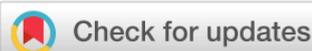


Original Research

View Article Online



Received 27 August 2021  
Revised 12 October 2021  
Accepted 13 October 2021  
Available online 14 October 2021

Edited by Carlos L. Cespedes  
Acuña

## KEYWORDS:

*Acanthoscelides obtectus*  
*Moringa oleifera*  
*Phaseolus vulgaris*  
Chemical characterization  
Insecticidal effect

Natr Resour Human Health 2022; 2 (2): 114-120  
<https://doi.org/10.53365/nrfhh/143056>  
eISSN: 2583-1194  
Copyright © 2022 Visaga Publishing House

## Chemical characterization and insecticidal effect of *Moringa oleifera* L. seeds extracts on common bean weevil (*Acanthoscelides obtectus* Say)

Thierry Atindo Songwe<sup>1,\*</sup>, Bekolo Ndongo<sup>1</sup>, Norbert William Tueguem Kuate<sup>1</sup>, Désiré Anaba Manga<sup>2</sup>, Patrice Zemko Ngatsi<sup>1</sup>, Mustafa Abdullah Yilmaz<sup>3</sup>, Kouadio Ibrahime Sinan<sup>4</sup>, Gokhan Zengin<sup>4,\*</sup>, Zachée Ambang<sup>1</sup>

<sup>1</sup>Department of Plant Biology, Phytopathology and Crop Protection Laboratory, Faculty of Science, University of Yaoundé I, PO Box 812, Yaoundé-Cameroon

<sup>2</sup>Department of Plant Biology, Environmental Management and Plant Production Laboratory, Faculty of Science, University of Yaoundé I, PO Box 812, Yaoundé-Cameroon

<sup>3</sup>Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Dicle University, Diyarbakir, 21280, Turkey

<sup>4</sup>Department of Biology, Physiology and Biochemistry Research Laboratory, Science Faculty, Selcuk University, Campus, Konya, Turkey

**ABSTRACT:** Some insects cause high losses of the common bean during storage, namely, *Acanthoscelides obtectus* Say. Chemical insecticides are commonly used to control insects, but their overuse adversely affects the environment and consumers' health. There is, therefore, the need for an alternative control method. This study was aimed to evaluate the chemical characterization and insecticidal property of *Moringa oleifera* seed extract on the developmental stages of *A. obtectus* in stored beans. Three types of *M. oleifera* seed extracts, namely methanol, ethanol and acetone extracts, were used at doses of 12.5, 25 and 50  $\mu$ l/ml each. HPLC-MS was used to characterize these extracts. The toxicity of extracts against the adults, the number of eggs and the viability rate of laid or emerged eggs of *A. obtectus* were evaluated. The results show that *M. oleifera* seed extract is rich in Hesperidin, Quinic acid, gallic acid, protocatechuic acid, 4-OH benzoic acid, cynaroside, isoquercitrin, cosmoisin, quercitrin, luteolin, naringenin, salicylic acid, Apigenin and Fumaric acid. The acetone extract, from day 2, showed a 100% mortality rate in all doses compared to about only 14% in the control treatment. The number of eggs laid in control (236.67) was higher than the null (0) in acetone treatment at 50  $\mu$ l/ml. *M. oleifera* seed extracts contain chemical molecules. They significantly reduced the damage caused by *A. obtectus* on stored *P. vulgaris* grains. Therefore, they can be used as an alternative to chemicals for the protection of stored foodstuffs.

## 1. INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is a food crop originating from Central and South America (Chacón et al., 2005). It is rich in starch, protein and plays an essential role in the human diet, especially in some tropical regions. Its high protein content makes it one of the most important food crops for people in the South (Blair et al., 2006; Broughton et al., 2003). Globally, the common bean is ranked as the most essential consumed food crop, with an estimated annual production of 26,902,672 tons on an area of 33,066,183

hectares in 2019 (Anonymous, 2019).

Cameroon is the second most cultivated leguminous after groundnuts, with a national estimated production of 413,723 tons on 307,020 hectares (Anonymous, 2019). The Western highland is the central production zone with a production of 284,676 tons on an area of 183,592 hectares in 2016 (Anonymous, 2017). Beans belong to the group of crops capable of fixing and using atmospheric nitrogen thanks to the rhizobium located in the nodules (Doucet, 1992).

However, due to the loss of weight and nutritional value, the control of storage pest is gaining importance (Baoua et al.,

\* Corresponding authors.

