SOIL FERTILITY MANAGEMENT AND CROP SELECTION IN A SCREEN HOUSE USED FOR GIANT AFRICAN LAND SNAIL (*Archachatina marginata*) FARMING

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BENIN CITY

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CERTIFICATION

This is to certify that this project was carried out by Cephas Ehizogie AIMAKHU, with the Matriculation Number AGR2008793, of the Department of Animal Science, Faculty of Agriculture, University of Benin, Benin City, Nigeria.

PROF. J.M. OMOYAKHI
(PROJECT SUPERVISOR)

DATE

DR. N.C. AKAEZE
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DATE

DEDICATION

This project work is dedicated to my Parents, Rev. F.O. Aimakhu and Mrs. J.E. Aimakhu for the huge help, continued support and love.

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ABSTRACT

The soil is a major habitat for snails and a medium for crops to grow, but it is sometimes limited in the required nutrient needed by crops for optimum growth. This study investigated the most effective soil fertility management practices that are harmless to the snails and that are needed by snail-friendly crops: plantain, banana, pawpaw, sweet potato, waterleaf and cocoyam to grow to their maximum potentials in a screen house system. These different practices were: cover cropping, weeding and mulching. The implementation of these practices at the right time and in the right proportion, enhances the performance of the crops which are important to the snails as source of nutrition, environment enrichment, shell formation and reproduction. The data collected were plant height, number of leaves, greenness of leaves, clutch size, incubation and hatching. The results demonstrated that good soil fertility management enhances the performance of both the crops and the snails.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The amount and quality of soil organic carbon (SOC) is often used as indicator of soil quality and productivity (Amundson *et al*., 2015; Powlson *et al*., 2011). At the global scale, agricultural soils constitute a large C pool in the form of soil organic matter, and there is thus scope for large amounts of C to be lost or gained from soils as a consequence of farming practices (Smith, 2012). Management of arable land through repeated disturbance has turned many arable soils into C sources (Lat *et al*., 2007), contributing to climate change. Crop production and related soil management implies a multitude of decisions and activities on soil tillage, crop choice, rotation design, nutrient supply, water supply and crop protection. Within each of these management categories, many options are usually available to farmers, and the choices to be made and the resulting outcomes are subject to a wide range of economic and environmental objectives and constraints (Hengsdijk and Vanittersum, 2002; Groot *et al*., 2012). Finding ways to maintain farm profitability while reducing undesirable emissions or maintaining carbon stocks is complicated by interactions and feedbacks among agricultural practices. For example, the addition of organic materials to the soil, such as animal manures and composts, potentially increases SOC content, and increased yields resulting from fertiliser application can result in increased crop residue additions to the soil organic matter pool (Blair *et al*., 2006). However, large additions of mineral and organic fertilisers to the soil may enhance nitrogen losses to water and atmosphere or result in phosphorus saturation of agricultural soils. These and other examples illustrate the existence of conflicts or trade-offs between objectives of soil management (Powlson *et al*., 2011a). Given the complexity of interactions and conflicts, the selection of management options that result in a maximization of the net benefits from agriculture is no easy task.

Heliciculture is the scientific practice of farming or raising edible land snails, specifically for human consumption or other uses (National Research Council, 1991). The practice involves managing the entire lifecycle of snails, from breeding and hatching to maturation and harvest (Food and Agriculture Organization of the United Nations, 2021. Edible insects: Future prospects for food and feed security. p. 98). A primary component of heliciculture is creating and maintaining controlled environments, often called snaileries, to protect the snails from predators and optimize growth conditions (University of California, Division of Agriculture and Natural Resources, 2002, Snail Production Publication 7250). These systems carefully regulate factors like temperature, humidity, and diet to ensure the health and productivity of the snail colony (Gomot-de Vaufleury, 2000. "Standardized growth toxicity testing (Cu, Hg, Zn) with *Helix aspersa*". The most commonly farmed species in commercial heliciculture belong to the genera Helix and Cornu, such as *Helix pomatia* and *Cornu* *aspersum* (Chevallier, 2003). The global market for snail meat, or escargot, is the primary economic driver for this agricultural sector, with significant demand in European and North American markets (Barker 2004). Beyond meat production, heliciculture also supplies snails for the cosmetic industry, which utilizes their slime (mucin) for skincare products (Tsoutsos *et al*., 2009). Furthermore, snail eggs, sometimes referred to as "white caviar," are another high-value product harvested through these farming practices (Lafargue, and Wahl, 2009).

