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Controlling *Anomala denuda* (Coleoptera: Scarabaeidae), *a* Maize Pest, Using an Aqueous Extract of *Ricinus communis*

Gueu Adolphe Gbon[1*], Jean Pierre Boga[1], Félicia Johnson[1, 2]

[1]Laboratory of Natural Environments and Biodiversity Conservation, UPR-Entomology and Ecosystem Management, Félix Houphouët-Boigny University, Abidjan, Côte d'Ivoire.
[2]The Centre of Excellence WASCAL/CEA-CCBAD, Félix HOUPHOUET-BOIGNY University Abidjan, Côte d'Ivoire.

ABSTRACT

A. denuda adults are not recognized as major crop pests. However, the presence of up to 46.508 individuals of the species was reported in one night in a maize field in Songon. The loss caused by their damage was estimated at 32% of the maize yield. This observation prompted this study. This work was conducted on an experimental plot covering 2592m². Concentrations 110g/l(T1), 135.5g/l(T2), and 165g/l(T3) of the aqueous extract were applied with 6 replicates. Four (4) applications were made per crop cycle in 2020 and 2021. The reference chemical insecticide used was Viper 46EC (16 Acetamiprid, 30 indoxacarb). Over the 2 crop cycles, all applied treatments were relatively effective compared to the control ($p < 0.05$). They reduced the number of insects visiting the treated plots to an average of 5.16 insects/plant compared to the 21.10 insects/plant noted on the control, resulting in an average reduction rate of 75.54%. T3 (165g/l) was the most effective treatment, which recorded the lowest amplitude of insects/plant (3.03) as well as the lowest production loss rate (4.49%) compared to the control (26.17%). Maize yield was significantly improved by 26.25% in 2020 and 17.80% in 2021 on T3, averaging 22.03% over the 2 years. The use of *R. communis* extract at 165g/l could, therefore, be an alternative to synthetic chemical pesticides for the control of *A. denuda* in maize fields.

Keywords: Control, Pest, *Anomala denuda,* Biopesticide, *Ricinus communis.*

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Corresponding author: Gbon Gueu Adolphe
E-mail ✉ gueuadolphegbon@yahooo.fr
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INTRODUCTION

A cereal is a plant cultivated mainly for its grains used in human and animal food. In 2020-2021, 715 million hectares of cereals were cultivated in the world and 2.714 billion tons of cereals were produced [1]. Among these cereals, maize is one of the 3 most important cereal crops in the world, the other 2 being wheat and rice [2]. It is a strategically important crop for food security in sub-Saharan Africa.

In Côte d'Ivoire, with a national production of more than 840,000 tons, maize is the 2nd cultivated cereal product after rice [3]. It is a raw material for the agri-food (brewery, oil mill, soap factory) and food manufacturing industries. Such production represents a considerable source of income and employment for rural populations [4]. Although maize is of undeniable economic importance, its cultivation is confronted with multiple biotic and abiotic constraints that greatly reduce yields. Indeed, the major constraints to maize production include low soil fertility, rainfall variability caused by climate change, phytopathogenic diseases, and above all, attacks by insect pests such as termites [5] and maize stem borers [6].

In addition to the pests listed above, a night survey aimed at capturing stem borers in an experimental maize plot in Songon, southern Côte d'Ivoire, Boga *et al.* [7] unexpectedly observed a very large outbreak of *A. denuda* adult beetles (46,508 individuals/night). Indeed, several studies in the literature have shown that

their larvae are known as crop pests. As for the adults, they are little known as important pests. However, it appeared from Boga *et al.* [7, 8] that the adults of this beetle attack and feed extensively on the reproductive organs of maize (male and female flowers), causing an unacceptable loss of 32% in maize production.
Given the high incidence of damage by this beetle on maize production, we set ourselves the objective of carrying out experiments to control the *A. denuda* beetle using an aqueous extract of *R. communis* (pesticidal plant). Such endeavor aims to reduce the attacks of this beetle and to improve maize production.

MATERIALS AND METHODS

Site of the study

The study was conducted in Songon (5°19'32.3"N 4°15'24.0"W) in southern Côte d'Ivoire.
In 2020, an average temperature of 27.85° C, an average rainfall of 151.34 mm, and a relative humidity of 82.3% was recorded at the site Tutiempo [9]. The average temperature recorded in 2021 was 26.45 ° C with a relative humidity of 79.3% and an average rainfall of 126.61 mm [10, 11].

Material

Biological material

The biological material is composed of *A. Denuda* adult beetles and of the *Zea mays* maize species. It is a local variety (PR9131-SR) with an average yield of 2 t/ha and a potential yield of 3 t/ha. It has a short cycle of 90 days (3 months). An aqueous extract of the insecticidal plant *R. Communis* L. (Euphorbiaceae) was used for field experiments against *A. Denuda* populations.

