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Field Evaluation of a Nitenpyram-Pyriproxyfen Formulation against Key Cotton Pests, Including the Invasive Jassid *Amrasca biguttula*, in Two Contrasting Cotton-Growing Zones of Côte d'Ivoire

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Abstract

Cotton production in Côte d'Ivoire is constrained by a complex of sucking and fruit-feeding pests, among which the invasive jassid *Amrasca biguttula* has emerged as a major concern. This study evaluated the field efficacy of a binary formulation containing nitenpyram (200 g/L) + pyriproxyfen (150 g/L) against key cotton pests under contrasting agroecological conditions. Trials were conducted at Bouaké and Nambingué using a randomized complete block design with four replicates. Three doses of the formulation (375, 500, and 750 mL/ha) were compared with an untreated control and a reference insecticide containing acetamiprid (64 g/L) + spinetoram (56 g/L). After treatment, we monitored the abundance of the dominant jassid, *Bemisia tabaci*, *Helicoverpa armigera*, and *Earias* spp., together with jassid damage. Across both sites, all doses of the nitenpyram-pyriproxyfen formulation significantly reduced jassid abundance and associated damage compared with the untreated control and the reference product, with 750 mL/ha providing the most consistent suppression. Effects on *Bemisia tabaci* were detected only at the site with higher whitefly pressure, whereas no meaningful control of *H. armigera* or *Earias* spp. was observed. These findings indicate that the tested formulation was most effective against the dominant jassid and provided only limited control of the other monitored pests under the conditions of this study.

Keywords

Cotton, Cotton Pest Complex, *Amrasca biguttula*, *Bemisia tabaci*, Nitenpyram, Pyriproxyfen, Field Efficacy

1. Introduction

Cotton remains a strategic cash crop in Côte d'Ivoire and across West Africa, and maintaining effective crop protection is essential for the performance and resilience of the sector [1].

Among the arthropod constraints currently affecting cotton, the invasive leafhopper *Amrasca biguttula* has become a major concern. Historically, the local cotton jassid complex in Côte d'Ivoire was mainly composed of *Jacobiasca lybica* and *Jacobiella facialis*. Since 2022, however, surveys have shown a major shift in species composition, with *A. biguttula* representing 90% - 100% of recorded jassids depending on locality [2] [3]. This shift helps explain why recent work in Côte d'Ivoire has reported strong annual and geographical variation in jassid composition and damage, while regional reports indicate that *A. biguttula* is now an expanding invasive pest in West and Central Africa capable of causing substantial cotton losses [2]-[4]. In Côte d'Ivoire, this pest has become especially problematic in northern and central cotton-growing areas, where recurrent infestations have increased the need for effective and operational field control options [2] [5].

Management of cotton jassids in Côte d'Ivoire has relied mainly on chemical control, but the recent dominance of *A. biguttula* within the local jassid complex has raised questions about the adequacy of products previously used against the former leafhopper community [2] [3]. In this context, evaluating formulations that combine complementary modes of action is important. Nitenpyram is a fast-acting systemic neonicotinoid with strong activity against piercing-sucking insects, whereas pyriproxyfen is an insect growth regulator that may help suppress population renewal by affecting immature stages [6] [7]. Their combination may therefore provide more stable field control than products designed primarily for broader pest complexes, especially under variable pest pressure across production zones, as suggested by previous studies on sucking pests in cotton [8] [9].

The objective of this study was to determine whether a nitenpyram-pyriproxyfen formulation proposed for cotton protection could effectively reduce the abundance of the main pest groups monitored in Ivorian cotton fields under two contrasting production conditions. Particular attention was given to the invasive jassid *Amrasca biguttula*, while *Bemisia tabaci*, *Helicoverpa armigera*, and *Earias* spp. were included to assess the extent of activity of the formulation across the monitored cotton pest complex.

