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# Efficiency of *Chromolaena odorata* and *Pteridium Aquilinum* extracts on *Spodoptera Frugiperda* (Lepidoptera: NoctuideA) of maize (*Zea Mays*) During the two planting date in Highland zone of Cameroon

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**Key words:** FAW, *Chromolaena odorata*, *Pteridium aquilinum*, Emamectin benzoate, Maize.

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## Abstract

A study was conducted from December 2020 to July 2021 in the application and research farm of the University of Dschang to test the efficiency of two botanical insecticide extracts on FAW (Fall Army Worm). The randomized complete block design with three replications and two maize varieties Panar 53 (white) and Panar 12 (yellow), was used. The treatments (control; Emamectin benzoate 10g / sprayer; 1.5l *Chromolaena odorata* / sprayer; 1l *C. odorata* / sprayer; 1.5l *Pteridium aquilinum*/sprayer) were tested. FAW and other pests encountered were counted weekly until flowering. FAW has been present as well as grasshoppers and leafhoppers and the natural enemies of FAW (ants, spider and ladybug). Leafhoppers transmit viruses to maize in the dry season. The dry season registered the highest average leaf infestation rate (24.39±0.55%) than the rainy season (2.10±0.20%) only on yellow maize. Caterpillars were observed more during the dry season than the rainy season. The peak of FAW infestation reached on the 34$^{th}$ day after planting in both seasons. The control plots were most infested (0.46±0.07; 37.48±1.47%) than the treated one. *Chromolaena* 1l and *Pteridium* 1.5l plots were less infested with the lowest FAW (0.34±0.15; 0.15±0.09) and lowest average leaf infestation (18.26±1.02%; 22.63±1.13%). The yields obtained in the rainy season (5.58±0.18t/ha) were higher than in the dry season (4.34±0.20t/ha) on Pannar 12. *Chromolaena* 1l and *Pteridium* presented the best yields compared to control in both seasons. In summary, *Chromolaena* 1l and *Pteridium* are botanical insecticides substitutes for Emamectin benzoate during the high FAW infestations.

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**Introduction**

Maize production in the world represents more than 26,730 kilos every second (meter), which represents a production of 843 million tons in 2013 against 860 million tons in 2012 (FAO, 2014). This makes maize the most cultivated cereal in the world, ahead of wheat 681 million tons and rice 678 million (Maybelline and Abdou, 2012). Worldwide, 1,060,247,727 tons of corn are produced per year. The United States of America is the largest maize producer with 384,777,890 tons of production volume per year. China comes second with 231,837,497 tons of annual production (Atlas, 2020). In Cameroon, this speculation is currently gaining importance in agro-industry where these products are gradually replacing imported raw materials (PIDMA, 2014). It is one of the strategic cereals for food security in developing countries and an essential basic resource for human nutrition (Fongang *et al.*, 2016).

The mean yield of maize in the world is 4.3 tons per hectare. The United States of America has a yield of 5-6 t/ha. On the other hand, Africa, which has a low production because of rudimentary production systems, has an average yield of 2-3 t/ha.

Ranked 13th among African producers, Cameroon has made progress in maize production since the last shortage in 2011 (Atlas, 2020). According to figures from the Ministry of Agriculture and Rural Development (MINADER), in 2015, maize production stood at 2,148,679 tons, an increase of 4.2% compared to 2014. In 2019, the yield was estimated at 2.43 t/ha (FAO, 2019), thus materializing a trend towards an increase over the years. This progress is, unfortunately still weak and unable to meet the national grain demand estimated at nearly 2.5 million tons by MINADER and 3 million tons, according to an FAO report (FAO, 2019). That is an average deficit of nearly 600,000 tons (Atlas, 2020). And to make up for this deficit, Cameroon is obliged to import the cereal. Cameroon imported 11,270 tons of corn or more than 540 million FCFA in 2013. And according to the Investment Promotion Agency (API), imports of maize and its by-products are estimated at 150 billion FCFA per year (FAO, 2019).

From the above, it becomes essential to increase yields through the improvement of cultural practices and the fight against the main pests (Momphidae, Gelechiidae, Pyralidae, and Noctuidae) of maize (Ngamo and Hance, 2007). Among the Noctuidae, *Spodoptera frugiperda* (fall armyworm, FAW) is the most important, attacking more than 80 crops of different species, making it one of the most damaging crop pests (Prasanna *et al.*, 2018; Tindo *et al.*,2000). So she has a preference for maize (Abrahams *et al.*, 2017), the main staple food of the African population.

According to Day *et al.* (2017), the losses caused by *S. frugiperda* are in the order of 8.3 to 20.6 million tons of maize each year in the absence of effective control methods for the 12 largest maize producers in Africa. In Cameroon, it can therefore be responsible for 15 to 73% yield loss on farms when 50 to 100% of the plants are infested (Bikitig, 2020).

Since the appearance of the armyworm, chemical control has been one of the most effective and fastest methods to reduce the pest population. Nevertheless, several problems related to the excessive and indiscriminate use of insecticides for long periods are evoking. Its mainly about the risk of environmental contamination, the loss of biodiversity, the development of populations of pests resistant to insecticides, the appearance of secondary pests (Gutiérrez-Moreno *et al.*, 2018), the increase in inputs on chemicals and toxicological hazards due to the accumulation of pesticide residues in the food chain. To this end, the use of chemical insecticides in the fight against bio-aggressors becomes limited.

In order to reduce the excessive use of chemical insecticides on maize crops, environmentally-friendly control methods have been developed, including the use of bioinsecticides: they can be used in the form of plant extracts in foliar protection (Mondedji *et al.*, 2014), in association with other crops, essential oils (concentrated liquid of volatile organic compounds of plants) or whole plants are also used in storehouses.

