

Agronomic and Phytosanitary Determinants of Cotton Yield in Côte d'Ivoire: A Five-Year Multi-Site Analysis (2021-2025)

Kouakou Malanno*, N'Goran Kouadio Emmanuel, Kouakou Brou Julien, Amangoua Nogbou Ferdinand, Bini Kouadio Kra Norbert, Kobenan Koffi Christophe, Gnapi Diane Estelle

National Center for Agronomic Research (CNRA) of Côte d'Ivoire, Cotton Research Program, Bouaké, Côte d'Ivoire
Email: *malanno.kouakou@cnra.ci

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Abstract

Cotton (*Gossypium hirsutum* L.) is a strategic cash crop in Côte d'Ivoire, yet substantial yield variability continues to constrain productivity under smallholder farming conditions. This study aimed to identify and quantify the principal agronomic and phytosanitary factors associated with cotton yield variation across the Ivorian cotton belt. We monitored 2693 farmer-managed cotton plots over five consecutive cropping seasons (2021-2025) in 59 localities distributed along a latitudinal gradient from 7.02°N to 10.49°N. Recorded variables included sowing date, variety, cultivation type, previous crop, and pest infestation levels. Descriptive summaries were established for the full monitored dataset, whereas non-parametric analyses (Kruskal-Wallis tests, Dunn's post-hoc comparisons, and Spearman correlations), Principal Component Analysis, and multiple regression were applied to an analytical subset of 1514 plots with non-zero yield and complete information for the variables analyzed. Within the monitored dataset, mean seed cotton yield was 1146.25 ± 314.18 kg/ha, with a median of 1115.00 kg/ha. Year was the strongest determinant of yield ($\eta^2 = 0.23$), followed by cultivation type ($\eta^2 = 0.13$). Animal traction was associated with substantially higher yields than manual cultivation (1167 vs. 899 kg/ha; $p < 0.0001$). Early sowing (May 21 - June 20; D1 - D3) improved yield by 15% - 20% relative to late sowing (July 1 - 20; D5 - D6). Among phytosanitary variables, jassids exhibited the strongest negative association with yield ($\rho = -0.28$; $p < 0.0001$), and PCA indicated that jassid pressure was the dominant axis structuring pest-related variation. Cotton yield in Côte d'Ivoire is shaped primarily by inter-annual environmental variability, cultivation practices, and jassid infestation. The results support the promotion of animal traction, timely sowing, and strengthened jassid management as practical lev-

ers for improving productivity in smallholder cotton systems.

Keywords

Cotton Yield, Côte d'Ivoire, Jassids, *Amrasca biguttula*, Sowing Date, Cultivation Practices

1. Introduction

Cotton (*Gossypium hirsutum* L.) is one of the most important cash crops in West Africa, playing a crucial role in the economies of producing countries and the livelihoods of millions of smallholder farmers [1]. In Côte d'Ivoire, cotton cultivation is concentrated in the northern and central regions, where it constitutes the primary source of income for rural communities. Despite its economic importance, cotton production in Côte d'Ivoire faces numerous challenges that limit yield potential. These include erratic rainfall patterns associated with climate change, declining soil fertility, limited access to inputs, and persistent pest pressure [2] [3]. Among arthropod pests, the cotton pest complex includes bollworms (*Helicoverpa armigera*, *Diparopsis watersi*, *Earias* spp., *Pectinophora gossypiella*), sucking pests (jassids, aphids, whiteflies), and stainers (*Dysdercus* spp.) [4]. Previous studies in Côte d'Ivoire have characterized the spatial distribution of cotton pests and identified distinct pest pressure zones across the cotton belt [2]. More specifically, jassids have been documented as an increasingly important constraint in Ivorian cotton systems. Long-term analyses showed a rise in damage levels, marked spatial heterogeneity, and a relationship between infestation patterns and rainfall variability [5]. Recent work has also highlighted annual and geographical shifts in jassid species composition and damage in cotton-growing areas of Côte d'Ivoire, reinforcing the need to consider jassids as a major and evolving phyto-sanitary issue [6]. However, the relative contribution of agronomic practices versus pest infestation to yield variability remains poorly quantified under real farming conditions. In parallel, varietal evaluation studies conducted in Côte d'Ivoire have shown that currently cultivated cotton varieties differ in agro-morphological, agronomic, sanitary, and technological performance, highlighting the importance of variety choice for both yield expression and fiber quality [7] [8]. Understanding the determinants of cotton yield is essential for developing targeted recommendations to improve productivity. While controlled experiments provide valuable insights, on-farm studies across multiple sites and seasons offer a more realistic assessment of factors affecting yield under actual production conditions. The objectives of this study were to: 1) characterize the variability of cotton yield across the Ivorian cotton belt over five cropping seasons (2021–2025); 2) identify the agronomic factors significantly affecting yield; 3) quantify the impact of major pest groups on yield; and 4) provide evidence-based recommendations for improving cotton productivity.

2. Materials and Methods

2.1. Study Area and Period

The study was conducted in the main cotton-growing areas of Côte d'Ivoire over five consecutive cropping seasons, from 2021 to 2025. Monitoring covered a wide latitudinal gradient ranging from 7.02°N to 10.49°N and included 59 production localities representative of the national cotton belt. These areas encompass contrasting agro-ecological conditions, particularly in terms of rainfall regime, temperature patterns, and cropping systems, thereby capturing a broad range of production environments within the Ivorian cotton belt.