Technical equipment

The material used for the extraction of the aqueous extracts of the plant is a mortar, a mixer, a graduated cylinder, a Denver branded electronic precision balance, white poplin fabrics, cotton wool, a funnel, porcelain plates, and an oven set at 50°C. Two (2) Tropical branded backpack sprayers with a capacity of 10 liters were used to apply the treatments. Gloves and muffs were used to protect the applicator.

Methods

Experimental set-up (setting up the crops and treatments)

The experimental setup is a plot of 2592m^2 (54mx48m). It is subdivided into 3 blocks with 3 m distance between them. The blocks are divided into 3 sub-blocks separated by 2 m. Each sub-block is 48 m long and 16 m wide and contains 9 elementary plots. Each elementary plot has an area of 16 m^2 and contains 30 maize seedlings. There is a total of 15,147 seedlings on the whole experimental plot. Among the 3 blocks of the experimental setup, one block was reserved for other observations while the 2 others were treated. Each sub-block was randomly assigned 4 treatments (T1, T2, T3, Ti). The control was named To.
Viper 46EC is the reference insecticide used in our experiments. It is a systemic contact and ingestion insecticide. It belongs to the family of neonicotinoids and Oxadiazines.

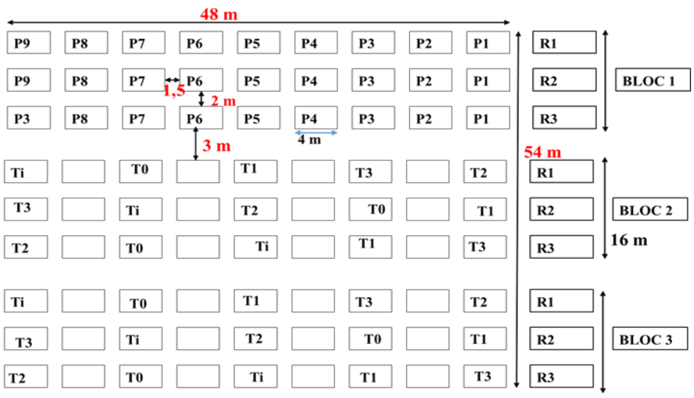


Figure 1. Experimental set-up for the crops and treatments
110 g/l (dos 110 g/l (80% effective dose in the laboratory): Treatment (T1)
110 g/l + a quarter of 110 or 137.5 g/l: Treatment (T2)
110 g/l + half (1/2) of 110 i.e. 165g/l: Treatment (T3)
VIPER 46 EC (16 Acetamiprid 30 indoxacarb): Treatment (Ti).

Soil preparation and fertilization

To favor the good growth of maize seedlings, chicken droppings (10 tons/hectare) and urea (150 kg/ha) were used as organic amendments on the experimental plot.

Extraction of the aqueous extract of Ricinus communis

The preparation protocol suggested by Zirihi and Kra [12, 13] was used. Seed capsules of *R. communis* were collected and dried in the shade for 5 weeks. The organs were ground with a blender. One hundred grams (100g) of powder from each plant was diluted in 2 liters of distilled water. The resulting mixture was homogenized in a blender for 5 minutes, then filtered through a white poplin fabric. The 1st filtrate was homogenized in the blender and then filtered for the 2nd time with Whatman paper. A 3rd filtration was then carried out using a funnel containing cotton wool. The last filtrate obtained was concentrated by evaporation in an oven set at 50°C for 48 hours.

Determination of the concentrations of extracts applied in the field

Beforehand, toxicity tests were carried out in the laboratory on 2 plants (*R. communis* and *Azadirachta indica*) on the *A. denuda* beetles. Such tests consisted in evaluating the insecticidal effect of these 2 plants on the mortality of *A. denuda* to determine the most effective plant and concentration. The results of the laboratory tests showed that the aqueous extract of *R. communis* was the most effective on the Coleoptera as it induced a mortality rate of 80% on *A. denuda* at a lethal concentration of 110g/l [14, 15]. *R. Communis* was, therefore, selected for the field experiments. Based on these laboratory results, 3 concentrations of *R. Communis* extract were determined while taking into account the non-laboratory conditions in the natural environment (field):

110 g/l (*80% effective dose in the laboratory*): Treatment (T1)

110 g/l + one quarter (1/4) of 110 or 137.5 g/l: Treatment (T2)

110 g/l + half (1/2) of 110 or 165g/l: Treatment (T3)

VIPER 46 EC (16 Acetamiprid 30 indoxacarb): Treatment) (Ti)

Application of the treatments

Two 10-liter backpack sprayers were used to treat the individual plots. One labeled (Ti) was used to apply the reference chemical insecticide and the other (T) was used to apply the aqueous extract of *R. Communis* seed capsules. The field experiment for the control of *A. Denuda* beetles were carried out over 2 years (2020 and 2021). For treatments, 4 applications were made:

For the year 2020, a 1st application was made on the 42nd day after sowing (DAS) before the arrival of beetles on the plot. The second application was made on the 50th DAS, i.e. 2 days after the arrival of the beetles. The third application was made on the 56th DAS and the fourth was made on the 62nd DAS, which is 6 days between treatment applications.

