ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research

Vol. 12, Issue, 09, pp. 59181-59185, September, 2022

https://doi.org/10.37118/ijdr.25219.09.2022

RESEARCH ARTICLE OPEN ACCESS

THE EFFICIENCY OF BIOPESTICIDES, HYPTIS SUAVEOLENS, AZADIRACHTA INDICA AND ALLIUM SATIVUM IN CARROT PRODUCTION IN THE MUNICIPALITY OF PARAKOU (BENIN)

Yemadje A. S. Alda[1,*], Aïzoun Nazaire[2], *Sebo Vifan Eric L.S.C[3]* and Yome Gbèdji Stanislas[4]

[1]Higher Normal School of Technical Education (ENSET) Lokossa, National University of Sciences, Technologies, Engineering and Mathematics (UNSTIM), Abomey, BENIN, Multidisciplinary Research Laboratory for Technical Education (LaRPET); [2]Laboratory of Pluridisciplinary Researches of Technical Teaching (LaRPET), Normal High School of Technical Teaching (ENSET) of Lokossa, National University of Sciences, Technologies, Engineering and Mathematics (UNSTIM) of Abomey, P. O. Box 133 Lokossa; [3]National School of Public Works (ENSTP), National University of Sciences, Technologies, Engineering and Mathematics (UNSTIM), Abomey, BENIN, Laboratory of Geosciences, Environment and Application (LaGEA); [4]Department of Agricultural Sciences and Techniques/Higher Normal School of Technical Education (ENSET) Lokossa, National University of Sciences, Technologies, Engineering and Mathematics (UNSTIM), Abomey,

ARTICLE INFO

Article History:

Received 19th August, 2022
Received in revised form
11th August, 2022
Accepted 29th September, 2022
Published online 30th September, 2022

Key Words:

Parakou, Biopesticide, Pesticides, Pest, Carrot.

****Corresponding author:***
Yemadje A. S. Alda

ABSTRACT

Carrot production in the municipality of Parakou and in Benin in general encounters losses problems caused by pests, the great cost of chemical products as well as the dangers related to their misuse. Thus, the aim of this research is to assess the efficiency of three biopesticides solutions (Hyptis suaveolens, Azadirachta indica and Allium sativum) in order to promote them and improve carrot cultivation. The experimental device was a randomized complete block design with four repetitions and four treatments: (T0 = no biopesticide), (T1 = Allium sativum treatment), (T2 = Azadirachta indica treatment) and (T3 = hyptis suaveolens treatment). The statistical analysis of the data was performed using Excel software. The results from the biopesticide test of the three plant species have proven their effectiveness in varying proportions against the pests responsible for the damage or losses in the production of the carrot crop. The Allium sativum biopesticide solution show the best performance with crops free from crown rot, root galleries and plant death. Indeed, attacks were observed on the leaves with a low average of one attacked leaf per block. In terms of root weight, this treatment also has a higher yield with an average of 605g/1.5m2. From these results, the treatment with the solution of the biopesticide Allium sativum could be an alternative to synthetic pesticides in the framework of the integrated management of carrot pest groups.

Citation: ***Yemadje A. S. Alda, Aïzoun Nazaire, Sebo Vifan Eric L.S.C and Yome Gbèdji Stanislas.*** "The efficiency of biopesticides, hyptis suaveolens, azadirachta indica and allium sativum in carrot production in the municipality of parakou (benin)*", International Journal of Development Research*, 12, (09), 59181-59185.

INTRODUCTION

Agriculture is first and foremost the main foundation on which any confidence in food security rests. It is a major contributor to the national economy. The farmer must therefore ensure effective protection of these crops in order to achieve his objectives. Production losses of major world crops due to pests (insects, micro-organisms) and weeds are estimated at 35% (Popp ans *et al*, 2013 cited by J. Deravel *et al*, 2013, p. 220).

