Original Research Article

Evaluation of the effectiveness of new phytosanitary protection programs in cotton crops adapted to jassids

Abstract

In recent years, jassids have become a problem for cotton and the current control program for this pest seems ineffective. This study was therefore initiated with the objective of evaluating the effectiveness of three new phytosanitary protection programs against jassids. Trials were conducted at the Nambingué observation post. The study designs were Fisher blocks with 5 objects and 4 replications. Each elemental plot had a length of 10 m and a width covering 10 lines, 8 of which were treated. The spacing between rows was 0.8 m. The distance between patches on a line was 0.4 m. The distance between blocks was 2 m. Six insecticide treatments were carried out. Treatments were started on the 45th day after cotton emergence, at 14-day intervals. These three new programs, which differ according to the composition and positioning of the active substances, were tested during two years in a fisher block design with four repetitions. Two programs, labelled programs B and C, had an efficacy threshold greater than 80%. Program B was characterized by a positioning spiromesifen or chlorantraniliprole in T1 and T2, cypermethrin + abamectin in T2 and T3 and spinetoram + sulfoxaflor in T5 and T6 respectively. And program C was characterized by a positioning spinetoram + sulfoxaflor in T1 and T2, Deltamethrin + chlorpyrifos ethyl in T3 and T4 and dinotefuran 14% + alphacypermethrin 22% in T5 and T6 respectively. They both contributed to a significant reduction in jassid outbreaks during the two years of experimentation. Programs B and C can be used as an alternative to the extension program to manage resistance

Key words: *jassids, phytosanitary protection, efficacy threshold, programs, active substances, Nambingué*

1. **Introduction**

Cotton is a natural textile fiber whose production covers more than 50% of the world's fiber needs. It is classified as a protein and edible vegetable oil producing crop (Tereta, 2015).

In West Africa, cotton cultivation is the engine of rural development in the savannah regions. It is grown on more than 50% of the agricultural land and is an important source of income for many small farmers who cultivate it. It contributes to the socioeconomic development of the populations living in the savannah zones (Center and North) of Côte d'Ivoire and has fostered the emergence of private economic operators in the transport, livestock, handicrafts, banking, and ginning sectors (Koné et al., 2017; Edmond, 2015).

In the absence of phytosanitary protection, the cotton crop is subject to many attacks by pests, causing crop losses. The cotton crop is subject to strong parasitic pressure induced by many pests, which are responsible for significant crop losses for producers (Rodrigues et al., 2013). These crop losses varied according to years. They are perceived both at the qualitative and quantitative levels. They are evaluated on average at 30% of production potential (Koné et al., 2017; Ochou & Martin, 2002).

For a long time, plant protection strategies were built around carpophagous lepidopterans such as *H. armigera*, which were considered the main pests of cotton. However, in recent years, some pests that were once considered minor have become a concern for producers. This is the case of jassids, which have become increasingly abundant in cotton growing areas (Koné et al., 2017). The pullulation of jassids can be explained by the pockets of drought observed each year at the beginning of the agricultural season, between July and August (Koné et al., 2017), a sensitivity of the cultivated varieties (Koné, 2019), the weakness of certain active ingredients used in the phytosanitary protection programs in force, and the cohabitation of several species.

Indeed, pest surveillance conducted in the production areas revealed a change in the seasonal and geographical distribution pattern with a steady increase in jassids infestation levels, with stronger attacks in localities located in the Northeast and persistence throughout the cropping season Koné et al., 2017). Toxicity tests conducted by Koné et al. (2018) revealed a low sensitivity of jassids to the main insecticides used in the current plant protection program.

In view of the neglect of jassids in the development of plant protection programs, their persistence throughout the cotton growing season and the identification of areas of high infestation of jassids, it is therefore important to build control programs to adapt to their management and recommend them in areas of high outbreak.

The objective of this study is to evaluate the effectiveness of new plant protection programs adapted to jassids.