E-mail addresses: [panthierry@yahoo.com](mailto:panthierry@yahoo.com) (Thierry Atindo Songwe), [gokhanzengin@selcuk.edu.tr](mailto:gokhanzengin@selcuk.edu.tr) (Gokhan Zengin)

This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

2015; Czembor et al., 2015). Insect pests are therefore the major constraint to seed storage, and among these storage pests of common beans, *Acanthoscelides obtectus* (Say) (Coleoptera: Chrysomelidae: Bruchinae), is a common pest on legumes especially common bean (*Phaseolus vulgaris* L.). Several papers have been reported a important yield loss with the pest infection (Hagstrum & W, 2014; Savkovic' et al., 2019).

In order to solve these problems and ensure food security, many countries are using synthetic pesticides. Though effective and easy to use, their intensive and uncontrollable use has many drawbacks (Salim, 2011). These include; the appearance of resistant insect strains, consumer poisoning and environmental pollution (Belkebir, 2018; Guèye et al., 2011). Faced with these nuisances, the need for friendly alternatives to human health and the environment is necessary. Therefore, plant extracts could present a solution in regulating insect pests of grains stocks (Oliveira et al., 2020; Shah et al., 2017; Sherin, 2018; Sujatha et al., 2012). The antiparasitic activity of *Moringa oleifera* seeds has already been the subject of numerous studies, at the end of which it has been identified with fungicidal (Ayirezang et al., 2020), bactericidal properties (Valarmathy et al., 2010), insecticidal properties (Ezeaku et al., 2015; Oliveira et al., 2020; Shah et al., 2017; Sujatha et al., 2012). Given the biopesticide character of this plant, this study aimed to evaluate the chemical characterization and insecticidal effect of *Moringa oleifera* seed extracts on the developmental stages of *Acanthoscelides obtectus* in stored beans at different stages of its development.

## 2. MATERIAL AND METHODS

### 2.1. Material

#### 2.1.1 Plant material

The plant materials used were seeds of *Moringa oleifera* obtained in the mokolo market situated in Yaoundé. The common "MEX 142" bean variety (small white bean) was obtained from the Institute of Agricultural Research for Development (IRAD).

#### 2.1.2 Insect material

The insect populations of *Acanthoscelides obtectus* were reared in Polystyrene buckets under optimal conditions for their development (temperature 27 °C; relative humidity 75% for 15 days) following the method described by Damerджи (2009).

#### 2.1.3 Chemical material

The chemical material used in the experiment consisted of: Three extraction solvents: pure Acetone, Ethanol 90° and Methanol (100% pure alcohol); and Chemical insecticide: SINOGRAIN 2% Dp with 20 g of pyrimiphos methyl as the active ingredient.

### 2.2. Methods

#### 2.2.1 Preparation of organic extract

Mature *Moringa oleifera* seeds were previously dried at room temperature for seven days in the laboratory. These seeds were then weighed and ground to obtain the powder. 500 g of seed powder were weighed and macerated in 2 litres of organic solvent and incubated for 72 hours (Stoll, 1994). The whole solvent + solute was filtered, and the filtrate obtained was concentrated with a rotary evaporator.

#### 2.2.2 Phytochemical analysis

The chemical profiles of the studied extracts was determined by a Shimadzu brand LC-MS-8040 model tandem mass spectrometer. All analytical details were given in earlier paper (Yilmaz, 2020). The detailed analytical parameters of the applied validated method were given in Appendix A (Table S1).

#### 2.2.3 Insecticidal activity

**2.2.3.1 Collection and rearing of insects** Mass rearing was carried out on healthy common bean seeds (large red bean with white spots, black and white). After twenty days (time required for perfect oviposition), the rearing medium was sieved to remove all live and dead insects. The rest is then kept under the same conditions to allow a new generation of adult insects.

**2.2.3.2 In vivo evaluation of the insecticidal activity of the extracts** *In vivo* evaluation of the insecticidal effect of extracts was done at doses of 12.5, 25 and 50 µl/ml each. Extracts were obtained by diluting the volumes of crude extracts in 1 ml of ethanol. In each jar, 15 *A. obtectus* adults were introduced in transparent polystyrene jars containing pre-weighed 50 common bean seeds of the MEX 142 variety. To these, different doses of *M. oleifera* seed extracts were added. The negative control jars, prepared under the same conditions, were treated only with ethanol (1 ml). A synthetic insecticide, SINOGRAIN 2% DP (20 g pyrimiphos methyl as the active ingredient), commonly used to control insect pests of stored grains, was used as a positive control. The jars were arranged and stored randomly at a photoperiod of 12/12 h.

