Repellency and Bioactivity of Caatinga Biome Plant Powders against Callosobruchus maculatus (Coleoptera: Chrysomelidae: Bruchinae)

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Source: Florida Entomologist, 98(2) : 417-423

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.098.0204
Repellency and bioactivity of Caatinga biome plant powders against *Callosobruchus maculatus* (Coleoptera: Chrysomelidae: Bruchinae)

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Abstract

The Caatinga biome represents the 4th-largest area covered by single vegetation in Brazil and contains dry forests rich in aromatic bushes, vines, herbs, and trees. The flora of this ecological region is widely known and employed in folk medicine and has other utilitarian and economic uses; however, its potential for controlling or repelling insects is poorly investigated. In this study, we evaluated the potential use of Caatinga plant species for controlling infestations of *Callosobruchus maculatus* F. (Coleoptera: Chrysomelidae: Bruchinae), the most important insect pest of cowpea, *Vigna unguiculata* (L.) Walp. (Fabales: Fabaceae). Powders of the leaves and stems of 9 plant species, including *Amburana cearensis* A. C. Smith (“cumaru”) (Fabales: Fabaceae), *Croton sonderianus* Müll. Arg. (“marmeleiro”) (Malpighiales: Euphorbiaceae), *Cleome spinosa* Jacq. (“mussambê”) (Capparales: Cleomaceae), *Mimosa tenuiflora* Benth. (“jurema-preta”) (Fabales: Fabaceae), *Aspidosperma macrocarpa* (Benth.) Brenan (“angico-vermelho”) (Fabales: Fabaceae), *Aspidosperma pyrifolium* Mart. (“pereiro”) (Gentianales: Apocynaceae), *Senna occidentalis* (L.) H.S. Irwin & R.C. Barneby (“manjerioba”) (Fabales: Fabaceae), *Hyptis suaveolens* (L.) Poit. (“alfazema-brava”) (Lamiales: Lamiaceae), and *Ziziphus joazeiro* Mart. (“juazeiro”) (Rosales: Rhamnaceae), were applied on masses of cowpea seeds, and their effects on *C. maculatus* longevity as well as their repellent activities were evaluated. All the leaf and stem powders reduced only the longevity of males and showed strongly repellent activities against females. The preference level of females for untreated beans varied between 73 and 94%, indicating that all the leaf and stem powders can be a part of the integrated management of *C. maculatus* in storage facilities.

Key Words: stored grain pest; bruchid; *Vigna unguiculata*; plant powder; alternative pest control

Resumo

O bioma Caatinga representa a quarta maior área coberta por um único tipo de vegetação no Brasil. Este bioma se constitui de florestas secas com considerável diversidade de arbustos, ervas, trepadeiras e árvores aromáticas. A flora desta região é amplamente conhecida e tem sido utilizada para diversos fins utilitários e econômicos, principalmente na medicina popular. No entanto, o potencial de espécies de plantas da Caatinga para controlar infestações de *Callosobruchus maculatus* F. (Coleoptera: Chrysomelidae: Bruchinae), uma das mais importantes pragas do feijão, *Vigna unguiculata* (L.) Walp. (Fabales: Fabaceae). Pó das folhas e de caules de nove espécies de plantas, incluindo *Amburana cearensis* A. C. Smith (“cumaru”) (Fabales: Fabaceae), *Croton sonderianus* Müll. Arg. (“marmeleiro”) (Euphorbiaceae), *Spinosa cleome* Jacq. (“mussambê”) (Capparales: Cleomaceae), *Mimosa tenuiflora* Benth. (“jurema-preta”) (Fabales: Fabaceae), *Aspidosperma macrocarpa* (Benth.) Brenan (“angico-vermelho”) (Fabales: Fabaceae), *Aspidosperma pyrifolium* Mart. (“pereiro”) (Gentianales: Apocynaceae), *Senna occidentalis* (L.) H.S. Irwin & R.C. Barneby (“manjerioba”) (Fabales: Fabaceae), *Hyptis suaveolens* (L.) Poit. (“alfazema-brava”) (Lamiales: Lamiaceae), e *Ziziphus joazeiro* Mart. (“juazeiro”) (Rosales: Rhamnaceae), foram aplicados em massas de feijão-caupi e seus efeitos sobre a longevidade e repelência de *C. maculatus* foram avaliados. Todos os pó de folhas e de caules reduziram apenas a longevidade de machos de *C. maculatus*. Entretanto, estes mesmos pó mostraram alta atividade repelente contra fêmeas destes insetos. O nível de preferência de fêmeas de *C. maculatus* para grãos não tratados variou entre 73 e 94%, indicando que os pó das folhas e de caules destas plantas podem se constituir importantes ferramentas para o manejo integrado de *C. maculatus* em unidades de armazenamento.

