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RESEARCH PAPER

Efficacy of aqueous plant extracts for control of bedbugs on cowpea (Vigna unguiculata (L.) Walpers) cultivars in northwestern Benin

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Abstract

Cowpea [Vigna unguiculata (L.) Walpers] cultivation is facing in farm field to abandonment issues, or even to the disappearance of varieties, and to a low grain's yield due to the strong pressure of pests in the field and in stocking. The present study leaded in three villages of the commune of Djougou located in the Northwest of Benin allowed evaluating the effects of five treatments of insecticides plants water extracts on the populations and the damages of bugs during cultural cycle and the grain's yield of six most preferred cowpea cultivars of the study area. Plants water extracts were made with Hyptis suaveolens, Azadirachta indica, Manihot esculenta, Thevetia neriifolia and Cymbopogon nardus. Six producers from three villages of the study area have been involved in an experimental deisgn of Fisher in scattered blocks of five (05) repetitions. Collected data are the number and the damages of bugs on cowpea cloves at 34, 41, 48, 55 and 62 days after sowing, the yield and the one thousand weight of grains, which have been submitted to the analysis of variance according to the general linear model of three ways (cultivar, period, water extract) and to the Tukey test for means comparison at 5% level of significance with the softwares Minitab 16 and Statistik 8.0. Results showed that water extracts of Thevetia neriifolia, Hyptis suaveolens, Azadirachta indica and Manihot esculenta have very significantly reduced ($p < 0{,}001$) bugs populations, better than the water extract of Cymbopogon nardus and the control. Cultivars Katché péha, Katché sôwôho, Kpodjiguègué and Toura pera have showed a certain resistance and or tolerance comparatively to the two others, Katché péha nan sôorii et Katché Sénégal. Grains yield levels of these cultivars varied respectively in this rank from 723.46 kg/ha to 747.50 kg/ha for the first group and from 519.10 kg/ha to 646.45 kg/ha for the second group. Water extracts of Thevetia neriifolia, Hyptis s., and indifferently those of Azadirachta indica and of Manihot esculenta, and then of Cymbopogon nardus and the control allowed having in this order, cowpea' grains yields levels, from 710.51 to kg/ha 885.76 kg/ha for the first group and from 387.28 kg/ha to 587.06 kg/ha for the second group. Valuing of cultivars into a varietal improvement program and the utilization of the plants water extracts for an agrobioecological pest management control of cowpea has been suggested.

Keywords: clove, botanical pesticide, population, ravager, yield

Introduction

Varietal diversity is confronted in developing countries with a changing environment, governed by the commodification of plant genetic resources, to the extent that secular practices for their conservation are struggling to achieve real development. In sub-Saharan Africa, a decline in per capita agricultural output has been observed for more than two decades, linked to a significant decline in food production with perceptible signs of environmental degradation (FAO, 1998).

In Benin in general, and particularly in the northern region, where the population is growing at a growth rate of over 4% and increasing rural poverty (World Bank, 2003), the situation of agriculture and its biological diversity seem even more critical. Land is degraded (Akker van den, 1999) by long-term soil-depleting cultivation techniques, resulting in a significant decline in agricultural yields and the abandonment of some traditional varieties (Zoundjihékpon *et al.,* 1997).

The introduction of high yielding varieties in many third world countries has led to the gradual replacement of traditional varieties, which are sources of genetic diversity. In addition, even if the productivity of traditional populations remains lower than that of improved varieties, they are more adapted to local constraints and develop various natural resistance against pests, especially pests and pathogens (Eyzaguirre, 1995).

The low yield of cowpea grown in Benin is due to constraints including pests and the low production potential of some cultivated varieties (Abadassi 1997, Kossou et al., 2001, Kpangon 2002). The major insect pests of cowpea in the world and causing the most damage to cowpea are Maruca vitrata Fabricius (Lepidoptera: Crambidae), Megalurothrips sjostedti Trybom (Thysanoptera: Thripidae), Clavigralla tomentosicollis Stål (Heteroptera: Coreidae) and Aphis craccivora Koch (Homoptera: Aphididae) (Tamo et al., 1993). Among these insects, the legume borer, Maruca vitrata, is reported to be causing serious damage to cowpea in the tropical and subtropical regions of Asia, Latin America and Africa (Liao and Lin, 2000).). It feeds on stalks, flower buds, flowers and pods that are still fresh, resulting in depreciation (Okech and Saxena 1990). Yield losses are from 30 to 86% (Singh et al., 1990, Tamo et al., 2003). Although chemical control is the most prevalent method today, in addition to the many dangers it creates and its prohibitive price, it has unfortunately proved to be a threat to human health, animal health and the environment (IITA, 1988). The identification of effective alternative methods of combating pests in general, and particularly bedbugs, is now imperative.

Several studies were conducted on cowpea in southern and central Benin (Abadassi 1985, Ahohuendo 1985, Zannou 1995, Lafia Mora 2003, Zannou and Quenum 2003, Zannou et al. Benin (Baco et al., 2003, Bello 2005, Baco et al., 2008, Bello and Baco 2015). These studies, while addressing varietal diversity and management practices, have obscured the phytosanitary and efficacy of botanical pesticides for pest control in cultivars. The present study was conducted to answer the concern of the producers of the Rural Organization for Sustainable Agriculture (ORAD) in the commune of Djougou located in the North-West of Benin, to develop methods to fight against cowpug bugs based on pesticides of biological origin. It focused on the efficacy of aqueous extracts of neem (Azadirachta indica), Thevetia neriifolia, lemongrass (Cymbopogon nardus), Hyptis suaveolens and cassava (Manihot esculenta) for the control of bed bugs and their effects. seed yield of six cowpea cultivars.

Material and methods

Location and agro-ecological characteristics of the study area

The present study was conducted in the commune of Djougou which covers an area of 3966 km2 and is one of the four communes that make up the department of Donga. It is limited in the North by the communes of Kouandé and Péhunco, in the South by the commune of Bassila, in the East by the communes of Sinendé, N'dali and Tchaourou, all located in the department of Borgou and the West by the communes of Ouaké and Copargo (figure 1). The city of Djougou, chief town of the Donga and the commune, is located about 450 km north of Cotonou. In this commune, three villages namely Passari, Kpayeroun and Kpafoungou were selected for the study.