The mortality rate was calculated by the following formula (Singh & Jakhmola, 2011):

$$\text{Mortality rate} = (\text{Number of dead insects} / \text{Total number of insects}) \times 100$$

**2.2.3.3 Assessment of extract activity on egg-laying and emergence** The total number of laid eggs and the percentage of hatched eggs were counted. After the death of the insects introduced in different jars, the bean seeds were observed with a magnifying glass to count the eggs laid by the insects before their death. These seeds were then reintroduced into the same jars and kept until the new generation (F1) appeared. Once they had appeared, they were also counted. This allowed us to calculate the emergence rate following the formula used by Singh and Jakhmola (2011):

$$ER = ((AC-AT) / AC) \times 100$$

Where ER = Emergence rate; AC = Number of adults emerged in control jars; AT = Number of adults emerged in the treated jars

### 2.3. Statistical analysis

The data were subjected to one-way analysis of variance (ANOVA) using SPSS version 16.0 software. The multiple comparisons of means were made at the 5% threshold using the Duncan MRT (Multiple Range Test).

## 3. RESULTS

### 3.1. Phytochemical analysis

The data collected of the three extracts' chemical composition and the concentration of specific molecules were presented in Table 1. It was noted that extraction solvent affected the chemical composition of extracts. For instance, 12 and 13 molecules were found in the methanol and ethanol extract, respectively. Remarkably, of the 53 molecules, none was found in the acetone extract. Fumaric acid and 4-OH benzoic acid levels were highest in the methanol extract (1.263 and 0.570, respectively), suggesting that methanol might be more suitable for obtaining fumaric acid, quinic acid and 4-OH benzoic acid.

### 3.2. Effect of *M. oleifera* seed extracts on the mortality rate of *A. obtectus* adults

The survival of *A. obtectus* adults on the application of *M. oleifera* seed extracts is presented in Table 2. In general, adults of *A. obtectus* can survive for at least four days. However, the mortality rate was more pronounced in batches treated with *M. oleifera* extracts. The analysis of the mortality rate shows significant differences ( $P < 0.05$ ) between the treatments at the same concentrations. The increase in the mortality rate of treatment varies proportionally with the increase in concentration.

Methanol extract showed a higher mortality rate of 88.78%, 93.8% and 96.55% for the concentrations 12.5, 25 and 50  $\mu\text{l/ml}$  respectively on day 1. Contrarily, a low mortality rate of 7.80%, 13.94% and 60.6% was recorded in control on days 1, 2 and 3, respectively. Also, treatment with chemical insecticide had a mortality rate of 100% from the first day of treatment.

### 3.3. Effect of *M. oleifera* seed extracts on the egg-laying and emergence rate of *A. obtectus* adults

Data in Table 3 shows the number of eggs laid by *Acanthoscelides obtectus* adults and the emergence rate of the latter. In general, the different Moringa seed extracts significantly reduced egg-laying in *A. obtectus* adults and the emergence rate of *A. obtectus* lava ( $P < 0.05$ ) compared to the negative control. However, the number of eggs laid decreased with an increased concentration of extract used. These rates vary from 236.67 % in control to 0.00 % in the acetone extract treatment at a dose of C3 (EA3). On the other hand, there was no significant difference between the results obtained with

insecticidal treatment and the treatment with AE3, where no eggs were laid.

As concerns emergence rate, it decreased with an increase in the concentration of extracts used. Generally, no significant difference was observed in the control treatment (87.76 %), methanol extracts at a dose of C1 (ME1: 84.66 %) and ethanol extract at a dose of C1 (EE1: 84.39 %). Also, no significant difference was observed between treatments with insecticide and acetone at a dose of C3 (AE3), where no emerged insects were recorded

## 4. DISCUSSION

Three hundred gram of *Moringa oleifera* seeds extracted with methanol yielded 15.5 %, 19.1 % with acetone and 16.6 % with ethanol. The yield difference between the organic solvents is due to the solubility of the compounds, which depend on the properties of the solvent (Muhammad et al., 2013). Furthermore, the high polarity of organic solvents (methanol, ethanol, and acetone) would bind to many compounds in *M. oleifera* seeds, thereby increasing the extraction yield (Muhammad et al., 2013).