As for the year 2021, following the preventive treatment on the 42nd DAS, the other 3 treatments were spaced 3 days apart, namely, 50th DAS for the second application, 53rd DAS for the third, and 56th DAS for the last one.

Efficacy of aqueous extracts of R. communis on the A. denuda beetles

denuda beetle is active at night. Its activity is intense between 10:00 p.m. to 12:00 a.m. Individuals gather on the apical flowers and hair of maize cobs on which they feed [7]. This activity only lasts about 2 weeks. From the first application of the treatments, data were collected every night from 10:00 p.m. to 12:00 a.m. on the seedlings until the maize cobs reached maturity. The parameters recorded are 1. / the number of seedlings attacked per plot and 2. / the number of beetles per seedling/plot. These data were used to calculate the average number of beetles per seedlings and the various reduction rates in beetle numbers after the application of the treatments:

$$\text{Mean number of insects per seedlings} = \frac{\text{Total number of insectes}}{\text{Total number of attacked seedlings}} \quad (1)$$

$$\text{TXre} = \frac{\text{NCT0} - \text{NCT}}{\text{NCT0}} \times 100 \quad (2)$$

Txre: Reduction rate in beetle numbers per seedlings
NCT0: Number of beetles visiting the control plot
NCT: Number of beetles visiting the treated plot

Impact of R. communis extracts on yield loss caused by A. denuda

Anomala denuda is a nocturnal beetle that attacks and devours the male (apical flower cluster) and female (hair) reproductive organs of maize. To assess the impact of this damage on maize production, we counted the maize cobs whose hairs have been completely eaten (wiped out) by the insects. The stems of these cobs were marked with ribbons of different colors according to the time intervals that are: [1 to 3]; [4 to 6]; [7 to 9] [10 to 12] DAS.

Thus, all the attacked cobs were marked with ribbons and the others that were not attacked were left untouched. At maturation (91 days), the cobs were harvested and classified into two batches labeled by plot and by treatment. For each plot, the cobs were divided into 2 labeled bags: One bag containing the cobs whose flowers had been wiped out and the other containing the ears that were not attacked. In the batch containing the wiped cobs, the cobs were divided into 4 bags according to the time intervals ([1 to 3]; [4 to 6]; [7 to 9] [10 to 12] DAS in which the cobs were wiped out by the insects. The cobs were transported to the laboratory, stripped, and dried at room temperature for 21 days before they were dehulled. The different batches of maize grains were weighed according to the treatments using a Denver electronic precision balance.

The yield loss caused by insect attacks as well as the rate of loss reduction after treatments were calculated according to the following formulas [16].

$$\text{Yield loss (T/ha)} = \frac{\text{Weight of unattacked cobs} - \text{weight of attacked cobs}}{\text{Area}} \quad (3)$$

$$\text{Loss rate} = \frac{\text{Yield loss}}{\text{Total yield}} \times 100 \quad (4)$$

$$\text{TXre} = \frac{\text{Loss rate on plot T0} - \text{Loss rate on treated plot}}{\text{Loss rate on plot T0}} \quad (5)$$

Txre: Reduction rate

Statistical analysis

Data processing was done using 2 software programs. Microsoft Office 2010's Excel software for data entry and graphical representations, on the one hand, and Windows SPSS 21.0 for statistical data analysis, on the other hand. Data were subjected to analysis of variance (ANOVA) and means categorized by the Student-Newman-Keuls (S-N-K) test at a 0.05 significance level. Pearson's correlation test was used to study the relationships between attack rates caused by the *A. Denuda* beetle and the average number of individuals that visited the plot.