Palavras Chave: pragas de grãos armazenados; bruquídeo; *Vigna unguiculata*; plant powder; alternative pest control

The Caatinga biome accounts for about 60% of the northeast Brazilian territory and extends to a small part of the northeastern Minas Gerais State (Sampaio et al. 2002). This area is mainly covered by xeric shrub lands rich in aromatic bushes, vines, herbs, and trees (Almeida et al. 2005) with its native plants presenting utilitarian and economic potential (Albuquerque & Andrade 2002; Lucena et al. 2007, 2008; Ca...
Many of the Caatinga plant species are used by native communities as firewood (Ramos et al. 2008), in carpentry (owing to their recognized durability), as seasoning (Canuto et al. 2012), or in folk medicine to treat several diseases (Leal et al. 2000; Albuquerque et al. 2007; Alviano et al. 2008; Cartaxo et al. 2010; Canuto et al. 2012). The great diversity of the Caatinga vegetation is underexploited, and few searches for active biological substances, including those with insecticidal or repellent activity, have been conducted (Almeida et al. 2005; Albuquerque et al. 2007).

Food availability in the Brazilian Caatinga heavily depends on the capacity of farmers (most of them are subsistence producers) to preserve the post-harvest quality of their production. In this region, cereals and beans are grown predominantly by small farmers with little or no technological inputs (Vieira 2004; Ferreira et al. 2013). These farmers have low family income, and they usually keep their production inside their own small storage facilities with high quantitative and qualitative losses, most of them due to insect damage. Natural products from locally available plants with insecticide activity represent a low-cost and sustainable alternative to protect agricultural production. Furthermore, botanical insecticides supposedly pose little threat to the environment or human health compared with synthetic insecticides, and they represent a suitable alternative to controlling mites and insect pests worldwide (Isman 2006; Regnaut-Roger et al. 2012; Kedia et al. 2013).

The cowpea weevil, *Callosobruchus maculatus* F. (Coleoptera: Chrysomelidae: Bruchinae), damages 20–30% of legume seeds in the tropical countries (Kirado & Srivastava 2010) and can cause up to 100% loss when masses of cowpea beans are untreated (Gbaye et al. 2011). Adults mate after emergence and typically live not more than 2 wk depending on ambient temperature. The females deposit eggs on the surface of maturing cowpea pods and seeds. The newly emerged larvae burrow into and feed on a single seed until pupation, and adults do not need to feed (Mitchell 1975; Southgate 1978). Several holes are left in the seed by the emerging adults with severe weight loss facilitating fungal and mycotoxin contamination, which reduces the commercial bean value (Kirado & Srivastava 2010; Kedia et al. 2013).

Insecticidal natural products, such as powders of locally available plants, used by farmers in developing countries in their storage facilities, appear to be safe and promising (Paul et al. 2009; Silva et al. 2013; Tavares et al. 2013, 2014; Fouad et al 2014; Melo et al. 2014). Thus, we evaluated the repellent activity and the effects of powders from 9 Caatinga plant species on *C. maculatus* longevity.

**Material and Methods**

**INSECT REARING**

The original population of *C. maculatus* was field-collected from small farms in the region of Pombal (Paraíba State, Brazil) and established under laboratory conditions (25 ± 2 °C, 70 ± 5% RH, and 12:12 h L:D photoperiod), starting with at least 500 individuals. The identification was based on the traits described previously (Athié & Paula 2002). The population was reared on cowpea bean (*Vigna unguiculata* [L.] Walp.; Fabales: Fabaceae) grains (free of insecticides) bought from the local market. In order to avoid possible infestations from the field and to reduce any potential insecticide residual effect, the bean grains were kept a temperature of −10 °C for 14 d prior to being offered to *C. maculatus*. To obtain newly emerged *C. maculatus* of the same generation, adult insects were released in cowpea bean grain masses that were kept a temperature of −10 ºC for 14 d prior to being offered to *C. maculatus*. To obtain newly emerged *C. maculatus*, the bean grains were ground and placed in plastic containers (0.4 L capacity) covered with “organza” cloth. After 5 d of colonization, the adults were removed and the egg-infested grains were maintained under laboratory conditions. The new adults emerged after around 4 wk.

