Potential of sorghum and physic nut (*Jatropha curcas*) for management of plant bugs (Hemiptera: Miridae) and cotton bollworm (*Helicoverpa armigera*) on cotton in an assisted trap-cropping strategy

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Abstract

The cotton bollworm (CBW) *Helicoverpa armigera* and to a lesser extent plant bugs (PB) (Hemiptera: Miridae) are important pests of cotton in Africa. For sustainability reasons, it is necessary to reduce use of chemical control measures for these pests. A promising alternative to chemical control of both CBW and PB is trap cropping, assisted with botanical pesticides sprays, if needed. We report studies conducted from 1995–98 on sorghum attractiveness to PB and CBW, on the potential of physic nut (*Jatropha curcas*) extracts [particularly the phorbol ester (PE) fraction of the oil] for sorghum protection from PB damage, and on the insecticidal activity of *Jatropha* extracts on CBW. At the ICRISAT research station (Samanko, Mali), infestation by the five main species of PB (accounting for 96% of total) was much higher on sorghum than on cotton. In the Kolokani region, CBW infestation was negligible on the *Guinea* loose-panicled sorghum cultivar Bibalawili, while it was significant on both compact-panicled PB susceptible ICSH 89002 and PB resistant Malisor 84-7. At Samanko, *Jatropha* oil application on sorghum panicles showed some effect on PB when damage level was high, better than *Jatropha* and neem aqueous extracts. However, it did not compete with pyrethroid protection level. PE contact toxicity on CBW larvae was too low to determine a LC 50. An ingestion insecticidal activity of PE was found on all tested larval instars. Contact toxicity LC 50 of PE on eggs was 1.66 g ml^{-1}. Development of larvae and reproductive ability of adults derived from new-laid eggs treated with solutions of 0.35 g ml^{-1} PE and above were considerably affected. Prospects for using sorghum and *Jatropha* extracts for cotton protection against insect pests in an assisted trap-cropping strategy are discussed.

Introduction

The harvest loss occasioned to cotton (*Gossypium* sp) by insect pests alone is estimated at 24% in Sub-Saharan Africa (Deguine et al. 2008). Plant bugs (Hemiptera: Miridae) are important pests of cotton in Africa (Cadou 1994), where their attacks mainly target fruiting parts at their early stages. On the other hand, the cotton bollworm (CBW) *Helicoverpa armigera* is considered as a major pest of cotton across all West African cotton producing countries (Youm et al. 2005). Chemical pesticide application has long been the mainstay of cotton crop protection strategies against these pests. However, there is increasing evidence of serious undesirable secondary effects arising from the manipulation of highly toxic molecules, their lack of specificity of action, the persistence in the environment of certain degradation products and the capacity of the pests to evolve resistance to the compounds (Deguine et al. 2008). It is therefore urgent to pay more attention to alternative pest control strategies, including those offered by cultural practices.

A promising, environmentally sound approach to manage insect pests in agricultural systems is trap cropping (Hokkanen 1991, Shelton and Badenes-Perez 2006, Cook et al. 2007). Trap crop strategies have proven themselves highly effective on tough pests in cropping systems in recent years and offer the potential to minimize or eliminate the use of insecticides and preserve natural enemies that control pests, while maintaining or increasing crop quality and yield (Hokkanen 1991). The practice of trap cropping is based upon the exploitation of insect preferences for certain host plants. By planting highly attractive plant species as intercrops or borders, insect pests can be diverted from the susceptible primary crop.

Generalist insect herbivores, such as plant bugs and CBW, are therefore good candidates for such a management strategy that involves host-plant choice. Trap cropping has actually been successfully used for management of mirid pests worldwide, particularly for cotton protection. Alfalfa (*Medicago sativa*) strips are inter-planted with cotton and managed distinctively to control *Lygus hesperus* in the US (Godfrey and Leigh 1994) and *Creontiades dilutus* in Australia (Mensah and Khan 1997). In the US, sorghum (*Sorghum bicolor*) is an important host plant for panicle-feeding bugs and was thus considered to have potential as a trap crop for some of them (Tillman 2006). *Helicoverpa* spp attack maize (*Zea mays*) and grain sorghum preferentially over most other crop hosts (Kring et al. 1989). Studies showed that sorghum is attractive to *H. armigera* moths during the period between flowering and anther drying.