Since the green revolution in the 1960s, pesticides have been an integral part of the agricultural system (M. C. Laurin, 2007, p.1). They have become the main means of controlling so-called 'pests' in agriculture. The decrease in the number and diversity of beneficial organisms (predators and parasites), as well as the increase in the resistance of target organisms to these synthetic products, have led to an increasing use of pesticides (Haubruge and Amichot, 1998 cited by M. C. Laurin, 2007, p.2). Despite the benefits of the research work, the negative impacts are no less significant. Thus, the effectiveness of registered pesticides is not entirely safe because even if an adjuvant is considered inactive, it can become toxic depending on how it is applied (J. F Bourque, 1999 cited by C. Gagné, 2019, p.5). The fate of pesticides concerns the whole natural environment (soil, water, and air) but the soil remains a key compartment because a large proportion of the pesticides applied during crop treatment reach the soil through direct application and/or through foliage leaching (Calvet *et al*, 2005, cited by K. Ilyes and B. Redha, 2019, p.2). The application of chemicals does not spare market gardening activities, while the same causes always produce the same effects. Practices are becoming recurrent and vegetable crops once considered sacred commodities are becoming dubious in terms of quality. Carrots, a root vegetable in high demand thanks to its carotenoid content (provitamins A); group B vitamins; vitamin K and vitamin C; minerals such as potassium, calcium, magnesium and iron; and energy, are today confronted with the use of lambda super, Gammalin, etc., which are synthetic chemical products for the control of their main pests, including white flies (leaf and root pests) and certain locusts. These problems urge several researchers to develop other protective treatments for the environment and health. Examples include the use of nets, predators, neem oil and aqueous extracts of certain leaves. But expectations are not always met. This article is a contribution to the adoption of a policy of promoting biopesticide plants in order to have healthy and better quality crops.

Presentation of the study area: The municipality of Parakou is located between 9°15' and 9°27' of North latitude and 2°30' and 2°46' of East longitude. Capital of Borgou Department, it covers an area of nearly 441 km2; and is bordered to the north by the municipality of N'Dali, to the south, east and west by the municipality of Tchaourou. It is subdivided into three districts with a total of 58 neighborhoods (Municipality of Parakou, 2006, p.14) (Figure 1) and is the largest northern metropolis. The town enjoys a humid tropical continental climate, dominated by rainy and dry seasons. Average monthly temperatures range from 25 to 31°C.

Its population increased from 60,915 in 1979 to 254,254 in 2013, an increase of 76.04% in 34 years. The municipality of Parakou also recorded the highest growth rates with 3.86% between 1979 and 1992; 3.76% between 1992 and 2002 then 4.81% between 2002 and 2013 (I. Yolou *et al*., 2015, p.1089). This population growth has been accompanied by a growing demand for market garden produce. This has resulted in the misuse of chemicals to maximize yields and meet the ever-increasing needs of the population. This state of affairs constitutes a source of pollution for the environment, the crops, and a nuisance for the health of market gardeners and consumers.

MATERIAL AND METHODS

Trial site*:* The test was carried out in Wansirou district in the municipality of Parakou, especially in the third arrondissement.

Biological material : The 75-day cycle taki carrot variety was used. Aqueous extracts of Hyptis suaveolens, Azadirachta indica and Allium sativum were used for the phytosanitary treatment.

Material used for measurements: These are: a tape measure and a string, which are used to mark the boundaries of the plots and to make the seedpots, and a scale to weigh the quantity of compost, cow dung and crops. Data collection sheets for the parameters studied.

Fertilizers: The fertilizers used are cow dung and compost (well-decomposed organic matter) at a rate of 4kg/plot unit as a bottom dressing. Two other fertilizers are applied during vegetation, i.e. 2 kg three and six weeks after sowing respectively.

Preparation of water extracts

Azadirachta indica leaves (80g), Hyptis suaveolens leaves (0.3kg) and Allium sativum pods (50 g) were respectively pounded in a mortar until a paste-like content was obtained. The pasty content was introduced into a bowl containing one litre of soapy water;

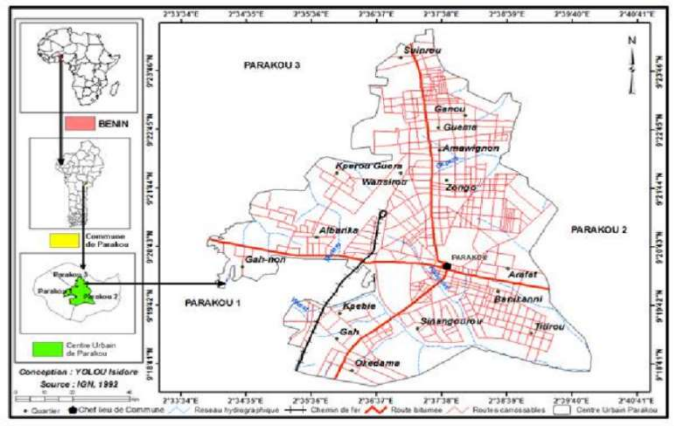


Figure 1. Geographical location of the municipality of Parakou

- Mixtures were obtained by maceration of the collected material for 24 hours in the dark;
- These mixtures were filtered through a fine sieve to collect the aqueous extracts;
- The resulting solutions were diluted with water;
- The filtrate is then poured into a backpack sprayer and the individual carrot plots are treated.