1.2 Justification of the Study

Screen house systems for snail farming create a semi-controlled environment where temperature, humidity, light, and other microclimatic factors can be optimized. Within such systems, soil fertility must be managed to avoid nutrient depletion and promote the development of beneficial microbial communities. Concurrently, integrating appropriate crops such as vegetables, legumes, or fruit plants can enhance habitat complexity, contribute organic matter, and serve as supplemental feed. Effective soil fertility management, including compost use, organic amendments, and Mixed cropping, can directly impact the growth, reproduction, and shell development of *Archachatina marginata*. Therefore, understanding the interactions between soil fertility, crop choice, and snail performance is key to developing a sustainable and productive system. Two critical, interconnected factors that directly affect snail growth, reproduction and farm profitability are: (a) the nutrient quality of the substrate/soil and (b) the types of crops/forage and cover plants grown inside the structure (which serve as feed, cover, or contribute to substrate organic matter). Despite practical importance, there is limited, systematic research on how soil fertility management and crop selection combine to influence snail performance under screen-house conditions.

In recent years, heliculture commonly known as snail farming has emerged as a promising area within agricultural development, particularly in regions seeking sustainable and profitable livestock alternatives. Traditionally consumed as a delicacy in parts of Europe, Asia, and Africa, snails are increasingly recognized for their nutritional value, being high in protein, iron, and essential amino acids while low in fat. This makes them an attractive option for health-conscious consumers and a viable contributor to food security initiatives. The growing demand for snail products, not only for human consumption but also in the pharmaceutical and cosmetic industries particularly snail slime used in skin care has positioned heliculture as a high-value niche enterprise. In many developing countries, especially across sub-Saharan Africa, heliculture offers opportunities for rural employment, income generation, and economic diversification. It is particularly accessible to women and youth due to its relatively low capital requirements and space-efficient farming methods. Despite these advantages, heliculture remains underdeveloped in many regions. Limited awareness, inadequate technical knowledge, and lack of institutional support continue to hinder its growth. Moreover, environmental factors, breeding conditions, and snail health management require careful attention for successful operations. Therefore, there is a growing need for academic and practical investigations into the biological, environmental, and economic aspects of heliculture. This study aims to contribute to the body of knowledge necessary to improve heliculture practices and promote its adoption as a sustainable agricultural venture.

The purpose of this research is to determine how substrate fertility amendments and choice of inside-screen house crop species influence growth, survival, reproduction and economic returns of Giant African land snails, and to develop low-cost, scalable management recommendations for smallholder producers.

1.3 Objectives of the Study

The objectives of this study are to:

1. Evaluate the effects of different soil fertility management practices on the growth performance of *Archachatina marginata* in a screen house.
2. Investigate the impact of selected crops on soil nutrient content and their compatibility with snail habitat needs.
3. Determine the interaction between crop type, soil fertility, and snail productivity.

CHAPTER TWO

LITERATURE REVIEW

2.1 An Overview of Snail Farming

Heliculture, or snail farming, involves the domestication of snails in controlled environments that closely replicate their natural habitats (Munywoki, 2022). Despite its notable profitability, snail farming remains under-utilised within the agro-industry, primarily due to limited awareness of its economic value (Munywok, 2022). In countries like Nigeria, the Republic of Benin, and other parts of West Africa, snail farming presents not only a promising business opportunity but also serves as an important business opportunity but also serves as an important source of high-quality animal protein, often regarded as a delicacy (Nnodim and Ekpo, 2019; Ibidapo *et al*., 2021).

Snails are invertebrates with bilateral symmetry and soft, segmented bodies enclosed in hard, calcareous shells (Etukudo and Okon, 2025). They belong to the phylum Mollusca and the class Gastropoda (Okon and Ibom, 2012; Etukudo, 2024). Several species of giant African land snails are distributed across the continent, including *Achatina achatina* in Ghana, *Archachatina marginata* in Nigeria, *Achatina fulica* in East Africa, and various *Limicolaria* species found in West African countries such as Guinea, Nigeria, Cameroon, and Gabon (Okon and Ibom, 2012; Etukudo, 2024).

