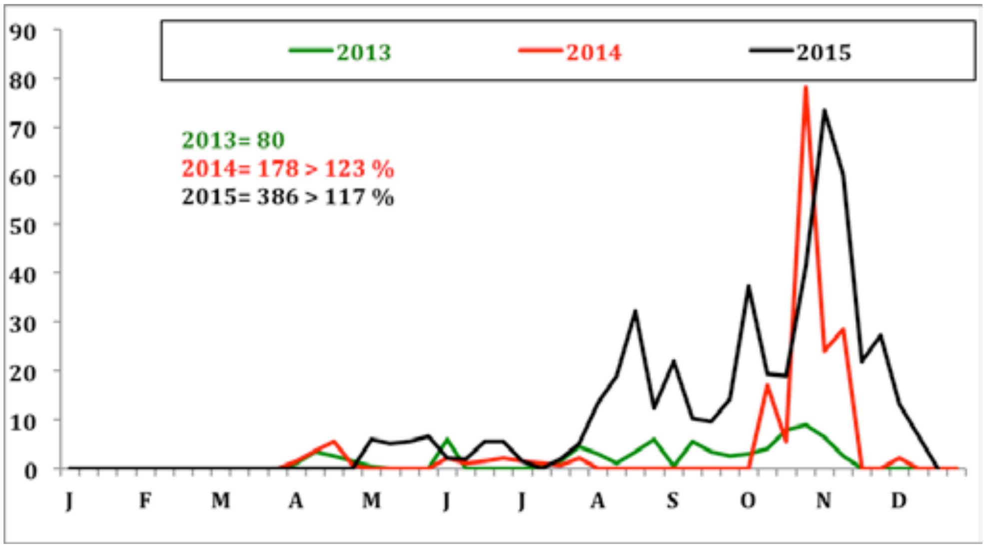

Fig 16: Pink Bollworm Male Moth Catches per Week/Trap in 2013, 2014 & 2015

Redistribution of Cotton Pests Following the Adoption of Transgenic Cotton in Burkina Faso

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Introduction

Cotton is the most exported agricultural product in Burkina Faso, accounting for more than half of all agricultural exports (Traoré *et al.*, 2006). Cotton is cultivated by more than 350,000 rural producers and directly provides a living for more than three million people. Over time, it has been found to work as a genuine tool in the fight against poverty and the improvement of living conditions for rural populations.

The problem is that cotton cultivation is ravaged by many pests, mainly insects, with a prime position for the Lepidoptera, whose larvae feed extensively on parts of the cotton plant. Damage done by these insects can affect up to 90% of the harvest. This has made cotton production strongly dependent on insecticide treatment to reduce the adverse effects of these pests. Since the start of the 1980s, cotton plants were protected by insecticides, whose active ingredient is essentially drawn from the pyrethroids chemical family, which offered several advantages: low cost, low dose effective on pests, non-persistence in the environment since they are degraded by UV rays, etc. Unfortunately, at the start of the 1990s, there were some treatment failures in the field (Héma *et al.*, 2009a). The analysis showed that certain cotton plant pests had become resistant to pyrethroids (Martin *et al.*, 2000; Héma *et al.*, 2009a). Efforts were made to find alternatives to the use of pyrethroids in order to maintain, even increase, cotton plant productivity. Thus, they integrated the notion of window programs, which took into account insecticides that are the most toxic for the user and the environment, without reducing the pests' level of resistance to pyrethroids (Tabashnik *et al.*, 1989; Gunning *et al.*, 1996). The window program consisted of six treatments divided into three windows of two treatments each, each window corresponding to a family or association of two insecticides of different families. It is in this context of limited credible alternatives that Burkina Faso opted for the transgenic Bt cotton (biotech cotton*)*, in order to better control the pests (Héma *et al.*, 2009b). Seven years after this new technology was adopted, this document reviews the redistribution of the main cotton plant pests on both types of cotton.