Several plant extracts have already been certified as bio-insecticides against the Fall Armyworm. Neem oil at 7l/ha (*Azadirachta indica*) was used with a reduction of 52.21% and 55.82% in the infestation rate (Bikitig, 2020); *Tephrosia vogelii* and Wild sage (*Lantana camara*) showed the least spike contamination (8.01%) (Nguimtsop, 2020); Jatropha (*Jatropha curcas*); Peppers (*Capsicum spp*); wild sunflower (*Tithonia diversifolia*) (Mugisha-Kamatenesi *et al.*, 2008; Stevenson *et al.*, 2009; Ogendo *et al.*, 2013).

Biological control is one of the best options for the sustainable management of species that causes serious problems in maize cultivation in Africa (Bikitig, 2020). It is in this framework that this study was proposed to evaluate the efficiency of bioinsecticides in the control of fall armyworm.

## Materials and methods

*Study site*

The study was carried out during the two cultural seasons from 19 of December to 10th of July, 2021 at the application and research farm of the University of Dschang. It is located in the Menoua Division of the West region of Cameroun, with an altitude of 1420m above sight level, between 05°26'N latitude and 10°26 ' of longitude E. The climate of the region is equatorial of the Cameroonian type with the rainy season which lasts from mid-March to mid-November and the dry season from mid-November to mid-March (Pamo *et al.*, 2005). Precipitation varies between 1,500 and 2,000 mm per year and temperatures vary from 14° C (July - August) to 25° C (February) with an average temperature of 21° C. Average annual insolation is 1873 hours and humidity relative average is 76.8%.

*Plant material*

The leaf harvest of *Pteridium aquilinum* and *Chromolaena odorata* was made between 5th December and December 10, 2021. The leaves of *C. odorata* were harvested in the locality of Kongsoung in Moungo division of the littoral region of Cameroon and the young leaves of *P. aquilinum* in the lowlands of the application and research farm of the University of Dschang. The plant material used was the PANAR maize varieties: it was PANAR 12, yellow variety and PANAR 53, the white variety.

*Extraction procedure*

The procedure consisted of finely cutting these leaves and weighing 1 kg of each plant using a sensitive scale. Each kg of plant cut was put in a container of 10 l of water and covered with a cloth without forgetting to turn every day. The maceration time was 15 to 21 days at a temperature of 15°C at the beginning of the launch and between 20 and 25°C at the end. After fermentation, the mixture was filtered and stored in cans in the shade.

*Experimental design*

The experimental design used in this trial was a randomized complete block design with ten experimental units each and three replications. Each experimental unit in the dry season and in the rainy season had a dimension of 3 m × 1.5 m. The units were separated from each other by 0.5 m on the same block and the blocks were separated from each other by 1 m. The spacing between the plants was 40cm on the line and 70cm between the lines. The treatments applied at the different sites are as follows: two doses of *C. odorata* extract were defined: 1.5l/sprayer and 1l/per sprayer, negative control, positive control (Emamectin benzoate) and a dose of *P. aquilinum* (1.5l /sprayer).

*Collection of data*

Data collection began at 27 DAP because it is at this stage that the plant is most vulnerable to pest attack. 10 plants were sampled on each experimental unit following a collection sheet and this was done every week and 6 times before flowering. The first collection consisted of tearing up the plants and opening it with a blade to count the number of larvae inside.

The following parameters were considered:The developmental stage of the plant: it was determined according to the age of the plant; The total number of leaves per plant sampled: the count was made on all the leaves except the last leaf of the cone which was not yet developed; The total number of attacked leaves per plant sampled: it was a function of the perforations on the leaves; The number of live larvae per plant sampled; The number of dead larvae per plant sampled: larvae killed by treatments; The number of natural enemies per plant sampled; Height and girth per plant sampled: height was taken using a measuring tape and girth using a vernier caliper and other pests present on the plant or experimental unit were count.

The stage of development of the plant was determined by the level of evolution of the different parts of the plant. The number of leaves, attacked leaves, larvae, dead larvae and natural enemies were determined by counting on the plants.

*Leaf damage*

The identification of the damage of *Spodoptera frugiperda* larvae on the leaves was made by visual observation using a scale from David and Williams (2019) to assess their degree of attack. This scale has 10 levels varying from 0 to 9 depending on the level of attack.

0: no visible damage to leaves;
1: pinhole damage only on the leaves;
2: damage to the pinhole and leaf shot hole;
3: small elongated lesions (5-10 mm) on 1 to 3 leaves;
4: medium-sized lesions (10-30 mm) on 4 to 7 leaves
5: large elongated lesions (> 30 mm) or small eaten portions on 3 to 5 leaves;
6: elongated lesions (> 30mm) and large portions eaten on 3 to 5 leaves;
7: elongated lesions (> 30cm) and 50% of the leaves eaten;
8: elongated lesions (30cm) and large portions eaten on 70% of the leaves.

*Data analysis*

The data collected on this trial were ordered and classified in the Microsoft Excel 2013 spreadsheet. These data were transferred to SAS JMP 802 software for analysis of variance (ANOVA) and the means were separated with the aid of the test of the student at the probability threshold of 5% for variety and season parameters and the Tukey test for treatments.

## Results and discussions

*Identification of pests and natural enemies on maize in fields*

Table 1 shows the various pests and natural enemies of FAW recently recorded in fields. It appears that as pests, a class has been identified (insects) and 03 orders have been identified Lepidoptera, Orthoptera and Homoptera and as natural enemies, 02 classes of Arthropoda have been identified (insects and arachnids) and in the class of insects, we have 02 orders Coleoptera and Hymenoptera and in the class arachnid we have the order Araneidae.