Ideally, trap plants should have the inherent property of not allowing the development of the pests once they are trapped (Cook et al. 2007). When such "dead-end" trap plants are not available for a given pest, one may also consider increasing the effectiveness of trap crops by targeted use of other control methods, such as insecticide sprays (Hokkanen 1991, Shelton and Badenes-Perez 2006).

In Mali, studies conducted in the Kolokani region (about 100 km North of Bamako) have shown that introduced improved sorghum cultivars of the *Caudatum* race with compact panicles were highly attractive for mirid bugs (Ratnadass et al. 2008). Panicle compactness also makes *Caudatum* cultivars prone to infestation and damage by *H. armigera*, which is otherwise virtually absent on local cultivars of the *Guinea* race (Youm et al. 2005). On the other hand, the potential of physic nut (*Jatropha curcas*) oil and its phorbol ester (PE) fraction has been established on two noctuid pests of sorghum in Mali (Mengual 1997) and on *H. armigera* in the Philippines (Solsoloy and Solsoloy 1997).

We present here studies that were conducted from 1995 to 1998, respectively on infestation of sorghum vs cotton by plant bugs and on sorghum infestation by *H. armigera*, and on insecticidal effects of physic nut extracts on plant bugs and on *H. armigera*. Although a decade-old, these unpublished results shed a new light on prospects for using sorghum and physic nut in an assisted trap-cropping strategy for an agroecological protection of cotton in the Sudanian zones of West Africa. Such prospects for alternative technical crop protection options are welcome in response to strong society-driven environmental concerns, particularly if they can be implemented in a flexible manner to comply with the volatile context of cotton, cereals (as food or bio-fuel) and other fuels (including non-edible vegetal oils) prices on local and international markets (Berti et al. 2006, Kumar and Sharma 2008, Tenenbaum 2008).

Materials and methods

Assessment of sorghum attractiveness to mirid bugs. This study was conducted during the 1996 rainy season at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Samanko, Mali located about 20 km southwest of Bamako (longitude 8°04' W, latitude 12°31' N, 328 m amsl). Two 25 m × 100 m strips of cotton cv STAM 42 (following fallow) and sorghum cv ICSV 1063 (following cotton) were planted adjacently. No insecticide was applied. These strips were subdivided in 12 subplots and observations were made on 6 non-contiguous subplots. Starting at the flowering stage, a random sampling of 10 plants was performed weekly in each subplot of sorghum and cotton. Sorghum panicles were covered by a 41 cm × 44 cm transparent polyethylene bag and shaken so as to dislodge all insects, from onset of anthesis until grain maturation. As for cotton, a 49 cm × 100 cm transparent polyethylene bag was used to cover the whole plant before lifting it and shaken as described above. All bags were then put in a deep freezer in order to kill all insects prior to their identification and enumeration. The student t-test (P = 0.01) was used for statistical comparison of means.

Assessment of sorghum attractiveness to the cotton bollworm. In 1998, in the villages of Wenia and Ntiobougou, located within a radius of 30 km from the town of Kolokani (13°55' N; 8°20' W), we observed populations of *H. armigera* on the panicles of four sorghum cultivars (including one local *Guinea* cv with loose panicle, the other three being compact-panicle types), planted both in small and large plots, in a field design described elsewhere (Ratnadass et al. 2008). Differences between cultivars and treatments were determined with the F-test, and means were compared using LSD at P <0.05.

Assessment of the potential of *Jatropha curcas* oil extracts for sorghum protection from mirid bug damage. The potential of physic nut extract vs mirid bugs of sorghum was assessed in two tests conducted at

Samanko in 1995 and 1996. Four sorghum cultivars, S34, ICSV 1063, Malisor 84-7 and CSM 388 were tested in two dates of sowing in randomized complete block design (RCBD) with four replications in 1995 and three replications in 1996. In 1995, there were four treatments; 2.4 L ha^{-1} of an EC formulation with a methanolic extract of physic nut from Mali (Mengual 1997) with 30% PE content, a "blank" consisting in a treatment at 2.4 L ha^{-1} with only the adjuvants of the EC formulation, particularly methanol, an EC formulation of deltamethrin (12.5 g ai $ha^{-1} \times 3$) and an unprotected control (tap water). Two treatments were added to those four in 1996, namely neem (*Azadirachta indica*) and *Jatropha* aqueous extracts, obtained by filtration of 100 g L^{-1} of ground seeds and applied after one night of soaking, with a knapsack sprayer at the dose of 900 L ha^{-1}. In both years, all treatments consisted of three sprayings, at weekly intervals, starting at end of flowering. Observations were made on head-bug visual damage score on a 1–9 scale (Ratnadass et al. 2008).

