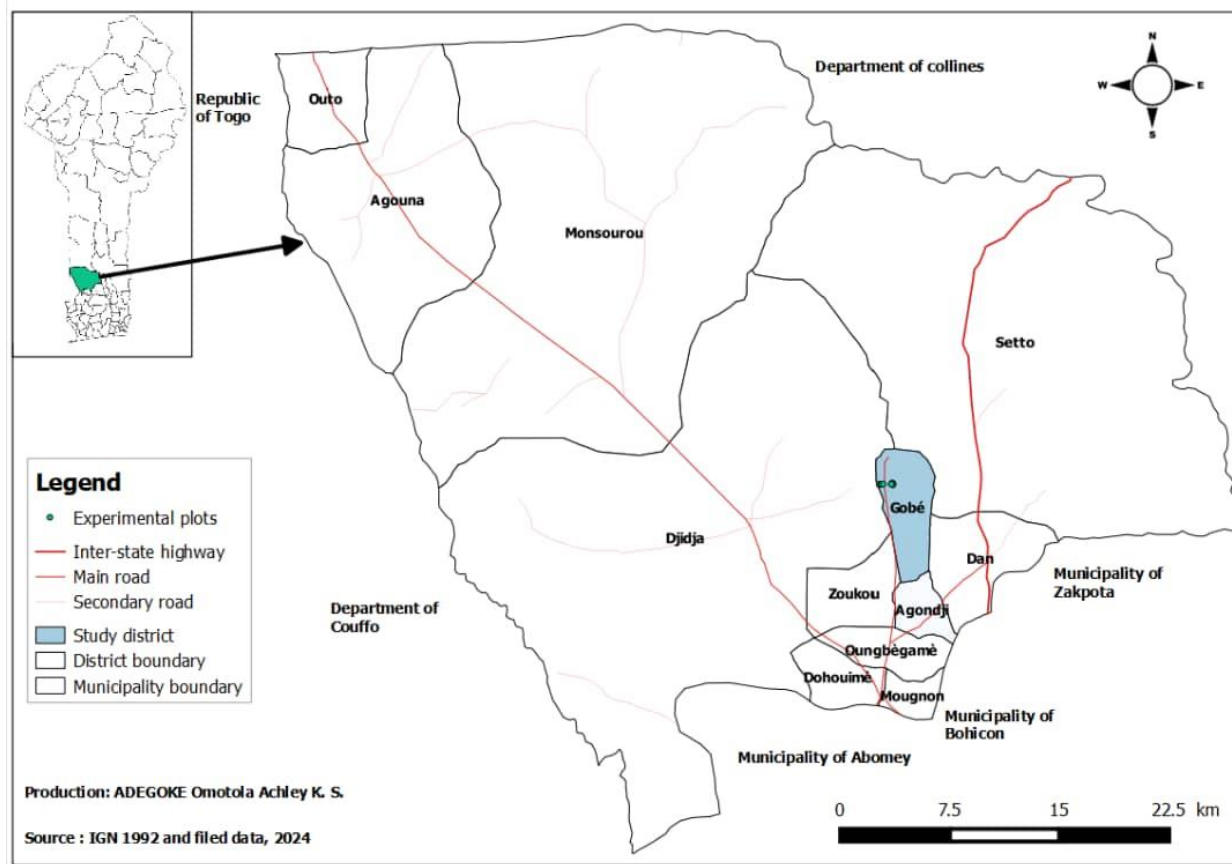


Figure 1. Geographic map of Djidja Municipality in Benin

Plant material and inputs:

The plant material used was the cotton variety KET 782, developed by the Cotton Research Institute (CRI) and recommended for the South-Central zone of Benin excluding the Collines departments. The mineral fertilizers were Super Simple Phosphate (SSP) and urea (46% N), applied according to doses recommended by CRI. The organic matter used was *Mucuna pruriens* (velvet bean) biomass, a cover legume recognized for its soil fertility improvement properties.

Experimental design:

The experiment was established according to a randomized complete Fisher block design with two treatments and four replications, for a total of eight experimental plots of 0.5 ha each (**Figure 2**). The studied treatments were:

Recommended Fertilizers (FR): Application of 200 kg/ha of SSP and 100 kg/ha of urea according to CRI technical recommendations.