Technical Operations of Cotton Production in Burkina Faso

Cotton production in Burkina Faso is rather demanding in terms of technical operations to optimize profitability. The main operations to carry out are the following:

- Labor: In animal traction or by tractor

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- Seeding: To do after rain of at least 20 mm (avoid any seeding after July 20)
- Spacing: 70 to 80 cm between lines and 30 to 40 cm between seed holes with 4 to 5 seeds/seed hole
- Quantity of seed sown/ha: 12 kg of delinted seeds to 20 to 25 kg of undelinted seeds
- Planting depth: 3 cm (do not exceed 5 cm)
- Singling: 2 plants per seed hole, to thin between the 15th and 20th day after emergence
- Weeding: Done as needed, the cotton field must always stay clean
- Herbicide: Use pre-emergence herbicides (the same day or day after sowing) or post-emergence (15 to 20 days after sowing), following the standards written on the product label
- Fertilization
  - Organic fertilizer (essential): 6 tons/ha of manure or compost every 3 years, applied when plowing work starts
  - Mineral fertilizer in multiple doses: 150 kg/ha NPKSB (14-23-14-6-1), 20 days after sowing and 50 kg/ha of urea 40 days after sowing
- Earthing up: As of the 40th day after sowing, preferably the day when spreading urea, for the case of multiple dose fertilizers;
- Insecticide treatments: Sprayings are done with knapsack sprayers with constant pressure or with battery-operated devices with centrifugal discs or sprays:
  - Conventional varieties (FK37 and FK64): Do 6 insecticide treatments every 14 days and the first treatment is applied 30 days after the emergence of the cotton plants:
    - º During the first two treatments, use profenofos (500 g/ha), indoxacarb (25 g/ha), emamectin benzoate (9 to 12 g/ha), rynaxypyr (20 g/ha), cyantraniliprole (40 g/ha), etc.
    - º Use a pyrethroid+organophosphorus acaricide (profenofos+ cypermethrin 30-200 g/ha, deltamethrin chlorpyriphos-ethyl 12-200 g/ha, lambdacyhalothrin-profenofos 12-200 g/ha, etc.) for the third and fourth treatments
    - º Use a pyrethroid+neonicotinoid association (cypermethrin-acetamiprid 36-16 g/ha, deltamethrin-imidacloprid 12-50 g/ha, etc. or emamectin+ neonicotinoid, indoxacarb+neonicotinoid, etc.) for the fifth and sixth treatments.
  - FK95 transgenic variety: Only two treatments are performed on the 86th and 100th day after emergence with the pyrethroid+neonicotinoid association (cypermethrin-acetamiprid 36-16 g/ha, deltamethrin-imidacloprid 12-50 g/ha, etc.) or emamectin+neonicotinoid, indoxacarb+neonicotinoid;
- Harvest and storage: First harvest once half of the bolls open and second harvest once all the remaining bolls are open.

Analysis Methodology on the Presence of Cotton Plant Pests

Parasite counting data from 2006 to 2015 of cotton plant companies as well as those of Institute of the Environment and Agricultural Research's (INERA) agricultural research stations were used to summarize the level of pest presence in different areas. Cotton companies' consulting agents perform weekly observations on thirty plants in the small landholdings that were treated according to the disseminated program of six insecticide treatments. At research stations, observations were made on untreated areas. In total, 3,900 observations in the landholdings and 270 observations at research stations were taken into account for this analysis. Two periods were compared: the period before transgenic (biotech) cotton seed was disseminated (2006 to 2008) and the cultivation period of biotech cotton varieties (2009 to 2015). An ANOVA was performed in both periods at a 5% threshold, using XLSTAT 2007 software. The spider histogram posted showed a significant difference between the compared averages.

For the purposes of comparing the levels of sensitivity over a short period, data from the *Helicoverpa armigera* and *Bemisia tabaci* studies were analyzed from individual plants collected in producer fields in 2009 and 2014. Regarding *H. armigera*, insecticide was topically applied on second- and third-stage larvae of the first laboratory generation, while the method of soaking leaves in insecticides was used in the *B. tabaci* study. Strains were compared between years based on the resistance coefficient, which is the ratio of the LD_{50} (or LC_{50}) of the field strains on that of the sensitive reference strain (Brévault *et al.*, 2003). For *H. armigera*, we selected BK77 as a sensitive strain and for *B. tabaci*, we selected the Sud-S strain.

