INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 23, No. 4, p. 1-16, 2023

RESEARCH PAPER OPEN ACCESS

Effects of the BioArt product on the dynamics and incidence of major cabbage pests

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Key words: Biological control, Biopesticides, Cabbage, Pests

http://dx.doi.org/10.12692/ijb/23.4.1-16 Article published on October 03, 2023

Abstract

Cabbage is important in the human diet for its richness in vitamins and other nutrients. Unfortunately, many constraints hinder the development of this crop. The objective of this study is to propose biological control alternatives by testing the effectiveness of the biological product Bioart on the main cabbage pests. Tests were carried out on an experimental plot in the Djilakh area. The experimental device used was a randomized method consisting of a total of nine elementary plots corresponding to two treatments and one untreated control plot. The plots were treated with Bioart biocide and Rapax biocide (reference bio insecticide). Treatments were applied every two weeks after transplanting. Data on the population of the main cabbage pests, the number of leaves attacked and damage were collected before and after each treatment. At harvest, the resulting yield from each plot was assessed. Results revealed that the highest population of different pests was found in untreated plots. Bioart plots had fewer pest populations and higher yields than untreated controls. On the other hand, the Bioart treatment and controls did not show a significant difference in the main cabbage pests.

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Introduction

Agriculture is one of the sectors of activity that contributes to the socio-economic development of populations and employs nearly 40% of the world's workforce (Momagri, 2016). In this sector, market gardening occupies an important place for human food (FAO, 2012). In fact, market gardening is mainly focused on vegetable production. Nowadays, they are becoming increasingly important in terms of nutrition, economic and social aspects, as well as the area planted (Mondedji *et al.*, 2014). Among vegetables, cabbage (*Brassica oleracea* L. Brassicaceae) appears to be one of the most important in both economic and food respects (Tano *et al.*, 2019). In West Africa, it appears to be one of the main components of urban and peri-urban crops of the utmost importance in the economic development of cities (Boni *et al.*, 2017).

In Senegal, cabbage is a part of the culinary tradition (PAPSEN, 2015). Indeed, it is a speculation that is consumed almost daily in households because it enters the composition of most dishes. Thus, with the increase of the population, there is a growing and permanent demand for the product both in Senegal and in the sub-region (Sakho, 2013). The possibility of growing it all year round, both in dry and rainy seasons, makes it possible to fund other activities and/or other crops (AUMN, 2009). Unfortunately, this crop is very susceptible to attacks from several insects and pathogens (Sow *et al.*, 2013; Labou *et al.*, 2016; Labou *et al.*, 2017).

The cruciferous moth, *Plutella xylostella* L, the cabbage borer, *Hellula undalis* F., and the noctuelle *Helicoverpa armigera* are major pests that can induce significant yield decreases. ISRA (Senegalese Institute of Agricultural Research) estimates that in some regions of the country, up to 80% of crops are lost.

Different active substances are used alone or in mixture to control cabbage pests (Sow *et al.*, 2013). Pesticides used in excessive or unsuitable amounts, including broad-spectrum insecticides, are the source of contamination of vegetable products, particularly cabbage (Sow and Diarra, 2013; Tendeng *et al.*, 2017). Today, chemical pesticides that are undeniably effective show their limits through negative effects on the ecosystem, fauna, flora and consequently on humans (Gnago *et al.*, 2010). Indeed, several authors have already highlighted the harmful effects of chemical pesticides that cause enormous damage to human and environmental health. The risk is especially worrying, given that endosulfan has been detected in agricultural products (Deguine *et al.*, 2008; Ngom *et al.*, 2012; Ngom *et al.*, 2013). In addition, uncontrolled use of synthetic insecticides results in the development of resistance within pest and pathogen populations (Kranthi *et al.*, 2001; Anstead *et al.*, 2005). Given their harmfulness to humans and the environment and the selection of resistant populations among bio-aggressors, a search for alternative solutions turned out to be necessary (Yarou *et al.*, 2017). Thus, to ensure a better intervention while preserving as much as possible the natural environment, new preventive methods and new products are constantly sought. Biological control is the most effective method of fighting against pest populations resistant to chemical insecticides (Amoabeng *et al.*, 2014). However, biological control takes various forms, but the one that is currently drawing researchers' attention is biological control based on using natural plant-based substances as insecticides.

This group of insecticides is readily biodegradable and their use in crop protection is a sustainable alternative to synthetic products (Immaraju, 1998; Juan and Sans, 2000; Carpinella *et al.*, 2002; Roy *et al.*, 2005; Isman, 2006; Asogwa *et al.*, 2010). The use of plant extracts as insecticides has long been known; in fact, nicotine is already known as an insect control agent (Biever, 2003). In Senegal, some authors have already underlined the importance of biocides in the protection of crops and stored food products (Thiaw and Sembène, 2007; Diome *et al.*, 2019; Ngom *et al.*, 2020). It is in this context that we set ourselves the objective of knowing the effectiveness of the biocide BIOART on the main cabbage pests.

Equipment and methods

Presentation of the study area

The study is carried out in Djilakh (Fig. 1.), a village in the commune of Sindia, located west of Senegal. This commune is part of M'bour Department located in the Thiès Region. The geographic coordinates of Djilakh are 14°31'0'N and 16°52'60'W. It has favourable soil and climatic conditions for vegetable crops. The Sudano-Sahelian climate is characterized by two seasons: a dry season that lasts about eight months (November to June) and a rainy one that lasts about four months (July to October). The average annual temperature is 24.3°C and precipitation averages 537.7mm per year.