METHOD

The method is essentially one of data collection, processing and analysis of the results.

Data collection

The data collected is both quantitative and qualitative. They cover:

- demographic data: the population dynamics of the municipality of Parakou,
- climatic data: this includes rainfall and temperature data,
- Soil data: these include the types of soil in the municipality of Parakou,
- The data related to the parameters to be assessed: The number of attacked leaves, plants with crown rot, galleries, dead plants, then the average weight of the harvested roots.
- Data collection tools and techniques

Tools: This is the data collection sheet. It served as a support for recording data on observations made from sowing carrots to harvesting.

Data collection techniques

Documentary research: This consisted in the collection and exploitation of different existing documents on biopesticides and carrot cultivation. It allowed the identification of scientific works, reviews and articles necessary for the knowledge of the research area and the understanding of the production of carrot crops, the techniques of manufacturing and application of biopesticides and the different pests that disrupt carrot growth and development. The data from the different sources was supplemented by research on the internet.

Experimental device: The trial is single factorial with (04) application variants that constitute the treatments. It is fixed in a real environment (garden) in collaboration with the producers. The experimental device is the Fisher block. The plot unit is 1.5m2. For each treatment, 1.5 m2 x 4 was made taking into account the 04 repetitions. The sowing distances are respectively 20 cm between the rows and 10 cm between stakes, i.e. 75 plants/experimental unit of 1.5m2. Each plot unit receives the corresponding aqueous extract as a soil treatment.

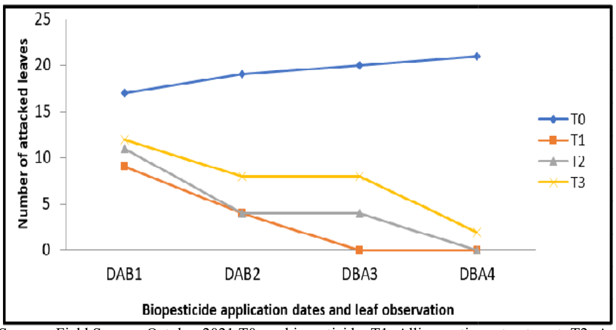
The treatments are defined as follows: (T0 = no biopesticide), (T1 = Allium sativum treatment), (T2 = Azadirachta indica treatment) and (T3 = hyptis suaveolens treatment). Four applications of biopesticides were made, a first 50 days after sowing and an interval of six after the first application for the others.

Sampling technique : Data were collected on the nine (09) plants located on the two diagonals of each elementary plot.

Data processing and analysis of results: The data collected in the observation grid were manually processed. The Excel spreadsheet was used for descriptive statistics. Means, standard deviations and coefficients of variation were carried out. The coefficient of variation was used to check the homogeneity of the variances in order to assess the level of significance of the differences observed on the effectiveness of the treatments applied to the parameters studied. The same spreadsheet was also used to create tables, graphs and curves. The map was made using Arc-View software. The analysis of the results was descriptive, analytical and comparative.

RESULTS

Influence of treatments on carrot leaves in relation to time: The different treatments had different effects on leaf attack by pests. The evolution of leaf attack as a function of time is shown in figure 2.



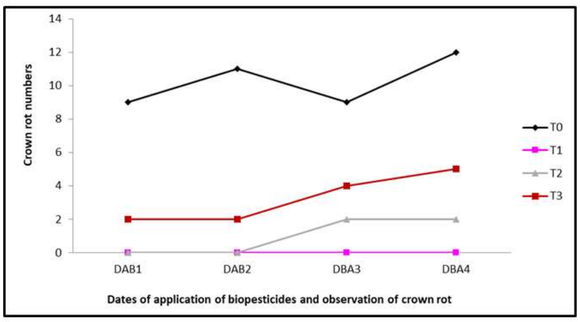
Source : Field Survey, October 2021 T0: no biopesticide, T1: Allium sativum treatment, T2: Azadirachta indica treatment, T3: hyptis suaveolens treatment, DAB1: First application of biopesticides (30/09/2021), DAB2: Second application of biopesticides (06/10/2021) DAB3: Third application of biopesticides (12/10/2021), DAB3: Fourth application of biopesticides (18/10/2021),

