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DÉPARTEMENT DE BIOLOGIE ET PHYSIOLOGIE VÉGÉTALES

DEPARTMENT OF PLANT BIOLOGY

Study of the interaction between nematodes and PIF plants of *Xanthoma sagittifolium* L. Schott

A dissertation presented in partial fulfillment of the requirement for the award of a master's degree in Plant Biology

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DEDICATION

To my late mother BIA Victorine

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ABBREVIATION	SIGNIFICANCE
ANOVA	:Analysis of Variance
DNA	:Deoxyribonucleic Acid
FAO	:Food and Agricultural Organization
FAOSTAT	:Food and Agricultural Organization Statistics
GI	:Germination index
H2O	:Water
IPM	:Integrated Pest Management
$MgCl_2$	:Magnesium Chloride
NaCl	:Sodium Chloride
NPK	:Nitrogen, Phosphorus, and Potassium
SD	:Standard Deviation
spp	:Species
VOC	:Volatile Organic Compound
OM	:Organic Matter
OC	:Organic Carbon

LIST OF ANNEXES

ABSTRACT

Xanthosoma sagittifolium contains calcium oxalate and is vulnerable to pests and diseases, including nematodes, which can affect its growth as well as that of neighboring crops. This study examines the nematodes in the rhizosphere of *X.* sagittifolium and their impact on *L. sativa* and *A. esculentus*. Five harvest sites in the Central Region (Akonolinga, Mbankomo, Bafia, Ndji, Mbalmayo) were selected. Agronomic growth parameters were evaluated on randomly selected plants from different age groups (6-9 and 9-12 months). At each harvest site, soil from the rhizosphere X. sagittifolium were collected. The physicochemical characteristics of the soils were analyzed. The nematode status of *X.* sagittifolium plants and their morphological characterization were carried out based on the harvest site. A biochemical analysis was conducted after the interaction to assess the content of chlorophyll, sugars, proteins, and phenolic compounds. The results showed the presence of *Radopholus* sp., *Ditylenchus* sp., and *Xiphinema* sp. under the rhizosphere of *X. sagittifolium*. The genus of *Radopholus* sp.was the most present. From the Newman and Keuls test during interaction of plant with *Radopholus* sp., analysis showed that the agronomic growth parameters were significant, with plant height values of 134.80±33.76 cm for the white cultivar and 144.76±17.29 cm for the red cultivar. The average number of leaves did not show significant differences for both cultivars across the five sites. Soil pH ranged from 4.9 to 5.5 across all sites. The sterilized soils, as well as those from Akonolinga, Mbankomo, Bafia, Ndji, and Mbalmayo, exhibited varying soil textures ranging from sandy clay silt to sandy silt. The biochemical analysis revealed that the highest chlorophyll content was 1.30±0.00 $mg.g^{-1}$ in the red cultivar of *X. sagittifolium* at the first month in Mbankomo, and the total sugar content was 633.69±85.44 $mg.g^{-1}$ in the white cultivar of *X.* sagittifolium at the first month in Mbalmayo. The nematodes collected from the rhizosphere of cocoyam caused damage to *Lactuca sativa* and *Abelmoschus esculentus* plants, with respective plant height values of 134.80±33.76 cm for the white cultivar at Bafia and 144.76±17.29 cm for the red cultivar at Ndji. This study provides essential information for crop management and food security, highlighting the impact of nematodes in the rhizospheres of *X. sagittifolium* and their effect on neighboring crops.

Keywords: *Xanthosoma sagittifolium*, rhizosphere, nematodes, *Abelmoschus esculentus*, *Lactuca sativa*.

RESUME

Xanthosoma sagittifolium contient de l'oxalate de calcium et est vulnérable aux ravageurs et aux maladies, y compris les nématodes, qui peuvent affecter sa croissance ainsi que celle des cultures voisines. Cette étude vise à examiner les nématodes présents dans la rhizosphère de *X. sagittifolium* et leur impact sur *Lactuca sativa* et *Abelmoschus esculentus*. Cinq sites de récolte dans la région du Centre (Akonolinga, Mbankomo, Bafia, Ndji, Mbalmayo) ont été sélectionnés. Des paramètres de croissance agronomique ont été évalués sur des plantes sélectionnées au hasard, appartenant à différents groupes d'âge (6-9 et 9-12 mois). Pour chaque site, les sol de la rhizosphère de *X. sagittifolium* ont été collectés. L'analyse des caractéristiques physico-chimiques des sols a été effectuée. Le statut des nématodes des plantes *X. sagittifolium* ainsi que leur caractérisation morphologique ont été réalisées. Une analyse biochimique a été réalisée après interaction afin d'évaluer la teneur en chlorophylle, en sucres, en protéines et en composés phénoliques. Les résultats ont montré la présence de *Radopholus* sp., *Ditylenchus* sp., et *Xiphinema* sp. sous la rhizosphère of *X. sagittifolium*. Le genre *Radopholus* sp.était le plus present. Les analyses au test de Newman et Keuls durant l'interaction des plantes avec *Radopholus* sp., ont montré que les paramètres de croissance agronomique étaient significatifs, avec une taille de plante de 134,80±33,76 cm pour le cultivar blanc et 144,76±17,29 cm pour le cultivar rouge. Le nombre moyen de feuilles n'a pas montré de différences significatives pour les deux cultivars sur les cinq sites. Le pH du sol variait entre 4,9 et 5,5 sur tous les sites. Les sols stérilisés, ainsi que les sols d'Akonolinga, Mbankomo, Bafia, Ndji et Mbalmayo, présentaient des textures variées allant de la limon-sableuse à la limon-silty. L'analyse biochimique a révélé que la teneur en chlorophylle la plus élevée était de 1,30±0,00 $mg.g^{-1}$ dans le cultivar rouge de *X. sagittifolium* au premier mois à Mbankomo, et la teneur totale en sucre était de 633,69±85,44 $mg.g^{-1}$ dans le cultivar blanc de *X. sagittifolium* au premier mois à Mbalmayo. Les nématodes récoltés sous la rhizosphère de cocoyam ont causé des dommages aux plantes *Lactuca sativa* et *Abelmoschus esculentus*, avec des valeurs de taille de plante respectives de 134,80±33,76 cm pour le cultivar blanc à Bafia et de 144,76±17,29 cm pour le cultivar rouge à Ndji. Cette étude fournit des informations essentielles pour la gestion des cultures et la sécurité alimentaire, en mettant en lumière l'impact des nématodes dans les rhizosphères de *X. sagittifolium* et leur effet sur les cultures voisines.

Mots-clés : *Xanthosoma sagittifolium*, rhizosphère, nématodes, *Abelmoschus esculentus*, *Lactuca sativa*

INTRODUCTION

Plants are naturally occurring organisms and well known to mankind, scientific studies have been able to group them into various families based on their characteristics and differences. These organisms are either cultivated or naturally distributed where life can be favorable with Asteraceae, Orchidaceae, and Fabaceae being the most species-rich families (Judd et *al*., 2007). The Araceae family includes unique species valued for ornamental use and nutrient-rich roots. *X. sagittifolium* (cocoyam) is an underutilized Araceae species that serves as a staple food for over 400 million people worldwide (Judd et *al*., 2007). Cocoyam is one of the world's six most important roots and tubers crops. Ranked third most consumed root and tuber in African countries after cassava and yam and contributes 60% of Africa total production (Onyeka, 2014; FAOSTAT, 2021). Cameroon is the second highest producer in Africa after Nigeria (FAOSTAT, 2021). Several species in this family, including *X. sagittifolium, Epipremnum pinnatum,* and *Colocasia esculenta,* are considered toxic due to their calcium oxalate content (Sena et *al*., 2017). This substance participates in the toxic mechanism, causing injury and exposing the organism of the individual to the toxic substance (Ilarslan et *al*., 1997; de Oliveira & Pasin, 2017). The *X. sagittifolium* is composed of proteins, carbohydrates, vitamins, thiamine, riboflavin, niacin, fibers, among others. However, it can also present antinutritional factors, substances such as oxalates, proteinase inhibitors, phytates, tannins, alkaloids, steroids, and cyanogenic glycosides (Puiatti, 2002; Lewu et *al*., 2010). A study with rhizome extract from *X. sagittifolium* was efficient in reducing hatching and causing mortality of *Meloidogyne megadora* (Galhano et *al*., 1997). *Meloidogyne enterolobii* is a relevant nematode because it causes damage to several hosts, most of them resistant to other nematode species (Bitencourt & Silva, 2010). This species has higher virulence and reproductive potential than other *Meloidogyne* species (Brito et *al*., 2015). *Meloidogyne enterolobii* has been reported in many countries such as Mexico, in watermelon plants (Ramírez-Suárez et *al*., 2014), in jackfruit, tomato, and pepper in Florida, in the USA (Brito et *al.,* 2015) and yam in Nigeria, with irreversible damage to these crops (Kolombia et *al*., 2016). In Brazil, this nematode has been found in several states, parasitizing guava (Silva et *al.,* 2008), and in vegetables, mainly tomatoes and peppers (Carneiro et *al.*, 2006). The nematode can break the resistance conferred by Mi-1 gene to *Meloidogyne arenaria, Meloidogyne incognita,* and *Meloidogyne* javanica in tomato (Fargette et *al*., 1994). Besides soybean 'Forrest, sweet potato (Carneiro et *al*., 2001; Cantu et *al*., 2009; Bitencourt and Silva, 2010; Melo et *al*., 2011), and 'Prata' bell pepper (Carneiro et *al.,* 2006). *X. sagittifolium* can be susceptible to viral infections. They include; *X. sagittifolium* mosaic virus (XSMV) and *X. sagittifolium* bacilliform virus (XSaBV), reported

as viral pathogens affecting *X. sagittifolium* (Sánchez & Berrocal, 2017). Various fungal pathogens can cause diseases in *X. sagittifolium.*

A crop following tannia would not be damaged by *M. incognita*, race 2 because of low residual soil populations. Therefore, where soils are infested with this root-knot nematode race at levels below 5000/1. Host suitability of *X. sagittifolium* was not favorable to *Meloidogyne megadora* which did not reproduce on any *Xanthosoma* plant obtained either by vegetative or in vitro propagation, thus *X. sagittifolium* is a non host for this Genus of nematodes (Cristina et *al*., 1997). In Cameroon, *X. sagittifolium* is commonly intercropped with crops like *Lactuca sativa* and *Abelmoschus esculentus* to optimize land use and improve soil fertility (Salako et *al*., 1995). Both plants are susceptible to root-knot nematodes (*Meloidogyne spp.*), which can damage roots and reduce yield potential (Jones et *al*., 2013). The role of *X. sagittifolium* in nematode management within mixed cropping systems is not fully understood. It's deep root system may influence nematode populations in the rhizosphere, potentially acting as a trap crop or as a buffer against nematode infestations in companion crops (Nicol et *al*., 2011). Therefore, the research question arises: How do other associated nematodes, affect the health and productivity of companion crops intercropped with *X. sagittifolium*, and what role does *X. sagittifolium* play in managing nematode infestations in mixed cropping systems? Understanding these interactions could lead to improved pest management strategies (IPM) and contribute to more sustainable farming practices in Cameroon.

Research hypothesis

X. sagittifolium may serve as trap crop or habour other harmful species of nematodes.

General objective

Identify Nematode species present in the rhizosphere of *Xanthosoma sagittifolium* and test their intercropping effect with *Lactuca sativa* and *Abelmoschus esculentus.*

Specific objectives

- Characterize nematode species present in the rhizosphere of *Xanthosoma sagittifolium* plant for each harvest site.
- Evaluate the ffect of nematodes on the growth of *X. sagittifolium, L. sativa* and *A esculentus*.
- Analyse the content level of metabolites in leaves of *X. sagittifolium, L. sativa* and *A. esculentus*.

CHAPTER I : LITERATURE REVIEW

I.1. General features of *Xanthosoma sagittifolium*

I.1.1 Origin and distribution

Cocoyam, *X. sagittifolium* is a herbaceous plant native to tropical America (Crop trust, 2010). *X. sagittifolium* probably hails from South America in the northern part of the Amazon basin (northern Brazil. Colombia. Peru. Ecuador and Venezuela) (Ramanatha et *al*., 2010), cultivated in southern Mexico, Central America, Bolivia and even more intensively in the West Indies. Its introduction into Africa where it became a subsistence crop, dates back to the time of slave trade in the 16th and 18th century. *X. sagittifolium* was introduced via the Gold Coast (Ghana) from the West Indies (Giacometti & Léon, 1994). In Cameroon. *X. sagittifolium* is grown in three of the country's five agro-ecological zones but production is most abundant from the Highlands in the West to the forested lowlands in the south.

Several vernacular names are given to the plant depending on the region: Yautia (Ya-ou-tia), (Arawak), chou-caraïbe (West Indies), matabala (Sao tome and Principe), boron (Columbia), tiquisque or macal (Costa rica), mafafa (Mexico), quequisque (Nicaragua), otoy (Panama), nampi or malanga (Brazil and Haiti), cocoyam (Nigeria) and macabo, cocoyam, macabu, lebanga, ekabe, ekaba (Cameroon) (INPN, 2003; Anonymous, 2011).

I.1.2. Taxonomy and genetic diversity

The genus *Xanthosoma* comprises 50-60 species (Steven, 2012), many of which are cultivated for food or ornamental purposes (Madison, 1978; Gonçalves, 2011). The cultivated Genuses are grouped into 4 species: *X. atrovirens X. caracum X. sagittifolium* and *X. violaceum* (CABI, 2014). The most cultivated and economically important are *X. sagittifolium* and *X. violaceum* (Vaneker & Slaats, 2013). The taxonomic tree for *X. sagittifolium* is as shown as described below:

Domain : Eukaryote
Kingdom : Plantae
Phylum : Spermatophytes
Sub-phylum : Angiosperms
Class : Monocotyledons
Order : Arales
Family : Araceae
Genus *:* Xanthosoma
Species *:Xanthosoma sagittifolium* L. Schott

Three main varieties are grown in Cameroon, they are classified according to the colour of tubers, leaves and petioles, giving diploid white (2n=2x=26) (Fig.1A), diploid red (2n=2x=26) (Fig.1B) and tetraploid yellow (2n=4x=52) (Fig.1C) cultivars (Mbouobda et *al.*, 2007; Oumar et *al.*, 2011).

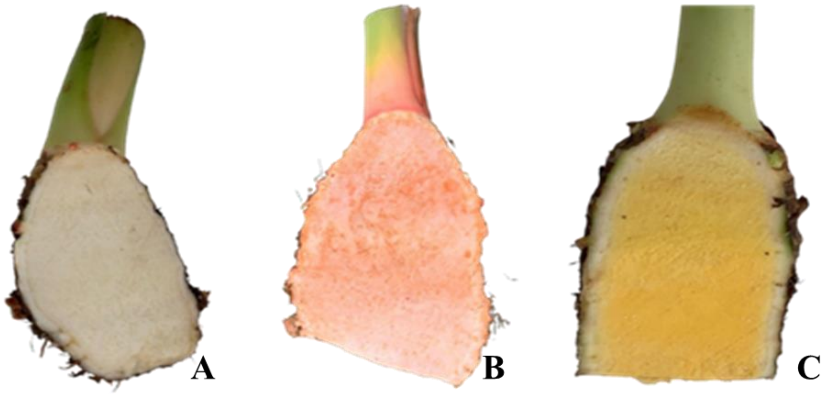


Fig.1. Transversal cut of the 3 cultivars of *Xanthosoma sagittifolium.* White cultivar (A), Red cultivar (B), Yellow cultivar (C), (Picture by NENGI, 2025).

I.1.3. Biology

The *X. sagittifolium* plant consists of two conspicuous parts (Fig.2), which are distinguished by an aerial, and an underground part

- **An aerial part**: The aerial part consists of stem, leaves and inflorescences. The stem is generally short and underground but the petioles are long and robust this supports the plant's characteristic large leaves (Watson & Dallwitz 1992). They are typically green with prominent veins (Nyadanu et *al.*, 2017). The inflorescence of *X. sagittifolium* is a typical Araceae structure formed by a spadix surrounded by a spathe (Ngouo et *al.*, 1989). The fruits of *X. sagittifolium* are berries containing seeds, but reproduction is mainly by tubers, which is more efficient for commercial cultivation (Hammer & Heller, 2001).
- **An underground part:** The rhizosphere is made of roots, rhizomes and tubers. The root system including adventitious roots supports the plant's growth and nutrient uptake, the rhizomes of *X. sagittifolium* are underground stems that allow the plant to multiply vegetatively (Ngouo et *al.*, 1989). The tubers of *X. sagittifolium* are one of the most important parts of the plant consumed after cooking to eliminate oxalates. They are rich in starch and are an important source of energy in tropical regions (Löffler, 2000).

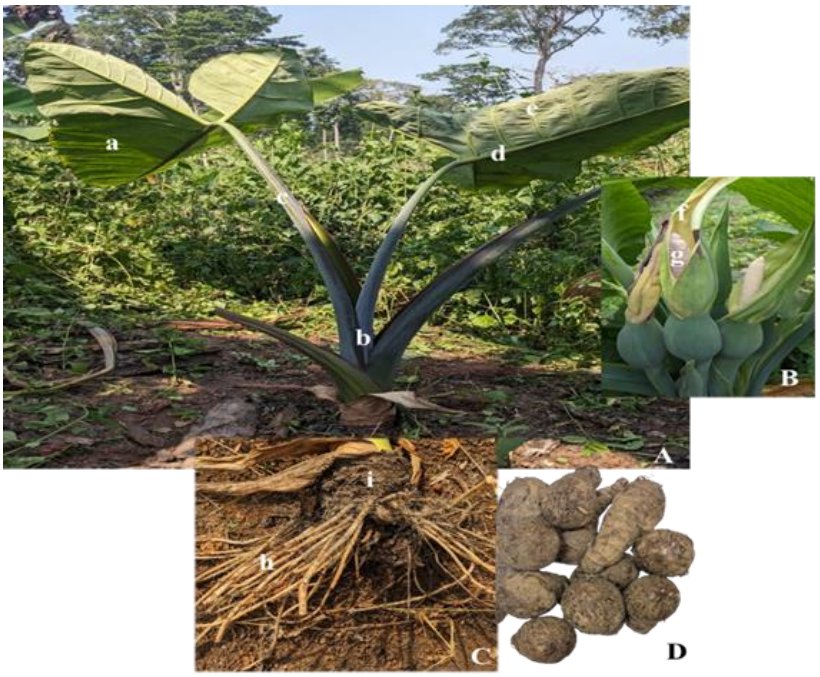


Fig.2. Biology of *X. sagittifolium* in a farm Aerial part (A), Inflorescence (B), Underground part (C), Corms or Tubers (D), leaf veins (a), psedo-stem (b), petiole (c), midrib (d), leaf margin (e), spadix (f), pedoncle (g), roots (h), rhizome (i), (Picture by NENGI, 2025).

I.1.4. Ecology

In general, *X. sagittifolium* grows well in the southern part of Cameroon more specifically in agro-ecological zones III, IVand V, which are respectively the Western Highlands agro-ecological zone, the humid forest agro-ecological zone with monomodal rainfall and the humid forest agro-ecological zone with bimodal rainfall (Onyeka, 2014) Growing *X. sagittifolium* requires a warm, fairly humid climate. It is a coastal plant that likes shade, so it grows well in areas with high rainfall and prefers temperatures of between 18 and 29°C, an altitude of less than 2000 mm and rainfall of between 1500 and 2000 mm light sandy-clay soils rich in organic matter, well drained, deep and well loosened, with a pH of 5.5 to 6.5 are ideal for growing *X. sagittifolium* which does best in old fallow lands (Manner, 2011).

I.1.5. Reproduction of *X. sagitifolium*

Reproduction is done essentially by the vegetative way and the plant material is constituted of fragments of tubers or whole tubers (Bell et *al*., 2000). It is a shade plant most often cultivated in association with other perennial cultures such as; plantain, palm trees, cocoa plants. It is equally a plant of plains (Onwueme, 1978). The life cycle of cocoyam extends between 9 to 11 months. The maximum development of leaves and tubers is achieved between 6 to 9 months. The growth and development cycle can be divided into three main periods. During the first two months, the growth is slow. This period begins with budding of shoots and

ends when the bulb emerges. The second period is characterized by a rapid increase in growth of shoot between the sixth-seventh month after planting and it is during this period that the plants obtain the maximal surface of their leaves same as their height. During the third period, the leaves start to wither and the total dry weight of the plant above the soil diminishes until harvest. At this moment, the plant has made the photo-assimilate transfer of the leaves to the bulbs (Lopez et *al*., 1995; Tiki, 2023). Cultivators use senescence of the plant at the end of this period as an index for the harvest.

I.1.6. Significances

I.1.6.1. Nutritional significance

In Cameroon, cocoyam plays an important role in the fight against food insecurity. Its production is almost exclusively used for human consummation (Onwueme & Charles, 1994; Onyenweaku & Okeye, 2007). It is a staple food in the tropics and subtropics and one of the six most important root and tuber crops worldwide (Onwueme & Charles, 1994). The corm, cormels and leaves of *X. sagittifolium* are an important source of carbohydrates for human nutrition, animal feed (Sefa-Dedeh & Agyir-Sackey, 2004), and of cash income for farmers (Tambong & Höfte, 2001). Africa produces about 75 % of the world production which is about 0.45 million tons (FAO, 2006). All its parts can be consumed, however, the tubers have to be boiled or roasted because of the presence of small calcium oxalate crystals, which has an irritating effect. Its leaves are consumed as vegetables because they contain about 20 % proteins and constitute of an excellent source of thiamine, folic acid, riboflavin and vitamin A (Agueguia et *al.*, 2000), In many factories of agricultural transformations, for instance in Hawaï and Latin America, cocoyam tubers are the first matter of fabrication of flour and food for children. They are transformed to fermented mashed cocoyam, cocoyam flakes and cocoyam chips ready to be consumed (Giacometti & Léon, 1994). Cocoyam tubers are a non-negligible source of vitamin and mineral salts (Sefa-Dedeh & Agyir-Sackey, 2004). They contain about 5 % protein. 25 % starch. 1.5 % alimentary fibers and little lipid (0.5 %) (Sefa-Dedeh & Agyir-Sackey, 2004), consumed in different forms according to the localities.

