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Research Paper

Observation of the persistence of aqueous extracts of three local plants on the incidence and severity of the fall armyworm (*Spodoptera frugiperda* J. E. Smith) of maize (*Zea mays* L.) with a view to biological control in Gbadolite, Democratic Republic of Congo

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Abstract
The aim of this study was to evaluate the persistence of aqueous extracts of three bio-pesticidal plants on the incidence and severity of fall armyworm (Spodoptera frugiperda J. E. Smith) in Gbadolite, Democratic Republic of Congo. Randomized blocks with 3 blocks and 4 treatments including T0 (Witness) : control or untreated plot, T1 : Ocimum gratissimum, T2: Canabis indica and T3: Chromolaena odorata. After 60 days, the average infestation severity was 2 for plots treated with aqueous extracts and 6 for control plots. The infestation rate varied between 15 and 17.5% in the treated plots, and 60% in the control plots. The plant species Canabis indica, Ocimum gratissimum and Chromilaena odorata were found to be bio-pesticidal plants.

Key words: *extracts, aqueous, persistence, severity, incidence, Gbadolite*

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I. Introduction

Maize (*Zea mays* L.) is one of the world's most widely grown cereals. It occupies more than 33 million hectares worldwide each year. It accounts for 41% of global cereal production and its output was estimated at more or less 843 million tonnes for the period 2013-2014 (FAO, 2016).

It is therefore the most widely grown cereal in the world and the leading cereal in terms of production, ahead of soft wheat (*Triticum aestivum* L.) and rice (*Oriza sativa* L.) (N'Guetta *et al.*, 2005).

Maize is grown not only for human food and livestock (large and small), but also for numerous uses in the textile, pharmaceutical, alcoholic and non-alcoholic beverage, biodegradable plastic and biofuel production industries (van Den Abeele & Vandenput, 1956 ; Vandenput, 1981; Ristanovic, 2001; Issa et al., 2011; Kaho et al., 2011; Useni et al., 2014).

Cultivated all over the world, mainly for its grains, maize is one of the most important sources, due to its nutritional (rich in starch and carbohydrates, the presence of proteins and minerals) and economic (simple crop to produce, harvest and store) assets, both of which are essential to the maintenance of living organisms.Its worldwide cultivated area is smaller than that of wheat and rice, but its average yield of 5.5 t/ha is far higher than that of wheat and rice (Issa et al., 2011).

For human consumption in Mexico and South Africa, for example, figures can range from 50 to over 100 kg/year/per person of maize consumed; hence the importance of maize in global production (Anzala, 2006).

In the Democratic Republic of Congo (DRC), maize is the second most important food crop after cassava (Nyembo et al., 2014). It is widely grown in the DRC, and national production has grown steadily despite climatic and social disruptions, rising from 118,400 tonnes in 2000 to 2,078,352 tonnes in 2018, a growth rate of 56.97%.

Average national yields remain low (0.7 to 1 t/ha) (SENASEM, 2008) compared with those of the Community of East African Countries (EAC) and this is partly due to the low use of improved varieties and agricultural inputs (Nyembo et al., 2012) as well as the extent of damage from various pests and plagues (Kalonji et al., 2004).

Since 2016, the African continent has been faced with the threat of the armyworm. Native to America, the armyworm (*Spodoptera frugiperda*) was first reported on the African continent in January 2016 (Goergen et al., 2016).

Previous studies have revealed that the pest is present in almost all of sub-Saharan Africa, where it causes considerable damage, particularly in fields of maize and to a lesser extent sorghum and other crops (Prasanna et al., 2018). It is a polyphagous pest, attacking over 80 plant species in its native environment, causing damage to economically important cultivated cereals, with a preference for maize, as well as vegetable crops and cotton (FAO, 2019).

Currently, more than 30 African countries have identified the pest on their territories, including the Democratic Republic of Congo (Hama et al., 2016).

In North Ubangi maize is the second most important crop after cassava and is used in the fight against food insecurity (WFP & FAO, 2019).

Average national yields remain low (0.8 to 1 t/ha) compared with those of countries such as Italy (9.53 t/ha) (Zamir et al., 2011) and this is partly due to the low use of improved varieties and agricultural inputs (Useni et al., 2014) and the extent of damage caused by various pests (Kalonji et al., 2004).

