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Managing *Anomala denuda* (Coleoptera: Scarabaeidae), a Pest of Maize, Through the Use of an Aqueous Extract Derived from *Ricinus communis*

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ABSTRACT

Anomala denuda adults are not usually considered major crop pests. However, an infestation of up to 46,508 individuals was observed in a maize field in Songon, causing a yield reduction of approximately 32%. In response to the extensive damage caused by this beetle to maize crops, the objective of this study was to test the efficacy of an aqueous extract of *Ricinus communis*, a known pesticidal plant, in controlling *A. denuda* and increasing maize production. The experiment was conducted on an experimental plot covering 2592 m², applying concentrations of 110 grams per liter (T1), 135.5 grams per liter (T2), and 165 grams per liter (T3) of the extract in six replicates. The treatments were applied four times during the 2020 and 2021 crop cycles, with Viper 46 EC (16 acetamiprid, 30 indoxacarb) as the chemical insecticide control. Over the two growing seasons, all treatment groups showed significant effectiveness in reducing beetle presence compared to the untreated control ($P < 0.05$). Treated plots had an average of 5.16 insects per plant, whereas the control had 21.10 insects per plant, resulting in a 75.54% reduction in pest numbers. The T3 treatment (165 g/l) was the most effective, with the lowest number of insects per plant (3.03) and the smallest production loss rate (4.49%) compared to the control (26.17%). Maize yield significantly improved by 26.25% in 2020 and 17.80% in 2021 for the T3 treatment, with an average increase of 22.03% over both years. Therefore, the use of *Ricinus communis* extract at 165 grams per liter offers a viable alternative to synthetic insecticides for the control of *A. denuda* in maize fields.

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

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Introduction

Cereal crops are primarily grown for their grains, which serve as essential food sources for both humans and animals. During the 2020-2021 period, a total of 715 million hectares worldwide were dedicated to cereal cultivation, yielding approximately 2.714 billion tons [1]. Among the various cereal crops, maize ranks as one of the top three globally, alongside rice and wheat [2]. This crop plays a crucial role in ensuring food security across sub-Saharan Africa.

In Côte d'Ivoire, maize holds the position of the second most cultivated cereal after rice, with national production exceeding 840,000 tons [3]. It serves as a key raw material in industries such as brewing, oil processing, and soap manufacturing, contributing significantly to employment and income generation in rural communities [4]. Despite its economic significance, maize cultivation faces numerous challenges that severely impact yields. These challenges include poor soil fertility, unpredictable rainfall patterns due to climate change, the prevalence of phytopathogenic diseases, and, most notably, infestations by insect pests like termites [5] and maize stem borers [6].

Among the various threats to maize cultivation, an unexpected outbreak of *Anomala denuda* adults was recorded during a nocturnal survey in an experimental maize field in Songon, southern Côte d'Ivoire, by Boga *et al*. [7]. The survey revealed an exceptionally high population density, with 46,508 beetles observed in a single night. While previous studies have established the pest status of their larvae, the role of adult beetles in crop damage has received little attention.

However, research by Boga *et al*. [7] demonstrated that adult *A. denuda* beetles heavily feed on maize reproductive structures, including female and male flowers. This intense feeding activity significantly affected maize productivity, causing a 32% reduction in yield, a loss considered unsustainable for farmers [7, 8].

Given the substantial damage inflicted by this beetle, this study aimed to evaluate the efficacy of an aqueous extract of *Ricinus communis*, a plant with pesticidal properties, as a control measure. The objective was to mitigate the impact of *A. denuda* on maize fields and enhance crop yield.

Materials and Methods

Site of the study

The research took place in Songon (5°19'32.3" N 4°15'24.0" W), located in southern Côte d'Ivoire. Meteorological data from Tutiempo [9] indicated that in 2020, the site experienced an average temperature of 27.85 °C, with a mean rainfall of 151.34 millimeters and a relative humidity level of 82.3%. In the following year, 2021, climatic conditions varied slightly, with an average temperature of 26.45 °C, a relative humidity of 79.3%, and an average precipitation level of 126.61 millimeters [10, 11].

Material

Biological material

The study utilized *A. denuda* adult beetles and maize plants of the Zea mays species as biological material. The maize variety PR9131-SR, a locally grown type, has an average productivity of 2 tons per hectare, with a potential yield of up to 3 tons per hectare. This variety follows a short growth cycle lasting 90 days (three months). To control *A. denuda* populations in the field, an aqueous formulation prepared from the insecticidal plant *R. communis* (Euphorbiaceae) was employed.

Technical equipment

The tools utilized for extracting the aqueous plant extracts include a mortar, a mixer, a graduated cylinder, a Denver-brand electronic balance, white poplin cloth, cotton wool, a funnel, porcelain plates, and an oven heated to 50 °C. The treatments were applied using two 10-liter backpack sprayers from the Tropical brand. Protective gear, including gloves and ear muffs, was worn by the applicator for safety.

