Physic nut (*Jatropha curcas*) oil as a protectant against field insect pests of cowpea in Sudano-Sahelian cropping systems

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Abstract

Cowpea is a profitable food and fodder crop in the Sudano-Sahelian region of Africa. Unfortunately, it is extensively damaged in the field by a range of insect pests. The use of locally available insecticidal plant extracts is a promising alternative to chemical crop protection, which is the most popular management strategy but shows many drawbacks. In this respect, oil extracted from seed of the physic nut shrub (*Jatropha curcas*) showed promise. The insecticidal properties of *J. curcas* oil were thus assessed against cowpea insect pests at the ICRISAT research station, Sadoré, Niger. In 2002, four concentrations of physic nut oil extract, formulated as an emulsifiable concentrate (EC) (namely 2.5%, 5%, 7.5% and 10%), were evaluated as field sprays along with an untreated control (water spraying) and a conventional insecticide (Deltamethrin Decis® EC) treatment. In 2009, these latter two checks were evaluated alongside four concentrations of a "blank" formulation consisting of only the adjuvants of the 2002 EC formulation (namely 1.25%, 2.5%, 3.75% and 5%). In 2002, application of Deltamethrin and physic nut oil at 7.5% gave the highest seed yields, with more than 1000 kg ha^{-1}. Both treatments, alongside the one with 10% oil, sustained significantly lower thrips (*Megalurothrips sjostedti*) infestation than the water-sprayed control. All oil extract treatments and the Deltamethrin treatment sustained significantly lower infestation by *Clavigralla tomentosicollis* bugs than the untreated control, with the lowest infestation occurring with 7.5% oil. Furthermore, correlations between oil concentration and thrips and bug infestation were negative and significant, while correlation between oil concentration and seed yield was not significant, due to a phytotoxic effect of oil at high concentrations. The follow-up studies in 2009 confirmed that effects of *Jatropha* oil on cowpea insect infestation and seed yield observed in 2002 could be ascribed to the physic nut oil fraction alone.

Introduction

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and its partners are promoting water-saving and income generating systems such as the water-harvesting based Dryland Eco-Farm (DEF) system (Fatondji et al. 2011) and the African Market Garden (AMG) system (Woltering et al. 2011) and higher-value crops like grafted jujube (*Ziziphus mauritiana*), watermelon (*Citrullus lanatus*) (Fatondji et al. 2008), roselle (*Hibiscus sabdariffa*) and cowpea (*Vigna unguiculata*) in the Sudano-Sahelian region. Cowpea is the most popular food legume grown in this region for its grain and fodder production.

Unfortunately, cowpea is extensively attacked by a range of field and storage pests, which translates into extensive damage, if crop protection measures are not taken (Jackai and Daoust 1986). On the other hand, chemical control, which is the only management option available to farmers is expensive, products are not always available at farm level, and repeated application is detrimental to human health and the environment.

The potential of the physic nut (*Jatropha curcas*) oil as a diesel oil substitute is likely to take increasing importance in the near future, particularly in Sub-Saharan Africa. ICRISAT is therefore evaluating the potential of the physic nut shrub in the Sahelian environment, either in pure stands/plantations, or in mixed systems, eg, as live fences to protect the drip irrigation-based AMG system (Pasternak et al. 2006) from domestic animals.

In this context, other properties of the oil or its byproducts should be investigated (Kumar and Sharma 2008), including their insecticidal properties, either via direct application on the crop or targeted application on trap crops (Ratnadass et al. 2009), which would make it even more economical, added to the fact that phytotoxic effects are less concerning on trap crops than on main crops.

In view of identifying alternatives to chemical control, physic nut oil from Burkina Faso was assessed at the ICRISAT research station, Sadoré, Niger (13°15' N, 2°17' E), as a biopesticide for cowpea (cv TN5-78) field pest control in a field trial in 2002. Another trial was conducted in 2009 to confirm that the highlighted effects were due to the physic nut oil and not the adjuvants used in the formulation.