This situation is a permanent source of food insecurity for around 9 million inhabitants, production of this crop is limited by several concepts including insects diseases and weeds that cause considerable damage in the order of 20 to 50 percent among small producers (FAO, 2016).

Since 2015, this pest has not been reported in any other part of the world apart from America. Identified for the first time in Central and West Africa in 2016, this insect is currently spreading across most of the African continent, with the exception of the Maghreb. Its presence has also been reported on the Asian continent.

In the case of the Democratic Republic of Congo, losses on maize crops can reach around 633,000 tonnes per year. For other crops under attack, notably vegetables, losses remain unknown (Day & Toephter, 2018).

Identification of the bio-aggressor constitutes a crucial element in decision-making in terms of management strategies (Cokola, 2019).

The paucity of information on this bio-aggressor in the agro-ecological environment of Gbadolite inspired us to design this study with a view to evaluating the effects of liquid extracts of four plants presumed to be botanical insecticides, namely: *Canabis indica*, *Chromolaena odorata* and *Ocimum gratissimum*.

This study seeks to answer the following research question : are aqueous plant extracts persistent during the growing season of maize crops ?

The present study answers the following specific questions :

- Will the severity and incidence of CLA decrease in proportion to the vegetation period ?
- Can these aqueous extracts retain their persistence up to 60 days of vegetation ?

The main hypothesis of this study is to verify whether aqueous extracts from local plants would be persistent during the corn growing season.

This study exploits the following specific hypotheses:

- CLA severity and incidence would decrease in proportion to the vegetation period,
- These aqueous extracts would retain their persistence for up to 60 days of growing corn.

The overall aim of this study is to assess the persistence of aqueous plant extracts and their efficacy on the severity and incidence of CLA during the maize growing season.

This study has the following specific objectives :

- Evaluate the severity and incidence of CLA during the maize growing season,
- Assess the persistence of aqueous extracts after 60 days of maize vegetation.

This research is limited to studying the effect of aqueous extracts on the incidence and severity of fall armyworms of maize in the agro-ecological region of Gbadolite from June 15 to August 15, 2024, i.e. 2 months.

II. Material and methods

Environment

The present study was conducted in Gbadolite, in the north Ubangi province of the Democratic Republic of Congo, in the Pangoma district from June 15 to July 30, 2024, i.e. one month and 2 weeks.

The town of Gbadolite is located in the north-west of the Democratic Republic of Congo, stretching from the Ubangi river basin to 25 km from the Central African Republic (CAR). The geographical coordinates of the experimental site using GPS were as follows: North Latitude: 4° 15′ 46.0674″; East Longitude: 20°59'14.59932″ East and Altitude: 403.1 m.

The town of Gbadolite is bounded :

- To the North: by the commune of Nganza and as a boundary the Ubangi River,

- To the South: by the commune of Molegbe, bounded by the equatorial forest, the source of the Lowa river and the Sokoro river,
- To the East: through the commune of Nganza and the village of Nyaki, Mobayi-Mbongo territory, Sokoko river,
- West: via the commune of Molegbe, bounded by the Mbimbi river, the Bosobolo road and the Loba river on the Businga road.

The prevailing climate is tropical, with two seasons:

- The dry season: 4 months, from November 15 to March 15 and from June 15 to July 15, respectively the long and short dry seasons,
- The rainy season: 8 months, from March 15 to June 15 and August 15 to November 15, the short and long rainy seasons respectively.

The soil is generally clayey-sandy. The vegetation was once characterized by an evergreen rainforest. However, this has been replaced by a grassy savannah dominated by *Imperata cylindrica, Penisetum purperum and Chromolaena odorata* (Molongo *et al.*, 2023; Molongo, 2024).