2. Study zone

Tests were conducted at the Nambingué observation post in 2019 and 2020. Nambingué is in the Northeast of the cotton production area, with a monomodal rainfall regime. The choice of this locality for the study is justified by the fact that it is the area where heavy infestations of jassids are encountered (Koné et al., 2017) (Figure 1).

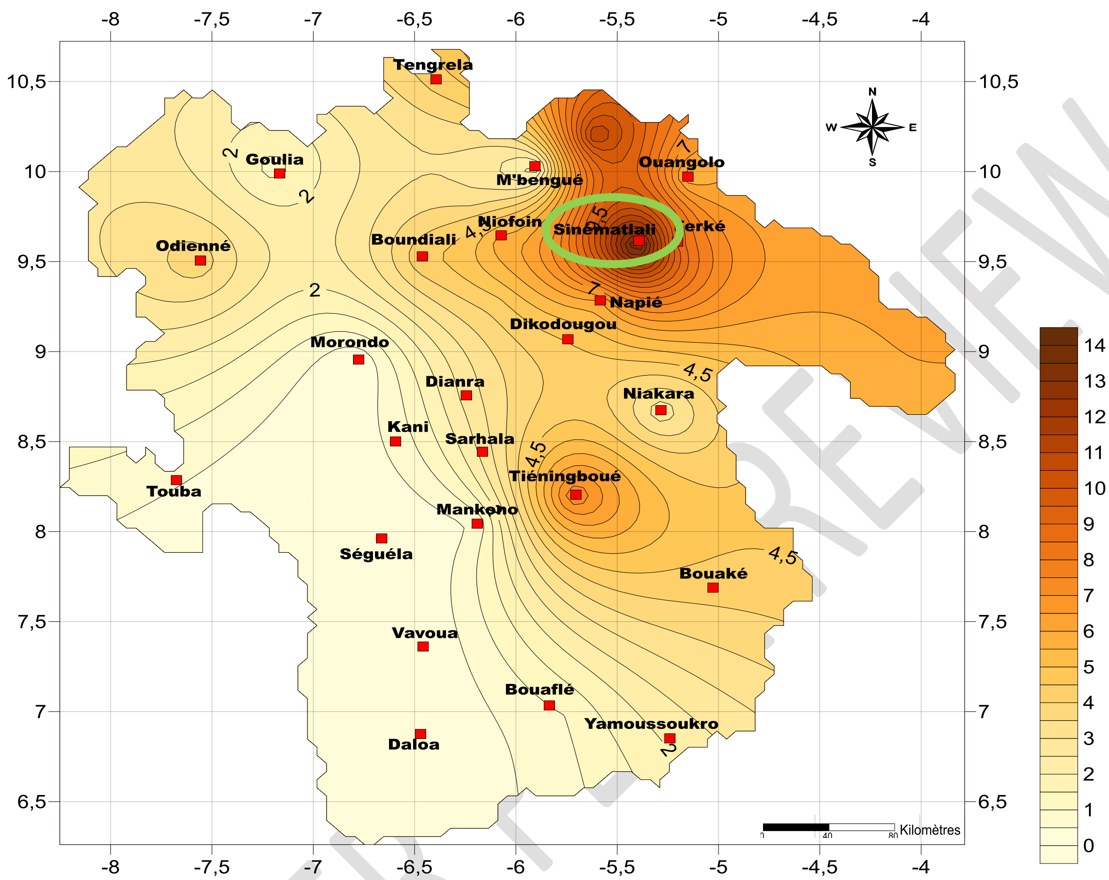

Fig. 1**.** Geographical distribution of jassid infestation levels in the cotton production area of Côte d'Ivoire (Koné et al., 2017)

3. Material and methods

3.1. Material

The study material is composed of technical and biological material. Ten insecticidal formulations were used as technical insecticidal material (Table 1). The biological material consists of jassids present on the cotton plant during insecticide treatments.