2.2. Sampling Design

Table 1. Plot selection according to geographic position (North/South).

Abbreviation	North	South
D1 (May 21 - 31)	1	
D2 (June 01 - 10)	2	1
D3 (June 11 - 20)	3	3
D4 (June 21 - 30)	2	3
D5 (July 01 - 10)	1	2
D6 (July 11 - 20)	1	1
Total by locality	10	10

A total of 2693 cotton plots established in farmers' fields were monitored throughout the study period. The study followed an observational design based on farmer-managed plots rather than controlled experimental units. Sampling was distributed over five cropping seasons (2021-2025) and 59 localities of the national cotton belt. The sampling design was stratified by locality and balanced across years. Annual sampling effort ranged from 509 to 560 plots per year (mean = 538.6 ± 21.3 plots; CV = 4.0%), supporting temporal representativeness of the monitoring network. At the locality level, sampling intensity ranged from 20 to 70 plots per locality over the study period (median = 50; mean = 45.6), with 67.8% of localities contributing between 48 and 52 plots. Within each locality, plots were selected to reflect the dominant sowing periods practiced by farmers. Sowing calendars were first documented separately for each region, and the proportional representation of the main sowing windows was then used to guide plot selection. Consequently, in the northern region, where most sowing activities occurred between June 1 and June 30, approximately 70% of monitored plots were selected within this period. In contrast, in the southern region, the period from June 11 to July 10 encompassed about 80% of the monitored plots (**Table 1**). Plot selection

was regionally structured to reflect the diversity of cotton production situations across the Ivorian cotton belt. In practice, localities and monitored plots were selected to reflect the dominant sowing windows observed in the northern and southern production zones, so that the temporal distribution of sowing dates in the sample remained broadly representative of actual farmer practices within each region. This approach also ensured variation in cultivation type, varietal choice, cropping history, and local pest pressure. All monitored plots were farmer-managed. The monitoring design did not rely on a fixed panel of the same farmers or the same fields across all seasons; rather, plots were reselected each year within the study localities to maintain regional representativeness of ongoing farmer practices. All plots were managed according to farmers' usual practices, without researcher-imposed treatment allocation. Each plot was treated as one observational unit in the statistical analyses, with the objective of describing yield determinants under real production conditions rather than estimating treatment effects under experimental control.

2.3. Data Collection

2.3.1. Agronomic Variables

For each monitored plot, the following agronomic variables were recorded: sowing date, classified into six sowing decades: D1 (May 21 - 31), D2 (June 1 - 10), D3 (June 11 - 20), D4 (June 21 - 30), D5 (July 1 - 10), and D6 (July 11 - 20); cotton variety (CI-128, CI-123, Gouassou Fus1, Sicama Vir1, IRMA Q302 and Y331 BLT); previous crop grown before cotton (cotton, maize, rice, groundnut, bush fallow (cleared land), cashew, managed fallow, soybean, sesame, millet, or no previous crop); cultivation type (manual, animal traction, or motorized); plant density (plants ha⁻¹); number of insecticide treatments applied during the cropping season; treatment frequency, expressed as the average interval (days) between successive insecticide applications; and adjacent crops coded as binary variables indicating presence or absence of surrounding crop types.

2.3.2. Pest Monitoring

Pest infestations were monitored weekly on 30 randomly selected plants per plot. The following pest groups were assessed: bollworm complex (*Diparopsis watersii*, *Helicoverpa armigera*, *Earias* spp., *Pectinophora gossypiella*, and *Thaumatotibia leucotreta*, expressed as larvae per 30 plants); sucking pests including jassids, both attacked plants and adult populations, aphids (*Aphis gossypii*; attacked plants), and whiteflies (*Bemisia tabaci*; adult populations); cotton stainers (*Dysdercus* spp.; adult populations); and capsule damage, expressed as the percentage of damaged and rotten capsules.

2.3.3. Yield Measurement

Seed cotton yield (kg/ha) was calculated from the total seed cotton harvested from each plot and converted to a per-hectare basis using plot area. Yield values were used as the primary response variable in all analyses.