Evaluation of the insecticidal activity of Jatropha extracts on *H. armigera.* Biological tests were conducted in 1997 in the laboratory (temperature 25°C; RH 70%; photoperiod 12:12) at CIRAD, Montpellier, France, on an *H. armigera* strain originating from Bouaké (Côte d'Ivoire), and reared for 20 years following mass rearing technique as described by Couilloud and Giret (1980). The *Jatropha* extract used was obtained by methanol extraction on physic nut oil performed at CNESOLER, Bamako, Mali (Mengual 1997). Its PE content as determined by HPLC at the University of Heidelberg (Germany) was 35%.

The assessment of PE contact toxicity was conducted with 15 acetonic solutions at increasing concentrations of the raw extract (in a geometrical progession from 0.003 to 17.5 µg of PE extract per insect), compared with a control (0 µg per insect). For each concentration, five replications of 30 freshly molted 3rd and 4th instar larvae with average weights of 40 and 60 mg were tested respectively. Acetonic drops were dorsally applied on the 1st thoracic segment at the dose of 1 µl per insect, with an Arnold (Burkard) micro-applicator. Mortality was recorded after 48 h.

Ingestion toxicity tests were conducted on the 1st four larval instars. Larvae (30 per lot) were put in containers with individual compartments filled with nutritive diet. Individual compartments, whose surface was 450 mm², were treated by application of 100 µl of acetonic solution. Each concentration was tested in five replications and the mortality was recorded at 24, 48, 72, 96, 120 and 144 h after treatments. Mean lethal concentration (LC 50) was determined using the working probits method (Finney 1971).

For assessment of PE toxicity on *H. armigera* egg hatchability, a pair of young adults was released in oviposition cage in the rearing room. Cotton gauze served as an egg-laying substrate, and the gauzes having similar aged eggs were collected, and divided in four sections each bearing approximately the same number of eggs. These sections were then randomly distributed, one being treated with pure acetone (control) and the others with three PE extract concentrations in acetonic solutions. All treatments were performed on eggs aged a few hours, by dipping gauze sections in 3 ml of each solution for 60 seconds. Treated and dried gauzes were then put in containers in the rearing room until hatching. Three days after egg-laying, unhatched eggs were counted. The trial consisted of 10 replications, and data were analyzed in a RCBD design.

LC 50 on *H. armigera* eggs was determined using four PE concentrations prepared in acetonic solutions in geometric progression of reason 3.5 (0.35, 1.22, 3.5 and 12.25 g ml^{-1}), and pure acetone (control) for treating new-laid eggs. Eggs laid on cotton gauze as reported above were dipped in above-mentioned solutions for 60 seconds. Data (unhatched eggs) were analyzed following the probit/log method. This test was replicated twice.

Effects of PE on *H. armigera* larvae derived from the eggs treated with 0.035, 0.35 and 3.5 g PE ml^{-1} and acetone were studied on 30 neonate larvae per treatment. The observations were recorded on weight of 5- and 15-day-old larvae and pupae of *H. armigera*, and the fecundity and fertility of the adults that emerged from these pupae. Data were analyzed using completely randomized design.

Results and discussion

Study of sorghum attractiveness to mirid bugs. The five main species of mirid bugs recorded at Samanko (representing >96% of all plant bugs) are shown in Figure 1. *Helopeltis* sp (the most damaging bug on cotton) represented 0.2 ± 0.41 on cotton and was absent on sorghum. Mean infestation per plant was much higher on sorghum than on cotton for all species. Unidentified plant bug species accounted for 12.0 ± 5.80 on cotton and 1.8 ± 2.99 on sorghum.

Assessment of sorghum attractiveness to the cotton bollworm. Effects of sorghum genotype in both small and large plots and of distance from the plot border in the large plots (see Ratnadass et al. 2008) and their interactions were significant, but not the effect of locality. In both small and large plots, infestation by *H. armigera* was negligible on Bibalawili, while it was significant on both ICSH 89002 and Malisor 84-7 (Fig. 2).