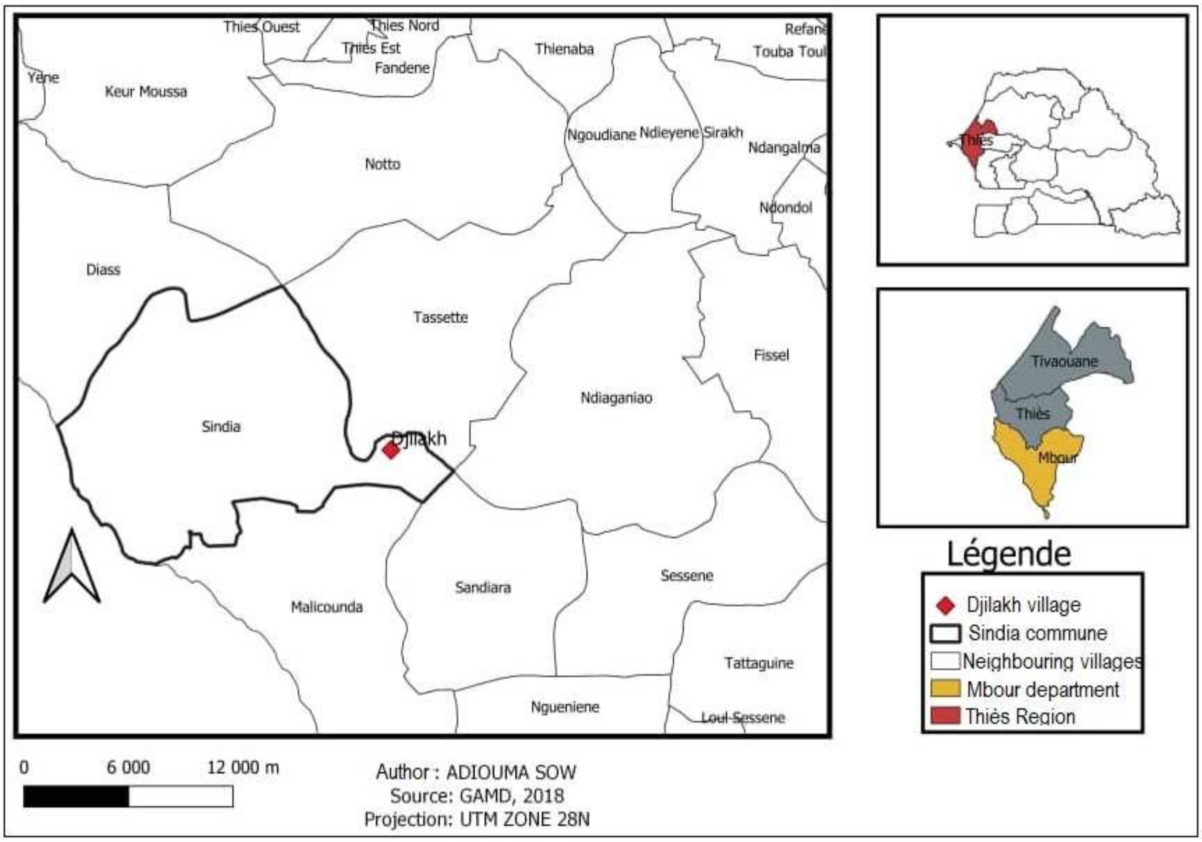

Fig. 1. Presentation of Djilakh.

The study site is located at the end of a deformed track bordered by onion, okra, aubergine and other crops; it extends over 12 hectares exploited in irrigated vegetable crops.

Plot preparation

To delimit the plots, we used a cord, a ribbon, a decametre, stakes and a hammer. As a plough tool, we used a rake. Daily irrigation was provided by the drip system. A camera and reading sheets for recording data were also used. At harvest, an electronic scale was used as a tool for weighing apples.

Choice of variety

The cabbage variety used in this study is SHANI F1 (ChouSHF1). It is a hybrid variety of Japanese origin with excellent flavour. The cycle is short, with high yields, and the average weight is about 1.5 kg.

Experimental mechanism

The experimental device (Fig. 2.) is a completely randomized random block with 3 repetitions: B1, B2, and B3. The experimental test is installed on a length of 10 m and a width of 9.5 m or an area of 95 m2. Each of the three blocks of the plot consists of 3 elementary plots (EP) corresponding to 2 treatments and one untreated control.

A distance of 1 m separates the elementary plots. Each elementary plot (3 m 2.5 m) consists of 5 lines of 6 cabbage plants spaced 0.4 m on the lines and 0.5 m between the lines or 30 feet of cabbage per (EP).

Cultivation techniques

Seedling and nursery

The surface of the nursery was in full sun. The nursery was fenced with a mosquito net fabric to avoid damage caused by small rodents and insects from the okra crops that were next door. Planting took place on January 27, 2021. Activities carried out during the nursery were watering, hoeing, and application of beef manure with sand based on *Faidherbia albida* as fertilization but also the use of organic fertilizer. Watering was provided using watering cans. The duration of the nursery was 30 days.

Field transplanting

The field was developed on Thursday, February 25, 2021, measuring an area of 95 m2 divided into 9 elementary plots of 7.5 m2 each. The transplanting soil was weeded and mixed with fertilizer. Then, the next day, even before sunrise, the entire demarcated surface was watered. After moistening the soil, the gaps between the cabbage feet were measured by taking 40 cm gaps on the line. Plants were transplanted by hand. Each elementary plot received 30 feet of cabbage spaced 50cm between the lines. The roots of the cabbage are buried in the first leaves.

Cultivation maintenance

Watering

Irrigation was done every morning by drip using drippers connected to a borehole. Plants were watered every day until the end of the cabbage harvest.

Weeding

Plots were weeded once every two to three weeks, depending on weed development.

Fertilization

A first application of organic fertilizer FERTINOVA4-3-3 (NPK4-3-3) and DAP18-46-00 (phosphorus di-ammonium) was carried out on the field even before transplantation. A MOCA application (ETHOPROPHOS 100G/KG) was applied on the same day at a rate of 15kg/ha. A second application of mineral manure at a rate of 5g per NPK plant (15-15-15) was performed three weeks after transplanting on cabbage seedlings to speed up the maturation of plants. Applications of liquid Nutritop foliar fertilizer were also performed on all cabbage plants during each treatment. Regular applications of urea have also been made to boost the development of cabbage seedlings.