2.4. Statistical Analysis

All statistical analyses were performed using Python 3.12 with the *scipy*, *pandas*, and *scikit-learn* libraries. The full monitoring dataset comprised 2693 farmer-managed plots. Descriptive summaries of the monitoring network were first established for all monitored plots, whereas inferential analyses were conducted on an analytical subset restricted to 1514 plots with non-zero yield and complete information for the variables required by each model. Because yield data in this analytical subset violated the assumptions of normality and homogeneity of variances (Shapiro-Wilk $W = 0.65$, $p < 0.001$; Levene $p < 0.001$), non-parametric methods were used for group comparisons. Specifically, the Kruskal-Wallis H test was applied to compare yield across categories of variety, sowing decade, previous crop, cultivation type, company, and year. Effect size was quantified using eta-squared ($\eta^2 = H/(n - 1)$), with the following interpretation thresholds: <0.01 negligible, $0.01 - 0.06$ small, $0.06 - 0.14$ medium, and >0.14 large [9]. When the Kruskal-Wallis test was significant, Dunn's post-hoc test with Bonferroni correction was used for pairwise comparisons. Relationships between pest infestation variables and yield were evaluated using Spearman's rank correlation coefficient (ρ). Principal Component Analysis (PCA) was performed on standardized phytosanitary variables to identify the main multivariate gradients structuring pest pressure across plots; yield was projected as a supplementary variable to facilitate interpretation without contributing to construction of the principal axes. Finally, a multiple linear regression model was fitted to identify predictors independently associated with yield. Candidate predictors included agronomic variables retained from the univariate analyses together with quantitative phytosanitary indicators, plant density, and insecticide-treatment variables. Categorical predictors were introduced through indicator coding with explicit reference categories, as reflected in the regression results table. Unstandardized coefficients (B) were used to express the expected change in yield associated with a one-unit change in each predictor or with a comparison against the reference category, whereas standardized coefficients (β) were used to compare relative effect sizes among predictors measured on different scales. The regression model was interpreted as an explanatory model of association rather than a causal model, and the final model was fitted on the same analytical subset of 1514 plots with non-zero yield and complete information for the included predictors. Of the 2693 monitored plots, 1179 had missing data for at least one variable included in the multivariable model and were therefore excluded by listwise deletion. Multicollinearity was assessed using variance inflation factors (VIF), and all VIF values were below 2.0 (range: 1.02 - 1.80), well below the commonly used threshold of 5.0. The highest bivariate correlation among predictors was observed between jassid infestation and *Bemisia* abundance ($r = 0.67$). Residual diagnostics showed slight positive skewness ($\gamma_1 = 0.99$) and leptokurtosis ($\gamma_2 = 1.85$), both considered acceptable for this explanatory field-based model. The Durbin-Watson statistic ($DW = 1.29$) indicated mild positive autocorrelation, likely reflecting spatial clustering among monitored plots. Unless

otherwise specified, statistical significance was assessed at $\alpha = 0.05$.

3. Results

3.1. Descriptive Statistics of Cotton Yield

Across the full monitoring dataset of 2693 plots, the observed yield values used for descriptive reporting ranged from 600 to 2653 kg/ha, with a mean seed cotton yield of 1146.25 ± 314.18 kg/ha and a median of 1115 kg/ha. All subsequent inferential analyses reported in Sections 3.2 to 3.5 were performed on the analytical subset of 1514 plots with non-zero yield and complete information for the variables analyzed. This distinction is important for interpreting sample sizes consistently across the paper (**Table 2**).

Table 2. General yield statistics.

Indicator	Value	Unit
Mean yield	1146.25 ± 314.18	kg/ha
Median yield	1115.00	kg/ha
Standard deviation	314.18	kg/ha
Coefficient of variation	27.41	%
Minimum yield	600	kg/ha
Maximum yield	2653	kg/ha

3.2. Effect of Agronomic Factors on Yield

All agronomic factors tested showed significant effects on cotton yield (**Table 3**). Year was the strongest determinant, with a large effect size ($H = 350.96$, $p < 0.001$, $\eta^2 = 0.23$), followed by cultivation type, with a medium effect size ($H = 200.42$, $p < 0.001$, $\eta^2 = 0.13$). Sowing decade, company, previous crop, and variety showed smaller but significant effects ($\eta^2 = 0.008$ to 0.029).

Table 3. Kruskal-Wallis tests and effect sizes for agronomic factors.

Factor	df	H	p-value	Significant
Variety	5	16.80	0.004	Yes
Sowing decade	5	48.53	<0.001	Yes
Year	4	350.96	<0.001	Yes
Previous crop	10	29.85	<0.001	Yes
Cultivation type	2	200.42	<0.001	Yes
Company	3	46.97	<0.001	Yes

3.2.1. Effect of Sowing Date

Early sowing (D1 - D3, May 21 - June 20) produced significantly higher yields than late sowing (D5 - D6, July 1 - 20). Median yield for D2 (June 1 - 10) was 1139 kg/ha, compared with 1073 kg/ha for D4 (Jun 21 - 30), 962 kg/ha for D5 (July 1 - 10) and 892 kg/ha for D6 (July 11 - 20). Dunn's post-hoc tests confirmed significant differences between early and late sowing decades (**Figure 1**).

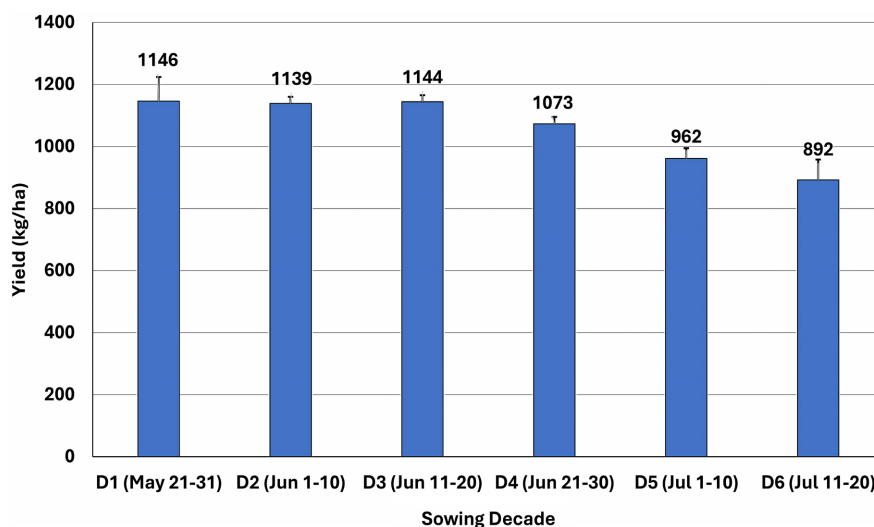


Figure 1. Yield distribution by sowing decade.