Methods

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

The experimental area spans 2592 m² (54 m by 48 m) and is divided into 3 blocks, each separated by 3 meters. The blocks are further split into 3 sub-blocks with a 2-meter gap between them. Each sub-block is 48 meters long and 16 meters wide, containing nine elementary plots. Each elementary plot covers 16 m² and hosts 30 maize seedlings, making a total of 15,147 seedlings across the entire experimental area. Out of the 3 blocks, 1 is kept for additional observations, while the remaining 2 blocks are subjected to treatments. Each sub-block is randomly allocated one of the four treatments (T1, T2, T3, Ti), with the control designated as To. Viper 46EC, a systemic insecticide belonging to the neonicotinoid and oxadiazine families, is used as the reference insecticide in the experiments **(Figure 1)**.

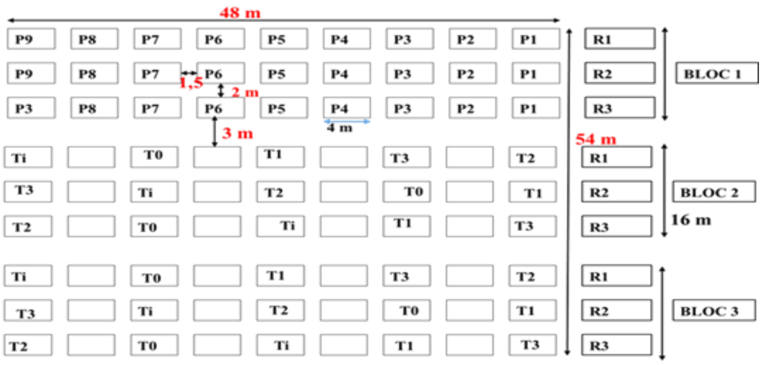


Figure 1. Layout of the experimental design for crops and treatments; treatment (T1): 110 g/l (80% effective dose in laboratory conditions), treatment (T2): 110 g/l + one-quarter of 110, or 137.5 g/l, treatment (T3): 110 g/l + half (1/2) of 110, i.e., 165 g/l, and treatment (Ti): VIPER 46 EC (16 acetamiprid, 30 indoxacarb)

Soil preparation and fertilization

To promote healthy growth of the maize seedlings, the experimental plot was amended with chicken manure (10 tons per hectare) and urea (150 kg per hectare) as organic fertilizers.

Extraction of the aqueous extract of R. communis

The extraction process followed the protocol established by Zirihi and Kra. *R. communis* seed capsules were gathered and dried in the shade for five weeks before being ground into powder using a blender [12, 13]. A total of 100 g of the powdered material was mixed with two liters of distilled water, and the mixture was blended for five minutes. It was then filtered through white poplin fabric. The first filtrate was blended once more and filtered again using Whatman paper. A third filtration was done with cotton wool placed in a funnel. The final liquid obtained was concentrated through evaporation in an oven at 50 °C for 48 hours.

Determination of the concentrations of extracts applied in the field

Toxicity assessments were initially performed in the laboratory to test the effectiveness of two plant species, *R. communis* and *Azadirachta indica*, on *A. denuda* beetles. The objective was to determine which plant and concentration had the greatest insecticidal effect. The results indicated that the aqueous extract of *R. communis* was the most effective, achieving an 80% mortality rate in *A. denuda* at a concentration of 110 grams per liter [14, 15]. Based on these findings, *R. communis* was chosen for the field trials. Three different concentrations of the extract were selected for the experiments, taking into account the natural environmental factors present in the field.

Treatment (T1): 110 g/l (80% effective dose in the laboratory)
Treatment (T2): 110 g/l + one quarter (1/4) of 110 or 137.5 g/l
Treatment (T3): 110 g/l + half (1/2) of 110 or 165 g/l
Treatment (Ti): VIPER 46 EC (16 acetamiprid, 30 indoxacarb)

Application of the treatments

The treatments for the field trials were applied using two 10-liter backpack sprayers, one designated for the reference chemical insecticide (Ti) and the other for the aqueous extract of *R. communis* seed capsules (T). The field experiments aimed at controlling *A. denuda* beetles took place over two consecutive years (2020 and 2021). The treatment schedule for both years included four separate applications:

In 2020, the first treatment was applied on day 42 after sowing (DAS), before the beetles' presence. The second treatment occurred on the 50th DAS, two days after the beetles were observed. The third application took place on day 56, and the final treatment was on day 62, with six days between each application.

For 2021, the first treatment was applied preventively on the 42nd DAS. The remaining treatments were spaced three days apart, with the second treatment on day 50, the third on day 53, and the fourth on day 56.