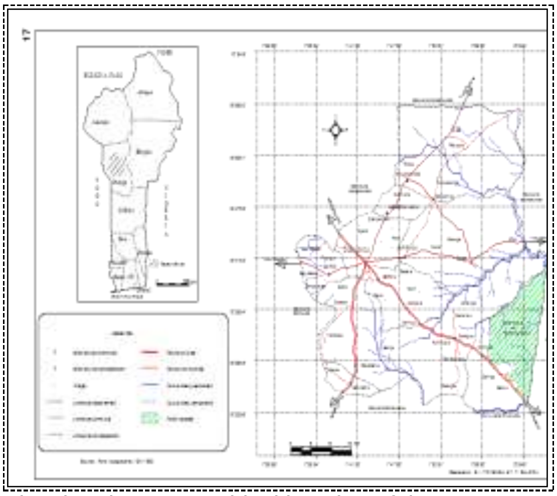


Figure 1: Administrative map of Benin showing the geographical location of the commune of Djougou (Source: Fond topographie IGN, 1992)

The climate is Sudano-Guinean with a rainy season from April to October and a dry season from October to March. The average annual precipitation is between 1200 mm and 1300 mm, with variations between 1000 mm and 1500 mm of water for 75 to 140 days of rain. At the beginning of the rainy season, the region periodically experiences the passage of a hurricane blowing from east to west. The soils, sandy clay or lateritic texture, gravelly or stony, are generally favorable to agriculture. The cultivable area represents 35.7% of the area of the municipality.

The commune of Djougou has a plateau relief dotted with hills of low unevenness. The vegetation of the town is dominated by wooded savannahs and shrubs including 37182 ha of forests classified under development. Nevertheless, significant relics of clear forests and dense forests are observed in some places. The town is crossed and watered by four (04) important rivers namely: Donga, Affon, Momongou and Daringa over a total length of 21 km (PDC Djougou, 2003).

Sampling and choice of villages

The study was carried out in the three villages mentioned above, which were selected on the basis of the participation of some households in the activities of the farm organization "ORAD", the Rural Organization for Sustainable Agriculture, which works in synergy with the Laboratoires Hors Murs and the Laboratory of Ecological Genetics in recent years. In each village, two producers who were members of this organization had been chosen to host the trials.

Tested cowpea cultivars

The agro-morphological study focused on six (06) local cultivars of cowpea most cultivated in the commune of Djougou (Table 1). They are called Katché peha, Katché sôwôho, Katché peha nan sôorii, Kpodjiguègué, Toura pera and Katché Senegal. These cultivars are owned and handled by producers in Kpayèroun, Kpafoungou and Passari villages, some of which participated in the study in a participatory manner.

Table 1: Local names of the cultivars and villages belonging to the holder producers who took part in the stud

Order number	Local name	Short name	Village belonging to the producers
1	Katché péha	KPG	Kpayèroun Kpafoungou
2	Katché sôwôho	KSÔ	Kpayèroun Kpafoungou
3	Katché péha nan sôorii	KPN	Kpayèroun Kpafoungou
4	Kpodjiguègué	KPODJI	Kpayèroun Kpafoungou
5	Toura pera	TOURA	Passari Kpayèroun Kpafoungou
6	Katché Sénégal	KSEN	Kpayèroun Kpafoungou

Insecticidal plants tested

Five (05) insect repellent and / or insecticidal plants were tested. These are Hyptis suaveolens (photo 1), Thevetia neriifolia (photo 2), Cymbopogon nardus or lemongrass (photo 3), Manihot esculenta or cassava (photo 4) and Azadirachta indica or neem (photo 5).

Photo 1 : Plant d'*Hyptis suaveolens*

Photo 2 : Plant de Thevetia neriifolia

Photo 3: Cymbopogon nardus (Lemongrass) plant

Photo 4 : Plant de Manihot esculenta (manioc)

Photo 5: Azadirachta indica (Neem / Mangosier) plant

Cassava (Manihot esculenta) is a plant used as a "trap crop" in cowpea culture to significantly reduce the number of flower thrips and pod sucking insects.

Thevetia neriifolia is a white latex plant that is considered a poisonous plant whose roots, leaves, seeds and latex are used. From an ecological point of view, Thevetia neriifolia is considered as an insecticidal plant (Jackai, 1983).

Hyptis suavuolens (Linn.) Poit. is an annual plant native to India, belonging to the family Labiaceae. Aromatic, it is found today in tropical and semi-arid areas. The aqueous leaf extract of Hyptis suavuolens has very potent insect repellent and / or insecticidal properties after Roy and Pande cited Anand and Rao (1996), Kerharo and Adam (1974), Boeke et al. (2004) cited by Tchibozo, 1996; Ketoh et al. (2005) cited by Tchibozo (1996), then by Guèyé et al. (2011).

Azadirachta indica A. Juss. called neem or neem is a plant of the family Meliaceae and the order Meliales (Safowora, 1982). Neem grows well in semi-arid to semi-humid climates, supports even climates with rainfall less than 500 mm and shows little requirement for soil (Radwanski and Wickens, 1981). This plant has repellent, insecticidal and insect repellent properties (Lim and Dale 1984, Kossou 1989, Seck 1993 cited by Tchibozo 1996, Guèyé et al. Neem (Neem) is a very effective natural insecticidal herb against a wide range of crop pests. It is very little toxic to humans and is not harmful to the environment. The preparation of an aqueous neem solution is inexpensive (Youdeowei, 2004). Aqueous extracts of neem (Azadirachta indica) and Hyptis suaveolens are used to control cowpea pests (Schmutterer 1990, Schmutterer 1995, Kossou et al.

Cymbopogon nardus belongs to the family of poaceae. It is a clump of grass that is cultivated on a large scale, particularly in tropical and subtropical regions with unrestricted distribution in mountainous regions, plains and arid zones (Rocha et al., 2000). In Central Africa, lemongrass is most often planted around houses, as its odor repels mosquitoes (Rocha et al., 2000, Hmamouchi 1995, Boeke et al., 2004 cited by Tchibozo 1996, Ketoh et al. (2005) cited by Tchibozo, 1996, Guèyé et al., 2011).

The producers considered, according to their endogenous technical knowledge, that the aqueous extracts of these plants can be used as biological pesticides of botanical origin to fight against the pests of the cowpea in general and particularly the bedbugs in vegetation.

Technical materials

The different materials used consist of a measuring tape and strings to measure the dimensions of experimental sites and blocks, stakes to delimit, a marker and labels to identify cultivars, working tools such as the hoe and the cutter to install plots and maintain crops, a scale (photo 1), a mortar (photo 2), a magnifying glass for bedbugs (photo 3), plastic buckets for preparation and use plant extract solutions, a pressure-operated backpack sprayer for the application of plant protection products (photo 4), a digital photography camera for taking pictures and a four-digit manual counter.