2. Materials and Methods

2.1. Study Sites

The study was conducted during the 2024 cotton-growing season at two experimental sites in Côte d'Ivoire representing contrasting agroecological conditions. The first site was the cotton research station of the National Agricultural Research Center (CNRA) in Bouaké, located in the central cotton basin. The second site was Nambingué, a small research station in the northern cotton-producing zone used by CNRA to repeat field experiments under hotter and drier far-northern conditions. The two sites were selected deliberately because previous surveys in Côte d'Ivoire showed clear geographic differences in the abundance and damage caused by major cotton pests, including jassids [2] [5]. Bouaké and Nambingué therefore provided a relevant contrast for testing whether treatment efficacy remained stable under different pest-pressure profiles and environmental backgrounds.

2.2. Plant Material and Target Pests

The cotton variety CI-128 (*Gossypium hirsutum*), developed by CNRA, was used in all trials because it is adapted to local production conditions and is routinely used in agronomic and plant-protection evaluations in Côte d'Ivoire, allowing insecticidal performance to be assessed against a representative crop background [10]. Pest assessments were designed to test the field spectrum expected from the proposed formulation. The monitored pests therefore included the invasive jassid *Amrasca biguttula*, the whitefly *Bemisia tabaci*, and the bollworms *Helicoverpa armigera* and *Earias* spp., which together represent important components of the cotton pest complex in the study zones [4] [5]. Because recent outbreaks have made *A. biguttula* the dominant species within the local jassid complex in Côte d'Ivoire, special attention was given to its abundance and damage, whereas the other pests were included to determine whether the formulation could also contribute to broader pest management under field conditions [2] [3].

2.3. Insecticidal Treatments

Five treatments were evaluated: an untreated control, three doses of a binary formulation containing nitenpyram (200 g/L) and pyriproxyfen (150 g/L) applied at 375, 500, and 750 mL/ha, and a reference insecticide combining acetamiprid (64 g/L) and spinetoram (56 g/L) applied at 250 mL/ha (**Table 1**). The three rates of the test formulation were selected to compare field efficacy over a low-to-high dose range and to identify the rate associated with the most consistent response under local conditions. The acetamiprid + spinetoram treatment was included as a positive control because it represents an insecticidal standard already used in cotton protection programs and provided a benchmark for comparison under the same field conditions.

2.4. Experimental Design

A randomized complete block design with four replicates was used at each site. Each block contained the five treatments randomly assigned to elementary plots. As shown in Figure 1, each elementary plot measured 10 m × 9.6 m (96 m^2) and consisted of 12 rows spaced 0.80 m apart, each 10 m long. This layout provided a sufficiently large, treated area while preserving internal rows for assessment and reducing border interference between adjacent plots. Three foliar applications were made at 14-day intervals beginning 45 days after sowing, a crop stage corresponding to active vegetative development and the period when early jassid colonization becomes agronomically important in local cotton systems. This schedule was selected to assess treatment effects during the period when sucking-pest pressure usually increases. Treatments were applied with a calibrated backpack sprayer fitted with a constant-pressure system and a horizontal boom. A spray volume of 60 L/ha was maintained for all applications because the trial was conducted over a relatively narrow crop-development window and the same delivery conditions were required for all treatments and sites. Under these conditions, the fixed spray volume was intended to standardize treatment comparisons rather than optimize canopy coverage at each growth stage. Before each application, sprayer output was checked to verify that the target dose per hectare was delivered accurately, and the equipment was thoroughly rinsed between treatments to avoid cross-contamination.

Table 1. Insecticidal treatments evaluated in the study.

Treatment code	Treatment description	Application rate (mL/ha)
A	Untreated control	—
B	Nitenpyram 200 g/L + pyriproxyfen 150 g/L (EC)	375
C	Nitenpyram 200 g/L + pyriproxyfen 150 g/L (EC)	500
D	Nitenpyram 200 g/L + pyriproxyfen 150 g/L (EC)	750
E	Acetamiprid 64 g/L + spinetoram 56 g/L (EC)	250