Assessment of the potential of *Jatropha curcas* oil for sorghum protection from mirid bug damage. Both years, cultivar, treatment and interaction effects were positive (Table 1). There were no significant differences between control and blank. Deltamethrin offered total protection, while significant effect of PEs was observed when damage level was high (eg, in S34 and ICSV 1063). In 1995, this effect was significant only on 2nd date of sowing, while in 1996, it was significant on both dates of sowing, with an effect of neem extract only on 2nd date of sowing.

Evaluation of the insecticidal activity of *Jatropha* extracts on *H. armigera.* PE contact toxicity on *H. armigera* larvae was too low to determine LC 50. On the other hand, ingestion tests showed an insecticidal activity of PE on all tested larval instars, although more marked on younger instars (Table 2). LC 50 of PE on eggs was 1.66 g ml^{-1}. Egg toxicity was more marked with 0.35 and 3.5 g ml^{-1} PE solutions (Fig. 3).

Treatment of new-laid eggs with solutions at rates of 0.35 g ml^{-1} and above considerably affected growth and development of larvae derived from these eggs

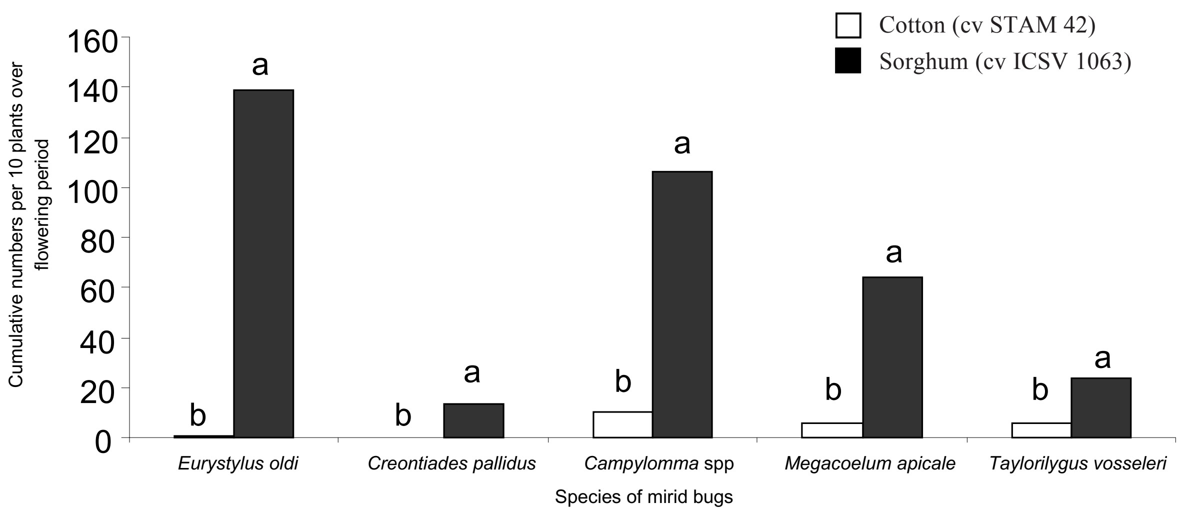

Figure 1. Main mirid bug species recorded on cotton and sorghum at Samanko, 1996. (Note: The paired bars following different letters for the same species are statistically significant at $P = 0.01$.)