I.1.6.2. Medicinal significance

Leaves consumed as vegetables contain nutritional properties (Souza Araújo et *al*., 2019). Since they contain calcium they can be used as a dietary supplement to prevent and treat osteoporosis (de Oliveira et *al*., 2012), rich in flavonoids, these leaves have antioxidant properties (Souza Araújo et *al*., 2019; Rahman et *al*., 2019) and their hydroethanol extract has

chelating activity and induces apoptosis in leukaemia cells (Caxito et *al*., 2015). As for tubers, the methanol extract is an antioxidant (Nishanthini & Mohan, 2012), analgesic and anti-inflammatory properties (Noor et *al*., 2015) and have the potential to be used in the dietary management of patients with type II diabetes mellitus as they significantly decrease blood glucose levels and increase glycogen levels in diabetic patients (Handajani et *al*., 2018). In addition, it helps to improve sperm quality, motility and sperm count which could address diabetes-related male infertility (Oridupa et *al*., 2017). *X. sagittifolium* is a source of minerals including sodium (Na), calcium (Ca), magnesium (Mg) and potassium (K). The fairly high iodine content (79.5ug/100g) in fresh tubers helps to combat iodine deficiency disorders in children, adolescents and pregnant women (Taga et *al*., 2004). It is traditionally used to prevent and treat bone disease due to its calcium content, although levels vary depending on the preparation (de Oliveira et *al*., 2012), and demonstrates potential antitumor properties with its leaf extract showing cytotoxic effects against leukaemic cells while sparing non-tumour cells (Caxito et *al*., 2015).

I.1.6.3. Economical significance

X. sagittifolium is grown more in Africa than anywhere else in the world. Africa accounts for more than half of the annual yield of 83.1% production (FAOSTAT, 2022) whereby Nigeria is the world's largest producer of cocoyam. However, this production is not very representative as 90% of the world's tuber production is sweet potato, cassava and yam with *X. sagittifolium* and *Colocasia esculenta* accounting for the remaining 10%. Production is concentrated in Asia (Thailand, Peru, China etc.), Africa (Nigeria, Ghana, Cameroon) (Anonymous, 2021). Oceania and Latin America. Global production is estimated at 17 million tons in the world's top 5 producing countries. As the table (Table I) Nigeria is in first place with a production of 7,941.705 tons, followed by China (1,887.305 tons), Cameroon (1,796.337 tons), Ethiopia (1,665.893 tons) and Ghana (1,551.769 tons) (FAOSTAT, 2022).

Table I. FAOSTAT: World-producing countries of *X. sagittifolium* (published by FAOSTAT.in 2022)

World ranking	Country	Total production (tons)	World percentage
1	Nigeria	7 941 705	44. 82
2	China	1 887 305	10. 65
3	Cameroon	1 796 337	10. 13
4	Ethiopia	1 665 893	09.40
5	Ghana	1 551 769	08.75

Source : FAOSTAT 2022.

I.1.7. Production constraints

The culture of cocoyam is confronted to many difficulties notably:

- In adapted traditional cultural practices, cocoyam is generally cultivated in association with other plants. The plantation material consists of a fragment of rhizome or tubers, which favorizes the dissemination of pathogen agents such as *Pythium myriotilum.* The use of part of the harvest as seeds causes insufficiency of quality plantation material. These practices are adapted with an intensive culture.

- The essential way of reproduction is vegetative; well that it guarantees the genetic stability of the biologic material. It favors the propagation of diseases (viral fungal and bacterial) and ravagers (white ants) from one plant to another (Reyes Castro et *al*., 2005). However, the weak scale of sexual reproduction limits the genetic brewing and does not offer possibilities of adaptation.

- Fungal attacks :
  - Root rot caused by *Pythium myriotylum* (Tambong & Höfte, 2001; Djuidje et *al.*, 2022) is the most devastating disease of *Xanthosoma sagittifolium* with production losses of up to 90%. The disease also manifests itself through dwarfing: plant development is affected from the outse and leaves turn yellow;
  - Bulb rot caused by *Rhizoctora spp* is a constraint to the profitability of *X. sagittifolium* cultivation (Thavabalachandran & RGAS, 2015);
  - *Sclerotium rolfsii* degrades *X. sagittifolium* (Yeboa, 2012) more specifically leads to crown rot by attacking older leaves. It is characterised by a sudden collapse of the petiole which appears healthy;
  - *Fusarium oxysporum* causes yellowing of plants, (Djeuani et *al.,* 2020) have shown that its presence in the growing medium is responsible for root death. It should also be noted that this fungus is opportunistic to attacks by *Pythium myriotylum* (Wokocha & Aduo, 2011).

- Bacterial attacks :
  - Bacterial necrosis caused by *X. comprestris*. Which is responsible for the reduction of leaves. Mosaic of cocoyam (Dashen Mosaic Virus, DMV) (Chen et *al*., 2001) caused by a phyto virus which manifests by the appearance of yellowish strands

going from the veins and destroying the limb which ends up stunted. We generally find infections of microbial origins whose manifest in diverse forms translated by the appearance of leaf stains caused by *Leptosphaeulina trifolii* and rotting of the collar attributed to *Sclerotium rofsii*. The most important fungal disease is the root rot disease caused by *Pythium myriotilum* (Tambong et *al*., 2001). It can cause the total loss of production of cocoyam (Saborio et *al*., 2004). Cameroon is responsible for the loss of close to 90 % of harvest in some plantations and 60 % of the national production (Westphat et *al*., 1985).

❖ Viral attacks :

- Bacterial necrosis caused by *Xanthosomas comprestris* which is responsible for the reduction of leaves. Mosaic of cocoyam (Dashen Mosaic Virus. DMV) (Chen et *al*., 2001) caused by a phyto virus which manifests by the appearance of yellowish strands going from the veins and destroying the limb which ends up stunted. We generally find infections of microbial origins whose manifest in diverse forms translated by the appearance of leaf stains caused by *Leptosphaeulina trifolii* and rotting of the collar attributed to *Sclerotium rofsii*. The most important fungal disease is the root rot disease caused by *Pythium myriotilum* (Tambong et *al*., 2001). It can cause the total loss of production of cocoyam (Saborio et *al*., 2004a). In Cameroon. It is responsible for the loss of close to 90 % of harvest in some plantations and 60 % of the national production (Westphat et *al*., 1985).

❖ Pest attacks :

- The aphid. *Alphis gossypii* is a vector of viruses belonging to the order Hemiptera. It prefers to position itself on the underside of the leaves but the whole plant may be covered in the event of a heavy attack causing wilting of the leaf blade downward curling and general weakening of the plant in the event of severe attacks (Jenifer et *al.,* 2005);
- *Papuana huebneri*: a black soil-dwelling beetle whose larvae dig galleries in tubers rendering them unfit for consumption (Venin &Vernier, 1994);
- Caterpillars (*Spodoptera litura*): A defoliating caterpillar/striped noctuid. They devour the leaf blade and young *Xanthosoma sagittifolium* plants may be cut to the ground. This can lead to the disappearance of young plants if the attack is strong or if the stem is cut and a weakening of large plants (Anonymous, 2011).

I.1.8. Strategies of ameliorating *X. sagittifolium*

Many methods have been put in place to overcome the difficulties faced with the culture of cocoyam:

- The development of methods for biological and chemical fights each of which constitutes the use of antagonist microorganisms with *P. myriotilum* such as *Trichoderma haziarnun* and *Pseudomonas fluorescens* and pesticides respectively permitting the control of the disease (Xu et *al*., 1995; Perneel et *al*., 2004) equally showed that it is possible to control the infections of *P. myriotilum* by using manure.
- The application of plant biotechnologies, which makes it possible to obtain disease-free in vitro plants through plant tissue culture. This approach is helping to develop new varieties that ensure rapid propagation and effective seed conservation (Omoloko et *al*., 2003). Mini tuberisation (Djeuani et *al*., 2014; 2018) are also noted as alternatives to basic seeds produced from seedlings obtained in vitro. These very expensive techniques are beyond the reach of traditional farmers (Youmbi & Ngaha, 2004). However, the FIP technique is a less complex approach that is accessible to all.

I.2. General features on Nematodes

I.2.1. Origin

The phylum Nematoda originated millions of years ago and has successfully adapted to various ecosystems (Nicol et *al*., 2011). Nematodes are taxonomically classified along with arthropods, tardigrades and other moulting animals in the clade Ecdysozoa (Nicol et *al*., 2011). They have a tubular digestive system with openings at both ends distinguishing them from flatworms (Nicol et *al*., 2011).

I.2.2. Types of Nematodes

Plant-parasitic nematodes (PPNs) are a specialized group that feed on plants causing significant agricultural losses worldwide. They utilize a style to penetrate plant cells and extract nutrients and the major types of PPNs include:

- Root-Knot Nematodes (*Meloidogyne* spp.): The female is pear-shaped and sedentary with a distinct neck region. Diagnostic features include a perineal pattern unique to the species observed under a microscope and molecular markers for species identification (Karssen et *al*., 2013).

- ❖ Cyst Nematodes (*Heterodera* spp & *Globodera* spp.): Females are lemon-shaped and sedentary forming protective cysts filled with eggs. Diagnostic features include the cyst shape vulval cone structure and cuticular patterns on the cyst (Turner & Subbotin, 2013).
- ❖ Lesion Nematodes (*Pratylenchus* spp.): Females are vermiform and migratory endoparasites. Diagnostic traits include a well-developed stylet with rounded knobs and a distinct ovary extending toward the esophagus (Castillo & Vovlas, 2007).
- ❖ Burrowing Nematodes (*Radopholus similis*): Females are vermiform slender and migratory endoparasites. Key features include a stylet with small rounded knobs and a single ovary that overlaps the intestine (Pinochet et *al*., 1995).
- ❖ Spiral Nematodes (*Helicotylenchus* spp.): Females are semi-endoparasitic and coiled. Diagnostic features include a spiral body shape when relaxed, a short stylet and a distinct vulval position (Ravichandra, 2013).
- ❖ Stubby-Root Nematodes (*Trichodorus* spp.): Females are stout and ectoparasitic. They are distinguished by their short robust stylet and rounded tails along with their ability to stunt root growth (Decraemer, 1995).
- ❖ Reniform Nematodes (*Rotylenchulus* spp.): Females are kidney-shaped and semi-endoparasitic. Key diagnostic traits include their reformed body shape and a short stylet with small basal knobs (Robinson et *al.,* 1997).
- ❖ Awl Nematodes (*Dolichodorus* spp.): Females are ectoparasitic and vermiform. They have long spear-like stylets and distinct labial and cephalic regions (Thorne, 1961).
- ❖ Pin Nematodes (*Paratylenchus* spp.): Females are minute and ectoparasitic. Diagnostic features include their small size, short stylet and rounded tails (Raski, 1952).
- ❖ Dagger Nematodes (*Xiphinema* spp.): Females are long and ectoparasitic. They are identified by their exceptionally long odonto style with flanges and ability to transmit plant viruses (Taylor & Brown, 1997).

I.2.3. Life cycle Nematodes

The life cycle of nematodes involves an egg stage, four juvenile stages (J1-J4) and adult stages (females and males). Eggs are produced within the swollen female bodies forming cysts. Juveniles hatch from the eggs and start feeding on plant roots where they go through molts to

reach adulthood. Mating occurs and females produce cysts containing eggs (Evans et *al*., 2001; Jones et *al*., 2013).

I.2.4. Interaction between Plant parasitic nematodes (PPN) and plants

Certain nematodes are plant parasites and can cause significant damage to agricultural crops and plants. These nematodes invade plant roots, establish feeding sites and extract nutrients from the plant cells. Plant-parasitic nematodes can lead to reduced plant growth yield losses and increased susceptibility to other pathogens. (Jones et *al*., 2013). Research indicates that *X. sagittifolium* exhibits resistance to several *Meloidogyne* species, commonly known as root-knot nematodes. A study by (Gomes et al., 2020) demonstrated that *X. sagittifolium* did not host *Meloidogyne incognita*, *M. javanica*, or *M. enterolobii*, even when exposed to high nematode populations. The absence of gall formation and external egg masses, along with reproductive factors less than one, classified *X. sagittifolium* as resistant to these nematode species. Beyond its inherent resistance, *X. sagittifolium* has been explored for its biofumigation potential (Gomes et *al*., 2020) investigated the effectiveness of soil biofumigation using macerated *X. sagittifolium* leaves against *M. enterolobii*. The study found that incorporating *X. sagittifolium* leaves into the soil significantly reduced the number of galls and egg masses of *M. enterolobii* on subsequent tomato plants. This nematicidal effect is attributed to volatile organic compounds (VOCs) emitted by the decomposing leaves, which adversely affect nematode viability. In addition to Meloidogyne species, the interaction between *X. sagittifolium* and the yam nematode, *Scutellonema bradys*, has been examined. Research by Bridge (1996) indicated that *X. sagittifolium* is a non-host to *S. bradys*, as the nematodes were unable to survive in the roots and cause damage. This finding suggests that *X. sagittifolium* could be utilized in crop rotation schemes to manage *S. bradys* populations in yam cultivation.

The resistance of *X. sagittifolium* to various nematode species and its biofumigation capabilities present valuable opportunities for integrated nematode management. Utilizing *X. sagittifolium* in crop rotation or as a biofumigant could reduce reliance on chemical nematicides, promoting sustainable agricultural practices. However, further field studies are necessary to optimize application methods and confirm efficacy under diverse environmental conditions (Vanessa et *al.*, 2020).

I.3. Generalities on some plant secondary metabolites

I.3.1. Chlorophyll in plants

Chlorophyll is a plant pigment responsible for the green colouring of plants. This pigment which is found in the chloroplasts of plant cells is used with other pigments by the

plant to carry out photosynthesis. This process enables the plant to use light energy from the sun to convert carbon dioxide and water into oxygen and sugar (Taiz et *al*., 2015) responsible for capturing the light energy used in photosynthesis. Chlorophyll is made up of several chemical structures, the main ones being chlorophyll (a) and chlorophyll (b). Chlorophyll biosynthesis can be influenced by the types of fertiliser applied (Djeuani, 2018; Poveda et *al*., 2019; Beesigamukama et *al*., 2020; Adounga, 2023). The presence of nematodes can negatively impact chlorophyll content in plants. Nematodes, particularly root-feeding species like root-knot nematodes (*Meloidogyne* spp.), disrupt the root system, impairing the plant's ability to uptake water and nutrients. This leads to reduced chlorophyll synthesis and lower chlorophyll levels in leaves. The physiological stress caused by nematode infestation hampers photosynthesis, resulting in stunted growth and yellowing of foliage (Melakeberhan, 1997; Vieira et *al*., 2018).

I.3.2. Total solubles sugars in plants

Carbohydrates such as soluble sugars are important for the development and functioning of a cell or organ. Indispensable for eukaryotic cells they are produced by photosynthesis. They are transported to tissues and stored in the form of starch or other complex carbohydrates (Nemouchi, 2003). In this way they will eventually be broken down according to the plant's growth and development needs. These sugars are used during respiration and play a structural and energetic role in plants. It should be noted that in plants they play a role as signal molecule in the morphogenetic process and in particular in the control of leaf morphogenesis (Xiao et *al*., 2006). In addition, under stress conditions such as frost. There is a significant accumulation of soluble sugars which is interpreted as stress tolerance (Korn et *al*., 2008; Brahimi, 2017). These carbon compounds are involved in the biosynthesis of phenols and amino acids (El Hadrami et *al*., 1997). Authors have shown that their synthesis in plants is influenced by environmental conditions such as fertilisation, biotic and abiotic stress soil types etc (Korn et *al*., 2008; Djeuani et *al*., 2018) and pathogen attacks (Adounga, 2023). Nematode infestations disrupt plant metabolism, often leading to alterations in the levels of soluble sugars. Pathogenic nematodes cause stress, triggering plants to redirect resources toward defense mechanisms, which includes the synthesis of soluble sugars as part of the stress response. For instance, root-knot nematodes (*Meloidogyne* spp.) can cause localized increases in soluble sugars in infected tissues due to changes in metabolic activities and impaired sugar transport to other parts of the plant. However, excessive stress can deplete sugar reserves, ultimately weakening the plant (Vieira et *al*., 2018; Korn et *al*., 2008).

I.3.3. Total solubles proteins in plants

Proteins are important nitrogenous macromolecules that are composed of amino acids linked together by peptide linkages and proteins play a significant biological function in humans as well in plants. These can be analyzed from seeds and other parts of plants such as leaves and stems (Shen et *al*., 2003; Vision et *al.,* 2003). Protein synthesis occurs in leaves and green stems and is mobilized into seeds or fruits (Schiltz et *al*., 2004). Proteins have been assayed from almost all parts of plants including leaves, nodules, stem fruit and seed (Burstin, 2008; Schiltz et *al*., 2005). Nematode infestations significantly alter protein levels in plants. For instance, parasitic nematodes like root-knot nematodes (*Meloidogyne* spp.) induce the formation of specialized feeding structures such as giant cells, which are rich in proteins but require the plant to reallocate resources from its normal metabolic processes. This leads to the synthesis of stress-related proteins, such as pathogenesis-related (PR) proteins, as part of the plant's defense mechanism (Vieira et *al*., 2018; Hussey & Williamson, 1998). However, nematode-induced stress can also disrupt normal protein synthesis, reducing protein content in critical plant tissues and affecting overall growth and productivity (Fuller et *al*., 2008).

I.3.4. Phenolic compounds in plants

Phenolic compounds are highly diverse cyclic organic substances of secondary origin derived from phenol. They are widely distributed in the plant kingdom and are present throughout the plant. The largest and most represented group of phenols is that of flavonoids (Macheix et *al*., 2005), which are constituents of phenolic compounds (Kamboh et *al.*, 2019). These are secondary metabolites involved in the plant's defense against exogenous, biotic, and abiotic stresses (Belmihoub & Ghabani, 2022). Thus, an accumulation of polyphenols has been observed in Musa sp. Leaves in the presence of oyster shell ash (Ewané et *al*., 2019), along with an increase in flavonoids in tomato leaves in the presence of arbuscular mycorrhizal fungi (Aseel et *al*., 2019). They also protect the plant against ultraviolet rays (Gea, 2018). Phenolic compounds play a crucial role in plant defense against nematodes by acting as toxic agents, structural reinforcements, and signaling molecules. These secondary metabolites, including flavonoids, tannins, and salicylic acid, accumulate in plant tissues in response to nematode infection, inhibiting their movement, feeding, and reproduction (Baldridge et *al*., 1998; Wuyts et *al*., 2006). They contribute to cell wall lignification, enhancing root resistance to nematode penetration, while their oxidation produces toxic quinones that suppress nematode activity (Zacheo et *al*., 1997). Additionally, phenolics participate in plant immune signaling,

particularly through salicylic acid, which activates systemic acquired resistance (Gheysen & Mitchum, 2019). Studies have shown that plants with higher phenolic content exhibit greater resistance to root-knot nematodes (*Meloidogyne spp.*) and cyst nematodes (*Heterodera spp.*), as these compounds localize around feeding sites, disrupting nematode development (Faostat et *al*., 2003; Mokbel & Alharbi, 2014). The practical application of phenolics in nematode management includes breeding resistant crop varieties, using phenolic-rich plant extracts as natural nematicides, and applying salicylic acid to induce resistance (Chitwood, 2002; Oka et *al*., 2007). Understanding and utilizing these natural defense mechanisms could lead to sustainable nematode control strategies in agriculture.

CHAPTER II : MATERIAL AND METHODS

II.1 Presentation and description of the sites: sample sites and working site

II.1.1. Soil sample sites

Soil sampling was carried out in the central region of Cameroon which represents the Agroecological zone V. Akonolinga (107.9km), Mbankomo (21.3km), Bafia (127.3), Ndji (67.9km) and Mbalmayo (49.5km) away from Yaounde central town according to the standard sampling protocol, where the collection of soil samples from the rhizosphere of the white and red cultivars of *X. sagittifolium* plants within ages of 6-9 and 9-12 months of age (Fig.3).