Figure 2. Evolution of the number of attacked leaves as a function of time

Figure 2 shows that the number of attacked leaves in the control (T0) increases with time but decreases in the biopesticide treatments. The decrease in the number of attacked leaves as a function of time seems similar for all treatments with biopesticides (T1, T2 and T3). However, it should be noted that over time, treatment T1 (Allium sativum treatment) did not experience any more leaf attacks, followed by treatment T2 (Azadirachta indica treatment).

Effect of treatments on collar rot of carrot crop by time

The effect of the different treatments on crown rot appears to vary with time (Figure 3).

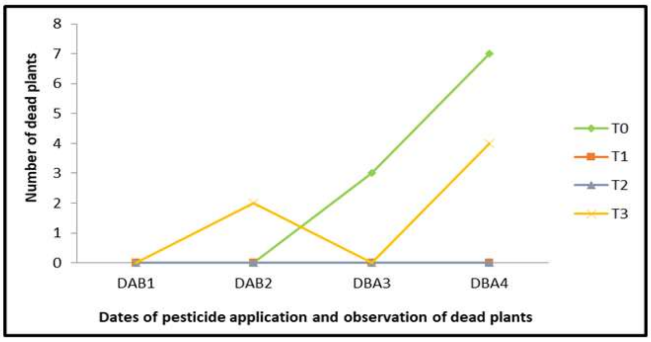


Source: Field Survey, October 2021 T0: no biopesticide, T1: Allium sativum treatment, T2: Azadirachta indica treatment, T3: hyptis suaveolens treatment, DAB1: First application of biopesticides (30/09/2021), DAB2: Second application of biopesticides (06/10/2021) DAB3: Third application of biopesticides (12/10/2021), DAB3: Fourth application of biopesticides (18/10/2021),

Figure 3. Evolution of the number of crown rots as a function of time

Figure 3 shows that the other treatments had few plants suffering from crown rot except the treatment without biopesticide (T0) which had a high number of plants with crown rot. However, no cases of crown rot were observed in treatment T1 (treatment with Allium sativum) over time.

Influence of the different treatments on the survival of the plants as a function of time: Figure 4 shows the influence of the treatments on the survival of the plants as a function of time.

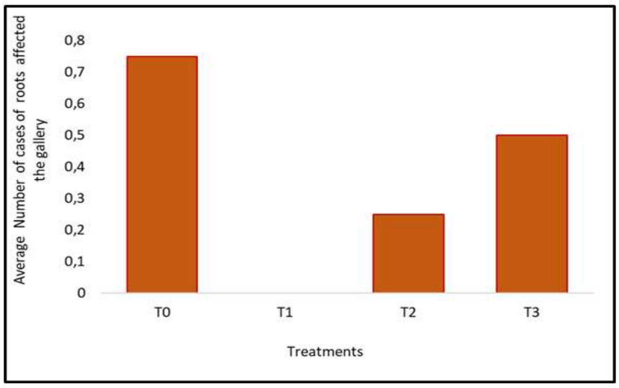


Source : Field survey, October 2021 T0: no biopesticide, T1: Allium sativum treatment, T2: Azadirachta indica treatment, T3: hyptis suaveolens treatment, DAB1: First application of biopesticides (30/09/2021), DAB2: Second application of biopesticides (06/10/2021). DBA3: Third application of biopesticides (12/10/2021), DAB3: Fourth application of biopesticides (18/10/2021),

Figure 4. Evolution of the number of dead plants as a function of time

Figure 4 shows that in treatments T1 (Allium sativum treatment) and T2 (Azadirachta indica treatment), no plant losses were observed. In contrast, plant losses were recorded in the other treatments. However, the number of dead plants was higher and evolved over time in the treatment without biopesticide (T0).