Results

The analysis of data on levels of average infestations of conventional cotton plants covers the periods before the Bt transgenic cotton plant was put on the market (2006-2008) and during the cultivation of this new technology (2009-2015); data were collected from real environments and research stations. The data acquired in the real environments were drawn from landholdings treated six times, according to the disseminated protection program (Fig. 1). A significant difference was found in the number of seed-feeding larvae (*Helicoverpa armigera, Earias* spp. and *Diparopsis watersi*). The data observed an average of almost two larvae per thirty plants in the 2006-2008 period, while in 2009 and 2015, an average of one seed-feeding larva on the observed plants was recorded. For the three other major pests (*Haritalodes derogata* larva, the *Bemisia tabaci* white fly, and the *Aphis gossypii* aphid), no significant difference was observed, even if the overall trend was the same as in 2006-2008 period with the most significant presence of pests. Analysis of the data acquired at the research stations (Fig. 2) on untreated areas indicated significant differences in *H. armigera*, *Earias* spp. and the white fly *B. tabaci*. Almost four *H. armigera* larvae per thirty plants in the 2006-2008 period and only 2.4 larvae in the 2013-2015 period were observed. For *Earias*, an average of 0.6 larva per thirty plants was recorded between 2013 and 2015, while in 2006 and 2008 close to 1.5 larvae of this species were found. For *B. tabaci*, untreated areas recorded an average of two infested plants per thirty observed plants between 2013 and 2015, while close to five infested plants were counted in the 2006-2008 period. Regarding *D. watersi, H. derogata, A. gossypii* and the *Jacobiella fascialis* jassids, no significant difference was reported between the levels of outbreaks in the two periods under consideration.

The levels of infestation of the main pests were compared on both types of cotton plants between 2010 and 2015 in a real environment (Fig. 3) on treated parcels of land, following the programs disseminated (six treatments on conventional cotton plants and two treatments on Bt transgenic cotton plants) and in research stations (Fig. 4) on untreated land. In a real environment, a significant difference was observed only for the average number of seed-feeding larvae per thirty plants. While we counted only 0.2 less larva per Bt transgenic cotton plant, we had 0.8 larva on the conventional cotton plant treated six times with insecticides. When controlling for other pests like *H. derogata, B. tabaci, A. gossypii, J. fascialis and Dysdercus völkeri*, both kinds of cotton plants were statistically equivalent. The untreated areas at research stations reported significant differences on two pests: *H. armigera* and *H. derogata*. Indeed, for both these Lepidoptera, the conventional cotton plant harbored a significantly greater number of these pests.

The *H. armigera* resistance coefficients to deltamethrin were 25 in 2009 and 27 in 2014 (Fig. 5). The LD_{50} confidence intervals were 0.039-2.728 µg/g in 2009 and 0.018-40.57 µg/g in 2014. The confidence intervals overlap, which leads one to conclude that these two strains do not present any difference in sensitivity with regard to deltamethrin. For *B. tabaci*, the resistance coefficients to acetamiprid (Fig. 6) were 83 in 2009 and 118 in 2014 with LC_{50} confidence intervals of 3.58 to 8781.55 mg/l in 2009 and $2.32.10^{-4}$ to $9.35.10^{7}$ mg/l in 2014; for deltamethrin on *B. tabaci*, the resistance coefficients were 115 in 2009 and 78 in 2014, with confidence intervals from 0.10 to 67,645.50 mg/l in 2009 and 0.95 to 2,432.36 mg/l in 2014.