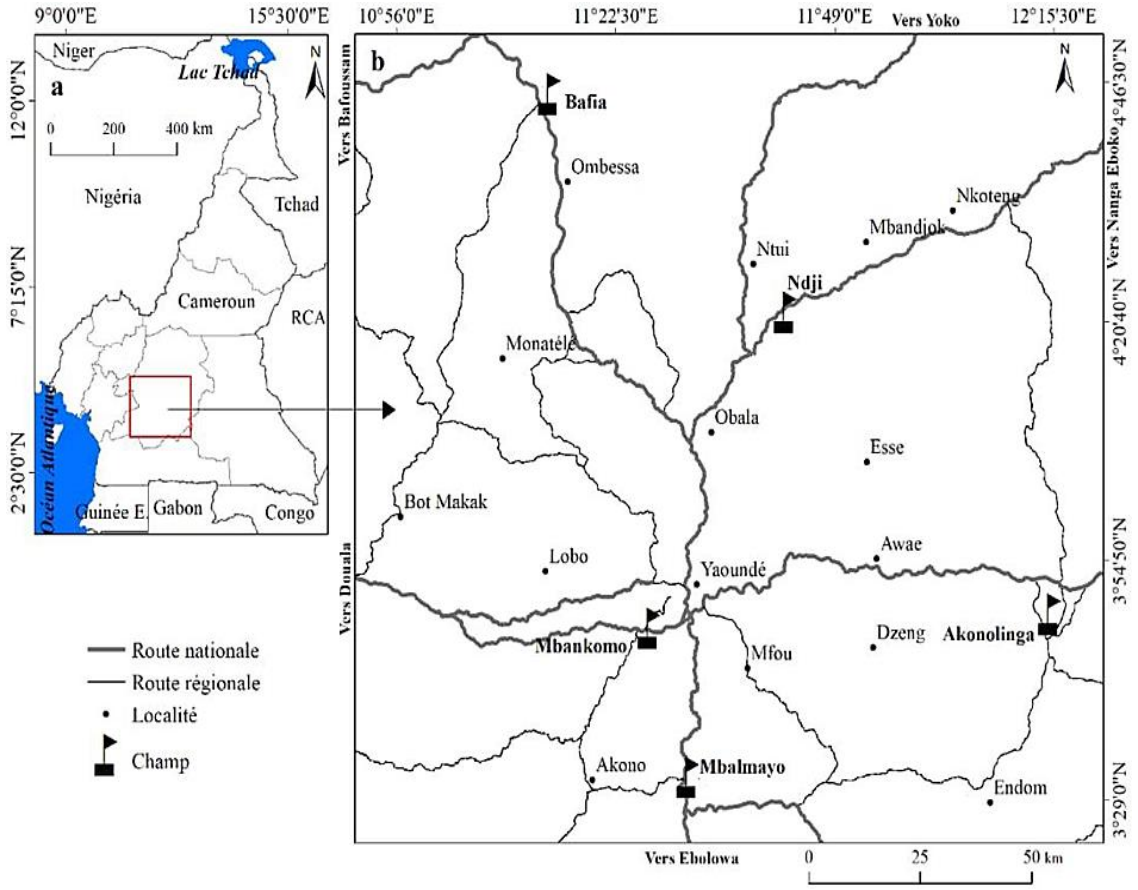


Fig.3. Geographical locations for the soil sampling sites from the rhizosphere of *Xanthosoma sagittifolium*.

II.1.2. Experimental site

The experimental site in which the research work was carried out is located on the campus of the Higher Teacher Training College of Yaoundé 1. This subdivision is part of the Mfoundi Division which belongs to the Bimodal Rainforest Zone (Zone V). The work area was located in the right wing of the former university restaurant. The geographical coordinates of this work site were 03.51°62'8" northern latitude and 11°51'4" Eastern longitude with an altitude of 747 m (Fig.4).

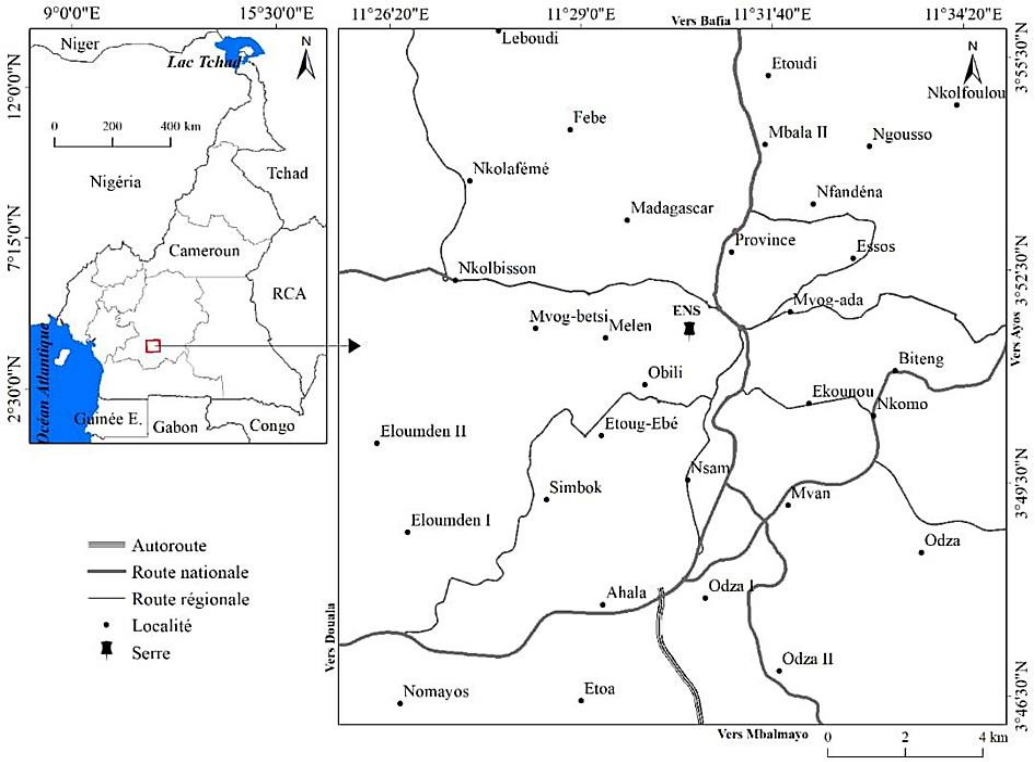


Fig.4. Geographical location of the experimental site

II.1.3. Material

II.1.3.1. Biological material

The plant material consisted of PIF plants of two apparently healthy cultivars (Cultivar white and red) of *X. sagittifolium* produced at the Higher Teacher Training College of Yaoundé 1 of ages within 3-4 months, the seeds of *Lactuca sativa* and *Abelmoschus esculentus* were bought at an agri-shop of Marché MFOUNDI (Fig.5).

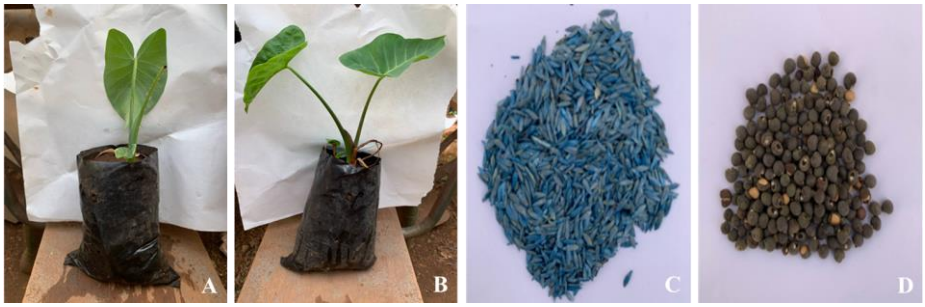


Fig.5. PIF plant of white (A) and red (B) cultivars of *X. sagittifolium*, Seeds of *Lactuca sativa* (C) and *Abelmoschus esculentus* (D), (Picture by NENGI, 2025).

II.1.3.2. Soil material

Soils from the rhizosphere of *X. sagittifolium* were sampled from Akonolinga, Mbankomo, Bafia, Ndji, and Mbalmayo and Sterilized soil used to grow red and white cultivars of *X. sagittifolium*, *Lactuca sativa* and *Abelmoschus esculentus* at Ecole Normale Superieure Yaounde as shown in Figure (6).

Fig.6.Soil material used in the experimentation: sterilised soil(A), sampled soils from the aforementioned sites Akonolinga, Bafia, Ndji, Mbankomo and Mbalmayo: B, C, D, E, and F respectively, (Picture by NENGI, 2025).

II.1.3.3. Laboratory equipment

- Erlenmeyer flask; Used for the preparion of reagents needed for different dosages.
- Beaker; Abeaker was used to measure volumes of water needed for the extraction of nematodes.
- Pipette; was used to make precision volumetric measurements during dosages.
- Petri-dish; Dishes were used to carry out germination tests in the laboratory.
- Light microscope. A light microscope was used for the isolation of nematodes and their eggs before proper characterisation on an electronic microscope.
- Slides and coverslips; They were used to mount nematode eggs that were to be observed under a microscope.
- Reagents; Used according to specific protocols to catalyse chemical reactions for metabolite extractions.
- Eppendorf tubes: Used to store nematode suspensions.

II.1.3.4. Other materials

- Iphone camera was used for all pictures.
- Bowls were used to contain ground
- Ground; Black soil was used for the setup.
- Sand; the black soil was mixed with sand to reduce argile nature of the soil.

- ❖ Furnace; Used as an alternative for soil sterilisation before use.
- ❖ A set of sieves; They were used for extracting nematode eggs at different sizes and juvenile satges.
- ❖ Black plastic bags; Black polythene sachets were used to acclimatate the *X. sagittifolium* pifs.
- ❖ Watering cans ; Used for watering plants daily
- ❖ Measureing tape; Used for collecting agronomic parameters.
- ❖ Caliper; Used for taking agronomic parameters.
- ❖ *Ipomoea batatas:* For the rapid multiplication of Nematodes

II.2. Method

II.2.1 Characterise Nematode species in the rhizosphere of *X. sagittifolium*

II.2.1.1. Agronomic parameters of *X. sagittifolium*

The agronomic parameters of *X. sagittifolium* for each of the five sites were taken. Soil samples from the rhizosphere of *X. sagittifolium* were collected.and Table (II) shows the different plants that were found in polyculture with *X. sagittifolium*.

Table II. Plants in polyculture with *X. sagittifolium.*

Sample area	Mixed plants in the farm
Akonolinga	*-Manihot esculenta* *-Arachis hypogea* *-Musa sp* *-Elaeis guineensis*
Mbankomo	*-Talinum fruticosum* *-Musa sp* *-Carica papaya* *-Vaccinium membranaceum* *-Vernonia amygdalina* *-Abelmoschus esculentus* *-Ipomoea batatas*
Bafia	*-Musa sp* *-Abelmoschus esculentus*
Ndji	*-Musa sp* *-Theobroma cacao* *-Dioscorea sp*
Mbalmayo	*-Theobroma cacao* *-Musa sp*

The growth parameters taken at the harvest spots were:

- Plant height: The height measured using a measuring tape on all plants in each field. Measurements taken from the collar to the "V" of the last emitted leaf on the pseudostem.
- Collar diameter: The collar diameter of the pseudostem of each plant measured using a caliper. Measurements taken at the collar level of the plants.
- Number of leaves: Counted manually for each plant.
- Leaf area: Measured and calculated using the formula: Sf = 2/3 (L × W), where L and W represent the length and width of the leaf, respectively. These dimensions previously measured using a measuring tape (Champion, 1963).
- Number of roots: Counted manually.
- Average root size: Done by the use of a measuring tape.
- Average root weight: Determined using a high-precision electronic balance of the BK-JA5003B brand.

II.2.1.2. Soil physicochemical analyses of the different soils used

The composite soil sampling proposed by (McBride, M. B, 1991) was carried out during the dry season in Cameroon, in April 2024, around the first and second weeks in the order; Akonolinga, Mbankomo, Bafi, Ndji and Mbalmayo. Soil sample of 5 kg collected from the rhizosphere of *X. sagittifolium* plants of the white and red cultivars at a depth of 50cm, following age intervals of 6–9, and 9–12 months. Ten (10) soil samples in total were collected across the five sites. From the 10 soil sampled per site (each weighing 5 kg), they were each pretreated, 50g weighed out then parcelled and sent for physicochemical analysis in the Soil Analysis and Environmental Chemistry Laboratory of the Faculty of Agronomy and Agricultural Sciences at the University of Dschang. The remaining soils were used for the inoculation with *A. esculentus*, *L. sativa* and pif plants of *X. sagittifolium* red and white cultivars.Only the soil from the rhizosphere of the white cultivar was used in this entire experimentation.

II.2.1.2.1. Soil analysis

The physicochemical and chemical parameters of the soil substrate used in the nursery and for cultivation were determined following the standard methods recommended by (Pauwels et *al*.,1992) and complying with ISO. AFNOR NF and EN standards.

II.2.1.2.2. Physical soil analysis methods

The physical analyses of the soil consist of determining the texture by evaluating the proportions of clay fine silt, coarse silt, fine sand and coarse sand, These particles were dosed and classified according to their diameter: clays (< 2 μm), fine silts (2 to 20 μm), coarse silts (20 to 50 μm), fine sands (50 to 200 μm) and coarse sands (200 to 2 000 μm), using the Robinson-Kôhn pipette method based on Stokes' law (1851), after destruction of organic matter by hydrogen peroxide and iron oxides as well as carbonates by hydrochloric acid (NF X 31-107 standard) and sedimentation of the fine to very fine particles according to Stokes' law (1851), The mineral texture of the soil was determined based on its relative proportion of clay, silt and sand according to the texture triangle reference.

II.2.1.2.3 Soil chemical analysis methods

A. Soil pH

According to the pH interpretation standards from the pedological reference (INRA, 1995), the pH was measured by potentiometry using a "Hanna Instruments" pH meter in the aqueous and acidic soil extract at a ratio of 1:2,5 (ISO standard 10390). (Table III).

Table III. Soil pH interprétation standards (INRA, 1995)

pH	< 3.5	3.5 – 4.2	4.2 – 6.5	6.5 – 7.5	7.5 – 8.7	> 8.7
	Hyper acidic	**Very acidic**	**Acidic**	**Neutral**	**Basic**	**Very Basic**

B. Soil organic matter content

Organic carbon was determined by oxidation of 0.5 g of sample with potassium dichromate (K2Cr2O7) and back-titration of the remaining dichromate with ferrous sulfate heptahydrate (FeSO4. 7 H2O). (AFNOR standard NFU 44 - 051) (Table IV).

Table IV . Organic matter interpretation standard (Duprarque, 2011)

Organic carbon	< 1	1 à 2	2 à 4	> 4
	Very poor	**Poor**	**Average**	**Rich**

C. Total nitrogen content and C/N ratio

The ratio of carbon to total nitrogen was calculated to assess the decomposition level of organic matter, one of the main indicators of soil fertility and physicochemical quality. Total nitrogen was determined by sulfuric acid mineralization of 2 g of sample using the Kjeldahl method (NFISO 11261 standard) (Calvet & Villemin, 1986; Kloepffer, W. (2008). (Table V).

Table V. Interpretation standards for nitrogen and C/N ratio

Nitrogen (%)	**< 0.05**	**0.05 - 0.1**	**0.1 - 0.15**	**0.15 - 0.25**	**> 0.25**
	Very poor	Poor	Average	Rich	Very rich
C/ N	**<6**	**6 to 8**	**9 to 11**	**12 to 14**	**>14**
	Very low	Low	Normal	High	Very high

D. Available Phosphorus Content of Soil

The available phosphorus was determined by the ammonium molybdate blue colorimetry method after extraction with the Bray II acid solution (HCl + NH4F) from 2.5 g of the sample and reading at a wavelength of 665 nm (NF X 31 - 130 standard); the interpretation standards for available phosphorus are those of (Calvet & Villemin, 1986), (Table VI).

Table VI. Interpretation standards for available phosphorus (Calvet & Villemin 1986)

Pass (ppm)	< 30	30 – 50	50 – 100	100 – 200
	Very poor	**Poor**	**Averagely poor**	**Rich**

E. CEC of Soils and Base Saturation Ratio

The cation exchange capacity (CEC) was determined by the method that consists of saturating the exchange complex with ammonium acetate (1N) at pH 7, then displacing the NH4+ ions with a 1N KCl solution and then determining the nitrogen after distillation (Pansu & Gautheyrou, 2003). The CEC represents the total quantity of exchangeable cations that the soil can adsorb on its complex and exchange with the surrounding solution under well-defined pH conditions. This CEC was determined by extraction of exchangeable cations, washing with alcohol, replacement of NH4+ ions by K^+ ions of 1N KCl, steam distillation and titration with 0,01 N sulfuric acid (NF EN ISO 23470 standard) (Table VI), The exchangeable bases (Na^+, Ca^{2+}, Mg^{2+}, K^+) were determined by atomic absorption after saturation with 1N ammonium acetate at pH 7, The base saturation ratio (Vx) of the Ca^{2+}, Mg^{2+}, Na^+, K^+ elements were calculated using the following formula: Vx = ([X]/CEC) x 100, With [X], the ion concentration; CEC, the cation exchange capacity, The evaluated potassium and sodium were determined by the flame emission spectrometry method by direct reading in the ammonium acetate extract at pH 7 of the sample (AFNOR NF T 90 - 019 standard); Calcium and magnesium by complexometry and the titrimetric method 33 of an ammonium acetate extract at pH 7 of the sample. (AFNOR NF U 44 -146 standard), (Table VII, Table VIII).

Table VII. Interpretation standards for soil CEC

CEC ($cmol.kg^{-1}$)	< 5	5 – 10	10 – 15	15 - 20	> 20
	Very low	Low	Medium	High	Very high

Table VIII. Interpretation standards for soil base saturation ratio (Beernaert & Bitondo. 1992)

SBE ($cmol.kg^{-1}$)	<2	2-5	5-10	10-15	>15
	Very low	Low	Normal	High	Very high

II.2.1.3. Extraction and Characterization of nematodes present in the rhizosphere of *X. sagittifolium*

II.2.1.3.1. Extraction of nematodes present in the rhizosphere of *X. sagittifolium*

The soils after collection were labelled, Akonolinga soil, Mbankomo soil, Bafia soil, Ndji soil and Mbalmayo soil respectively. Each soil mixed thoroughly, but gently when tumbling to broke clumps, remove stones and to homogenize the nematodes within the soil then passed through a coarsed sieve with holes of 1-2mm.

A method proposed by Jenkins (1964). Was used for the extraction of Vermiform (free-living nematodes), endoparasites and ectoparasitic nematodes from the soil. A measured volume of soil 100g was put in a 250ml volumetric flask and filled with water up to the mark, gently agitated then allowed the water and soil in the flask to settle for 20 seconds. The suspension was is poured over through coarsed sieves of 0.5mm, 0.25mm, 0.125mm and 0.625mm arranged in this order to maximize the quantity of nematodes to be retained. This process is repeated two to three times, the content of the sieves washed off in into a beaker under a running tap, the beaker was left to settle for an hour then excess water poured out. This procedure was used for all the sampled soils and the nematode sediment at the buttom of the beaker stored in labelled Eppendorf tubes and set for characterization under a compound microscope. This sieving method was used to extract nematodes is suitable for as technique for migatory nematodes.

II.2.1.3.2.Characterization of nematodes present in the rhizosphere of *X. sagittifolium*

The nematode from the aforementioned Eppendorf tubes were poured in a dish, handled in a fluid medium due to their microscopic size differences. This medium was prepared by preparing formalin glycerol (formaldehyde10ml + formalin 40% +1ml of glycerol and 89ml distilled water) added to 2ml of the nematode suspension (Freckman et *al*. 1977)., easily

obtaining a death shape to ease identification**.** They were picked using a splinter and mounted as individual and pure culture then observed using a convenient lighting and magnification of 10x then 40x.(Coyne et *al*., 2007). These nemetades were captured and images later on classified and identified at genera level.

II.2.2. Evaluate the ffect of nematodes on the growth of *X. sagittifolium, L. sativa* and *A esculentus*.

II.2.2.1. Germination test

Healthy seeds of *L. sativa and A. esculentus* were carefully selected and disinfected using bleach at a concentration of 5% and 10% for 20 minutes. 400 seeds each. These seeds at 5% and 10% of bleach were rinsed three times at different intervals of 5 minutes. 10 minutes and 15 minutes respectively. These seeds were then wrung out for an hour respecting the protocol (ISTA Zurich, 2020). The germination was followed up by carefully placing 50 seeds in each Petri dish repeated four times for one treatment and for one plant (32 dishes) lined with cotton preliminarily watered before planting. Collection of germination parameters begun after 24h of incubation at room temperature, germinated seeds were counted until it was the 6th day, Germination parameters were calculated: the germination percentage (GP) (AOSA, 1990), Germination index (GI) (AOSA, 1983), coefficient of velocity (CV) (Maguire, 1962), mean germination time (MGT) (Ellis & Roberts, 1981), time to 50% germination (T_{50}) which is the time at the end of which 50% of the experienced seeds had taken root (Kouam et *al.*, 2017) duration of germination which is the time after which no more germination is recorded and length of radicle. Sugar and protein were assessed on grains before germination and after germination on cotton soaked in water.

The germination percentage: $\mathbf{GP\ (\%) = \frac{Number\ of\ germinated\ seeds \times 100}{Total\ seed\ number}}$

Germination index (GI): ∑Gt/Dt

Where; Gt :is the number of germinated seeds on day t and,

Dt :is the time corresponding to Gt in days

Coefficient of velocity (CV): $CV = \frac{(G1+G2+\cdots+Gn}{(1xG1+2xG2+\cdots+nxGn)}$ **x 100**

With G: number of germinated seeds and n is the last day of germination

Mean germination time (MGT): $\mathbf{MGT=\frac{\Sigma(Dn)}{\Sigma n}}$

Where, n is the number of seeds germinated on each day and D is the day of counting

Time to 50% germination (T_{50}): $\mathbf{T_{50}\,(day) = T1+ \frac{T2-T1)\ x\ (0{,}5-G1)}{(G2-G1)}}$

With G_1 is the cumulative GR with the value closest to 50% by lesser

Value, G_2 is the cumulative GR with the value closest to 50% by upper

Value, T_1 is the day whose cumulative GR is closer to 50% by lesser

Value, T_2 is the day whose cumulative GR is closer to 50% by upper value

II.2.2.2. Multiplication of Nematodes and Innoculation of the plants

II.2.2.2.1. Multiplication of Nematodes

The available materials permitted us to use a Cobb's method for this multiplication whereby;

A colander lined with filter paper was suspended on a bowl, then 500g of the previously sampled soil added to the colander, A reasonable amount of sweet potatoes (*Ipomoea batatas*) roots added to the soil, then covered with another 500g of soil and distilled water was added until muddy solution formed. This proceduce was carried out simultaneously setting all the five sampled soils for multiplication. The bowls were covered and kept for a week while adding distilled water every day for 7 days.