Material

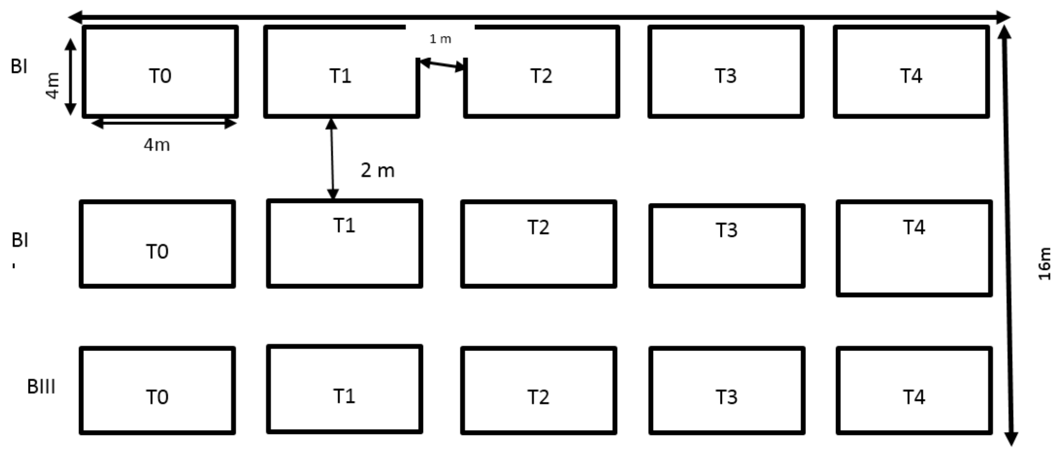
The material used in this study consisted of maize of the improved variety, Samaru, and aqueous extracts of the following plants : *Ocimum gratissimum*, *Canabis indica* and *Chromolaena odorata.*

Severity, which is the level of pest damage on leaves, was assessed using the scale (CYMMIT, 2008 ; Prasanna et *al*., 2018) :

- Level 1 : no visible attack,
- Level 2 : few small holes on one or two older leaves,
- Level 3 : several perforation lesions on a few leaves and a small circular hole damaging the leaves,
- Level 4 : several perforation lesions on 6 to 8 leaves or small circular lesions,
- Level 5 : elongated lesions on 8 to 10 leaves and a few small and medium-sized irregularly-shaped holes on the upright and/or rolled leaves,
- Level 6 : several large elongated lesions on several whorls and or several large irregularly-shaped holes on whorled and rolled leaves,
- Level 7 : numerous elongated lesions of all sizes on several whorled and rolled leaves,
- Level 8 : numerous elongated lesions of all sizes on most whorled and rolled leaves, as well as numerous medium-sized and large holes,
- Level 9 : the whorled and rolled leaves are almost completely destroyed, and the plant dies as a result of the considerable damage.
-

Methods

The experimental set-up chosen for this study was that of a complete randomized block on a 22 m x 16 m plot divided into 3 blocks, each block having 4 plots. Each plot measured 4m x 4m, with a 2m inter-plot distance and a 2m inter-block distance with a 2m aisle separating the plots.
Figure 1 illustrates the experimental set-up.



Légende : T0 : Witness ; T1 : *Canabis indica* ; T2 : *Ocimum gratissimum* ; T3 : *Chromolaena odorata* ; T4 : *Schlorodophelus zenkeri*

Figure 1 : Experimental set-up

Observations

Observations were made on the following parameters:

- Emergence rate (TL%) $= \frac{\text{Number of emerged plants per plot}}{\text{Total number of plants per plot}}\ x\ 100$ using the following formula: (Molongo, 2024),
- Plant height using a tape measure,
- Leaf index or leaf length to width ratio,
- Pest severity using the CYMMIT (2008) and Prasanna et *al*. (2018) scale,
- Attack rate or incidence by the following ratio: IC (%) $= \frac{\text{Number of plants attaked per plot}}{\text{Total number of plants sown per plot}}\ x\ 100$ (Prasanna *et al.*, 2018).
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Statistical analysis

Data from this research were analyzed using *SPSS Statistics* IBM 20 software. Single-criterion Analysis of Variance for classification without sampling and Fisher's F test were used to establish the significant difference, and Tukey's test was adopted to group treatments according to their affinity or to detect the significant difference between treatments (Spiegel, 1992).

III. Results and discussion

Lift rate

The recovery rate was evaluated and the results are shown in figure 2.