**Table 1.** Orders, families and scientific names of pests and natural enemies.

| Category | | Ordres | Famillies | Scientifiques name |
|---|---|---|---|---|
| Pest | Fall army Worm | Lepidoptera | Noctuidae | *Spodoptera frugiperda* |
| | Grasshopper | Orthoptera | Acrididae | *Nomadacris septemfasciata* |
| | Leafhopper | Homoptera | Cicadellidae | *Cicadulina mbida* |
| | Ant | Hymenoptera | Formicidae | *Solenopsis invicta* |
| Natural Enemies | Spider | Aranéidés | Sparassidae | *Micrommata ligurina* |
| | Ladybug | Coléoptère | Coccinellidae | *coccinella septempunctata* |

Among the various pests identified on-site, it appears that the order of Lepidoptera was highly represented in the insect's class of arthropods because the main pest dependent on maize belongs to this order. The other pests encountered are from the orders Orthoptera and Homoptera from the same class. It should also be noted that some important orders were also observed.

These are Coleoptera, Hymenoptera from the insect class and Araneidea from Arachnids class of arthropods. These groups represent orders of the natural enemies of the Fall Armyworm. Nguimtsop (2020) found the same pests and the same predators of the fall armyworm in the western zone of Cameroon. He also discovered Dermaptera and Diptera. Guitierrez *et al.* (2010) and Elvira (2013) found the same results in their research.

**Table 2.** Mean leaf infestation rate and mean abundance of caterpillar according to treatment and cultural seasons.

| Season | Treatments | Mean rate of foliar infestation | Mean number of carterpillar |
|---|---|---|---|
| Dry season | T0=Negative control | 3.05 ± 0.07a | 0.25 ± 0.01a |
| | T1=E. benzoate | 2.16 ± 0.07bc | 0.14 ± 0.01b |
| | T2=1.5L chromolaena | 2.31 ± 0.07b | 0.07 ± 0.01cd |
| | T3=1L chromolaena | 1.96 ± 0.07c | 0.10 ± 0.01bc |
| | T4=1.5L Pteridium | 2.31± 0.07b | 0.05 ± 0.01cde |
| Rainy season | T0=Negative control | 0.37 ± 0.07d | 0.02 ± 0.01de |
| | T1=E. benzoate | 0.19 ± 0.07d | 0.00 ± 0.01de |
| | T2=1.5Lchromolaena | 0.20 ± 0.07d | 0.00 ± 0.01$^{e}$ |
| | T3=1L chromolaena | 0.34 ± 0.07d | 0.00 ± 0.01$^{e}$ |
| | T4=1.5L Pteridium | 0.08 ± 0.07d | 0.00 ± 0.01$^{e}$ |

Levels not connected by the same letter are significantly different in the column per season.

*Mean leaf infestation rate and number of caterpillars according to the season*

Fig. 1 shows the evolution of the mean leaf infestation rate and the average abundance of caterpillars and other pests according to the seasons. It shows that the dry season was more infested by caterpillars (32.47%) than the wet season (4.05%). Fig. (1) also shows that the dry season had a higher total number of caterpillars (1.16) compared to the wet season (0.03). The average abundance of caterpillars decreases overtime during the dry season and is constant and almost zero during the rainy season.

**Table 3.** Average **a**bundance of natural enemies per seasons and treatments.

| Seasons | Treament | Mean number of Ants | Mean number of Ladybug | Mean number of Spider |
|---|---|---|---|---|
| | T0=Negative control | 0.04 ±0.00b | 0.01 ± 0.00a | 0.03 ± 0.00a |
| | T1=E. benzoate | 0.03 ± 0.00ab | 0.01 ± 0.00a | 0.03 ± 0.00a |
| Dry | T2=1.5L chromolaena | 0.06 ± 0.00ab | 0.01 ± 0.00a | 0.02 ± 0.00a |
| Season | T3=1L chromolaena | 0.05 ± 0.00ab | 0.00 ± 0.00a | 0.02 ± 0.00a |
| | T4=1.5L Pteridium | 0.08 ± 0.00a | 0.01 ± 0.00a | 0.01 ± 0.00a |
| Rainy season | T0=Negative control | 0.00 ± 0.00c | 0.00 ± 0.00a | 0.00 ± 0.00b |
| | T1=E. benzoate | 0.00 ± 0.00c | 0.00 ± 0.00a | 0.00 ± 0.00b |
| | T2=1.5L chromolaena | 0.00 ± 0.00c | 0.00 ± 0.00a | 0.00 ± 0.00b |
| | T3=1L chromolaena | 0.00 ± 0.00c | 0.00 ± 0.00a | 0.00 ± 0.00b |
| | T4=1.5L Pteridium | 0.00 ± 0.00c | 0.00 ± 0.00a | 0.00 ± 0.00b |

Levels not connected by the same letter significantly different within column per season.

The analysis showed that there is a significant difference between the two seasons in the leaf infestation rate; therefore, the dry season was more infested than the wet season. This is explained by the fact that insects are highly dependent on the temperature of their environment to ensure all their vital biological functions such as feeding, reproduction, movement and growth. *Spodoptera frugiperda* is specifically adapted to hot climates and low-temperature conditions (Fontaine *et al.*, 2018); it slows down because the optimal temperature for the development of caterpillars is 28°C. This is in agreement with the results of Plessis *et al.* (2020) who varied the temperatures between 18, 22, 26, 30 and 32°C on the development rate of *S. frugiperda* and obtained that the development rate increased linearly with increasing temperatures and larval survival was higher between 26 and 30°C.