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

The *A. denuda* beetle is active during the night, with the highest level of activity observed between 10:00 p.m. and 12:00 a.m. During this time, the beetles feed on the apical flowers and hairs of maize cobs [7]. This behavior typically lasts for approximately two weeks. After the initial treatment application, data were collected nightly from 10:00 p.m. to 12:00 a.m. until the maize cobs matured. The following parameters were recorded: 1) the number of seedlings affected per plot, and 2) the number of beetles per seedling/plot. These observations allowed for the calculation of the average beetle count per seedling and the determination of reduction rates in beetle populations following the treatment applications.

Mean number of insects per seedlings = (Total number of insects)/(Total number of attacked seedlings) (1)

$$TXre = (NCT0-NCT)/NCT0 \times 100 \quad (2)$$

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

The *A. denuda* beetle is active during the night, feeding on the reproductive organs of maize, including both the male (apical flower cluster) and female (hair) parts. To evaluate the damage caused by these beetles, we counted the maize cobs that had been completely consumed by the insects, particularly those with their hairs eaten off. Cobs affected by the beetles were marked with ribbons in different colors, corresponding to the periods: 1-3, 4-6, 7-9, and 10-12 days after sowing (DAS). Cobs that remained unaffected were left unmarked. Once the maize reached maturity at 91 days, the cobs were harvested and categorized by plot and treatment. Each plot's cobs were separated into two bags: one for the cobs that had their flowers consumed and the other for the untouched cobs. The cobs with consumed flowers were further categorized into four groups, based on the DAS intervals in which the damage occurred. These cobs were then transported to the laboratory, where they were stripped of their husks, air-dried at room temperature for 21 days, and dehulled. The maize grains from each batch were weighed using a Denver electronic precision balance. The yield loss due to the insect attacks and the subsequent reduction in loss after treatment applications were computed using the formulas outlined in previous studies [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 carried out using two software applications: Microsoft Excel 2010 for data input and graphical displays, and SPSS version 21.0 for statistical analysis. The data were analyzed using analysis of variance (ANOVA), and the means were compared using the Student-Newman-Keuls (S-N-K) test with a significance level set at 0.05. Pearson's correlation was applied to examine the relationship between the beetle attack rates and the average number of beetles visiting the plots.

Results and Discussion

Results

Effect of R. communis aqueous extracts on the reduction in numbers of A. denuda beetles

Crop year 2020

The analysis of the control curve revealed two main phases. The first phase, from the 48th to the 58th DAS, showed a sharp increase in the number of *A. denuda* beetles visiting the plot. Following this, a second phase began from the 58th DAS, during which the number of beetles per seedling gradually decreased, eventually dropping below 5 by the 64th DAS. Insect activity on the maize ceased completely by the 76th DAS **(Figure 2)**. After the second treatment at 50th DAS, no beetles were found on the plots treated with the reference insecticide. Conversely, the plots treated with the *R. communis* aqueous extract showed an average of 0.59 ± 0.003 beetles, whereas the control plots had 6.28 ± 1.08 beetles **(Figure 2)**. 4 days after the second treatment at 50th DAS, the beetle count began to rise and peaked on the 54th DAS, just before the third application, with average counts of 19.25 ± 5.12, 14.25 ± 2.09, and 14.08 ± 0.99 beetles per seedling in treatments T1, T2, and T3, respectively. In contrast, the control reached an average of 36.64 ± 4.6 beetles per seedling. The corresponding reduction rates compared to the control were 47.44 ± 7.23% (T1), 61.57 ± 5.11% (T2), 61.11 ± 11.5% (T3), and 96.66 ± 2.57% for the Ti treatment. Statistical analysis (ANOVA and Newman-Keuls test, $p < 0.001$) confirmed significant differences between the insect reduction rates for treatments T1, T2, T3, and the control (T0). Furthermore, an important difference ($P < 0.001$) was also observed between the reduction rates for T1, T2, T3, and Ti.

After the second round of treatments, the insect influx into maize seedlings was not fully stopped, but the numbers remained significantly lower compared to the untreated control **(Figure 2)**. Following the third treatment on the 56th DAS, the population of beetles on the treated plots began to decline, whereas it continued to increase on the control plots, which had an average of 30.78 ± 3.65 insects per seedling. By the 58th DAS, the reductions in beetle numbers were 93.88 ± 20.29%, 96.51 ± 9.65%, 97.15 ± 9.24%, and 100% for the T1, T2, T3, and Ti treatments, respectively. Statistical analysis through ANOVA and the Newman-Keuls test (at a 5% level) revealed significant differences ($P < 0.001$) in insect reduction between the treatments (T1, T2, T3, T0, and Ti). Notably, the T2 and T3 treatments induced reduction rates that were similar to those achieved by the chemical insecticide Viper at the 58th DAS **(Figure 2)**.