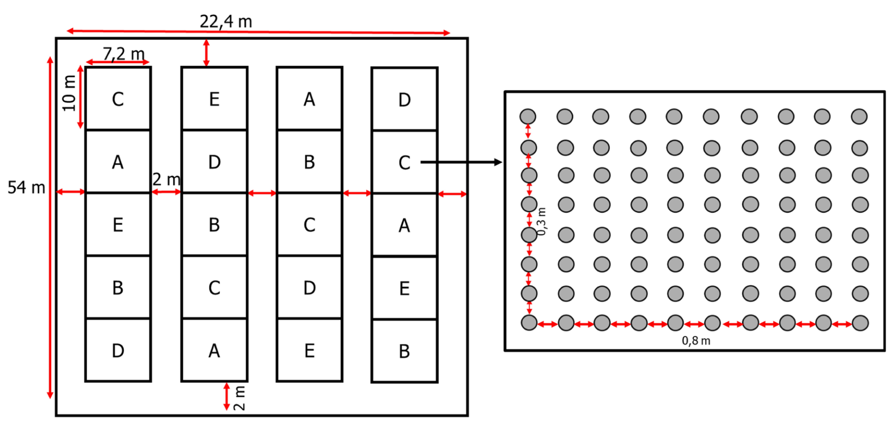

Figure 1. Arrangement of elementary plots.

2.5. Pest Assessments

Pest assessments were conducted one day before each application (T − 1) and at 3 and 7 days after treatment (T + 3 and T + 7, respectively) to document pre-treatment infestation levels and short-term treatment effects. Thirty plants per plot were sampled along the diagonal of each plot following the method of Nibouche *et al.* [11], as previously applied in cotton pest surveys in Côte d'Ivoire [2]. The main response variables were jassid abundance and jassid damage. For the dominant jassid, adults were counted on five well-developed terminal leaves per sampled plant, and a plant was recorded as damaged when at least one terminal leaf showed characteristic hopperburn symptoms. Adults of *Bemisia tabaci* were counted to assess activity on another major sucking pest. Larvae of *Helicoverpa armigera* and *Earias* spp. were counted by whole-plant inspection to assess activity on fruit-feeding Lepidoptera.

2.6. Data Analysis

Data were first examined for distributional assumptions. Because normality and homoscedasticity were not satisfied, nonparametric analyses were used. Site effects were first assessed to determine whether pest pressure differed between Bouaké and Nambingué. Because the two locations represented contrasting agroecological conditions and showed significantly different baseline pest abundance, treatment effects were then analyzed separately within each site rather than pooled across locations. This approach was adopted to avoid masking treatment responses under site-specific pest-pressure profiles and to keep the interpretation of treatment effects directly linked to each field context. For each plot and response variable, post-treatment observations from the three application cycles were pooled by averaging the T + 3 and T + 7 assessments after each spray, resulting in one plot-level mean based on six post-treatment observations. These plot-level means were then used as the analytical units for treatment comparisons within each site. Pre-treatment observations collected at T − 1 were used only to check baseline comparability among treatments before spraying and were not included in the post-treatment efficacy means. Kruskal-Wallis tests were used to compare treatments for each response variable, and when significant differences were detected ($p < 0.05$), multiple comparisons were performed to separate homogeneous groups. Analyses were conducted using the agricolae package in R [12], and seasonal dynamics were visualized with ggplot2 [13] in R version 4.4.2 [14]. Because the same plots were assessed repeatedly over time and were nested within blocks and sites, a mixed-effects modelling framework would provide a more complete assessment of treatment, time, site, and interaction effects. However, given the distributional characteristics of the present data and the objective of providing a field-efficacy comparison under site-specific pest-pressure conditions, nonparametric analyses were retained. This limitation is acknowledged in the interpretation of the results.

3. Results

3.1. Site-Related Variation in the Monitored Cotton Pest Complex

The monitored pest complex differed significantly between the two study sites, confirming that Bouaké and Nambingué represented contrasting field contexts for evaluating the spectrum of the tested formulation. Nambingué showed the highest infestation levels of *Bemisia tabaci*, *Helicoverpa armigera*, and jassid damage, whereas Bouaké recorded higher abundance of the dominant jassid and higher densities of *Earias* spp. (**Table 2**). All pest parameters differed significantly between sites ($p < 0.01$), indicating that the field performance of the formulation had to be interpreted against two distinct pest-pressure profiles rather than under a single homogeneous infestation context.

Table 2. Mean abundance of monitored pest parameters at Bouaké and Nambingué, with associated Kruskal-Wallis test statistics.