Comparative effect of treatment efficacy on attacked leaves, crown rot and plant survival: Table I shows the average number of cases counted for each parameter on nine carrot plants (average of four replications) and the coefficient of variation per treatment. It results from table I that all treatments have high coefficients of variation except treatments T1 and T2 which have zero coefficients of variation for crown rot and dead plants. The high coefficients of variation observed show that the efficiency of the treatments within each of the parameters studied (attacked leaves, crown rot and dead plants) is varied. This efficiency is then very different from one treatment to another for each parameter studied and is very significant between T0 (treatment without biopesticide) and the other treatments for leaf attack. For crown rot, the difference in effectiveness is highly significant between T1 (Allium sativum treatment) and the rest of the treatments. In terms of plant monitoring, the difference in efficacy is strictly significant for treatments T1 and T2 compared to treatments T0 and T3. But T1 and T2 treatments have similar characteristics in terms of efficacy (Figure 4).



Source: Fiels survey, October 2021

Figure 5. Average number of cases of roots affected by treatment

Table 1. Number of cases and coefficient of variation by parameter and treatment

Treatments	Number of cases for each parameter and coefficient of variation per treatment					
	Attacked leaves	CV (%)	Crown rot	CV (%)	Dead plants	CV (%)
T0	19	28,15	10	27,06	3	30,34
T1	03	47,84	00	00	00	00
T2	05	75,93	01	78,87	00	00
T3	08	83,16	03	105,75	02	57,74

Source: Field survey, October 2021

Table 2. Number of carrot fly disease cases, root weight and coefficient of variation per treatment

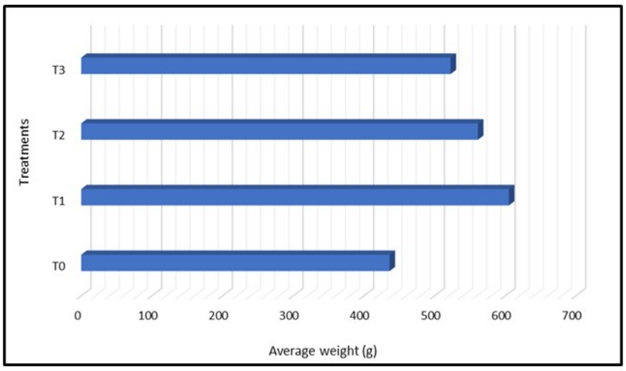
Treatments	Number of cases of carrot maggot disease and root weight (carrots) and coefficient of variation per treatment			
	Number of cases of MC disease	CV (%)	Sampled root weights (g)	CV (%)
T0	03	66,67	1745	10,64
T1	00	00,00	2420	06,29
T2	01	200	2245	01,52
T3	02	200	2090	04,02

Source: Field survey, October 2021, MC: Carrot flies

Effect of treatments on root diseases (carrot): Out of nine carrot plants (average of four replicates), six (06) cases of disease were recorded on the sampled roots. These (06) six cases are exclusively those of carrot flies that have dug galleries in the roots (Photo 1). Photo 1 shows fly larvae which penetrated and made galleries in the carrot, leaving rust-coloured spots. The number of carrots attacked by these pests in the selected sample varied according to the treatment (Figure 5). Figure 5 shows that T0 (treatment without biopesticide) recorded more cases of carrot fly attack. As for treatments T1 (Allium sativum treatment), T2 (Azadirachta indica treatment) and T3 (Hyptis suaveolens treatment), T1 did not record any cases of carrot fly attack. The analysis of the coefficients of variation (Table II) shows very strong inequalities in the effectiveness of the treatments against carrot fly attack on the sampled roots. Thus, the efficacy of the treatments against these pests is highly divergent and very significant between T0 (treatment without biopesticide) and the other treatments.

Shoot: Yêmadjè, October 2021

Photo 1. Galleries observed in the roots



Source: Field survey, October 2021

Figure 6. Average weight of roots (cores) sampled per treatment

Impact of treatments on root weight (carrot): The analysis of the coefficients of variation of the root weight parameter by treatment (table) reveals that the efficacy of the treatments is relatively similar. This means that the treatments had no significant effect on root weight. However, the observation of figure 6 shows that this parameter tends to vary in relation to the different treatments applied. Figure 6 shows that the roots that are treated with biopesticides (treatments T1, T2 and T3) have higher weights than the control treatment (T0: treatment without biopesticide). T1 (Allium sativum treatment) comes first with an average weight of 605 g. Treatment T2 (Azadirachta indica treatment) with an average weight of 561.25 g occupies the second place followed by treatment T3 with 522.5 g.