**PLANT POWDERS**

The plant powders used in this study were obtained from the leaves and stems of 9 Caatinga plant species, including *Amburana cearensis* A. C. Smith ("cumuru-nordestino") (Fabales: Fabaceae), *Croton sonderianus* Müll. Arg. ("marmeleiro-do-mato") (Malpighiales: Euphorbiaceae), *CLEOMA SPINOSA* Jacq. ("mussambê") (Capparales: Cleomaceae), *Mimosa Tenuiflora* Benth. ("jurema-preta") (Fabales: Fabaceae), *ANANANTHERA MACARCARPA* (Benth.) Brenan ("angico-vermelho") (Fabales: Fabaceae), *Aspidosperma pyrifolium* Mart. ("pereiro") (Gentianales: Apocynaceae), *Senna occidentals* (L.) H.S. Irwin & R.C. Barney ("man-giriba") (Fabales: Fabaceae), *HYPTIS SUAVEOLENS* (L.) Poit. ("alfazema-brava") (Lamiales: Lamiacae), and *Ziziphus Joaheiro* Mart. ("juazeiro") (Rosales: Rhamnaceae) (Table 1), collected in the region of Pombal (Paraíba State, Brazil). We chose only plant species that are used by native communities to treat several diseases, and some of their biological activities have been described (Table 1). During the period between the years of 2009 and 2012, leaves and stems were randomly collected from the adult plants by using pruning scissors. Samples of these plants were compared with material deposited in the herbarium of the Universidade Federal Rural do Semi-Árido (UFERSA, Mossoró-RN, Brazil). All the plant materials were individually wrapped in plastic bags, identified, and brought to the laboratory. Then, these materials were dried by direct exposure to sunlight over a 7 d period, and leaves and stem were separately milled with a manual grinder to powder. The resulting powder was passed through a 25 mesh sieve to obtain a fine dust. The fine dusts were stored individually in glass containers (hermetically closed) that were maintained at a controlled temperature (5 °C) to ensure supply of the material throughout the investigation period.

**LONGEVITY BIOASSAYS**

The effects of each plant powder on insect longevity were assessed in survival bioassays conducted according to previously described methods (Procópio et al. 2003). Briefly, a pair of newly emerged weevils was confined in a plastic container (100 mL) containing 45 g of untreated (control) or plant powder treated cowpea bean seeds. Each weevil pair in 45 g of bean seeds was an experimental unit. In the treated bean unit, 2 g of the plant powder had been homogeneously distributed among the seeds. Five replicates were used for each plant powder tested, and the male and female insect mortality was monitored daily until the last day of survival. As these insects are excellent fliers, we customized an escape-proof cage that allowed measurements of mortality. This cage had the following dimensions: 40 cm length × 20 cm width × 20 cm height, and its base, back, and front sides were made of wood. Openings of 10 cm diameter were drilled in the back and front sides and were closed with organza cloth. These openings facilitated the insertion and handling of experimental materials. Furthermore, complete and easy viewing and handling of the experimental materials were achieved through the glass used at the top and lateral sides of the cage. The bean seeds were carefully poured onto the plastic trays placed inside the cage. After counting the number of dead insects, all the live insects, bean grains, and plant powders were added back into the experimental units. The insect longevity measurements were subjected to analysis of variance and subsequently to Tukey’s test (α = 0.05), when appropriate.

**FREE-CHOICE REPULLENCE TEST**

The repellent activity of each plant powder was assessed in bioassays conducted in custom-made plastic arenas (35 cm diameter, 12 cm high), according to the modified protocols reported previously (Burkholder & Dicke 1966; Phillips & Burkholder 1981). Six 50 mL plastic
Table 1. Caatinga plant species collected in the county of Pombal, Paraíba State, Brazil.