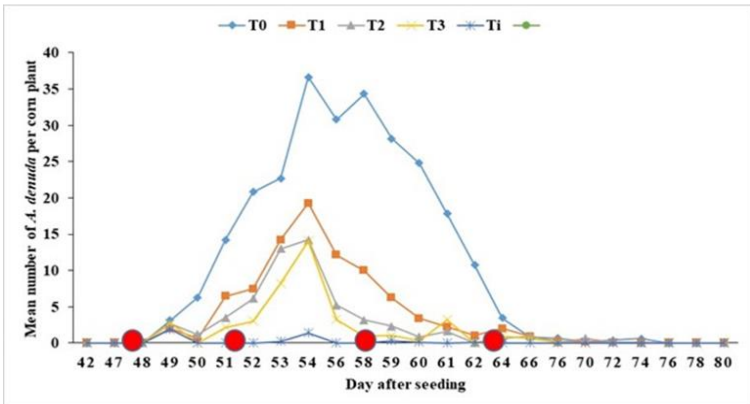


Figure 2. Impact of *R. communis* aqueous extract applications on the frequency of *A. denuda* beetles visiting maize seedlings in 2020; note: treatments with aqueous extracts of *R. communis* grains: T1: 110g /l; T2: 137.5g /l; T3: 165 g /l; treatments with the reference chemical insecticide: VIPER 46EC 16g / l: Ti; and - the control: T0; ⬭ treatment days

Throughout the key attack period in the 2020 growing season, the treatments effectively limited the number of insects per seedling (5.17 versus 22.48 insects per seedling) and shortened the duration of their presence on the plot by six days.

Crop year 2021

The control curve indicates three distinct peaks in the average insect population per seedling. The 1st peak, observed on the 51st day after sowing (DAS), showed 21.47 ± 1.16 insects per seedling, occurring 1 day after the 1st treatment. The 2nd peak appeared on the 56 DAS, with 30.78 ± 2.99 insects per seedling, and the third occurred on the 60th DAS, reaching 24.78 ± 1.04 insects per seedling. A rapid increase in insect numbers was noted between the 48th and 56th DAS, followed by a steady decrease from the 56 DAS, with the insect population dropping below five per seedling by the 64th DAS and completely disappearing by the 72nd DAS **(Figure 3)**.

Post-second application of *R. communis* extract on the 50th DAS, the treatments T1, T2, and T3 recorded an average of 7.57 ± 0.63, 4.24 ± 0.9, and 0.98 ± 0.07 insects per seedling on the 51st DAS, respectively. The reductions in insect numbers correspond to averages of 64.74 ± 13.87%, 80.25 ± 18.5%, and 95.44 ± 13.6%, respectively. Treatment T3 at 165 g/l exhibited a reduction almost equivalent to the reference insecticide (Ti) that decreased the insect population by 97.90 ± 11.6% **(Figure 3)**.

Statistical comparisons show an important difference ($P = 0.0001$) in insect population reductions between the treatments (T1, T2, T3) and the control (T0), and also between T1, T2, and Ti.

After the third treatment on the 53rd DAS, insect populations in the control plots continued to increase, reaching a peak of 30.78 ± 2.99 insects per seedling on the 56th DAS. Meanwhile, the T1, T2, T3, and Ti treatments recorded 13.47 ± 0.9, 6.78 ± 0.06, 0, and 0 insects per seedling, respectively. These results translated to insect reductions of 56.23 ± 6.25%, 77.97 ± 11.79%, 100%, and 100%, respectively. Statistical analysis confirmed that the treated plots had significantly fewer insects compared to the control (P = 0.0001). The T3 treatment performed similarly to the synthetic insecticide, with a P-value greater than 0.05 **(Figure 3)**.

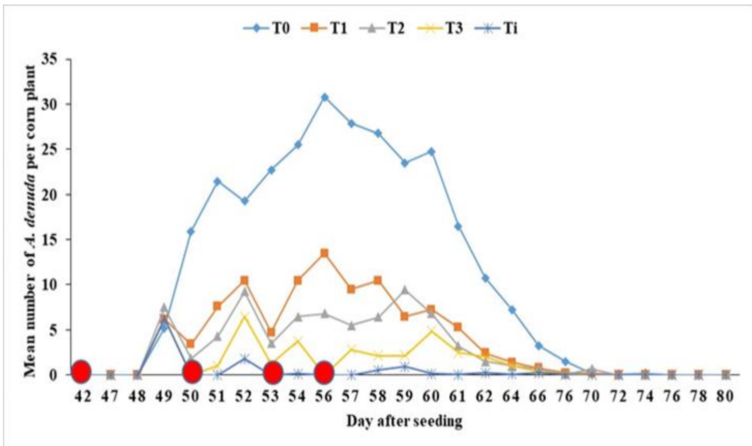
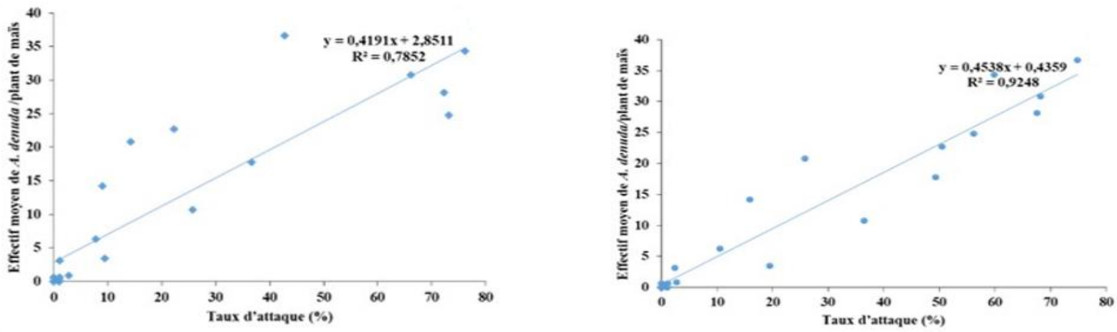