Formulated Fertilizer (FRME): Recommended Fertilizer + Buried *Mucuna pruriens* (FRME):

Application of mineral fertilizer (FR) + incorporation of *Mucuna pruriens* residues. *Mucuna pruriens* was sown in 2023 with a density of 47,619 plants/ha (spacing of 0.60 m × 0.70 m), generating an estimated biomass of 3,000 kg/ha of dry matter. Residues were preserved in the field and incorporated into the soil during plowing preceding cotton crop establishment

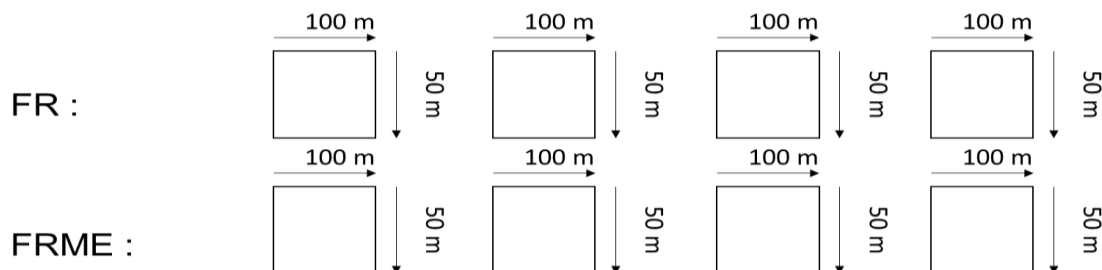


Figure 2. Experimental design. FR: Recommended Fertilization – control, FRME: Recommended Fertilization + Buried Mucuna

Experiment conduct and data collection:

Cotton sowing was performed during the optimal period from June 25 to July 15 with spacing of 0.80 m between rows and 0.40 m between hills, corresponding to a theoretical density of 62,500 plants/ha, or 31,250 plants per experimental plot. Cultural practices (weeding, earthing up) and the phytosanitary program were applied uniformly to all treatments according to CRI technical recommendations. Pest inventories were conducted weekly on 25 plants per plot, systematically selected, from 14 to 126 days after emergence (JAL). Data collected for each pest species included the number of individuals per species, the number of attacked plants, and the developmental stage of pests. Inventoried species included: *Anomisflava*, *Syleptederogata*, *Dysdercusvölkeri*, *Cryptophlebialeucotreta*, *Pectinophoragossypiella*, *Amrascabiguttula*, *Earias* spp., and *Helicoverpaarmigera*. Seed cotton yield was determined by weighing the total production of each experimental plot at harvest, then extrapolated to kg/ha.

Statistical data analysis:

The Shannon diversity index (H') was calculated for each treatment using the 'vegan' package of R software according to the formula (Equation (1)):

$$H' = -\sum_{i=1}^s p_i \cdot \log_2(p_i) \quad (1)$$

where p_i = the relative abundance of species i ($p_i = n_i/N$), n_i = the number of individuals counted for a present species, N = the total number of individuals counted, all species combined, s = the total number or cardinal of the list of present species.

The effect of treatments on pest abundance was analyzed using generalized linear models (GLM) of the Poisson family, appropriate for count data. Yield comparison between treatments was performed by Student's t-test for independent samples, after verifying application conditions (normality and homoscedasticity). The significance threshold retained for all tests is $\alpha = 0.05$. Statistical analyses were performed using R software version 4.3.2 (2023-10-31).

Results:-

Influence of mineral and organic fertilization on pest diversity:

Shannon diversity indices:

Shannon diversity indices calculated for the two treatments reveal a significant difference: FR = 1.6 and FRME = 1.1 (Table 1). This difference of 0.5 points indicates that the FR treatment exhibits higher pest diversity than the FRME treatment.

The FRME treatment, with a lower index, suggests a less diversified pest community structure.