Herbal treatments

Herbal treatments were carried out with the organic products BIOART and RAPAX (Positive Control), which are bio-insecticides from Europe. The biocide BIOART is composed of plant extracts and has an insecticide, acaricide and nematicide action. Once in the field, the aqueous extracts of the biocides were applied to plants. (250 ml for each plant) from the 15th day after transplanting until the 15th day before harvest. Treatment was done every 15 days and pest inventory and incidence were done 24 hours before and 48 hours after each treatment. A total of five applications of biocides were made on the crop in the ten-week interval, with one application every two weeks. The control plot was not treated; it was simply watered with water (250 ml like the treated plots) but went through all cabbage growing processes.

Sampling and data collection

Sampling was conducted at random for each EP and 9 plants from the middle were randomly selected and carefully examined for insects on the upper and lower parts of the leaves. The different types of pests and the auxiliaries present in the plots were inventoried. Surveys were conducted twice every 15 days, one day before and two days after treatment.

The surveys focused on counting insects according to the different phenological stages depending on the treatment. Monitoring of the cabbage plants was also carried out by counting the total number of leaves and the number of leaves attacked in the different plots. The weight of the harvested apples was recorded for each plot.

Parameters studied

To assess the biocidal effect of the products, measurements were made on the 9 feet of each EP. These observations were made one day before and two days after the application of treatments on cabbage feet. Records included counts of caterpillars and adults, the number of leaves attacked, and number of infected feet. The marketable apples were weighed by the plot. These observations determined several parameters:

Relative abundance of species: It is defined as the ratio of the number of species i for example (ni) to the total number of individuals of the different species of the stand (N) *100: Pi=ni/N *100 (Ngom *et al.*, 2020)
Incidence: which is equal to the number of feet infested by a given species (Pi) on the total number of feet (Pt). I = Pi/Pt *100 (Ba *et al.*, 2019).

Frequency of occurrence or consistency of species: the consistency c of a species is the ratio (in %) between the number of surveys that contain this species and all surveys.
When c is more than 50% of surveys: the species is constant;
When c is between 25-50% of surveys: the species is accessory;
When c is less than 25% of surveys: the species is accidental.

Diversity indices

Shannon H Index

H = - Sum (ni/N x log ni/N) or represents the list of the number of individuals of each of the n species of the survey.
N represents the total number of individuals.
The H-Index makes it possible to compare the diversity of different communities. The Shannon index is derived from information theory and is used to calculate the diversity of signals conveyed by a channel. It is successfully applied to the assessment of diversity in communities. Species take value from signals.

Simpson D Index

Simpson's index is the probability that two randomly selected individuals belong to the same species in a stand. The closer this index is to 1, the more homogeneous the stand. Finally, the value D = 1 would appear where an infinite number of species are present, but all have almost zero probability.

D= Sum (Xi (Xi-1) /X(X-1)
Xi: number of individuals of a given species.
X: total number of individuals. 0 D 1
Leaf attack rate: number of leaves attacked out of total number of leaves per sampled plant *100
Yield: This is the ratio of Total Harvested Apple Mass (M) in kg to Area (S) in m2. R= M/S (Sora and Hgaza 2014).

Statistical analyses of data

Data processing was performed using the Microsoft Office Excel 2013 spreadsheet to enter data and plot histograms and R version 3.6.0 software for statistical testing. To assess the effect of the treatment on pests and crop yield, the non-parametric test of Kruskal wallis was used, as the data did not follow the normal law. The analysis focused on the average insect population observed on the Formica sp. before and after treatment and the yields obtained according to the different plots. Wilcox tests were used for a two-to-two comparison of modalities. The Fisher test was applied to assess differences in the proportions of leaves attacked in the different plots. The difference between the two values is considered significant when the p-value is less than 5% ($p < 0.05$).

Results

Inventory of species encountered in the environment
The entomological fauna encountered (7 species) during the establishment of cabbage cultivation is distributed mainly in 5 orders: Lepidoptera; Coleoptera; Diptera; Araneae and Hymenoptera. This fauna is listed in Table 1.

Abundance of different species

Throughout the study 3870 individuals were identified. The species P. xylostella is the most abundant, with 2521 individuals and a relative abundance of 65.14% followed respectively by Syrphus sp., 726 individuals (18.75%), H. undalis, 387 individuals (10%), Coccinella sp., 192 individuals (4.96%), Araneus sp., 20 individuals (0.51%), H. armigera, 17 individuals (0.43%) and Formica sp., 7 individuals (0.18%) (Table 2).

These results show that P. xylostella is by far the most abundant species in the environment.

Table 1. Insects encountered during cabbage cultivation.

Groups	Orders	Families	Species
Pests	Lepidoptera	Plutellidae	*Plutella xylostella*
		Pyralidae	*Hellula undalis*
		Noctuidae	*Helicoverpa*
armigera			
Auxiliaries	Coleoptera	Coccinellidae	*Coccinella sp*
	Diptera	Syrphidae	*Syrphus sp.*
	Hymenoptera	Formicidae	*Formica sp.*
	Araneae	Araneidae	*Araneus sp.*

Pest incidence

The species P. xylostella has a maximum incidence of 100% in all elementary plots while the cabbage borer (Hellula undalis) has an incidence of 14.81% in control plots (T0); 7.40% in plots treated with Bioart (T2) and zero incidence in those treated with Rapax (T1). Helicoverpa armigera caused no damage on all plots with no impact. It should be noted that this species was accidental in the environment.

Consistency or frequency of occurrence of species

The frequency of occurrence in the different elementary plots T0, T1, T2 is presented by Fig. 3. It is respectively 83.33%, 86.66% and 80% for *P xylostella*, 73.33%, 66.66% and 63.33% for *H. undalis*, 30%, 23.23% and 26.66% for *Coccinella sp.*, 10%, 6.66% and 6.66% for *H. armigera*, 6.66%, 3.33% and 3.33% for *Formica sp.* and 13.33%, 6.66%, and 3.33% for *Araneus sp.* As for *Syrphus sp.*, the frequency of occurrence is 23.33% in all elementary plots. Thus, taking into account the frequency of occurrence, *P. xylostella* and *H. undalis* are considered to be the most constant in the medium (present in more than 50% of the surveys). *Coccinella sp.* were seen as accessory in plots T0 and T2 (present in 25-50% of surveys) and accidental in plots T1 (present in less than 25% of surveys). *Formica sp.*, *Araneus sp.* and *H. armigera* are retained as accidental species in the environment (present in less than 25% of surveys).