| Scientific name                          | Common name | Family | Isolated compounds                                                                 | Biological activity                                                                 |
|------------------------------------------|-------------|--------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Amburana cearensis A. C. Smith           | “cumaru”    | Fabaceae | coumarin, phenolic glycosides                                                        | anticholinesterase, antinociceptive, antimicrobial, antifungal, healing properties   |
| Cleome spinosa                          | “nurseleiro”| Cleomaceae | “muscambê”                                                                          | antifungal, healing properties                                                       |
| Mimosa tenuiflora                        | “alfazema-brava” | Fabaceae | tannins and flavonoids                                                              | antifungal, healing properties                                                       |
| Anadenanthera macrocarpa (Benth.) Brenan  | “pereiro”   | Fabaceae | “pereiro”                                                                           | antifungal, healing properties                                                       |
| Aspidosperma pyrifolium Mart.           | “cumaru”    | Euphorbiaceae | saponins                                                                             | antifungal, healing properties                                                       |
| Senna occidentalis (L.) H.S. Irwin & R.C. Barneby | “juazeiro” | Fabaceae | tannins and flavonoids                                                              | antifungal, healing properties                                                       |
| Hyptis suaveolens (L.) Pol.              | “jucfio”    | Lamiaceae | “jucfio”                                                                             | antifungal, healing properties                                                       |
| Ziziphus joazeiro Mart.                  | “jucfio”    | Lamiaceae | “jucfio”                                                                             | antifungal, healing properties                                                       |

**References**

(Araújo et al. 2007)

°Fabaceae

(Desmarchelier et al. 1999; Farias et al. 2013; Ribeiro et al. 2013)

(Collins et al. 2004)

(Faulkner 2001; Hanson 2002; Peerzada 1997; Araújo et al. 2008)

(Ribeiro et al. 2013)

**RESULTS**

**LONGEVITY BIOASSAYS**

There were no significant differences ($F_{1,\alpha} = 1.99; P > 0.05$) among the longevities of females exposed to leaf or stem powders of each plant tested, which allowed us to pool these longevity data and compare them with the longevity of females on untreated bean masses (Fig. 1). In general, the average longevity of females treated with plant powders was $7.4 \pm 1.01$ d and did not differ significantly ($F_{1,\alpha} = 0.86; P > 0.05$) from that of the control females ($7.8 \pm 1.09$ d; Fig. 1A). Likewise, the males showed similar longevities ($F_{1,\alpha} = 0.82; P > 0.05$) when exposed to leaf or stem powders of each plant tested. However, the average longevity of males was significantly reduced ($F_{1,\alpha} = 8.15; P < 0.01$) from $7.8 \pm 1.79$ d (control males) to $6.06 \pm 1.25$ d (males that lived on plant powder–treated beans) (Fig. 1B).

**REPELLENT ACTIVITIES**

All of the Caatinga plant powders were strongly repellent to females. The percentages of the females that preferred untreated beans ranged from 77% to 94% and were significantly greater ($P < 0.01$, binomial test) than those of females that preferred the leaf powder–treated beans (Fig. 2A). Similar results were obtained in the repellency bioassays with stem powders, where females significantly preferred ($P < 0.01$, binomial test) untreated bean seeds (Fig. 2B).

Although all the plant powders significantly repelled females, the leaf powders of *A. pyrifolium*, *S. occidentalis*, *H. suaveolens*, and *Z. joazeiro* exhibited greater repellency levels (Table 2). With regard to the stem powders, the plant species *C. sonderianus*, *C. spinosa*, *H. suaveolens*, and *Z. joazeiro* presented greater repellency levels. Furthermore, the leaf and stem powders of *A. pyrifolium* and *S. occidentalis* showed differential repellent activities (Table 2), with the leaf powders presenting greater repellency levels.
Despite its great territorial expanse and significant biodiversity, the Caatinga biome is still an underexploited source of molecules with insecticidal/repellent activities. Most studies with plant products from this ecological region have focused on extracts or essential oils to control insect disease vectors (Lima et al. 2006; Farias et al. 2010; Souza et al. 2011; Santos et al. 2012; Barbosa et al. 2014). Few studies investigated the potential of Caatinga plant powders as commodity protectants, and they normally evaluated only mortality effects (Souza & Trovão 2009; Cruz et al. 2013). Here, we evaluated the insecticidal and repellent activities of 9 Caatinga plant species (A. cearensis, C. sonderianus, C. spinosa, M. tenuiflora, A. macrocarpa, A. pyrifolium, S. occidentalis, H. suaveolens, and Z. joazeiro) against the cowpea weevil, C. maculatus. Leaf and stem powders from these plants had major insecticidal effects on males and repelled the females, demonstrating their potential for use in the integrated management of C. maculatus in storage facilities.