Table 1. Shannon diversity indices according to treatments

Practice	Shannon Index (H')
RF	1.6
FRME	1.1

FR: Recommended Fertilization – control, FRME: Recommended Fertilization + Buried Mucuna

Species richness and community structure:

Pest inventory reveals an identical species richness of 8 species for both treatments (Table 2). However, detailed abundance analysis reveals significant differences in pest community structure between the two treatments, with a

generalized suppressive effect of the FRME treatment. The FRME treatment presents systematically lower numbers for all pest species compared to the FR control. This reduction is particularly marked for: *Cryptophlebia leucotreta* (20 individuals versus 29 in FR, a 31% reduction), *Anomis flava* (26 versus 36, a 27.8% reduction), *Helicoverpa armigera* (18 versus 24, a 25.0% reduction), *Earias spp.* (30 versus 39, a 23.1% reduction), and *Pectinophora gossypiella* (28 versus 35, a 20% reduction). Other species also show notable reductions: *Amrasca biguttula* (35 versus 44, a 20.5% reduction), *Dysdercus völkerei* (32 versus 38, a 15.8% reduction), and *Syllepte derogata* (1 versus 2, a 50% reduction). In total, the FRME treatment recorded an overall reduction of 22.3% in the total number of individuals (190 individuals versus 247 in FR).

Table 2. Pest abundance according to treatments

Species	Number of individuals		Variation (%)*
	FR	FRME	
<i>Anomisflava</i>	36	26	-27.8
<i>Sylleptederogata</i>	2	1	-50
<i>Dysdercusvölkeri</i>	38	32	-15.8
<i>Cryptophlebialeucotreta</i>	29	20	-31
<i>Pectinophoragossypiella</i>	35	28	-20
<i>Amrascabiguttula</i>	44	35	-20.5
<i>Earias spp.</i>	39	30	-23.1
<i>Helicoverpaarmigera</i>	24	18	-25
Total individuals	247	190	-22.3
Species richness	8	8	0

FR: Recommended Fertilization; **FRME:** Recommended Fertilization + Buried *Mucuna pruriens*; ***Variation (%) = [(FRME Value - FR Value) / FR Value] × 100**

Effect of treatments on pest presence:

Statistical analysis of treatment effects on the presence of the eight inventoried pest species reveals significant differences at the 5% threshold for all species considered (**Table 3**). P-values ranging from 0.03199 to 0.04415 (all less than 0.05) confirm that the type of fertilization significantly influences cotton pest presence. The FRME treatment systematically presents lower numbers compared to the FR control for all pest species. The most marked reductions are observed in *Cryptophlebia leucotreta* (7 individuals versus 14 in FR), *Earias spp.* (9 versus 14), *Anomis flava* (13 versus 19), and *Helicoverpa armigera* (7 versus 10). Other species also show significant reductions: *Dysdercus völkerei* (8 versus 13), *Pectinophora gossypiella* (9 versus 12), *Syllepte derogata* (1 versus 4), and *Amrasca biguttula* (12 versus 17).

Table 3. Independence test (χ^2) between treatments and pest presence

Treatments	Number of caterpillars							
	<i>Anomis flava</i>	<i>Sylepted erogata</i>	<i>Dysdercus völkerei</i>	<i>Cryptophlebia leucotreta</i>	<i>Pectinophora gossypiella</i>	<i>Amrasca biguttula</i>	<i>Earias spp.</i>	<i>Helicoverpa armigera</i>
Recommended fertilization	19	4	13	14	12	17	14	10
Recommended fertilization + <i>Mucuna Pruriens</i>	13	1	8	7	9	12	9	7
χ^2 statistic	0.6864	0.833	0.6286	0.74	0.624	0.435	0.36	0.769
Degrees of freedom	1	1	1	1	1	1	1	1
Pr(>chisq)	0.04074*	0.04228*	0.03199*	0.0386*	0.0447*	0.0348*	0.03625*	0.04415*

*Significant at 5% threshold ($p < 0.05$)

Effect of fertilization practices on foliage-feeding pests:

Statistical analysis of treatment effects on the presence of the eight inventoried pest species reveals significant differences at the 5% threshold for all species considered (Table 3). P-values ranging from 0.03199 to 0.04415 (all less than 0.05) confirm that the type of fertilization significantly influences cotton pest presence. The FRME treatment systematically presents lower numbers compared to the FR control for all pest species. The most marked reductions are observed in *Cryptophlebia leucotreta* (7 individuals versus 14 in FR), *Earias spp.* (9 versus 14), *Anomis flava* (13 versus 19), and *Helicoverpa armigera* (7 versus 10). Other species also show significant reductions: *Dysdercus völkerei* (8 versus 13), *Pectinophora gossypiella* (9 versus 12), *Sylepte derogata* (1 versus 4), and *Amrasca biguttula* (12 versus 17).