Materials and methods

Extract formulation and application. In 2002, the emulsifiable concentrate (EC) was obtained by mixing 50% v/v physic nut oil, 30% Ethanol 95% (as a solvent/preservative), 20% gum arabic diluted at 10% (as a non-active wetting adhesive) and liquid soap (2 ml L^{-1}).

The EC was thus diluted in the laboratory as follows, to get 4 L of diluted product per plot (4 m × 4 m): 100 ml of EC in 3.9 L of water for the 2.5% dose; 200 ml of EC in 3.8 L of water for the 5% dose; 300 ml of EC in 3.7 L of water for the 7.5% dose; and 400 ml of EC in 3.6 L of water for the 10% dose. Physic nut oil concentrations tested were selected following a preliminary test that showed a phytotoxic effect on leaves starting slightly at the 7.5% concentration, and being total at the 40% concentration.

Similarly, in 2009, a "blank" consisting of only the adjuvants used in 2002 (excluding physic nut oil) was obtained by mixing 60% v/v Ethanol 95% and 40% gum arabic diluted at 10% and adding 2 ml L^{-1} liquid soap. Dilution was then conducted the same way as for the physic nut oil EC experiment, namely 50 ml of blank in 3.95 L of water for the 1.25% dose; 100 ml of blank in 3.9 L of water for the 2.5% dose; 150 ml of blank in 3.85 L of water for the 3.75% dose; and 200 ml of blank in 3.8 L of water for the 5% dose. The formulated extract or blank was applied at dusk every week until the vegetation dripped, respectively with a ULV sprayer from 16 Sep to 11 Nov 2002, and with a knap-sack sprayer from 30 Jun to 22 Sep 2009.

Layout designs. In 2002, the layout was a randomized complete block design (RCBD) with six treatments [T1: control = water (0% physic nut oil); T2: insecticide (Deltamethrin Decis EC 12®); T3: 2.5% oil; T4: 5% oil; T5: 7.5% oil; T6: 10% oil] and three replications. Crop precedent was roselle (*Hibiscus sabdariffa*), following a pearl millet (*Pennisetum glaucum*) crop. Cowpea (cv TN5-78) was planted in 4 m × 4 m plots at 56,250 plants ha^{-1} density, with 2 m inter-plot spacing.

In 2009, due to field space availability and heterogeneity, there were four distinct experiments (Ea, Eb, Ec and Ed) in RCBD layouts with three treatments (the same controls T1 and T2 as above, and a third treatment with the blank corresponding to each of the four oil concentrations tested in 2002, namely T3/Ea: 1.25% adjuvants; T3/Eb: 2.5% adjuvants; T3/Ec: 3.75% adjuvants; and T3/Ed: 5% adjuvants) and two replications.

Cowpea (cv TN5-78) was planted in 6.2 m × 6 m plots at a 31,250 plants ha^{-1} density, on 16 Jun after an okra (*Abelmoschus esculentus*) precedent following a pearl millet crop. In each block, plots were staggered, displayed with their angles at a distance of 11 m from each other.

Field observations. In 2002, observations were taken on flower thrips (*Megalurothrips sjostedti*), heteropteran bugs (*Clavigralla tomentosicollis*) and aphids (*Aphis craccivora*) followed by seed yield. During 2009, observations were taken on thrips, all heteropteran bugs and leafhoppers (*Empoasca* sp) followed by seed yield at harvest.

Discrepancy between 2002 and 2009 observations were due to the fact that a preliminary pest survey conducted in 2008 on cowpea plots, adjacent to the ones followed in 2009, had shown the virtual absence of aphids, the dominance of heteropteran bug species other than *C. tomentosicollis* and the high incidence of leafhoppers, while confirming the high infestation by flower thrips (Akourki 2008). This trend was actually confirmed in the 2009 study.

Furthermore, following preliminary observations made in 2008 (Akourki 2008), the sampling procedure was changed as compared to 2002. In 2002, observations on flower thrips consisted in harvesting at random 10 flowers per plot twice a week (every third or fourth day), starting just before the first spraying. Collected flowers were preserved in vials filled with 75% ethanol for observations on thrips under the microscope. Bugs (*Heteroptera*) populations were assessed using a sweeping net over six cowpea hills per plot, twice a week.