Table 1 Insecticide products and their characteristics

Active substances	**Dose (g/ha)**	**Chemical family**
Cypermethrin 72 + Abamectin 28	36-14	Pyrethroid / Avermectin
Dinotefuran 14% + Alphacypermethrin 22%	11,2-17,6	Neonicotinoid / Pyrethroid
Spinetoram 200 + Sulfoxaflor 200 (g/Kg)	14-14	Spinosyn / sulfloximin
Spiromesifen 240 g/l	144	Tetronic and Tetramic acid derivatives
Deltamethrin + Chlorpyrifos ethyl	12-200	Pyrethroid / Organophosphate
Emamectin + Acetamiprid	12-16	Avermectin / Neonicotinoid
Cypermethrin + Profenofos	36-300	Pyrethroid / Organophosphate
Alphacypermethrin + Acetamiprid	18-8	Pyrethroid / Neonicotinoid
Buprofezin	200	Buprofezin
Chlorantraniliprole	20	Diamide

3.2. Methods

The study designs were Fisher blocks with 5 objects and 4 replicates. Each elementary plot had a length of 10 m and a width covering 10 lines, 8 of which were treated. The spacing between rows was 0.8 m. The distance between patches on a line was 0.4 m. The distance between blocks was 2 m. For each protection program, six (6) insecticide treatments were made, following indications in Table 2. The number of insecticide treatments is the one recommended for the phytosanitary protection of cotton crops in Côte d'Ivoire. Treatments were made at interval of 14 days, from the 45th to the 115th days after plant emergence.

T1 (45th DAE)	T2 (59th DAE)	T3 (73rd DAE)	T4 (87th DAE)	T5 (101st DAE)	T6 (115th DAE)
A : program P1					
Spinetoram +Sulfoxaflor		Cypermethrin + Abamectin		Buprofezin	
B : program P2					
Spiromesifen or Chlorantraniliprole		Cypermethrin + Abamectin		Spinetoram + Sulfoxaflor	
C : program P3					
Spinetoram + Sulfoxaflor		Deltamethrin + chlorpyrifos ethyl		Dinotefuran 14% + Alphacype Alphacypermethrin 22%	
D : programme vulgarisé (PV)					
Emamectin + Acetamiprid		Cypermethrin + Profenofos		Alphacypermethrin + Acetamiprid	
E : Untreated control					

**DAE: Day After Emermence*

Table 2. Phytosanitary protection programs showing the alternance of insecticide products and application periods

The assessment of jassids infestations were made by direct observations on cotton plants. Observations were made weekly, from the 30th to the 122nd day. Observations of plant damage were made on a sample of 30 plants taken in groups of 5 consecutive plants per row, following the sequential method known as "the diagonal" (Michel et al., 2000 ; Nibouche, 2009) (Figure 2). On each selected plant, the 5 terminal leaves were examined. The plant was considered attacked when one of these leaves showed symptoms of jassid attack. The count of the attacked plants allowed to establish the levels of infestation due to jassids. The number of jassids were also counted on plants.