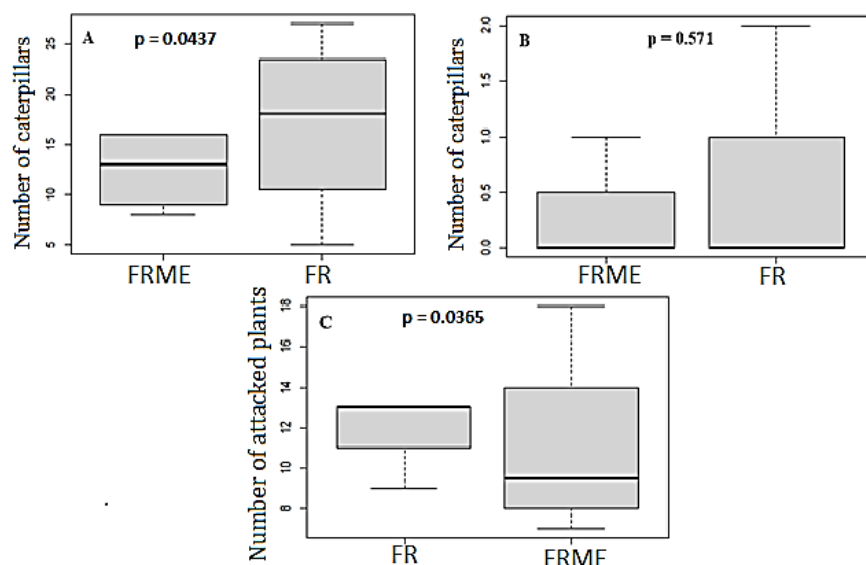


Figure 3. Number of *Anomisflava* caterpillars (A), *Sylleptederogata* (B), and plants attacked by *Amrascabiguttula* (jassids) (C) during the cotton cycle. FR: Recommended Fertilization – control, FRME: Recommended Fertilization + Buried *Mucunapruriens*

Effect of fertilization practices on fruit organ pests:

Analysis of fruit organ pest abundance (**Figure 4**) highlights a beneficial and significant effect of combined fertilization (FR + *Mucuna pruriens*) on the majority of studied species. The FRME treatment significantly reduces populations of 4 of the 5 carpophagous and polyphagous pests monitored. Significant reductions were thus recorded. For *Cryptophlebia leucotreta* (**Figure 4A**), the number of caterpillars is significantly lower under FRME treatment (median = 5) than under FR treatment (median = 8), with a p-value = 0.0389. No significant effect of fertilization practices was detected ($p = 0.729$) for *Earias* sp. (**Figure 4B**). Infestation levels for this pest remained similar between the two treatments. The abundance of *Helicoverpa armigera* (**Figure 4C**) is significantly reduced ($p = 0.0379$), going from a median of 7 caterpillars under RF to 5 under FRME. A similar trend is observed for *Pectinophora gossypiella* (**Figure 4D**), where the FRME treatment presents a lower number of caterpillars (median = 9) than FR (median = 10; $p = 0.488$) but this difference is not statistically significant at the 5% threshold. Finally, the population of *Dysdercus völkerei* (**Figure 4E**) is also significantly lower with FRME treatment (median = 8 bugs) than with FR (median = 10; $p = 0.0434$).