Discussion

Despite its great territorial expanse and significant biodiversity, the Caatinga biome is still an underexploited source of molecules with insecticidal/repellent activities. Most studies with plant products from this ecological region have focused on extracts or essential oils to control insect disease vectors (Lima et al. 2006; Farias et al. 2010; Souza et al. 2011; Santos et al. 2012; Barbosa et al. 2014). Few studies investigated
Table 2. The repellency index (RI) obtained for each plant powder tested against Callosobruchus maculatus (Coleoptera: Chrysomelidae).

| Plant species                  | Leaves         | Stems         |
|--------------------------------|----------------|---------------|
| Amburana cearensis             | 0.46 ± 0.05 Aa | 0.42 ± 0.04 Aa|
| Croton sonderianus             | 0.22 ± 0.10 Ba | 0.15 ± 0.03 Ba|
| Cleome spinosa                 | 0.35 ± 0.08 Aa | 0.26 ± 0.06 Ba|
| Mimosa tenuiflora              | 0.39 ± 0.07 Aa | 0.54 ± 0.07 Aa|
| Anadenanthera macrocarpa       | 0.46 ± 0.05 Aa | 0.42 ± 0.06 Aa|
| Aspidosperma pyrifolium        | 0.20 ± 0.06 Bb | 0.43 ± 0.07 Aa|
| Senna occidentalis             | 0.16 ± 0.03 Bb | 0.36 ± 0.08 Aa|
| Hylotelephium suaveolens       | 0.11 ± 0.04 Bb | 0.20 ± 0.07 Bb|
| Ziziphus joazeiro              | 0.25 ± 0.02 Ba | 0.14 ± 0.04 Ba|

*Means followed by the same lowercase letter in a row or the same capital letter in a column are not significantly different based on the Scott–Knott groupment analysis test at P < 0.05.

Similar to the lack of insecticide activity against C. maculatus females observed here for all the plant powders, root powder of M. tenuiflora showed very small insecticidal activity against termites (Isoptera) (Cruz et al. 2013), and powders of A. macrocarpa did not show any insecticidal activity against the maize weevil, Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae) (Souza & Trovão 2009). Furthermore, powders from other medicinal plants (thyme, Thymus vulgaris L. [Lamiales: Lamiaceae]; lavender cotton, Santolina chamaecoeparissus L., and stinking bean trefoil, Anagyrus foetida L. [Fabales: Fabaceae]) neither affected the longevity of southern cowpea weevil, Callosobruchus chinensis L. (Coleoptera: Chrysomelidae) males nor females (Righi-Assia et al. 2010). These differential insecticidal activities of plant powders might have resulted from multiple factors involving the way they work and the resistance mechanisms of the insects. Plant powders can control insects by eroding the cuticle layer and causing dehydration (Kedia et al. 2013); blocking the spiracles and causing asphyxiation (Denloye 2010); or impairing physiological processes by penetrating the insect body via the respiratory or alimentary system (Ofría & Dawodu 2002). Plant powders of S. occidentalis caused significant mortality in C. maculatus (Adesina et al. 2011), and insecticidal properties of A. pyrifolium (Torres et al. 2006), C. sonderianus (Moraes et al. 2006; Lima et al. 2006, 2013), A. cearensis (Farias et al. 2010; Souza et al. 2011), and Z. joazeiro (Souza et al. 2011) have been documented in different insect species. The repellent activities of Caatinga plant powders need further study although the repellency of many other plant powders against stored pests has been reported (Elhag 2000; Kéita et al. 2001; Mazzonetto & Vendramin 2003; Silva-Aguayo et al. 2005; Sanon et al. 2006; Kabir & Muhammad 2010).

The present study extends knowledge on Caatinga plants for use as stored product protectants because it demonstrates that the leaf and stem powders of 9 Caatinga plants show strong repellent activities against C. maculatus females. Leaf powders of A. pyrifolium and S. occidentalis repelled C. maculatus more efficiently than the stem powders of these plants, suggesting that these plants possess different active constituents or that they have the same constituents but with different concentrations in various plant parts (Ravi Kiran et al. 2006; Autran et al. 2009). Such differential activities of the powders of leaves and stems of other plants such as neem, Azadirachta indica A. Juss. (Sapindales: Meliaceae) (leaf and stem bark powders), have been described, with the leaf powder showing higher repellent activities against C. maculatus than the stem powder (Kabir & Muhammad 2010). The striking repellency results obtained here for M. tenuiflora and A. macrocarpa powders are noteworthy, because these plant products had been previously reported to have no (Souza & Trovão 2009; Santos et al. 2012) or very low insecticidal activity (Cruz et al. 2013). We also found that S. occidentalis strongly repels C. maculatus females, which differs from the results described by Pålsson & Jaenson (1999), who observed no repellent activities of this plant against mosquitoes (Diptera: Culicidae), reinforcing the hypothesis that repellent activity of plant products might be species specific.