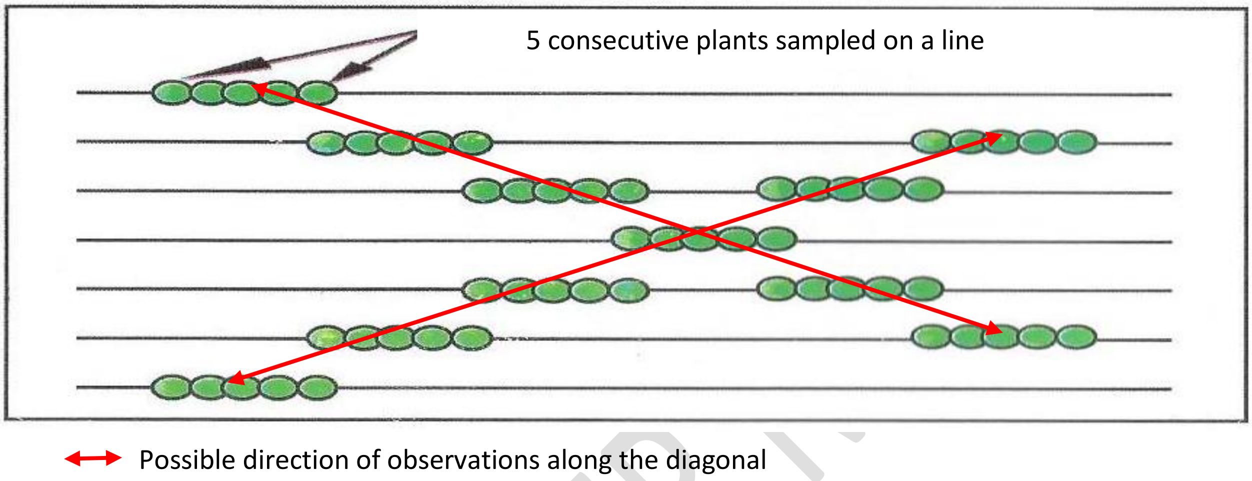

Fig. 2. Diagram of pest observations in cotton plots (Ochou, 2011)

3.3. Statistical analysis

The analysis was done on the number of plants with symptom and the number of jassids on 30 plants. The one-factor analysis of variance was performed to determine the effect of the phytosanitary programs on these parameters. In case of significant difference within the factors at the 5% threshold, the Tukey's post hoc test called HSD test was performed to identify the homogeneous groups. Difference estimates were determined from the untreated control to determine which program was more effective for the two parameters studied by subtracting the untreated populations with the treated program populations. The program with the smallest estimator is the most efficient. The graphical representations of the results of the post hoc test have been made to graphically appreciate the groups, as well as the estimators of differences in absolute values. The estimators with the largest histograms indicate the most effective programs. The threshold of effectiveness of the programs was determined according to the following formula:

$$Threshold = \frac{(Untreated - Programs)}{(Untreated)} * 100$$

The program is considered effective if the threshold is greater than 80%.

Statistical analyses were performed with R 4.0.3 software. The Tukey post hoc test was performed using the *agricolea* package downloaded in R for the determination of homogeneous groups after the analysis of variance. The Excel 2016 office was used for-the determination of the thresholds of efficiencies of the programs, and the graphical representations.

4. Results

4.1. Effect of phytosanitary programs on jassid populations

The average number of adult jassids observed per 30 plants varied in both years. In the first year, an average of 5.15 adult jassids were observed per 30 plants. In the second year, 8.01 adult jassids were observed per 30 plants. Thus, a high number of jassids was observed in the second year. As for the effect of the programs, a highly significant difference was observed ($p < 0.001$) (Table 3). Programs A, B and C were the most effective (Fig. 3).