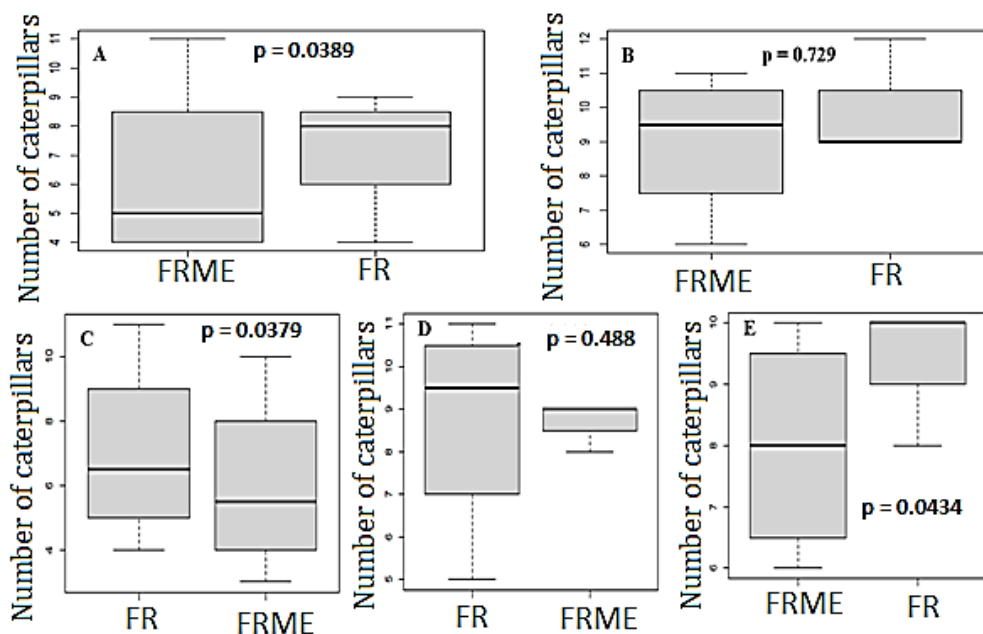


Figure 4. Number of caterpillars of *Cryptophlebia leucotreta* (A), *Earias spp.* (B), *Helicoverpa armigera* (C), *Pectinophora gossypiella* (D), and *Dysdercus völkerei* (E) during the cotton cycle. FR: Recommended Fertilization – control, FRME: Recommended Fertilization + Buried *Mucuna pruriens*

Temporal dynamics of pests:

Analysis of pest temporal evolution allows distinguishing three main categories according to their activity period.

Foliage-feeding pests (vegetative stage):

Pests attacking vegetative organs present distinct dynamics. *Anomis flava* presents an infestation peak at 28 days after emergence (JAL), with more marked persistence on FR plots until 56 JAL (**Figure 5A**). *Syllepte derogata* appears early (14 JAL) then disappears rapidly, testifying to the effectiveness of the first phytosanitary treatments (**Figure 5B**). *Amrasca biguttula* (jassids) is characterized by continuous activity throughout the cultural cycle, with variable abundance peaks according to treatments (**Figure 5C**). Plots under mineral fertilization alone (FR) showed stronger infestation between 70 and 84 JAL, while FRME plots presented later peaks, between 84 and 98 JAL, then from 126 JAL. A notable absence of jassids was observed between 28 and 42 JAL, coinciding with the application of the first insecticide treatments specifically targeting this pest in the phytosanitary program.