The toxicity results of *M. oleifera* seed extracts on *Acanthoscelides obtectus* show that its extracts influenced adult survival. This could be explained by the presence of secondary compounds in the extracts, such as Salicylic acid, Quinic acid, Hesperidin, Fumaric acid etc. According to Boulogne and Sciences du Vivant [q-bio] (2011), almost 116 molecules are identified to have insecticidal activity in plant extracts and the molecules most often responsible for this are terpenoids, alkaloids and phenolic compounds. However, the insecticide activity of organic extracts of *M. oleifera* is due to the biological activity of the compounds present in these extracts, which have an anti-nutritional effect and cause respiratory disorders. They inhibit nutrition and cause death and malformations in future generations of phytophagous insects (Carpinella et al., 2003). The results of this work are similar to those of Oliveira et al. (2020). They showed that phytochemical analysis of water extract (WE) from *M. oleifera* seeds and water-soluble lectin (WSMoL) revealed the presence of biological active components in WE. With the application of wheat flour with WE or WSMoL, the extract exhibited toxic effect to *S. zeamais*. In another study conducted by Ibrahim and Aliyu (2014), the application with African nutmeg oil and moringa seed oil exhibited the lowest hole number in the cowpea seeds. Moreover, Ouedraogo et al. (2016) showed that *Ocimum gratissimum* oil at the dose of 75  $\mu\text{l}$  causes 80% mortality of *Sitophilus zeamais* adults within 24h compared to 99.5% when 100  $\mu\text{l}$  of *Cimbopogon nardus* essential oil is used for 72h. After the application of 50  $\mu\text{l}$  of *O. gratissimum* oil for 48 h on the adults of *Rhyzopertha dominica*, the mortality rate was 100%.

The insects were able to lay eggs during the experimental period. This was observed from the presence of eggs in control and some treated jars. However, the significant differences ( $P < 5\%$ ) observed between the treated and control jars showed that the extracts influenced the laying of eggs. This result can

**Table 1**  
Chemical composition of the tested extracts (mg/g extract)

Chemical compounds	Methanol	Acetone	Ethanol	Chemical class	Biological activity	Reference
Hesperidin	0.006	nd	0.009	Flavonoid	Fungicide and insecticide	Ilboudo et al. (2016); Kopustinskiene et al. (2020)
Quinic acid	0.933	nd	0.297	Phénolic acid	Insecticide	El-Kady et al. (2010)
Fumaric acid	1.263	nd	0.153	Organic acid	Nd	Nd
Gallic acid	0.014	nd	0.013	Phénolic acid	Fungicide	Dang-Minh-Chanh et al. (2013)
Protocatechuic acid	0.051	nd	0.020	Phénolic acid	Fungicide	Nguyen et al. (2014)
4-OH Benzoic acid	0.570	nd	0.207	Phénolic acid	Nd	Nd
Cynaroside	nd	nd	0.012	Flavone	Fungicide	Amoroso et al. (2021)
isoquercitrin	0.037	nd	0.017	Flavonol	Fungicide	Buško et al. (2014)
Cosmosiin	nd	nd	0.003	Flavonoid	Nd	Nd
Quercitrin	0.089	nd	0.077	Flavonol	Fungicide	Buško et al. (2014)
Luteolin	0.003	nd	0.002	Flavone	Fungicide	Buško et al. (2014)
Naringenin	0.002	nd	nd	Flavonoid	Fungicide	Buško et al. (2014)
Apigenin	0.001	nd	0.001	Flavonoid	Fungicide	Buško et al. (2014)
Salicylic acid	0.030	nd	0.010	Phénolic acid	Fungicide, insecticide, growth hormone and stimulator of the natural defenses of the plant.	Dierycckx et al. (2015); Ola (2016)

nd: not determined

**Table 2**  
Effect of *Moringa oleifera* seed extracts on the mortality rate of *Acanthoscelides obtectus* adults

Treatments	Mortality rate per day (%)		
	Day 1	Day 2	Day 3
Control	7.80 <sup>h</sup> ± 1.25	13.94 <sup>d</sup> ± 0.76	60.6 <sup>d</sup> ± 2.91
ME1	88.78 <sup>e</sup> ± 1.07	94.43 <sup>b</sup> ± 1.46	100 <sup>a</sup> ± 00
ME2	93.8 <sup>c</sup> ± 1.08	100 <sup>a</sup> ± 00	100 <sup>a</sup> ± 00
ME3	96.55 <sup>b</sup> ± 0.35	100 <sup>a</sup> ± 00	100 <sup>a</sup> ± 00
EE1	82.07 <sup>g</sup> ± 1.92	86.17 <sup>c</sup> ± 0.84	93.33 <sup>c</sup> ± 00
EE2	86.83 <sup>f</sup> ± 0.47	93.88 <sup>b</sup> ± 0.96	95.33 <sup>b</sup> ± 1.73
EE3	90.87 <sup>d</sup> ± 0.31	97.77 <sup>b</sup> ± 0.35	100 <sup>a</sup> ± 00
AE1	88.22 <sup>e,f</sup> ± 0.19	100 <sup>a</sup> ± 00	100 <sup>a</sup> ± 00
AE2	91.11 <sup>d</sup> ± 1.92	100 <sup>a</sup> ± 00	100 <sup>a</sup> ± 00
AE3	96.37 <sup>b</sup> ± 0.19	100 <sup>a</sup> ± 00	100 <sup>a</sup> ± 00
Chemical insecticide	100 <sup>a</sup> ± 00	100 <sup>a</sup> ± 00	100 <sup>a</sup> ± 00
<b>Means</b>	<b>83.85<sup>a</sup> ± 25.72</b>	<b>91.67<sup>a</sup> ± 25.83</b>	<b>95.39<sup>a</sup> ± 11.76</b>