Aphid infestation level was assessed by visually counting the insects on six hill-subplots, every third or fourth day, using a 0–5 rating scale with 0 = 0–50 aphids and 5 = >400 aphids. Seed yield was assessed on a 1 m × 1 m square per plot, by weighing seed grain at harvest.

In 2009, for thrips observations, 10 flowers were randomly selected in an observation plot of six hills, which was itself randomly selected in each plot twice a week, one day before and two days after weekly spraying. Collected flowers were preserved in vials filled with 75% ethanol for onward dissection and enumeration of thrips under the microscope. Both heteropteran bugs and leafhoppers were sampled with a D-Vac (Dietrick 1961) twice a week after flower collection, on the same randomly selected hills. Seed yield was measured on a randomly selected subplot of six hills (2.4 m × 0.8 m) on which no insect sampling/observation had been conducted.

Data analysis. In 2002, data on insect infestation were analyzed using the General Linear Models Procedure of software SAS (SAS Institute 1997), while those on seed and fodder yield were analyzed using the ANOVA module of GenStat (Lawes Agriculture Trust 2000). In 2009, all data were analyzed using the ANOVA module of (XLSTAT) (Addinsoft 2009), after square root transformation for pest infestation data. Means were compared using the Newman-Keuls method.

Results and discussion

In 2002, we observed a clear effect of physic nut oil on flower thrips, proportional to the concentration (Fig. 1). Thrips infestation was significantly lower at the 10% concentration as compared to the water control, while infestations at both 10% and 7.5% concentrations were not significantly different from that of the deltamethrin treatment.

We also observed a significant effect of all physic nut oil concentrations, similar to the deltamethrin treatment, on *Clavigralla* bug infestation as compared to the water-sprayed control (Fig. 2). On the other hand, there was no significant effect on aphids of any of the oil concentrations tested (Fig. 3). Actually, the only significant difference was surprisingly between the deltamethrin treatment and the 2.5% oil concentration.

In terms of seed yield, plots sprayed with deltamethrin and physic nut oil at the 7.5% concentration showed the highest yield (above 1,000 kg ha^{-1}) (Fig. 4).

Regarding thrips infestation in 2009, there was no significant difference but a tendancy at the 10% level in Experiment Ed, while differences between treatments

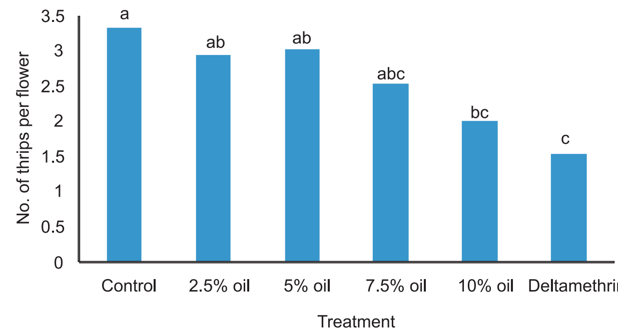

Figure 1. Infestation of cowpea flowers by thrips in different treatments at Sadoré, 2002. [Note: Means with the same letter are not signifiantly different (Newman-Keuls test) at $P = 0.05$.]

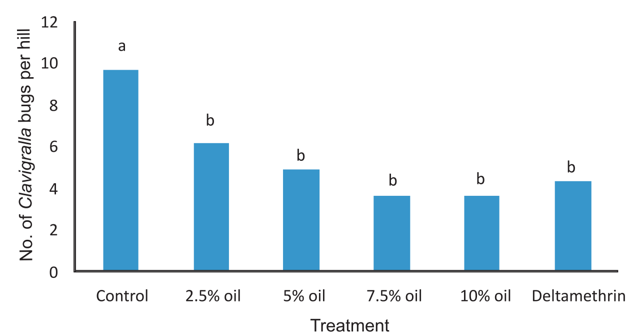

Figure 2. Infestation of cowpea by *Clavigralla* bugs in different treatments at Sadoré, 2002. [Note: Means with the same letter are not signifiantly different (Newman-Keuls test) at $P = 0.05$.]