Figure 3. Impact of *R. communis* aqueous extract treatments on the number of *A. denuda* beetles observed on maize seedlings (2021); note: treatments with aqueous extracts of *R. communis* grains: T1: 110g /l; T2: 137.5g /l; T3: 165 g /l; treatments with the reference chemical insecticide: VIPER 46EC 16g / l: Ti; and the control: T0; ⬭ treatment days

The number of insects visiting the plot remained low at an average of 05.14 insects per seedling until it was eliminated by the 64th DAS, compared to 19.72 insects per seedling in the control group, resulting in a 73.93% reduction. Although the insect numbers were low, they remained on the maize plants for a longer period than in 2020 **(Figure 3)**. The combination of treatments led to a 04-day reduction in the presence of *A. denuda* on the plot.

Regarding the correlation between attack rates and insect numbers, the results demonstrated a strong positive correlation between the number of *A. denuda* beetles and the extent of damage, with correlation coefficients of 0.88 in 2020 **(Figure 4a)** and 0.92 in 2021 **(Figure 4b)**. This indicates that as insect numbers increase, the damage to maize plants also increases, meaning that reducing the insect population could reduce attacks and potentially enhance maize yield.



a) b)

Figure 4. The relationship between the number of *A. denuda* beetles visiting the plot and the attack rates in the years 2020 (a) and 2021 (b).

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

Attacks that occur during the 7th-12th DAS period do not affect the yield [7, 17]. Consequently, this part of the study focuses on evaluating the effects of attacks only during the 1-3 and 4-6 DAS periods. Most of the cob damage happened between the 1st and 6th DAS, leading to the abortion of unfertilized grains followed by partial cob filling, unlike the cobs that were unaffected by the beetle attacks. Yield loss was estimated by comparing the weight of grains from the damaged cobs with those from the healthy cobs during the 1-6th DAS period. The treatment's effectiveness was inversely related to the amount of yield loss, with more effective treatments leading to less yield loss.

Crop year 2020

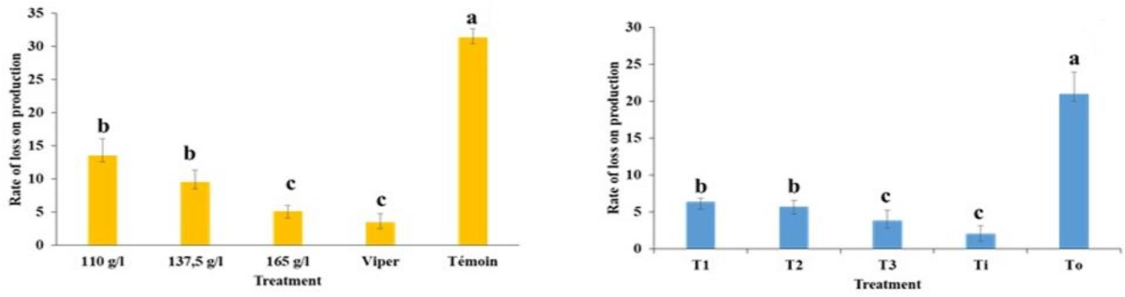
In the control plot, the total production from unattacked cobs was 2.1561 t/ha, while that from attacked cobs was 1.4793 t/ha, revealing a yield loss of 0.6768 ± 0.056 t/ha, or 31.39 ± 2.58%. For treatments T1, T2, and T3, the yield loss rates were notably lower, with values of 13.58 ± 2.47%, 9.54 ± 1.79%, and 5.14 ± 0.89%, respectively, all significantly reduced compared to the control ($P < 0.001$). The T3 treatment was the most effective, showing the least yield loss of 5.14 ± 0.89%, which was similar to that of the reference insecticide (3.48 ± 0.28%) with $P > 0.05$. The yield loss in the control plot was 0.6768 ± 0.056 t/ha, while T3 saw a reduced loss of 0.1108 t/ha. This resulted in an additional 0.5659 t/ha of maize production, representing a 26.25% increase in yield, which would have been lost without the application of the treatment. The T3 treatment significantly reduced insect-induced damage, leading to higher maize production.