Photo 1: Electric scale used for weighing the leaves of tested plant species and the weight of cowpea seeds at harvest

Photo 2: Mortar piling of the leaves and stems of the five tested plant species

Photo 3: Manual magnifier with three stackable magnifications used for observation and counting of bedbugs

Photo 4: Pressed pressure sprayer used for phytosanitary treatments

Experimental apparatus

The experimental design adopted is that of Fisher with six treatments representing the aqueous extracts of the five plant species mentioned above and a control treatment without product, for each of the six (06) cowpea cultivars. Five (05) repetitions of the trial were set up at six producers in the three villages in split blocks. The elementary plots measure 24 m², 8 m long and 3 m wide. In each block, the elementary plots separated by a 2 m alley, measure 24 m2 and represent the treatments including cultivars and aqueous extracts.

Conducting the cowpea culture

The cowpea was sown on 28 May 2015 following a rain the day before, after clearing the experimental plots with a cutter, followed by manual plowing with daba. Online seeding was carried out at 0.80 m intervals between lines and 0.60 m between pockets or plants. Two to three seeds were sown per pouch and the pruning was done at one plant per plant. During start-up, the missing plants were replaced. The weeding was done on June 22, 2015 at the hoe, the 25th day after sowing (JAS).

Preparation of aqueous extract solutions

The leaves of the insecticide plants were harvested from the fields of the cowpea producers who proposed the test of their insect repellent and insecticide effects. The aqueous extracts were made the day before the planned day for the spraying of the plots of cowpea. For each plant species, 10 liters of water added to five (05) times the equivalent weight of leaves were used to obtain the aqueous extract formulations.

The fresh biomass amounts of neem leaves, cassava, Thevetia and hyptis leaves and stems were retained in agreement with the producers for 24 m2 representing the area of each elementary plot (Table 2).

The weighed leaves and stems were then crushed in a mortar until a more or less homogeneous paste was placed in a container. The mortar is rinsed and the residual paste solution is poured onto the dough. The contents of the container are well stirred after adding thereto for the five repetitions of aqueous extract treatments distributed over 120 m²; 62.5 g of palmida soap as an adjuvant.

The resulting mixture is covered and deposited in a fairly shady place. On the day of treatment, 24 hours later, the mixture is stirred before being filtered and used.

Table 2: Quantities of fresh leaves and stems (kg) per elementary plot of 24 m² and per hectare used for the preparation of aqueous extracts based on the five (05) species of plants

Plants tested	**Quantity (g) of leaves used to treat 24 m²**	**Dose (kg/ha)**
Hyptis suaveolens	400 (avec tiges)	167
Manihot esculenta	400	167
Azadirachta indica	300	125
Thevetia neriifolia	250	104
Cymbopogon nardus	300	125

The resulting solution is subdivided into five (05) equal parts to treat each parcel of 24 m² when spraying. This dose is applied for each cultivar. For each of the plant species, the applied doses were diluted in 833 litres of water per hectare.

Application of aqueous extracts of plants

Applications of aqueous extracts of plants were made six times during the vegetative cycle of cowpea.

Phytosanitary treatments started in the vegetative growth phase of cowpea, after the emission of a large amount of leaves observed at 28 JAS. From this date, applications were made weekly at 28, 35, 42, 49, 56 and 63 JAS. Spraying was carried out early in the morning from 10 hours to enhance the effect of morning dew on the absorption of the slurry through the stomata of cowpea plants and to prevent degradation of the product during the hot hours of the day.

Sampling of the plants observed

In the experimental setup, each elementary parcel has five (05) lines. To avoid edge effects, one line is left on each parcel on each parcel and the remaining three (03) lines are observation lines for the measured parameters.

All sampling is done at random on the diagonals and medians, then at the intersection of the medians and diagonals so as to use representative, the parcel surface concerned.

Sampling started as soon as a large number of leaves appeared. A magnifying glass was used to directly observe the plant bugs and a four-digit manual counter was used to count the bugs. The observations are made at a regular frequency of seven (07) days apart.

Measured parameters

Assessment of bedbug populations

The observation and count of bedbugs was done on the leaves, at regular intervals of seven (07) days at 27, 34, 41, 48, 55 and 62 JAS. Visual observation of bedbugs was performed on the three central lines of each observation square on twenty (20) plants per plot unit and per cultivar. Each portion of 1 m is spaced so that on all three lines, the observation sites do not coincide in parallel.

Parcel weight of seeds and weight of 1000 seeds of cowpea at harvest

The evaluation of the yield is made on a square of density of 1 m2 located between the three central lines of each parcel. Harvesting of all useful plants was carried out on the central lines reserved for yield. After harvest, drying and seeding of the seeds was done in the sun until the moisture level was sufficiently reduced. Finally, the measurement of the parcel weight of the seeds and the weights of 1000 seeds of each sample were evaluated.

Counting and assessing bug damage

Bugs were counted on the pods and inside pods at 34, 41, 48, 55 and 62 days after sowing (JAS). Bed bug identification and damage assessment were performed on the three center lines of each observation square on twenty (20) plants per plot unit and per cultivar. Thus, 20 cloves were collected at random, then observed and the damage was appreciated. In the experimental setup, each elementary parcel has 5 lines. To avoid edge effects, one line is left on each side of each experimental plot.

Samples are taken at random on the diagonals and medians, so as to make a representative use of the surface of the elementary plots representing the treatments. Thus, each portion of 1 m is spaced so that on the three lines, the observation sites do not coincide in parallel. Sampling started as soon as a large number of leaves appeared. A four-digit manual meter and a magnifying glass were used to observe and directly count the bugs. The observations were made at a regular frequency of seven (7) days apart. This approach was adopted for all cultivars tested.

Different species of bedbugs cause damage to the young pods that they suck causing damage of more or less variable importance. The pods can be completely shriveled and no longer carry seeds. In this case, the damage is serious. These pods are considered to be completely curled up without seeds (Gt). They can carry more or less empty places which indicate the abortion of the seeds. Pods may have aborted seeds on less than half the length (Gam). Pods may contain half-aborted seeds (Gma) or aborted over half (Gp). The assessment grid adopted for assessing bedbug damage is presented in Table 3.

Evaluation of yield of cowpea seed at harvest

The performance evaluation was done in 1 m2 yield squares including the three centerlines of each parcel. All the useful plants of these lines in the squares were harvested and dried up. After drying the pods in the sun, the weight gain of the seeds was done by treatment and for each cultivar.