3.2.2. Effect of Cultivation Type

Cultivation type had the second largest effect on yield after year. Plots cultivated with animal traction achieved mean yields of 1167 kg/ha, significantly higher than manually cultivated plots (899 kg/ha; $Z = 14.13$, $p < 0.0001$). Motorized cultivation (1182 kg/ha) did not differ significantly from animal traction, but it outperformed manual cultivation (**Figure 2**).

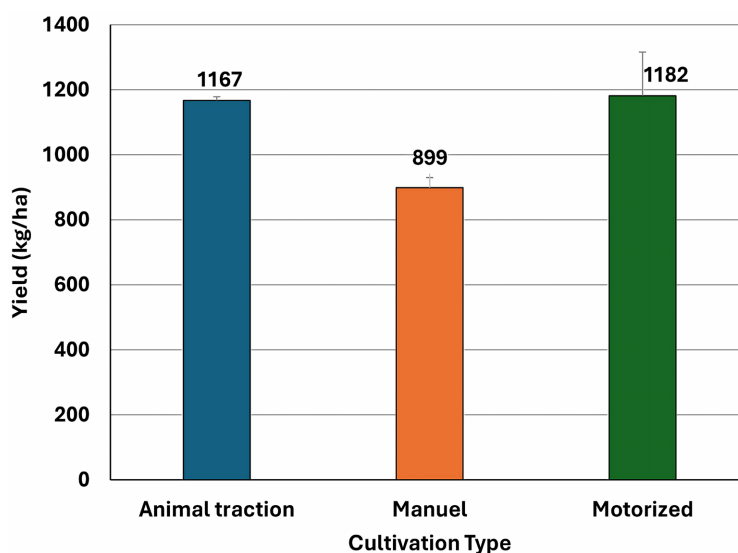


Figure 2. Yield distribution by cultivation type.

3.2.3. Effect of Variety

Significant differences were observed among varieties ($H = 16.80$, $p = 0.005$), although the effect size was small ($\eta^2 = 0.008$). CI-123 achieved the highest mean yield (1200 kg/ha), significantly outperforming GOUASSOU FUS1 (1100 kg/ha; $p = 0.004$) and SICAMA VIR1 (1031 kg/ha; $p = 0.004$) (Figure 3).

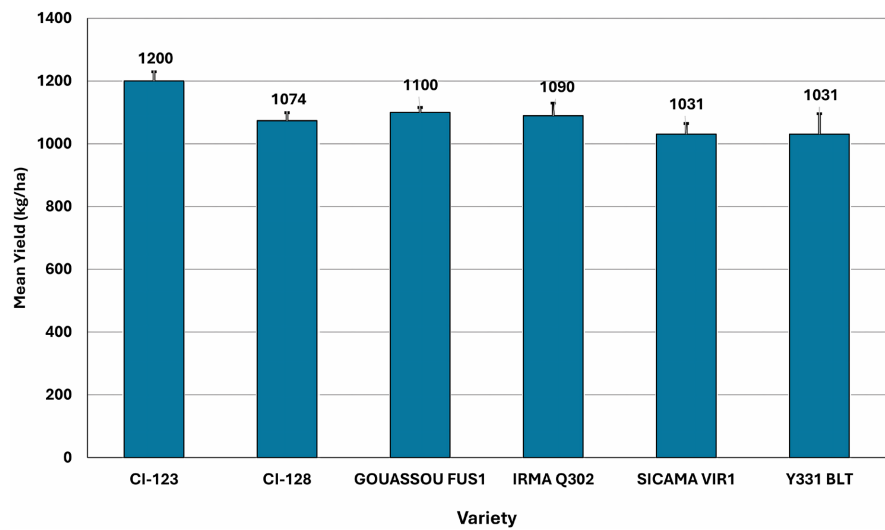


Figure 3. Yield distribution by cotton variety.

3.3. Temporal Variation in Yield (2021-2025)

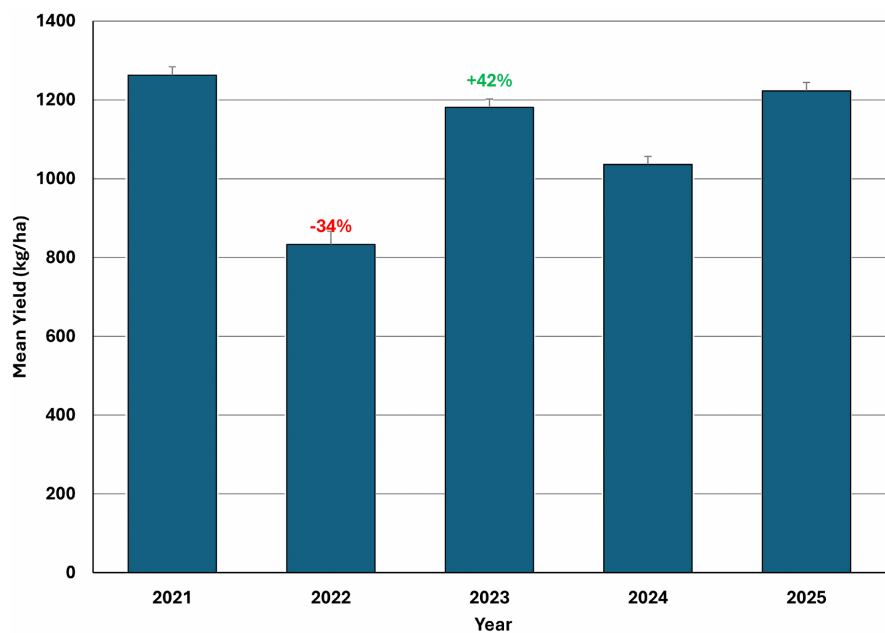


Figure 4. Temporal evolution of cotton yield (2021-2025).