The same letter markings indicate insignificant differences, and markings with different letters have significant differences at the level of  $p \leq 0.05$  (Duncan test). ME: methanol extract; EE: ethanol extract; AE: acetone extract. 1: concentration 1 (12.5  $\mu\text{l/ml}$ ); 2: concentration 2 (25  $\mu\text{l/ml}$ ) and 3: concentration 3 (50  $\mu\text{l/ml}$ )

**Table 3**  
Variation in the number of eggs laid by *Acanthoscelides obtectus* adults and their viability rate according to the different treatments

Treatments	Number of eggs laid	Emergence rate (%)
Control	236.67 <sup>a</sup> ± 9.6	87.76 <sup>a</sup> ± 4.7
ME1	56.67 <sup>c</sup> ± 3.05	84.66 <sup>a</sup> ± 2.48
ME2	23 <sup>e</sup> ± 2.64	73.62 <sup>ab</sup> ± 6.02
ME3	2.66 <sup>g</sup> ± 0.57	17.77 <sup>c</sup> ± 13.47
EE1	79 <sup>b</sup> ± 3.6	84.39 <sup>a</sup> ± 1.09
EE2	35.667 <sup>d</sup> ± 2.52	80.27 <sup>ab</sup> ± 3.66
EE3	9.33 <sup>f</sup> ± 2.31	65.28 <sup>b</sup> ± 16.83
AE1	51.67 <sup>c</sup> ± 1.53	82.03 <sup>ab</sup> ± 5.72
AE2	14.33 <sup>f</sup> ± 3.21	79.34 <sup>ab</sup> ± 3.48
AE3	0 <sup>g</sup> ± 00	-
Chemical insecticide	0 <sup>g</sup> ± 00	-

The same letter markings indicate insignificant differences, and markings with different letters have significant differences at the level of  $p \leq 0.05$  (Duncan test). ME: methanol extract; EE: ethanol extract; AE: acetone extract. 1: concentration 1 (12.5  $\mu\text{l/ml}$ ); 2: concentration 2 (25  $\mu\text{l/ml}$ ) and 3: concentration 3 (50  $\mu\text{l/ml}$ )

be explained because the seed extracts' toxicity at these doses would have prevented the adults from laying eggs before dying. This phenomenon is confirmed by the emergence rate where a low appearance of individuals was observed in the treated batches compared to the untreated batches. This result could be explained by the fact that the extracts caused the insects' early death, reducing egg-laying by the females or the non-viability of the eggs laid. The results are similar to those of Sherin (2018), who obtained 84.64% of oviposition in the control batches with little or no oviposition treated with *M. oleifera*, *Simmondsia chinensis* and *Prunus dulcis* oil at 25, 30 and 35% concentrations.

In the presence of Moringa extract, the emergence of F1 individuals of *A. obtectus* showed a decrease in the number of emerged individuals with an increase in the doses of Moringa oil applied. The maximum reduction was observed at a dose of 50 µl/ml. This decrease in emerged individuals could be due to a reduction in gas exchange between the *A. obtectus* larva and the medium, increasing with the concentration. These results agree with those of Wahedi et al. (2013) who showed that neem seed extract significantly prevented the emergence of F1 adults of *C. maculatus*, and no subsequent weight loss was made due to pests. Moreover, Sherin (2018) obtained a maximum reduction (100%) in the emergence of *Callosobruchus maculatus* F1 for concentrations of 25, 30 and 35% of Jojoba, Moringa, Fenugreek and sweet almond oils. Woguem (2017) obtained complete inhibition of F1 emergence of *A. obtectus* with a dose of 1.6 µl/g of *Mondia whitei* essential oil and 0.64 µl/g of *Echinops giganteus* essential oil.

## 5. CONCLUSION

This work has demonstrated the biopesticidal potential of *M. oleifera* extracts against *Acanthocelides obtectus* in stored *.vulgaris*. It also presented the substances present in the extracts of *M. oleifera* seeds that could be responsible for its biopesticidal activity and their effect on the viability and multiplication of *A. obtectus* in natural conditions. However, the results obtained show that the substances contained in *M. oleifera* seed extracts are likely to reduce the infestation of common bean seeds in storage by the pest *A. obtectus*. Therefore, it is clear that using *M. oleifera* seeds from 25 µl/ml in the control of *A. obtectus* is an alternative to chemical control.