Table 3: Pod damage assessment grid for bedbugs

State of the pods	Photo of typical damage
Healthy pods whose seeds did not abort (Gs)	 **Photo 1:** Healthy pods
Pods with seeds aborted on less than half the length (Gam)	 **Photo 2:** Aborted seed pods on less than half
Pods whose seeds aborted halfway down (Gma)	 **Photo 3:** Half-seeded seed pod
Aborted pods on more than half (Gp)	 **Photo 4:** Aborted seed pod on more than half
Pods totally curled up without seeds (Gt)	 **Photo 5:** Seedless curled pods

Statistical processing and analysis of data

The database was made in an Excel workbook. Bed bug damage on cowpea pods was expressed as a percentage (%) of the number of cowpea pods attacked on the total number of cowpea pods. Weights of harvested cowpea seed were used to calculate the yield expressed in kg / ha. Using statistical software Minitab 16 and Statistix 8.0, quantitative variables such as the number of bedbugs, the percentage of pods attacked, the weight of cowpea seeds and the weight of 1000 seeds of cowpea at harvest were subjected to part in a statistical analysis of the three-factor variance (cultivar, aqueous extract, and observation period) following the general linear model for determining the probability of significance at the 5% threshold. On the other hand, they were subjected to the comparison test of means with the Tukey test at the 5% threshold.

Results

Effect of aqueous extracts of plants on the bedbug population

Mean values for bedbug populations in pods and cowpea pods varied by cultivar, aqueous extract treatment and vegetative cowpea period (Tables 4a, 4b and 4c). They varied, depending on the vegetative period and the treatment, from 1 to 41 to 34th JAS at levels ranging from 16 to 61 at the 62nd JAS.

The results of the statistical analysis of variance carried out showed that the cultivar, aqueous extract and vegetative period factors of the crop cycle had very very highly significant effects (p <0.0001) on the bedbug population and that all these factors also interacted very strongly (p <0.0001) with the presence of bedbugs. Significant differences (p <0.0001) were observed between mean values of bedbug populations counted by treatments and vegetative period.

For all cultivars, bedbug populations increased significantly from 34 days after sowing to 48 days after sowing before dropping to 55 days after sowing. Two periods of population growth peaks were observed, the first was observed at 48 days after sowing and the second at 62 days after sowing after a significant decrease at 55 days after sowing.

Table 4a: Bed Bug Population Counted by Processing at Observation Periods (JAS) for cultivars Katché péha and Katché sôwôho

Cultivars	**Katché péha**					**Katché sôwôho**				
Treatments	**34th JAS**	**41th JAS**	**48th JAS**	**55th JAS**	**62th JAS**	**34th JAS**	**41th JAS**	**48th JAS**	**55th JAS**	**62th JAS**
Témoin	13,25 defghijklmno	28,00 PQRST	38,95 GHIJ	28,25 NOPQRST	49,25 BCD	13,85 cdefghijklmn	30,75 KLMNOPQ	42,10 DEFG	32,80 IJKLMNOP	50,90 BC
Hyptis s.	1,85 tu	12,00 fghijklmnopq	20,65 UVWXYZabc	10,95 jklmnopq	22,45 STUVWXYZa	7,35 nopqrstu	17,00 Zabcdefghijk	27,25 OPQRSTU	11,700 ghijklmnopq	15,90 abcdefghijkl
Manioc	1,30 u	12,20 fghijklmnop	22,25 STUVWXYZab	10,00 klmnopqrs	27,50 OPQRSTU	5,40 pqrstu	11,55 hijklmnopq	20,35 UVWXYZabcd	10,45 jklmnopqr	17,55 XYZabcdefghij
Neem	4,75 qrstu	11,80 fghijklmnopq	27,00 OPQRSTUV	15,00 bcdefghijklm	37,05 GHIJK	6,05 opqrstu	13,00 efghijklmno	21,85 TUVWXYZab	12,85 efghijklmno	22,85 RSTUVWXYZa
Thevetia	0,85 u	7,15 nopqrstu	18,80 XYZabcdefgh	7,70 nopqrstu	28,90 MNOPQRST	3,25 rstu	13,20 defghijklmno	19,750 VWXYZabcde	10,700 jklmnopq	18,950 WXYZabcdefg
Citronnelle	9,05 lmnopqrst	26,15 PQRSTUVW	40,00 EFGHI	24,75 QRSTUVWX	33,60 HIJKLMNO	9,65 lmnopqrs	19,00 WXYZabcdef	30,75 KLMNOPQ	17,40 YZabcdefghij	35,35 GHIJKLMN
Great average =	**21,317**							**CV (%) =**	**23,92**	
Sources of variation										
	JAS	Traitement	Cultivar	JAS* Traitement		JAS*Cultivar	Traitement*Cultivar		Traitement*Cultivar*JAS	
ddl	4	5	5	20		20	25		100	
Probability	0,0000	0,0000	0,0000	0,0000		0,0000	0,0000		0,0000	

Average values followed by different letters are significantly different at the 5% threshold

Table 4b: Bed Bug populations enumerated by observation period (JAS) treatment for Cultiuvars Katché peha nan sôorii and Kpodjiguègue (continued)

Cultivars	**Katché péha nan sôorii**					**Kpodjiguègue**				
Treatments	**34th JAS**	**41th JAS**	**48th JAS**	**55th JAS**	**62th JAS**	**34th JAS**	**41th JAS**	**48th JAS**	**55th JAS**	**62th JAS**
Témoin	40,90 EFG	35,55 GHIJKLM	47,00 CDEF	50,05 BC	59,55 A	13,85 cdefghijklmn	29,90 KLMNOPQR	50,00 BC	32,55 JKLMNOP	50,40 BC
Hyptis	9,80 Klmnopqrs	18,75 XYZabcdefgh	29,40 LMNOPQRS	13,00 efghijklmno	21,95 TUVWXYZab	4,75 qrstu	11,80 fghijklmnopq	27,00 OPQRSTUV	15,00 Bcdefghijklm	37,05 GHIJK
Manioc	3,25 rstu	12,15 fghijklmnop	22,75 RSTUVWXYZa	16,25 abcdefghijkl	17,70 XYZabcdefghij	0,85 u	7,15 nopqrstu	18,80 XYZabcdefgh	7,95 mnopqrstu	28,90 MNOPQRST
Neem	5,40 pqrstu	12,75 efghijklmno	23,60 QRSTUVWXYZ	11,25 ijklmnopq	18,25 XYZabcdefghi	1,85 tu	12,00 fghijklmnopq	20,65 UVWXYZabc	10,95 jklmnopq	22,45 STUVWXYZa
Thevetia	3,00 stu	10,95 jklmnopq	18,80 XYZabcdefgh	11,95 fghijklmnopq	24,70 QRSTUVWXY	1,30 u	12,20 fghijklmnop	22,25 STUVWXYZab	10,00 klmnopqrs	27,50 OPQRSTU
Citronnelle	7,95 Mnopqrstu	20,65 UVWXYZabc	36,50 GHIJKL	28,75 MNOPQRST	33,05 IJKLMNOP	9,50 lmnopqrs	19,05 WXYZabcdef	41,70 EFG	32,05 JKLMNOP	39,80 FGHI
Great average = 21,317							**CV (%) = 23,92**			
Sources of variation										
	JAS	Treatment	Cultivar	JAS* Treatment		JAS*Cultivar	Treatment*Cultivar		Treatment*Cultivar*JAS	
Ddl	4	5	5	20	20	25	100		100	
Probability	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000		0,0000	