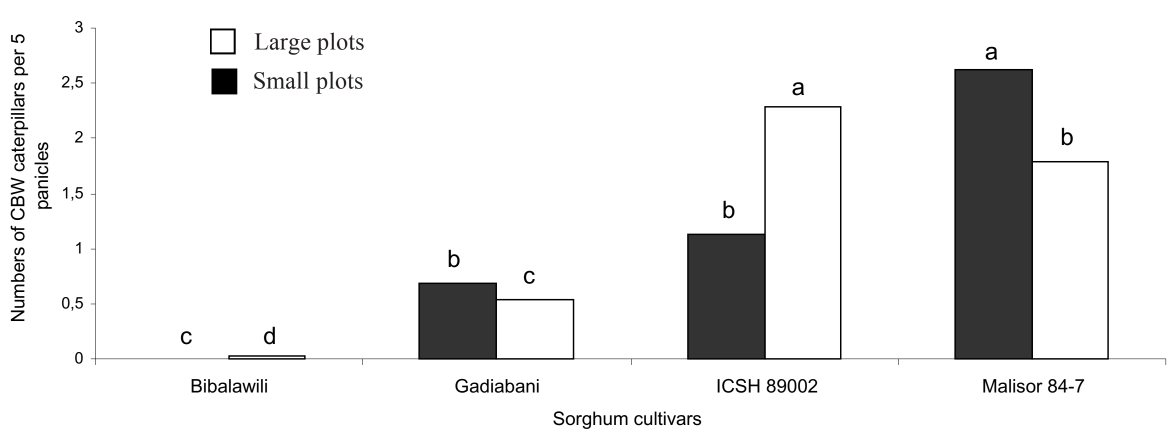

Figure 2. Cotton bollworm (CBW) infestation observed on sorghum on-farm at Wenia and Ntiobougou, Mali, 1998. [Note: Means with the same letter for the same plot size are not significantly different (LSD test) at $P = 0.05$.]

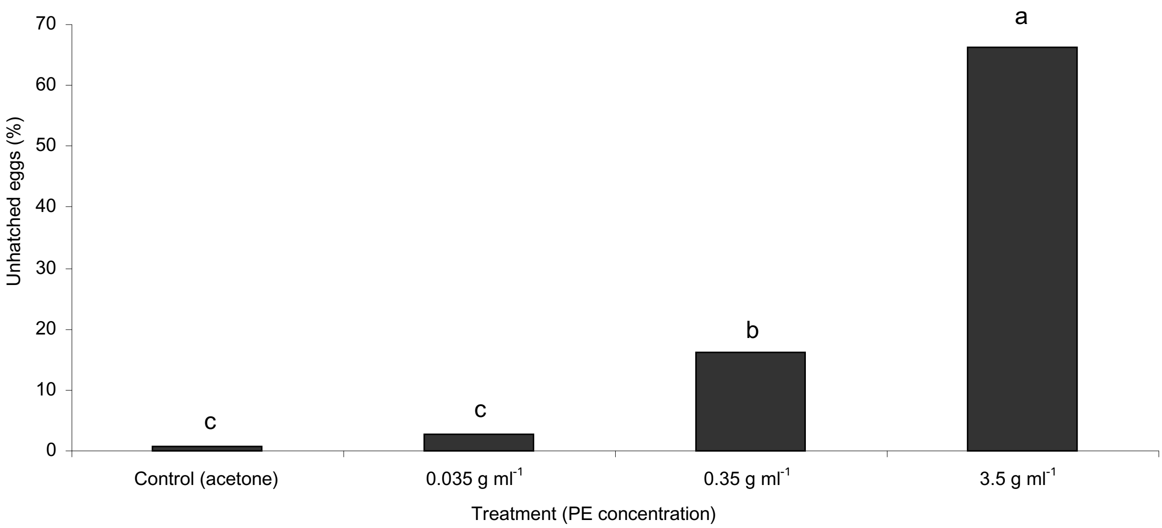

Figure 3. Assessment of phorbol ester (PE) toxicity on cotton bollworm hatching rate. [Note: Means with the same letter are not significantly different (Newman-Keuls test) at $P = 0.05$.]

Table 1. Effect of phorbol ester application on mirid bug damage ratings on sorghum panicles at Samanko in 1995 and 1996[1].

Trial[2]	Control	Blank	Neem aqueous extract	*Jatropha* aqueous extract	Phorbol ester	Deltamethrin
1995 DOS1	3.4a	3.3a	NA[3]	NA	3.3a	1.0b
1995 DOS2	4.3a	3.9a	NA	NA	3.1b	1.0c
1996 DOS1	3.9a	3.6a	3.7a	3.3ab	2.8b	1.0c
1996 DOS2	4.7a	4.3ab	3.8b	4.0ab	3.8b	1.0c

1. Values presented in the table are means of four cultivars. Means followed by the same letter in a row are not significantly different (Newman-Keuls test) at $P = 0.05$).
2. DOS = Date of sowing.
3. NA = Not applicable.

(including molt interruption resulting in the death of some insects). Reproductive ability of adults emerging from pupae was also reduced (low fecundity and high sterility rates) (Table 3).