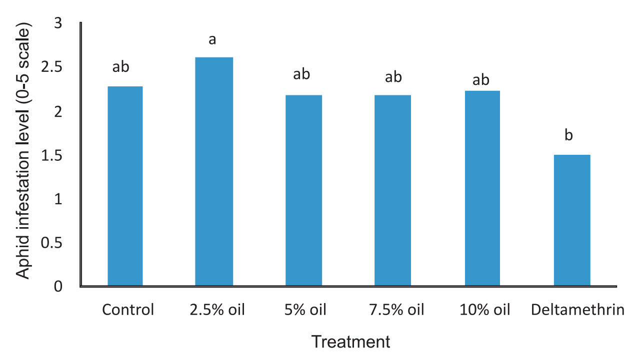

Figure 3. Infestation of cowpea by aphids in different treatments at Sadoré, 2002. [Note: Means with the same letter are not signifiantly different (Newman-Keuls test) at $P = 0.05$.]

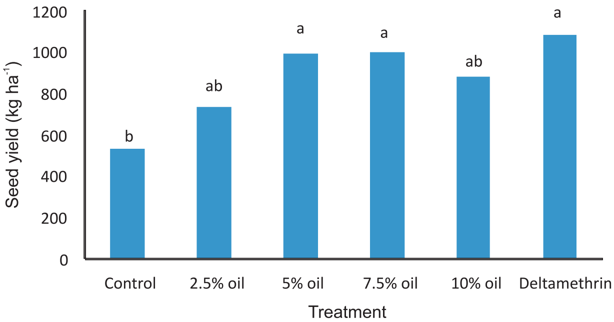

Figure 4. Seed yield of cowpea in different treatments at Sadoré, 2002. [Note: Means with the same letter are not signifiantly different (Newman-Keuls test) at P = 0.05.]

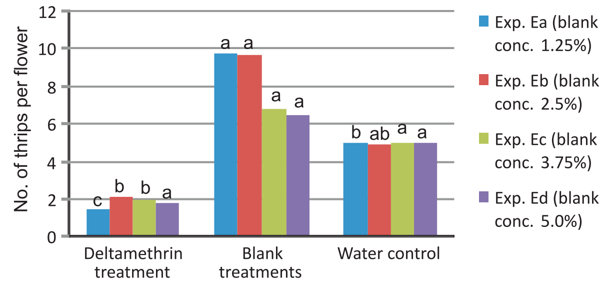

Figure 5. Infestation of cowpea flowers by thrips in different treatments at Sadoré, 2009. [Note: Means with the same letter are not signifiantly different (Newman-Keuls test) at P = 0.05.]

were significant in the other three experiments (Fig. 5). In all four experiments, thrips infestation was higher in the blank treatment and lower in the Deltamethrin treatment, with significant differences between these three treatments in Ea, Eb and Ec.

On the other hand, deltamethrin treatment was significantly different from water control only in Ea and Ec, while water control was significantly different from blank treatment only in Ea. This could probably be ascribed to a combination of repelling effect of the blank and lower flower setting due to phytotoxic effect on cowpea, resulting in higher concentration of thrips on lower number of flowers.

Still, this trend supports that the suppressing effects of the physic nut extracts on flower thrips, as observed in 2002, are due to the oil fraction rather than to the adjuvants.

In 2009, all heteropteran bugs were counted together, with no distinction made between *C. tomentosicollis*, and other abundant species like *Dysdercus voelkeri*, *Nezara viridula*, *Anoplocnemis curvipes* and various plant bugs (Miridae). There was no difference on any of the experiments between the three treatments in terms of bug infestation, and results are therefore not presented.

On the other hand, while there was virtually no aphids in 2009, the infestation by leafhoppers was very high. In all four experiments, infestation on blank-sprayed plots was intermediate between that on water-sprayed and deltamethrin-sprayed plots, as shown in Figure 6. However, while differences were significant between infestation on deltamethrin-sprayed treatments on the one hand, and both blank- and water-sprayed treatments on the other, they were not significant between blank- and water-sprayed treatments.