Average values followed by different letters are significantly different at the 5% threshold

Table 4c: Bed Bug Populations Counted by Treatment at Observation Periods (JAS) for Toura pera and Katché Senegal Cultivars (continued and end)

Cultivars / Periods	**Toura pera**					**Katché Sénégal**				
	Periods (JAS)					**Periods (JAS)**				
Treatments	**34**	**41**	**48**	**55**	**62**	**34**	**41**	**48**	**55**	**62**
Témoin	16,10 abcdefghijkl	40,35 EFGH	50,40 BC	30,75 KLMNOPQ	56,40 AB	13,85 cdefghijklmn	42,10 DEFG	50,40 BC	47,20 CDE	61,45 A
Hyptis	3,25 rstu	13,20 defghijklmno	19,75 VWXYZabcde	10,70 jklmnopq	18,95 WXYZabcdefg	9,05 lmnopqrst	26,15 PQRSTUVW	40,05 EFGHI	24,75 QRSTUVWX	33,60 HIJKLMNO
Manioc	6,05 opqrstu	13,00 efghijklmno	21,85 TUVWXYZab	12,85 efghijklmno	22,85 RSTUVWXYZa	7,35 nopqrstu	17,00 Zabcdefghijk	27,25 OPQRSTU	11,70 ghijklmnopq	15,90 abcdefghijkl
Neem	7,35 nopqrstu	17,00 Zabcdefghijk	27,25 OPQRSTU	11,70 ghijklmnopq	15,90 abcdefghijkl	6,05 opqrstu	13,00 efghijklmno	21,85 TUVWXYZab	12,85 efghijklmno	22,85 RSTUVWXYZa
Thevetia	5,40 pqrstu	11,55 hijklmnopq	20,35 UVWXYZabcd	10,45 jklmnopqr	17,55 XYZabcdefghij	4,75 qrstu	11,80 fghijklmnopq	27,00 OPQRSTUV	15,00 bcdefghijklm	37,05 GHIJK
Citronnelle	9,05 lmnopqrst	26,15 PQRSTUVW	40,05 EFGHI	24,75 QRSTUVWX	33,60 HIJKLMNO	13,90 cdefghijklmn	29,90 KLMNOPQR	50,00 BC	32,55 JKLMNOP	50,40 BC
Great average = 21,317						**CV (%) =** 23,92				
Sources of variation										
	JAS	**Treatment**	**Cultivar**	**JAS * Treatment**		**JAS*Cultivar**	**Treatment*Cultivar**		**Treatment*Cultivar*JAS**	
ddl	4	5	5	20		20	25		100	
Probability	0,0000	0,0000	0,0000	0,0000		0,0000	0,0000		0,0000	

Mean values followed by different letters are significantly different at the 5% threshold.

For all cultivars, application of all aqueous extracts significantly (p <0.0001) reduced bedbug populations throughout the crop cycle compared to control without a botanical pesticide. Apart from the aqueous extract of citronella, all the other four aqueous extracts of Thevetia neriifolia, cassava, Hyptis suaveolens and neem reduced the bedbug populations to levels very significantly lower than those of aqueous extract of lemongrass and the witness that remained the highest.

Effects of aqueous extracts on bedbug damage on cowpea pods

Bed bug attack analysis showed that the cultivar factor (Table 5) and the treatment factor (Table 6) each had a very highly significant effect (p <0.0001) on attack levels. pods by bedbugs.

This concerns as much the percentages of healthy pods (Gs), as the percentages of pods having aborted on less than half (Gam), the percentages of semi-aborted gouses (Gma), the percentages of pods aborted on more than half (Gp) and percentages of pods curled up without seeds (Gt).

Table 5: Percentage (%) of cowpea pods attacked by bedbugs by cultivar, for all treatments combined

Variables	Gs	Gam	Gma	Gp	Gt
Katché péha	73,33a	15b	5,83a	3,33c	2,50c
Katché sôwôho	67,50ab	17,5b	5ab	4,67c	4,17bc
Kpodjiguègué	65,83b	13,33b	5,83a	8,33b	6,67b
Toura pera	66,67b	13,33b	7,5a	5c	5,83b
Katché péha nan sôorii	59,17c	26,67a	2,5b	5c	6,67b
Katché Sénégal	53,33c	16,67b	7,5a	11,67a	10,83a
Moyenne	64,31	17,08	5,69	6,25	6,11
Source of variation	**Cultivar**	**Treatment**	**Cultivar * treatment**		
Ddl	5	5	25		
Probability	0,0000	0,0000	0,0000		

Mean values followed by different letters are significantly different at the 5% threshold, according to the Tukey test

Table 6: Percentages (%) of cowpea pods attacked by bedbugs by treatment, for all cultivars combined

Variables	Gs	Gam	Gma	Gp	Gt
Témoin	40,83d	21,67a	9,17a	15a	11,67a
Hyptis suaveolens	61,67c	20,83ab	7,50ab	6,67b	3,33bc
Manoic	71,67b	16,67bc	5bc	0,83d	4,17bc
Neem	67,50bc	15d	5bc	6,67b	5,83b
Thevetia	80a	11,67d	2,5c	3,33cd	2,50c
Citronnelle	64,17c	16,67bc	5bc	5bc	9,17a
Moyenne	64,31	17,08	5,69	6,25	6,11
Source of variation	**Treatment**	**Cultivar**	**Cultivar * treatment**		
Ddl	5	5	25		
Probability	0,0000	0,0000	0,0000		

Mean values followed by different letters are significantly different at the 5% threshold, according to the Tukey test

A very highly significant (p <0.0001) interaction effect was observed between cultivar and treatment factors (Tables 5 and 6). The most reliable average healthy percentage of pods (Gs), 41%, was recorded with the control treatment which had the highest average values of percentages (i) of aborted pods (p <0.0001) on minus half (Gam), (ii) half-aborted gums (Gma) and (iii) more than half aborted pods (Gp), compared to those based on aqueous extracts (Table 6).