Table 3 Analysis of variance of the program

Parameter	Df	Mean Sq	F value	Pr(>F)
Adult Jassids	4	1367.91	20.4422	<.001

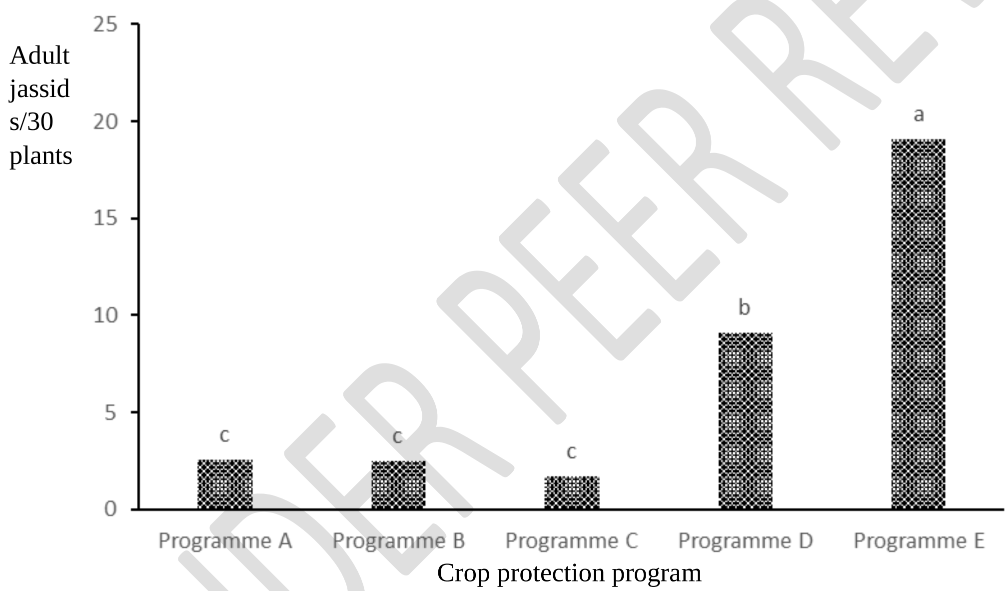

Fig. 3. Impact of treatments on jassids with a, b and c indicating homogeneous classes

They were followed by the current program ((Fig. 3). However, determination of the difference estimators (Table 4) showed that program C was the most effective. It was followed by program B and program A. Determining the threshold for program effectiveness (Fig. 4) in the first year of study showed that Program C was the most effective. It was followed by program B. In the second year of study, three programs were found to be the most effective. These were program C, the most effective, program A and program B.

Table 4. Difference Estimator expresses the impact of programs on jassid populations

Year	Program	Jassid population difference estimator
	A	-8.555556
	B	-10.333333
2019	C	-10.444445
	D	2.555556
	A	-21
	B	-20.125
2020	C	-21.3125
	D	-10.3125