Among these, *Archachatina marginata*, particularly prevalent in the rainforest regions of Southern Nigeria, is especially valued for its commercial potential. This species can reach a mature weight of 500 to 800 grams, making it economically superior to other varieties (Ibidapo *et al*., 2021; Etukudo, 2024). As Uboh *et al*. (2014) highlight, *Archachatina marginata* plays a significant role in the diets of both rural and urban populations in Southern Nigeria, where it is widely consumed as both a delicacy and staple.

Despite increasing interest, much of the snail meat sold in Nigerian markets still originates from wild harvests by local inhabitants (Adewale and Belewu, 2022). The growing demand for snail meat, coupled with the diminishing availablity of wild snails and the recognised benefits of heliculture, has fueled a renewed interest in domesticated snail farming as a sustainable agricultural venture (Adewale and Belewu, 2022). Snail farming entails raising snails in enclosed, controlled environments where essential resources such as food, water, and lime are provided to promote healthy growth (Etukudo, 2017). Upon reaching maturity, the snails are harvested, processed, and either consumed locally or sold. The seasonal nature of wild snail availability further underscores the need for organised, year round farming operations at both small-scale and commercial levels (Etukudo, 2017). According to Ikegwuonu (2013), snail farming is relatively simple to manage. Snails are seldom affected by various diseases, including parasitic, bacteria, and fungal infections, require minimal capital investment, and do not depend on commercial feed. Moreover, they reproduce prolifically; certain species can lay over 100 eggs per cycle, making them an efficient and profitable livestock option. However, successfully operating a snail farming enterprise for wealth creation demands the acquisition of key entrepreneurial skills (Nwarieji and Anene, 2013).

These skills, defined as learned competencies that enable individuals to achieve goals efficiently, are vital for optimising resources, time, and energy (Nwarieji and Anene, 2013). As Nwariej and Anene (2013) assert, entrepreneurial skills are the essential tools that empower individuals to initiate, manage, and scale a successful business. While snail farming is gradually gaining global recognition, its growth in parts of Nigeria remains sluggish. Many farmers still depend on harvesting snails from the wild, a practice largely attributed to inadequate entrepreneurial competence (Odo, 2016). This challenge is compounded by environmental pressures, including deforestation, bush burning, and overharvesting, exacerbated by a growing population. These factors have led to a decline in wild snail populations, with many being collected before reaching maturity, thus threatening sustainability (Okon *et al*., 2012; Etukudo, 2017; Okon *et al*., 2017; Etukudo and Okon, 2025).

Although some individuals have begun domestication and small-scale breeding, large-scale adoption remains limited. Many youths continue to rely on traditional snail hunting, overlooking the substantial benefits of commercial snail production. This persists despite a consistently high market demand for snail meat, even in the face of widespread poverty and unemployment (Onah *et al.*, 2021).

2.2 Description of the Giant African Land Snail (*Archachatina marginata*)

Archachatina marginata (big black snail, giant African land snail) is a large snail, generally growing to about 20 cm and a live weight of 500g. The shell is much less pointed than the Achatina species, the roundness being especially obvious in young animals. Striation on the shell may give the appearance of a woven' texture. The head of the snail is dark-grey; its foot is a lighter shade. This species has been the object of a series of stocking and feeding experiments in Nigeria.

2.1.1 Distribution

Archachatina marginata is native to the humid African rainforest belt, from Southern Nigeria to Congo, but is now found in other parts of the African rainforest zone.

2.1.2 Growing conditions

In the Nigerian experiments, juvenile growth was found to be inversely proportional to temperature, falling sharply at temperatures > 30 °C, and directly proportional to rainfall and humidity. Body weight gain slows down significantly during the dry season (December to March in Southern Nigeria, where the breeding trials took place).

2.1.3 Life history

Reproduction: The species reaches sexual maturity at an age of around one year, when the individuals reach a live weight of 100-125 g. Reciprocal copulation must occur to produce viable eggs.