Table 2. Abundance of studied species.

	P. xylostella	*H. undalis*	*H. armigera*	*Syrphus sp.*	*Coccinella sp.*	*Formica. sp.*	*Araneus sp.*	*Total*
Strength (ni)	2521	387	17	726	192	7	20	3870
Relative abundance (Pi)	65.14%	10%	0.43%	18.75%	4.96%	0.18%	0.51%	100%

Species diversity indices

The analysis of Table 3 of the diversity indices shows a very low diversity in the different elementary plots (PE) with a value of the Shannon index H = 0.434. Although the overall diversity is low, *Plutella xylostella*, *Hellula undalis* and *Syrphus sp.* have, in absolute value, the greatest diversities in the different PE with the values of H equal respectively to 0.121; 0.1 and 0.136. *Coccinella sp.* have an absolute value of H = 0.064. *H. armigera*, *Araneus sp.* and *Formica sp.* have the lowest indices of diversity with an absolute value of H equal to 0.010; 0.011 and 0.004, respectively.

The value of the Simpson index (D = 0.470) confirms that there is a low degree of species biodiversity.

Table 3. Species diversity indices.

Espèces	-(ni/N x log ni/N)
P. xylostella	0.121
H. undalis	0.1
H. armigera	0.010
Coccinella sp.	0.064
Syrphus sp.	0.136
Formica sp.	0.004
Araneus sp.	0.011
H = Sum (ni/N x log ni/N)	0.434
D = Sum (Xi (Xi-1) /X(X-1))	0.470

Effect of treatments on different species studied

The analysis of the graph (Fig. 4) of the average numbers of individuals of different species according to the treatments applied reveals that this differs according to the treatment assigned. Indeed, there is a non-significant decrease (P-value = 0.2407) in the average number of individuals of *P. xylostella* present on Rapax (23.26±4.80 individuals) and Bioart (25.53 5.10 individuals) compared to T0 control plots that have an average number of individuals of (35.23±6.47 individuals). For *H. undalis*, the average number of individuals in the Rapax (3.26±0.77 individuals) and Bioart (4±0.90 individuals) plots is lower compared to the T0 control plots (5.63±1.08 individuals). However, the effect of the treatments is not significant on *H. undalis* (P-value = 0.3085). Under treatment, the average number of individuals of *H. armigera* slightly decreased with the two biocides, Rapax (0.16±0.08) and Bioart (0.20±0.08) compared to controls T0 (0.16±0.11). This decrease in the number of individuals of *H. armigera* is also not significant (P-value = 0.9231). However, Rapax (T1) and Bioart (T2) plots averaged 9.30±4.33 individuals and 8.56 individuals higher than T0 controls, respectively (6.33 individuals). For ladybirds, the average number of individuals increased slightly to T1 (3.43±1.78 individuals) and T2 (1.53±0.61 individuals) compared to controls T0 (1.43±0.61 individuals). As for Formica sp. and *Araneus sp.*, their average number of individuals was very low according to the treatments.

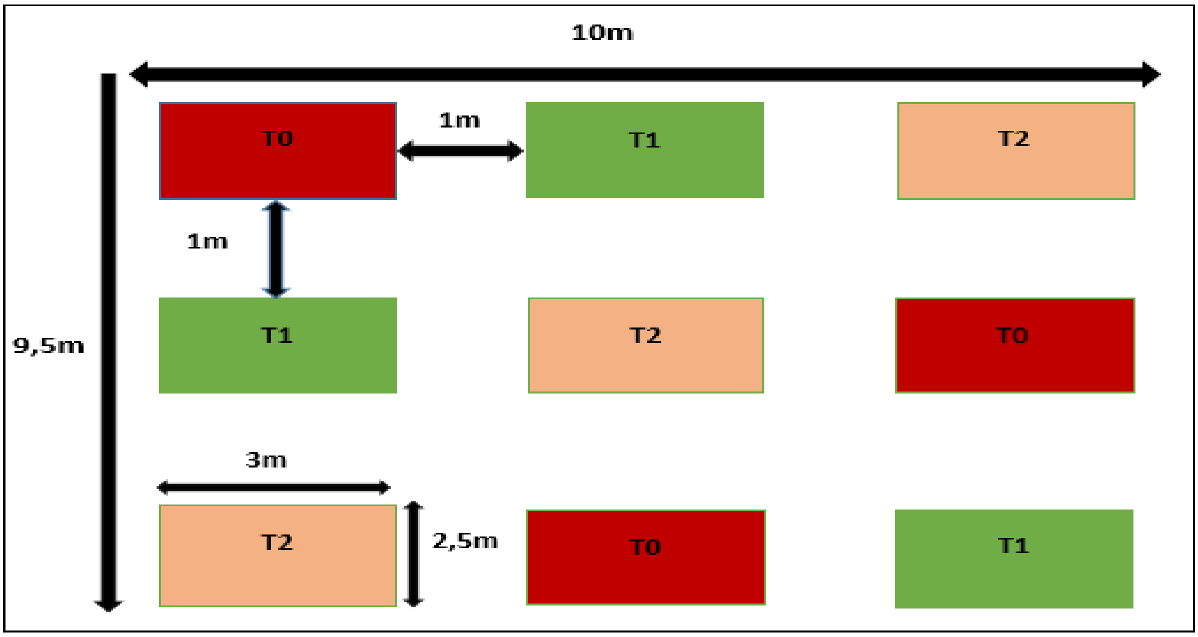

Fig. 2. Diagram of the experimental design.

T0 = untreated PE; T1= EP treated with RAPAX biocide control; T2= EP treated with BIOART biocide.