New prospects for using sorghum and physic nut for cotton protection against insect pests in an assisted trap-cropping strategy

These unpublished results shed a new light on prospects for using some sorghum cultivars and physic nut extracts in an assisted trap-cropping strategy for protection of high-value crops such as cotton from insect pests in Sudanian zones of West Africa. Furthermore, the recent changes in the economic context (eg, collapse of world cotton prices), added to above-mentioned human health and environmental considerations, makes it even more urgent to find alternative solutions to chemical insecticide-based cotton and other high-value crop protection. Indeed, given the above-mentioned fluctuating economic context, which translates in rapid changes of fuel, cereal and cotton prices on local and international markets (Berti et al. 2006, Kumar and Sharma 2008,

Table 2. Variation of phorbol ester LC 50 according to time and *Helicoverpa armigera* larval instar.

	LC 50 (µg mm^{-2})			
Time (h)	L1	L2	L3	L4
24	10.3	–	–	–
48	0.09	1.6	6.6	41.6
72	0.03	0.4	4.6	15.3
96	0.02	0.2	1.3	4.89
120	0.01	0.2	1	3.03
144	0.01	0.2	0.9	1.51

Table 3. Effect of phorbol ester (PE) egg treatment on further developmental parameters of *Helicoverpa armigera*[1].

Treatment (PE concentration)	Weight (mg per larva or mg per pupa)			Fecundity (no. of eggs female^{-1})	Egg hatchability (%)
	5-day larvae	15-day larvae	Pupae		
Control (acetone)	44.3a	222.9a	341.5a	262a	98.3a
0.035g ml^{-1}	28.8b	175.2b	267.4b	251a	95.7a
0.35 g ml^{-1}	19.7c	106.8c	232.7c	180b	68.7b
3.5 g ml^{-1}	14.6c	96.1c	220.0c	144b	5.3c

1. Means followed by the same letter in a column are not significantly different (Newman-Keuls test) at $P = 0.05$.

Tenenbaum 2008), one could even consider using cotton as a trap crop for protecting not only vegetable crops, but also sorghum from CBW damage.

Due to the potential of *Jatropha* oil as a diesel oil substitute in the current economic context, physic nut is likely to take increasing importance in the near future, particularly in Sub-Saharan Africa, and other properties of the oil or its byproducts should be investigated (Kumar and Sharma 2008). Rather than direct application on the crop (Solsoloy and Solsoloy 1997), targeted application on trap crops makes it even more economical, and phytotoxic effects are less concerning on trap crops than on main crops.

In this respect, further research is needed on the potential of combined use of trap crops and plant extracts in an “assisted” push-pull strategy for managing plant bugs and CBW. For instance, in the case of mirid bugs on sorghum, only a general effect on damage was assessed, and no detailed evidence of either repellent, deterrent, ingestion or contact toxicity was provided. Similarly, in the case of CBW, it is not known whether PEs have a repellent effect on moths.

On the other hand, the absence of contact toxicity on larvae is partly compensated by contact toxicity on eggs. Our results also open prospects for investigating the use of extracts of different plants for the “push” effect on the main crop, and the “kill” effect on the trap crop (eg, neem extracts vs *Jatropha* extracts), of different extracts or fractions of extracts of the same plant, eg, aqueous extracts vs oil or PEs in the case of *Jatropha*.

Also, in our study, sorghum attractiveness to CBW was not specifically compared to that of cotton. However, the fact that sorghum can be used as a trap crop for both pests is certainly an advantage. Indeed, although mirid bugs are considered as secondary pests of cotton compared to CBW in Africa, they may emerge as major pests in substitution to CBW and other bollworms, with the development of genetically modified cotton in some countries (eg, Burkina Faso).

In any case, attention should be given to cultivars used since those are not necessarily the same that are “highly attractive to both pests, eg, mirid bug-resistant” Malisor 84-7, which is highly attractive to CBW, while ICSH 89002 is both mirid bug-susceptible and CBW-attractive, and ICSV 1063, of which Gadiabani is partly derived, is both mirid bug-susceptible and moderately CBW-attractive (Ratnadass et al. 2008).

Further to the use of its byproducts in an assisted push-pull strategy, parallel studies are being conducted at ICRISAT in Niger on the potential “top-down” effect of *Jatropha* hedge-rows on crop pests. Also, results of preliminary studies conducted by ICRISAT and its partners in Niger showed that pigeonpea (*Cajanus cajan*) was more promising than sorghum for okra (*Abelmoschus esculentus*) protection against *H. armigera*, and other studies are underway on the potential of both crops for CBW management on tomato (*Lycopersicon lycopersicum*), which also happens to be a high-value crop grown in the Kolokani region. Further to risks of phytotoxicity, risks of toxic residues make the assisted push-pull strategy even more relevant on edible crops than on fiber crops.