Laying eggs: After a successful mating, each snail can dig a nest in soft soil and lay a clutch of between 5 to 14 large, creamy-yellow, calcified eggs (Akinnusi, 1997). The eggs are comparatively large at 17 × 12 mm, with an average weight of 4.8 g in a Nigerian stocking trial. For that reason the number of eggs per clutch is low, 4-18 eggs. Eggs are laid in the soil at a depth of about 10 cm

Hatching hatchlings: The incubation period, from egg to hatchling, is around 4 weeks. Hatchlings have a thin, transparent shell; they generally remain in the soil for 5 to 7 days before emerging, but sometimes wait even longer. Because of the relatively high weight of the eggs the number of hatchlings from a clutch is low compared to the other two species. During the first weeks after emerging, hatchlings repeatedly burrow into the soil.

Juveniles: In laboratory trials shell length of the juvenile snails increased by an average of 0.33 mm/day for the first 8 months (c. 8 cm), slowing down to 0.2 mm/day at 15 months. Shell length hardly increases after that time.

Adults: The snails reach sexual maturity at around 10-12 months (Plummer, 1975).

2.2 The Free- Range System

2.2.1 Description

Essentially, free-range pens are large mini-paddock pens: a fenced area of up to 10 × 20 m, planted with plants, shrubs and trees that provide food and shelter from wind, sun and rain. Just like in a mini-paddock pen, the vertical fence must be extended inwards, to prevent snails from escaping. If the fence is constructed of fine chicken wire mesh, the overhang is not obligatory because snails dislike crawling on wire mesh. The fence must be dug at least 20 cm into the ground. The free-range pen might even be completely enclosed and roofed.

2.2.2 Application and use

Free-range pens may serve as the sole snail enclosure in an extensive snail farming system, or as growing and fattening pens in a semi- intensive one.

In the extensive snail farm the entire life cycle of the snail develops within the open pen: mating, egg laying, hatching, hatchling development, and growth of the snails to maturity. Snails feed on the plants provided in the pen.

In a semi-intensive snail farm the free-range pen serves as a growing and fattening pen for adult snails, which were raised through the egg- hatchling-juvenile stages in hutch boxes or trench pens.

2.2.3 Advantages and disadvantages

In an extensive system using a free-range pen the snails develop in a near normal habitat. They will take shelter in the vegetation or the soil during the day, coming out at night to feed.

A simple fenced free-range pen is relatively simple and cheap to construct. Management is restricted to occasional replanting of food and shelter plants. If the vegetation within the pen is kept in shape, additional feeding of the snails is not necessary.

A fully enclosed and roofed pen is quite costly to build, obviously, especially if provided with a concrete apron and drain. Both types require the availability of land with a secure title, considering the investment involved, specifically for the fully enclosed and roofed variety.

2.2.4 The free-range pen has several disadvantages

1. It requires more land than other types of snail farming.
2. It is difficult to locate and protect eggs and small snails. This may lead to poor disease management and higher mortality compared to other snail production systems.
3. It is difficult to keep track of snail performance and, for that reason, to keep useful records of inputs and output.

4. In the open type of free range pen it is more difficult to keep out predators and poachers.

Besides the natural shelter provided in mini-paddock and free-range pens, it is advisable to also provide other forms of shelter to ensure that the snails are not exposed to too much heat. For example, concave tiles or split bamboo can be placed on stones on the ground, with the concave side facing downwards. On very hot days, the soil can be cooled by sprinkling water on it.

2.3 Selected Crops in the Screen House for Giant African Land Snail

1. Plantain

2. Banana

3. Water leaf

4. Cocoyam

5. Sweet potato

6. Pawpaw (Semi- dwarf specie).

1. Plantain: Plantains (*Musa spp.,* AAB genome) are plants producing fruits that remain starchy at maturity (Marriot and Lancaster, 1983; Robinson, 1996) and need processing before consumption. Plantain production in Africa is estimated at more than 50% of worldwide production (FAO, 1990). The majority (82%) of plantains in

Africa are produced in the area stretching from the lowlands of Guinea and Liberia to the central basin of the Democratic Republic of Congo. West and Central Africa contribute 61 and 21%, respectively (FAO, 1986). It is estimated that about 70 million people in West and Central Africa derive more than 25% of their carbohydrates from plantains, making them one of the most important sources of food energy throughout the African lowland humid forest zone (Swennen, 1990).