Furthermore, H. suaveolens plant powders demonstrated noticeable repellent activity against C. maculatus females, as demonstrated with other insect species (Sanon et al. 2006; Ilboudo et al. 2010; Benelli et al. 2012). However, products from this plant species can cause detrimental effects on natural enemies in storage environments (Sanon et al. 2011), thus requiring caution when used as grain protectants. In addition, other plant species of the Cleome genus showed repellent actions against ticks (Parasitiformes) and insects (Ndungu et al. 1995; Nyalala & Grout 2007), but the present study is the first to report on the insecticidal/repellent potential against C. spinosa.

The application of plant materials with insecticidal or repellent properties to stored grains is a common traditional method in rural areas around the world (Regnault-Roger et al. 2012; Kedia et al. 2013). Tropical ecosystems (such as the Caatinga biome) are particularly rich in plants that are used by local communities to treat diseases, thus indicating the potential to discover new compounds (Albuquerque et al. 2007, 2008). Further investigations exploring the toxicological aspects of the major constituents or identifying the principal volatiles produced by the Caatinga plants tested here will provide new insights on how these plants exhibit their insecticidal/repellent activities.

Our findings not only extend the knowledge on the Caatinga plants but also provide information about plants that can be used to protect cowpeas against C. maculatus infestations. All the plants tested are readily available in the Caatinga Region, and these anti-insect materials are affordable to low-income farmers who are normally constrained to sell their production early after harvest or, even worse, have their stored bean seeds (normally saved on the farm from the previous harvest) prone to infestation by stored product pests.
of medicinal plants from the Caatinga (Northeast Brazil). Journal of Arid Environment 62: 127-142.
Alviano WS, Alviano DS, Diniz CG, Antonioli AR, Alviano CS, Farias LM, Carvalho MAR, Souza MMG, Bolognese AM. 2008. In vitro antioxidant potential of medicinal plant extracts and their activities against oral bacteria based on Brazilian folk medicine. Archives of Oral Biology 53: 545-552.
Araújo Jr JK, Antheaume C, Trindade RCP, Schmitt M, Bourguignon J-J, Sant’Ana AEG. 2001. Isolation and characterisation of the monoterpenoid indole alkaloids of Aspidosperma pyrifolium. Phytochemistry Reviews 6: 183-188.
Araújo TAS, Alencar NL, Amorim ELC, Albuquerque UP. 2008. A new approach to study medicinal plants with tannins and flavonoids contents from the local knowledge. Journal of Ethnopharmacology 120: 72-80.
Athié I, Paula D.C. 2003. Insetos de grãos armazenados: aspectos biológicos e identificação, 2nd edition. Varela, São Paulo, Brazil. 244 pp.
Araújo ES, Neves IA, da Silva CSB, Santos GKN, Câmera CAGD, Navarro DMAF. 2009. Chemical composition, oviposition deterrent and larvicidal activities against Aedes aegypti of essential oils from Piper marginatum Jacq.. (Piperaceae). Bioresource Technology 100: 2284-2288.
Barbosa PBBM, de Oliveira JM, Chagas JM, Rabelo LMA, de Medeiros GF, Giosani, RB, da Silva EA, Uchoa AF, Ximenes MDDM. 2014. Evaluation of seed extracts from plants found in the Caatinga biome for the control of Aedes aegypti. Parasitology Research 113: 3565-3580.
Benelli G, Flamin G, Canale A, Moffetta I, Cioni PL, Conti B. 2012. Repellence of Hyptis suaveolens whole essential oil and major constituents against the adults of the granary weevil Sitophilus granarius. Bulletin of Insectology 65: 177-183.
Branco JAB, Sauvain M, Gimenez TA, Muñoz OV, Calamita J, Menéndez L, Mas EFF. 2013. Modulation of the antibiotic activity by extracts from Aspidosperma pyrifolium. Neotropical Entomology 32: 145-149.
Branco JAB, Sauvain M, Gimenez TA, Menéndez L, Mas EFF. 2013. Modulation of the antibiotic activity by extracts from Aspidosperma pyrifolium. Neotropical Entomology 32: 145-149.
Braz JAB, Sauvain M, Gimenez TA, Muñoz OV, Callapa J, Le Men-Olivier L, Mas EFF. 2013. Modulation of the antibiotic activity by extracts from Aspidosperma pyrifolium. Neotropical Entomology 32: 145-149.
Braz JAB, Sauvain M, Gimenez TA, Muñoz OV, Callapa J, Le Men-Olivier L, Mas EFF. 2013. Modulation of the antibiotic activity by extracts from Aspidosperma pyrifolium. Neotropical Entomology 32: 145-149.
Braz JAB, Sauvain M, Gimenez TA, Muñoz OV, Callapa J, Le Men-Olivier L, Mas EFF. 2013. Modulation of the antibiotic activity by extracts from Aspidosperma pyrifolium. Neotropical Entomology 32: 145-149.
Braz JAB, Sauvain M, Gimenez TA, Muñoz OV, Callapa J, Le Men-Olivier L, Mas EFF. 2013. Modulation of the antibiotic activity by extracts from Aspidosperma pyrifolium. Neotropical Entomology 32: 145-149.
Braz JAB, Sauvain M, Gimenez TA, Muñoz OV, Callapa J, Le Men-Olivier L, Mas EFF. 2013. Modulation of the antibiotic activity by extracts from Aspidosperma pyrifolium. Neotropical Entomology 32: 145-149.
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Ofula TI, Dawodu EO. 2002. Aspects of insecticidal action of Piper guineense Schum and Thonn fruit powders against Callosobruchus maculatus (F.) (Coleoptera: Bruchidae). Niger Journal of Entomology 19: 40-50.