Site	***B. tabaci*** (individuals/30 plants)	**Jassid abundance** (individuals/30 plants)	**Jassid damage incidence** (damaged plants/30 plants)	***H. armigera*** (larvae/30 plants)	***Earias* spp.** (larvae/30 plants)
Bouaké	0.53 ± 0.06 b	31.27 ± 1.31 a	5.06 ± 0.41 b	0.02 ± 0.01 b	0.34 ± 0.04 a
Nambingué	7.37 ± 0.80 a	11.97 ± 0.65 b	9.91 ± 0.73 a	0.08 ± 0.02 a	0.05 ± 0.01 b
Kruskal-Wallis χ^2	25.00	167.24	21.21	9.80	55.11
df	1	1	1	1	1
p-value	<0.0001	<0.0001	<0.0001	0.002	<0.0001

Means followed by different letters are significantly different according to the Kruscal-Wallis test at 5% significance level.

3.2. Efficacy of Insecticidal Treatments at Bouaké

At Bouaké, most treatment differences were driven by the response of the dominant jassid, which represented the clearest signal within the monitored pest complex. All three doses of the nitenpyram-pyriproxyfen formulation significantly reduced jassid abundance and jassid damage ($p < 0.001$) relative to both the untreated control and the acetamiprid + spinetoram reference treatment. Mean jassid densities ranged from 16.80 to 19.63 individuals per 30 plants in the treated plots, compared with 47.23 in the untreated control and 52.68 in the reference treatment (**Table 3**). Jassid damage followed the same pattern, remaining below one infested plant per 30 plants in all nitenpyram-pyriproxyfen treatments, whereas it exceeded 10 plants in the control and reference plots. By contrast, no significant treatment effects were detected at this site for *Bemisia tabaci*, *Helicoverpa armigera*, or *Earias* spp. ($p > 0.05$), indicating that, under Bouaké conditions, the contribution of the formulation was essentially confined to management of the dominant jassid.

Table 3. Mean pest parameters at Bouaké according to insecticidal treatment, with associated Kruskal-Wallis test statistics.

Treatment	***B. tabaci*** (individuals/30 plants)	**Jassid abundance** (individuals/30 plants)	***H. armigera*** (larvae/30 plants)	***Earias* spp.** (larvae/30 plants)	**Jassid damage incidence** (damaged plants/30 plants)
Untreated control	0.25 ± 0.09	47.23 ± 2.34 a	0.00 ± 0.00	0.53 ± 0.11	10.63 ± 0.09 a

Continued

Nitenpyram 200 g/L + pyriproxyfen 150 g/L (375 mL/ha)	0.59 ± 0.17	18.69 ± 1.72 b	0.02 ± 0.02	0.22 ± 0.06	0.63 ± 0.20 b
Nitenpyram 200 g/L + pyriproxyfen 150 g/L (500 mL/ha)	0.72 ± 0.16	19.63 ± 1.61 b	0.05 ± 0.03	0.34 ± 0.07	0.72 ± 0.23 b
Nitenpyram 200 g/L + pyriproxyfen 150 g/L (750 mL/ha)	0.59 ± 0.15	16.80 ± 1.52 b	0.03 ± 0.02	0.28 ± 0.08	0.75 ± 0.31 b
Acetamiprid 64 g/L + spinetoram 56 g/L (250 mL/ha)	0.49 ± 0.12	52.68 ± 0.32 a	0.00 ± 0.00	0.34 ± 0.09	12.15 ± 0.98 a
Kruskal-Wallis χ^2	7.93	157.99	5.90	6.47	165.84
df	4	4	4	4	4
p-value	0.09	<0.001	0.21	0.17	<0.001

Means followed by different letters are significantly different according to the Kruscal-Wallis test at 5% significance level.