Population dynamics of P. xylostella before and after treatment with BioArt

Variation in the number of individuals of *P. xylosteylla* as a function of the treatment period with Bioart is shown in Fig. 5. During the first treatment (15th day after transplanting), no observations of *P. xylostella* were made on the Bioart plots. The second treatment corresponding to the fourth week, the biocide Bioart, caused a decrease in the population of *P. xylostella* from 52 individuals (24 hours before treatment) to 41 individuals (48 hours after treatment). During the third treatment (sixth week), there was an increase in the number of *P. xylostella* (before treatment). However, this number increased from 79 individuals (24 hours before treatment) to 52 individuals (48 hours after treatment). At the fourth treatment (eight weeks), there was a sharp increase in pre-treatment strength. However, under the influence of Bioart, the population size of *P. xylostella* before treatment (278 individuals) had decreased to 148 individuals (48 hours after treatment). As for the last treatment (10 weeks), the number decreased from 93 individuals (24 hours before treatment) to 23 individuals (48 hours after treatment). Statistical analysis on the comparison of population dynamics of *P. xylostella* before and after treatment is not significant in the second (P-value=0.07) and third (P-value=0.26) processing period but it is significant during the last two processing periods (P-value=0.04).

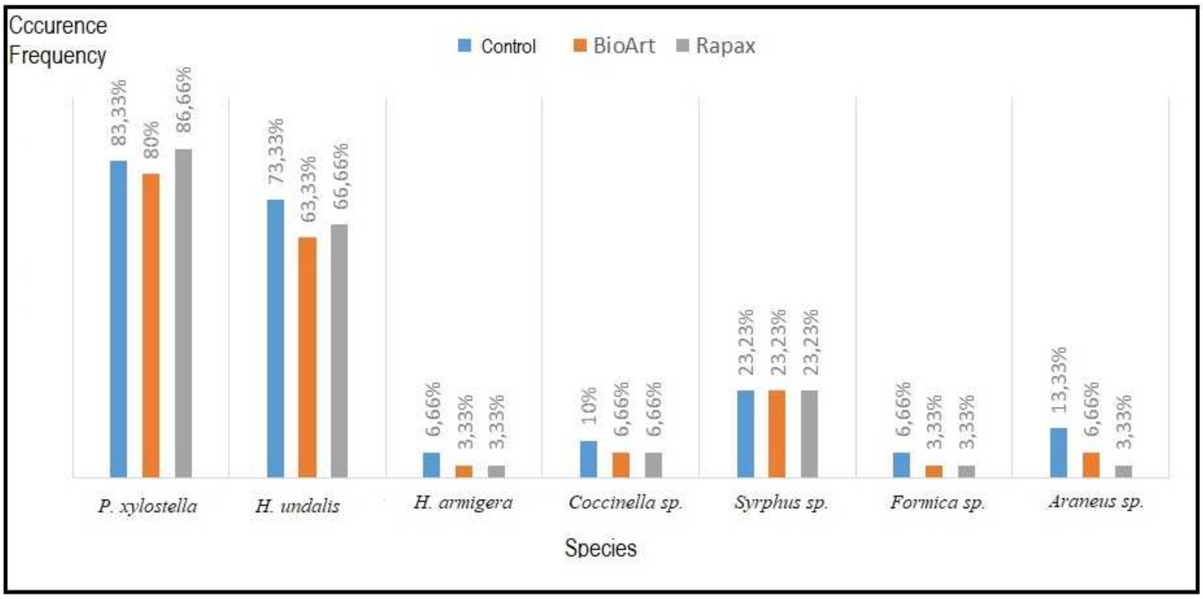

Fig. 3. Frequency of occurrence of insects encountered in different cabbage EP.

For the same treatment period the histograms followed by exposing the same alphabetical letter are not significantly different at the threshold of $p<0.05$.

When comparing the number of individuals in plots treated with Bioart between treatment periods, it is apparent that Bioart has a significant difference between the third and fourth treatment periods (P-value=0.004).

In the same vein, when comparing the number of individuals between treatment periods, we also realize that the number of individuals differs significantly between the fourth and fifth treatment periods (P-value=0.003).

Leaf attack rate in different plots

Proportions of leaves attacked in different plots are shown in Fig. 6. At the control plots (T0), the proportion of leaves attacked, which is equal to 50.73(4.05) %, is greater than the proportion of leaves attacked in Bioart plots (T2) which is equal to 47.14(3.51) %. Rapax plots (T1) have the lowest proportion of leaves attacked, which is 43.43(3.53) %.

Statistical analysis indicates highly significant differences in the proportions of leaves attacked in the different plots. Indeed, the Fisher test gave a highly significant difference between control and Bioart (P-value = 0.000351) and also between Bioart and Rapax (P-value = 0.0001652).

Histograms followed by exposing the same alphabetic letter are not significantly different at the $p<0.05$ threshold.

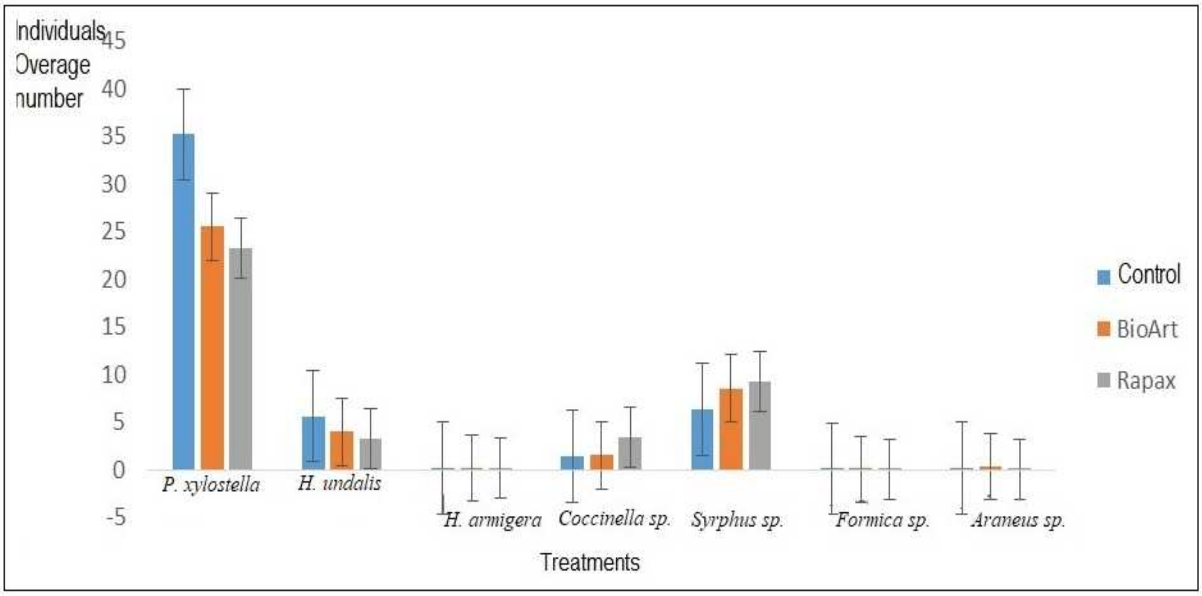

Fig. 4. Average of individuals of different species according to treatments.