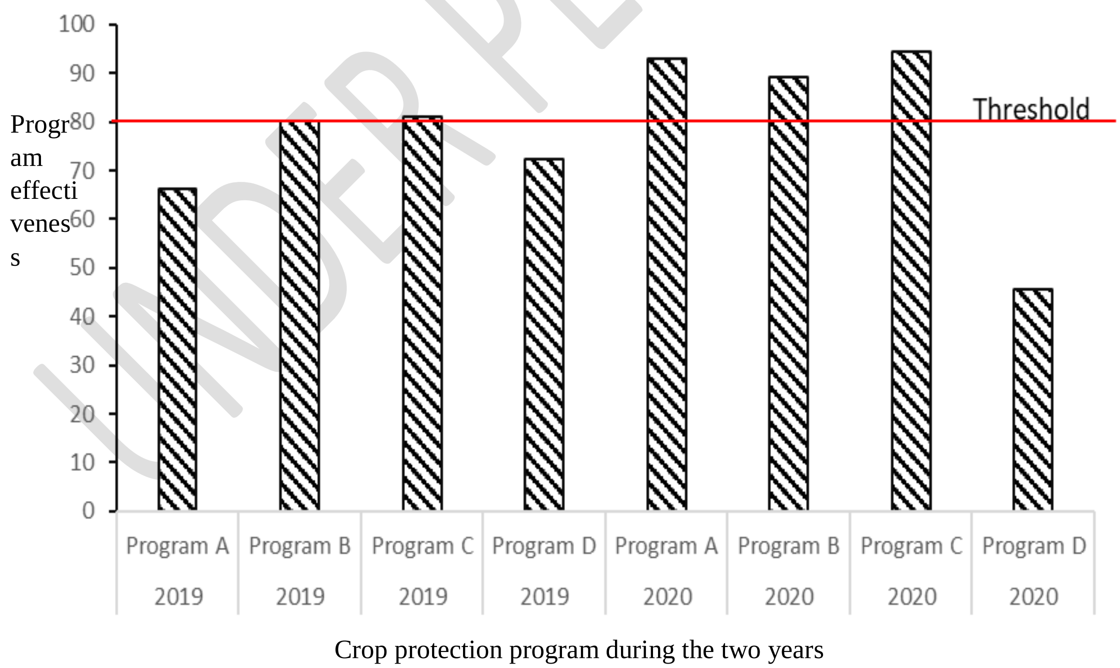

Fig. 4. threshold for program effectiveness in managing jassids populations

4.2. Effect of programs on the number of plants attacked

The average number of attacked plants per 30 plants varied during the two years. In the first year, there was an average of 0.38 attacked plants per 30 plants observed. In the second year, there was an average of 1.13 attacked plants per 30 plants observed. Thus, there were more infected plants in the second year of the trial as opposed to the first year of the trial. The analysis of variance performed on the programs revealed a highly significant difference ($p<0.001$) (Table 5).

Table 5 Analysis of variance performed on the programs

Parameter	Df	Mean Sq	F value	Pr(>F)
Plants attacked	4	27.812	7.2065	<0.001

As for the effect of the programs, programs A, B, C and D were effective as shown in Table 6. Figure 5 shows the results of the difference estimators obtained during the first year of experimentation. It reveals that through the absolute difference estimators showed that the most effective programs were program B with spiromesifen or chlorantraniliprole in T1 and T2, cypermethrin + abamectin in T2 and T3 and spinetoram + sulfoxaflor in T5 and T6, and program C with spinetoram + sulfoxaflor in T1 and T2, deltamethrin + chlorpyrifos ethyl in T3 and T4 and dinotefuran 14% + alphacypermethrin 22% in T5 and T6 and the popularized program positioning respectively emamectin + acetamiprid in T1 and T2, cypermethrin + profenofos in T3 and T4 and alphacypermethrin + acetamiprid in T5 and T6. While in the second year of the trial, program C positioning respectively spinetoram + sulfoxaflor in T1 and T2,

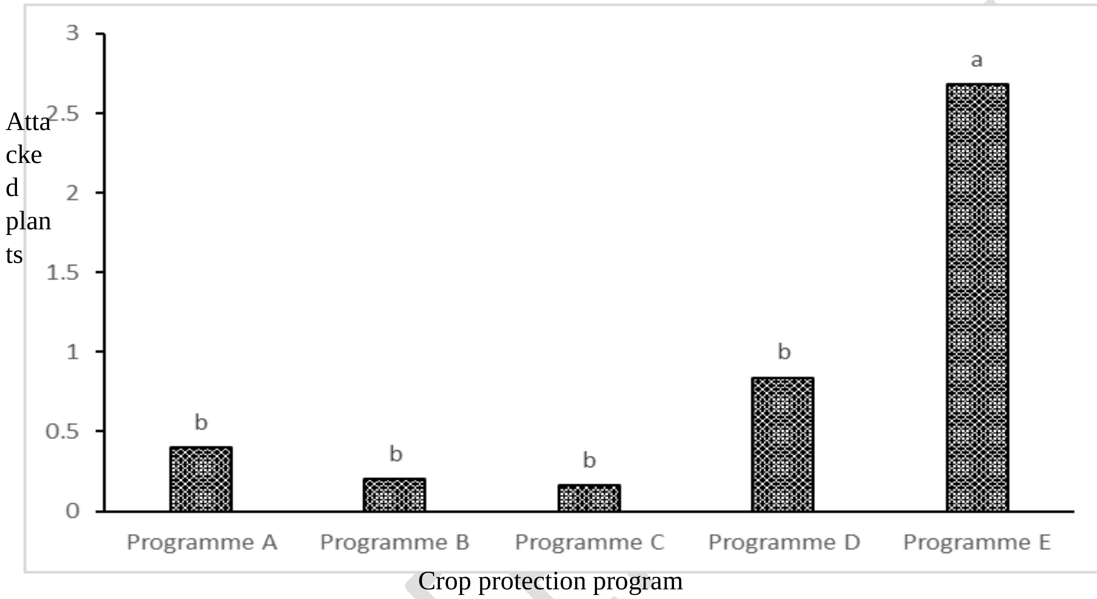

Figure 5 Impact of treatments on symptoms with a, b and c indicating the homogeneous classes