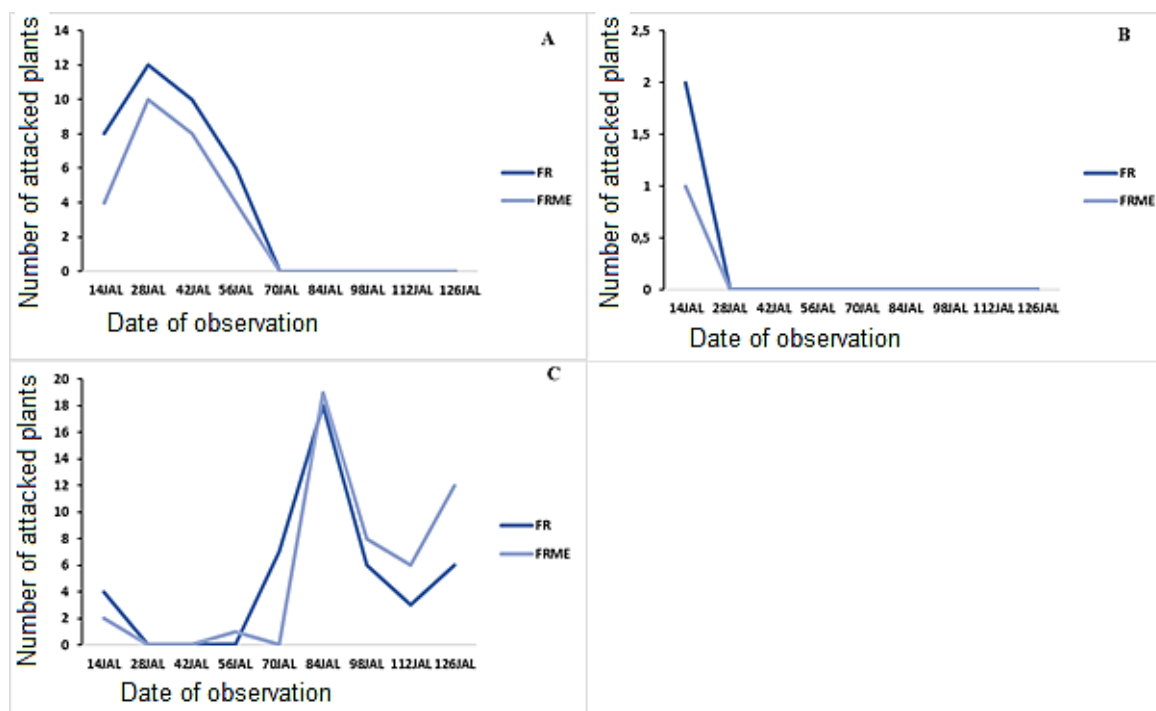


Figure 5. Evolution of the number of plants attacked by *A. flava* (A), *S. derogata* (B), and *A. biguttula* (C) as a function of time. JAL: Days After Emergence, FR: Recommended Fertilization – control, FRME: Recommended Fertilization + Buried *Mucuna pruriens*

Carpophagous pests (fruit organs):

Carpophagous pests, which specifically target fruit organs, present temporal dynamics closely linked to cotton reproductive development. *Cryptophlebia leucotreta* (**Figure 6A**) and *Pectinophora gossypiella* (**Figure 6B**) display maximum activity between 70 and 98 days after emergence (JAL), a period that coincides with fruiting and boll formation stages. Although first infestations were often observed earlier in the FRME treatment, suggesting potentially increased initial attractiveness, the persistence of these pest populations generally proved more marked in the RF treatment. *Dysdercus vólkeri* is distinguished by its late appearance, observed from 112 days after emergence (JAL), which coincides with the boll opening stage (**Figure 6C**). Although present in both treatments, its abundance was significantly higher in control plots (FR) than in those amended with *Mucuna pruriens* (FRME).

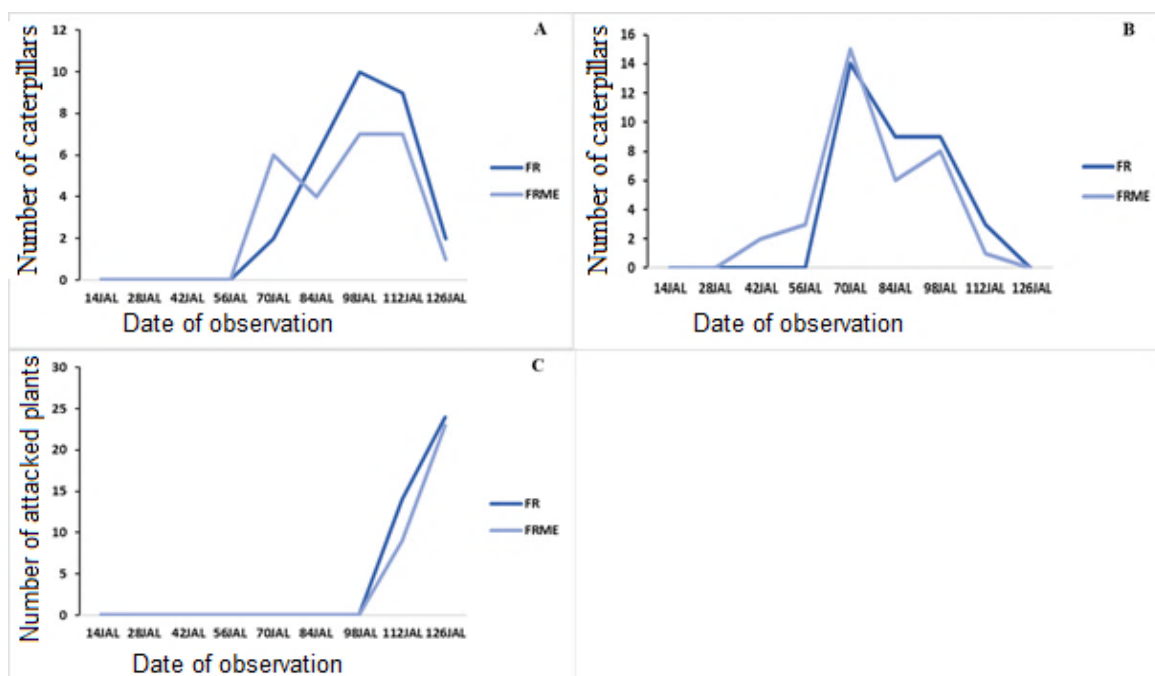


Figure 6. Evolution of the number of *C. leucotreta* (A), *P. gossypiella* (B), and *D. völkerei* (C) as a function of time. JAL: Days After Emergence, FR: Recommended Fertilization – control, FRME: Recommended Fertilization + Buried *Mucuna pruriens*