3.3. Efficacy of Insecticidal Treatments at Nambingué

At Nambingué, the strongest treatment effect was again observed on the dominant jassid, although this site also showed a detectable response in whiteflies. Significant treatment effects were observed for both jassid abundance and jassid damage ($p < 0.05$). The highest jassid densities occurred in the untreated control (24.84 individuals per 30 plants), followed by the acetamiprid + spinetoram treatment (15.47 individuals per 30 plants), whereas all doses of the nitenpyram-pyriproxyfen formulation significantly reduced infestations, with the 750 mL/ha dose resulting in the lowest level (3.05 individuals per 30 plants) (**Table 4**). Treatment effects were also significant for *Bemisia tabaci*, with the 375 mL/ha dose producing the lowest adult densities and the untreated plots showing the highest infestation. In contrast, no significant treatment effects were detected for *Helicoverpa armigera* or *Earias* spp., confirming that under Nambingué conditions the formulation contributed mainly to the management of sucking pests and did not provide meaningful control of the monitored fruit-feeding Lepidoptera.

4. Discussion

This study assessed the extent to which a nitenpyram-pyriproxyfen formulation could reduce the abundance of the pest groups monitored in Ivorian cotton fields. The results show that its effects were not uniform across pest groups. The strongest and most consistent effect was observed against the invasive jassid *Amrasca biguttula*, for which all tested doses reduced both pest abundance and visible plant damage at Bouaké and Nambingué. In contrast, the reference treatment based on acetamiprid + spinetoram performed poorly against this invasive pest and, in several cases, remained close to the untreated control. This result is especially important in the current Ivorian context because the local jassid complex is no longer dominated by the formerly common species *Jacobiasca lybica* and *Jacobiella facialis*; instead, it is now dominated by *A. biguttula* in most localities [2] [3]. The present findings therefore indicate that the formulation was primarily effective against the currently dominant jassid rather than being equally effective against all monitored pests, which is consistent with the changing jassid context reported for Côte d'Ivoire and nearby cropping systems [2] [15].

Table 4. Mean pest parameters at Nambingué according to insecticidal treatment, with associated Kruskal-Wallis test statistics.

Treatment	*B. tabaci* (individuals/ 30 plants)	Jassid abundance (individuals/ 30 plants)	*H. armigera* (larvae/ 30 plants)	*Earias* spp. (larvae/ 30 plants)	Jassid damage incidence (damaged plants/30 plants)
Untreated control	13.97 ± 2.88 a	24.84 ± 1.48 a	0.16 ± 0.06	0.11 ± 0.05	29.20 ± 0.41 a
Nitenpyram 200 g/L + pyriproxyfen 150 g/L (375 mL/ha)	5.03 ± 1.32 b	9.64 ± 1.07 c	0.05 ± 0.03	0.06 ± 0.03	2.42 ± 0.51 c
Nitenpyram 200 g/L + pyriproxyfen 150 g/L (500 mL/ha)	5.52 ± 1.29 ab	6.86 ± 0.88 d	0.05 ± 0.03	0.06 ± 0.03	2.05 ± 0.56 c
Nitenpyram 200 g/L + pyriproxyfen 150 g/L (750 mL/ha)	5.19 ± 1.16 ab	3.05 ± 0.44 e	0.11 ± 0.04	0.02 ± 0.02	0.41 ± 0.17 d
Acetamiprid 64 g/L + spinetoram 56 g/L (250 mL/ha)	7.16 ± 1.49 ab	15.47 ± 1.40 b	0.02 ± 0.02	0.02 ± 0.02	15.45 ± 1.74 b
Kruskal-Wallis χ^2	10.70	162.60	8.70	4.95	205.70
df	4	4	4	4	4
p-value	0.03	<0.0001	0.07	0.29	<0.0001

Means followed by different letters are significantly different according to the Kruscal-Wallis test at 5% significance level.

This efficacy pattern is biologically plausible. Nitenpyram is a systemic neonicotinoid with rapid activity against piercing-sucking insects, whereas pyriproxyfen acts as an insect growth regulator and may reduce population renewal, especially in pests with susceptible immature stages [6] [7]. The combination therefore provides a plausible mechanistic basis for good performance against sucking pests, in line with previous field studies reporting efficacy against cotton pest complexes dominated by sucking insects [8] [9]. In the present trial, the 750 mL/ha dose provided the most stable suppression of the dominant jassid across both sites. However, the magnitude of jassid suppression varied by site and dose, indicating that the response should not be generalized beyond the tested conditions without further multi-season and multi-location validation.

