Final Project Report (to be submitted by 20th September 2018)

Instructions:

- Document length: maximum 10 pages, excluding this cover page and the last page on project tags.
- We welcome the submission of Annexes (i.e. bachelor or master thesis, references, species lists, maps, drawings, pictures) to further HeidelbergCement's understanding and future use of your findings, however they will not be reviewed by the Jury, and we kindly ask for these to be sent separately to the National Coordinators.
- Please use the attached template for species data collected during the project and submit with the project report.
- Word/PDF Final Report files must be less than 10 MB.
- If you choose to submit your final report in your local language, you are required to also upload your final report in English if you wish to take part in the international competition.
- To be validated, your file must be uploaded to the Quarry Life Award website before **20th September** 2018 (midnight, Central European Time). To do so, please log in, click on 'My account'/ 'My Final report'.
- In case of questions, please liaise with your national coordinator.
- You should not publish additional private information in your final report (e.g.: address, day of birth, email-address, phone number), just complete the categories we ask for below under "Contestant profile".

The final reports should comprise the following elements:

For research stream projects:

- Abstract (0,5 page)
- Introduction :
  - For projects that are building upon a previous project, write a summary of actions that were already completed in the previous project.
  - Project objectives
- Methods: a detailed description of the methods used during the project is required.
- Results: the results of the project should be outlined and distinguished from the discussion.
- Discussion:
  - Results should be analysed and discussed with reference to region/country taking into account other publications.
  - Outline the added value of the project for science and for the quarry / company.
  - Recommendations and guidance for future project implementation and development on site is requested. Where possible, please mention the ideal timing and estimated costs of implementation.
- Final conclusions: a short summary of results and discussion.

For community stream projects:

- Abstract (0,5 page)

- Introduction
  - For projects that are building upon a previous project, write a summary of actions that were already completed in the previous project.
  - Project objectives
  - A short description of the site and the team members and the targeted audience of the project.
- Actions and activities: a detailed description of planned or implemented actions and outreach activities done to elaborate the project, list of stakeholders involved.
- Discussion:
  - Project teams should discuss the pros and contra and illustrate experiences.
  - Outline the added value of the project for biodiversity, the society and the quarry / company.
- Deliverables: practical implementation and development recommendations of the project are required. Where possible, please mention the ideal timing and estimated costs of implementation.
- Final conclusions: a short summary of the project findings and discussion.

1. Contestant profile

▪ Contestant name:	**Dr. TOUNDOU Outéndé; WOGLO Iréné**
▪ Contestant occupation:	**Dr. TOUNDOU Outéndé**: Associate Researcher (Université de Lomé) in Plant Physiology and Soils Fertilization. **WOGLO Iréné**: Pedologist and Cartographer (SNPT, Togo)
▪ University / Organisation	Université de Lomé; SNPT (National Phosphate Society of Togo).
▪ Number of people in your team:	**12**

2. Project overview

Title:	**Natives plants and geo-ecological mapping to improve soil fertilization and vegetables production**
Contest: (Research/Community)	**Research: Beyond Quarry Borders**
Quarry name:	Tabligbo East quarry (Sika-Kondji)

Abstract

Agriculture is the key force of economic development in Africa. However, this sector faces several problems among which land degradation and climate change are relevant. In mining areas, the installation of plants and quarries also reduces arable land and its fertility thus promoting the use of fertilizers. Around the SCANTOGO mining area, more than 60% of farmers are mainly market gardeners and face this scourge. The present study is a part of this framework and aims at contributing better vegetable production via an efficient planting of plant species. All this is possible by the use of local spontaneous biofertilizing and bioinsecticide species associating fertility mapping for sustainable use of agricultural soils and reforestation. From this work, it appears that:

- *Chromolaena odorata* and *Pseudovigna argentea* are the two main spontaneous biofertilising plant species whose development into compost or green manure will help improve vegetable production in the study area;
- four (4) spontaneous bioinsecticide plant species have been identified and a protocol for their development into bioinsecticide has been set up. These are *Chromolaena odorata*, *Morinda lucida*, *Azadirachta indica* and *Ludwigia decurens*. So, aqueous extract from the mixture of dry powders of these species leaves, used at the dose of 100% revery 03-04 days reduces by 76-81.5% the attack of cultures by pathogens. In the same time, chemical insecticide used according to the prescribed dose (diluted at 20%) every 04 days allows pathogens attack by 79%;
- among pathogen agents of vegetable crops in the area, *Aphtona spp* is the most dangerous insect which affects the production and the yield of garden coret and okra;
- farmers and the company have now a soil fertility map for the use of agricultural land and reforestation of the area.

One can note that some of the identified species are listed by IUCN as invasive ones. The development of these species in agriculture is then a way to reduce their proliferation. The results of this project contribute to increase the list of fertilizing and bio-insecticide plants of local Togolese flora and the implementation of the map for agricultural land use in order to boost agriculture and reforestation. The achievements of this project could be used by the HSSE departments of company for social responsibility and the whole community for a sustainable and harmonious development.

Key words: local spontaneous plants; biofertilizers; bioinsecticides; Agricultural Land Use Map; vegetable crops; reforestation.

Final report

1. INTRODUCTION AND OBECTIVES

The installation of a mining unit involves the cutting of plant species and the occupation of agricultural land. These phenomena constitute a constraint on the protection of biodiversity and the reduction of poverty. The Tokpli district (located in the south-east of Togo) is a mining area occupied by SCANTOGO Mines SA (an industrial unit of Heidelbergcement) which extracts limestone from the subsoil of the zone. The peoples of the villages in this mining zone are essentially farmers whose main crops are market gardeners. First, these crops face some problems including soil degradation and common pathogenic attacks. Facing these problems, farmers use chemical fertilizers and insecticides. However, these chemical fertilizers do not generally provide all the needed elements for plants. In addition, the mere use of chemical fertilizers and insecticides causes the loss of soil fertility, the erosion of biodiversity, and the proliferation of several diseases for peoples. Secondly, despite the presence of environmental services and social responsibility in the Tokpli mining area that reforest more than 20.000 plants per year of about 10 different species, the situation is that the survival rate of reforested plants is usually less than 50%. This does not boost efficiently the plant species diversity of this area. This phenomenon indicates that some reforested plant species are not adapted to the soil type on which they are put in.

According to its environmental plan action, SCANTOGO seeks to promote organic farming and agroecology in its implantation zone in order to help the population to preserve the soil, the biodiversity, and human health by contributing to the achievement of the SDGs. The use of local spontaneous plant species fertilizing and insecticidal properties is a way for sustainable agricultural production with preservation of biodiversity and human health (Carsky *et al.,* 1999; Eagleshan *et al.,* 1982; Sogbedji *et al.,* 2006;. INS, 1988; Ayeva, 1993; Toundou *et al.,* 2014; Bokobana *et al.,* 2016).

This project fits into this context and has the general objective of contributing to better production of market garden crops and efficient and sustainable reforestation through the use of biofertilizers and bioinsecticides associated with a global geo-ecological mapping.

Specific objectives aim to:

• make an inventory of spontaneous plant species with potential fertilizing and insecticide effects in the study area;

• establish a correlation between the soil types, the edaphic requirements of the dominant market gardening crops, and the species used in the reforestation program of the area;

• evaluate the effects of the main bio-fertilizing plant species and bioinsecticides on the two abundant vegetable crops in the study area;

• set up a practical protocol for the development and use of the bioinsecticide based on the identified insecticidal plants.

2. MATERIAL AND METHODOLOGY

2.1. Presentation of the study area

The study area is mainly composed of market gardening soils of the villages bordering the SCANTOGO mining zone (Sikakondji, Tokpli district). These villages are: Ziome-Kondji, Asu-Kondji, Anagonou-Kpota, Nyinda-kondji, and Ahlimegnikondji. Indeed, these villages are the ones immediate of the quarry and their agricultural land area is occupied by more than 50% by the mining activities. Figure 1 (in annex) presents the map of the area with the location of agricultural market gardens in relation to the quarry and the mine.

2.2. Methodology of ethnobotanical surveys, floristic inventories, and selection of fertilized and bioinsecticide plant species

The surveys were carried out by questioning individually and in focus groups approaches to the residents of the 5 villages (Ahlimegni Kondji, Anagonou Kpota, Assou Kondji, Nyinda-kondji, and Ziome kondji). They are all aged at least 18, without distinction of sex, occupation, ethnicity, and level of education. The questions focused on: knowledge of biofertilizing and bioinsecticide plants, the most common vegetable crops that use more fertilizers and insecticides, and the main pathogens which attack these vegetable crops in the area. Table 1 (in annex) presents the number of respondents by sex and village. The species mentioned by peoples were collected and identified at the Laboratory of Botany and Plant Ecology of Université de Lomé.

In order to get some biofertilizing and bioinsecticide species out of the survey but present in the area, 2 scientific reports (Kokou *et al.,* 2016, Mabafei, 2016) in the literature were checked.

An oriented floristic inventory was then obtained from the list of species from survey and those identified in the literature. This inventory allowed the determination of the frequencies of different species identified.