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References

Berti F, Hofs JL, Zagbaï HS and **Lebailly P.** 2006. Le coton dans le monde, place du coton africain et principaux enjeux. Biotechnologie, Agronomie, Société et Environnement 10:271–280.

Cadou J. 1994. Les Miridae du cotonnier en Afrique et à Madagascar. Série les déprédateurs du cotonnier en Afrique tropicale et dans le reste du monde N°8. Paris, France: CIRAD. 74 pp.

Cook SM, Khan ZR and **Pickett JA.** 2007. The use of push-pull strategies in integrated pest management. Annual Review of Entomology 52:375–400.

Couilloud R and **Giret M.** 1980. Multiplication d'*H. armigera* Hbn (Lep. Noctuidae): Améliorations possibles grâce à l'adoption d'une technique d'élevage en groupe de chenilles. Coton et Fibres tropicales 35:217–224.

Deguine JP, Ferron P and **Russell D.** 2008. Sustainable pest management for cotton production. A review. Agronomy for sustainable Development 28:1–25.

Finney DJ. 1971. Probit analysis. 3rd edition. London, UK: Cambridge University Press.

Godfrey LD and **Leigh TF.** 1994. Alfalfa harvest strategy effect on *Lygus* bug (Hemiptera: Miridae) and insect predator population density: implications for use as trap crop in cotton. Environmental Entomology 23:1106–1118.

Hokkanen H. 1991. Trap cropping in pest management. Annual Review of Entomology 36:119–138.

Kring TJ, Yearian WC and **Steward VB.** 1989. Within-field and within-panicle distribution of *Heliothis zea* (Lepidoptera: Noctuidae) and *Celama sorghiella* (Lepidoptera: Noctuidae) eggs in grain sorghum. Environmental Entomology 18:150–156.

Kumar A and **Sharma S.** 2008. An evaluation of multipurpose oil seed crop for industrial uses (*Jatropha curcas* L.): A review. Industrial Crops and Products 28:1–10.

Mengual L. 1997. Extraction of bioactive substances from *J. curcas* L. and bioassays on *Zonocerus variegatus*, *Sesamia calamistis* and *Busseola fusca* for characterisation of insecticidal properties. Pages 211–215 *in* Biofuel and industrial products from *Jatropha curcas* (Gübitz GM, Mittelbach M and Trabi M, eds). Graz: Dbv-Verlag University.

Mensah RK and **Khan M.** 1997. Use of *Medicago sativa* (L.) interplantings/trap crops in the management of the green mirid, *Creontiades dilutus* (Stal) in commercial cotton in Australia. International Journal of Pest Management 43:197–202.

Ratnadass A, Cissé B, Cissé S, Cissé T, Hamada MA, Chantereau J and **Letourmy P.** 2008. Combined on-farm effect of plot size and sorghum genotype on sorghum panicle-feeding bug infestation in Mali. Euphytica 159:135–144.

Shelton AM and **Badenes-Perez FR.** 2006. Concepts and applications of trap cropping in pest management. Annual Review of Entomology 51:285–308.

Solsoloy AD and **Solsoloy TS.** 1997. Pesticidal efficacy of formulated *J. curcas* oil on pests of selected field crops. Pages 216–226 *in* Biofuel and industrial products from *Jatropha curcas* (Gübitz GM, Mittelbach M and Trabi M, eds.). Graz: Dbv-Verlag University.

Tenenbaum D. 2008. Food vs. fuel: Diversion of crops could cause more hunger. Environ Health Perspect 116:A254–A257.

Tillman PG. 2006. Sorghum as a trap crop for *Nezara viridula* L. (Heteroptera: Pentatomidae) in cotton in the Southern United States. Environmental Entomology 35:771–783.

Youm O, Sithanantham S, Vaissayre M, Nibouche S, Martin T, Ochou GO and **Momanyi G.** 2005. Bio-ecology and management of Helicoverpa for sustainable crop production in Africa. Pages 63–90 *in* Heliothis/Helicoverpa management: emerging trends and strategies for future research (Sharma HC, ed.). New Delhi, India: Oxford & IBH Publishing Co Pvt Ltd.