Table 6 Difference estimators expressing the impact of the programs on the number of plants attacked

Year	Program	Jassid population difference estimator
	A	-1
	B	-1.4444444
	C	-1.4444444
2019	D	-1.4444444
	A	-3
	B	-3.0625
	C	-3.125
2020	D	-2.0625

deltamethrin + chlorpyrifos ethyl in T3 and T4 and dinotefuran 14% + alphacypermethrin 22% in T5 and T6 distinguished itself by its efficiency from the three other programs. It was followed by program B positioning respectively spiromesifen or chlorantraniliprole in T1 and T2, cypermethrin + Abamectin in T2 and T3 and spinetoram + sulfoxaflor in T5 and T6 and A spinnetoram + sulfloxaflor in T1 and T2, cypermethrin + abamectin in T3 and T4 and buprofezin in T5 and T6.

5. Discussion

The results obtained during the two years of study indicate that the new programs are effective in controlling the jassids present on cotton. The innovative programs that proved to be the most effective were program C and B. They were the programs that stood out during the two years of evaluation with an efficacy threshold ≥ 80%. Program C positioned spinetoram + sulfoxaflor in T1 and T2, deltamethrin + chlorpyrifos ethyl in T3 and T4 and dinotefuran 14% + alphacypermethrin 22% in T5 and T6, respectively. While program B positioned spiromesifen or chlorantraniliprole respectively in T1 and T2, cypermethrin + abamectin in T2 and T3 and spinetoram + sulfoxaflor in T5 and T6. The positioning of pyrethroid alternatives, associated with a specific active ingredient has a better control of sucking biters (Sarr et al., 2016)

The inclusion of new active substance in the plant protection program allows to control the jassid outbreak, thus slowing down their damage on cotton plants. Thus, the low outbreaks of jassid observed with the application of the new programs show that alternatives to pyrethroids can be used in the plant protection program to maintain this pest at low levels of infestation. These alternatives thus reduce the overuse of pyrethroids. The active substance used in these programs (spinetoram, sulfoxaflor, cypermethrin, abamectin, spiromesifen or chlorantraniliprole, deltamethrin, chlorpyrifos ethyl, dinotefuran and aphacypermethrin) are therefore effective.

This decrease in the jassid population is the effect of the introduced new active substances, alternated and associated with pyrethroids. This combination would avoid behavioral adaptation of jassids to the active substance used in the popularized program. These results are confirmed by those of Sarr et al., 2016; Ayeva et al., 2014; Barrania & Abou-Taleb, 2014; Aslam et al., 2004, which highlight the efficacy of active substances such as Spirotetramat, Acetamiprid, Pyriproxene, Imidacloprid, Profenofos, Spinetoram, Emamectinbenzoate, Pyriproxifen, Novaluron, Flubendiamide, Spirotetramat and Imidacloprid. Indeed, heavy use of an active substances over a long period of time induces a behavioral change in individuals exposed to them, hence the degradation of active ingredients highlighted by Koné et al., 2019, 2018 ; Ochou & Martin, 2002; Martin et al., 2000 in jassids and in Helicoverpa armigera.

Conclusion

The objective of this study was to evaluate the effectiveness of new phytosanitary protection programs adapted to jassids, and it was shown that jassids could be controlled by the new programs, in this case programs B and C. They could be alternatives in the control of these pests to guarantee an effective protection and avoid a behavioral change. The programs can be extended while monitoring populations for changes.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we

do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. This research was supported by INTERCOTON (interprofessional cotton association) and FIRCA (interprofessional fund for agricultural research and advice) of Côte d’Ivoire.
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