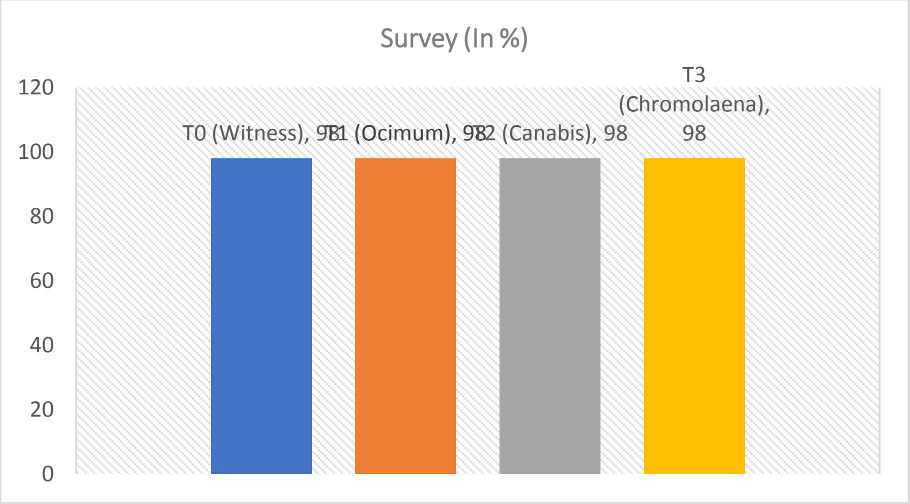

Figure 2 : Recovery rate (%)

This study shows that the emergence rate for all treatments was 98.3%. An indicator of good seed.
The coefficient of variation was 8.5% below 30%. Thus, the emergence rates of the treatments were homogeneous during this experiment. Statistical analysis shows that there was no significant difference between treatments.

Plant height

Plant height was measured and the results are shown in figure 3.

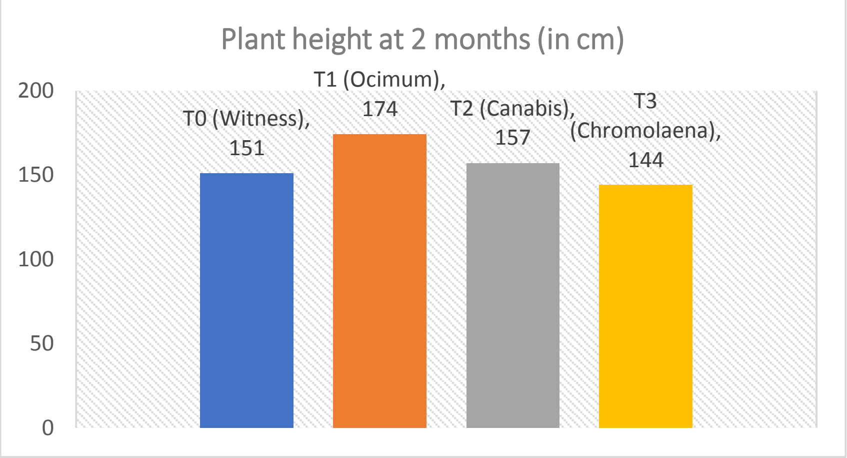

Figure 3 : Plant height (in cm)

Results relating to plant height show that plants ranged in size from 151.2 cm to 174.3 cm after 2 months of cultivation. This height enables the plant to resist lodging

Coefficients of variation for some treatments were below 30%, although plants treated with aqueous extract of *Canabis indica* were exceptionally heterogeneous. This situation provides information on the fertility gradient of this sole during this study. Statistical analysis certified that there was no significant difference between treatments.

Leaf area index

Figure 4 shows the leaf area of the plants in this experiment.

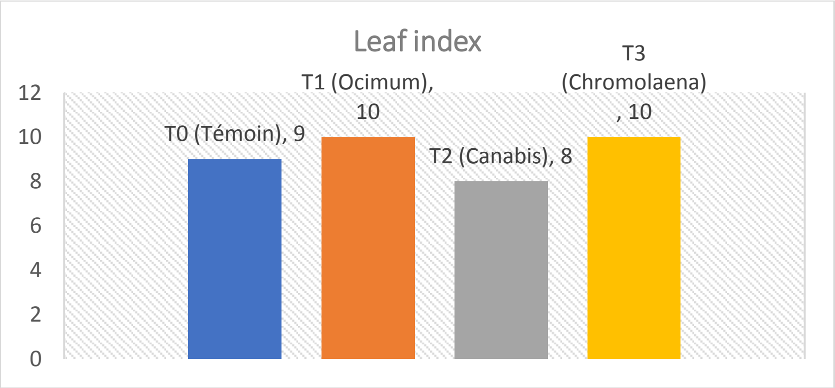

Figure 4 : Leaf index (coefficient)

Leaf indices ranged from 8.3 to 9.7. One situation shows that plants produced wider leaves, an indicator of good plant nutrition. Coefficients of variation ranged from 3.1% to 3.6% below 30%. Leaf indices were therefore homogeneous. However, the leaves of subjects not treated with aqueous plant substances showed signs of leaf mining by armyworms (CLA).