Pålsson K, Jaenson TGT. 1999. Plant products used as mosquito repellents in Guinea Bissau, West Africa. Acta Tropica 72: 39-52.

Paul UV, Lossini JS, Edwards PJ, Hilbeck A. 2009. Effectiveness of products from four locally grown plants for the management of Acanthoscelides obtectus (Say) and Zabrottes subfasciatus (Bohemian) (both Coleoptera: Bruchidae) in stored beans under laboratory and farm conditions in northern Tanzania. Journal of Stored Product Research 45: 97-107.

Peerzada N. 1997. Chemical composition of the essential oil of Hyptis suaveolens. Molecules 2: 165-168.

Phillips JK, Burkholder WE. 1981. Evidence for a male-produced aggregation pheromone in the rice weevil (Coleoptera, Curculionidae). Journal of Econonomic Entomology 74: 539-542.

Procópio SO, Vendramin JD, Ribeiro Júnior JI, Santos J.B. 2003. Bioactivity of diversos pós de origem vegetal em relação a Sitophiles zeamais Mots. (Coleoptera: Curculionidae). Ciencia e Agrotecnologia 27: 1231-1236.

Ramos MA, Medeiros PM, Almeida ALS, Feliciano ALP, Albuquerque UP. 2008. Use and knowledge of fuelwood in an area of Caatinga vegetation in NE Brazil. Biomass Bioenergy 32: 510-517.

Ravi Kiran SR, Bhavani K, Devi PS, Rao BRR, Reddy KJ. 2006. Composition and larvicidal activity of leaves and stem essential oils of Chloroxyylon swietenia DC against Aedes aegypti and Anopheles stephensi. Bioreosource Technology 97: 2481-2484.

Regnault-Roger C, Vincent C, Arnason JT. 2012. Essential oils in insect control: low-risk products in a high-stakes world. Annual Review of Entomology 57: 405-424.

Ribeiro BD, Alviano DS, Barreto DW, Coelho MAZ. 2013. Functional properties of saponins from sisal (Agave sisalana) and juá (Ziziphus jaozeiro): critical micellar concentration, antioxidant and antimicrobial activities. Colloids and Surfaces A 436: 736-743.

Righi-Assia AF, Khellil MA, Medjdoub-Bensaad F, Righi K. 2010. Efficacy of oils and powders of some medicinal plants in biological control of the pea weevil (Callosobruchus chinensis L.). African Journal of Agricultural Research 5: 1474-1481.