## CONFLICTS OF INTEREST

Given his role as Associate Editor, Gokhan Zengin has not been involved and has no access to information regarding the peer review of this article. Full responsibility for the editorial process for this article was delegated to Co-Editor Carlos L. Céspedes Acuña. There is no conflict of interest among the authors or any other person.

## ACKNOWLEDGMENTS

Authors are thankful to the members of the Laboratory of Plant Biotechnology and Environment, Plant Pathology and Protection Research Unit of the Department of Plant Biology

and Physiology, Faculty of Science, University of Yaoundé I for providing laboratory facilities.

## ORCID

Thierry Atindo Songwe	0000-0001-5618-0192
Bekolo Ndongo	0000-0002-2479-8382
Norbert William Tueguem Kuate	0000-0002-3591-0085
Désiré Anaba Manga	0000-0002-0534-1600
Patrice Zemko Ngatsi	0000-0001-6416-4918
Mustafa Abdullah Yilmaz	0000-0002-4090-7227
Kouadio Ibrahim Sinan	0000-0002-5165-6013
Gokhan Zengin	0000-0001-6548-7823
Zachée Ambang	0000-0003-2133-3130

## A. APPENDIX. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at <https://doi.org/10.53365/nrhh/143056>.

## AUTHOR CONTRIBUTIONS

TAS, NB - Research concept and design, WNKT - Collection and/or assembly of data, WNKT, DMA, MAY, KIS - Data analysis and interpretation, DMA, PNZ, MAY, KIS - Writing the article, PNZ, GZ, ZA - Critical revision of the article, GZ, ZA - Final approval of the article.

## REFERENCES

- Amoroso, V.B., Mendez, A.R., Junio, H.A., Molino, R.J.E., Pescadero1, I.R., Villalobos, A.P., 2021. Characterization of a natural fungicide from an indigenous plant *Tasmania piperita* (hook.f.) Miers extract: stability, metabolomics, and in silico studies. *Philippine Journal of Science*. 150(2), 355–370.
- Anonymous., 2017. *Annuaire statistique du secteur agricole du Cameroun*, . .
- Anonymous., 2019. <http://www.fao.org/faostat/en>. Date accessed: September 2021
- Ayirezang, F.A., Azumah, B.K., Achio, S., 2020. Effects of Moringa oleifera leaves and Seeds Extracts against Food Spoilage Fungi. *Advances in Microbiology*. 10, 27–38. <https://doi.org/10.4236/aim.2020.101003>
- Baoua, I.B., Amadou, L., Abdourahmane, M., Bakoye, O., Baributsa, D., Murdock, L.L., 2015. Grain storage and insect pests of stored grain in rural Niger. *Journal of Stored Products Research*. 64, 8–12. <https://doi.org/10.1016/j.jspr.2015.04.007>
- Belkebir, S., 2018. Évaluation de l'effet insecticide, sur les pucerons, de l'extrait aqueux de feuille et fleur de Moringa oleifera Lam.
- Blair, M.W., Muñoz, C., Garza, R., Cardona, C., 2006. Molecular mapping of genes for resistance to the bean pod weevil (*Apion godmani* Wagner) in common bean. *Theoretical and Applied Genetics*. 112, 913–923. <https://doi.org/10.1007/s00122-005-0195-9>
- Boulogne, I., Sciences du Vivant [q-bio], 2011. Evaluation du potentiel insecticide et antifongique sur *Acromyrmex octospinosus* (Reich) d'une sélection de plantes à usages ethnopharmacologiques TRAMIL.