Nigeria is one of the largest plantain producing countries in the world (FAO, 2006). Despite its prominence, Nigeria does not feature among plantain exporting nations because it produces more for local consumption than for export. National per capita consumption figures show its importance relative to other starch staples (FAO, 1986). However, these figures do not show regional reliance, which is often very important for highly perishable crops that are usually consumed in or near areas of production. The consumption of plantain has risen tremendously in Nigeria in recent years because of the rapidly increasing urbanization and the great demand for easy and convenient foods by the non-farming urban populations. Besides being the staple for many people in more humid regions, plantain is a delicacy and favored snack for people even in other ecologies. A growing industry, mainly plantain chips, is believed to be responsible for the high demand being experienced now in the country.

2.4 Review of Plantain Production, Problems and Prospects

The soils in Nigeria fall into four zones: (a) the northern zone of sandy soils; (b) the interior zone of laterite soils; (c) the southern belt of forest soils; and (d) the zone of alluvial soils. Forest soils in the southern belt are naturally fertile as a result of dense vegetation cover. This zone also contains laterite soils. Forest soils are good for cocoa, palm and rubber production and are also the main soil types in the plantain and banana producing regions of Nigeria. Plantain production is mainly in the Southern states of Nigeria, which include Akwa-Ibom, Cross River, Akwa-Ibom, Imo, Enugu, Rivers, Edo, Delta, Lagos, Ogun, Osun and Oyo States (Ogazi, 1996). Annual rainfall in these areas is usually above 1000mm year 1, spread over 7 to 9 months. Plantain is transported to other parts of the country from these states.

2.5 Importance of Plantain in Nigeria

The demand for plantain within the country is high, with supply struggling to meet demand. This has hampered the status of this crop as a foreign exchange earner. It remains an important staple food, as well as the raw material for many products. It also serves as a source of revenue for many people and as raw material for industries producing value-added products in many parts of Nigeria. Plantain occupies a strategic role in rapid food production, being a perennial ratoon crop with a short gestation period.

The crop ranked third among starchy staples after cassava (*Manihot escultenta*) and yam (*Dioscorea spp.*). It is a major source of carbohydrate for more than 50 million people. In Nigeria, all stages of the fruit (from immature to overripe) are used as a source of food in one form or the other. The immature fruits are peeled, sliced, dried and made into powder and consumed as 'plantain fufu'. The mature fruits (ripe or unripe) are consumed boiled, steamed, baked, pounded, roasted, or sliced and fried into chips. Over ripe plantains are processed into beer or spiced with chili pepper, fried with palm oil and served as snacks ('dodo-ikire'). Industrially, plantain fruits serve as composite in the making of baby food ('Babena' and 'Soyamusa'), bread, biscuit and others (Ogazi, 1996; Akyeampong, 1999).

Though fruits are produced all year round, the major harvest comes in the dry season (November to February), when most other starchy staples are unavailable or difficult to harvest. Thus, it plays an important role in bridging the hunger gap (Wilson, 1986) as well as assisting farmers in having cash at hand through sales of plantain. In Nigeria, plantain peels are used as feed for livestock, while the dried peels are used for soap production. The dried leaves, sheath and petioles are used as tying materials, sponges and roofing material. Plantain leaves are also used for wrapping, packaging, marketing and serving of food.

2.6 Biological Evolution and Nomenclature of Banana Plant

Banana is one of the most widely grown tropical fruits, cultivated over 130 countries, along the tropics and subtropic of Capricorn. Edible bananas are derived from Australimusa and Eumusa series, which have different origins from same genus. Most of the edible or are hybrid between two wild diploid species, M. bananas are either derived solely from *Musa accuminata* Colla and *M. balbisiana* Colla; which contributed to A and B genomes, respectively. Plant has an origin from India and eastern Asian region (Malaysia and Japan) and some varieties are found to be genetically linked with some species from Africa. Polyploidy and hybridization of A and B genomes has given rise to diploid (AA, AB, BB), triploid (AAA, AAB, ABB, BBB) and tetraploid (AAAA, AAAB, ABBB, AABB) bananas. Various other varieties also exist naturally or developed by hybridisation of these genomes, which have different nomenclatures 3, 4. Three common species of Musa (*M. cavendishii, M. paradisiaca* and *M. sapientum*) are widely grown in the world.

Banana Fruit

Banana is highly nutritious and easily digestible than many other fruits. Digestion time of banana fruit is less (105 min) than apple (210 min). Bananas are popular for aroma, texture and easy to peel and eat, besides rich in potassium and calcium and low in sodium content.