Sampaio EVSB, Giuiietti AM, Gamarra-Rojas CFL. 2002. Vegetação e flora da Caatinga, 1st edition. Associação Plantas do Nordeste, Recife, PE, Brazil, p. 176.

Sanon A, Iriboudo Z, Dabiré CLB, Nebié RCH, Dicko IO, Monge JP. 2006. Effects of Hyptis spicigera Lam. (Labiatae) on the behaviour and development of Callosobruchus maculatus F. (Coleoptera: Bruchidae), a pest of stored cowpeas. International Journal of Pest Management 52: 117-123.

Sanon A, Ba MN, Dabiré LC, Nébié RCH, Monge JP. 2011. Side effects of grain protectants on biological control agents: how Hyptis plant extracts affect parasitism and larval development of Dinarmus basalis. Phytoparasitica 39: 215-222.

Santos EA, Carvalho CM, Costa ALS, Conceição AS, Moura FBP, Santana AEG. 2012. Bioactivity evaluation of plant extracts used in indigenous medicine against the snail, Biomphalaria glabrata, and the larvae of Aedes aegypti. Evidence-Based Complementary and Alternative Medicine 846583: 1-9.

Santos FA, Jefferson FA, Santos CC, Silveira ER, Rao VSN. 2005. Antinociceptive effect of leaf essential oil from Croton sonderianus in mice. Life Sciences 77: 2953-2963.

Scott AJ, Knott M. 1974. A cluster analysis method for grouping means in the analysis of variance. Biometrics 30: 507-512.

Silva ML, Silva LB, Fernandes RM, Lopes GS. 2013. Efeito do extrato aquoso e etânolico do angico preto sobre larvas de Rhipicephalus (Boophilus) microplus. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 65: 637-644.

Silva-Aguayo GI, Kiger-Meliviu R, Hepp-Gallo R, Tapia-Vargas M. 2005. Control de Sitophilus zeamais con polvos vegetales de tres especies del género Chevropodium. Pesquisa Agropecuária Brasileira 40: 953-960.

Southgate BJ. 1978. The importance of the Bruchidae as pests of grain legumes, their distribution and control, pp. 219-229 in Singh SR, van Emden HF, Taylor TA. [eds.], Pests of Grain Legumes: Ecology and Control. Academic Press, London, United Kingdom.

Souza MCC, Trovão MBM. 2009. Bioatividade do extrato seco de plantas da Caatinga e do Nim (Azadirachta indica) sobre Sitophilus zeamais Mots em milho armazenado. Revista Verde de Agroecologia e Desenvolvimento Sus tentável 4: 120-124.

Souza TM, Farias DF, Soares BM, Viana MP, Lima GPG, Machado LKA, Morais SM, Carvalho AFU. 2011. Toxicity of Brazilian plant seed extracts to two strains of Aedes aegypti (Diptera: Culicidae) and nontarget animals. Journal of Medical Entomology 48: 846-851.

Tavares WD, Grazziotti GH, de Souza AA, Freitas SD, Consolaro HN, Ribeiro PED, Zanuncio JC. 2013. Screening of extracts of leaves and stems of Psychotria spp. (Rubiaceae) against Sitophilus zeamais (Coleoptera: Curculionidae) and Spodoptera frugiperda (Lepidoptera: Noctuidae) for maize protection. Journal of Food Protection 76: 1892-1901.

Tavares, WD, Faroni LRD, Ribeiro RC, Fouda HA, Freitas SD, Zanuncio JC. 2014. Effects of astilbin from Dimorphandra mollis (Fabaceae) flowers and Brazilian plant extracts on Sitophilus zeamais (Coleoptera: Curculionidae). Florida Entomologist 97: 892-901.

Torres AL, Boiça Junior AL, Medeiros CAM, Barros R. 2006. Efeito de extratos aquosos de Azadirachta indica, Melia azedarach e Aspidosperma pyrifolium no desenvolvimento e oviposição de Plutella xylostella. Bragantia 65: 447-457.

Trevisan MTS, Macedo FVV. 2003. Seleção de plantas com atividade anticolinesterase para tratamento da doença de Alzheimer. Química Nova 26: 301-304.

Vieira C. 2004. Memórias de meio século de estudo sobre a cultura do feijão. Editora UFV, Viçosa-MG, Brazil. 214 pp.