In order to select the leading species that could have good impact in agriculture, 3 criteria-questions have been set: Is the species usually mentioned in the literature? If so, can be found in the area? If more so, does it grow spontaneously? Based on these issues, it has been possible to select the species which have the potentiality to be developed as biofertilizers and bioinsecticides.

2.3. Physicochemical characterization of farming soils, and identification of adapted soils to garden crops and reforested species in the area

In order to identify the different types of soils in the study area and their physicochemical characteristics, the whole area has been partitioned into 16 sections (Figure 2 in annex). Homogeneous samples were prepared from samples taken at each section to obtain in total 8 homogeneous samples. Chemical analyzes (contents of organic matter, nitrogen, total phosphorus, calcium, potassium, and pH) and particle size analyzes were performed on these samples after drying, grinding, and sieving processes. These analyzes were done in the Analytical Laboratories of the Graduate School of Agronomy at "Université de Lomé" and at the Togolese Institute of Agronomical Research (ITRA).

The suitable soils for market garden crops and for species to be reforested were determined using 3 databases (**www.génial.vegetal.net**, **www.aujardin.info**, **Pl@ntUse**) and the literature.

The XLSTAT software was then used to establish a correlation between the physicochemical characteristics of soils and the 5 most abundant market garden crops and between the physicochemical characteristics of soils and the species usually used in the reforestation program. This approach allowed the identification of market garden crops and plant species suitable to each type of soil in the area.

In order to locate the species adapted to each type of soil in the area, a geo-ecological map has been drawn up. The geo-ecological global map was designed after the establishment of a database and the calculation of the Pearson correlation coefficient between several variables such as N, P, K, Ca, MOT, pH, granulometric parameters (clay, sand, and gravel), and needs in minerals and soil types for the plant species to be reforested and the 5 main vegetable crops. All this incorporated into the Qgis and Paint software's, the map was then developed. This map highlights the synthesis - degree of soil degradation (comparison between nutrient contents in the soils of the bordering villages to the quarry on the one hand, and the area rehabilitated during the exploitation on the other hand) - the physicochemical parameters of the different soils, their texture - the plant species to be reforested according to their affinity with the various parameters raised - the main vegetable crops.

2.4. Fertilizing effects of selected spontaneous plant species

After the identification of biofertilizing plant species, their fertilizing potentials must be reversed or confirmed by agronomical tests. Thus, the poorest soil was used to assess the fertilization potential of the biofertilizing species identified. Table 2 presents the main physicochemical characteristics of this soil.

Table 2: Physico-chemical characteristics of soil used for agronomic tests

Organic Matter (%)	pH	Nitrogen (%)	Potassium (ppm)	Phosphorus (ppm)	Clay (%)	Limon (%)	Fine Sand (%)	Coarse Sand (%)	gravel (%)
5.07	7.63	0.0134	1252.75	2.15	4.6	9.5	58.2	27.4	0.3

The fertilizing potential of these plant species has been evaluated in the form of green manures. Thus, the aerial biomass (leaves and fresh stems) of the fertilizing species was harvested. After drying under ambient conditions for about a week, they were ground and buried in the soils of plots at a dose of 1 kg/m^2 according to experimental plan. The experimental system consists of 5 treatments corresponding to the green manures of the three selected species, their mixture and one control treatment. Each experimental plot occupies an area of 5 m^2 with 48 plants per plot. The two most common vegetable crops in the area (*Abelmoschus esculentus; Corchorus olitorius*) are those used for these agronomical tests. The height and number of leaves of the plants per treatment as well as the number of fruits are the main parameters evaluated.

2.5. Bioinsecticide effects of selected spontaneous plant species

To determine the bioinsecticide effects of the selected species, extraction of the fresh leaves was performed according to the slightly modified method of Liwayway (2017) and Sukhthankar *et al.* (2014) at Laboratoire Chimie Organique et des Substances Naturelles (Lab COSNat) of "Université de Lomé". So, the leaves of each species were collected and dried at room temperature in the laboratory for a week. They were then ground and sieved. Extraction was prepared for each powder sample (100g of powder in 1 L of Alcohol). Flasks were put in the dark for 3 days and filtration was performed using Wattman#2 paper. The filtrates were used for agronomical tests on okra (*A. esculentus*). Here, experimental system plot consists of 6 treatments including extracts of the 5 selected species and one control treatment. The filtrates were diluted at 10% with water (10 ml water/100 ml extract) before use. 60 mL of the obtained extract was sprayed over 100m^2 per plot every 7 days. The evaluated parameter is the number of plant specimens from which more than half of the leaves were affected by pathogens after 9 weeks of treatment.

After getting fertilizing effects of the 5 species, it is important to set up a practical method accessible common peoples of the zone. For this, 100 g of dry powder of the 4 best species were mixed with 4 L of local drilling water (Satti *et al.,* 2010, Udebuani *et al.,* 2015). After stirring manually for 5 minutes, the mixture was placed in the dark for 4 days while taking care to stir it every 24 hours. Then, two successive agronomical tests were conducted to get the economic and effective dilution dose and the efficient frequency of treatment. For the dose identifying test, 0%, 25%, 50%, 75%, and 100% are the different doses tested under 1L/100m^2 (30 ml for the 3m^2) in comparison with a chemical insecticide (LAMBDA POWER) diluted to 20% before applying.

After identifying the effective dose, a frequency test was performed to determine the most effective treatment frequency. Thus, the 100% effective dose identified was used at frequencies of 1 day, 2 days, 3 days and 4 days. Both tests lasted 2 weeks (14 days) after plants germination. The number of flea beetles (*Aphtona spp*: common pathogenic insect) per plot is the main parameter collected daily for the 2 tests.

3. RESULTS

3.1. Biofertilizing plants, bioinsecticides, different vegetable crops, and the main pathogens in the study area

- **Biofertilizing plants and selected species for the promotion of market gardening in the area**

Ethnobotanical surveys, floristic inventories, and bibliographic research have identified in all 10 spontaneous plant species in the area (Figure 3). These are *Chromolaena odorata*, *Lonchocarpus sericeus*, *Sorghum arundinaceum*, *Imperata cylindrica*, *Pseudovigna argentea*, *Launaea taraxacifolia*, *Typha australis*, *Physalis unguiculata*, *Mucuna poggei*, and *Commelina benghalensis*. Among them, 3 species fulfill the criteria (frequency, citations in the literature, spontaneous aspect of their regeneration) for their selection for fertilizing (biofertilizers). These are *Chromolaena odorata*, *Lonchocarpus sericeus,* and *Pseudovigna argentea*. Table 3 presents some references that testify to the use of these species in soil fertilization.

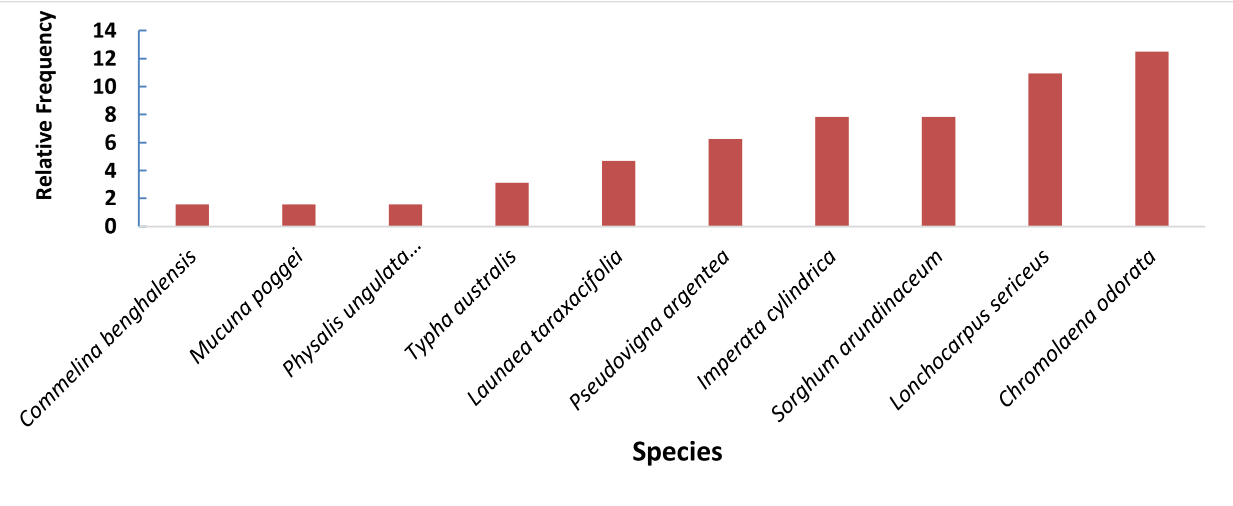

Figure 3: Identified spontaneous biofertilizing plant species and their relative frequencies in the study area

Table 3: Biofertilizing plant species selected in relation to the set criteria for their development in market gardening in the zone

Species	Families	Some references showing their fertilization properties
Chromolaena odorata	Asteraceae	Ognalaga *et al.* (2016); Ognalaga *et al.* (2015), Anaclet *et al.* (2017)
Lonchocarpus cericeus	Fabaceae	ICRAF (1996)
Pseudovigna argentea	Fabaceae	Robert et Harter (2009); IITA (1992).