1. Moisture Content: Moisture content in pulp increases during ripening process due to respiratory breakdown of starches into sugar and migration of moisture from peel to pulp. However, in AAB variety, moisture content could be 68% due to presence of starchier *balbisiana* genome and incomplete conversion of starch into sugar; even when banana is fully ripe, still some starch is left in pulp tissue.

2. Carbohydrates: During ripening process, starch is converted into sugar, through enzymatic breakdown process. In AAB group, starch content declines from 20-30% to 1-2%, but starch amount could be as high as 11% depending on variety. Sugar content of fully mature banana is quite high that makes it an ideal substrate for wine making. Carbohydrate type in banana is resistant starch and non-starch polysaccharides, which have low glycemic index or low digestibility. This property makes it an excellent ingredient for different functional and convenience foods like cookies and chips.

3. Proteins: Bananas protein (1-2.5%), depending on genome type, variety, altitude, and climate, increases over ripening process (3.8-4.2%).

4. Fat: Fat content in pulp remains almost constant (1%) during ripening process. Peel contains lipid (2.2-10.9 %) and is rich in polyunsaturated fatty acids, particularly linoleic acid and α-linolenic acid.

5. Pectins: Ripe pulp contains pectin (0.7-1.2%). During ripening, insoluble protopectin is converted into soluble pectin that causes loosening of cell wall and texture degradation leading to softening of fruit. Gel forming ability of pectin has a varied use as additives in jams, jellies and marmalades, as thickeners, texturizers, emulsifiers, fat or sugar replacer.

Waterleaf

Vegetables serve as indispensable constituents of the and certain hormone precursors, in addition to protein human diet supplying the body with minerals, vitamins and energy (Oyenuga and Fetuga, 1975) Several vegetable species abound in Nigeria and most West African countries where they are used partly as condiments or spices in human diets or as supplementary feeds to livestock such as rabbits, poultry, swine and cattle (Aletor and Adeogun, 1995). These vegetables are harvested at all stages of growth and fed either as processed, semi processed or fresh to man while they are usually offered fresh to livestock. Leafy vegetables are known to add taste and flavour, as well as substantial amount of proteins, fibre, minerals and vitamins to the diet (Oyenuga and Fetuga 1975; Adewunmi, 1987).

While the amounts of the nutrient constituents in the more commonly used leaf vegetable species in Nigeria have been studied to some extent (Kola, 2004), the lesser known regional and local species remain virtually neglected. Lack of information on the specific nutrients and phytochemicals in a large number of the native vegetables species with which Nigeria is richly endowed is partly responsible for their under exploitation especially in areas beyond the traditional localities where they are found and consumed. Among the leafy vegetables in which their phytochemicals and nutrients have not been extensively studies are leaves of water leaf.

Talinum triangulare (water leaf) is an herbaceous perennial, calescent and glabrous plant widely grown in tropical regions as a leaf vegetable (Ezekwe *et al*., 2001). It is consumed as a vegetable and constituent of a sauce in Nigeria. Nutritionally, water leaf has been shown to possess the essential nutrients like B carotene, minerals (such as calcium potassium and magnesium), pectin, protein and vitamins (Ezekwe *et al*., 2001). Water leaf has been also implicated medically in the management of cardiovascular diseases like stroke, obesity, etc (Adewunmi and Sofowora, 1980) and traditionally it is used as softener of other vegetable species. With recent wave of economic depression and it's attendant effect on the purchasing power of the populations of less developed nations it has become obvious that the local food stuffs will pay increasing role in the food, nutrition and health security of the rural people and the increasing urban poor. As popular as this vegetable is in Nigeria, There is still paucity of information on the phytochemical constituents of *Talinum triangulare*. Hence, a study was carried out to evaluate the phytochemical constituents of *Talinum triangulare* (water leaf) leaves.

Waterleaf (*Talinum fruticosum*) (L) Juss) is a perennial herb and a member of the Talinaceae (fenzl) Doweld family. Its genus is Talinum Adans. It is also known as *Talinum triangulare* (jacq) wild, *Talinum crassifolium* (jacq) wild and *Portuluca* *fruticosa* L. Due to its wide distribution it has different common names including waterleaf (West Africa), Ceylon spinach or Philippine spinach (parts of Asia). It is cultivated in tropical regions of America, Asia and Africa. Some records state that it originated from South America and was introduced to West Africa; however, there is still lack of clarity as to its true origin (Fontem, and Schippers, 2004 and Enete, and Okon, 2010).