Crop year 2021

In the control plot, the grain yield from cobs that were not attacked was 2.1183 t/ha, whereas the yield from attacked cobs was 1.6743 t/ha. This difference resulted in a yield loss of 0.444 ± 0.0637 t/ha, corresponding to a loss rate of 20.96 ± 3%. Treatments T1, T2, T3, and Ti were associated with significantly lower yield losses compared to the control. Specifically, the yield losses for these treatments were as follows: 6.41 ± 0.46% for T1, 5.7 ± 0.88% for T2, 3.85 ± 1.4% for T3, and 2.1 ± 1.04% for Ti **(Figure 5b)**, with all showing a statistically significant difference from the control ($P < 0.001$). Treatment T3, with a yield loss rate of 3.85 ± 1.4%, was nearly identical to Ti, which showed a loss of 2.1 ± 1.04%, with no significant difference between them ($P > 0.05$). The control plot saw a loss of 0.444 t/ha, while T3 experienced a much smaller loss of 0.0815 t/ha, resulting in a production gain of 0.3624 t/ha or a 17.80% improvement in maize yield for 2021. This increase in yield would not have occurred without the treatment.

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

The treatments applied were considerably effective in reducing insect populations when compared to the control ($P < 0.05$). On average, the treated plots saw only 5.16 insects per seedling, while the control had 21.10 insects per seedling, reflecting an overall reduction of 75.54%. Treatment T3 (165 g/l) stood out as the most effective, with insect counts of 3.30 per seedling in 2020 and 2.85 in 2021, averaging 3.03 insects per seedling. In terms of yield loss, T3 also demonstrated the lowest rates, with a 5.14% loss in 2020 and 3.85% in 2021. Over the two years, the average production loss on T3 was 4.49%, significantly lower than the 26.17% loss seen in the control. As a result, the yield on T3-treated plots increased by 26.25% in 2020 and 17.80% in 2021, amounting to an average gain of 22.03%.



a) b)

Figure 5. Production loss rate (The 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 enhance agricultural productivity, the widespread adoption of synthetic chemical pesticides has become a common practice worldwide. However, excessive and poorly managed use of these pesticides can disrupt the ecological balance by leaving behind persistent chemical residues. This not only leads to environmental pollution but can also be harmful to humans and non-target species, including beneficial insects like pollinators, decomposer flies, termites, and soil-dwelling organisms. The detrimental environmental impact of chemical pesticides has raised growing concerns. While these pesticides help increase crop yields by controlling pest populations, there is increasing interest in finding alternative solutions that reduce reliance on such chemicals. In this research, the focus was on managing an invasive nocturnal beetle species. As documented by Boga *et al*. [7], these beetles begin to infest maize fields around the time of flowering, with their numbers steadily rising until reaching a peak. Afterward, their population gradually declines as the maize cobs mature. Their activity typically begins at 18:00, peaking between 22:00 and midnight, during which they feed on the maize's reproductive organs and mate [7, 18]. Boga *et al*. [7] recorded an average of 32.67 beetles per seedling, resulting in a total population of 46,508 insects over 2,592 m². This beetle infestation led to a 32% yield loss in maize crops. The severity of this damage to maize prompted the search for a viable, eco-friendly biopesticide to manage the beetle population and improve maize yield, while also being safe for humans and the environment [7, 19]. Using this biopesticide can effectively control pests without relying on synthetic insecticides. The treatments in this study successfully reduced both the number of insects and the duration of their presence on maize plants, which contributed to lower production losses and higher maize yields in the treated plots.

In 2020, the four treatments were spaced six days apart. In the control plots, an average of 22.48 insects per seedling was observed, with a peak of 36.64 insects per seedling. The most effective treatment resulted in an average of only 5.17 insects per seedling, significantly lower than the control, and reduced the insect presence duration by 6 days.

By 2021, with the treatments spaced 3 days closer, the insect population on the treated plots was nearly identical to that of 2020, averaging 5.14 insects per seedling, compared to 19.72 in the control plots, leading to a 73% reduction. The treatments also shortened the duration of insect presence to four days. A strong positive correlation ($R^2 = 0.92$) between the number of *A. denuda* and attack rates was identified, indicating a direct relationship between insect numbers and the damage observed.

Of the three concentrations used—110 g/l (T1), 135.5 g/l (T2), and 165 grams per liter (T3)—the 165 grams per liter concentration (T3) was the most effective. Treatment T3 resulted in the lowest yield loss rate (5.14 ± 0.89%) in 2020, with a 26.25% increase in maize yield, and a 3.85 ± 1.4% yield loss in 2021, leading to a 17.80% increase in yield. These results were similar to those of the chemical insecticide control ($P > 0.05$). The success of T3 is likely because of its high ricin content, a potent toxin [20, 21]. The reduced *A. denuda* population in T3-treated plots can be attributed to the effect of this toxin. This finding confirms previous studies by Yao [14], which demonstrated that *R. communis* aqueous extract at 110 g/l led to 80% mortality in *A. denuda* in laboratory conditions.