In the dry season in Dschang, the average mean temperature is about 28°C, it is why the leaf infestation rate and the total number of larvae are high. The leaf infestation rate formed two peaks during the dry season and the wet season at 34 and 55 DAS. This is due to the fact that at 34 DAS, the plant is still young (the vegetative stage) and the leaves are still flexible and fragile, reasons why caterpillars can easily eat and feed on it. At 55 DAS which is the flowering stage, it is also a stage that the caterpillars prefer because they will hide in the flower horn and feed on it. The results of Christine and Josée (2009) are similar to these observations.

**Table 4.** Average leaf infestation rate, mean abundance of FAW and other pests according to varieties and seasons.

| Variety | Seasons | Mean leaf infestation rate | Mean number of larvae | Mean number Grasshopper | Mean number Leafhopper |
|---|---|---|---|---|---|
| White Pannar | Dry season | 23.04 ± 0.73 | 0.42 ± 0.09 | 0.06 ± 0.01 | 0.03 ± 0.01 |
| | Rainy season | 2.72 ± 0.34 | 0.02 ± 0.01 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Yellow Pannar | Dry season | 25.74 ± 0.82 | 0.19 ± 0.04 | 0.05 ± 0.01 | 0.02 ± 0.00 |
| | Rainy season | 1.50 ± 0.23 | 0.01 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |

Natural enemies such as ants, spiders and ladybugs were more numerous in the dry season than in the wet season and they form a peak at 48 DAP. It is at that same time that larvae of *S. frugiperda* were more numerous. During the dry season, the plants were attacked by viruses. This may be due to the presence of leafhoppers in the plot, even though their numbers were lower.

**Table 5.** Average number of natural enemies according to varieties and cultural seasons.

| Variety | Season | Mean number of ants | Mean number of ladybug | Mean number of spider |
|---|---|---|---|---|
| White Pannar | Dry season | 0.10 ± 0.01 | 0.01 ± 0.00 | 0.04 ± 0.01 |
| | Rainy season | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Yellow Pannar | Dry season | 0.09 ± 0.01 | 0.01 ± 0.00 | 0.04 ± 0.01 |
| | Rainy season | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |

The same seed was used in the wet season and the plants were not affected by viruses.

*Effect of insecticides on leaf infestation rate and the mean abundance of the caterpillars during the two planting date*

Analysis of the variance showed there is a significant difference ($p < 0.05$) between the seasons ($P=0.000$) and between the treatments ($p=0.0001$) depending on the average rate of infestation and average abundance of the caterpillars.

In Table 2, in the dry season (37.48%) as well as in the rainy season (3.31%), the treatment T0 of the untreated plot presented the highest rate of infestation than the treated plots. The treatment T3 (1L) of *Chromolaena* was the most effective treatment (18.26%) in the dry season mean, while in the rainy season, the treatment T4 (1.5l) *Pteridium Aquilinum* was the most effective (0.55%). With regard to the average abundance of *Spodoptera Frugiperda*, in the dry season (0.46) as in the wet season, untreated plots had a higher number of larvae than treated plots (0.03).

The treatment T2 (1.5l) of *Chromolaen*a considerably reduced the abundance of caterpillars in the dry season (0.12). On the other hand, in the rainy season, the treatments T1, T2, T3 and T4 were more effective (0.01) than the control.

**Table 6.** Yield (t/ha) depending on seasons and varieties.

| Season | Variety | Yield |
|---|---|---|
| Dry season | White maize | 3.83±0.22a |
| | Yellow maize | 4.34±0.20a |
| Rainy season | White maize | 5.45±0.24b |
| | Yellow maize | 5.58±0.18b |

a, b: values affected with the same letters in the same column are not significantly ( P>0.05) different.

The different histograms showed us that the control plot had a higher infestation rate (35.5%) in the dry season than in the rainy season (3.75%). The number of infested leaves was high during the same period and the scale damage too was the highest (6). The scale 6 is elongated lesions (> 30mm) and large portions ate on 3 to 5 leaves. This also indicates that 3 to 5 leaves among the average total leaves of 8 observed were attacked by FAW. Without insecticide treatment, the leaf infestation rate is severe. This result is similar to what Burhanu *et al.* (2019) obtained.

They observed that untreated control plants showed significant leaf damage compared to plants treated with a botanical insecticide. Nguimtsop (2020) in the same climate zone obtained 43.4% of the average leaf infestation rate during the dry season.

**Table 7.** Average yield (t/ha) according treatments to seasons.

| Treatments | Mean yields (t/ha) dry season | Mean yields (t/ha) rainy season |
|---|---|---|
| T0= Negative control | 3.66 ± 0.35a | 5.42 ± 0.26a |
| T1= Emamectine benzoate | 3.83 ± 0.32a | 5.44 ± 0.37a |
| T2= 1.5l *Chromolaena odorata* | 4.44 ± 0.40a | 5.56 ± 0.45a |
| T3= 1l *Chromolaena odorata* | 4.34 ± 0.34a | 5.38 ± 0.22a |
| T4= 1.5l *Pteridium aquilinum* | 4.15 ± 0.35a | 5.76 ± 0.40a |
| Total mean yields | 4.08b | 5.51a |

a, b: values affected with the same letters in the same column are not significantly ( P>0.05) different.

The treatment that considerably reduced the leaf infestation rate and the number of larvae was the 1l *Chromolaena odorata* treatment. This plant has a strong repulsive odor which repelled the adults of *Spodoptera frugiperda* thus preventing them from laying their eggs on the leaves and stems of the plant.