- **Bioinsecticide plants and selected species for the promotion of market gardening in the area**

Ethnobotanical surveys, floristic inventories and bibliographic research have identified 5 bioinsecticide plant species in the area (Figure 4). These are *Chromolaena odorata*, *Mallotus oppositifolius*, *Morinda lucida*, *Azadirachta indica*, and *Ludwigia decurens*. All these species have met the criteria for their development as bioinsecticides. Table 4 presents some references that classify these plants as species with bioinsecticide property.

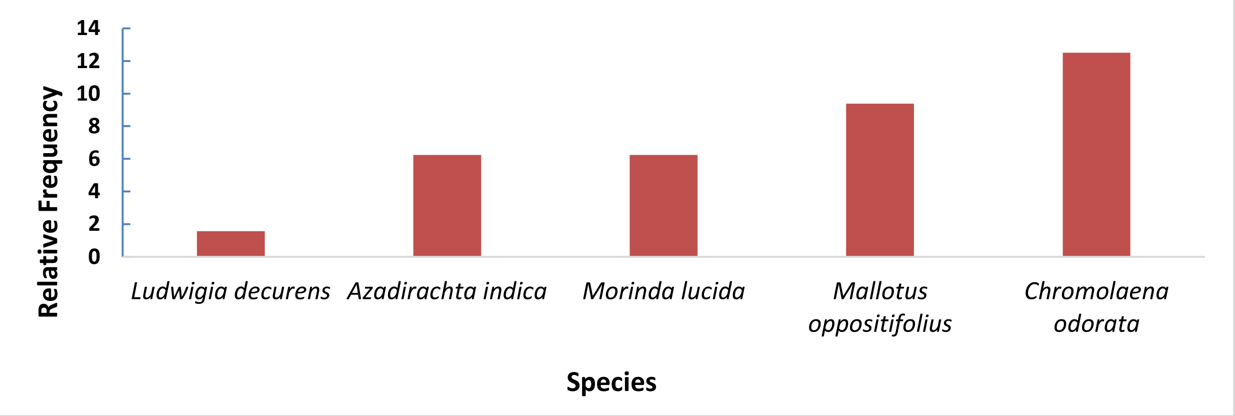

Figure 4: Spontaneous bioinsecticide plant species identified in the study area

Table 4: Bioinsecticidal plant species selected in relation to the fixed criteria for their valorisation in market gardening in the zone

Species	Families	Some references showing their bioinsecticid properties
Chromolaena odorata	Asteraceae	Owolabi *et al.* (2014); Degri *et al.*(2013); Onunkun(2012); Sukhthankar *et al.*(2014); Liwayway(2017); Udebuani *et al.*(2015)
Mallotus oppositifolius	Euphorbiaceae	Agyare *et al.*(2014); Kukuia *et al.* (2012)
Morinda lucida	Rubiaceae	Olufunmilayo(2012)
Azadirachta indica	Meliaceae	Seck(1997); Degri *et al*.(2013); Mondal et Chakraborty(2016); Satti *et a*l.(2010); Lokanadhan *et al.* (2012); Boadu *et al*.(2011)
Ludwigia decurens	Onagraceae	Oyedeii *et al*.(2011)

- **Main vegetable crops in the study area**

Ethnobotanical surveys have identified 14 vegetable crops in the area including the vegetable garden coret (*Corchorus olitorius*), okra (*Abelmoschus esculentus*), tomato (*Solanum lycopersicum*), chili (*Capsicum annuum*), and spinach (*Solanum macrocarpon*).

- **Main pathogens affecting vegetable crops in the area**

The main pathogens against market garden crops in the study area are insects (80%) and worms (20%). Of these insects ***Aphtona spp.*** and ***Harmonia axyridis*** are the most notable (Photo 1 in annex). After the first set of tests, it appears that *Aphtona spp.* is the most devastating insect that should be controlled in the area for sustainable development.

3.2. Physicochemical characteristics of the soils and the relationships between these characteristics; the 5 main vegetable crops and the plant species included in the reforestation program

- **Relationship between the physicochemical characteristics of the study area's soils and the 5 main market garden crops: identifying the adapted soil types for the main vegetable crops in the zone**

The results of the Principal Components Analysis allow establishing a link between the soils of the different villages and the 5 main market gardening crops in the area (Figure 5 in annex). The results show that tomato (*S. Lycopersicum*) and chili pepper (*C. annuum*) can grow and produce better on Ahlimegni soils. Okra (*A. esculentus*) might best succeed on Asukondi soil while spinach (*S. macrocarpon*) on Ziome-kondji and Anagonou-kpota soils. However, the garden coret (*C. olitorius*) does not exhibit any requirements for soil types. It can therefore produce on all types of soils.

- **Correlation between the physicochemical characteristics of the soils and the plant species included in the reforestation program of the zone: identifying soil types adapted to the plant species programmed for the reforestation of the area.**

The results of the Principal Component Analysis also allow identifying suitable soils for each plant species included in the reforestation program (Figure 6 in annex). For instance, *Salix babilonica*, *Khaya senegalensis*, *Eucalyptus spp.*, and *Terminalia superba* are more suited to slightly acidic clay soils which are rich in organic matter of Ahlimegni area (Sikpe, Trime and village). *Acacia auriculiformis*, *Azadirachta indica*, *Cola gigantea*, and *Albizia Zigya* can grow better on the slightly basic sandy soils of Anagonou-kpota and Ziome-kondji. However, species near the center of axes are not selective and can be reforested on all soils in the area.

- **Synthesis geo-ecological map: synthesis of the relationships between physicochemical characteristics of soils, the 5 main vegetable crops, and the species included in the reforestation program of the zone**

Figure 7 (in annex) presents the geo-ecological global map that allows simultaneous apprehension of the links between the physicochemical characteristics of the soils, the 5 main vegetables crops, and the species included in the reforestation program of the zone. In addition, this map allow the easy location of the soils adapted to each market gardening and plant species in order to boost the farmers' economy and the effectiveness of reforestation in the area. For instance, when one focus on the Ahlimegnikondji - Trime area (South East of the map), the following information can be gotten:

- physico-chemical characteristics of the soil: pH = 6.6-6.7; Total Organic Matter = 7.5-9.5; Clay content = 32-79% (clayey acidic soil moderately rich in organic matter)

- Main vegetable crops and plant species adapted to this soil: (1) *Khaya senegalensis*; (3) *Terminalia superba;* (4) *Gmelina arborea*; (8) *Citrus spp*; (11) *Eucalyptus*; (12) *Salix babilonica*; (16) *S. lycopersicum*; (18) *S. macrocarpon*; (19) *C. annuum*.

3.3. Fertilizing potential of selected plant species

The evaluation and the confirmation of the fertilizing potential of the selected biofertilizing plants on the 2 main market garden crops in the area enabled the histograms of Figures 8a, 8b and 9 to be plotted. Green manures of *Chromolaena odorata* and *Pseudovigna argentea* provided good growth and production in garden coret and okra compared to control ones. Pictures 2 and 3 in the annex shoWw the appearance of okra plants and garden coret according to the different treatments.

3.4. Bio-insecticidal effects of the selected bioinsecticide plant species, the dose and the using frequency of the mixture obtained from the 4 best species

- **Evaluation and confirmation of bioinsecticide potentials of selected plants**

The first bioinsecticide potential test allowed classifying species according to their effects (Figure 10). From the most efficient to the least, we have: *Ludwigia decurens*, *Morinda lucida*, *Chromolaena odorata*, *Azadirachta indica*, and *Mallotus oppositifolius*.

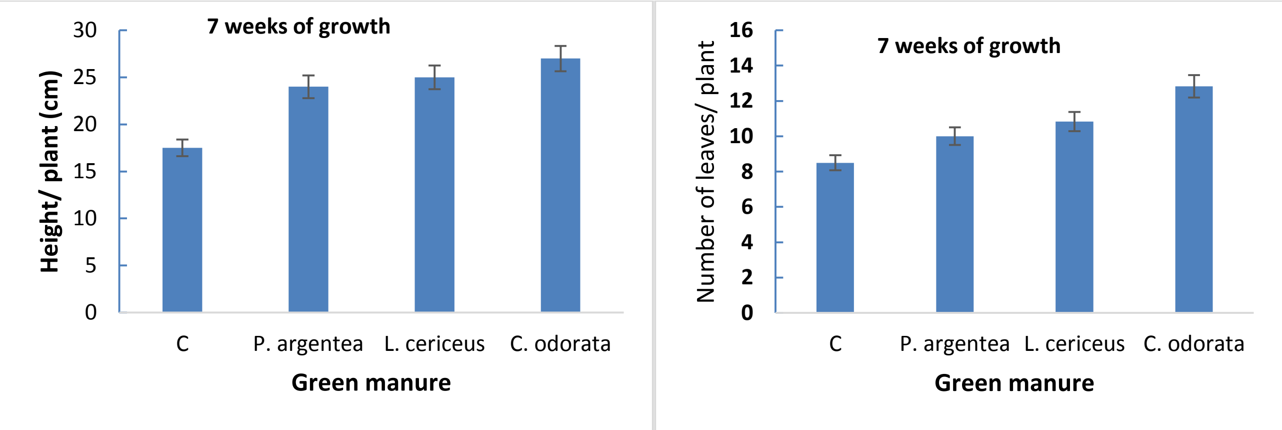

Figure 8 (from left to right, 8a and 8b): Effects of Selected Biofertilizing Plants on Okra Growth and Yield (C= Control Treatment)