Incidence of fall armyworm (ICLA)

The incidence of armyworm was evaluated and the results are shown in figure 5.

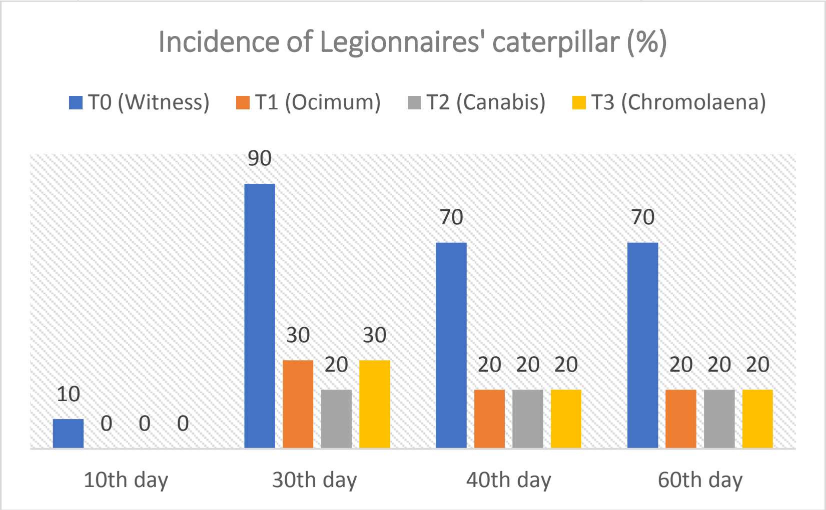

Figure 5 : Fall armyworm incidence (%)

The results confirm that on day 10, the control plants showed an incidence of 10%; the plants treated with*Ocimum*, *Canabis* and *Chromolaena* showed 0%; on day 30, they showed 90%, 30%, 20% and 30% respectively. On the other hand, at days 40 and 70, plants showed an incidence of 70% in control plants and 20% in biopesticide-treated plants. Aqueous extracts reduced infestation at day 30 from 66.7% to 77.8%, but at days 40 and 60 to 71.4%.

Statistical analysis showed that there was a significant difference between treatments, with Tukey's test revealing that the best treatment was the aqueous extract of *C. indica*, whose effect was no different from that of*O. gratissimum* and *C. odorata*, but different from that of controls or untreated subjects.

The reduction in incidence is due to the persistence of the aqueous extracts and the application of the substance regardless of the intense rainfall experienced during the trial period.

Severity of fall armyworm (SCLA)

Figure 6 shows the severity of armyworm following treatments in this study.