Relative effect of treatment efficacy on gallery and root weight: Table II shows the number of carrot fly disease cases, the weight of the nine carrot plants (average of four replications) and the coefficient of variation per treatment.

DISCUSSION

The control treatment (T0: treatment without biopesticide) shows a higher number of attacked leaves, dead plants, plants with crown rot and roots affected by carrot flies over time than the treatments with biopesticides (T1, T2 and T3). Treatment T1 (Allium sativum treatment) remained the best biopesticide. It was effective on all parameters. However, it was less effective and progressive over time in terms of leaf attack. This treatment is followed by treatment T2 (Azadirachta indica treatment) which also shows its limits in the parameters of attacked leaves, crown rot and root gallery damage. The biopesticide based on hyptis suaveolens (treatment T3) is the least efficient on all parameters studied. The statistical analysis also shows that the effectiveness of treatments on the parameters (leaf attack, crown rot, survival of plants and roots affected by the gallery) is heterogeneous and the inequalities are very significant. But in terms of plant survival, treatments T1 and T2 have similar characteristics in terms of efficacy and are not statistically different. The different aqueous extracts allowed the reduction of pests whose presence negatively impacts the development of the plants.

This situation can be fairly explained by the fact that biopesticides, although of low persistence, manage to keep the population of bio-aggressors below the nuisance threshold. This was confirmed by B.W. Amoabeng *et al*, 2014 cited by Y. Rabo1 *et al*, (2021 p. 715) who reported that plant extracts can have comparable efficacy to conventional insecticides under certain conditions. While this efficacy is not complete, it can nevertheless keep the pest population below the nuisance threshold. The efficacy of aqueous garlic extracts would be due to the sulphur constituents they contain, which have anti-pest, repellent, insecticidal, oviposition and larval development properties. Our results corroborate with those of Akaffou (2014) who evaluated the insecticidal activity of garlic on the coconut bug Pseudotheraptus devastans.

His research reveals that 72 hours after spraying the aqueous extract, the highest mortality rates of the adults of this insect were 47.07±1.51%, compared to 6.89±0.70% for the control while the number of bites observed after treatment of nuts with the extract was 4.25±0.25 compared to 18.25±1.5 for the control. Furthermore, the performance of the aqueous extract of neem leaves is believed to be due to its repellent, anti-appetant, ovicidal, larvicidal and growth regulating properties. Some authors have made the same findings. Déla *et al*. 2014 cited by F. Biao *et al*. (2018 p.6338) found that aqueous and hydroethanol extracts of neem leaves resulted in 95% mortality of Myzus persicae pupae as well as a decrease in adult survival and fecundity. According to Yarou and al, 2017 cited by F. Biao and al, (2018 p.6338), neem leaf extracts can affect oviposition in females as well as moulting and larval growth in a large number of pests, and they weaken the insects and inhibit their resistance. According to D. Bambara and J. Tiemtoré (2008, p. 54), neem leaves are known to possess insecticidal active substances such as azadirachtin ($C_{35}H_{44}O_{16}$), salanin ($C_{35}H_{44}O_9$) and nimbin ($C_{30}H_{30}O_9$). These authors stated that neem products are effective on stock insects and on Spodoptera litura. For the weight parameter, the analysis of the coefficients of variation showed a relatively similar efficiency in all treatments. The weight of the sampled roots is not influenced by the treatments. This implies that no significant difference is noted between treatments with respect to root weight. However, the roots that were treated with biopesticides (T1, T2 and T3) have higher weights than the control treatment (T0). The T1 treatment (Allium sativum treatment) comes first followed by the T2 treatment (Azadirachta indica treatment) with average weights of 605g and 561.25g respectively. The high yield observed in treatment T1 can be justified by the effectiveness of this treatment on the different parameters studied. For D. Bambara and J. Tiemtoré (2008, p. 54), it would be interesting to mix products and vary the doses of extracts in order to identify the best formula, as shown in other studies.

CONCLUSION

Carrot production in quality and quantity must take into account the control of diseases and various pest attacks (fungi, nematodes, insects). While all the biopesticide treatments applied were more effective than the control treatment without any application; that of garlic was more effective in the present work. It can thus be used as an alternative to synthetic pesticides in the integrated management of fungal diseases, nematode attacks, carrot flies and the various orders of insects that annoy carrot plants. The determination of the application frequencies of this plant extract and the development of formulations concentrated in active ingredients will favor its adoption, given its numerous properties, by gardeners who consider the difficulty of gathering the raw material and preparing plant extracts. The contribution of the public authorities to the promotion of biopesticides will constitute an asset to optimize the yield of agricultural products in general and market gardening in particular. This action will also help to alleviate the environmental and health problems caused by the misuse of pesticides and insecticides in agricultural and market gardening activities.