It also kills the larvae already in the maize plant. Udebuani *et al.* (2015) showed that phytochemical analysis revealed the presence of tannin, saponin, flavonoids and alkaloids in the leaves of *C. odorata* and the presence of these phytochemicals alters certain biochemical functions of the organisms. Man (2013) reported in a study that the increased mortality rate could be attributed to the phytochemical content of the leaf extract. Studies have shown that a high dose of flavonoids impairs the normal functioning of the body of insects (Acero, 2014). All this corroborates with the work of Udebuani *et al.* (2015) who tested *C. odorata* on *Periplaneta americana* and recorded a maximum mortality rate for the species after treatment with the plant extract. *Pteridium aquilinum* treatment significantly reduced the leaf infestation rate and the total number of larvae; this is explained by the fact that fern contains laquiline A substance (Fenwick, 1988) which is very toxic to insects, so this extract would have killed the caterpillars of FAW.

*Effect of treatment on the average abundance of natural enemies per seasons treatments*

Table 3 shows that statistically, in ants, there is a significant difference (P < 0.05) between seasons (p=0.0001), a significant difference between the dry season treatments but no significant difference between rainy season and treatments.

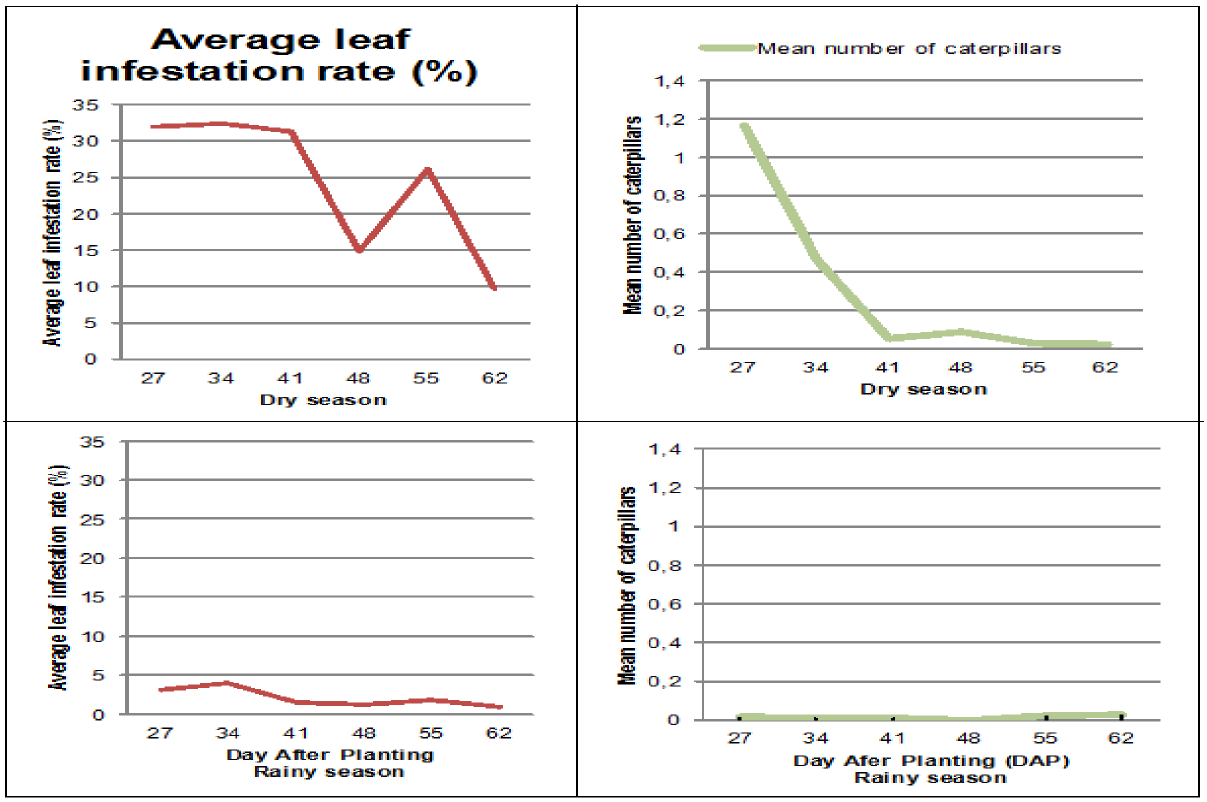


**Fig. 1.** Evolution of the leaf infestation rate and mean larvae number according to seasons and days after planting.

Numerically, in the dry season, ants are present more on the T4 *Pteridium aquilinum* treatment (0.15) and less on the T1 emamectin benzoate treatment (0.06). On the other hand, in the wet season, the presence of ants is statistically zero. In the dry season, ladybugs are more present on the T1 emamentin benzoate treatment (0.014) and less present on the T3 (1L) *chromolaena* treatment (0.003). In the rainy season the presence of ladybugs is statistically zero. Spiders are more present on the T1 Emamectine benzoate treatment (0.047) and less present on the T4 treatment (0.02) in the dry season. Meanwhile, in the wet season, the presence of spiders is statistically zero.

The T4 *Pteridium aquilinum* treatment was favorable for the ants because its toxicity has an effect only on the insects and the larvae and not on the ants.

The T1 emamectin benzoate treatment was favorable for spiders and ladybugs because the notice indicates that the active ingredient only works on caterpillars and certain insects and not on ants and ladybugs.

*Effect of maize varieties on leaf infestation rate, mean abundance of FAW, grasshopper and leafhopper per season*

The analysis of variance shows that there is no significant difference at the 5% threshold for the varieties and the treatments on the infestation rate and the number of larvae.