RESULTS AND DISCUSSION

Results

Effect of Ricinus communis aqueous extracts on the reduction in numbers of Anomala denuda beetles

Crop year 2020

The analysis of the control curve shows 2 phases. A phase in which the number of *A. Denuda* visiting the plot increases sharply (from 48th to 58th DAS). Another phase (from 58th DAS) where the number of insects per seedling progressively decreases until the number of insects per seedling falls below 5 (64th DAS). Then, the flow of insects visiting the maize seedlings is annihilated from 76th DAS **(Figure 2)**. After the 2nd application at 50th DAS, analysis of the nightly post-application surveys revealed that no insects visited the plots treated with the reference insecticide. However, an average of 0.59 ± 0.003 insects were recorded on plots treated with *R. Communis* aqueous extracts compared to 6.28 ± 1.08 insects on control plots **(Figure 2)**. Four days following the 2nd application of the treatments (at 50th DAS), the number of beetles progressively increased, reaching 54th DAS, the day before the 3rd application, with average numbers of 19.25 ± 5.12; 14.25 ± 2.09; and 14.08 ± 0.99 insects/seedling, respectively on treatments T1, T2, and T3. The control recorded a peak of 36.64 ± 4.6 insects/seedling on average. Compared to the control, these average numbers correspond to average reduction rates of 47.44 ± 7.23% (T1), 61.57 ± 5.11% (T2), 61.11 ± 11.5% (T3), and 96.66 ± 2.57% insects/seedling for the treatment (Ti). Statistical comparison (Anova test followed by the Newman-Keuls test at the 5% threshold) revealed that there was a significant difference ($p < 0.001$) between the insect population reduction rates for treatments T1, T2, T3, and the control (T0). This statistically significant difference ($p < 0.001$) is also expressed when the rates of insect population reduction recorded on treatments T1, T2, and T3 are compared to those induced by the treatment (Ti).

The 2nd application of the treatments did not annihilate the flow of insects onto the maize seedlings. Nevertheless, it kept the numbers low compared to the control **(Figure 2)**.

After the 3rd application of treatments on 56th DAS, the upward flow of beetle numbers on treated plots was interrupted and forced downward, while it remained high on the control (30.78 ± 3.65 insects/seedling). On the 58th DAS, T1, T2, T3, and Ti treatments reduced insect numbers by 93.88 ± 20.29; 96.51 ± 09.65; 97.15 ± 9.24%, and 100% per maize seedling, respectively. The ANOVA test followed by the Newman-Keuls test at the 5% threshold revealed a significant difference at the 5% threshold ($p <0.001$) between the rates of reduction of insect numbers/seedlings of treatments (T1, T2, and T3); T0, and Ti. Treatments T2 and T3 induced statistically similar reduction rates to the synthetic chemical insecticide Viper on 58ème DAS **(Figure 2)**.

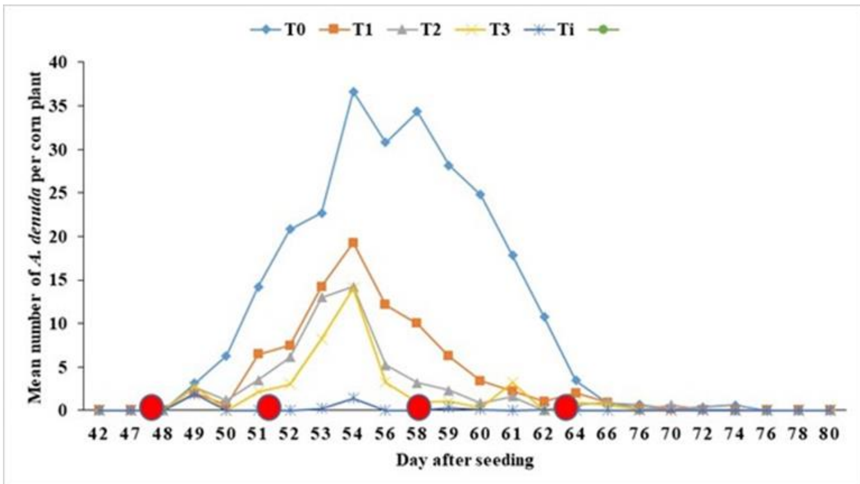


Figure 2. Effect of *R. Communis* aqueous extract treatments on the number of *A. Denuda* beetles visiting a maize seedling (the year 2020

NOTE: - treatments with aqueous extracts of R. Communis grains: T1: 110g /l; T2: 137.5g /l; T3: 165 g /l;

- treatments with the reference chemical insecticide: VIPER 46EC 16g / l: Ti; and

- the control: T0.

Treatment Days

During the critical period of attack in the 2020 crop cycle, the treatments kept the amplitude of insects/seedlings low (5.17 vs. 22.48 insects/seedlings) and reduced the duration of their presence on the plot by 6 days.