II.2.2.2.2 Innoculation of the plants

This multiplication technique above yielded a useful amount of nematode that was used to inoculate *X. sagittifolium, A. esculentus* and *L. sativa* throughout 3 months of the experimentation. The solution obtained at the end of day 7 was used inoculate these plants with an equal proportion of nemaodes. A method proposed by Hutangura et *al.*, 1998 was modifired to inoculate plants with approximately 720 juvenile 2 stages of nematodes for 6 plants.

II.2.2.3. Growth parameters and disease severity

II.2.2.3.1. Growth parameters

The arrangement used for the cultivation of the three speculations was a complete block with four repetitions of six treatments which were; Control (T0) made of only sterilized soil from none of the sample areas, and the other treatments made of sterilized soil and these treatments added to it, Mbalmayo Soil (T1), Mbankomo Soil (T2), Akonolinga Soil (T3), Ndji Soil (T4), Bafia Soil (T5) (Fig.7).

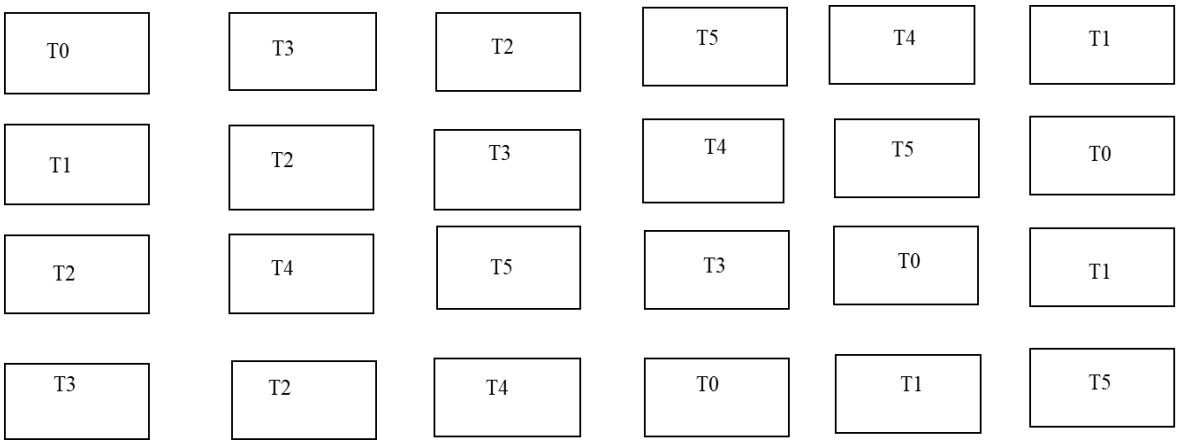


Fig.7. Experimental setup used for culture and inoculation of *X. sagittifolium*, *L. sativa* and *A. esculentus*. Control (T0), Mbalmayo Soil (T1), Mbankomo Soil (T2), Akonolinga Soil (T3), Ndji Soil (T4), Bafia Soil (T5).

For each treatment, 2 L of the sterile soil substrate, consisting of black soil and sand mixed at a 2:1 ratio, was introduced into 5 L basins. The soil was sterilized in an autoclave at 121°C for 1 hour. The mixture was then cooled in the open air for two days to allow reoxygenation of the substrate and volatilization of any compounds formed during sterilization. The basins were placed on a wooden shelf 60 cm above the ground to prevent contamination of the plants. Each basin, representing a treatment block, was replicated four times, with each containing 12 plants for *L. sativa* and *A. esculentus*, then four plants for each cultivar of *X. sagittifolium*. The treatments were spaced 0.5 m apart, with a 1.5 m distance between the two varieties. Watering was carried out twice daily, ensuring that excess water did not run off during the experiment.

The effect of nematodes infestation was evaluated in all three species by keeping records of agronomic parameters measured every after every month from the germination to the end of the experimentation, These parameters where;

- Average plant height
- Average collar diameter
- Average number of leaves
- Leaf surface area
- Incidence and Severity of disease

II.2.2.3.2 Disease incidence and severity

The disease incidence and severity of *X. sagittifolium*, *L. sativa* and *A. esculentus* were estimated using the method suggested by Tchumakov & Zahanova, (1990) with respect to the different treatments. Disease incidence which is a measurement for the proportion of diseased

plants within a given unit, irrespective of the severity of the attack on each plant, represents the percentage of diseased plants in relation to the total number of plants (Manikandan et *al*., 2010). Expressed in percentage and calculated using the formula:

$$\mathbf{I\ (\%) = Na\ /Nt \times 100}$$

Where

I: is the incidence of the disease in percentage (%),

Na: the number of plants affected and

Nt: the total number of plants.

The severity of the disease, which represents the degree of attack by the disease on an organ of the plant or the entire plant (Vakalounakis & Fragkiadakis, 1999), expressed according to the formular:

$$\mathbf{S = ((\Sigma AB/Nm)\ x\ 100)}$$

With ΣAB: multiplication of the sum of the number of diseased plants (A) with their corresponding degree (B) expressed in %.

Nm: Total number of diseased plants.

II.2.3. Analyse the content level of metabolites in leaves of *X. sagittifolium*, *L. sativa* and *A. esculentus*

II.2.3.1. Extraction and dosage of Chlorophyll contents

Total chlorophyll content was determined in *X. sagittifolium*, *L. sativa and A. esculentus* leaves using the ARNON (1949) method. 0.5g of plant leaves were ground in the presence of a pinch of fine sand until a homogeneous paste was obtained. 3 ml of acetone was added. The homogeneous mixture obtained was filtered through a Wattman filter paper previously soaked in acetone and the filtrate collected in a test tube. This filtrate, which constituted the crude chlorophyll extract, was used for quantitative analysis. The total chlorophyll content of the leaf was measured using a spectrophotometer (JENWAY 6305) at 652 nm against a blank consisting of the 80% acetone solution (Arnon, 1949). The optical densities obtained were used to determine the content in mg.g of fresh matter according to ARNON's formula: total **Chl = (D.O.652/34.5) mg.ml**.

II.2.3.2 Extraction and dosage of total soluble sugars

The sugar content was determined according to the method described by (Babu et *al*., 2002) modified. 0.5g of fresh leaves were ground in a porcelain mortar with 5 ml of 80% ethanol

then centrifuged at 3000 rpm for 10 min at 7°C, using a BECKMAN COULTER centrifuge (Allegra X-22R Centrifuge). The supernatant consisting of the crude sugar extract was recovered in Eppendorf tubes and stored at 20°C. The assay was carried out according to the method of Saha & Brewer (1994). In each tube. 5ml of orthophosphoric acid reaction medium and 100 µL of extract was introduced. The mixture was heated in a water bath at 80°C for 20 min. After cooling, the absorbance of the green complex formed was measured at 620 nm. The total soluble sugar content was assessed with reference to a calibration range (Appendix 3), using a solution of glucose (1 $mg.ml^{-1}$) in alcohol at 80°C. These total soluble sugar contents are expressed in mg.g of fresh weight.

II.2.3.3. Extraction and dosage of total soluble proteins

Total proteins were extracted using the modified protocol of (Pirovani et *al*., 2008). 0.5g of fresh leaves were cold-ground in 2 ml of extraction buffer (phosphate buffer). After vortexing for 10 min and incubating on ice, the mixture was cold centrifuged at 3000 rpm for 10 min at 7°C. The supernatant collected constituted the total soluble protein fraction. This supernatant was stored in Eppendorf tubes and kept at -20°C for quantitative analysis.

a. Principle

In an acid medium, the light brown Coomassie Brilliant Blue G250 binds to the hydrophobic residues of the amino acids making up the proteins to form a blue coloured complex absorbing at a maximum of 595 nm, the intensity of the coloration being proportional to the quantity of protein present in the medium.

b. Procedure

The following were added to each test tube

- 2µL of phosphate buffer pH 1 Molar ;
- 10µL of extract ;
- 2000 µL of Bradford reagent.

After incubation at room temperature for 30 min. The optical density (OD) was read at 595 nm using a JENWAY 6305 spectrophotometer against a blank in which the extract was replaced by distilled water. For each extract. 3 replicates were performed and the protein quantities were expressed in mg.g of fresh matter by reference to the calibration curve established with BSA.

II.2.3.4. Extraction and assay of phenolic compounds

Extraction was carried out according to the modified protocol of El Hadrami et *al* (1997). 0.5 g of fresh *X. sagittifolium*, *Lactuca sativa* and *Abelmoschus esculentus*. leaves were grinded cold (4°C) in 2 ml of hydrogen chloride. The mixture was then centrifuged at 3000 rpm for 10 min using a BECKMAN COTER centrifuge (Allegra X-22 R Centrifuge). The supernatant was recovered and placed in an Eppendorf prepared for the assay.

a) Principle

The Folin-Ciocalteu reagent, a strong yellow acid formed from phosphotungstic acid and phosphomolybdic acid, is reduced in an alkaline medium under heat during the oxidation of phenolic compounds to a mixture of blue tungsten oxide and molybdenum oxide. The blue colour produced, with an absorption of 760 nm, is proportional to the quantity of phenolic compounds present in the extract.

b) Procedure

In a test tube, successively:

- 100 µL of extract ;
- 2.5 ml distilled water ;
- 10 µL of Folin-Ciocalteu ;
- 0.5 ml 20% Na2CO 3 ;

The resulting mixture was incubated in a water bath at 40°C for 20 min. The Folin-Ciocalteu reagent turns blue in the presence of phenolic compounds. The intensity of the coloration was proportional to the phenolic compound content of the reaction medium. Absorbance was measured using a spectrophotometer (JENWAY brand) at 720nm against a blank in which the extract was replaced by distilled water. For each extract, 3 replicates were performed.

II.3. Statistical analysis

All the statistical analysis was done using excel for the treatment and realization of curves and histograms. Student-Newman Keuls and Duncan’s test with the least significant difference of 5 % used for the comparative analyses of the results with the help of SPSS 20.0.

CHAPTER III : RESULT AND SDISCUSSION

III.1. Results

III.1.1 Characterisation of Nematode species in the rhizosphere of *X. sagittifolium*

III.1.1.1. Agronomic parameters of *X. sagittifolium* from the harvest sites

The Table (IX) below provides a comparative analysis of two cultivars, 'White' and 'Red', of *Xanthosoma sagittifolium* across five localities: Akonolinga, Mbankomo, Bafia, Ndji, and Mbalmayo. The evaluated agronomic parameters include plant height, number of leaves, collar diameter, rhizome size, rhizome weight, and root number. This data highlights the influence of locality on plant growth and development, as well as the variation between the two varieties based on Student-Newman and Keul's evaluation.

For the white cultivars of *X. sagittifolium* the average plant height was higher in Bafia (134.80 ± 33.67cm), the average number of leaves showed little or approximately no significant difference in all of the farms, as for the average collar diameter, the apparent result was in Ndji with an average of (16.80±04.91cm), the average rhizome size was greater in Mbalmayo (15.10±02.67cm), average rhizome weight was high for the white cultivar (381.40±229.02cm) at Ndji then the highest average root number infers the sampling carried out in Akonolinga (96.00±45.63cm)

For the red cultivar of *X. sagittifolium*, the average plant height was higher at in Ndji giving (144.74±17.29cm), the average collar diameter was greater in Mbalmayo (18.30±07.57cm), the average rhizome size and weight showed greater results in Mbalmayo (14.40±07.27cm) and Ndji (512.00±467.73cm) respectively, and lastly the average number of roots were appreciative from the sampling in Akonolinga (77.00±22.28).

Table IX. Agronomic parameters of the two cultivars of *X. sagittifolium* from which soils were sampled

Variety	Locality	Agronomic parameters evaluated					
		Average plant Height (cm)	**Average number of leaves**	**Average collar diameter (cm)**	**Average height of rhizome (cm)**	**Average weight of rhizome (g)**	**Average number of roots**
'White'	**Akonolinga**	115.92±12.43a	01.20±00.44a	12.10±01.43a	11.30±01.98a	193.00±45.51a	96.00±45.63b
	Mbankomo	078.96±10.12a	02.00±00.70a	10.70±01.20a	14.10±03.57a	173.00±76.72a	66.40±09.44b
	Bafia	134.80±33.76a	02.80±01.30b	13.50±05.25a	11.40±05.59a	238.20±228.44a	14.40±03.78a
	Ndji	120.94±19.91a	02.20±00.44ab	16.80±04.91a	15.10±02.67a	381.40±229.02a	64.60±32.79b
	Mbalmayo	122.52±18.32a	03.20±00.83b	12.20±02.01a	14.87±07.59a	282.60±226.62a	90.80±25.98b
'Red'	**Akonolinga**	106.46±33.05a	01.20±00.44a	12.30±01.89ab	11.62±01.37a	171.00±057.95a	77.00±22.28a
	Mbankomo	106.46±33.05a	01.20±00.44a	08.10±02.30a	13.10±07.94a	156.20±151.99a	68.00±14.71a
	Bafia	109.47±35.08a	01.80±0.44a	10.70±3.23a	13.05±07.14a	310.20±193.76a	28.00±20.09a
	Ndji	144.76±17.29a	02.40±00.89a	14.40±01.29ab	13.80±00.83a	428.60±337.68a	73.40±42.87a
	Mbalmayo	130.04±50.16a	03.80±01.48a	18.30±07.57b	14.40±07.27a	512.00±467.73a	55.60±34.91a

Means with same letter in the same column are not significantly differents at P ≤0.05

III.1.1.2. Soil physicochemical properties of the different soils used

The Table (X) below shows the physicohemical analysis results of the sterilised soil and the sampled soils used for this experimentation. Organic matter (OM) is a key component of soil fertility as it serves as a reservoir for essential nutrients, enhances microbial activity, and improves soil structure. The results show that Mbalmayo (4.42%) and Mbankomo (3.08%) have the highest OM content, suggesting these soils are rich in decomposable organic materials that provide a steady supply of nutrients for plant growth. In contrast, Akonolinga (2.28%) and Bafia (1.41%) contain moderate levels of organic matter, which may support microbial activity but might require organic amendments over time. The lowest OM levels are observed in sterilized soil (1.07%) and Ndji soil (1.07%), indicating poor microbial activity and a reduced capacity to retain essential nutrients. High organic matter content generally favors better plant metabolism by supporting nitrogen mineralization and improving soil aeration.

Soil pH affects the solubility of nutrients and microbial activity, directly influencing plant growth. The analyzed soils exhibit pH values ranging from 4.9 to 6.3, indicating variations in acidity and potential nutrient availability. Mbankomo (6.3), Mbalmayo (6.2), and Ndji (6.1) have the most favorable pH levels, which allow for optimal phosphorus and nitrogen uptake. In contrast, Bafia (5.6) and Akonolinga (5.6) exhibit more acidic conditions that could limit nutrient availability, particularly phosphorus, calcium, and magnesium. The most acidic soil is Bafia, with a pH-KCl of 4.9.

Phosphorus is essential for plant development, particularly in root growth, energy transfer (ATP production), and nucleic acid synthesis. The results indicate significant differences in assimilable phosphorus levels across the soils. Mbalmayo (70.76 mg.kg) and Mbankomo (62.78 mg.kg) have an averagely poor concentrations, making them most ideal for plants requiring high phosphorus levels for metabolic processes amongst all soils. Bafia (17.93 mg.kg) and sterilized soil (14.72 mg.kg) have moderate phosphorus levels, which may still support growth but with potential deficiencies over time. The lowest phosphorus content is recorded was very poor in Ndji soil (12.13 mg.kg).

The carbon-to-nitrogen (C/N) ratio determines the rate at which organic matter decomposes and releases nitrogen into the soil. A high C/N ratio indicates slower decomposition and reduced nitrogen availability, while a low C/N ratio suggests rapid mineralization and efficient nitrogen supply. Among the studied soils, Mbankomo (75.79) has an extremely high C/N ratio, meaning organic matter decomposition is slow, and nitrogen availability is limited. This could lead to nitrogen deficiency in plants, restricting protein synthesis and slowing down growth. Mbalmayo (28.45) also has a relatively high C/N ratio,

though it still allows for some microbial decomposition. In contrast, Akonolinga (8.66) and Ndji (8.39) have moderate C/N ratios, balancing nitrogen release for plant uptake. Bafia (3.22) and sterilized soil (3.42) exhibit the lowest C/N ratios, indicating rapid nitrogen mineralization, which can favor protein accumulation in plants

Table X. Physico-chemical Analysis of each soil sample used in the experimentation

Physico-chemical Analysis							
Physico-chemical	**ELEMENTS**	**Sterilized**	**Akonolinga**	**Mbalmayo**	**Bafia**	**Ndji**	**Mbankomo**
Texture	Clay (%)	26.5	21	17	30	22.5	18.5
	Silt (%)	26.5	33	45	23.5	38	55.5
	Sand (%)	47	46	38	46.5	39.5	26
	Textural class	**SCSi**	**SCSi**	**SSi**	**SCSi**	**SSi**	**SSi**
	Apparent density (g/cm^3)	1.48975	1.186	1.045	1.25675	1.15075	1.143
Soil reaction	pH-water	5.8	5.6	6.2	5.6	6.1	6.3
	pH-KCL	5.1	5.9	5.4	4.9	5.8	5.5
	Electrical conductivity (µS/cm)	0.02	0.08	0.35	0.07	0.17	0.16
Organic matter	OC(%)	0.62	1.32	2.56	0.82	0.62	1.79
	OM (%)	1.07	2.28	4.42	1.41	1.07	3.08
	Total N (g/kg)	0.18	0.15	0.09	0.25	0.07	0.02
	C/N	3.42	8.66	28.45	3.22	8.39	75.79
Exchangeable cations (méq/100g)	Calcium	2.24	2,32	1.92	2.32	2.48	2.4
	Magnésium	0.72	0.16	0.08	1.6	0.88	0.16
	Potassium	0.5	0.5	1.28	0.96	1.44	0.5
	Sodium	0.02	0.02	0.03	0.03	0.03	0.01
	Sum of bases	3.48	3	3.31	4.91	4.83	3.08
Cation exchange capacity (méq/100g)	CEC pH7	12.1	11.21	11.21	10.24	11.35	12.23
	Saturation (%)	28.78	26.79	29.5	47.93	42.56	25.16
Assimilable phosphorus	Bray II (mg.kg)	14.72	14.31	70.76	17.93	12.13	62.78

Clay(C), Sand(S) and Silt(Si).
Sandy clay silt, Sandy clay silt, Sandy silt, Sandy clay silt, Sandy silt, Sandy silt.
Organic Matter (OM), Nitrogen (N), Organic Carbon (OC), Potassium chloride (KCL), Carbon to Nitrogen ratio (C/N).