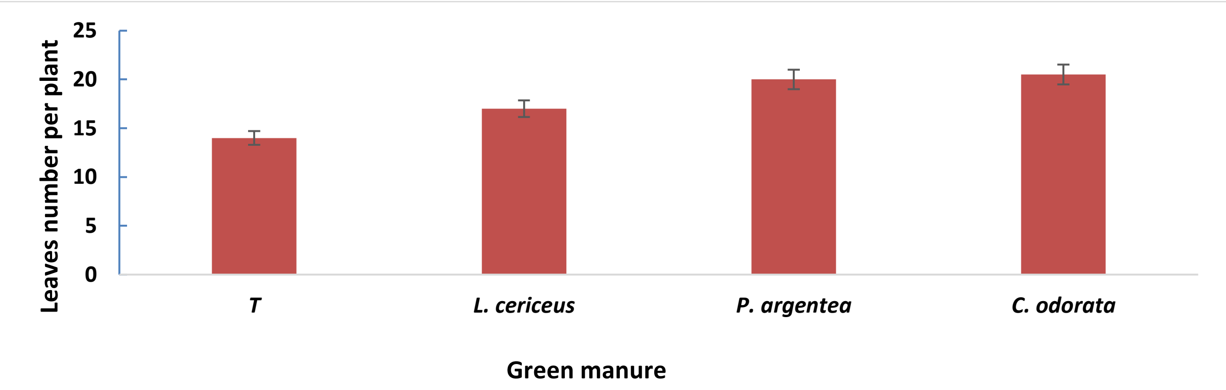

Figure 9: Effects of the selected biofertilizing plants on the growth and yield of the garden coret (T = Control Treatment)

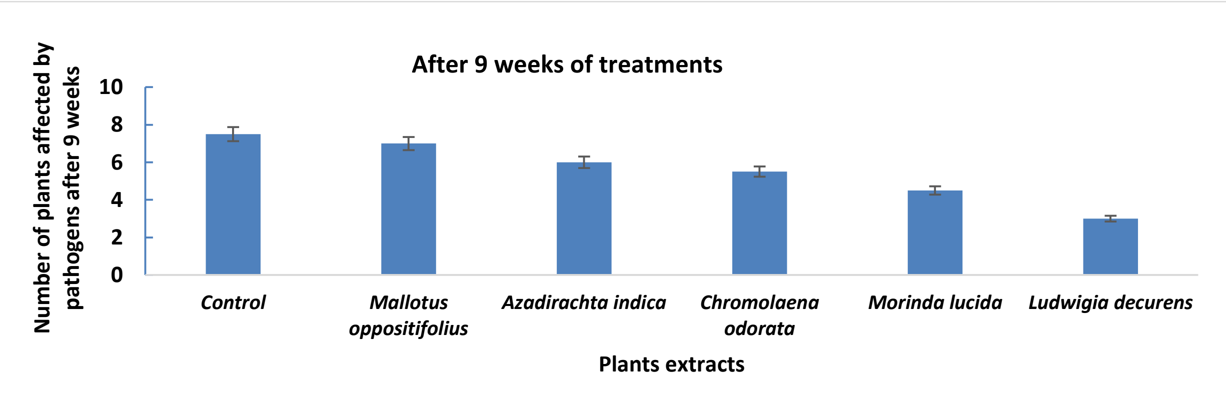

Figure 10: Effects of bioinsecticides species on the number of plants affected by pathogens after 9 weeks of treatment

- **Efficient doses and frequency of treatment of the mixture of the 4 best extracts samples**

Efforts to identify the efficient dose and the frequency of treatment show that bioinsecticide which is used at a dose of 100% and under a frequency of 4 days produces results similar to those of the chemical insecticide (Figure 11 and Table 5).

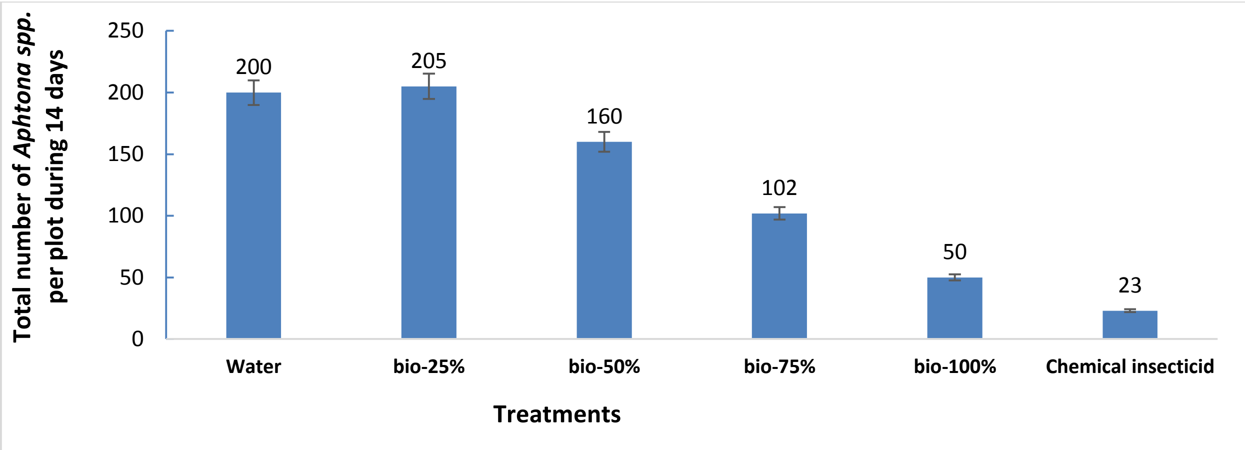

Figure 11: Effects of bioinsecticide doses vs Number of *Aphtona spp.*

Table 5: Treatment frequency parameter evaluated with bioinsecticide 100% (bio-100%) on the number of *Aphtona spp.*

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Average Number of insects	Treatment Efficiency Rate (%)
Bio-100% /Freq. 1 day	36	24	14	9	12	13	10	7	11	16	8	9	8	13	11,8462	88,1538
Bio-100% /Freq. 2 days	29	-	40	-	30	-	19	-	28	-	13	-	10	-	23,3333	76,6667
Bio-100% /Freq. 3 days	57	-	-	19	-	-	25	-	-	18	-	-	12	-	18,5	81,5
Bio-100% /Freq. 4 days	32	-	-	-	34	-	-	-	21	-	-	-	17	-	24	76
Chemical /Freq. 4 days	40	-	-	-	31	-	-	-	15	-	-	-	17	-	21	79

The day 1 was not taken into account since it is the number of insects (Aphtona spp) counted before administrating the Bioinsecticide.

4. GENERAL DISCUSSION

4.1. Ethnobotanical surveys and floristic inventories

Seven (7) plant species have been identified as good biofertilizing and bioinsecticide species for the promotion of market gardening in the study area. It should be noted that the presence of some of these species in this area has already been reported (Kokou 2016, Mabafei 2016). These are *Morinda lucida*, *Chromolaena odorata*, *Azadirachta indica*, *Mallotus oppositifolius*, and *Lonchocarpus sericeus*. However, to the best of our knowledge the presence of *Ludwigia decurens* and *Pseudovigna argentea* was not been reported. In addition, some of these plants are underutilized especially in the treatment of some diseases. With regard to their farming uses, only *Azadirachta indica* was locally known for its bioinsecticide properties. So, this study then grants skills to the population for a better use of these local plant genetic resources. Among these species, 2 are listed as invasive plants in West Africa. These are *Chromolaena odorata* and *Azadirachta indica* (IUCN, 2015). An intense economic development of these invasive exotic species might allow obtaining ecological benefits while protecting the environment.

Aphtona spp. and *Harmonia axyridis* are the main pests of vegetable crops in the study area. Their negative impacts on market garden crops have already been reported by some authors. Indeed, Gilles *et al.* (2005), Lambert (2010), Bourchier and Robert (2004), Bidiga and Nacro (2016) have pointed out that these insects help to reduce the yield of crops by destroying the leaves of plants. One control approach of these pests will improve vegetable production in the study area.