Crop year 2021

The analysis of the control curve shows three (3) peaks in the average number of insects per seedling. The first peak is recorded on 51st DAS (21.47 ± 1.16 insects/seedling), i.e., one day after the first treatment. The second peak was observed on the 56th DAS (30.78 ± 2.99 insects per seedlings) and the third on the 60th DAS (24.78 ± 1.04 insects/seedling). This curve shows a phase of a strong increase in the insect population (from 48th to 56th DAS). The 2nd phase is observed from the 56th DAS where the number of beetles progressively decreases until it falls below 5 insects/seedling on 64th DAS. These numbers are annihilated by the 72nd DAS **(Figure 3)**.

After the 2nd application of *R. Communis* extract on 50th DAS, treatments T1, T2, and T3 recorded average numbers of 7.57 ± 0.63; 4.24 ± 0.9; and 0.98 ± 0.07 insects/seedling on 51st DAS, respectively. These average numbers correspond to average reduction rates of 64.74 ± 13.87%; 80.25 ± 18.5%; and 95.44 ± 13.6% for insects/seedlings, respectively. The effect of the T3 treatment at the concentration of 165g/l is almost similar to that of the reference insecticide (Ti) which reduced the insect population by 97.90 ± 11.6% **(Figure 3)**.

Statistical comparison of insect/seedling population reduction rates reveals a significant difference (p = 0.0001) between treatments T1, T2, T3, and T0; but also, between T1, T2, and Ti.

After the 3rd application of the treatments on the 53rd DAS, beetle numbers continued to increase in the control plots until a peak of 30.78 ± 2.99 insects/seedlings was reached on the 56th DAS. At this peak, treatments T1, T2, T3, and Ti recorded 13.47 ± 0.9; 6.78 ± 0.06; 0 and 0 insects/seedling, respectively. At this date, T1, T2, T3, and Ti treatments reduced to 56.23 ± 6.25; 77.97 ± 11.79; 100 and 100% insects/seedling respectively. Statistical analysis to date shows that the mean numbers of insects recorded on the treated plots are significantly lower (p = 0.0001) compared to the control. The average number of insects recorded at T3 is almost similar to that of the synthetic chemical insecticide with p > 0.05 **(Figure 3)**.

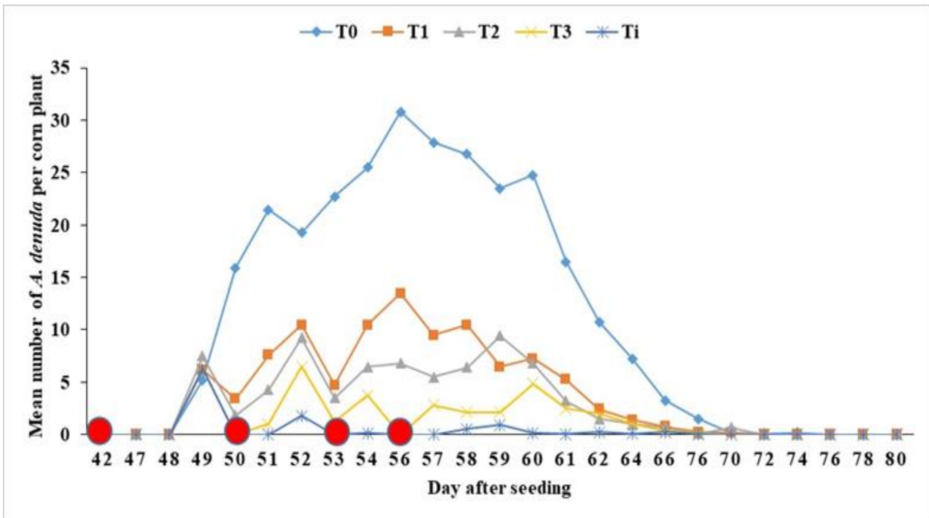


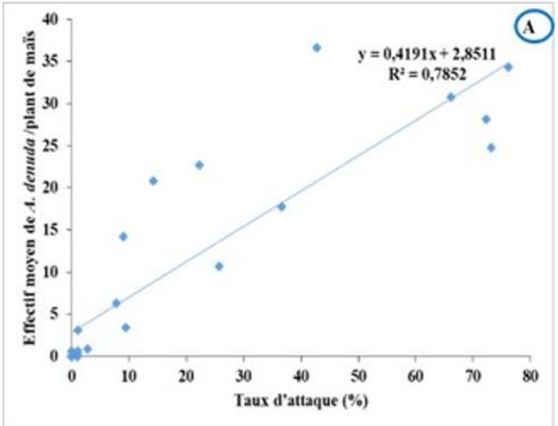
Figure 3. Effect of *R. communis* aqueous extract treatments on the number of *A. denuda* beetles visiting a maize seedling (year 2021)

NOTE: - treatments with aqueous extracts of R. Communis grains: T1: 110g /l; T2: 137.5g /l; T3: 165 g /l;
- treatments with the reference chemical insecticide: VIPER 46EC 16g / l: Ti; and
- the control: T0.
Treatment Days