In 2009, none of the blank concentrations corresponding to the four physic nut oil concentrations tested in 2002 resulted in significant seed yield differences with the water-sprayed controls, while there

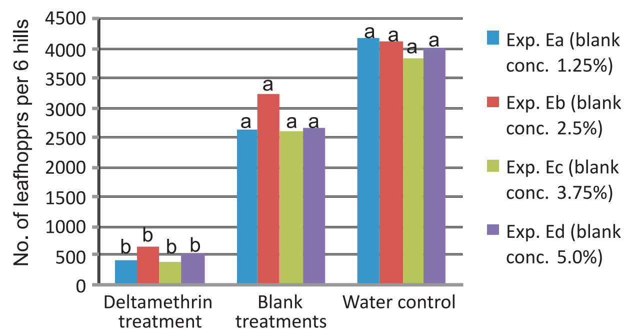

Figure 6. Infestation of cowpea by leafhoppers in different treatments at Sadoré, 2009. [Note: Means with the same letter are not signifiantly different (Newman-Keuls test) at P = 0.05.]

was a tendency (P <0.10) with the deltamethrin-sprayed treatments (Fig. 7). Highest seed yields were obtained with the latter (ranging from 541 to 654 kg ha^{-1}), while in all four experiments, seed yields of both water controls and blank treatments were less than 100 kg ha^{-1}.

Results of the 2009 tests, which conclude the absence of effect of the adjuvants used in the physic nut oil EC formulation, provide an *a posteriori* confirmation of the conclusions of the 2002 tests, namely a significant effect of cowpea treatment with physic nut oil on its main pests, with a positive effect on seed yield. This is further confirmed by the analysis of correlations between oil and blank concentrations and their impact on the various parameters measured, as shown in Table 1. Except for aphids where physic nut oil had no effect at any concentration, and the decline in seed yield, which was due to phytotoxic effect at the higher concentration, there was a clear significant negative correlation between oil concentration and insect (thrips and bug) infestation, while there was no significant correlation between blank concentration and any of the parameters measured.

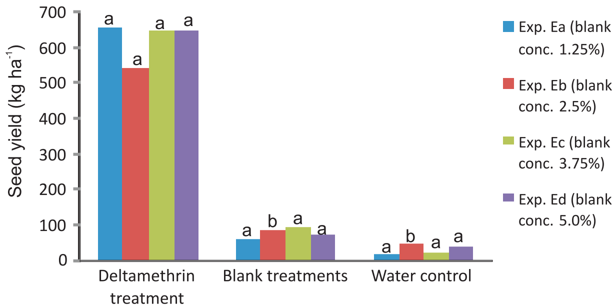

Figure 7. Seed yield of cowpea in different treatments at Sadoré, 2009. [Note: Means with the same letter are not signifiantly different (Newman-Keuls test) at *P* = 0.05.]

Table 1. Correlation coefficients between measured parameters and oil/blank concentrations and their significance (4 df)[1].

Parameter	Oil (2002)	Blank (2009)
Thrips/flower	–0.948*	0.006
Aphids/hill	–0.480	NA
Leafhoppers/hill	NA	–0.708
Bugs[2]/hill	–0.922*	0.244
Seed yield	0.775	0.760

1. NA = Data not available; * = Significant at 5% level.
2. *Clavigralla tomentosicollis* only in 2002; all heteropteran bug species in 2009.

Conclusion

Insecticidal effects of the physic nut oil have generally been ascribed to its phorbol ester (PE) fraction (Ratnadass et al. 2009). However, the physic nut oil from Burkina Faso provided by the NGO "Enterprise Works" was not subject to a PE analysis. In this respect, the ICRISAT-Niger *Jatropha* collection shows a broad range of PE contents (A Nikiema, personal communication, 2009), and further insecticidal tests with extracts of both high PE and low PE content oils should confirm or not the role of this fraction.

On the other hand, although yield results obtained in 2002 look convincing, the cost-benefit ratio of physic nut oil extract application remains to be determined. It should also be mentioned that 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 via natural enemies of the same (in which case it could also be considered for inclusion in water-harvesting systems like DEF).

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