Figure 1: Average Pest Infestation Levels on Conventional Cotton Plants Before and After Transgenic Cotton Plant Cultivation in Natural Environment in Treated Area

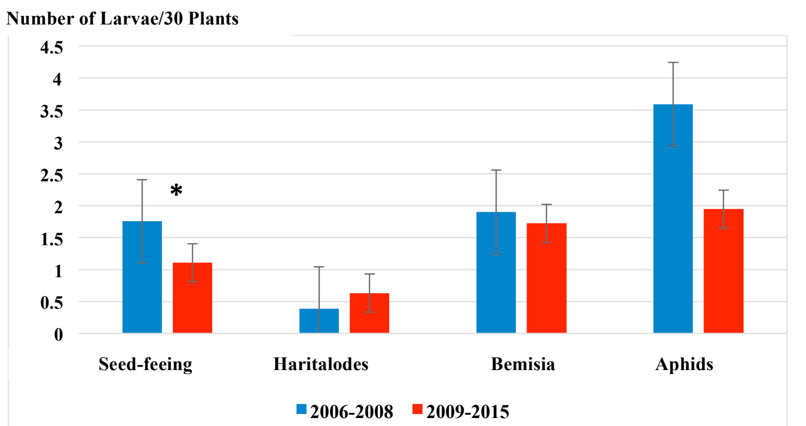


Figure 2: Average Pest Infestation Levels on Conventional Cotton Plants Before and During the Cultivation of Transgenic Cotton Plants in Research Station on Untreated Area

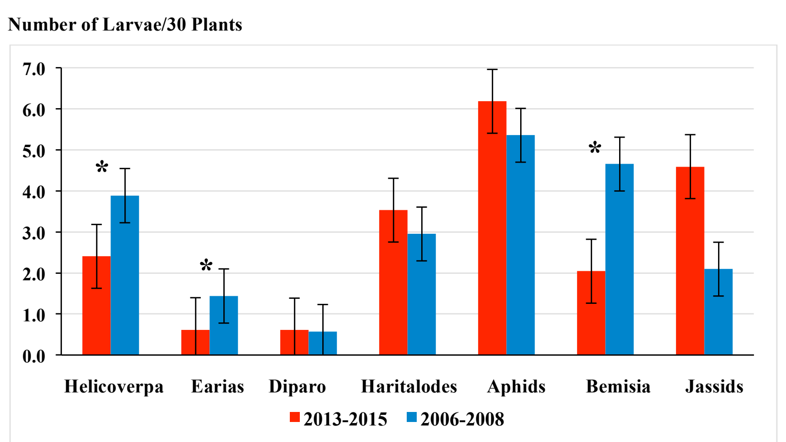


Figure 3: Average Pest Infestation Levels on Conventional Cotton Plants and Transgenic Cotton Plants in a Real Environment on Treated Land

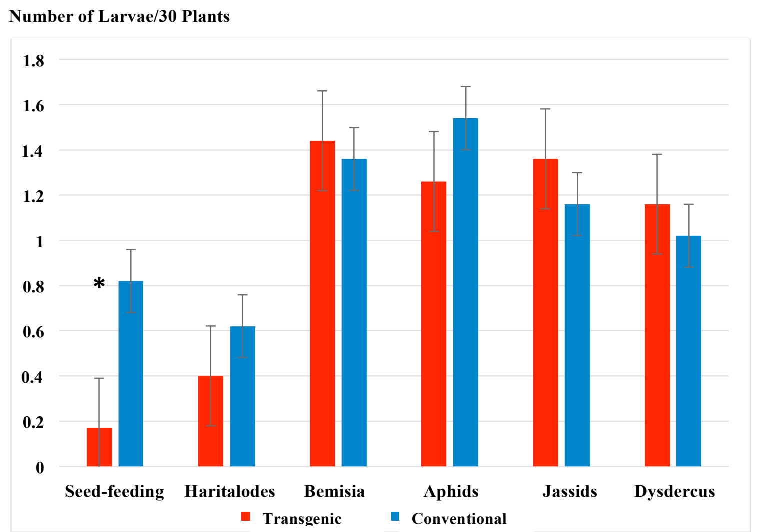


Figure 4: Average Pest Infestation Levels on Conventional Cotton Plants and Transgenic Cotton Plants in the Research Station on Untreated Land