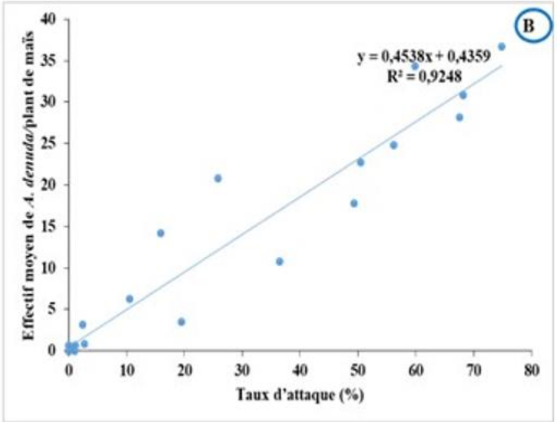
The number of insects that visited the plot was maintained at a low level of 05.14 insects/seedling on average before canceling from 64th DAS compared to 19.72 insects/seedling in the control, a reduction rate of 73.93%. Although at low numbers, the insects remained on the maize plants longer compared to the year 2020 **(Figure 3)**. The combination of treatments reduced *A. Denuda*'s presence time on the plot by 04 days.

Correlations between numbers of A. Denuda visiting the plot and attack rates

This study showed that there is a very strong positive correlation between average *A. Denuda* numbers and attack rates. The different correlation coefficients are 0.88 for the year 2020 **(Figure 4a)** and 0.92 for the year 2021 **(Figure 4b)**. This means that damage increases with insect numbers. Therefore, reducing insect numbers on the plot would reduce attacks and in turn, probably improve maize yield.



a)



b)

Figure 4. Correlations between *A. Denuda* numbers visiting the plot and attack rates in 2020 (a) and 2021 (b).

Impact of R. communis extracts on yield loss caused by Anomala denuda

Attacks that occur in the [7^{th} to 12^{th} DAS] period have no impact on yield [7, 17]. Therefore, in this part of our study, the impact of attacks on yields will only be assessed in the [1-3]; [4-6 DAS] periods. The cob attacks that occurred (mostly) between 1^{st} to 6^{th} DAS, caused abortion of the unfertilized grains, followed by a partial filling of the cobs, unlike the cobs whose development was not disturbed by the insect attacks. The estimation of the yield loss was, therefore, based on the difference in weight between the grains from the wiped cobs and those from the healthy cobs (in the period from 1^{st} to 6^{th} DAS). The more effective the treatment applied, the lower the yield loss and vice versa.

Crop year 2020

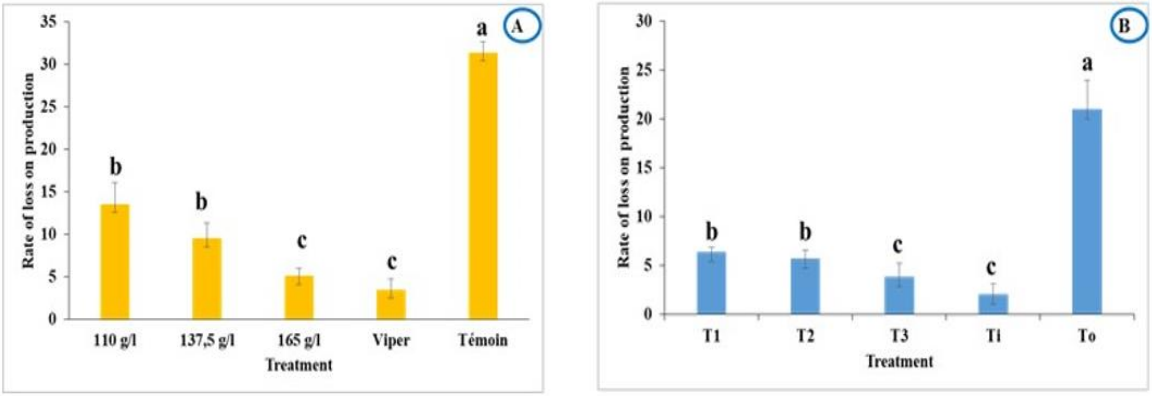
In the control plot, the production of unattacked cobs was estimated at 2.1561 t/ha and that of grains from attacked cobs was 1.4793 t/ha. The difference between the 2 expresses the yield loss due to the attacks of the *A. denuda* beetles. Thus, on the control plot, a yield loss of 0.6768 ± 0.056 t/ha was recorded, corresponding to a loss rate of 31.39 ± 2.58%. The yield loss rates obtained on treatments T1, T2, T3 are respectively 13.58 ± 2.47; 9.54 ± 1.79; 5.14 ± 0.89% **(Figure 5a)**. These yield loss rates are low and significantly lower than the control ($p < 0.001$). The most effective treatment was T3, which had the lowest yield loss rate (5.14 ± 0.89%). This loss was statistically identical to that of the reference chemical insecticide (3.48 ± 0.28%) with ($p > 0.05$). The yield loss in the control was 0.6768 ± 0.056 t/ha and that in the T3 treatment was 0.1108t/ha. Treatment T3 resulted in a production gain of 0.5659 t/kg, an improvement in maize yield of 26.25%. This production would have been lost if the treatment was not applied. The treatment significantly reduced insect damage to maize and consequently yield losses, resulting in higher maize production.