The results obtained from this study carried out under varying climatic conditions, clearly indicate that *R. communis* possesses bioactive compounds that exhibit both insecticidal and repellent effects. This aligns with earlier findings by Tano *et al*. [22] and Obodji *et al*. [23], who also observed the effectiveness of *R. communis* aqueous seed extract. In Tano *et al*.'s research, which focused on controlling Hellula undalis, a nocturnal Lepidopteran pest of cabbage in Côte d'Ivoire, they reported that the extract at a 70 g/l concentration achieved a larval mortality rate of 73.24%. Similarly, Obodji *et al*. [23], investigating Leucinodes orbonalis larvae, a pest of eggplant in Azaguié, found that the extract at concentrations of 50 and 60 g/l resulted in high reduction rates in pest attacks, recorded at 83.46% and 86.80%, respectively. In contrast, the concentration in our study (165 g/l) was significantly higher, as our research targeted a more resilient and mobile adult Coleoptera, rather than the relatively stationary Lepidopteran larvae studied by the other authors. This difference in pest types and their mobility likely explains the higher concentrations used in our study compared to theirs.

Conclusion

The search for alternatives to chemical insecticides has prompted the exploration of *R. communis* aqueous extract as a potential solution for controlling *A. denuda* infestations and enhancing maize production without relying on synthetic pesticides. The results from our study demonstrated that all treatments significantly reduced both the number and duration of insect presence on the maize plants. The application of *R. communis* aqueous extract effectively minimized the beetle population, which in turn helped reduce production losses and improve maize yield on the treated plots.

Across the two growing seasons, the treatments were notably effective when compared to the control ($P < 0.05$). The average number of insects per seedling in the treated plots dropped to 5.16, compared to 21.10 insects per seedling in the control, reflecting an average reduction of 75.54%. The most efficient treatment, T3 (165 g/l), showed the lowest insect count per seedling (3.03) and the smallest production loss rate (4.49%) when compared to the control, which had a 26.17% loss. Yield improvement with T3 was significant, with an increase of 26.25% in 2020 and 17.80% in 2021, averaging a 22.03% boost. These field results support the notion that *R. communis* contains potent compounds with insecticidal and repellent properties. The use of *R. communis* extract at a concentration of 165 g/l offers a viable alternative to synthetic insecticides for controlling *A. denuda* in maize cultivation.

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Conflict of Interest: None

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Ethics Statement: None

References

1. FAO. FAO Bulletin on cereal supply and demand. [Internet]. Regional office for Africa: FAO; 2021 [updated in February 2021; Accessed on September 7, 2022]. Available from: http://www.fao.org/worldfoodsituation/csdb/en/
2. FAO. FAO Bulletin on cereal supply and demand. [Internet]. Regional office for Africa: FAO; 2019 [updated in February 2019; Accessed on December 19, 2022]. Available from: http://www.fao.org/worldfoodsituation/csdb/en/
3. ANADERSTAT. Technical and economic datasheet of maize. [Internet]. Côte d'Ivoire - Abidjan: directorate of support for agricultural sectors; 2018. [updated in September 2017; Accessed on November 24, 2022]. Available from: "http://www.anader.ci/anader/fichetech/Fiche%20technico-economique%20du%20Mais.pdf
4. CNRA. Cultivating maize successfully [Internet]. Côte d'Ivoire - Abidjan: directorate of research programs and development support; 2006 [updated in November 2006; Accessed on December 12, 2022]. Available from: https://pdf4pro.com/view/bien-cultiver-le-ma-239-s-en-c-244-te-d-ivoire-cnra-ci-f0c10.html
5. Akpesse AA, Kouassi PK, Tano Y, Lepage M. Impact of termites in rice and maize fields in sub-Saharan savannah (Booro-Borotou, Côte d'Ivoire). Sci Nat. 2008;5(2):121-31.
6. Anna LR. Biological control of corn earworm using Trichogramma in sweet corn cultivation. Canada-Québec: Quebec vegetable Growers council; 2000. p. 5. Report No: 041.
7. Boga JP, Gbon GA, Johnson F. Attacks of *Anomala denuda* (Coleoptera: Scarabaeidae) on corn (Zea mays) inflorescences in songon, southern côte D'ivoire. In: Sévilor K, Antoine S, Mauricette O-NSW, Gisèle F, et al., eds. Biodiversity and sustainable development in Africa: contributions of insect science to agricultural development and the enhancement of human, agricultural, and environmental health. Proceedings of the 23rd meeting and conferences of the African association of entomologists; 2019 Nov 18–22; Abidjan, Côte d'Ivoire: National Institute of Public Health; 2019. 142 p.
8. Oran IB, Yilmaz S, Erol M. The impacts of artificial intelligence and Covid-19 on Brics and performance analysis of South-African republic. J Organ Behav Res. 2021;6(2):89-99. doi:10.51847/cLL8rdINmJ
9. Tutiempo. Meteorological data for the city of Abidjan for the year 2020 [Internet]. Data provided by weather station 655780 (DIAP). [Updated on January 10, 2021; cited on February 13, 2021]. Available from: http://www.tutiempo.net/climate/ws-655780-html/
10. Tutiempo. Meteorological data for the city of Abidjan for the year 2020 [Internet]. Data provided by weather station 655780 (DIAP). [Updated on January 4, 2022; cited on January 24, 2022]. Available from: http://www.tutiempo.net/climate/ws-655780-html/