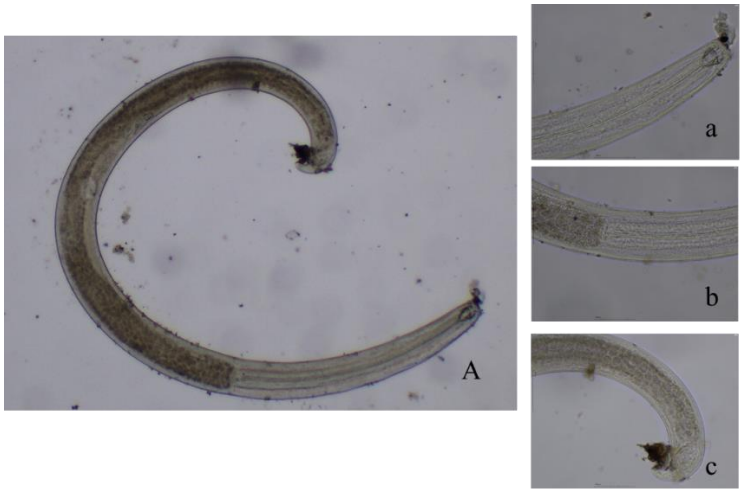
III.1.1.3. Characterization of nematodes

Six nematode taxa were recovered, including key plant-parasitic genera (*Radopholus, Ditylenchus, Xiphinema*) and families (*Hoplolaimidae, Criconematidae*) alongside non-parasitic groups (*Nemertodermatidae*). *Radopholus sp*. occurred in Akonolinga, Mbankomo, Ndji, Bafia, and Mbalmayo soils, whereas *Ditylenchus sp*. was absent only in Ndji. Plant-parasitic nematodes were ubiquitous, yet cultivar growth often outpaced root damage, especially in low C/N sites where rapid biomass accumulation likely buffered parasitism

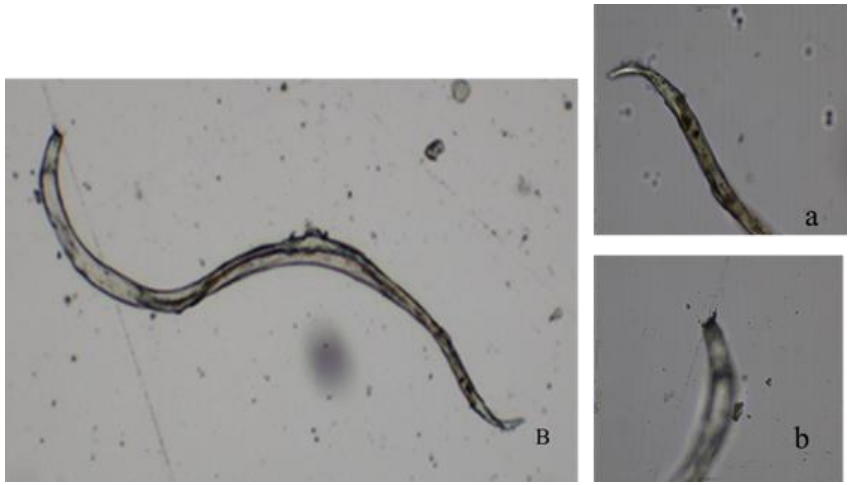
Table XI. Morphological characterization of the different nematodes obtained from the rhizosphere of *X. sagittifolium*

Type	Species	Morphological characteristics	Occurence
Parasitic nematodes	*Radopholus sp.*	-Robust Stylet: Features prominent, rounded knobs for effective feeding. -Elongated Vermiform Body: Adapted for burrowing through plant tissues. -Target Plants: Primarily infests banana, citrus, and other tropical crops.	- Akonolinga soil - Mbankomo soil - Ndji soil - Bafia soil - Mbalmayo soil
	Ditylenchus sp.	-Slender Body: Vermiform, slightly curved shape. -Esophageal Overlap: Esophagus overlaps the intestine. -Rounded Tail: Tapered but with a blunt tip -Commonly infests bulbs, stems, and tubers like Potatoe. Causing ; Yellowing and Wilting of leaves, Stunted Growth,	- Mbalmayo soil - Akonolinga soil - Mbankomo soil
	Xiphinema sp	-Long Stylet: Needle-like, used for deep root penetration. -Elongated Body: Vermiform and slender. -Odontostyle Present: A spear-like structure for feeding.	- Mbankomo soil - Akonolinga soil - Ndji soil

		-Target Plants: Affects grapevines, fruit trees, and various vegetables.	
	Nemertodermatidae family	-Flattened Body: Soft, ciliated, and worm-like. -Lack of Gut: No true digestive tract, absorbs nutrients directly. -Hermaphroditic: Possesses both male and female reproductive organs.	- Mbankomo soil of white *X. sagittifolium*
	Hoplolaimidae Family	-Robust Body: Cylindrical and moderately stout. -Esophageal Overlap: Glandular esophagus overlaps the intestine. -Slanted Stylet: Well-developed with basal knobs, aiding in plant penetration.	- Akonolinga soil - Mbankomo soil
	Criconematidae Family	-Thick Cuticle: Annulated with spiny or smooth rings. -Short Stylet: Well-developed for plant feeding. -Stubby Body: Small, stout, and coiled when relaxed.	- Ndji soil - Akonolinga - Bafia soil - Mbankomo

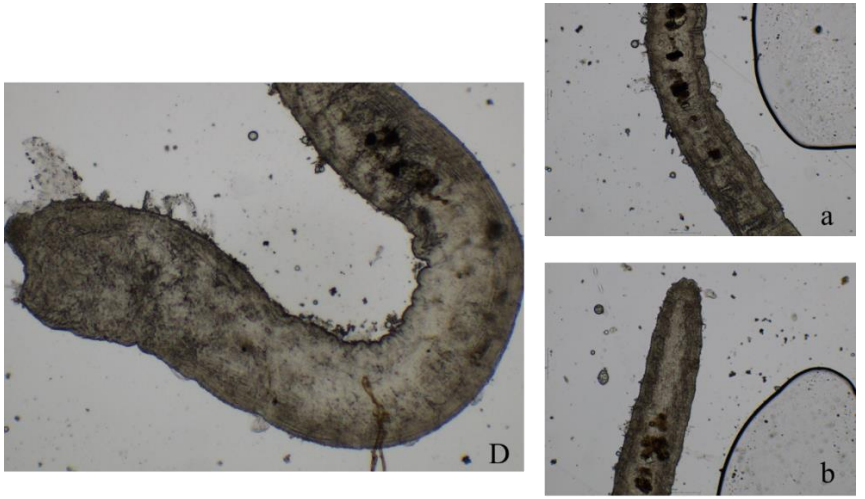


A:*Radopholus sp.*; Head region (a), Body(b) and Tail end(c).

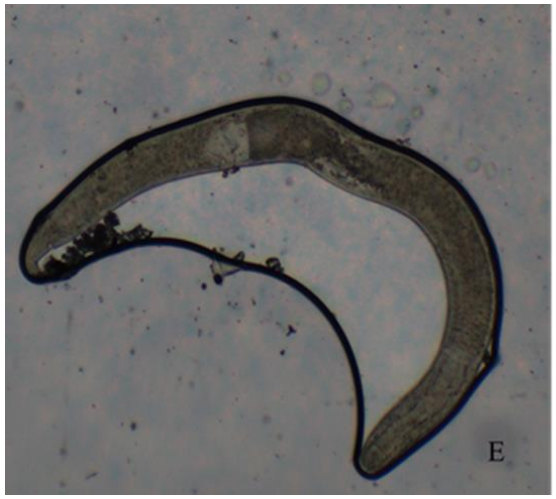


B:*Ditylenchus sp.* ; Head region (a), Body(b) and Tail end(c).

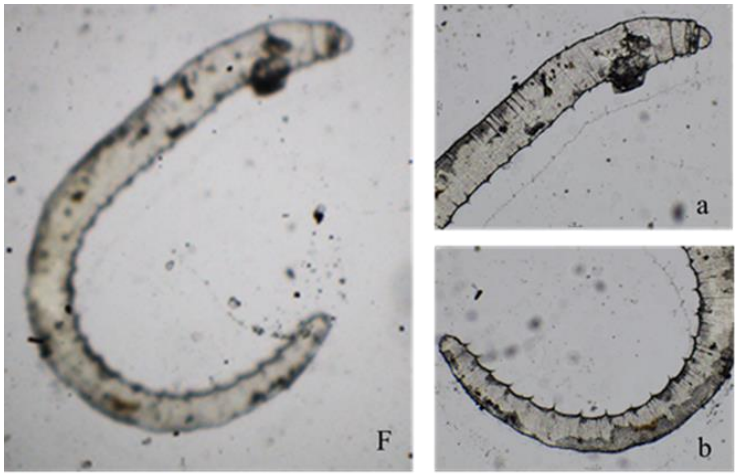
C:*Xiphinema sp.*; Head region (a), Body(b) and Tail end(c).



D:*Nemertodermatidae* family; Body (a) and Tail (b)

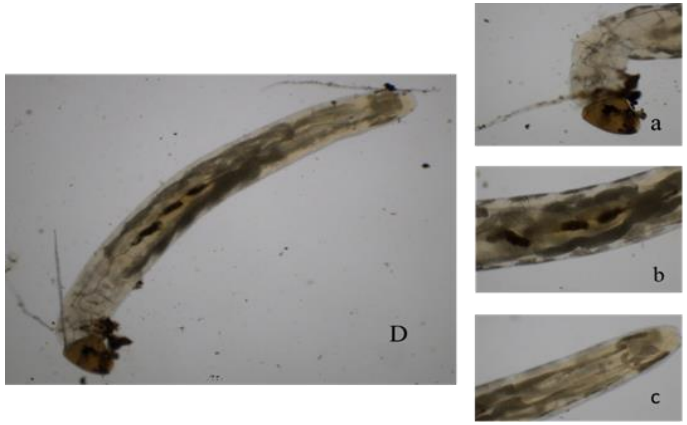


E: *Hoplolaimidae* Family (entire body).



F:*Criconematidae* Family; Head (a) and Tail (b)

G:Unknown nematode Head region (a), Body(b) and Tail end(c).



H:Unknown nematode, Head region (a), Body(b) and Tail end(c).

Fig.8. Images of identified and non identified plant Nematodes:*Radopholus* (A), *Ditylenchus* (B), *Xiphinema* (C), *Nemertodermatidae* (D), *Hoplolaimidae*(E), *Criconematidae* (F), Unknown nematode (G),Unknown nematode (H).

III.1.2.. Evaluating the effect of nematodes on the growth of *X. sagittifolium*, *L. sativa* and *A esculentus*.

III.1.2.1. Germination test

The results for the germination test of *L. sativa* and *A. esculentus* seeds varied increasingly over time for each treatment as shown in the Figure (Fig.9) shows the different germination rate for each treatment. As for growth, parameters calculated in the Figure (9) shows how an impressive germination was conveyed in 6 days with results of morer than 50% germination in the overall seeds.

In *L. sativa*, germination performed better under 10% bleach treatment, achieving 90.25% germination by Day 6, while *A. esculentus* showed optimal performance under 5% bleach with 97% germination.

The different germination parameters were calculated and for 400 seeds of *L. sativa*, germination index (82.08±07.56) was greater in the seed treatment done with bleach at 10% similar results for the mean germination time (608.17±035.15) and coefficient of velocity (00.26±00.005) with bleach at 10%.

For *A. esculentus*,the germination index (59.22±14.16) and the mean germination time (553.73±085.87) calculated happened to show significantly high results with the treatment of bleach at 5%.

Table XII1. Number of *Lactuca sativa* and *Abelmoschus esculentus* seeds germinated per day for 6 days

Varieties	Conditions	Number of seeds	Day 1	Percentage of germination (%)	Day 2	Percentage of germination (%)	Day 3	Percentage of germination (%)	Day 4	Percentage of germination (%)	Day 5	Percentage of germination (%)	Day 6	Percentage of germination (%)
Lactuca sativa	**Bleach at 5%**	400	155	38.75	228	57,00	307	76.75	331	82.75	337	84.25	337	84.25
	Bleach at 10%	400	207	51.75	247	61.75	322	80.50	346	86.50	361	90.25	361	90.25
Abelmoschus esculentus	**Bleach at 5%**	400	078	19.5	178	44.50	252	63,00	322	80.50	388	97,00	388	97,00
	Bleach at 10%	400	015	03.75	024	06,00	035	08.75	219	54.75	322	80.50	322	80.50

Table XIII . Parameters of *Lactuca sativa* and *Abelmoschus esculentus* seeds germinated per 6 days

Varieties	Conditions	Number of seeds	Germination indice (GI)	Mean germination time (MGT)	Coefficient of Velocity (CV)
Lactuca sativa	**Bleach at 5%**	400	72.20±06.77	568.81±033.03	00.25±00.006
	Bleach at 10%	400	82.08±07.56	608.17±035.15	00.26±00.005
Abelmoschus esculentus	**Bleach at 5%**	400	59.22±14.16	553.73±085.87	00.23±00.015
	Bleach at 10%	400	26.43±03.75	333.83±054.28	00.20±00.006

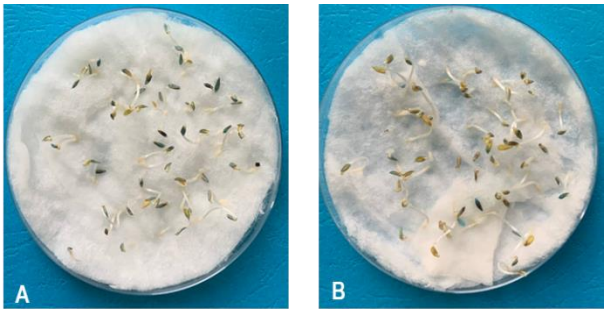


Fig.9. Germination of *Lactuca sativa* seeds in different conditions. Bleach 5% (A), Bleach 10%(B).

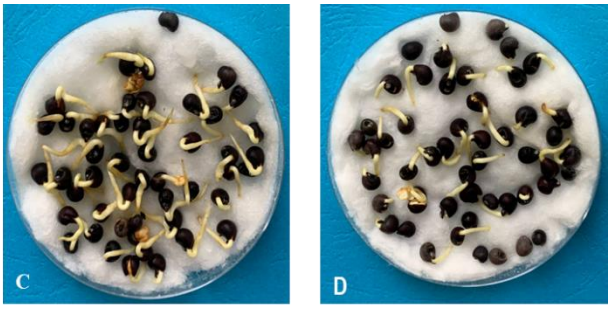


Fig.10. Germination of *Abelmoschus esculentus* seeds in different conditions. Bleach 5% (A), Bleach 10% (B).

III.1.2.2. Growth parameters and disease severity

III.1.2.2.1. Growth parameters

The Student-Newman and Keul's results indicate that soil origin plays a significant role in the growth performance of both the 'White' and 'Red' varieties. Across all treatments, plants grown in control conditions exhibited lower values in most agronomic parameters compared to those grown in soil collected from different locations. This suggests that native soil from these locations contains specific properties that enhance plant development, such as higher nutrient content, better microbial activity, or reduced nematode pressure.

In white *X. sagittifolium*, the average plant height was influenced by the Mbalmayo soil treatment, with maxima of 33.05±07.58 cm and 33.12±03.32 cm in month 2 and month 3, respectively. However, in red *X. sagittifolium*, a significant and important average plant heigh was recorded in the presence of Ndji soil in months 2 and 3, with values of 31.07±07.01 cm and 33.12±03.32 cm, respectively (Table XIII). The average collar diameter in white *X. sagittifolium* was influenced by Bafia soil, with a maximum of 10.04±02.37 mm in month 2. However, in the red cultivar of *X. sagittifolium*, a significant and important average collar diameter was recorded in the presence of Mbankomo soil in month 2, with a value of

09.58±02.94 mm (Table XIII). The average number of leaves in *X. sagittifolium* white cultivar was influenced by Akonolinga soil, with a maximum of 02.25±01.25 in month 2. However, in red *X. sagittifolium,* a significant and important average number of leaves was recorded in the presence of Ndji soil in month 1, with a value of 02.50±00.57 (Table XIII). The average leaf area in white *X. sagittifolium* was influenced by Ndji soil, with maxima of 113.38±045.87 and 112.47±044.47 cm² in month 2 and month 1, respectively. However, in the red cultivar of *X. sagittifolium,* a significant and important average leaf area was recorded in the presence of Ndji soil in month 2, with a value of 085.38±019.73 cm² (Table XIII).

In *Lactuca sativa*, the average plant height was influenced by Akonolinga soil, with a maximum of 05.87±02.17 cm and 06.47±02.17 cm in month 1 and month 2, respectively. The average collar diameter and average number of leaves were very high in the plants that received treatments, compared to the control plants (Table XIV). The average collar diameter was 03.82±01.65 mm in the presence of Ndji soil in month 3 of growth. As for the average number of leaves, it varied according to the applied treatments. In month 3, maxima of 04.83±00.93 and 04.83±02.12 were recorded in the presence of the control and Ndji soil, respectively. The average leaf area in *Lactuca sativa* was influenced by Ndji soil, with maxima of 11.45±09.31 cm² and 12.09±07.61 cm² in month 2 and month 3, respectively.

Table IXV. Agronomic parameters of the white and red cultivars of *Xanthosoma sagittifolium*

Varieties	Treatments	Time (month)	Agronomic parameters calculated			
			Average plant height (cm)	**Average collar diameter (mm)**	**Average number of leaves**	**Average leaf area (cm^2)**
'White'	**Control**	**1**	26.27±08.01a	08.23±02.72a	01.75±00.95a	057.07±031.81a
		2	26.50±08.13a	09.07±03.48b	01.75±00.95a	063.85±030.76a
		3	26.10±08.92a	06.28±02.92a	01.25±00.50a	058.61±032.02a
	Akonolinga Soil	**1**	30.60±06.78a	09.15±01.56a	01.75±00.50a	086.39±029.85a
		2	30.50±06.04a	09.71±03.06b	02.25±01.25a	089.64±029.09a
		3	28.47±05.86a	08.00±03.86a	01.75±00.50a	083.05±027.13a
	Mbankomo Soil	**1**	29.70±06.05a	07.63±02.67a	01.75±00.50a	079.56±019.09a
		2	26.75±05.05a	08.45±02.17b	01.75±00.50a	071.77±018.82a
		3	23.52±08.43a	06.88±02.78a	01.25±00.50a	067.89±034.71a
	Bafia Soil	**1**	27.12±07.17a	08.26±03.49a	02.00±00.81a	075.30±025.92a
		2	27.07±07.91a	10.04±02.37b	02.00±00.81a	078.13±029.75a
		3	18.10±02.61a	06.72±03.86a	01.25±00.50a	034.66±008.11a
	Ndji Soil	**1**	33.05±07.58a	09.73±02.23a	01.50±00.57a	113.38±045.87a
		2	33.00±07.26a	05.04±03.00ab	01.50±00.57a	112.47±044.47a
		3	25.80±08.46a	08.63±03.40a	01.50±00.57a	074.90±042.39a
	Mbalmayo Soil	**1**	32.27±03.71a	09.47±01.29a	01.25±00.50a	100.86±026.12a
		2	33.12±03.32a	01.41±00.64a	01.00±00.00a	104.54±023.86a
		3	31.92±06.75a	08.34±01.40a	01.50±00.57a	093.55±023.08a
'Red'	**Control**	**1**	21.27±06.75a	05.71±02.30a	01.50±00.57a	039.00±022.58a
		2	21.20±06.61a	05.84±02.88ab	01.50±00.57a	045.23±028.35a
		3	15.90±07.02a	05.27±02.08a	01.50±00.57a	030.01±026.21a
	Akonolinga Soil	**1**	29.90±06.13a	04.13±01.78a	01.75±00.50a	059.50±026.59a
		2	30.42±06.25a	08.70±01.56b	01.50±00.57a	062.25±032.25a
		3	26.30±07.18ab	07.37±03.20a	01.50±00.57a	048.07±019.18a
	Mbankomo Soil	**1**	24.87±08.56a	07.34±02.32a	01.75±00.50a	055.59±022.27a
		2	23.57±06.87a	09.58±02.94b	01.75±00.95a	064.84±011.56a
		3	25.75±02.96ab	07.05±01.37a	01.75±00.50a	061.80±004.85a
	Bafia Soil	**1**	27.12±07.17a	08.26±03.49a	02.00±00.81a	.075.30±025.92a
		2	24.72±11.51a	03.05±01.28ab	01.50±01.00a	052.46±028.17a
		3	24.87±10.50ab	06.21±02.61a	01.25±00.50a	058.11±032.14a
	Ndji Soil	**1**	31.07±07.01a	07.11±02.65a	02.50±00.57a	080.81±022.99a
		2	30.32±04.55a	02.54±02.54a	02.00±00.81a	085.38±019.73a
		3	31.20±04.46b	07.08±00.84a	01.75±00.50a	079.61±041.81a
	Mbalmayo Soil	**1**	25.52±07.48a	02.72±01.05a	01.50±00.57a	055.35±028.59a
		2	24.00±07.14a	01.92±02.04a	01.25±00.50a	060.88±028.50a
		3	24.97±03.28ab	07.66±02.24a	01.75±00.50a	058.00±017.84a

Means with same letter in the same column are not significantly differents at $P \leq 0.05$

Table XV . Agronomic parameters of the *lactuca sativa*

Varieties	Treatments	Time (Months)	Agronomic parameters calculated			
			Average plant height (cm)	**Average collar diameter (cm)**	**Average number of leaves**	**Average leaf area (cm^2)**
Lactuca sativa	**Control**	**1**	04.46±01.12ab	01.59±00.39a	03.41±00.79b	04.88±02.43a
		2	05.06±01.12abc	02.38±00.64a	03.75±00.62a	06.48±02.83ab
		3	03.87±00.79abc	03.02±01.08bc	04.83±00.93b	06.13±02.45a
	Akonolinga Soil	**1**	05.87±02.17b	01.60±00.51a	04.08±00.79b	08.82±00.79b
		2	06.47±02.17a	02.79±00.77a	04.08±00.79a	10.92±07.29b
		3	04.66±01.73bc	02.79±00.87b	04.41±01.08b	07.64±05.48a
	Mbankomo Soil	**1**	03.80±01.27a	01.55±00.57a	03.33±00.65b	02.86±02.19a
		2	04.40±01.27ab	02.24±00.53a	03.25±00.45a	04.12±02.64a
		3	02.94±01.26a	01.71±00.70a	03.41±01.24ab	03.43±03.78a
	Bafia soil	**1**	03.17±00.97a	01.62±00.47a	03.33±00.65a	02.46±01.89a
		2	03.77±00.97a	01.91±00.58a	03.25±01.05a	03.58±02.28a
		3	04.11±01.32abc	02.16±00.90ab	03.75±01.13b	05.59±02.77a
	Ndji soil	**1**	05.14±02.17a	02.52±01.58a	03.83±01.19b	09.47±08.35b
		2	05.74±02.17bc	02.58±01.80a	04.00±01.20b	11.45±09.31b
		3	05.07±02.08c	03.82±01.65c	04.83±02.12c	12.09±07.61b
	Mbalmayo Soil	**1**	03.54±01.08a	01.63±00.56a	02.83±00.71a	02.67±01.80b
		2	04.14±01.08ab	02.16±00.90a	03.75±00.62a	03.88±02.17a
		3	03.33±01.04ab	01.59±00.56a	02.41±01.16a	03.55±02.74a

Means with same letter in the same column are not significantly differents at $P \leq 0.05$

In *Abelmoschus esculentus*, the average plant height was influenced by Akonolinga soil and Mbalmayo soil, with maxima of 21.95±02.84 cm and 21.48±02.10 cm in month 3. The average collar diameter was influenced by Akonolinga soil and Ndji soil, with maxima of 03.52±00.64 mm and 03.54±00.44 mm in month 3. The average number of leaves and average leaf area were very high in the plants that received treatments, compared to the control plants (Table XV). The average leaf area was recorded as 12.39±02.49 cm^2 and 12.40±03.28 cm^2 in the control and Akonolinga soil treatments, respectively, in month 1. As for the average number of leaves, maxima of 02.25±00.62 and 02.25±00.45 were recorded in the control and Akonolinga soil treatments, respectively, in month 1.