Yield showed marked inter-annual variation (Figure 4). The year 2022 experienced a dramatic yield decline of 34% compared with 2021 (833 vs. 1263 kg/ha; $p < 0.0001$), followed by a strong recovery in 2023 (+42%; 1181 kg/ha). Yield de-

clined again in 2024 (1036 kg/ha) before recovering in 2025 (1223 kg/ha). These fluctuations likely reflect differences in seasonal and environmental conditions between years, although no weather variables were included in the present analyses.

3.4. Relationships between Pest Infestation and Yield

Spearman correlation analysis revealed significant negative correlations between several pest groups and cotton yield (Table 4). Jassids showed the strongest negative association with yield, both for attacked plants ($\rho = -0.273$, $p < 0.001$) and adult populations ($\rho = -0.281$, $p < 0.001$) (Figure 5). Aphids ($\rho = -0.092$, $p < 0.001$), *Dysdercus* ($\rho = -0.078$, $p = 0.002$), and *Diparopsis* larvae ($\rho = -0.070$, $p = 0.007$) also showed significant negative correlations. Unexpectedly, *Helicoverpa* larvae showed a weak positive correlation with yield ($\rho = 0.117$, $p < 0.001$). However, this association did not persist after multivariable adjustment, as *Helicoverpa* was not retained as an independent predictor in the final regression model, suggesting that the univariate signal was likely confounded rather than indicative of a positive effect on yield.

Table 4. Spearman correlations between pest variables and yield.

Variable	ρ (rho)	p-value	Significant
<i>Diparopsis</i> larvae	-0.07	0.006	Yes
<i>Helicoverpa</i> larvae	0.12	<0.001	Yes
<i>Earias</i> larvae	0.01	0.724	No
<i>Pectinophora</i> larvae	0.03	0.268	No
Aphids (attacked plants)	-0.09	<0.001	Yes
Jassids (attacked plants)	-0.27	<0.001	Yes
Jassids (population)	-0.28	<0.001	Yes
<i>Bemisia</i> (adults)	0.026	0.317	No
<i>Dysdercus</i> (adults)	-0.078	0.00248	Yes

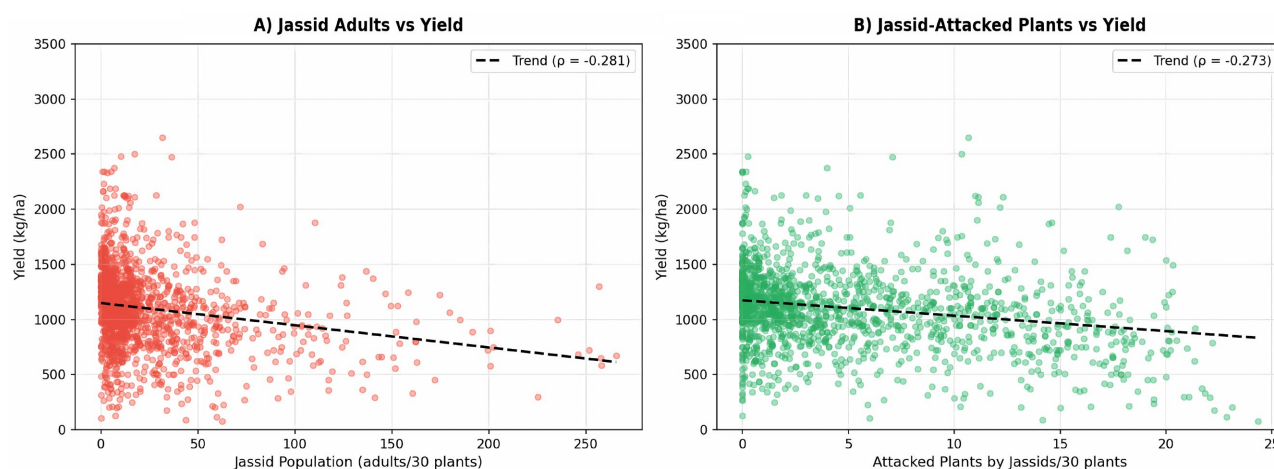


Figure 5. Relationship between jassid infestation and yield.

3.5. Multivariate Analysis of Pest Community Structure

3.5.1. Principal Component Analysis

Principal Component Analysis (PCA) performed on the phytosanitary variables (**Figure 6**) showed that the first two principal components together explained 41.9% of the total variance (PC1: 26.7%, PC2: 15.2%). PC1 was mainly associated with jassid infestation variables (attacked plants and adult populations), together with *Bemisia*, aphids, and *Dysdercus*, and can therefore be interpreted as a gradient of overall sucking-pest pressure. By contrast, PC2 was mainly structured by *Earias* and *Pectinophora*, corresponding more specifically to variation within the bollworm complex.