- . <https://hal.inrae.fr/tel-02810978/document>
- Broughton, W.J., Hernandez, G., Blair, M.W., Beebe, S., Gepts, P., Vanderleyden, J., 2003. Beans (*Phaseolus* spp.) Model Food Legumes. *Plant and Soil*. 252, 55–128. <https://doi.org/10.1023/A:1024146710611>
- Busko, M., Góral, T., Ostrowska, A., Matysiak, A., Walentyn, Perkowski, J., 2014. The Effect of *Fusarium* Inoculation and Fungicide Application on Concentrations of Flavonoids (Apigenin, Kaempferol, Luteolin, Naringenin, Quercetin, Rutin, Vitexin) in Winter Wheat Cultivars. *American Journal of Plant Sciences*. 5, 3727–3736. <http://dx.doi.org/10.4236/ajps.2014.525389>
- Carpinella, C., Defago, T., Valladares, G., Palacios, M., 2003. Antifeedant and insecticide properties of alimonoid from *Melia azedarach* (Meliaceae) with potential use for pest management. *Journal of Agricultural and Food Chemistry*. 51, 369–374. <https://doi.org/10.1021/jf025811w>
- Chacón, M.I., Pickersgill, S.B., Debouck, D.G., 2005. Domestication patterns in common bean (*Phaseolus vulgaris* L.) and the origin of the Mesoamerican and Andean cultivated races. *Theoretical and Applied Genetics*. 110, 432–444. <https://doi.org/10.1007/s00122-004-1842-2>
- Czembor, E., Stepien, L., Waskiewicz, A., 2015. Effect of environmental factors on *Fusarium* species and associated mycotoxins in maize grain grown in Poland. *PloS One*. 10, e0133644. <https://doi.org/10.1371/journal.pone.0133644>
- Dang-Minh-Chanh, N., Dong-Jun, S., Hyang-Burm, L., In-Seon, K., Kil-Yong, K., Ro-Dong, P., Woo-Jin, J., 2013. Antifungal activity of gallic acid purified from *Terminalia nigrovenulosa* bark against *Fusarium solani*. *Microbial Pathogenesis*. 56, 8–15. <https://doi.org/10.1016/j.micpath.2013.01.001>
- Dieryckx, C., Gaudin, V., Dupuy, J.W., Bonneau, M., V, G., D, J., 2015. Beyond plant defense: insights on the potential of salicylic acid and methylsalicylic acid to contain growth of the phytopathogen *Botrytis cinerea*. *Plant Science*. 6, 859. <https://doi.org/10.3389/fpls.2015.00859>
- Doucet, R., 1992. *La Science Agricole: Climat, Sol et Population végétale du Québec*. Deuxième édition revue., pp. 653–653.
- El-Kady, A.M.A., Mohamed, A.I., Mohamady, A.H., 2010. Insecticidal activity of citric acid and its soluble powder formulations against *Aphis craccivora* under laboratory conditions. *Egyptian Academic Journal Biological Science; F. Toxicology and pest control*. 2(1), 7–12. <https://dx.doi.org/10.21608/eajbsf.2010.17457>
- Ezeaku, P.I., Ndubuaku, U.M., Ndubuaku, T.C.N., Ike, E., Ike-mefuna, P., 2015. Effects of *Moringa oleifera* leaf extract on morphological and physiological growth of cassava and its efficacy in controlling *Zonocerus variegatus*. *African Journal of Biotechnology*. 14(32), 2494–2500. <https://doi.org/10.5897/AJB2015.14534>
- Guèye, M.T., Seck, D., Wathelet, J.P., Lognay, G., 2011. Lutte contre les ravageurs des stocks de céréales et de légumineuses au Sénégal et en Afrique occidentale: synthèse bibliographique. *Biotechnol. Agron. Soc. Environ.* 15(1), 183–194.
- Hagstrum, D., W, F.P., 2014. Modern stored-product insect pest management. *Journal of Plant Protection Research*. 54, 205–210. <https://doi.org/10.2478/jppr-2014-0031>
- Ibrahim, N.D., Aliyu, S.M., 2014. Evaluation of plant seed oil and bitter leaf powder for their repellency and control of cowpea beetle (*Callosobruchus maculatus* Fab.) (Coleoptera: Bruchidae) in stored cowpea. *Research Journal of Agriculture and Environmental Management*. 3(8), 370–375.
- Ilboudo, O., Bonzi, S., Tapsoba, I., Somda, I., Bonzi-Coulibaly, Y.L., 2016. In vitro antifungal activity of flavonoid diglycosides of *Mentha piperita* and their oxime derivatives against two cereals fungi. *Comptes Rendus Chimie*. 19, 857–862. <https://doi.org/10.1016/j.crci.2015.11.023>
- Kopustinskiene, D.M., Jakstas, V., Savickas, Bernatoniene, J., 2020. Flavonoids as Anticancer Agents. *Nutrients*. 12(2), 457. <https://doi.org/10.3390/nu12020457>
- Muhammad, Z., Sadia, H., Komal, R., Nasir, R., Muhammad, R., Zia-Ul-Haq, M., Vincenzo, D.F., 2013. Antioxidant potential and oil composition of *Callistemon viminalis* leaves. *Scientific World Journal*. 2013, 489071. <https://doi.org/10.1155/2013/489071>