4.2. Correlation between the physicochemical characteristics of soils, the 5 main vegetable crops, and the species included in the reforestation program

Edaphic factors are an important component for the growth, development, and production of a plant. This supposes that before any growing or cultivation, it is important for the farmer to know the physicochemical characteristics of the soil. The concept of fertility mapping for farming land and reforestation, developed in this study, solves this issue. Thus, the Principal Component Analyzes and the geo-ecological global map allow establishing correlation between the different soil types (the physicochemical characteristics of soils) and the plants grown in the area. The geo-ecological global map then constitutes cartography for the agricultural use and the reforestation in the zone in a reasoned approach. Indeed, there are 3 types of soils in this study area: clay soils slightly acidic rich in organic matter, sandy-clay soils moderately rich in organic matter, and slightly basic sandy soils very poor in organic matter. Taking these parameters into account before any cultivation and reforestation in the area will boost agriculture (farmers' economy) and biodiversity.

4.3. Fertilizing potential of tested biofertilizing species

The best growth and production rates obtained in plants grown under green manures from *Chromolaena odorata* (several floristic studies have highlighted the invasive potentiality of this plant in Africa) and *Pseudovigna argentea* can be explained by the nutritional properties of these plants (Ognalaga *et al.,* 2016; Anacclet *et al.,* 2017; Agbim, 1987; Assa, 1987; Ivens, 1974; Mohanlai, 1960; de Foresta et Schwartz, 1991; Herren-gemmill, 1991). It might be wise and ecological to reduce the invasion of this species by using them in the form of green manures, composts or bioinsecticides. The results obtained for plants grown on green manures from *P. argentea* can be explained by its ability to fix atmospheric nitrogen (Sanginga *et al.,* 1996; IITA, 2009).

4.4. Potentials of tested bioinsecticide species

The results of the first test show that *Ludwigia decurens*, *Morinda lucida*, *Chromolaena odorata*, and *Azadirachta indica* are the 4 best bioinsecticide species for controlling vegetable pathogens. These species have already been mentioned in the literature as being able to fight against several biotic agents (Oydeji *et al.,* 2011; Olufumilayo *et al.,* 2012; Owolabi *et al.,* 2014; Udebuani *et al.*, 2015; Mondal et Chakraborty, 2016; Lokanadhan *et al.,* 2012; Pathak et Tiwari, 2012; Seck, 1998). The efficiency of these species against pathogenic and invasive insects is an asset for the development of effective bioinsecticides for a sustainable and harmonious development.

For a better development of the 4 efficient bioinsecticide species, the effective dose and the treatment frequency were obtained. The 100% bioinsecticide dose used at a 4-day treatment frequency is efficient in controlling pathogenic insects (flea beetles: *Aphtona spp*.) At a 76% efficiency rate compared to the chemical insecticide (standard dose, rate efficiency of 79% with a frequency of 4 days)

5. ADDED VALUE OF THE PROJECT

The added value of the project:

- **In scientific research:**

-The concept of geo-ecological mapping development in this study is new. Indeed, from a single map, one can obtain much information on the physicochemical characteristics of soils and several categories of plant species. This is an innovation that can be the subject of further research in the creation of mapping applications for the promotion of agriculture and biodiversity.The geo-ecological synthesis map allows from a single map to get: the state of soil degradation, the species that must be grown on different types of soil during reforestation, and crops adapted to different soil types (economic profitability). Previously, the reforestation of the area was been doing without taking into account the physicochemical characteristics of the different types of soils. Thus, species pricked out to unsuitable soils used to die. This phenomenon caused economic loss to the company. Thanks to this study, the company and the population are now aware of the plant species adapted to each type of soil. Any pricked out plant might grow well. It supposed that the company and the people might not lose anymore. The training of the population on market gardening appropriate to each type of soil will improve the production and thus the economy of the population. The concept can be used in all mining areas of HeidelbergCement to promote agriculture and biodiversity.

- From the 5 spontaneous bioinsecticide plant species, only one was previously known by the population of the area. Of the 3 spontaneous fertilizing species, none has yet been the subject of scientific study in Togo. The results of this project will then widen the list of fertilizing plants of the Togolese flora. These species can thus be objects of future intensive scientific studies for optimizing their development in agriculture.

- The bioinsecticide species (exception of neem) can undergo a thorough scientific study that can result in the isolation of new molecules which can be used in several areas. In addition, the most effective species (*Ludwigia decurens*) has been little mentioned in the literature. Its identification here allows scientists to carry out more advanced studies on this species in order to characterize its active molecules.

- **To the company**:

-The state of degradation of farming soils all around the quarry and the area being rehabilitated is known. The company might be able to use these results for decision-making on the fertilization of agricultural soils in the area.

-The geo-ecological global map allows the HSSE and corporate social responsibility departments to adapt their reforestation plans according to the different soil types in the area. This allows reforesting the species adapted to each type of the soil to boost plant diversity.

- Other HC companies can use the concept of geo-ecological mapping for the promotion of biodiversity and agriculture in their areas of setting up.

- **To the community:**

- Vegetable producers are now aware of the types of combination soil-vegetable that need to be made for good production, that is to say best incomes and for biodiversity promotion.

- The use of those biofertilizers and bioinsecticides might decrease the use of their expensive chemical analogous that are harmful to human beings and biodiversity.

- Among the 7 main species identified, *C.odorata*, *P. argentea*, and *A. indica* are invasive species. According to the International Union for the Conservation of Nature (IUCN), invasive species occupy the second place behind habitat destruction concerning the threat of biodiversity. The intense development of those invasive species could limit their proliferation and therefore their negative impacts on crops and biodiversity.

6. RECOMMENDATIONS AND GUIDES FOR THE USE OF THE PROJECT AND ITS DEVELOPMENT ON THE SITE

The development of the achievements of this project will consist of:

- **Train** the community and the company HSSE department on the use of the geo-ecological map in the reforestation programs of the mining zone **(2000 Euros)**
- **Train and raise** agricultural groups awareness on: **(5000 Euros)**

• The use of identified fertilizing plants in agriculture;

• The production and use of the bioinsecticide developed for the market gardening sector;

• The highlighting of plant species and vegetable crops adapted to each type of soil in the area (promotion of biodiversity and agriculture);

• Reducing the proliferation of invasive identified species by the aid and for the population.

- **Produce** intensively bioinsecticides (using the elaborated protocol) and composts with spontaneous invasive species inventoried. Then promote their use in the upkeep of the reforested species, flowerbeds, and agro-tourism parks of the company with the main to limit their proliferation while having an ecological benefit. **(15000 Euros / year)**

7. CONCLUSION AND OUTLOOK

The objective of this project was to consider the use of spontaneous biofertilizing and local bioinsecticides plant species associated with geo-ecological mapping to improve vegetable production and the growth of reforested species in the study area. Seven species have been identified; five exhibit the expected effects according the agronomic tests. The geo-ecological map will also improve the reforestation program and market gardening production in the study area.

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THE QUARRY LIFE AWARD

HEIDELBERGCEMENT

To be kept and filled in at the end of your report

Project tags (select all appropriate):

This will be use to classify your project in the project archive (that is also available online)

Project focus:

- ☒Beyond quarry borders
- ☒Biodiversity management
- ☐Cooperation programmes
- ☐Connecting with local communities
- ☒Education and Raising awareness
- ☒Invasive species
- ☒Landscape management
- ☐Pollination
- ☒Rehabilitation & habitat research
- ☒Scientific research
- ☒Soil management
- ☒Species research
- ☐Student class project
- ☐Urban ecology
- ☐Water management

Flora:

- ☒Trees & shrubs
- ☐Ferns
- ☒Flowering plants
- ☐Fungi
- ☐Mosses and liverworts

Fauna:

- ☒Amphibians
- ☐Birds
- ☒Insects
- ☐Fish
- ☐Mammals
- ☐Reptiles
- ☐Other invertebrates
- ☒Other insects
- ☒Other species

Habitat:

- ☒Artificial / cultivated land
- ☐Cave
- ☐Coastal
- ☒Grassland
- ☐Human settlement
- ☐Open areas of rocky grounds
- ☐Recreational areas
- ☐Sandy and rocky habitat
- ☐Screes
- ☐Shrub & groves
- ☒Soil
- ☐Wander biotopes
- ☐Water bodies (flowing, standing)
- ☐Wetland
- ☐Woodland

Stakeholders:

- ☒Authorities
- ☒Local community
- ☒NGOs
- ☐Schools
- ☒Universities

ANNEX

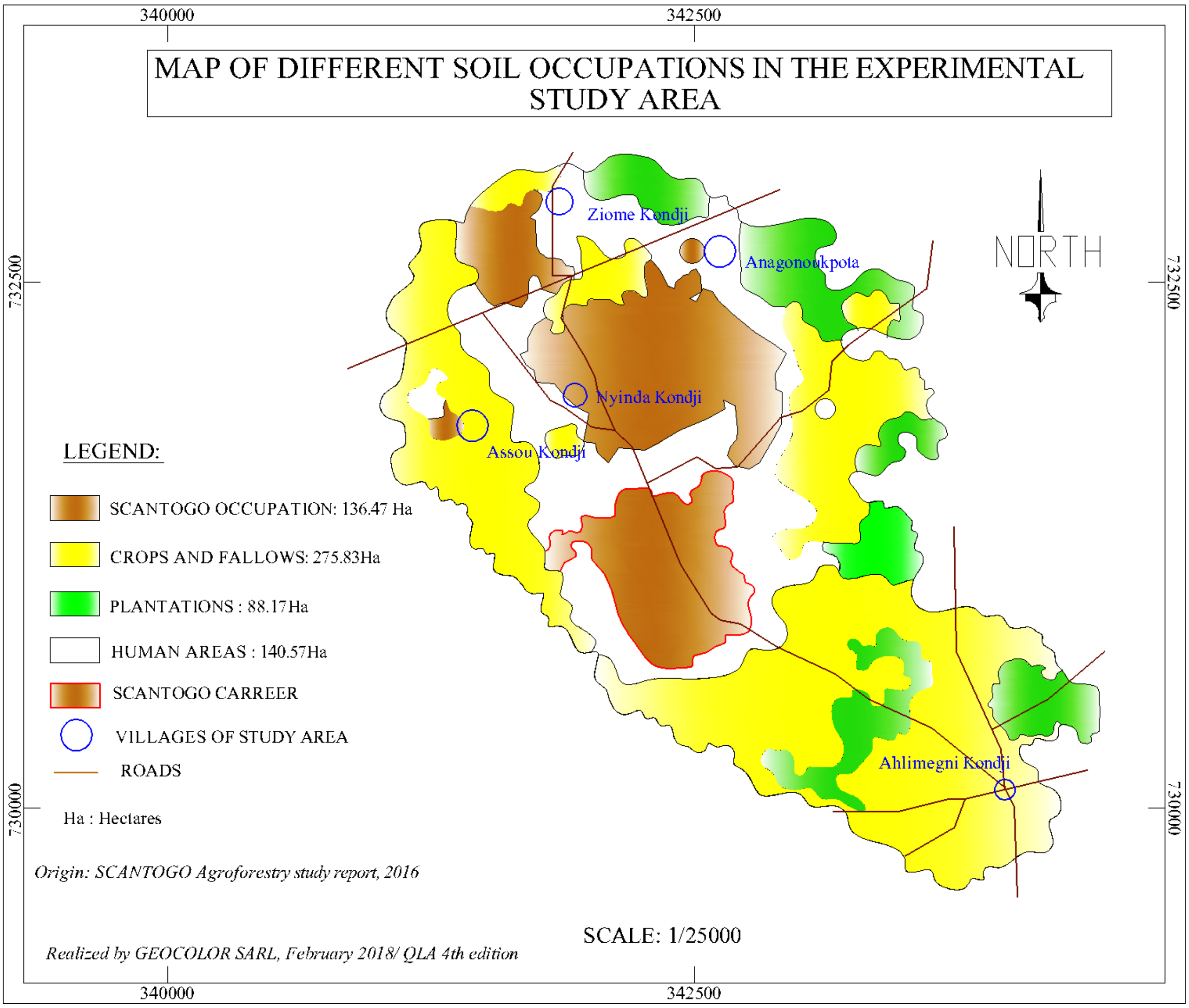


Figure 1: Map of the study area (in yellow the farming lands of the villages bordering the quarry and the plant)

Table 1: Number of respondents per village and gender during ethnobotanical surveys

Village	F	M	Total
Ahlimegni Kondji	10	7	17
Anagonou Kpota	9	8	17
Assou Kondji	25	8	33
Nyinda kondji	8	9	17
Ziome kondji	8	9	17
Total	60	40	100

F: Female **M: Male**

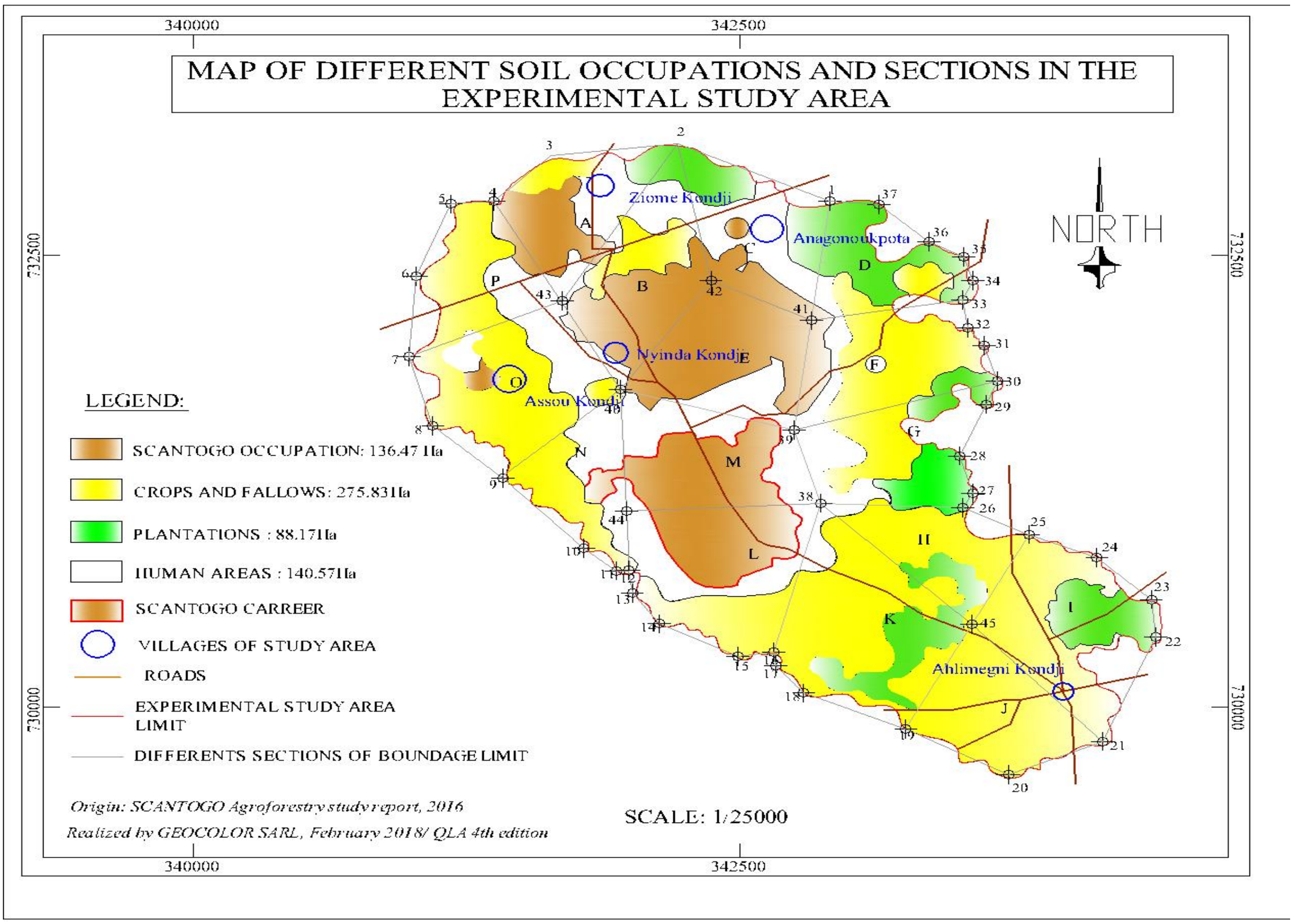


Figure 2: Map of the study area divided into sections according the way the soil samples were taken for physico-chemical analyzes

Table 6: Main vegetable crops in the study area (in bold scientific names represent the 5 main vegetable crops in the zone)

Species	Scientific Names	Families
eggplant	*Solanum melongena*	Solanacaea
carott	*Daucus carrota*	apiaceae
Cabbage	*Brassica oleracea*	Brassicaceae
bean	*Vigna sp.*	Fabaceae
onion	*Alium cepa*	Liliaceae
Green pepper	*Solanum capsicum*	Solanaceae
Cleome	*Gynandropsis gynandra*	Capparaceae
Tomato	***Solanum lycopersicum***	**Solanaceae**
Vegetable coret	***Corchorus olitorius***	**Tilliaceae**
peanut	*Hypogea arachis*	Fabaceae
Spinach	***Solanum macrocarpon***	**Solanaceae**
Okra	***Hibiscus esculentus***	**Malvaceae**
Lettuce	*Lactuca sativa*	Asteraceae
Chilli pepper	***Capsicum annuum***	**Solanacaea**