The percentages of healthy pods estimated for cultivars show very very highly significant differences. The cultivar Katche peha was much less attacked with 73.33% healthy pods, followed by Katché sôwôho with 67.50%, Kpodjiguègué and Toura pera with indifferently 66% to 67%, and finally Katché peha nan sôorii and from

Katché Senegal who presented 53% to 59% of healthy pods (Table 5). The cultivar Katché péha had the highest proportion of healthy pods, 73%, followed by Katché sôwôho in second position, Kpodjiguègué and Toura pera indistinctly in third position, then Katché peha nan sôorii and Katché Senegal in last position. .

Thevetia-based treatment yielded the highest percentage of healthy pods, 80%, followed by cassava, neem and, finally, those based on Hyptis sp. and Lemongrass. These treatments follow in reverse order for mean percentages of aborted pods on less than half (Gam), half-aborted (Gma) gins, and over half (Gp) aborted pods. In relation to the proportion of healthy pods, the cultivar Katché peha has fewer seedless curled pods, followed by Katché sôwôho in second position, in third position indiscriminately of Katché peha nan sôorii, Kpodjiguègué and Toura pera, and finally in fourth place. Katché Senegal's position.

Effects of aqueous plant extracts on cowpea seed yield

Treatments based on aqueous extracts influenced the yield of cowpea seeds differently (Table 7). The results of statistical analyzes show that the cultivar and treatment factors each had a very highly significant effect ($p < 0.001$), with a very significant interaction effect ($p < 0.01$).

The most effective aqueous extract treatment was Thevetia neriifolia at 886 kg / ha, followed by Hyptis sp. with 793 kg / ha, cassava with 741 kg / ha, and neem with 711 kg / ha, followed by citronella with 587 kg / ha compared to the control which only obtained 387 kg / ha. When considering cultivars, yield of cowpea seed ranged from 519 kg / ha to 748 kg / ha. Katché peha cultivar had the highest yield of 747.50 kg / ha, followed by Katché peha nan soorii with 646.45 kg / ha and Katché Senegal with 519.10 kg / ha. Ha. The three cultivars, Katché sôwôho, Kpodjiguègué and Toura pera, are then indifferently in the fourth, fifth and sixth positions, with yield levels of 732.49 kg / ha, 735.85 kg / ha and 723.46 kg / ha. which showed no significant difference ($p < 0.001$).

Table 7: Average seed yields (kg / ha) of cowpeas obtained with aqueous extracts

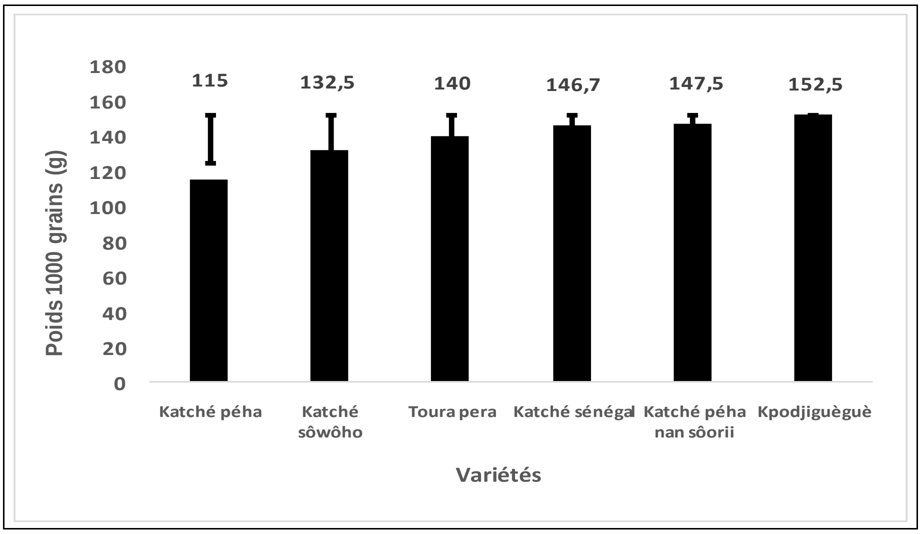
Treatments	Cultivars						Medium cultivars
	Katché péha	**Katché péha nan soorii**	**Katché Sénégal**	**Katché sôwôho**	**Kpodjiguègué**	**Toura pera**	
Témoin	435,9 ± 146,2	368,9 ± 126,7	255,0 ± 139,0	381,0 ± 170,9	467,5 ± 89,8	415,7 ± 159,3	387,28d
Hyptis	847,9 ± 119,0	859,6 ± 330,7	652,6 ±172,1	743,8 ± 152,2	719,9 ± 142,7	936,6 ± 115,8	793,36ab
Neem	829,0 ± 152,8	659 ± 336	522,5 ± 137,5	780,9 ± 134,2	698,9 ± 168,1	773,0 ± 150,0	710,51b
Thevetia	1015,0 ± 155,2	779,0 ± 243,8	684,5 ± 176,8	935,4 ± 148,7	946,1 ± 120,1	955,9 ± 91,5	885,76a
Citronelle	596,9 ± 100,9	542,1 ± 191,8	495,5 ± 118,5	705,3 ± 243,3	611,3 ± 138,1	572,1 ± 91,1	587,06c
Manioc	760,5 ± 113,8	670,9 ± 279,6	505,7 ± 186,8	849,5 ± 134,0	972,5 ± 92,0	687,7 ± 204,7	740,88b
Average treatments	747,50a	646,45b	519,10c	732,49ab	735,85ab	723,46ab	684,14
Source of variation	Cultivar	Treatment	Cultivar * treatment				
ddl	5	5	25				
Probability	0,000***	0,000***	0,0076**				

The average values of the same column or line followed by different letters are significantly different at the 5% threshold.

Evaluation of the weight of 1000 seeds of cowpea

The effect of treatments based on aqueous extracts on the weight of one thousand seeds of each cultivar is shown in Figure 2. The cultivar factor has a very highly significant effect ($p < 0.001$) on the weight of thousand seeds and Very highly significant differences were observed between the average weights of 1000 seeds of the varieties ($p < 0.001$).

Cultivars can be ranked in descending order of their 1000-seed weight as follows: (1) Kpodjiguègué with 152.5 g, followed by (2nd) Katché peha nan sôori with 147 g, (3rd) Katcké Senegal with 146 g, (4th) Toura pera with 140 g, (5th) Katché sôwôho with 132 g and finally (6th) Katché with 115 g.