Polyphagous pests (attack vegetative + fruit):

The infestation dynamics of *Earias spp.* reveal a distinct profile between treatments (Figure 7A). First infestations appeared earlier in FRME plots but experienced rapid decline until total disappearance at 84 days after emergence (JAL). Conversely, in FR plots, infestation reached a later peak (42 JAL) and was maintained until 98 JAL. The presence of this pest during both vegetative and reproductive phases of cotton confirms its polyphagous character, attacking both vegetative organs and fruit organs. *Helicoverpa armigera* presents contrasting infestation dynamics between treatments (Figure 7B). FRME plots recorded early infestation with an important peak at 42 JAL, followed by complete disappearance from 70 JAL. In contrast, FR plots maintained significant pest pressure beyond 70 JAL. This prolonged attack on vegetative and fruit organs throughout the cycle confirms the status of *H. armigera* as a particularly formidable polyphagous pest in cotton cultivation.

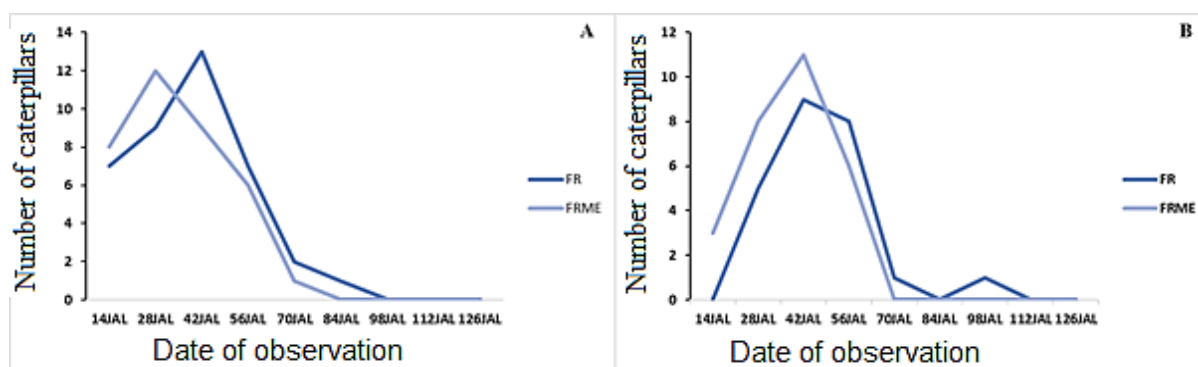


Figure 7. Evolution of the number of plants attacked by *Earias spp.* (A) and *H. armigera* (B) as a function of time. JAL: Days After Emergence, FR: Recommended Fertilization – control, FRME: Recommended Fertilization + Buried *Mucuna pruriens*.

Effect of treatments on yield:

Analysis of seed cotton yield reveals a numerical advantage for the FRME treatment compared to the FR control (Table 4). The average yield of the FRME treatment (Recommended Fertilization + Buried *Mucuna pruriens*) amounts to 1,728.5 kg/ha, versus 1,534 kg/ha for the FR treatment (Recommended Fertilization), representing a positive difference of 194.5 kg/ha in favor of combined fertilization. This difference is statistically significant ($p = 0.0462$) at the 5% threshold, indicating a real positive effect of *Mucuna pruriens* incorporation on yield. This improvement represents an economic gain of 58,350 FCFA per hectare, based on the standard selling price of seed cotton in Benin.

Table 4. Comparison of average yields according to treatments

Fertilization	Yield (kg/ha)	Difference (kg/ha)	Economic gain (FCFA/ha)
Recommended	1534		
Recommended + Buried <i>Mucuna pruriens</i>	1728.5	194.5	58,350
t statistic	-0.562	-	-
P-value	0.0462*	-	-

Discussion:

This study demonstrates that the integration of *Mucuna pruriens* residues into the cotton fertilization regime modulates both pest communities and yield, thus validating our initial hypotheses.