Picture 1: Leaves of okra showing some *Aphtona spp*. insects

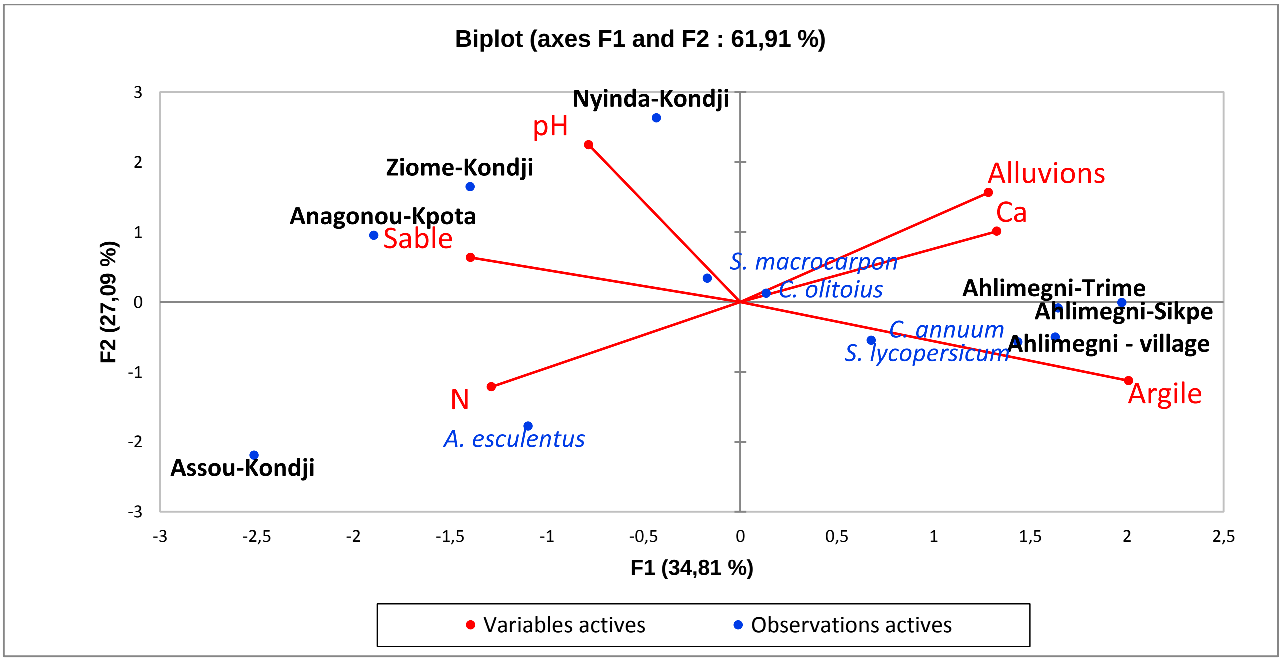


Figure 5; Correlation between the physico-chemical characteristics of the soils of different villages and the soil needs for the 5 main vegetable crops (indicates the vegetables that can produce well on the soil of each village)

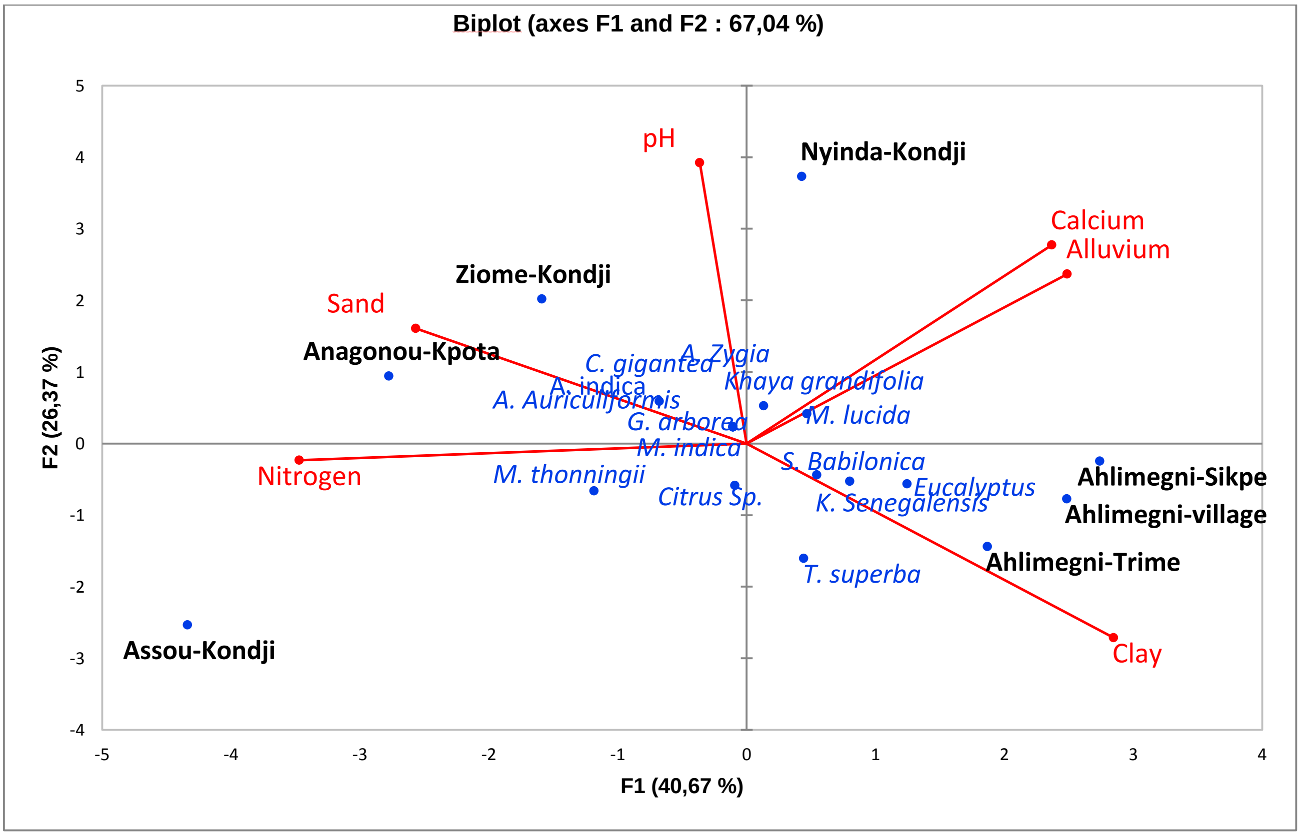
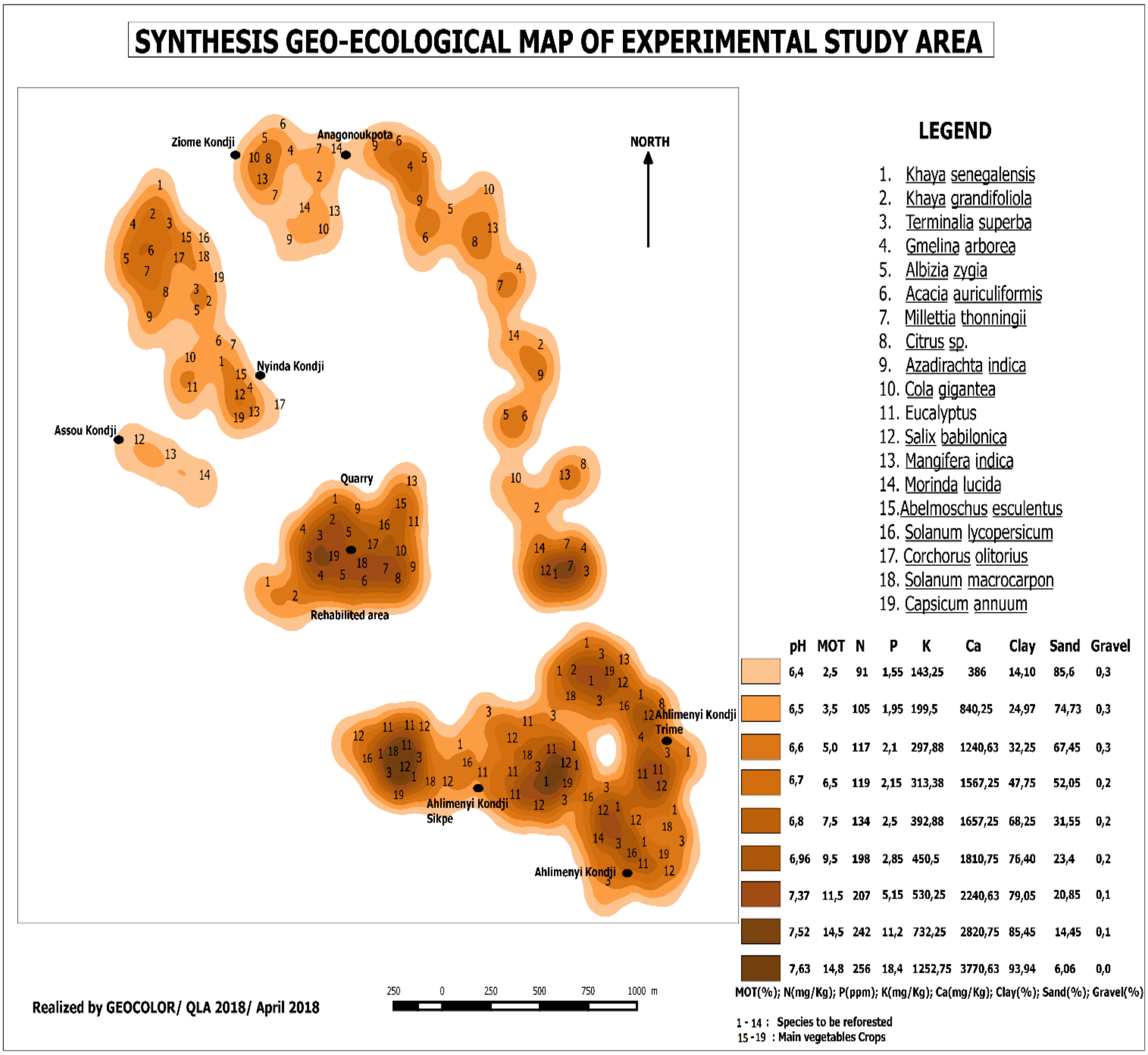