Table 4 below shows that in the dry season, yellow Panar maize was more infested (25.75%) than white Panar maize (23.04%). But regarding the number of larvae, white pannar had more larvae (0.42) than yellow pannar 2 (0.19) in the dry season. In the rainy season, white pannar was more infested (2.72%) and had more larvae (0.02) than yellow pannar (1.50%) for the leaf infestation rate and (0.01) for the number of larvae. The two varieties were more infested in the dry season than in the wet season because of the abundance of pests during this period and the favorable climatic conditions for their development. The Panar yellow maize variety was more infested than the Panar white maize because it is sweeter than the white one, so the pests prefer to feed on it.

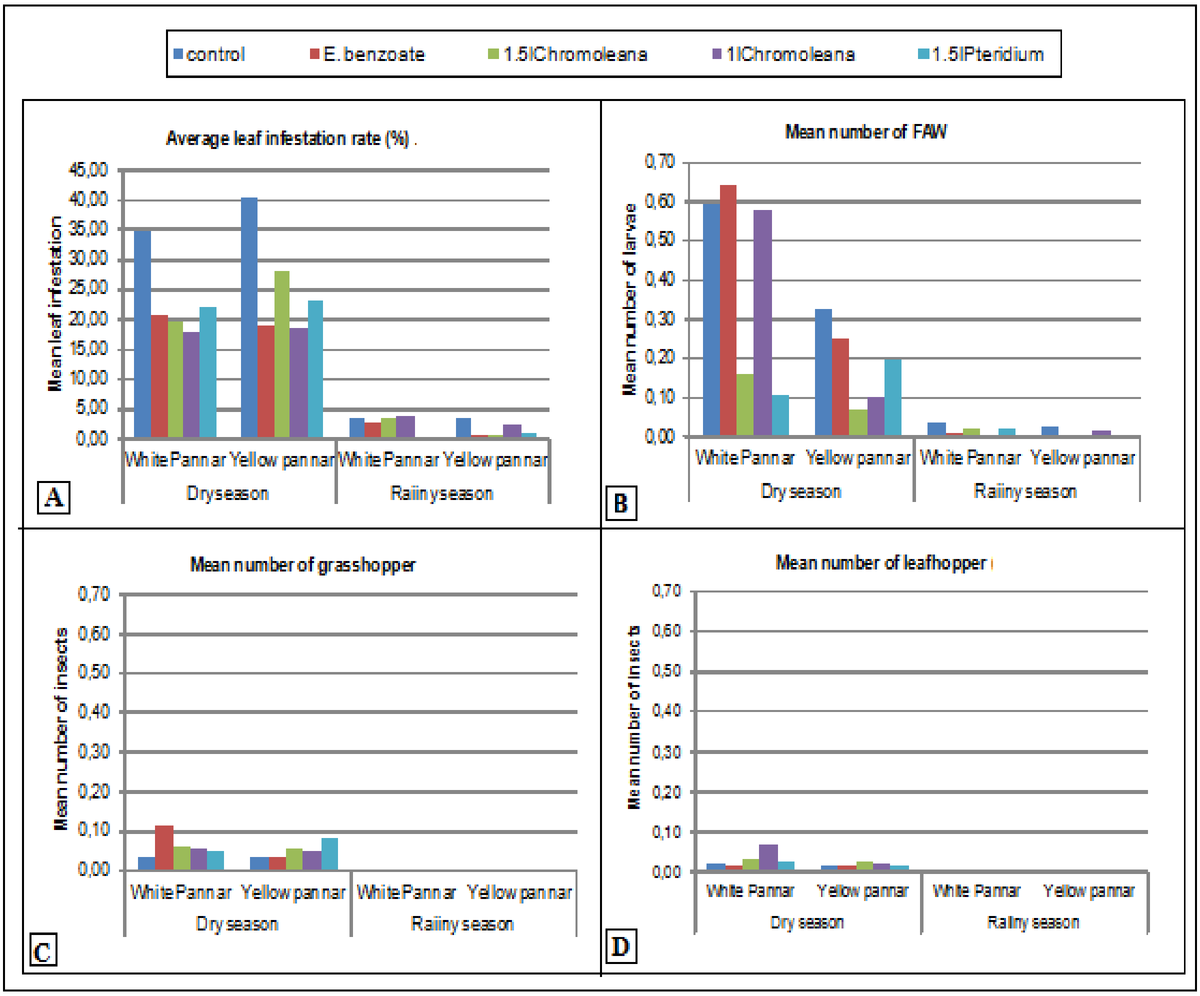


**Fig. 2.** Averages leaf rate infestation (A), number of caterpillars (B), grasshoppers (C) and leafhoppers (D) on maize varieties per treatments and seasons.

*Effect of maize varieties on FAW natural enemies*

The following table 5 shows that natural enemies were present in the field only in the dry season. In fact, it is on this variety white pannar that the caterpillars were more observed (Table 4).

*Effect of the interaction treatment and maize varieties on average leaf infestation rate, mean abundance of caterpillars and others pests per seasons*

The analysis of variance shows that there is a significant difference ($P < 0.05$) between the seasons, the varieties and the treatments on the rate of infestation ($p=0.03$).

The analysis of variance shows that there is no significant difference between seasons, varieties and treatments on the total number of larvae.

Fig. 2A shows that the dry season was the more infested, the T0 treatment was the most infested of the two seasons, the T3 and T1 treatments were the most effective and the yellow maize variety was more attacked.

Fig. 2B show that the interaction between cultural season varieties and treatments for the abundance of caterpillar during the dry season, the dry season had more caterpillar than the rainy. The treamentT0 had more caterpillars also with the white variety for the two seasons. Fig. 2 C and D present no interaction between treatments, varieties and seasons.