Table XVI. Agronomic parameters of *Abelmoschus esculentus*

Varieties	Treatments	Time (month)	Agronomic parameters calculated			
			Average plant size (cm)	Average collar diameter (cm)	Average number of leaves	Average leaf area (cm^2)
A. esculentus	Control	1	18.04±01.80ab	02.50±00.31a	02.25±00.62a	12.39±02.49a
		2	18.50±01.37a	02.93±00.44a	02.08±00.28a	09.23±02.06a
		3	18.51±01.94a	03.24±00.39a	01.33±00.49ab	05.53±03.25a
	Akonolinga Soil	1	20.46±02.05b	02.89±00.45a	02.25±00.45a	12.40±03.28a
		2	21.10±02.14b	03.15±00.26a	02.00±00.60a	09.83±02.90a
		3	21.95±02.84b	03.52±00.64a	02.00±00.85b	09.15±02.84a
	Mbankomo Soil	1	19.28±01.42b	02.96±00.59a	02.08±00.28a	11.81±03.47a
		2	20.15±01.96ab	03.07±00.46a	01.50±00.52a	10.00±02.30a
		3	19.20±02.45a	03.36±00.37a	01.50±00.52ab	05.05±02.18b
	Bafia Soil	1	19.60±01.82a	03.18±00.48a	02.16±00.38a	11.42±01.74a
		2	20.40±01.90ab	03.03±00.46a	01.50±00.52a	08.32±02.66a
		3	18.50±01.76a	03.30±00.48a	01.66±00.65ab	03.31±02.91a
	Ndji Soil	1	20.67±01.82b	02.90±00.39a	02.16±00.38ab	12.67±02.42a
		2	19.64±01.56ab	02.88±00.32a	01.50±00.52a	10.04±03.21a
		3	20.70±02.39ab	03.54±00.44a	01.25±00.45a	09.05±03.04a
	Mbalmayo Soil	1	20.05±01.49a	02.51±00.20a	01.75±00.45a	11.93±01.89a
		2	18.50±01.37a	03.09±00.29a	01.91±00.79a	09.28±01.97a
		3	21.48±02.10b	03.14±00.34a	01.58±00.51ab	07.81±02.94a

Means with same letter in the same column are not significantly differents at P ≤0.05

III.1.2.2.2. Incidence and disease severity

The incidence of disease varied across plant species and treatments indicated in figure 12 below, with *A. esculentus* displaying the highest susceptibility, followed by *L. sativa.* The two varieties of *X. sagittifolium* ('White' and 'Red') exhibited the lowest disease incidence across all treatments, suggesting potential resistance mechanisms or soil-related factors reducing disease pressure. The variation in disease incidence among treatments (T0–T5) indicates that soil conditions, nematode interactions, or other biotic and abiotic factors influenced disease development.

Necrotic spots

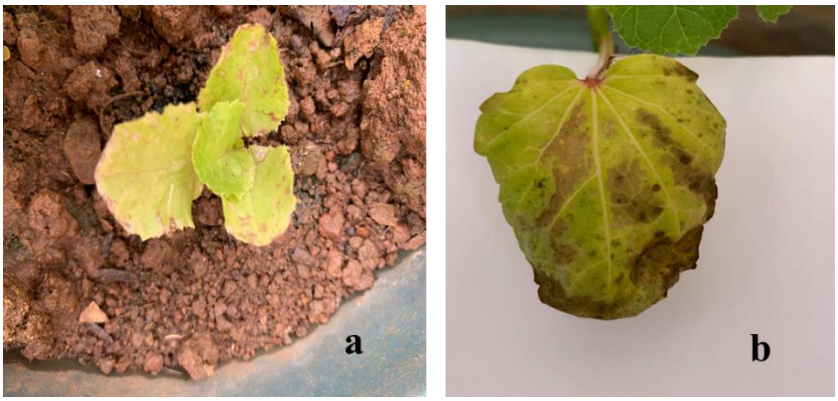


Fig.11. Disease symptoms for necrotic spots: *L. sativa* (a), necrotic spots in *A. esculentus* (b).

Greenish spots

Fig.12. Disease symptoms for greenish spots: *X. sagittifolium* white(c), greenish spots in *A. esculentus* (d).

Leaf rot

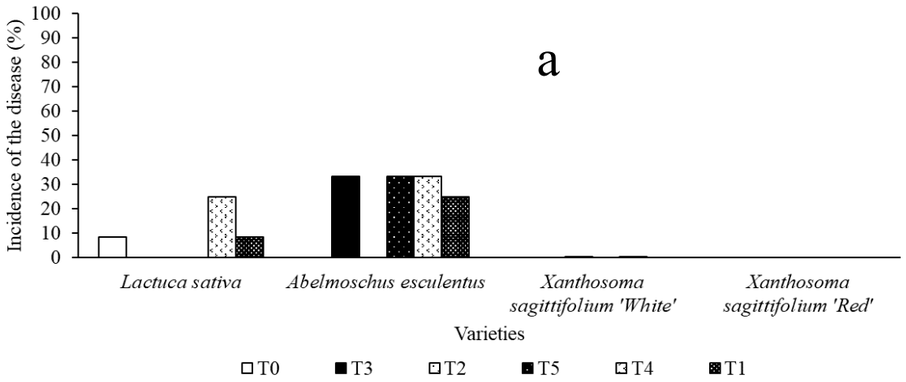
Fig.13. Disease symptoms for leaf rot : *X. sagittifolium* (e)), leaf rot in *L. sativa* (f), leaf rot in *A. esculentus* (g),entire plant organ (h).

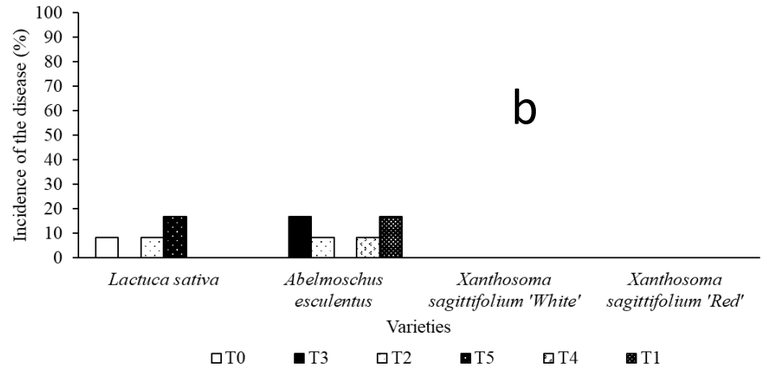
Yellow leaves

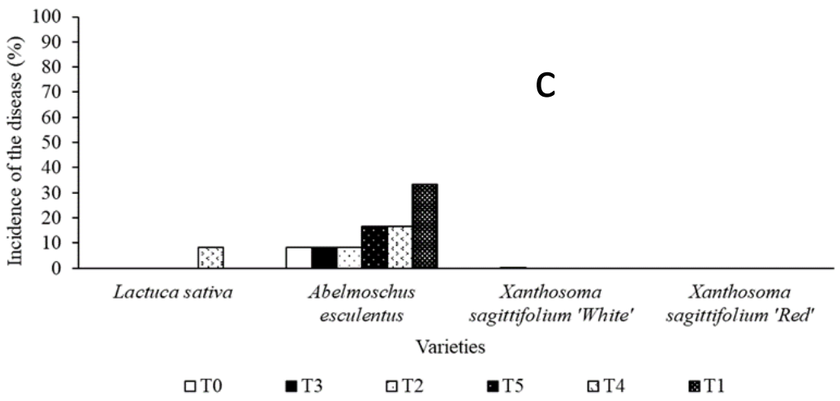
Fig.14. Disease symptoms for yellowish leaves: *X. sagittifolium* (i), yellowish leaves in *L. sativa* (j)yellowish leaves in *A. esculentus* (k).

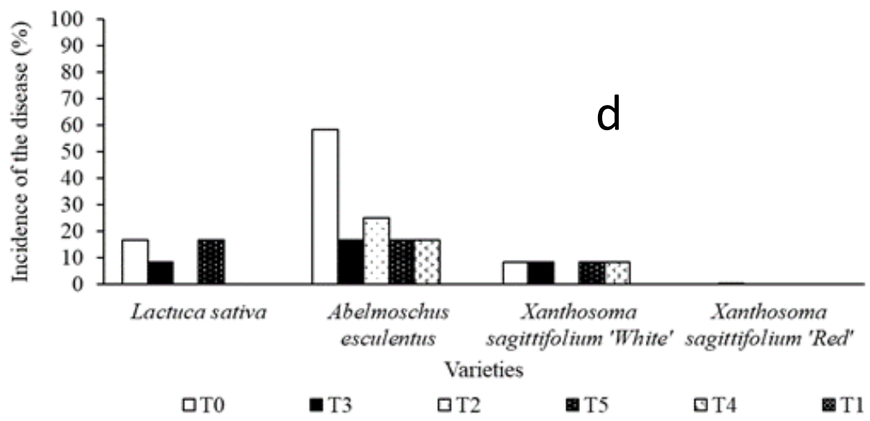
Chlorosis

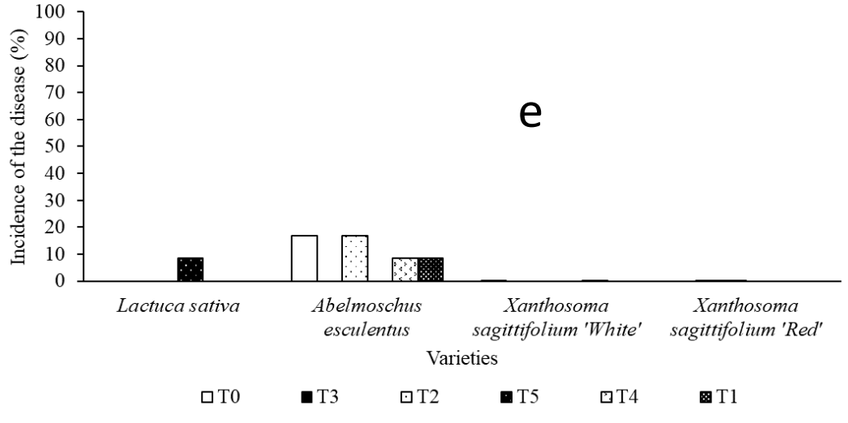
Fig.15. Disease symptoms for chlorosis: *X. sagittifolium* (l), chlorosis in *L. sativa* (m), chlorosis in *A. esculentus* (n).

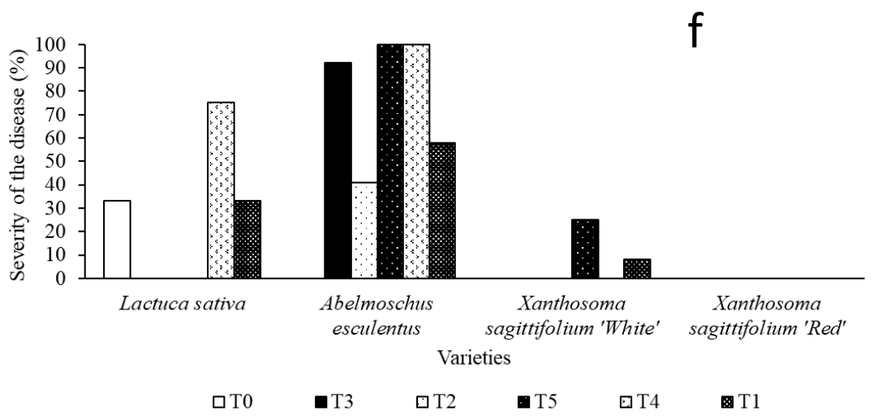

a
Incidence of the disease (%)
100
90
80
70
60
50
40
30
20
10
0
Lactuca sativa
Abelmoschus esculentus
Xanthosoma sagittifolium 'White'
Xanthosoma sagittifolium 'Red'
Varieties
T0
T3
T2
T5
T4
T1

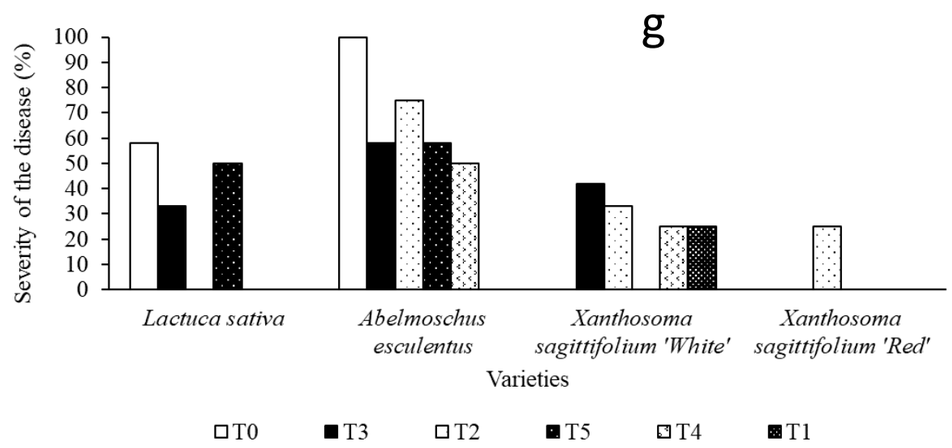

b
Incidence of the disease (%)
100
90
80
70
60
50
40
30
20
10
0
Lactuca sativa
Abelmoschus esculentus
Xanthosoma sagittifolium 'White'
Xanthosoma sagittifolium 'Red'
Varieties
T0
T3
T2
T5
T4
T1

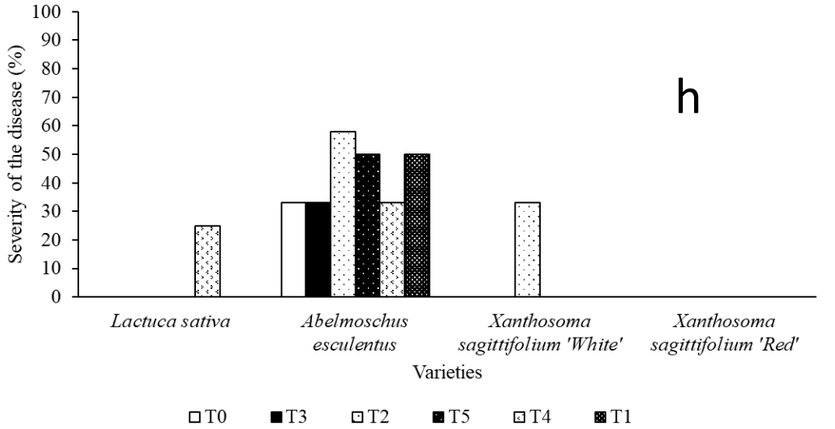

c
Incidence of the disease (%)
100
90
80
70
60
50
40
30
20
10
0
Lactuca sativa
Abelmoschus esculentus
Xanthosoma sagittifolium 'White'
Xanthosoma sagittifolium 'Red'
Varieties
T0
T3
T2
T5
T4
T1

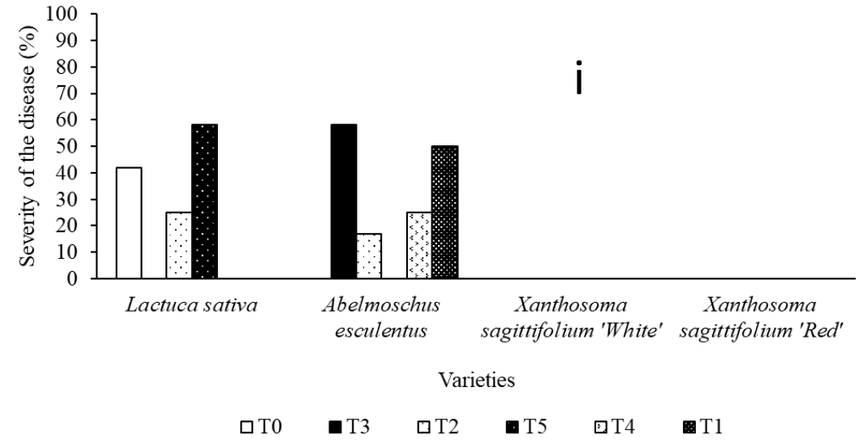

d
Incidence of the disease (%)
100
90
80
70
60
50
40
30
20
10
0
Lactuca sativa
Abelmoschus esculentus
Xanthosoma sagittifolium 'White'
Xanthosoma sagittifolium 'Red'
Varieties
T0
T3
T2
T5
T4
T1


e
Incidence of the disease (%)
100
90
80
70
60
50
40
30
20
10
0
Lactuca sativa
Abelmoschus esculentus
Xanthosoma sagittifolium 'White'
Xanthosoma sagittifolium 'Red'
Varieties
T0
T3
T2
T5
T4
T1









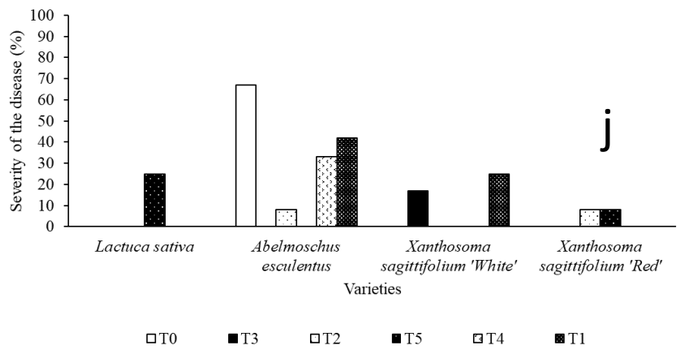


Fig.16 . Disease intensity calculated: Disease incidence Necrotic spots(a), Leaf rot(b), Greenish spots(c), Yellowish leaves(d), Chlorosis(e) and disease severity; Necrotic spots(f), Yellowish leaves(g), Greenish spots(h), Leaf rot(i), Chlorosis(j).

III.1.3. Analysing the content level of metabolites in leaves of *X. sagittifolium*, *L. sativa* and *A. esculentus*

III.1.3.1. Total chlorophyll content in plant leaves

The Student-Newman and Keul's results from the four graphs show variations in total chlorophyll content in *L. sativa, A. esculentus*, and two cultivars of *Xanthosoma sagittifolium* ("White" and "Red") over three months under different soil treatments. Overall, there is an initial peak in chlorophyll content in the first month, followed by a significant decline in the second month across all plant species. Some treatments show partial recovery in the third month, while others maintain low chlorophyll levels.

Lactuca sativa in the first month, there is no significant difference in total chlorophyll content among the treatments, as indicated by the common letter "a" across all bars. However, in the second month, there is a notable drop in chlorophyll content, with treatments showing significant variation (letters "d" and "e" for the lowest values, and "a" and "b" for the relatively higher values). This suggests that some soil treatments negatively affected chlorophyll retention during the second month. By the third month, the Akonolinga soil exhibits the highest chlorophyll content (marked "c"), while other treatments remain lower.

Abelmoschus esculentus in the first month, the Bafia soil treatment shows the highest chlorophyll content (marked "d"), while the control and other treatments have significantly lower levels. This suggests that Bafia soil initially enhances chlorophyll synthesis in *A. esculentus*. By the second and third months, however, the differences among treatments diminish, with most values converging to similar levels. This implies that although Bafia soil boosts early chlorophyll production, it does not provide sustained benefits over time, and the plants in all treatments eventually exhibit similar chlorophyll levels

At the first month, the control treatment has the highest chlorophyll content (marked "e"), while all other soil treatments show significantly lower values, indicating that the native soil conditions may have initially been more favorable for chlorophyll retention in this variety. By the second month, a sharp decline in chlorophyll content is observed across all treatments, with no significant differences among them (most marked "a"). This suggests a general depletion of chlorophyll over time, regardless of soil type. By the third month, there is a slight recovery in some treatments. However, overall chlorophyll content remains low, suggesting that no soil treatment provided long-term enhancement of photosynthesis in *X. sagittifolium* "White".