Figure 6: Correlation between the chemical characteristics of the soils of the different villages and the soil needs of the main plant species included in the reforestation program of the area (indicates the plant species that can grow well on the soils of each village



pH	MOT	N	P	K	Ca	Clay	Sand	Gravel
6,4	2,5	91	1,55	143,25	386	14,10	85,6	0,3
6,5	3,5	105	1,95	199,5	840,25	24,97	74,73	0,3
6,6	5,0	117	2,1	297,88	1240,63	32,25	67,45	0,3
6,7	6,5	119	2,15	313,38	1567,25	47,75	52,05	0,2
6,8	7,5	134	2,5	392,88	1657,25	68,25	31,55	0,2
6,96	9,5	198	2,85	450,5	1810,75	76,40	23,4	0,2
7,37	11,5	207	5,15	530,25	2240,63	79,05	20,85	0,1
7,52	14,5	242	11,2	732,25	2820,75	85,45	14,45	0,1
7,63	14,8	256	18,4	1252,75	3770,63	93,94	6,06	0,0

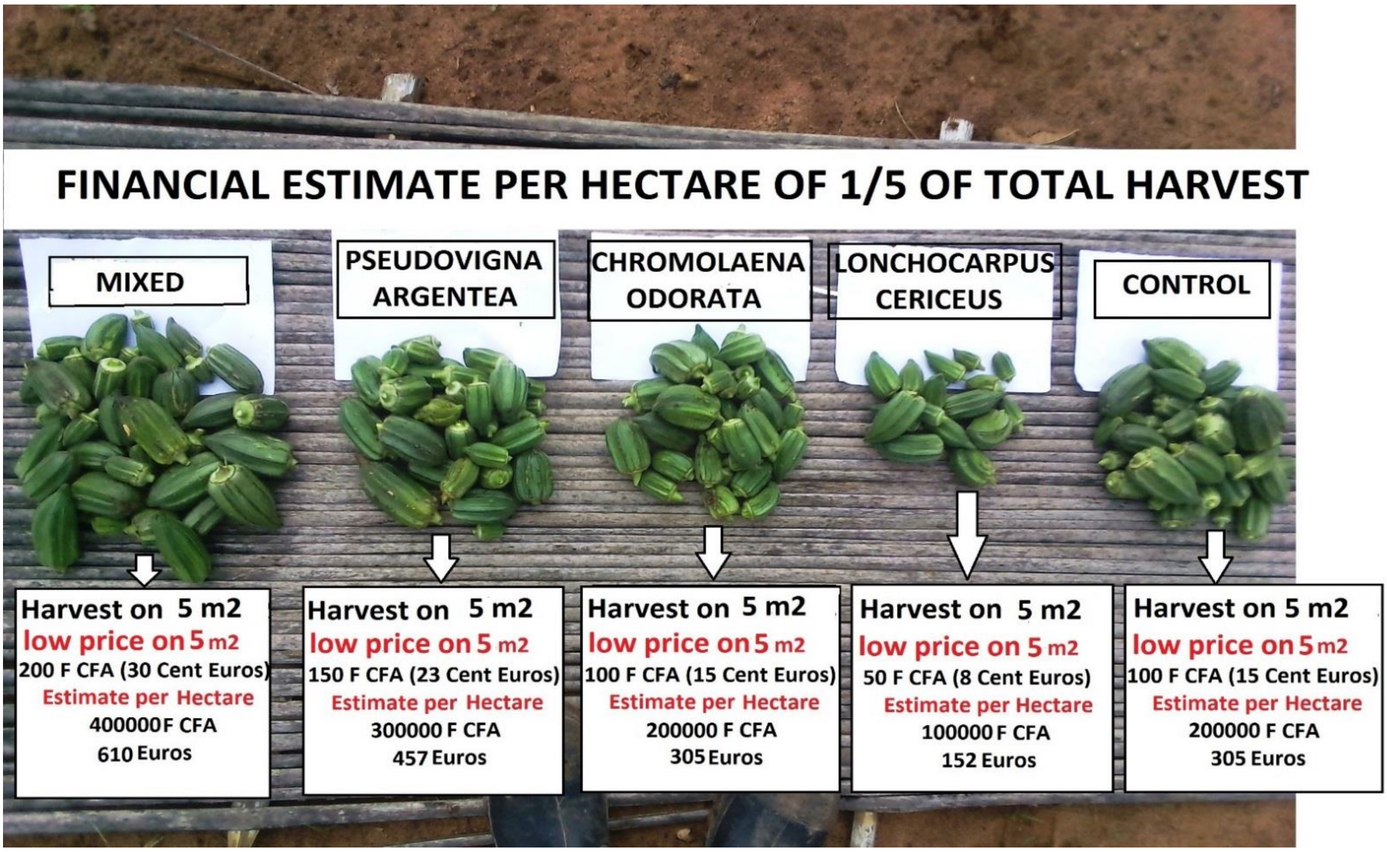
MOT(%); N(mg/Kg); P(ppm); K(mg/Kg); Ca(mg/Kg); Clay(%); Sand(%); Gravel(%)

1 - 14 : Species to be reforested
15 - 19 : Main vegetables Crops

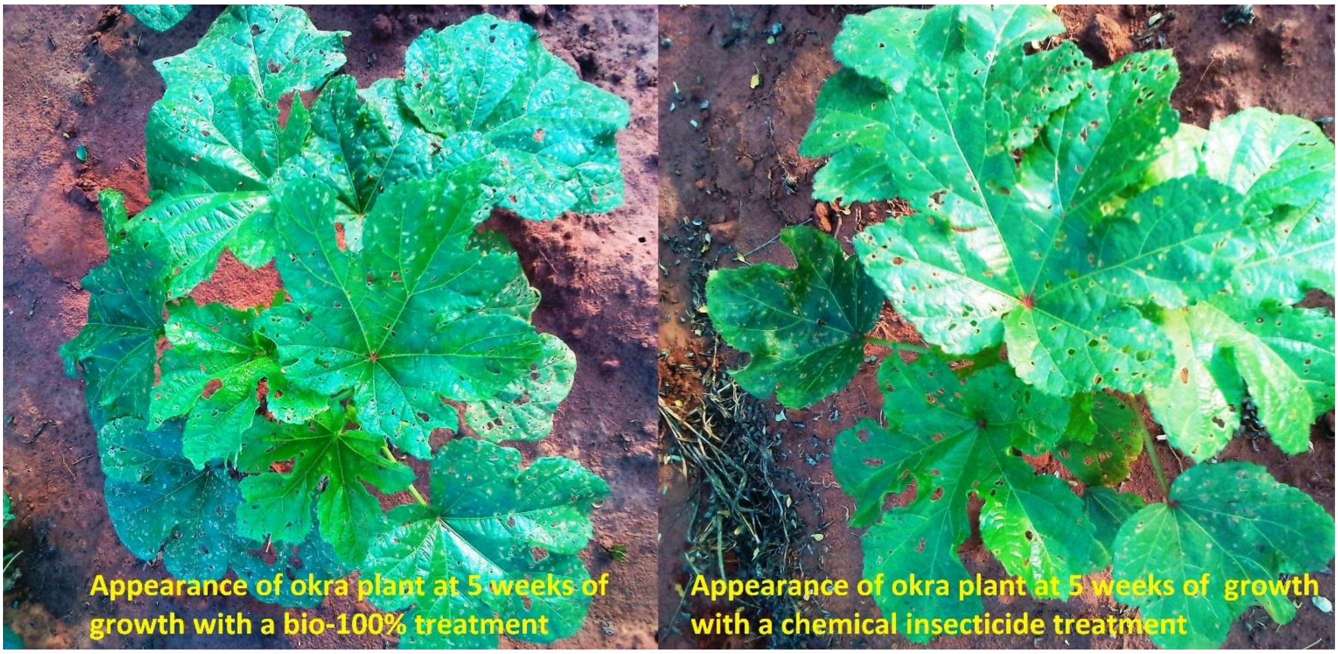
Figure 7: Geo-ecological map presenting the physicochemical characteristics of the soils and the precise localization of the soils adapted to the 5 market garden crops and the plant species included in the reforestation program

Picture 2: Fertilizing potential of selected biofertilizing plants (average height, average number of leaves, and number of okra fruits per plant)

Picture 3: Fertilizing potential of the selected biofertilizing plants (Average number of leaves of garden coret per plant, T = Control Treatment, LC = *Lonchocarpus cericeus*, PA = *Pseudovigna argentea*, CO = *Chromolaena odorata*)



Picture 4: Evaluation of economic potential of the different fertilizing species for the production of okra



Picture 5: Comparative look of okra under 100% bioinsecticide treatment and chemical insecticide used at 20%.