Agronomic impact of treatment effect on cabbage

Of the 270 transplanted plants, 178 apples were harvested. The remaining 92 apples were not harvested because some were not marketable and others had not completed their development cycle. The total weight of the harvest (154.04kg) is obtained by weighing the cabbage apples. In addition, the weighing was done in parcels. Thus, the histogram of the harvest yield according to each treatment (Fig. 7.) revealed that the control plots (T0) gave a lower yield (1.83 kg/m2) compared to the treated plots. The largest harvest, estimated at 60kg, came from plots treated with Rapax biocide (T1) with a yield of 2.66 kg/m2. At the same time, they gave more marketable apples compared to other plots. Bioart-treated plots (T2) yielded 2.34 kg/m2 and had more marketable apples than controls (T0). However, there was no significant difference in yield between the different plots T0, T1 and T2 (P-value = 0.3679).

Histograms followed by exposing the same alphabetic letter are not significantly different at the $p<0.05$ threshold.

Discussion

Understanding the biocidal effect of Bioart on the main cabbage pests in the Djilakh area was the goal of our study. The efficacy of the biological product Bioart was different according to pests and in comparison with the control (T0) and the biocide Rapax (T1). The main cabbage pests identified in our study belong to the order Lepidoptera: *P. xylostella* (64.14%), followed by *H. undalis* (10%) and H. *armigera* (0.43%). Auxiliaries such as *Syrphus sp.*, *Coccinella sp.*, *Formica sp.* and *Araneus sp.* were also listed.

P. xylostella is the main pest due to its abundance, frequency of occurrence and higher incidence than others. Our results corroborate those of Furlong *et al.*, 2012 who consider the species as the main cabbage pest. This massive attack of *P. xylostella* has already been reported by several authors (Bourdouxhe, 1983; Silva-Torres *et al.*, 2010; Zalucki and Furlong, 2011). According to Silva-Torres *et al.*, 2010, it is the most destructive pest of crucifers worldwide.

The fluctuation of pest populations is primarily related to the bio-ecology of species, environmental circumstances and, in particular, the impact of biocidal substances applied; the combined effect of these factors thus determines pest population dynamics (Diome *et al.*, 2021). Indeed, when the plants were young, the cruciferous moth was the most presented species in our plots. These results are consistent with the work of Sow *et al.*, 2013 which found that females of *P. xylostella* prefer young plants when laying eggs. Larval attacks *by P. xylostella* larvae can begin in nurseries, and these larvae prefer young leaves located in the heart of the host plant (Ouali-Ngoran *et al.*, 2014). However, we found that the population of *P. xylostella* increased with the age of the cabbage and its peak corresponded to the eighth week (56 days after transplanting), which coincided with the maturation period. This result is in agreement with that of Diome *et al.*, 2021 which shows a peak at the ripening period when the cabbage heads are well formed. However, a decrease in the population of *P. xylostella* was noted from the tenth week, 70 days after transplanting. This population decline may be related to the formation of mature cabbages that would not be preferred as laying substrates by females. Indeed, the evolution of cabbage is inversely proportional to the glucosinolates content of the plant and this could be a factor limiting egg laying (Sow *et al.*, 2013). These observations show that the abundance of *P. xylostella* depends not only on the treatment of the plots but also on the development stage of plants (Ngom *et al.*, 2020).

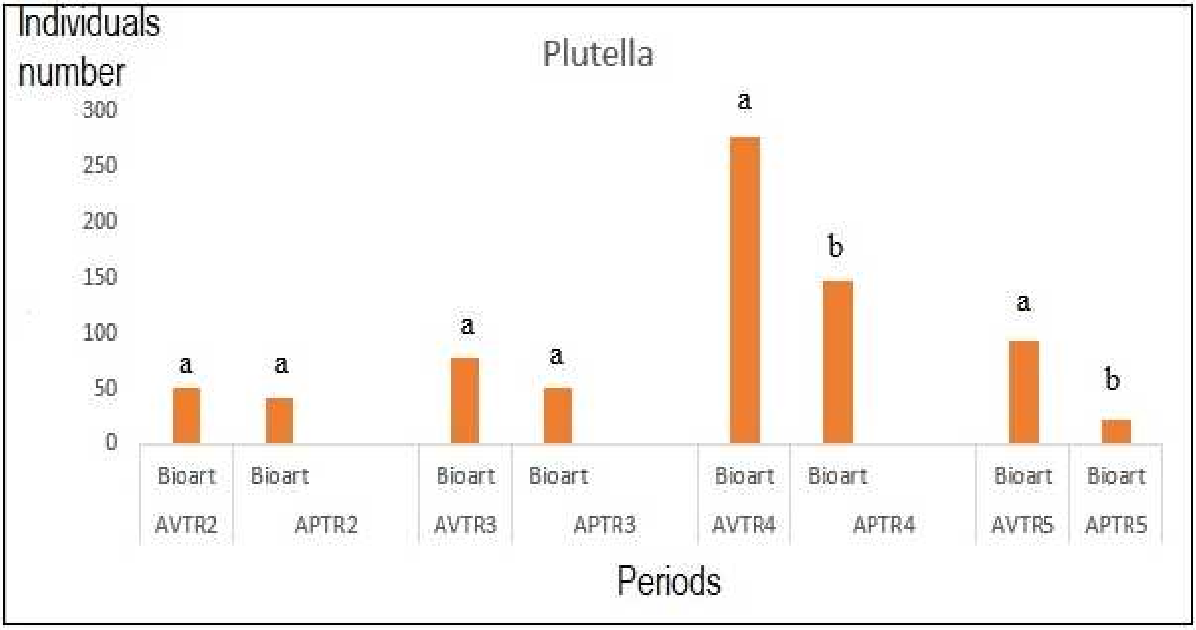

Fig. 5. Variation of the number of individuals of *P. xylostella* according to the periods of treatment of the biocide Bioart.