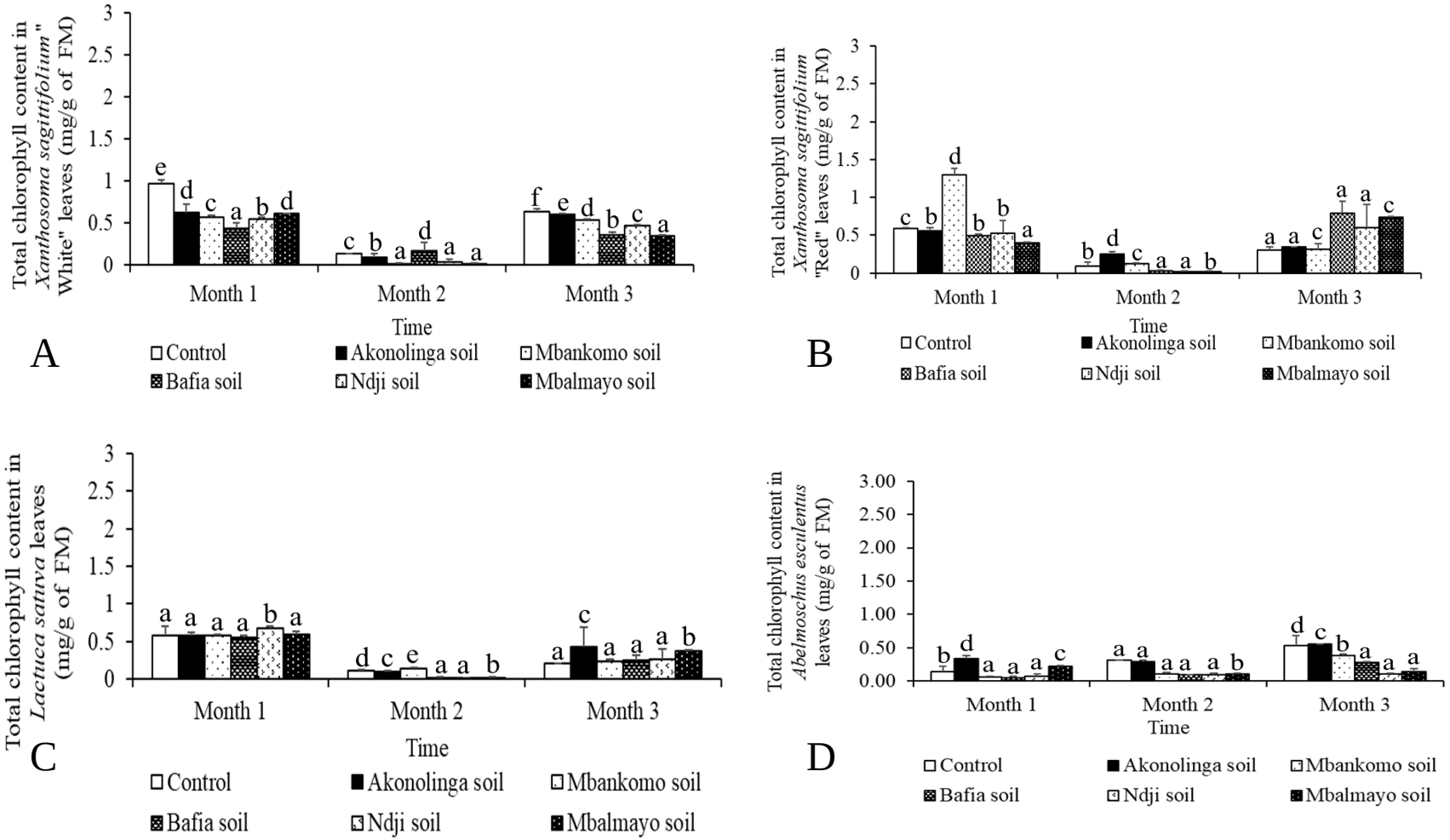


Fig.17. Total chlorophyll content in leaves of plants. *Xanthosoma sagittifolium* 'White' (A), *Xanthosoma sagittifolium* 'Red (B), *Lactuca sativa* (C) and ' *Abelmoschus esculentus* (D).

X. sagittifolium "Red" in the first month, Bafia soil results in the highest chlorophyll content (marked "d"), followed by Akonolinga soil (marked "c"), while other treatments show significantly lower values. This suggests that these soil types initially support better chlorophyll synthesis. However, by the second month, a sharp decline is observed across all treatments, with most values converging to the lowest levels (marked "a"). By the third month, some treatments, particularly Bafia and Akonolinga soils (marked "c"), show a slight recovery, but overall chlorophyll content remains lower than in the first month..

III.1.3.2. Total sugars in plant leaves

Total sugar content is a key physiological parameter that reflects plant metabolism, energy storage, and stress responses. In general, sugar content varies significantly across different soil treatments and time points. Some plants exhibit high sugar accumulation in the first or second month, followed by a decline, while others maintain stable or increasing sugar levels. The presence of different letters above bars indicates statistically significant differences between treatments within each time point. Certain soil types, such as Ndji and Mbalmayo, appear to enhance sugar accumulation in specific plants, suggesting variations in soil nutrient composition or microbial activity that influence carbohydrate metabolism.

The control treatment shows an exceptionally high sugar content in the first month, significantly higher than all other treatments. However, this value drastically declines in the second month and remains low through the third month. Most soil treatments exhibit low and stable sugar levels throughout the experiment, with slight increases in Mbalmayo and Ndji soils in the third month. This pattern suggests that initial sugar accumulation in *L. sativa* may be influenced by the absence of external microbial interactions in the control, which declines over time as plant metabolism adjusts to environmental conditions.

Abelmoschus esculentus first month, sugar content remains relatively low across all treatments, with minor variations. However, in the second month, there is a sharp increase in total sugar content for plants grown in Ndji soil, which exhibits the highest accumulation, followed by Mbalmayo soil. By the third month, sugar content decreases across all treatments, but Bafia and Mbalmayo soils maintain slightly higher values than the others. This suggests that Ndji soil may provide specific nutrients or conditions that enhance sugar accumulation in *A. esculentus* at intermediate growth stages, but this effect diminishes over time.

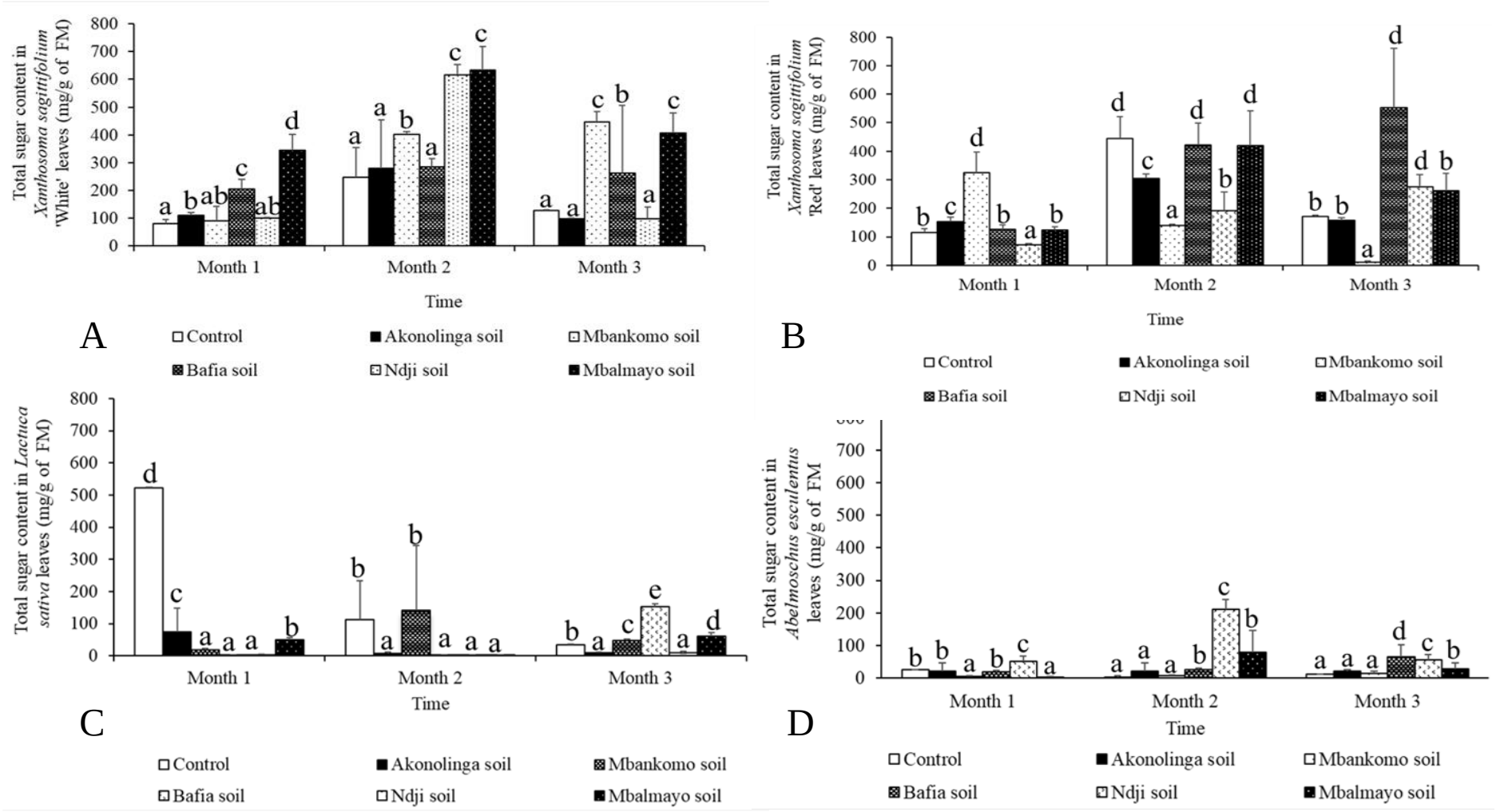


Fig.18. Total sugar content in leaves of plants. *Xanthosoma sagittifolium* 'White' (A), *Xanthosoma sagittifolium* 'Red (B), *Lactuca sativa* (C) and ' *Abelmoschus esculentus* (D).

Sugar accumulation in "White" *Xanthosoma sagittifolium* increases significantly over time, with Ndji soil consistently exhibiting the highest sugar content, particularly in the second and third months. Other soil treatments such as Mbalmayo and Akonolinga also show moderat increases. The control treatment, however, remains consistently lower than the treated soils, indicating that the presence of specific soil nutrients or microbial communities may enhance carbohydrate synthesis in this cultivar over time.

The "Red" cultivar exhibits a strong increase in total sugar content, particularly in the first month under Mbalmayo and Ndji soils, which show the highest accumulation. This trend continues into the second and third months, with Mbalmayo soil consistently supporting higher sugar levels than the control. The variation across treatments suggests that specific soil conditions influence sugar metabolism differently in the "Red" cultivar compared to the "White" cultivar, possibly due to genetic differences in carbohydrate storage or utilization.

III.1.3.3. Total Protein content in plant leaves

Protein content fluctuates across the experimental period according to Student-Newman and Keul's test result, with peaks in specific months depending on the plant species and soil type. Some treatments, particularly Ndji and Bafia soils, show significantly higher protein content, while others, such as Mbalmayo and Mbankomo soils, consistently maintain lower levels. The observed variations suggest that soil nutrient composition and microbial interactions play a significant role in influencing protein synthesis in plants.

Protein content in *L. sativa* shows a marked increase in the second month, with the highest accumulation observed in plants grown in Akonolinga soil. This peak is followed by a sharp decline in the third month. Control plants exhibit lower protein levels throughout the experiment, indicating that specific soil conditions significantly influence protein synthesis. The initial low protein levels in the first month suggest an adaptation phase, while the second-month peak may indicate optimal nitrogen assimilation under favorable soil conditions.

A. esculentus leaves display an interesting pattern where protein content is highest in control plants during the first month but subsequently peaks in Bafia soil during the second month. This suggests an initial stress response in the absence of external soil microbes, followed by an enhancement in protein synthesis in specific soil types. In the third month, protein levels decline across all treatments, suggesting a shift in metabolic focus from protein accumulation to other physiological processes.

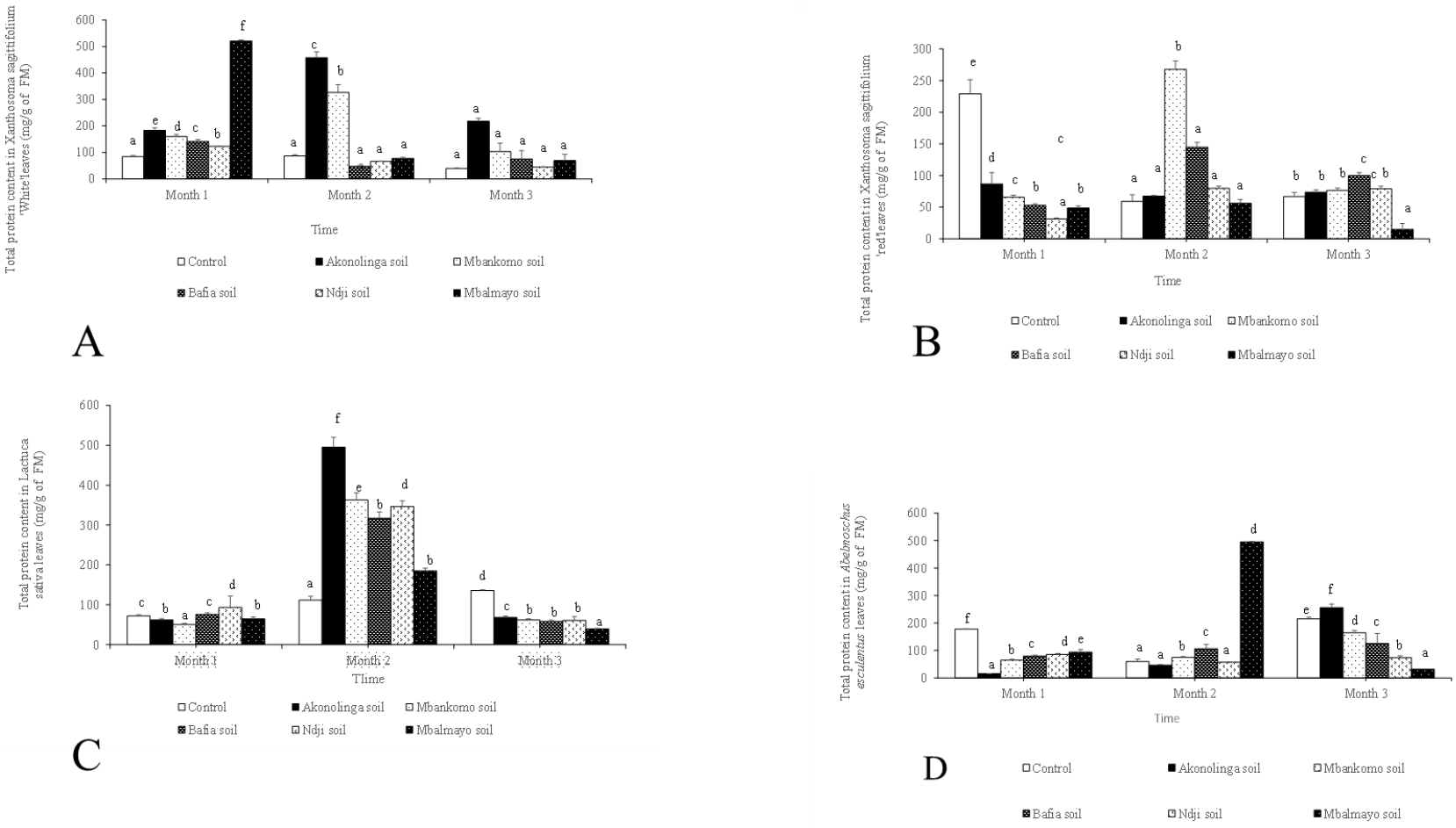


Fig.19. Total sugar content in leaves of plants. *Xanthosoma sagittifolium* 'White' (A), *Xanthosoma sagittifolium* 'Red (B), *Lactuca sativa* (C) and ' *Abelmoschus esculentus* (D).

The "White" *Xanthosoma sagittifolium* cultivar exhibits a consistent increase in protein content, particularly in Bafia and Akonolinga soils, which peak in the first and second months. By the third month, protein content stabilizes at lower levels. The high initial protein accumulation may indicate enhanced nitrogen metabolism in these soil conditions. The lower protein levels in the third month suggest a redistribution of resources towards other metabolic activities as the plant matures.

The "Red" cultivar shows a strong protein accumulation in control plants in the first month, followed by a peak in Ndji soil in the second month. This trend suggests that certain soil conditions may initially suppress protein synthesis but later promote it. By the third month, protein levels decline, with moderate retention in Bafia and Ndji soils. The variations indicate that this cultivar may have different nitrogen assimilation dynamics compared to the "White" variety

III.1.3.4. Phenolic compounds in plant leaves

Phenolic compounds play a crucial role in plant defense mechanisms, growth, and adaptation to environmental stressors. Their concentration can be influenced by soil composition, microbial activity, and other abiotic factors.

The phenolic concentration in *Lactuca sativa* increases significantly in Akonolinga soil compared to other soils, particularly in the first and second months. Control samples show the lowest accumulation, suggesting that soil composition plays a vital role in secondary metabolite production. Over time, there is a slight reduction in phenolic content in some soils, indicating possible adaptation or metabolic adjustments in the plants.

The Student-Newman and Keul's result in *A. esculentus* shows an initial low phenolic content in all samples during the first month. By the second and third months, tobacco plants grown in Akonolinga, Ndji, and Mbalmayo soils exhibit significantly higher phenolic concentrations. The control and Mbankomo soil samples maintain lower levels throughout the study period.

For *X. sagittifolium* 'white', Phenolic content is highest in plants grown in Akonolinga and Mbalmayo soils, particularly in the first month. A general decreasing trend is observed over time in most soil samples. Control and Mbankomo soils show consistently low levels, implying that these soil conditions may not stimulate secondary metabolite production as effectively as others.

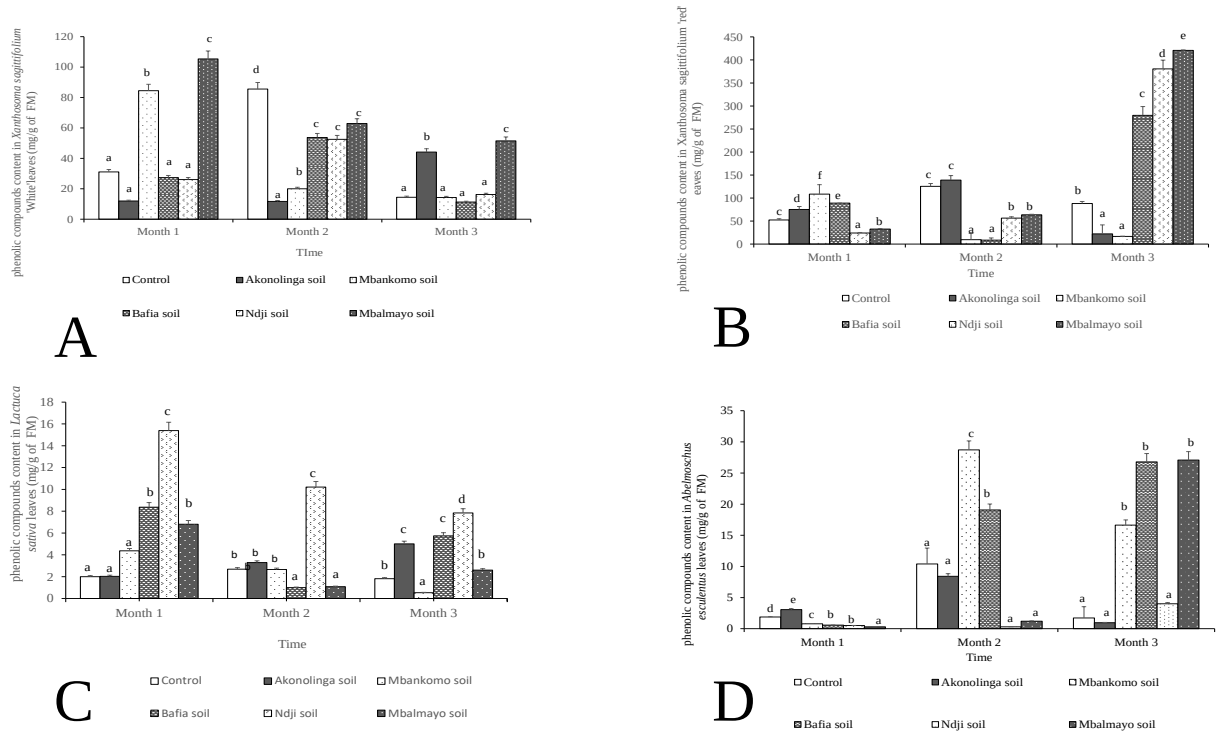


Fig.20. Phenolic content in leaves of plants. *Xanthosoma sagittifolium* 'White' (A), *Xanthosoma sagittifolium* 'Red (B), *Lactuca sativa* (C) and ' *Abelmoschus esculentus* (D).

For *X. sagittifolium* ‘red’ Phenolic content is significantly higher in this variety compared to white leaves, particularly in Mbalmayo and Ndji soils. A steady increase is observed across all samples, with Mbalmayo soil showing the highest values by the third month. This suggests that red-leafed varieties may have higher metabolic activity related to phenolic synthesis. Control samples maintain consistently lower values, reinforcing the influence of soil conditions on phenolic production. Akonolinga and Mbalmayo soils consistently promote higher phenolic content, suggesting they provide favorable conditions for secondary metabolite synthesis. Control and Mbankomo soils result in lower phenolic accumulation, indicating limited stimulation of plant defense mechanisms.