When yield was projected as a supplementary variable on the ordination plane (**Figure 7**), it was positioned in the opposite direction to the main PC1 pest gradient, indicating that higher sucking-pest pressure—particularly jassid pressure—was associated with lower cotton yield. This multivariate pattern is consistent with the negative correlations reported in **Table 4** and with the regression results identifying jassids as the strongest phytosanitary predictor of yield loss.

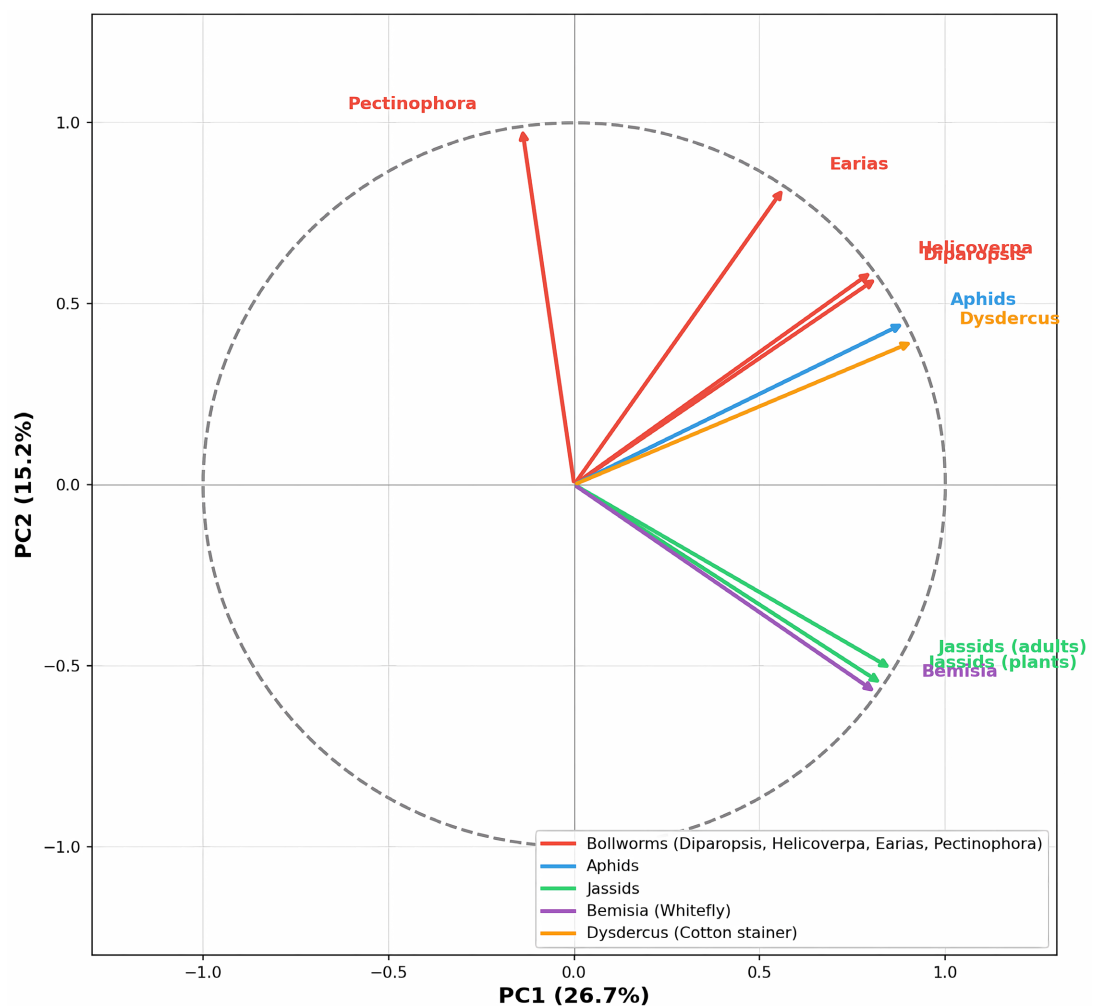


Figure 6. PCA correlation circle with pest variables.