- Nguyen, X.H., Naing, K.W., Lee, Y.S., Moon, J.H., Lee, J.H., Kim, K.Y., 2014. Isolation and characteristics of protocatechuic acid from *Paenibacillus elgii* HOA73 against *Botrytis cinerea* on strawberry fruits. *Journal of Basic Microbiology*. 54, 1–10. <https://doi.org/10.1002/jobm.201400041>
- Ola, S.M.A., 2016. Effect of salicylic acid and its mixtures with three insecticides on some cotton insect pests. Thesis of master degree., pp. 89–89.
- Oliveira, S.P.A.D., Agra-Neto, C.A., Pontual, V.E., Lima, T.D.A., Cruz, V., Melo, C.K.D., Oliveira, R.K.D., Coelho, S.A., Ferreira, B.B.C.L., Soares, A.R.A., Napoleão, L.A.L., Paiva, H.T., P, G.M., 2020. Evaluation of the insecticidal activity of *Moringa oleifera* seed extract and lectin (WSMoL) against *Sitophilus zeamais*. *Journal of Stored Products Research*. 87, 101615. <https://doi.org/10.1016/j.jspr.2020.101615>
- Ouedraogo, I., Sawadogo, A., & dakouo, D.C.N.R., 2016. Evaluation de la toxicité des huiles essentielles de *Cymbopogon nardus* (L) et *Ocimum gratissimum* (L) contre *Sitophilus zeamais* Motsch et *Rhyzopertha dominica* F, les principaux insectes nuisibles au maïs en stockage. *International Journal of Biological and Chemical Sciences*. 10(2), 695–705. <https://doi.org/10.4314/ijbcs.v10i2.20>
- Salim, M.M., 2011. Evaluation de l'effet insecticide et de la persistance des huiles essentielles de *Callistemon viminalis* G Don, de *Xylopi aethiopica* Dunal et de *Lippiache valieri* Moldenke sur *Callosobruchus maculatus* Fabricius et *Sitophilus zeamais* Motchulsky, principaux ravageurs des stocks du niébé et du maïs. Mémoire de Master II. 13, 35. <https://doi.org/10.4314/ijbcs.v13i3.46>
- Savkovic', U., Đorđević' m Stojkovic', Stojković, B., 2019. Potential for *Acanthoscelides obtectus* to Adapt to New Hosts Seen in Laboratory Selection Experiments. *Insects*. 10, 153. <https://doi.org/10.3390/insects10060153>
- Shah, F.M., Razaq, M., Ali, A., Han, .P., J, C., 2017. Comparative role of neem seed extract, moringa leaf extract and imidacloprid in the management of wheat aphids in relation to yield losses in Pakistan, Nicolas Desneux., pp. 24–24.
- Sherin, M.M.Y.H., 2018. Insecticidal and biological effects of four plant oils on the cowpea beetle, *Callosobruchus maculatus* (F.). *Journal of Entomology and Zoology Studies*. 6(2), 3111–3118.
- Singh, P., Jakhmola, S.S., 2011. Efficacy of botanical extracts on biological activities of pulse beetle *Callosobruchus maculatus* (Fab.) On green gram. *Trends in Biosciences*. 4(1), 25–30.
- Stoll, G., 1994. Protection naturelle des végétaux en zone tropicale. CTA AGRECOL, 95–99.
- Sujatha, A.S., Prabhudas, P, P., 2012. Efficacy of pulverised leaves of *Annona squamosa* (L.), *Moringa oleifera* (Lam.) and *Eucalyptus globulus* (Labill.) against the stored grain pest, *Tribolium castaneum* (Herbst.). *Recent Research in Science and Technology*. 4, 19–23.
- Valarmathy, K., Gokulakrishnan, M., Kausar, M.S., Kusum, P., 2010. A study of antimicrobial activity of ethanolic extracts of various plant leaves against selected microbial species. *International Journal of Pharma Sciences and Research (IJPSR)*. 1(8), 293–295.
- Wahedi, J.A., David, L.D., Edward, A., Mshelmbula, B.P., Bullus, A., 2013. Efficacy of seed powder and extracts of *Azadirachta indica*

- Linn. (Meliaceae) at graded levels on adult *Callosobruchus maculatus* (Coleoptera: Bruchidae) in nubi, north - eastern Nigeria. *International Journal of Science and Nature*. 4(1), 138–141.
- Woguem, V., 2017. Etude des activités insecticide, antifongique, antioxydante, antiproliférative et caractérisation chimique des huiles essentielles de cinq plantes aromatiques du Cameroun. *Sciences and Technology*, 140–140.
- Yilmaz, M.A., 2020. Simultaneous quantitative screening of 53 phytochemicals in 33 species of medicinal and aromatic plants: A detailed, robust and comprehensive LC-MS/MS method validation. *Industrial Crops and Products*. 149, 112347–112347. <https://doi.org/10.1016/j.indcrop.2020.112347>