Effect on pest diversity

The FRME practice exerted a differentiated but notable impact on pests. Although species richness remained identical between treatments, the significant reduction in Shannon index under FRME (1.10 versus 1.6 for FR) indicates a restructuring of the pest community. This decrease suggests increased dominance of certain species, potentially linked to a modification of host plant biochemical properties induced by organic matter (Zhang et al., 2021). This interpretation is supported by the overall 22.3% reduction in total pest abundance under FRME, observed in inventory data. Population dynamics allowed refining this overall finding. The effect of fertilization was not uniform on all pests but selective and dependent on ecological niche. For fruit organ pests, the beneficial effect of FRME was most marked, with significant reductions in populations of *Cryptophlebia leucotreta*, *Helicoverpa armigera*, and *Dysdercus völkerei*. This result is of major agronomic importance, as these species directly target production organs. Combined fertilization thus seems to induce increased resistance or tolerance of cotton during its reproductive phase, limiting damage to bolls. The absence of significant effect on *Earias sp.* and *Pectinophora gossypiella* indicates, however, that the mechanisms at play are complex and species-specific. Regarding foliage-feeding pests, the effect was more contrasting. The significant reduction of *Anomis flava* under FRME is consistent with a general suppressive effect. However, the increase in attacks by *Amrasca biguttula* (jassids) under FRME reveals a counter-intuitive effect. This could be explained by a modification of nutritional quality or leaf architecture more favorable to this sap-sucker, a documented phenomenon where nutritional imbalance can favor certain types of pests (Raynal et al., 2014; Badji et al., 2020). The absence of effect on *Syllepte derogata* is probably linked to its very low abundance in the trial. Temporal dynamics provided valuable complementary insight. The earlier occurrence of certain infestations (e.g., *Helicoverpa armigera*) under FRME, but their faster resolution, could indicate more efficient induction of plant defense mechanisms after stress recognition, a process known as "priming" (Badji et al., 2020). The longer persistence of pests in the FR treatment suggests, conversely, prolonged crop susceptibility.

Implications for integrated pest management

Finally, the most conclusive result of this study is the yield increase under FRME, with a gain of 194.5 kg/ha. This benefit is likely the synergistic result of better plant nutrition and globally reduced pest pressure, particularly on fruit

organs. This gain is in line with the work of Djenontin et al. (2003) and validates the third hypothesis of this study. It demonstrates the potential agronomic profitability of *Mucuna pruriens* integration, beyond its sole advantages for soil fertility. The incorporation of *Mucuna pruriens* into fertilization practices can play a key role in pest management by promoting a more balanced and diverse ecosystem. By using more sustainable fertilization methods such as FRME, farmers can reduce their dependence on chemical pesticides, contributing to a healthier environment. The reduction of certain pest populations through organic fertilization practices highlights the importance of monitoring pest biodiversity to adjust interventions. It is essential to educate farmers on the importance of biological diversity and the use of integrated pest management techniques that combine organic fertilization and cultural practices. Policy makers should encourage continued research on sustainable agricultural practices and support participatory research to adapt integrated pest management strategies to local conditions. Integrating sustainable fertilization methods such as FRME into national agricultural policies could promote wider adoption and significantly improve yields in the cotton sector.

Conclusion:

The incorporation of *Mucuna pruriens* residues into the cotton fertilization regime reduced pest communities and increased cotton yield. The application of this fertilizer by cotton producers will induce a beneficial effect potentiating phytosanitary treatments with a considerable gain of 194.5 kg/ha. This study contributes to the development of technical references for integrated and sustainable fertilization management in cotton cultivation, aimed at reconciling productivity and environmental preservation. To maximize these benefits, farmers are advised to adopt fertilization practices incorporating *Mucuna pruriens*, and policymakers are encouraged to promote awareness and training programs on this innovative technique. This approach would strengthen the economic viability of the sector while supporting environmentally friendly agricultural development.

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Not

Author Contributions: -

GCO, OAA, KJE and DC contributed in conceptualization and writing the original draft. FY and CEA realized the data analysis and results interpretation. GCO and KJE charged the editing of the manuscript. All authors read and approved the final manuscript.

Conflict of interest:

All authors declare no conflicts of interest in this paper.

Ethics Approval: -

Not applicable to this paper.

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