Kpodjiguèguè : 152,5a	Katché peha nan sôori : 147ab	Katcké Sénégal : 146ab	Toura pera : 140ab	Katcké sôwôha : 132bc	Katché peha : 115c
P = 0,001 ; great average = 138,75 ; CV (%) = 5,82					

Average values followed by different letters are significantly different at the 5% threshold

Figure 2: Weight (g) of 1000 cowpea seeds of cultivars

Discussion

Importance of bugs

Several studies had addressed the specific diversity and importance of baby bugs. A previous study of this behavior in the same study area by Bello *et al.* (2018) had identified the bugs Anoplocnemis curvipes F., Clavigralla (Acanthomia) tomentosicollis Stal and Nezaria viridula in baby crop. Dina (1973) and Singh (1973) had previously observed that sucking bugs belong to the Hemiptera and are divided into several families. In addition to these three species identified by Bello *et al*. (2018) and above, eight other species namely Acanthomia (= Clavigralla) horrida, Acanthomia brevirostris, Aspavia armigera, Clavigralla shadedi, Mirperus jaculus, Nezara spp, Piezodorus guldinii and Riptortus dentipes were identified by several authors.

According to Dina (1973) and Singh (1973), the largest bug family is Corcidae with pests such as Anoplocnemis curvipes (F), Riptortus dentipes (F), Acanthomia (= Clavigralla) horrida (Germ). Given the agronomic importance of the species, Kassam (1978) reported that "the most dangerous species are Acanthomia brevirostris, Acantomia horrida, Anoplocnemis curvipes and Mirperus jaculus."

The findings of these authors lead one to hypothesize that "the presence of Anoplocnemis curvipes (F), Clavigralla (Acanthomia) tomentosicollis Stal and Nezaria viridula within the nesting entomofauna identified in the area. This study explains the levels of pod damage and subsequent loss of registered baby seed yields."

The bug species have an uneven geographical distribution. So they only exist in Benin. Thus, Clavigralla tomentosicolis and Nezara spp had been identified in Kamboinsé in Burkina Faso (Dabire and Suh, 1988). C. shadedi, Mirperus jaculus and Nezara viridula had been cited by IITA (1981, 1983). In the same spearhead, C. tomentosicolis and other bugs such as Riptortus dentipes, Piezodorus guldinii, Anoplocnemis curvipes and Aspavia armigera were cited by IITA (1983), as was Nezara viridula (L) by Schmutterer (1969). Nebie (1992).

In this study, the losses caused by bedbugs varied according to the botanical pesticide treatment from 44% to 66%. This result of this study corroborates those of Singh (1973) who reported that 63% of Vigna unguiculata seeds can be damaged by corcidae. These values are lower than those between 60% and 90% reported by Maïga and Issa (1988) in case of strong attacks of Anoplocnemis Curvipes. However, lower levels of 35% losses were reported by IITA (1973) in case of Hemiptera infestation in the absence of control.

Effectiveness of aqueous extracts on bedbug control and cowpea yield

An increasing trend in the bug's population has been observed during the cowpea crop cycle in the absence of control. This observation was similar for all cowpea cultivars. The strongest populations of bedbugs observed in the 48th JAS are due in our humble opinion, that the cowpea plants were in full bloom, an assertion that had supported Singh (1977), Adeoti (1990) and Djossou (2001) .

The increasing increase in thrips populations between different sprays, except at the 55th JAS, suggests that aqueous extracts are not systemic products. As indicated by Atachi and Sourokou (1992) for thrips living inside and outside the flowers, spraying can only reach those living externally. Like thrips, bedbugs also live outside and inside the pods they are fond of in green pods. Thus, the sprays only reached the bugs that live outside the flowers, which justify the resurgence of their population observed between sprays.

The significant decline in bedbug populations at the 55th JAS can be explained not only by the cumulative action of the doses of pulverized aqueous extracts, but also by the fact that a first flowering leading to a

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production of green pods of cowpeas has fallen. Thus, the density of green pods is no longer sufficient to maintain previously observed population levels until the 48th JAS.

However, Yehounou (1998) observed, at the Ina and Angaradébou sites in north-eastern Benin, like Dreyer and Baumgartner (1995), cowpea pod damage caused by bugs at all the stages of pod formation.

The present study has demonstrated the effectiveness of the aqueous extracts téstés. However, the effectiveness of the aqueous citronella extract is less than that of Thevetia neriifolia, cassava, neem and Hyptis suaveolens. This result of this study corroborates those of Kossou et al. (2000), Radke et al. (1972), Remaudière et al. (1985) and Bello et al. (2018) who observed that the extracts of Thevetia neriifolia, neem, cassava and hyptis suaveolens make it possible to control, better than in the absence of treatment, the population of pests in general and bedbugs in particular.

The efficacy of the aqueous extracts found in this study is in our opinion related to their application in six weekly sprays at 28, 35, 42, 49, 56 and 63 JAS, a practice that was adopted in accordance with the recommendation of four (04) one-week sprays recommended by Atachi and Dannon (1999). This approach also took into account the recommendation for synthetic chemical insecticide spraying recommended at 45th, 55th and 65th days after sowing by Booker (1965), Singh and Allen (1980), and Atachi and Dannon (1999). to obtain satisfactory results against cowpea pests, particularly M. vitrata bug, which causes damage to flowers and pods. However, Dabire et al. (2005) suggested targeting during pod control the stage of pods being filled, as these are very vulnerable to attacks by the bug Clavigralla tomentosicollis STAL. It is undoubtedly the respect of all these recommendations that justify the efficiency levels of the aqueous extracts obtained in the context of this study.

The combined use of aqueous extracts of neem with other insecticides is already a concern for many researchers. This is how Kadri et al. (2013) found that the density of the Maruca vitrata and Megalurothrips sjostedti populations, although significantly reduced, is lower in the Super-Diforce treated plots than in the Neem treated plots and the viral preparation. Similar results have been reported by Abdoul Habou et al. (2014) who observed that "J. curcas oil at a concentration of 10% allows for a reduction of more than 80% in the population of bedbugs, aphids and thrips compared to the reference product deltamethrin and an increase in seed yield of 50% ".

In the same vein, Toffa Mehinto et al. (2018) also reported the inhibitory effect of the biological insecticide-based mixture of neem aqueous extract and M. vitrata-specific nuclear polyhedrosis virus provided by the IITA-Benin pathology laboratory on the presence of and Maruca vitrata caterpillar damage on flower buds, cowpea flowers and pods, and the presence of bedbugs in the central Benin cotton zone, compared to control, Decis insecticide and powder spores of the B. bassiana fungus strain 115 isolated from a M. vitrata larva and produced at the pathology laboratory of IITA-Benin. This efficiency was remarkable on the yield obtained with the two biological pesticide treatments that are statistically identical compared to the control and the chemical insecticide Decis.