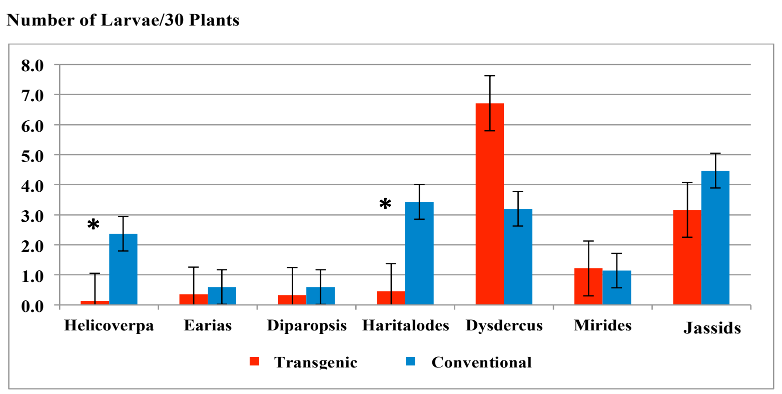
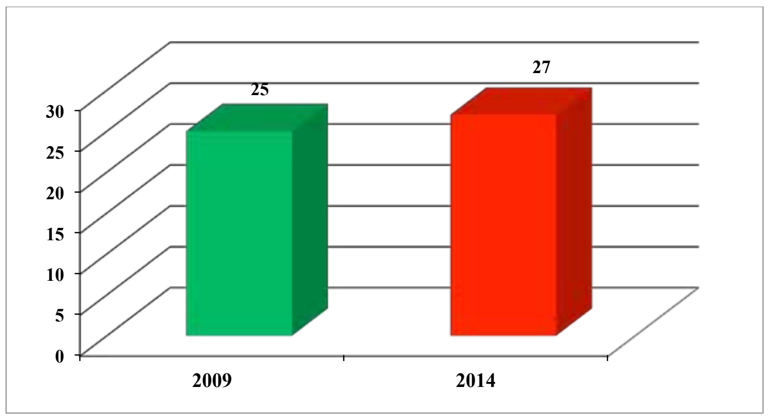


Figure 5: Resistance Coefficients of the *Helicoverpa armigera* Strains to Deltamethrin in 2009 and 2014 [Deltamethrin Confidence Interval/ *H. armigera*: 2009 = 0.039 - 2.728 µg/g and 2014 = 0.018 - 4.057 µg/g]



Discussion and Conclusion

The data analysis on the infestation levels of major pests in the period before the dissemination of the Bt transgenic cotton plants (2006-2008) showed a more marked infestation of the seed-feeding larvae on the conventional cotton plants than those of the seven years of cultivation of the Bt transgenic cotton plant. This observation was made on both cotton producers' treated land and untreated land at research stations of the Institute of the Environment and Agricultural Research. At research stations where the species were individually listed, the main cotton plant pest in Burkina Faso, which is *Helicoverpa armigera,* was the most represented seed-feeding larva during the period before the dissemination of the Bt transgenic cotton plant. This would probably be linked to the regular extension of Bt transgenic cotton varieties from 120,000 ha in 2009 to more than 500,000 ha in 2015 – more than 65% of the total cotton surface area. In addition to the effectiveness of the Bt transgenic cotton plant on the larvae of the main species of seed-feeding larvae present in Burkina Faso, which are *H. armigera*, *Earias* spp. and *Diparopsis watersi* (Héma *et al.,* 2009b), this technology influenced the duration of the larval stage, which is longer on the transgenic cotton plant than on the non-transgenic cotton plant (Khalique and Ahmed, 2003; Arshad *et al.*, 2009). This resulted in a drastic reduction of the populations of the following generations, and therefore a reduction of the number of individuals on the conventional cotton plant as well.