11. Mahmood H, Shahid AM, Usama M, Nadeem E, Zafar N, Bashir R. Relation between periodontitis and systemic health among young dental practitioners in twin cities of Pakistan. Ann Dent Spec. 2022;10(3):7-11. doi:10.51847/pn8XmEeCYL
12. Alkhayyat S, Khojah M, AlJehan M, Allali D, Tayeb A, Albukhari S, et al. Awareness of colorectal cancer in Saudi Arabia: cross-sectional study. Pharmacophore. 2021;12(1):38-43. doi:10.51847/f5Z7stoOfT
13. Zirihi GN, Kra AKM. Evaluation of the antifungal activity of Microglossa pyrifolia L. (Asteraceae) extract PYMI on the in vitro growth of Candida albicans. Afr Med Pharm Rev. 2003;17:01-19.
14. Yao DAA. Toxicity of aqueous extracts from *Ricinus communis* and Azadirachta indica on the invasive beetle *Anomala denuda* (Coleoptera: Scarabaeidae) in laboratory conditions. Master's thesis in biodiversity and ecosystem valorization (entomology and ecosystem management), UFR biosciences, Félix Houphouët-Boigny University, Abidjan, Côte d'Ivoire; 2020. p. 61.
15. Wahba AA. The role of joint review in reducing negative profit management practices in joint stock companies, Egypt. J Organ Behav Res. 2021;6(2):1-17. doi:10.51847/YzXEedfdeE
16. Koushik NR, Manjunatha M, Naik MI, Shivanna BK, Narayanaswamy H, Kalleswara SM, et al. Evaluation of eco-friendly approaches against brinjal shoot and fruit borer Leucinodes orbonalis (Guenee) (Lepidoptera: Pyralidae). Karnataka J Agric Sci. 2013;26(2):209-13.
17. Barri RM, Haroun NB, Mohammed HA, Faya AS, Murshid LE, Alothman SM, et al. Knowledge of students and general practitioners regarding the treatment of dentine hypersensitivity. Int J Pharm Res Allied Sci. 2021;10(4):67-75. doi:10.51847/bQtU1CeDuC
18. Tarbiah NI, Alkhattabi NA, Aldamen SA, Qutah BM, Al-Zahrani MH, Tayeb HO. Effect of psychological stress during the COVID-19 on patients with irritable bowel syndrome in Saudi Arabia. J Biochem Technol. 2021;12(3):14-21. doi:10.51847/b8QU0H2tMU
19. Oran IB, Cezayirlioglu HR. AI - robotic applications in logistics industry and savings calculation. J Organ Behav Res. 2021;6(1):148-65. doi:10.51847/jUXQmvCvqf
20. Djahra AB, Zoubiri F, Benkaddour M, Gouasmia S. Antioxidant and hepatoprotective activity of Ephedra alata extracts against intoxication with deltamethrin pesticide in male rats. Pharmacophore. 2023;14(1):19-24. doi:10.51847/JvqlbdZpR6
21. Thomas TSL, Steven SL. Purification and physicochemical properties of ricins and agglutinins from *Ricinus communis*. Eur J Biochem. 1980;105(3):453-9.
22. Tano DKC, N'Depo OR, N'Guessan AP, Obodji A, Yéboué NL, Aboua LRN. Insecticidal effect of aqueous extracts from two plants on Hellula undalis Fabricius, 1781 (Lepidoptera: Pyralidae), a pest of Brassica oleracea L. cabbage cultivation (Daloa, Côte d'Ivoire). Eur J Sci. 2019;154(2):168-80.
23. Obodji A, Aboua LRN, Tano DKC, Seri-kouassi BP. Assessment of the insecticidal activity of aqueous extracts of two local plants for the management of Leucinodes orbonalis Guenee, (Lepidoptera: Pyralidae), a pest of eggplant (Solanum aethiopicum), in the Guinean area of Côte d'Ivoire. J Adv Biol. 2016;9(2):1715-25.