Frequencies of occurrence of *H. undalis* show that it is a very constant species in cabbage culture. Indeed, *H. undalis* and *P. xylostella* are gregarious species, dependent on their host plant cabbage (N'goran *et al.*, 2021). In this regard, Kouassi *et al.,* 2019 showed that these two species represented the most numerous and constant pests of cabbage cultivation; in contrast to the work of Martin *et al.*, 2006 and Licciardi *et al.*, 2008, which showed the presence of the lepidopteran *Spodoptera littoralis* as an important cabbage pest at the level of vegetable perimeters in Benin, a country located in tropical zone.

However, our findings are in agreement with the studies conducted by Kouakou *et al.*, 2002, which showed the presence of two major Lepidoptera cabbage pests, *P. xylostella* and *H. undalis,* in southern Côte d'Ivoire. The extent of their damage could be explained by their proliferation and voracity.

The high number of plants attacked by *P. xylostella* (100%) could be related to its large population. Indeed, the larvae of *P. xylostella* have a defoliating action that can lead, in case of strong attacks, to the complete destruction of the leaf blade of cabbage. Our results are corroborated by those of Sall-Sy (2013), which showed that *P. xylostella* could consume up to 60% of the foliage of the plants Zalucki *et al.*, 2012 also estimated the damage of this species at harvest losses of up to 90%. However, the impact of *H.*

undalis is less important on cabbage. Thus, Borer abundance (10%) was low and its incidence (14.81% at the control plots, 7.40% at the Bioart plots and zero at the Rapax plots) compared to cruciferous moth. Despite the low incidence of Borer, damage to terminal buds was noted, causing the formation of multiple apples. This result joins that of Diome *et al.*, 2021 which stipulates that the consequence of the appearance of Borer was the appearance of additional buds on a number of stems. Our results for this species also confirm those of Sall-Sy (2013), who estimated its damage at 33% production loss, manifested by the secondary development of cabbage to several small, unmarketable apples.

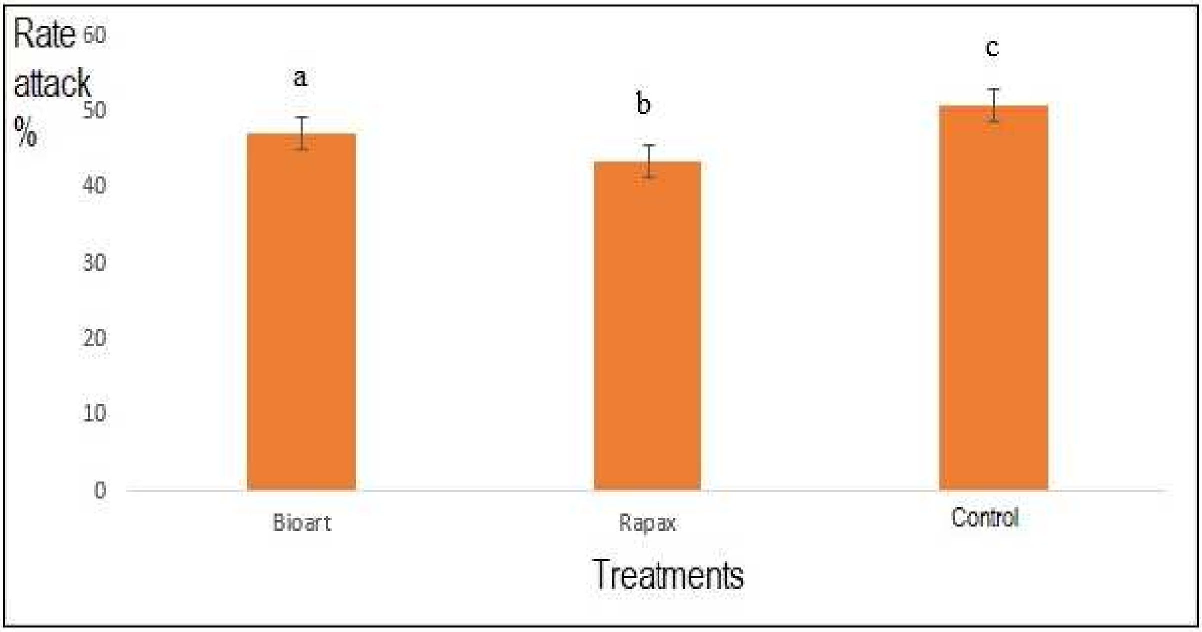

Fig. 6. Leaf attack rate according to treatments.

As for *H. armigera*, it was weakly represented from their appearance in plots in the sixth week. This could be explained by the fact that cabbage is not the main host plant for this polyphagous species. The presence of other plants, such as the tomato in the neighbouring plots, could undoubtedly promote the presence of the noctuelle *H. armigera* on cabbage plants. Indeed, our study site being in market gardening perimeters, the diversity of cultures (tomato, eggplant, okra, onion) can favour the presence of this species. According to Diatte *et al.*, 2017, it is the most common pest on tomatoes, with an occurrence of 91.8% in monitored plots and damage of up to 28% on fruits.

During the observations in the different plots, we also found in the treated plots (T1 and T2) the greater presence of auxiliaries; these are *Coccinella sp.* and *Syrphus sp.* This would be explained by the fact that treatments with biocides had a less toxic effect on natural enemies. Indeed, neem extracts have had to show selective and less toxic effects on the natural enemies of insect pests that play a role in reducing pest populations (Cloyd, 2004; Charleston *et al.*, 2005b). Concerning the other auxiliaries, namely Formica sp. and *Araneus sp.*, their very small number does not allow us to statistically compare their number between treatments.