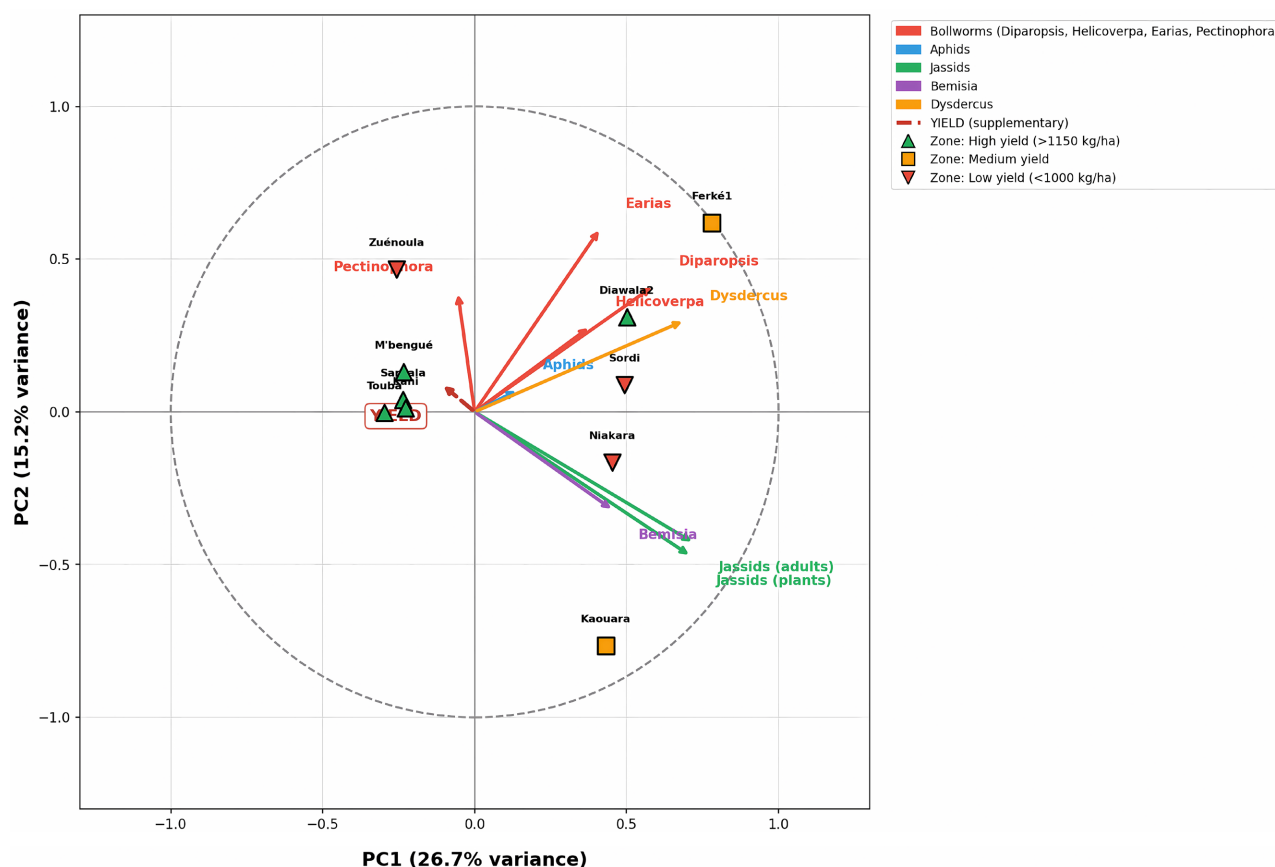


Figure 7. PCA biplot with yield as a supplementary variable.

3.5.2. Multiple Regression

1) Model Performance

The multiple regression model explained 16.12% of the variance in cotton yield ($R^2 = 0.16$). Although modest, this value is consistent with field-based agricultural studies in which yields are influenced by numerous unmeasured factors, including rainfall patterns, soil fertility, farmer expertise, and weed pressure. The model was highly significant ($F = 10.97$, $p < 0.0001$), confirming that the included predictors collectively contributed meaningfully to yield variation. As detailed in Section 2.4, this model was estimated on the complete-case subset of 1514 plots after listwise deletion of incomplete observations, and diagnostic checks indicated low multicollinearity together with only mild deviations from ideal residual assumptions.

2) Agronomic Factors

Manual cultivation was associated with a yield reduction of 156 kg/ha compared with animal traction ($p < 0.0001$), representing the largest agronomic effect identified in this study. Mechanized land preparation through animal traction likely improves soil preparation, reduces weed competition, and allows more timely field operations, all of which may contribute to higher yields (Table 5). Late sowing significantly penalized yield: D4 (June 21 - 30), -55 kg/ha compared with the optimal D3 period (June 11 - 20); D5 (July 1 - 10), -96 kg/ha compared with D3; and D6 (July 11 - 20), -168 kg/ha compared with D3. These results demon-

strate a clear gradient: each additional delay beyond June 20 resulted in progressively greater yield losses. Variety CI-128 underperformed Gouassou Fus1 by 119 kg/ha ($p = 0.0001$), suggesting that Gouassou Fus1 may be better adapted to local conditions or more tolerant of prevailing pest pressure.

3) Phytosanitary Factors

Jassid infestation on attacked plants showed the strongest negative effect among pests ($B = -8.98$, $p < 0.0001$). For every unit increase in jassid-attacked plants, yield decreased by approximately 9 kg/ha. This result confirms jassids as the primary yield-limiting pest in Ivorian cotton production. Each unit increase in *Dysdercus* infestation reduced yield by 13 kg/ha ($p = 0.001$). Both destroyed capsules (-3.17 kg/ha per 1% increase) and rotten capsules (-6.98 kg/ha per 1% increase) were also associated with significant yield reductions. Capsule damage likely integrates the cumulative effects of bollworm attacks together with environmental stressors (Table 5).

Table 5. Significant agronomic and phytosanitary predictors of cotton yield.