Crop year 2021

In the control plot, the weight of grain from unattacked cobs was 2.1183 t/ha and that of grain from attacked cobs was 1.6743 t/ha. The yield loss calculated from these values was 0.444 ± 0.0637 t/ha, a loss rate of 20.96 ± 3% recorded on the control plots. The lower the yield loss (or yield loss rate) induced by insect damage, the more effective the treatment applied. The data analysis showed that treatments T1, T2, T3, and Ti had low yield losses compared to the control. Such treatments T1, T2, T3, and Ti resulted in yield loss rates of 6.41 ± 0.46; 5.7 ± 0.88; 3.85 ± 1.4%, and 2.1 ± 1.04% respectively **(Figure 5b)**. These yield losses were significantly different from the control ($p < 0.001$). The lowest rate of yield loss was noted on treatment T3 (3.85 ± 1.4%), almost similar to that induced by the reference chemical insecticide Ti (2.1 ± 1.04%) according to the analysis of variance ($p > 0.05$). The yield loss of the control was 0.444 t/ha (loss rate 20.96 ± 3%) and that of treatment T3 was 0.0815 t/ha. Treatment T3 resulted in a production gain of 0.3624 t/kg or an improvement in maize yield of 17.80% in 2021. This production would have been lost if the treatment was not applied.

Analysis of the impact of treatments on the 2 crop cycles (2020 and 2021)

All treatments applied were relatively effective compared to the control ($p < 0.05$). They reduced the number of insects visiting the treated plots to an average of 5.16 insects/seedling compared to 21.10 insects/seedling noted on the control, i.e., an average reduction rate of 75.54%. Among these 3 treatments, the most effective was treatment T3 (165g/l). It recorded the lowest number of insects per seedling 3.30 in 2020 and 2.85 insects per seedling in 2021, for an average of 3.03 insects/seedling. Treatment T3's action with *R. communis* aqueous extract at 165g/l induced the lowest production loss rates in 2020 (5.14%) and 2021 (3.85%). Over the 2 years of the experiment, an average loss of 4.49% of production was recorded on T3 compared to a loss of 26.17% on the control. Thus, the yield was significantly increased by 26.25% in 2020 and 17.80% in 2021 on the plots treated with T3, i.e., an average of 22.03%.



a) b)

Figure 5. Production Loss Rate (Year 2020 (a) and Year 2021 (b))

NOTE: For the year 2020: P = 0.0001; ddl = 4. For the year 2021: P = 0.0001; ddl = 4

To improve production, the world's agricultural landscape regularly resorts to the use of synthetic chemical pesticides. Their massive use, poorly calibrated and repetitive in some cases, are likely to lead to a chemical imbalance of ecosystems by the persistence of their active chemical agents. In addition to polluting the environment, such chemical pesticides are to varying degrees potentially toxic to humans and non-target organisms (beneficial insects such as pollinators, necrophagous Diptera, termites, and soil engineering insects, etc.). The immeasurable negative impact of chemical pesticides on the environment is now a major concern. Although their use makes it possible to improve agricultural harvests by limiting the risks of production losses, the question of an alternative solution is strongly considered with a view to limiting the recourse to these synthetic chemical pesticides. Indeed, in the context of this study, we were confronted with invasive nocturnal beetles. According to the work of Boga *et al.* [7, 18], the insects arrive on the plot at the beginning of flowering. Their numbers gradually increase until they reach a peak. Thereafter, the numbers gradually decrease and then disappear once the cobs mature. Their daily activity starts at 18:00 and reaches its peak between 22:00 and 00:00. The activity of these insects consists in feeding on the reproductive organs of the maize and then mating. The above-mentioned authors counted an average of 32.67 Coleoptera/seedling, i.e., a population of 46,508 insects on an area of 2,592 m^2. According to Boga *et al.* [7, 19]. The damage caused by this cohort of insects resulted in a 32% yield loss in maize. The intensity of this damage and its impact on maize production prompted us to look for an effective biodegradable biopesticide that could control *A. denuda* populations and improve maize production without harming humans and the environment. The implementation of this biopesticide would thus allow efficient control of crop pests without resorting to synthetic insecticides. In this study, the treatments applied significantly reduced the number of insects and the duration of their presence (stay) on the maize seedlings. The combined impact of these 2 parameters minimized production losses and improved maize yield in the treated plots.