The contrast between Bouaké and Nambingué is important for interpreting this pattern. The two sites differed significantly in pest abundance and damage profiles, confirming that they represented distinct agroecological settings rather than simple duplicates of the same trial. Jassid abundance was higher in Bouaké, whereas jassid damage and whitefly pressure were greater in Nambingué. Despite this heterogeneity, the formulation remained effective against the dominant jassid at both sites, which strengthens confidence in its usefulness for managing this pest under variable field conditions. By contrast, an effect on *Bemisia tabaci* was detected only at Nambingué, where whitefly pressure was higher. This suggests that any field contribution of the formulation to whitefly management may depend on the local infestation context and possibly on the life stages present at the time of assessment, since pyriproxyfen is generally more active against immature stages than against adults [7] [16] and because whitefly responses to nitenpyram may also be influenced by emerging resistance patterns in field populations [17].

Another important result is that neither the tested formulation nor the reference product provided meaningful control of *Helicoverpa armigera* or *Earias* spp. under the conditions of this study. From an applied perspective, this negative result is useful because it clarifies the limits of the activity spectrum initially expected for the formulation. The results therefore do not support considering this treatment as a stand-alone solution for the entire cotton pest complex. Rather, under the present conditions, its measurable effect was concentrated on key sucking pests, particularly the invasive jassid, while additional measures remain necessary for the management of fruit-feeding Lepidoptera.

The findings should nevertheless be interpreted within the limits of the study. This work was designed as a field-efficacy evaluation and not as a full integrated pest management assessment. No data were collected on natural enemies, weather covariates, yield response, or resistance mechanisms, and the trial was conducted under a limited set of field conditions. Consequently, pest suppression observed in this study should not be interpreted as direct evidence of yield improvement or economic profitability. Additional trials including yield, cost-benefit analysis, longer-term population dynamics, and repeated assessments across seasons would be required before making broad agronomic or IPM recommendations. Consequently, while the present results clarify the main pattern of efficacy of the formulation under the tested conditions, stronger recommendations for field use will require additional evidence on seasonal performance, compatibility with beneficial arthropods, weather-related variability, and integration with complementary tools for pests that were not adequately controlled here [18]-[20].

5. Conclusions

This study evaluated a nitenpyram (200 g/L) + pyriproxyfen (150 g/L) formulation proposed for the management of key cotton pests in Côte d'Ivoire. Under field conditions in Bouaké and Nambingué, the formulation did not show uniform efficacy across all monitored pest groups, but it consistently reduced the two jassid-related response variables: jassid abundance, expressed as the number of individuals per 30 sampled plants, and jassid damage incidence, expressed as the number of damaged plants per 30 sampled plants. These reductions were observed for the invasive jassid *Amrasca biguttula* in comparison with both the untreated control and the reference product based on acetamiprid (64 g/L) + spinetoram (56 g/L).

Among the tested rates, 750 mL/ha produced the most consistent reduction in jassid abundance and jassid damage incidence across the two sites and therefore appeared to be the most effective rate against the dominant jassid under the conditions of this trial. However, this conclusion should be interpreted as evidence of short-term biological efficacy rather than as proof of yield gain or economic benefit. The formulation showed only site-dependent activity against *Bemisia tabaci* and no meaningful efficacy against *Helicoverpa armigera* or *Earias* spp., indicating that its activity under the present conditions was narrower than initially expected.

Overall, the results indicate that the nitenpyram-pyriproxyfen formulation may contribute to the management of sucking pests in cotton, particularly the invasive jassid *A. biguttula*, by reducing both pest abundance and visible damage incidence. Nevertheless, it should not be considered a stand-alone treatment for the entire cotton pest complex. Before broader integration into cotton IPM programs, its performance should be confirmed through multi-season and multi-location trials incorporating yield response, economic return, longer-term population dynamics, natural enemy assessments, and compatibility with complementary pest management tools.

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Data Availability

Data will be made available on request to the corresponding author.

Author Contributions

Kouakou Malanno conceived the study, developed the methodology, generated the data, supervised the research, and reviewed the manuscript. Kouadio Houphouët contributed to the statistical analyses and drafted the manuscript. Didi Roland Juste Gouzou and Bini Kouadio Kra Norbert reviewed and revised the manuscript.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this manuscript.

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