However, after five years of cultivation of the Bt transgenic cotton varieties in Burkina Faso, it was found that *H. armigera*'s level of sensitivity to deltamethrin had not changed (resistance coefficient 2009=25 and resistance coefficient 2014=27); while Wu *et al.* (2005) demonstrated a reduction in the resistance level in the *H. armigera* strains to lambdacyhalothrin of 9 to 15 times between 1994 and 2002 in China. Also, Wu *et al.* (2004) demonstrated that there is no cross-resistance between the Bt toxins and the chemical insecticides of the pyrethroid, organophosphorus and cyclodien families, indicating the option to use one if resistance to the other is found. Difficulties in proper rearing of *H. armigera,* which resulted in the reduction of strains tested in the laboratory could explain the difference

Figure 6: Resistance Coefficients of the Bemisia *tabaci* strains to Acetamiprid in 2009 and 2014
[Acetamiprid/ *B. tabaci* Confidence Interval: 2009 = 3.58 - 8781.55 mg/l and 2014 = $2.32.10^{-4}$ – $9.35.10^{7}$ mg/l]

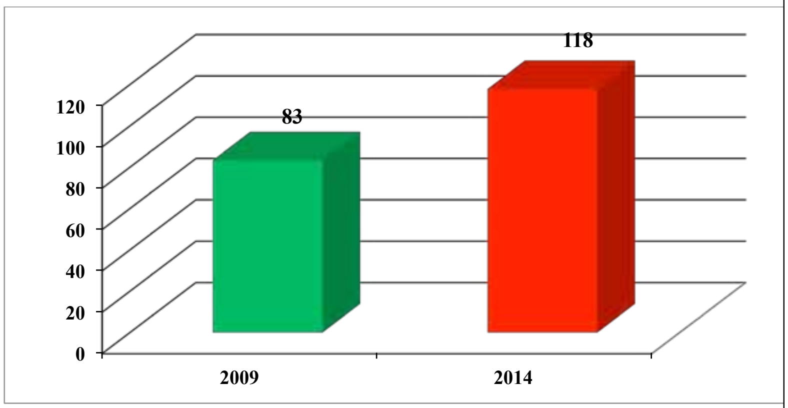
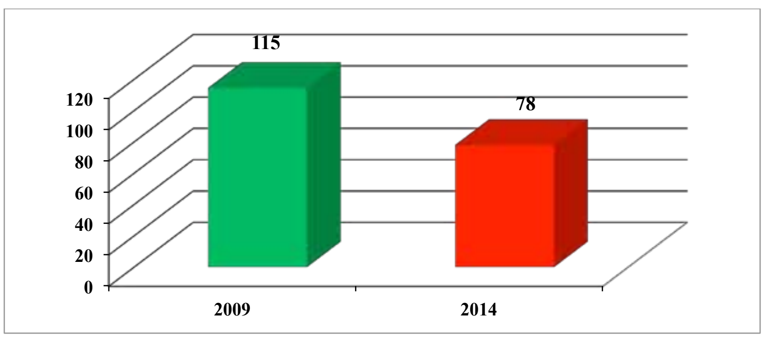


Figure 7: Resistance Coefficients of the *Bemisia tabaci* Strain to Deltamethrin in 2009 and 2014
[Deltamethrin/ B. *tabaci* Confidence Interval: 2009 = 0.10 - 67645.50 mg/l and 2014 = 0.95 - 2432.36 mg/l]



in results with those found in China. The proof is in the reduction in the average number of larvae of this pest on the conventional cotton plant in the cultivation period of the Bt transgenic cotton plant. Monitoring of the pest resistance level to the chemical insecticides must be followed because, at the level of the *B. tabaci*, there was no significant difference between the strains of both years compared (2009 and 2014); there was a downward trend of sensitivity to acetamiprid but an increase of sensitivity to deltamethrin.

In conclusion, the development of Bt technology in Burkina Faso allowed a significant decrease of infestations of seed-feeding pests, particularly *Helicoverpa armigera*, and a downward trend for the outbreak levels of certain phloem-feeding insects, such as the *Bemisia tabaci* whitefly and the *Aphis gossypii* aphid. However, what the study did not find was infestations of jassids, *Dysdercus* bugs and mirids, which been encountered in recent years in the West African sub-region, which are not necessarily related to the development of the Bt transgenic cotton plant.

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