In fact, in 2020, the 4 treatments applied were spaced 6 days apart. In the control plots, an average of 22.48 insects/seedling and a peak of 36.64 insects/maize seedling were recorded. The most effective treatment maintained a significantly low insect population range of 5.17 insects/seedling on average compared to 22.48 insects/seedling for the control. They also reduced the duration of insect presence on the treated plots by 6 days.

In 2021, with the treatments 3 days closer together, the average number of insects visiting the treated plots was almost maintained at the same level as in 2020. This number was 5.14 compared to an average of 19.72 insects/seedlings in the control, a 73% reduction rate. The treatments reduced the duration of presence to 4 days. The correlation study showed that there was a very strong positive correlation ($R^2 = 0.92$) between the average numbers of *A. denuda* and the attack rates. This means that damage increases with insect numbers.

Among the 3 concentrations, namely, 110 (T1); 135.5 (T2), and; 165 g/l (T3), used in the control experiments, the 165 g/l concentration (T3) was the most effective. Treatment T3 had the lowest rate of yield loss (5.14 ± 0.89%) for a 26.25% increase in maize yield in 2020 and 3.85 ± 1.4% for a 17.80% increase in 2021. Such yield losses were statistically identical to that of the reference chemical insecticide ($p > 0.05$). The effectiveness of T3 is thought to be due to its high concentration of ricin, one of the most toxic plant toxin molecules [20, 21]. The weak evolution of the *A. denuda* population on plots treated with T3 concentration would be directly linked to this composite. This study, thus, confirms the high sensitivity of *A. denuda* towards the *R. communis* aqueous extract at a concentration of 165g/l as shown by Yao [14]. Indeed, these authors during laboratory tests on *A. denuda,* showed that the *R. Communis* aqueous extract at a dose of 110 g /l induces a mortality rate of 80% of beetles.

The results obtained in the field under the various climatic conditions, thus, testify that *R. communis* indeed contains active composites with insecticidal and repulsive effects.

Similar results on the efficacy of the *R. communis* aqueous extract seed capsules had already been obtained by Tano *et al.* [22] and Obodji *et al.* [23]. Indeed, during their study on the control of *Hellula undalis*, a nocturnal Lepidoptera pest of cabbage crop in Côte d'Ivoire [22]. reported that the aqueous extract of *R. communis* seed capsules at the high concentration of 70g/l had recorded the highest larval mortality rate (73.24%). As for Obodji *et al.* [23]. They showed in their study for the control of *Leucinodes orbonalis* larvae*, a* pest of eggplant crop in Azaguié, that the best attack reduction rates (83.46 and 86.80%) were obtained with the aqueous extract of *R. communis* seed capsules at the concentrations of 50 and 60g/l. The effective concentration (165g/l) of our study is much higher than those of the cited authors. Contrary to these cited authors, our study focused on a tougher and highly mobile adult Coleoptera. On the other hand, these authors worked on naked Lepidoptera larvae, which are not very mobile in their galleries and, therefore, more exposed to the products over time.

CONCLUSION

The search for alternatives to synthetic chemical insecticides has led to trials of control of *A. denuda* by the use of aqueous extract of *R. communis* (pesticidal plant). This is to control the attacks of this Beetle and to improve the production of maize without resorting to chemical insecticides.

Analysis of the results of our work showed that all treatments applied significantly reduced the numbers and duration of insect presence on maize plants. The impact of the treatments with aqueous extracts of *R. communis* on the numbers of the populations of the beetle allowed to minimize the losses of production and to improve the yield of maize on the treated plots.

Indeed, over the 2 crop cycles, all treatments applied were relatively effective compared to the control ($p < 0.05$). They reduced the number of insects visiting the treated plots to an average of 5.16 insects/seedling compared to 21.10 insects/seedling noted on the control, i.e., an average reduction rate of 75.54%. The most effective treatment was T3 (165g/l). It recorded the lowest amplitude of insects/seedlings (3.03), but also the lowest rate of production loss (4.49%) compared to the control (26.17%). Yield was significantly improved by 26.25% in 2020 and 17.80% in 2021 with T3, for an average of 22.03%. These results obtained in the field thus testify that *R. communis* effectively contains active composites with insecticidal and repellent effects. The extract of *R. communis* used at 165g/l could be an alternative to synthetic chemical pesticides for the control of *A. denuda* in maize crops.

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