Rank	Variable	Type	Coefficient (B)	Std. Beta (β)	Std. Error	t-value	p-value
1	Manual cultivation (vs Animal traction)	Agronomic	-156.36	-0.498	22.65	-6.9	<0.0001
2	D6 (Jul 11 - 20) vs D3 (Jun 11 - 20)	Agronomic	-168.22	-0.536	68.27	-2.46	0.0139
3	CI-128 (vs GOUASSOU FUS1)	Agronomic	-118.52	-0.377	30.51	-3.88	0.0001
4	D5 (Jul 1 - 10) vs D3 (Jun 11 - 20)	Agronomic	-95.87	-0.305	29.17	-3.29	0.001
5	D4 (Jun 21 - 30) vs D3 (Jun 11 - 20)	Agronomic	-55.31	-0.176	19.01	-2.91	0.0037
6	Jassids (attacked plants)	Sanitary	-8.98	-0.152	2.16	-4.15	<0.0001
7	<i>Dysdercus</i>	Sanitary	-12.92	-0.097	4.02	-3.21	0.0013
8	Capsules destroyed (%)	Sanitary	-3.17	-0.077	1.09	-2.9	0.0038
9	Capsules rotten (%)	Sanitary	-6.98	-0.055	3.39	-2.06	0.0398

4. Discussion

This study provides a large-scale field-based assessment of the determinants of cotton yield under farmer-managed conditions in Côte d'Ivoire. By integrating five years of observations across 59 localities, the analysis offers a robust picture of yield variability under real production settings rather than controlled experimental environments. The predominance of year as the leading determinant of yield ($\eta^2 = 0.23$) indicates that substantial inter-annual variation affected cotton productivity during the study period. This pattern is consistent with the influence

of changing seasonal and environmental conditions across years, but the present dataset does not allow this effect to be attributed directly to climate or rainfall because no weather variables were included in the model. Among the manageable agronomic factors evaluated, cultivation type emerged as the most influential ($\eta^2 = 0.13$). The clear yield advantage associated with animal traction over manual cultivation suggests that labor organization and the timeliness of field operations are central components of productivity in Ivorian cotton systems, in line with previous work showing that animal traction helps overcome labor constraints and improve labor productivity in cotton-based farming systems in Côte d'Ivoire and West Africa [10] [11]. The broader structure of cotton-based cropping systems in Côte d'Ivoire also indicates that improvements in cultivation practices, crop management, and production organization are essential levers for increasing cotton output among Ivorian growers [12]. The effect of sowing date was also pronounced, with early sowing (D1 - D3) consistently outperforming later planting windows, consistent with earlier studies in Côte d'Ivoire and elsewhere in West Africa showing substantial yield penalties under delayed sowing in rainfed cotton systems [13] [14]. A central contribution of this study is the consistent identification of jassids as the pest group most strongly associated with yield reduction. Their negative relationship with yield was evident in both correlation analyses and the regression framework, indicating that jassids are a key phytosanitary constraint in the current production system, consistent with earlier reports from Côte d'Ivoire [5] [6]. The weak positive univariate association observed between *Helicoverpa* larvae and yield should therefore not be interpreted as evidence of a beneficial effect. Because this relationship disappeared after multivariable adjustment, it most likely reflects confounding by other plot-level characteristics associated with higher productivity, such as crop vigor, management conditions, or broader seasonal context. The comparatively weaker associations observed for bollworm-related variables should therefore be interpreted in the context of the recent restructuring of the pest complex following the invasion of *Amrasca biguttula*, which became dominant in Côte d'Ivoire from 2022 onward and shifted jassids from formerly minor pests to a major productivity constraint [6] [15] [16]. In this changed phytosanitary context, the growing weight of jassid pressure may partly explain why bollworm-related indicators appeared less strongly associated with yield in the present dataset. These results underscore the need to explicitly integrate jassids into the design of current phytosanitary protection strategies for cotton in Côte d'Ivoire [3] [17]. Varietal effects were statistically significant but comparatively modest, suggesting that variety choice contributes to productivity but does not override the stronger influences of seasonal conditions, crop management, and pest pressure. Several limitations should be acknowledged. Because the study was observational, the identified associations cannot be interpreted as definitive causal effects. In addition, the modest explanatory power of the regression model ($R^2 = 0.16$) indicates that other important drivers of yield, including rainfall distribution, soil fertility, weed pressure, farmer decision-making, and input qual-

ity, were not directly captured. Despite these limitations, the consistency of the major patterns across complementary analytical approaches strengthens confidence in the main conclusions.

5. Conclusion

In summary, this study shows that cotton yield performance in Côte d'Ivoire is jointly shaped by broad seasonal variability, farm-level agronomic decisions, and phytosanitary pressure. Across the factors evaluated, year, cultivation type, sowing date, and jassid infestation emerged as the most informative predictors of yield performance under farmer-managed conditions. Inter-annual variability was the dominant factor affecting yield ($\eta^2 = 0.23$), highlighting the sensitivity of cotton production to changing seasonal conditions across years rather than demonstrating a direct climatic effect. Among agronomic practices, cultivation type had the largest effect ($\eta^2 = 0.13$), with animal traction increasing yield by about 30% compared to manual cultivation. Early sowing before June 20 significantly improved yield relative to sowing during July 1 - 20. Jassids were the most damaging pest group ($\rho = -0.28$), negatively affecting yield across the cotton belt. Taken together, these findings provide a practical basis for strengthening cotton productivity strategies in Côte d'Ivoire. Priority actions should include improving access to animal traction and related field-operation support, securing earlier and more reliable sowing through timely input availability and advisory services, and reinforcing jassid-focused integrated pest management. Future research should combine agronomic, phytosanitary, edaphic, and climatic data to develop more predictive and decision-relevant models for cotton risk management.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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