The number of insects was more on white pannar than yellow pannar. Grasshopper was more count on E. benzoate plot than others and leafhopper was more present on 1l *chromoleana*.

*Effect of interaction treatment and varieties on average abundance of natural enemies per seasons*

Fig. 3A opposite shows that ants were more numerous on the two plots than the other natural enemies. The favorable season for the growth of natural enemies was the dry season. The white maize variety, the T4 and To treatment were favorable for the natural enemies. For ladybug (Fig.3 B) and spider (Fig.3C), the treatment E. benzoate was more suitable on white pannar than other plots for the first pest and on yellow pannar for the second pest.

*Effect of treatment and maize varieties on growth parameters and damage scale per seasons*

Fig. 4 below shows that the season effect is statistically significant so that all growth parameters are less important in the dry season than in the rainy season. The varietal effect is not statistically significant. The untreated plots had lower values for all growth parameters. The control plots also had the highest number of infested leaves and the highest damage score (6). This information shows that the caterpillars feed on the leaves and the foliar horn and their feeding affects the parameters of the plant.

This also better explains the observations obtained in the previous sections regarding the mean rate of leaf infestation, the abundance of caterpillars and later the yields that were obtained in the untreated plots. Thus, there is the need to treat maize against FAW.

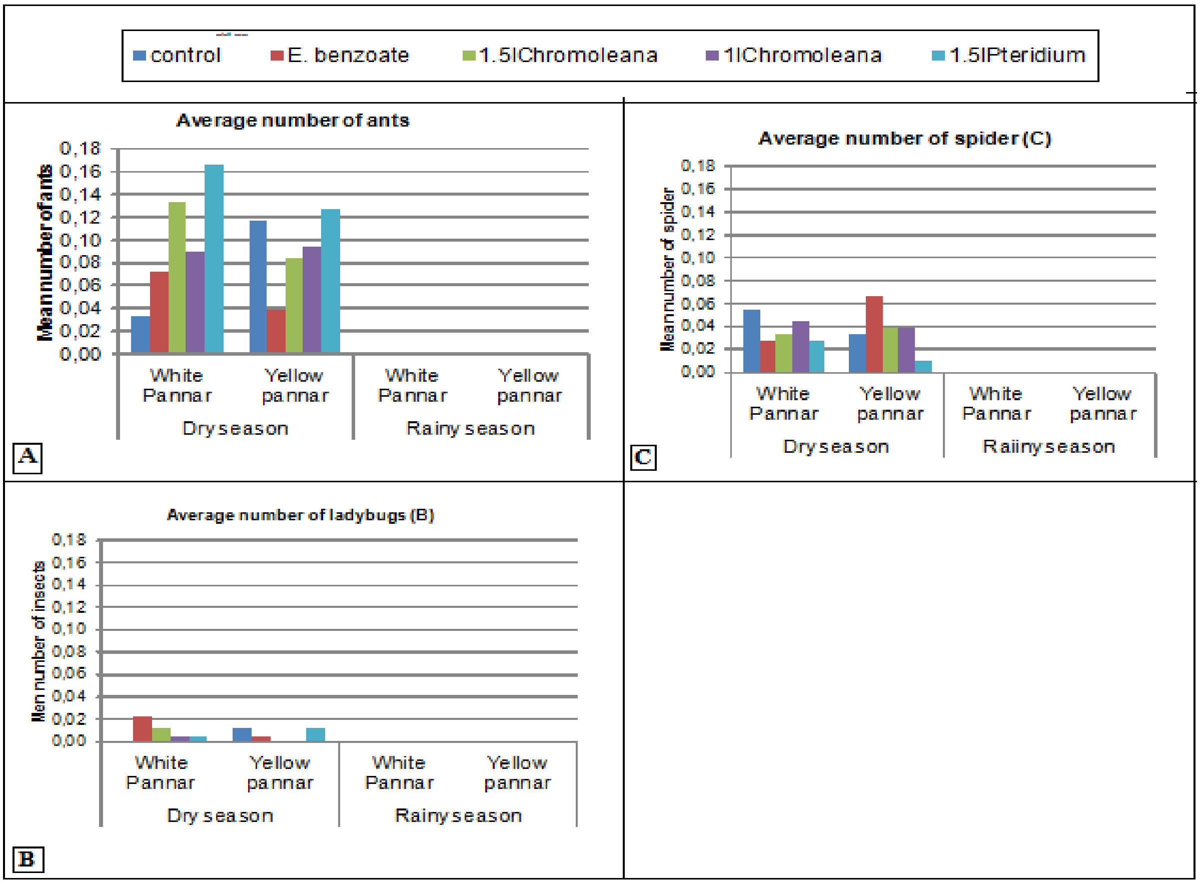


**Fig. 3.** Average number of ants (A), ladybug (B) and spiders (C) according to maize varieties, treatments and cultural seasons.

*Efficiency of varieties and planting dates on yield*

Table 5 shows that in the dry season as well as in the wet season, yellow maize had higher yields than white maize. The yields were higher in the wet season than in the dry season. This is because in the dry season, the maize plants were severely attacked by the maize streak transmitted by leafhoppers of Cicadulina-type, which acquire the virus by feeding on young developing leaves which cause slow growth, incomplete grain filling.