These observations in fact indicate the difficult production of cowpea linked to the necessity of the imperious control of its numerous pests. In fact, five kinds of bedbugs belonging to two large families are found in cowpea culture in Kamboinsé, Burkina Faso. These are the Coreidae and Pentatomidae of which the most important species, Clavigralla tomentosicolis, Mirperus jaculus and Nezara viridula represent respectively 90%, 5% and 2% of the total pest populations. Damage can exceed 50% of pod production and affects 57% of damaged seeds in the absence of insecticide treatment (Nebie, 1992).

The results of the present study are also similar to those of Sawadogo (2004) who observed that the extracts of three plants Cassia nigricans V., Cleome viscofa L. and Cymbopogon schoenanthus tested in the laboratory over four stages of C. tomentosicollis development shown after 10 days, a lethal effect on the larvae and adults of C. tomentosicollis in a proportion greater than or equal to the mortality rate caused by the average of resistant and sensitive controls. The mortality rate of C. tomentosicollis is less than 50% regardless of the stage of development of the insect tested. C. viscosa is low-acting, followed by C. nigricans and C. schoenanthus (Sawadogo 2004).

Bedbug populations have not been able to stabilize to be maintained at a given level. This reflects the growth in bedbug populations found in all cultivars. At this rate of infestation, the damage of the bugs was perceptible on the quality of the pods. The less healthy the pods, the less well they are filled. In the same way, the more the pods are aborted and the more they contain damaged seeds. Bachabi et al. (2003) achieved the same results with neem, hyptis and papaya extracts used singly or alternately or rotatively.

In addition, regardless of the effects of the treatments on insect populations, significant effects were noticeable on seed yield. The treatments with Thevetia neriifolia, Hyptis suaveolens, and Neem and Cassava, in this order, recorded the best seed yields in descending order, from 885.76 kg / ha to 710.51 kg / ha. . The aqueous extract of lemongrass and the control presented in the same order, the seed yields significantly low, respectively 587.06 kg / ha and 387.28 kg / ha.

Resistance of cowpea cultivars to bedbug attack

Economically and ecologically, varietal resistance is based on plant defense mechanisms that boil down to non-preference, antibiosis and tolerance to pests. In other words, it translates into the genetic capacity of a plant to produce a crop of good quality and in greater quantity than ordinary varieties for the same population density of insects. On this basis, the promotion of varietal resistance in the fight against pests remains the healthiest and most important method in the fight against pests.

The results of the present study showed that Katché peha and to a lesser extent Katché sôwôho cultivars appear to be tolerant and / or resistant to cowpea bugs attack with losses of pod yield estimated at not more than 1/3. The cultivars Kpodjiguègué and Toura pera appear moderately susceptible to bedbug attack with pod yield losses estimated at 1/3. As for the cultivars Katché peha nan sôorii and Katché Senegal, they can be considered very sensitive to the attacks of this group of pests with at least 50% loss of yield in pods.

Cultivars Katché péha, Katché sôwôho, Kpodjiguègué, and Toura pera showed more healthy pods compared to two others, Katché péha nan sôorii and Katché Sénégal. These first four cultivars can therefore be used in varietal improvement programs geared towards combating sucking insects of pods.

This result is similar to that of Roesingh (1980) and Salifou et al. (1988) who reported that VITA-1 and VITA-2 varieties are susceptible to M. vitatra bug, while VITA-4 is less susceptible and VITA-5 is resistant. These authors have nevertheless specified that these resistances are moderate and cannot completely control these pests.

The levels of resistance and / or tolerance attributed to the varieties under study deserve to be studied further, as very little information currently exists on their varietal resistance compared to varieties such as TVu 6863 and TVu 1890 which have been identified. by LITA (1983) as a source of resistance to pod bugs.

Relevance of the use of botanical biopecticides

The results of this study have demonstrated the effectiveness of biopexticides of botanical origin. More than one recognizes that pod bugs in general and Anoplocnemis curvipes in particular do a lot of damage in cowpea fields in tropical Africa, by their stinging actions on green pods, followed by the sucking of sap, resulting in their drying up and yield losses of the order of 30% to 70%.

Although the use of biological pesticides of botanical origin as well as synthetic pesticides has positive effects and should be encouraged, cultural control measures must also be taken to ensure better control of bedbug populations and limit their infestations. It is for this reason that Dugje et al. (2009) advocated that "in addition to the use of resistant varieties of cowpea and the application of insecticides, rid the field of debris from the previous harvest as long as this pest can survive until the next campaign ".

The use of biopesticides, whose efficacy has been documented in this study, is part of a draft control strategy developed by Jackie and Daoust (1986), and later by Projet-niébé (2000) and Sinzogan (2002).). Clearly, the approach of using botanical pesticides is a component of Integrated Pest Management against cowpea pests that integrates two compatible strategies namely (i) the conservation of natural enemies through the management of crop habitats and (ii) the use of insecticidal plants. Like the similar recommendations developed by (PRONAF Senegal, 2002), the use of the aqueous extracts studied in the context of the present study for the phytosanitary protection of cowpea participates in the use of products that are less harmful than synthetic insecticides. , for human health and the environment and are within the reach of small producers.

Conclusion

The present study has highlighted the effectiveness of aqueous extracts of plants in the fight against the bugs whose reduction of the negative impact of the damage is perceptible through the increase of the yield of seeds of the cowpea.

The plant extracts of Hyptis suaveolens, Azadirachta indica, Manihot esculenta, Thevetia neriifolia gave the best yields of cowpea seeds compared to that of Cymbopogon nardus and the control. These botanical biological insecticides can therefore be used for agro-bio-ecological control as alternative control measures in the protection of cowpea against bed bugs in particular and pests in general.

The resistance and / or tolerance performances suspected for cultivars Katché péha, Katché sôwôho, Kpodjiguègué, and Toura pera compared to the two others that are Katché péha nan sôorii and Katché Senegal deserve to be elucidated compared to varieties already characterized. Their valorization in a program of varietal improvement directed towards the fight against the biting insects of pods for their integration in the cropping systems with the application of measures of fight based on the recommendation of optimal and economically profitable doses of the aqueous extracts of plants tested insecticides should be promoted. However, the appropriate formulations and packaging of these insecticides and the possibilities of their wide availability should be considered.

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