III.2. Discussion

The aim of this study was to identify the nematodes present in the rhizosphere of *Xanthosoma sagittifolium* and test their intercropping effect with *Lactuca sativa* and *Abelmoschus esculentus*. The result for parameters evaluation obtained varied less significantly based on the varieties. The agronomic evaluation of the two *Xanthosoma sagittifolium* cultivars ('White' and 'Red') across five localities revealed that environmental factors, particularly soil physicochemical properties strongly influenced plant growth. The greater plant height observed in the White cultivar at Bafia (134.8 ± 33.7 cm) and in the Red cultivar at Ndji (144.7 ± 17.3 cm) suggests that site-specific conditions such as rainfall, temperature, or soil fertility favor one variety over the other (Brady & Weil, 2016). Although the number of leaves did not differ markedly among sites, variations in collar diameter and rhizome size indicate differential nutrient allocation, likely driven by soil nutrient availability (Lindsay & Norvell, 1978). Soil organic matter (OM) content was highest in Mbalmayo (4.42 %) and Mbankomo (3.08 %), correlating with higher rhizome weights in those soils. Organic matter enhances cation exchange capacity and nutrient retention, thereby promoting storage organ development in tuberous crops (Jenkinson & Powlson, 1976). Conversely, the low OM in sterilized soils and Ndji soils (1.07 %) may have constrained growth, as indicated by lower rhizome weights in those sites. Soil pH values ranged from mildly acidic (5.6 in Akonolinga and Bafia) to near-neutral (6.3 in Mbankomo), with optimal nutrient uptake reported around pH 6.0–6.5 for *Xanthosoma* species (Brady & Weil, 2016). Indeed, Mbankomo (pH 6.3) produced robust plants, supporting this relationship. Assimilable phosphorus was abundant in Mbalmayo (70.8 m.kg) and Mbankomo (62.8 mg.kg), coinciding with improved rhizome development; phosphorus is critical for energy transfer and tuberization (Lindsay & Norvell, 1978). However, Mbankomo also exhibited an extremely high C/N ratio (75.8), which may slow nitrogen mineralization and potentially limit protein synthesis in the long term (Jenkinson & Powlson, 1976). In contrast, Bafia and sterilized soils with low C/N ratios (< 3.5) would mineralize nitrogen rapidly but risk leaching losses (Brady & Weil, 2016). Nitrogen fuels synthesis of proteins (e.g. tubulins, expansins) and nucleic acids needed for meristem activity and cell wall loosening, more cells and larger cells in stems and leaves greater height and leaf area.(Hirel et *al*., 2007).

Soil conditions play a crucial role in determining the distribution and diversity of nematodes. The variations in nematode populations observed across different sampling sites can be attributed to differences in soil texture, organic matter, and pH levels. Research suggests that

sandy soils with moderate moisture content often harbor higher populations of plant-parasitic nematodes due to favorable aeration and root penetration properties (Van et *al*., 2013). Moreover, high organic matter levels can enhance microbial antagonism, potentially suppressing nematode populations (Neher, 2010). Soil physicochemical properties significantly impact nematode diversity and population density. The nematode survey uncovered a diverse community of plant-parasitic genera (e.g., *Radopholus*, *Ditylenchus*, *Xiphinema*) and families (Hoplolaimidae, Criconematidae). *Radopholus* spp., known to cause root lesions and yield losses in tropical root crops, were ubiquitous across soils, suggesting a latent threat to *Xanthosoma* productivity (Yeates & Bongers, 1999). The presence of *Xiphinema* a vector of nepoviruses raises additional phytosanitary concerns (Yeates & Bongers, 1999). Non-parasitic nematodes (Nemertodermatidae) indicate active microbial decomposition, particularly in high-OM soils (Jenkinson & Powlson, 1976). Overall, soils with moderate to high OM supported greater nematode diversity, reflecting enhanced microbial food webs (Yeates & Bongers, 1999).

High organic-matter (OM) soils supply abundant detrital carbon, fostering bacterial and fungal growth that non-parasitic nematodes exploit as food. These enriched microbial populations in turn support higher trophic levels, including predatory and omnivorous nematodes, thereby increasing overall diversity. Meanwhile, plant-parasitic nematodes persist across all soils because they directly tap into live root resources. In low-OM or sterilized soils, diminished microbial prey restricts non-parasitic groups, but root-feeding nematodes continue to survive on host tissues, potentially intensifying plant stress. Concurrently, plant-parasitic nematodes (*Radopholus*, *Ditylenchus*, *Xiphinema*) were present in all soils, inflicting root damage that further restricted water and nutrient uptake. The net result was stressed plants with compromised photosynthetic capacity (low chlorophyll) and depleted carbohydrate reserves (low sugars), which manifested aboveground as chlorosis, necrotic spots, and leaf rot once pathogens invaded. *L. sativa* grown in low-OM soils exhibited reduced height (≈4 cm vs. 6 cm in Akonolinga soil) and lower leaf area, reflecting nutrient stress. These plants also had sharply diminished phenolic contents (the primary chemical defense) and chlorophyll by month 2, undermining barrier and immune responses. Under these conditions, necrotic spots and yellowing (chlorosis) appeared early (Fig 12, 15) as cell death spread in tissues unable to mount adequate defense. High nematode feeding in poorer soils intensified root dysfunction, turning initial chlorosis into fulminant leaf-rot lesions (Fig 14) once opportunistic fungi or bacteria infected weakened tissue (Taiz & Zeiger, 2015). *A. esculentus* showed similar patterns but even

greater susceptibility: in soils with suboptimal nutrient–microbe balance, height stagnated (~18 cm vs. 21 cm in Akonolinga), and leaf area collapsed by month 3. Protein reserves critical for synthesizing pathogenesis-related enzymes peaked briefly then plummeted by month 3 in these soils. Consequently, *A. esculentus* leaves developed greenish spots (Fig 13) and progressed rapidly to necrosis and rot (Fig 12, 14), signifying overwhelm of diminished defense systems. High nematode loads further aggravated symptom severity by sustaining root-to-shoot stress signals that predispose foliage to pathogen entry.

Small, dead ("necrotic") patches on leaves of lettuce (Fig 12 a) and okra (Fig 12 b) explains that, Root-feeding nematodes such as *Radopholus* spp. and *Ditylenchus* spp. create microscopic lesions in root cortex, impairing water and nutrient uptake. The resulting localized water stress and nutrient deficiency triggers cell death in distal leaf tissues, appearing as necrotic spots (Bridge et *al*., 2005). Generalized yellow leaves and leaf decolorization in *L. sativa* (Fig 15 j) and *A. esculentus* (Fig 15 k), often preceding necrosis, then when nematode feeding disrupts root function, nitrogen and magnesium transport to leaves is reduced. Since chlorophyll molecules require both N and Mg, their shortage causes chlorosis. This is exacerbated in soils where low N mineralization already limited nutrient supply (high C/N soils). Irregular green-tinged patches on okra leaves (Fig 13 d), In early stages of root damage, plants may accumulate reactive oxygen species and stress ethylene in localized zones. These biochemical shifts can transiently alter leaf pigment composition, producing greenish or bronzed spots before full chlorosis or necrosis ensues (Perry & Moens, 2011).

Analysis of secondary metabolites revealed that *L. sativa* had a higher total soluble sugar content, which decreased with increasing bleach concentration. In contrast, *A. esculentus* exhibited an increasing trend in sugar content with higher bleach concentrations. Protein content showed a similar pattern: *L. sativa* had a lower initial concentration that increased with bleach exposure, whereas *A. esculentus* displayed a decline at higher bleach concentrations.

The superior germination performance of *L. sativa (*90.25 % by Day 6 under 10 % bleach; GI 82.08 ± 7.56) and *A. esculentus* (97 % under 5 % bleach; GI 59.22 ± 14.16) provided a vigorous, uniform cohort of seedlings entering the soil treatments. Early seedling vigor is well known to enhance leaf-area development and chloroplast biogenesis, because robust radicle emergence accelerates root-shoot coupling and nutrient uptake (Copeland & McDonald, 2001). In our metabolite assays, both *L. sativa* and *A. esculentus* showed a pronounced chlorophyll peak in Month 1with no treatment differences in *L. sativa* but elevated chlorophyll in *A.*

esculentus under Bafia soil. Those first-month peaks reflect carry-over of seed-derived reserves and rapid establishment driven by high germination uniformity. In contrast, weaker germination (e.g. 5 % bleach in lettuce) would likely delay leaf chlorophyll accumulation, compressing the Month 1 peak and exacerbating the Month 2 decline.

The morphological responses of *L. sativa*, *A. esculentus*, and both *X. sagittifolium* cultivars to five soil treatments over two months showed that, *L. sativa* under S3 and S4 doubled leaf area (~11 cm² vs. 6.49 cm² in control) and increased collar diameter by ~8 % in month 2, indicating enhanced N availability and microbial stimulation of root function. *A. esculentus* exhibited a ~12 % shoot-height boost under T3/T4 in month 1 (20.68 cm vs. 18.04 cm control) and higher leaf area (~12.68 cm² vs. 12.40 cm²) before converging by month 2. Both cocoyam cultivars achieved maximal leaf area and collar girth under S4 White: 113.39 cm² & 9.73 cm; Red: 80.81 cm² & 7.11 cm in month 1 demonstrating strong cultivar–microbe synergy. (Ninkuu et *al*., 2025) review how straw return enriches soil OM, boosts microbial diversity, and enhances nutrient availability, corroborating the critical role of organic amendments in driving such morphological vigor (Ninkuu et *al*., 2025). Comparative agronomic data confirm that soils with balanced OM and pH also yielded the highest collar and rhizome metrics in *X. sagittifolium*, while biochemical profiles link these growth surges to elevated protein and chlorophyll under the same treatments. So, soil treatments that optimize microbial activity and nutrient mobilization especially S4/S3 consistently enhance early vegetative vigor across diverse crops, underscoring the imperative of precision rhizosphere management.

All four species showed a strong chlorophyll peak in Month 1, a sharp decline in Month 2, and only partial recovery by Month 3 in the best soils. The initial peak reflects abundant soil-derived nitrogen and magnesium fueling chlorophyll biosynthesis during early growth. By Month 2, rapid uptake of these nutrients coupled with mounting root damage from plant-parasitic nematodes leads to nutrient depletion and impaired chloroplast maintenance, causing the observed collapse in chlorophyll. In treatments with higher organic matter (Akonolinga, Bafia soils) (Taiz & Zeiger, 2015), beneficial microbes partly restored nutrient cycling by Month 3, allowing a modest rebound in chlorophyll content.

Sugars peaked earliest in control lettuce an osmotic stress response to seedling establishment without microbial partners then fell as photosynthesis stabilized. In contrast, X. sagittifolium

"White" and "Red" in Ndji and Mbalmayo soils showed steadily rising sugars through Month 3. Those soils' richer microbial consortia likely enhanced phloem loading and sink strength, driving sustained carbohydrate synthesis and storage. Early sugar reserves also powered root regrowth after nematode feeding, explaining why treatments with high sugar retention corresponded to better biomass recovery (Rosa et *al*., 2009; Fiorilli et *al*., 2015). Proteins were low in Month 1 (adaptation phase), peaked in Month 2 under soils with moderate C/N (Ndji, Akonolinga, Bafia), then declined by Month 3. The Month 2 peak represents maximal nitrogen assimilation via GS/GOGAT (Glutamate Synthase (GOGAT, also called Glutamine:2-oxoglutarate Aminotransferase)) pathways when soil mineral N was highest. After this point, resources shifted from protein synthesis toward secondary metabolism and reproductive development, causing protein levels to drop. In high C/N soils (Mbankomo), slow N release blunted the protein peak, leaving plants less able to repair nematode-induced root damage. Phenolics critical for defense were highest in Month 1–2 in soils that imposed mild stress and hosted active rhizosphere microbes (Akonolinga, Ndji). Microbial elicitors and slight nutrient limitation stimulate the phenylpropanoid pathway (Dixon & Paiva, 1995), resulting in elevated phenolics. As plants adapted and soil N became limiting, phenolic synthesis tapered by Month 3. Low phenolic levels in control and Mbankomo soils reflect insufficient microbial signaling and carbon skeleton availability, correlating with greater disease symptoms under those treatments.

Agronomic parameters calculated showed no significant difference in all the treatments for the white cultivar of *X. sagittifolium* in month 2 and 3 and same for the red cultivar of *X. sagittifolium* in month 2 and 3 except at for a slight decrese in the Akonolinga treatment at Moth 3. Meanwhile, for L. sativa in month 2 we observe no significant difference the same control experiment whereas a variation is present amongs treatments in month 2 and in month 3. These findings suggest that nematode-infected plants alter their metabolic composition as a defense mechanism or in response to environmental stressors. Plant roots contain and release a wide range of bioactive secondary metabolites, many of which are known defense compounds against nematodes. Soluble sugars play a fundamental role in plant metabolism, serving as energy sources and signaling molecules in response to biotic stress. The study found that *L. sativa* exhibited higher initial sugar content, which subsequently decreased, while *Abelmoschus esculentus* showed an increasing trend. This suggests differential metabolic adjustments to nematode stress, as soluble sugars contribute to osmotic regulation and defense mechanisms (Couée et *al*., 2006). Protein analysis revealed that *L. sativa* increased protein content in

response to moderate bleach treatment, while *A. esculentus* exhibited protein depletion at higher concentrations. This aligns with studies showing that plants subjected to stress conditions, including pathogen attacks, synthesize stress-related proteins such as pathogenesis-related (PR) proteins (Kosová et *al*., 2011).

Finally, temporal trends across all metabolites illustrate a common trajectory: an early peak (month 1–2) followed by partial decline or stabilization by month 3. Such patterns reflect initial resource mobilization and adaptation phases, succeeded by resource reallocation as plants mature. The divergence between 'White' and 'Red' cultivars in sugar and protein retention points to genotype-specific metabolic strategies that could be harnessed in breeding. Overall, selecting soils rich in beneficial microbes (e.g., Ndji, Bafia, Akonolinga) can optimize both primary growth and defense readiness, offering a practical path for improving crop performance and stress tolerance in agroecosystems.

CHAPTER IV : CONCLUSION AND PERSPECTIVES

IV.1 Conclusion

The general objective of this study was to identify Nematode species present in the rhizosphere of *Xanthosoma sagittifolium* and test their intercropping effect with *Lactuca sativa* and *Abelmoschus esculentus* with the first specific objective targeted at the Characterisation of Nematode species in the rhizosphere of *X. sagittifolium*. This study demonstrates that *X. sagittifolium* growth and yield components are closely tied to soil fertility parameters especially organic matter, pH, and phosphorus availability and are further modulated by nematode community structure. White and Red cultivars exhibit site-specific performance, emphasizing the importance of matching cultivar to soil conditions. High organic matter and optimal pH promote rhizome development, while imbalanced C/N ratios and high populations of parasitic nematodes pose risks to tuber quality and yield. Integrated soil fertility management including organic amendments to adjust C/N ratio, liming to optimize pH, and targeted nematode control will be essential for maximizing *X. sagittifolium* production.

The second specific objective which was evaluating the effect of nematodes on the growth of *X. sagittifolium, L. sativa* and *A esculentus*.

This study demonstrates that interactions between nematodes and *X. sagittifolium* significantly influence plant health and development. Variations in agronomic parameters across different sites underscore the role of environmental factors in nematode prevalence and plant susceptibility. The germination trials revealed that surface sterilization with bleach boosted early seedling vigor. The susceptibility of *L. sativa* and *A. esculentus* to nematodes is evident through disease incidence, altered metabolite profiles, and growth inhibition. These findings provide a foundation for further research on nematode-resistant plant varieties and soil management strategies to mitigate nematode-induced damage. The presence of plant-parasitic nematodes in the rhizosphere highlights the potential threat to crop productivity, with variations in soil physicochemical properties playing a critical role in nematode population dynamics. The findings suggest that effective management strategies are needed to mitigate nematode-induced stress and maintain soil health.

Lastly *A. esculentus* proved even more susceptible because its protein reserves collapsed by Month 3, greenish stress spots appeared, and rapid progression to necrosis occurred when defense systems were overwhelmed. Conversely, soils with balanced OM and active microbial communities delayed symptom onset by sustaining metabolite defenses. This summarizes up to that the presence of *Xanthosoma sagittifolium* in a mixed culture with other

species susceptible to nematode attacks, will serve as a host for plant parasitic nematodes thus confirming the research hypothesis. However, soil ammendment methodes can be used to reduce the growth and developement of these nematodes in the rhizosphere of *X. sagittifolium*.

IV.2 Perspectives

In order to complete this study as per knowing what types of nematodes are associated with the rhizosphere of *X. sagittifolium*, a few more experimentations need to be conducted like;

- Carry out thesame experimentation with soil from the rhizosphere of the red cultivar of *X. sagittifolium*.
- Conduct analytic test for the individual effect of each nematode.
- Incorporating organic amendments (e.g., compost, green manures) in low-OM fields could elevate microbial activity, improve C/N balance, and suppress plant-parasitic nematodes via enhanced biological antagonism

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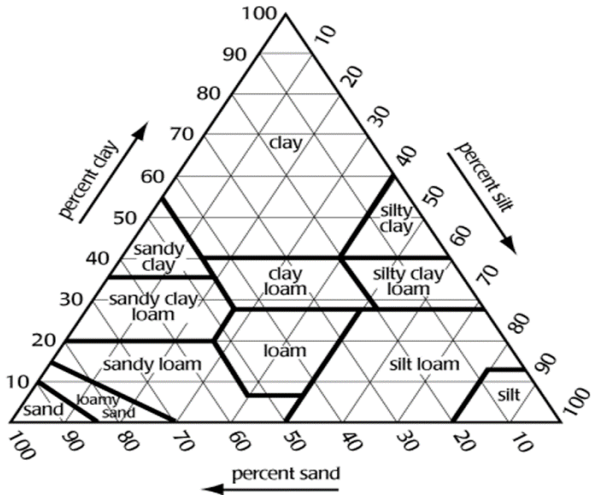
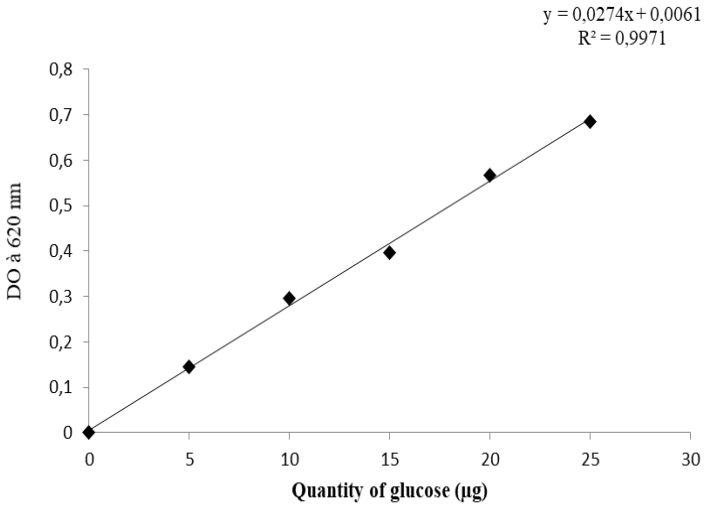
ANNEXES

ANNEXES

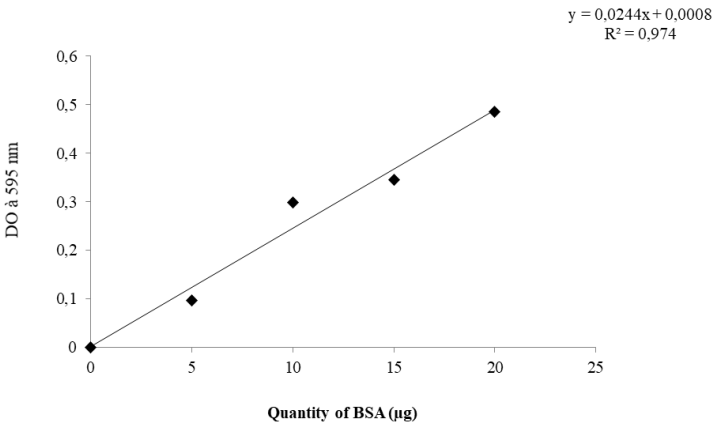
Annex 1: Triangle of mineral textures



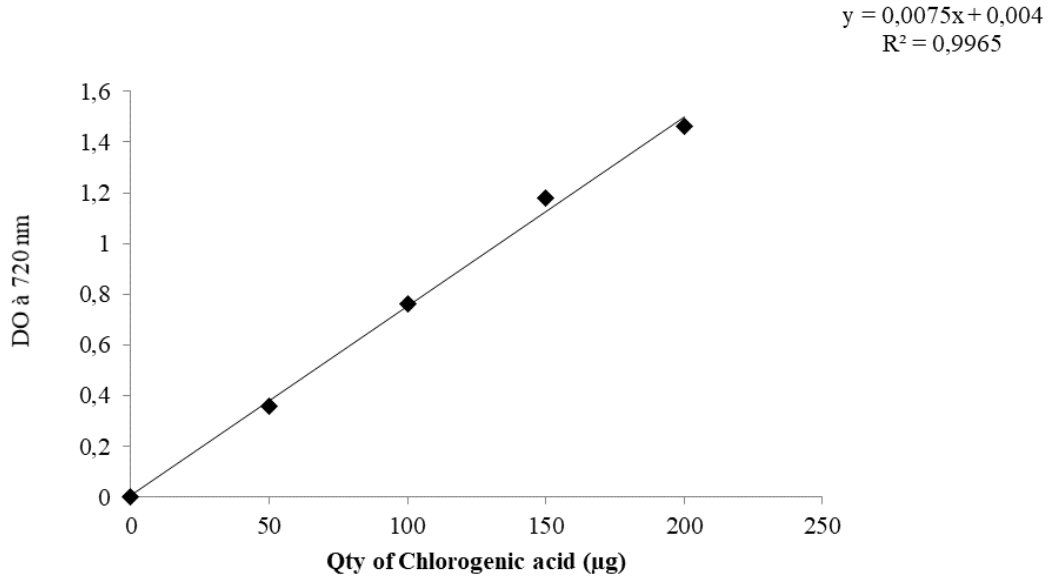
Annex 2: Standard curve of sugar



Annex 3: Standard curve of proteins for BSA



Annex 4: Standard curve for polyphenol oxidase



Annex 5: Sampling and parameters recording.

Pictures by Nengi 2025.