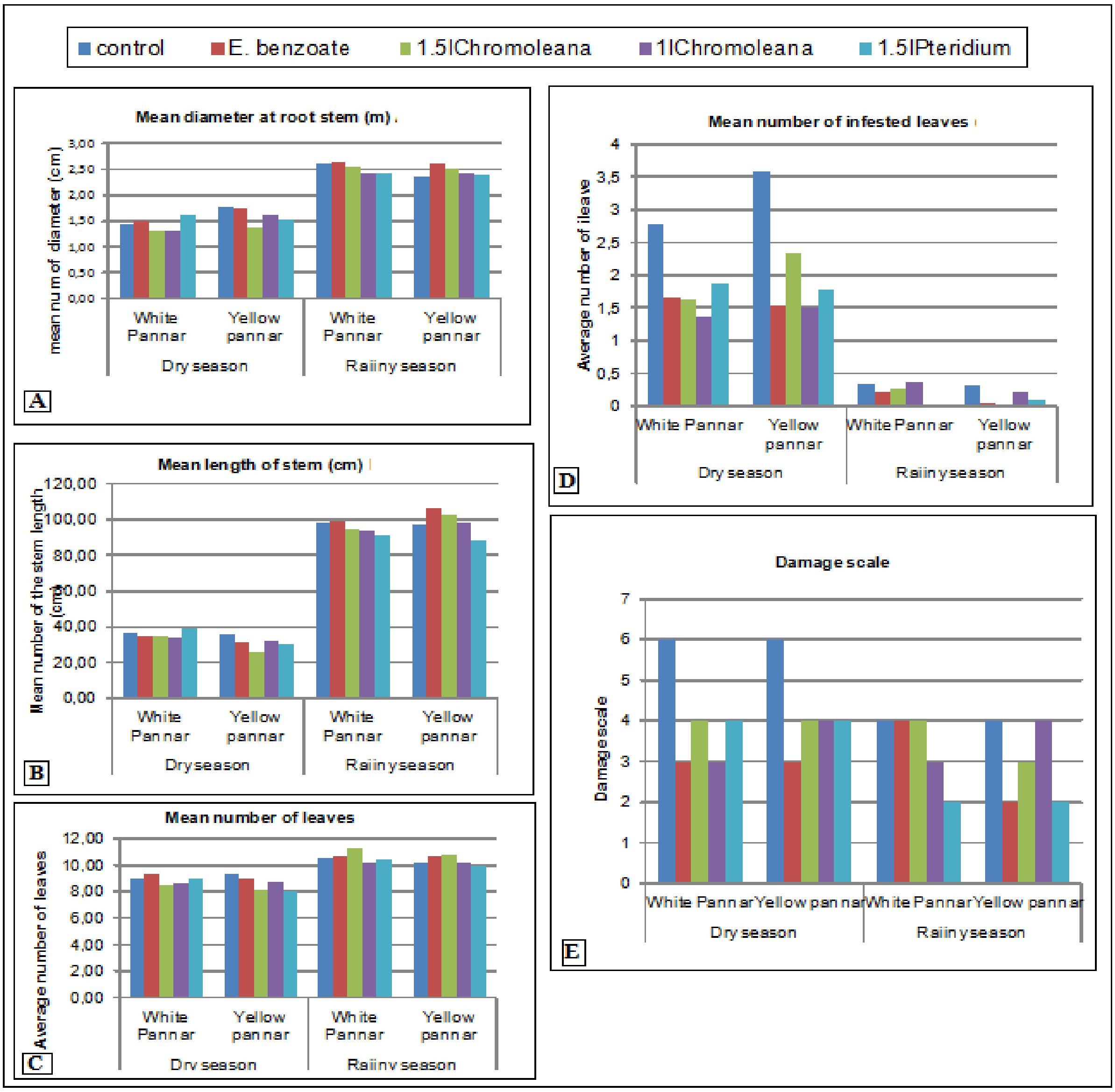


**Fig. 4.** Means of diameter at root stem (A), length of stem (B) number of leaves, infested leaves (D) and scale damage (E) per varieties, treatments and seasons.

*Efficiency of botanical insecticides and planting dates on maize yield*

Table 6 below shows that there is a significant difference between the seasons ($P < 0.05$), but no difference between the treatments of each season.

The wet season had a higher yield than the dry season. In the dry season, the 1.5 l *Chromolaena* treatment had the highest yield (4.44t/ha) compared to the other treatments, however in the wet season, it was the T4 *Pteridium aquilinum* treatment (5.76t/ha) that had the highest yield.

The treatments T2 1.5L *Chromolaeana odorata* and T4 had the highest yields in the dry and wet seasons because of their insecticidal and fertilizing effect, which agrees with the work of (Autfray, 2013 ) who also used *C. odorata* as a fertilizer on maize and obtained a higher yield. These findings are also similar to the work of Bertrand (2003). He registered that the fern has important fertilizing properties and the plots treated with these botanical insecticides showed less leaf damage and better plant growth parameters.

## Conclusion

At the end of our study which focused on the efficacy of *Chromolaena odorata* and *Pteridium aquilinum* on *Spodoptera frugiperda* (Lepidoptera: Noctuidae) on maize (*Zea mays*), several orders of insects have been identified in the field as pests but the Lepidoptera was the main pests order. Leafhoppers transmit viruses to maize in the dry season. The dry season was the most infested with all the pests identified on both plots. The treatments 1l *C.odorata* and 1.5l *P. aquilinum* were the most effective against pests during both seasons followed by the emamectin benzoate treatment. They have recorded the highest yields compared to the other treatments.The yellow maize variety had a slightly higher infestation rate than the white maize variety during both seasons but its yields were higher than the white maize variety. This work recommend the application of 1l *C.odorata* and/or 1.5l *P. aquilinum* insecticide treatments as soon as the first symptoms appear before 34 DAS and 55 DAS against FAW and other pests on boths varieties.

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