REFERENCES

Akaffou Tchimou Antoine, 2014. Insecticidal effect of the aqueous extract of Allium sativum: Liliaceae and Allium cepa: Liliaceae on the stages of development of Pseudotheraptus devastans DISTANT (Heteroptera: Coreidae), pp.37-39.

Arbuckle, T. E., Savitz, D. A., Mery L.S., et Curtis K. M., 1999. Exposure to phenoxy herbicides and the risk of spontaneous abortion, Epidemiology, vol.10, pp. 752-760.

Ayad-Monkhtari Nahida, 2012. Use and dosage of pesticides in agriculture and related environmental issues, p.11.

Yarou Boni Barthélémy, Silvie Pierre, Komlan Françoise Assogba, Mensah Armel, Alabi Taofic, Verheggen François, Frédéric Francis, 2017 : Pesticide plants and protection of vegetable crops in West Africa (bibliographical summary) ; Biotechnol. Agron. Soc. Environ. 2017 21(4), 288-304.

Bambara D. et Tiemtoré J., 2008 : Biopesticide efficacy of Hyptis spicigera Lam., Azadirachta indica A. Juss. and Euphorbia balsamifera Ait. on cowpea Vigna unguculata L. Walp., TROPICULTURA, 2008, 26, 1, 53-55.

Kossou Dansou K., Atachi Pierre, Annou Tohouédé E. Z and Ougourou Soulémane B, 2007: Evaluation of the insecticidal activity of two plants Hyptis suaveolens (Linn) and Khaya senegalensis (A. Juss) on insect pests of cowpea (*Vigna unguiculata* L. Walp.)/Use of two insecticidial plants for sustainable cowpea (*Vigna unguiculata* L. Walp.) protection, *Sciences & Nature Vol. 4 (1) 2007: pp. 17-26,* ISSN: 1812-0741.

Elleuch J., Tounsi S. & Zghal R. Z, 2016: Biopesticides formulated with Bacillus thuringiensis: reality and challenges, Moroccan Journal of Plant Protection, 2016, N° =10: 21-36.

Erikson, P. 1997: Developmental neurotoxicity of environmental agents in the neonate. Neurotoxicology, vol.18, no. 3, p. 719-726.

Formad environnement : neem or neem (*Azadirachta indica),* 2013, p.11

Haubruge, Éric et Amichot Marcel, 1998: Mechanisms responsible for insecticide resistance in insects and mites». Biotechnology, Agronomy, Society and Environment, vol. 2, no 3, p. 161-174.

YOLOU Isidore, 2016 : Market gardening activity in an urban environment in Parakou in North Benin: Characteristics and land issues, International Journal of Innovation and Applied Studies ISSN 2028-9324 Vol. 14 No. 4 Feb. 2016, pp. 1086-1095 © 2016 Innovative Space of Scientific Research Journals http://www.ijias.issr-journals.org/.

Jovana Deravel, François Krier & Philippe Jacques, 2013 : Biopesticides, supplements and alternatives to chemical phytosanitary products (bibliographic summary) Biotechnol. Agron. Soc. Environ. 2014 18(2), 220-232 pp.220-232

LAURIN Marle-Claude, 2007 : Biological and toxicological studies of pesticides used in Quebec apple growing on the predatory mite Anystis baccarum (l.) and critical analysis of Canadian and American pesticide toxicity assessment systems, p.1

Pohe Jean, Agneroh Thérèse Atcham, 2013: Neem seed oil, an alternative fungicide to copper oxide in the fight against brown rot of cocoa pods in Côte d'Ivoire, p. 4649

Popp J., Petö K. et Nagy J., 2013: Pesticide productivity and food security. A review. Agron. Sustainable Dev., 33, 243-255.

Popp J., Petö K. & Nagy J., 2013: Pesticide productivity and food security. A review. Agron. Sustainable Dev., p.243

Ramanou Y. M., Aboudou A., Joecker Christophe et Nica Ursula, 2003: The management of agricultural areas on the outskirts of West African urban centers: the case of Parakou au, p.3.

****