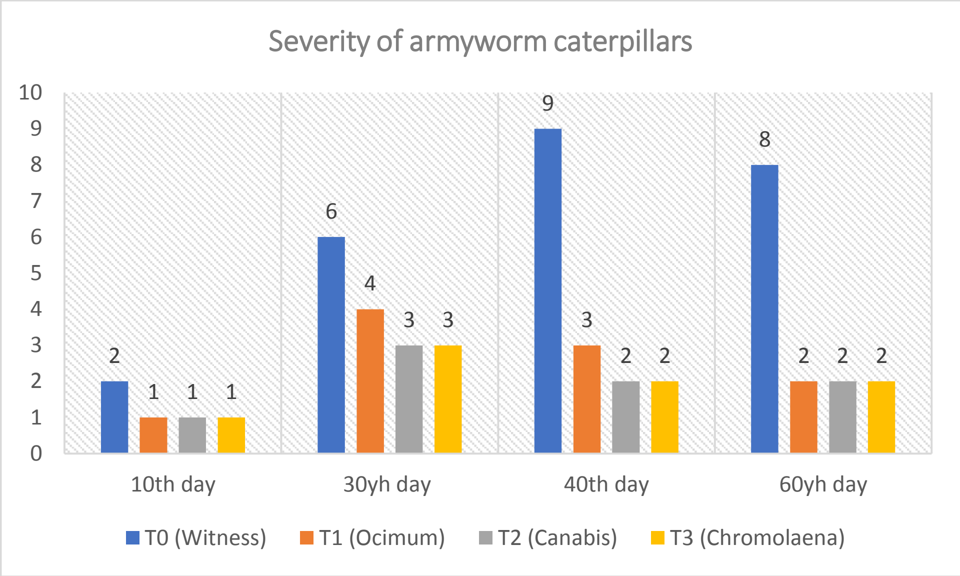

Figure 6 : Severity of armyworms caterpillar

At day 10, damage levels were 1 and 2 respectively for biopesticide-treated plants ; at day 30, damage levels were 6 for untreated plants and 3 and 4 for treated plants; at days 40 and 60, damage levels were 8 and 9 for untreated plants, but 2 for treated plants.

According to the aqueous extracts, the best treatments were the substances supplied by *C. indica*, *C. odorata* and *O. gratissimum*, but different from plants which had not been extracted. In other words, at 60 days, the extracts are still effective, whatever the rains that have recently fallen on the town of Gbadolite.

IV. Discussion

The aim of the present study was to observe the residual power of aqueous extracts from a number of plants, notably *C. indica*, *C. odorata* and Ocimum, in comparison with untreated plants.

Incidence of fall armyworm (CLA)

The armyworm (*Spodoptera frugiperda*) attacks over 80 plant species, making it one of the most damaging crop pests (Prasanna *et al.*, 2018 ; Cokola, 2019; Prasanna et *al.*, 2019).

This pest has a preference for maize, which is the main staple food for the population of Sub-Saharan Africa. It can also attack many other important crops including sorghum, wheat, sugarcane, cabbage, beet, groundnut, soybean, onion, pasture grasses, millet, tomato, potato, alfalfa, oats, bean, castor, sesame, melon, sunflower and cotton among others (Munene, 2018).

Losses caused by *Spodoptera frugiperda* range from 8.3 to 20.6 million tonnes of maize each year in the absence of effective control methods for the 12 largest maize producers in Africa (Day *et al*., 2017).

In this study, incidence varied between 15 and 17.5% in treated plots but 60% in control plots versus 50-75% infestation in farmers' fields in Tshopo Province (Looli et al., 2021).

Thas been observed that the countries most affected by this infestation are those in the Sahel and other countries where drought takes up a large part of the year, with over 90% of maize growers in Ethiopia reporting the presence of *Spodoptera frugiperda* in their fields, and almost 100% in Kenya. It has been reported that 75% defoliation causes a 15% drop in grain yield at the 12-leaf stage in maize (Kambale et al., 2023).

The armyworm has been reported in the province of Sud-Ubangi, the former province of Katanga, the city province of Kinshasa and the province of Ituri, where it causes economically significant damage to maize crops (FAO, 2018).

Over time, incidence rates were also virtually identical for all the maize genotypes tested, with only a slight difference between the incidence rates of armyworm attacks, ranging from 88.89% for genotype H613 to 100% for genotype Mugamba. This trend was upward from day [30] to day [58] after sowing, but dropped significantly to an incidence of less than 10% after spraying with the insecticide Rocket.

Severity of fall armyworm (CLA)

A level 2 severity was obtained for sprayed *C. indica* and *Ocimum* plants; 3 for treated *Chromolaena* subjects but 6 for plants from control plots at 60 days of cultivation. Treated plots showed a lower severity 5 found by Looli et *al.* (2021). Aqueous extracts therefore have a positive, long-lasting effect on the treated crop.

V. Conclusion and suggestions

The aim of this study was to observe the residual power of three local plants (*Canabis indica*, *Chromolaena odorata* and *Ocimum gratissimum*).

After testing the hypotheses, the following results were found :

- Aqueous extracts were remanent for 60 days of the trial regardless of rainfall during the trial period,
- CLA incidence varied between 15% and 17.5% in treated plots and 60% in control plots ; severity varied between 2 and 3 in treated plants and 5 in control plants,
- At 60 days of cultivation, the treated plants had less shredded leaves than the control plants. In other words, all the hypotheses were confirmed.

Perspectives

Given the socio-economic and scientific importance of maize, the following suggestions were made:

- Experiment with other plants presumed to be bio-pesticides, in particular *Datura stramonium, Tephrosia, Allium* sp, etc.
- Study the specific remanence time for each bio-pesticide plant.

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