Effects of treatment on pests

Under experimental conditions, the effectiveness of the products is assessed globally through the abundance of pest populations or the severity of the damage (Yarou *et al.*, 2017). Our results showed that untreated control plots recorded the highest number of pests compared to Bioart and Rapax plots. However, the treatment effect is not significant on pests and no significant differences were observed between treatments. Bioart biocide had an impact on *P. xylostella* because, 48 hours after each treatment, there is a reduction in the number of *P. xylostella*. However, we realize that it is more important for each treatment period that follows the preceding one. This could be explained by the fact that the neighbouring plots were treated with chemical products and that, unfortunately, this could promote the massive migration of these pests in our plots. Indeed, *P. xylostella* migrates passively in the wind (Honda, 1992; Honda *et al.*, 1992). Several authors have shown that these migrations are uncontrollable as to their final destination (Zalucki and Furlong, 2011; Wei *et al.*, 2013), which leads to a random and unpredictable infestation of the plots.

The slow persistence of the biocidal product can also be an explanatory factor. However, the reduction in the number of *P. xylostella* after each treatment was significant only in the fourth and fifth treatment period (P-value=0.04953). This biocide also had an effective impact on *H.undalis* because its number decreased during treatments. These results agree with those of Ngom *et al.*, 2020 which show that the biocide of aqueous extracts of *C. procera* leaves is effectively effective on *P. xylostella* and *H. undalis*.

The results obtained on the number of attacked leaves confirm the predominance of the pests in the control plots (T0). This is explained by the fact that the control plots had proportions of attacked leaves (50.73%) higher than the proportions of attacked leaves in plots T1 (43.43%) and T2 (47.14%). This could be explained by the effect of the Bioart biocide on pests. In addition, the impact of the biocide Bioart on cabbage pests could have reduced the damage caused by its pests.

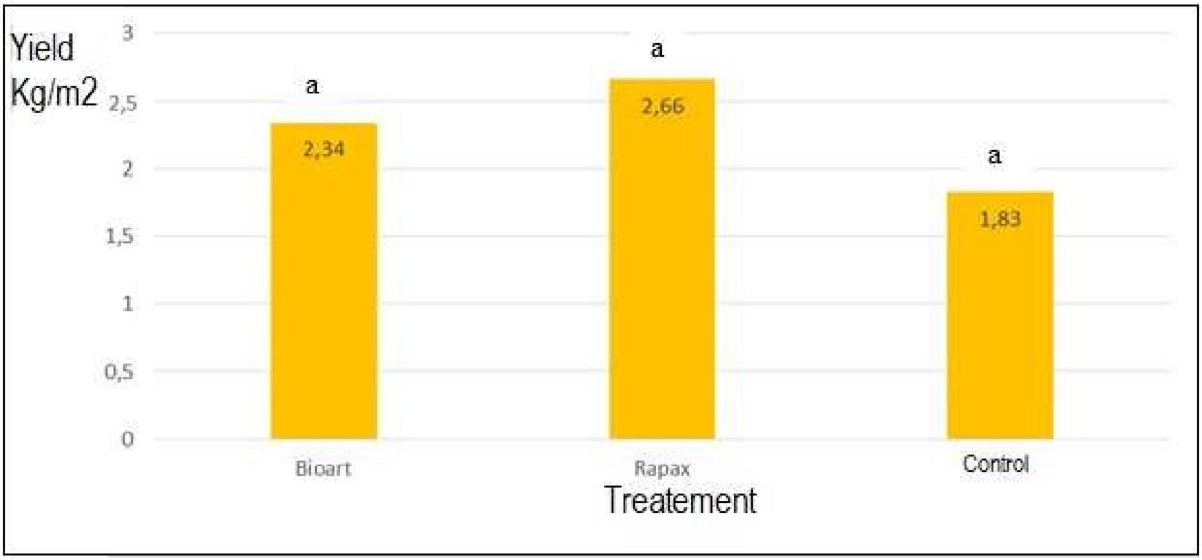

Fig. 7. Harvest yield in relation to different plots.

Effects of treatment on yields

The analysis of agronomic data shows that yields differ according to the treatment applied. Thus, it is necessary to point out that some plants had not yet completed their development cycle at harvest. This is because there was some delay in transplanting a few plants compared to other cabbage plants. However, plots treated with Rapax biocide yielded the highest yield. Plots treated with Bioart also yielded more than untreated controls. The latter had a higher level of infestation than the treated plots. These results are consistent with those of Sow *et al.*, 2013 which had the lowest yields in untreated controls. Higher cabbage yields in plots treated with biocides would be justified by the fact that treatments with biocides would have allowed the plants to be less attacked, be in good health and be more productive than plants on untreated plots. Similar results have been reported by several authors. Indeed, Mondedji *et al.*, 2014, in their study on the efficacy of aqueous extracts of *Azadirachta indica* against cabbage pests, obtained the highest marketable apple cabbage masses on plots treated with neem leaf hydro-ethanolic extract. Despite these results, yield does not vary significantly between plots. However, the application of Bioart treatment appears to have an effect on harvest yield, consistent with the studies of Amoabeng *et al.*, 2014 which have shown that natural products derived from plants can also increase yields with a cost/benefit ratio comparable to that of synthetic pesticides.

These results are very encouraging with respect to the possibility of making use of Bioart as a means of biological control against pests in order to avoid any treatment by conventional insects with adverse effects on man and the environment.

Conclusion

The research of phyto-insecticides is part of a strategy particularly adapted to the natural balance of the agricultural ecosystem while preserving the environment. The research work undertaken is part of the valorization of biological substances in pest control. Results obtained with the Bioart treatment in the control of cabbage pests reveal a decrease in the number of *P. xylostella* and *H. undalis*. Bioart had a remarkable insecticidal effect compared to the untreated control and the biologic Rapax. This is justified by the fact that plots treated with the Bioart product showed fewer leaves attacked by pests and also a higher absolute yield compared to untreated controls. From all the above, Bioart treatment appears as a good alternative in the management of cabbage insect pests, but its real effectiveness in the regulation of these pests deserves to be confirmed.

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