The leaves and stems of waterleaf is harvested and used to make vegetable soups in most parts of South and Eastern Nigeria. It is a nutritious complement to starchy and high carbohydrate foods such as cooked cassava, yam and rice. It has a high potassium content in the leaves; and is a source of calcium, carbohydrates, glycosides, starch, steroids and secondary compounds including saponins, phenolics and flavonoids, (Khaing, and Moe, 2019 and Bioltif, and Edward, 2020). It has a short duration to maturity (30-45 days), and can be planted all year round in Nigeria. It produces erect succulent stems and swollen roots and can reach a height of 3-10 ft. Its short duration of growth and its resistance to most pest and diseases makes it a favourable crop for fast subsistence farming and commercial production.

Cocoyam

Cocoyam, *Xanthosoma sagittifolium*, is cultivated in tropical regions for human nutrition, animal feed, and cash income for both farmers and traders. Cocoyam is vegetatively propagated using the corms and to a lesser extent the cormels. As food for human consumption, the nutritional value of the various parts of cocoyam is primarily caloric. The underground cormels provide easily digested starch; and the leaves are nutritious spinach like vegetable, which give a lot of minerals, vitamins and thiamine. In Ghana cocoyam is generally grown by small scale farmers and cocoyam farms under intensive management are highly limited. Since cocoyam tolerates shade, the crop is frequently grown in intercropping systems together with permanent crops such as banana, coffee, coconut, rubber, oil palm and cocoa. Cocoyam leaf is produced on subsistence basis and pickers who are not farmers dominate its harvesting and marketing.

Cocoyam (*Colocasia esculenta* (L.) Schott) also known as taro is regarded as an important staple crop in the Pacific Islands, Asia and Africa.

Taro (Cocoyam) (*Colocasia esculenta* (L.) Schott) is an important tropical root crop grown purposely for its starchy corms or underground stem. It is regarded as one of the most important staple crops in the Pacific Islands, Asia and Africa. It is one of the oldest world's food crops believed to have been first domesticated in Southeast Asia before its eventual spread to other parts of the world. The two most commonly cultivated species of Taro (*Colocasia esculenta* and *Xanthosoma sagittifolium*) belong to the Araceae family and are extensively cultivated in Africa. Taro is an herbaceous monocotyledonous plant of 1–2 m height. The plant consists of central corm (below the soil surface) making the leaves grow upwards, roots grown downwards, while cormels, daughter corms and runners (stolons) grow laterally. The root system is fibrous and lies mainly at a depth of up to one meter of soil.

Sweet Potato

Ipomoea batatas (L.) Lam. (Convolvulaceae, Dicotyledons) produces storage roots rich in carbohydrates and β-carotene, a precursor of vitamin A, and it's leaves are rich in proteins. The roots also contain vitamins C, B complex, and E as well as potassium, calcium, and iron. Purple-fleshed ones contain antioxidants such as anthocyanins. In world crop statistics, the sweet potato is ranked seventh, just after cassava, with an annual production around 9 Mt and a cultivated area of 110 Mha (FAO, 2009). In most developing countries, it is a small holder crop tolerant of a wide range of edaphic and climatic conditions and grown with limited inputs. It is also quite tolerant of cold and being cultivated at altitudes as high as 2,500m, it has become the staple of communities living in the highlands of Uganda, Rwanda and Burundi in Eastern Africa and in Papua New Guinea where annual per capita fresh roots consumption is over 150kg. Asia is the largest producing region and China alone accounts for almost 60% of world production. In the southern provinces of Sichuan and Shandong, sweet potato is a major source of raw material for food processing industries (Fuglie and Hermann, 2004). Nearly half of the Chinese production is for animal feed (roots and leaves), with the remainder primarily used for human consumption, either as fresh (boiled roots) or processed products (noodles and alcohol). In some temperate countries such as the United States, Japan, and New Zealand, the sweet potato is a high-quality luxury vegetable. The Convolvulaceae family is composed of herbaceous, woody, or climbing species, well distributed throughout the temperate and tropical latitudes in a wide range of habitats, including sand dunes. Convolvulaceae species have alternate and simple leaves. Their flowers are bisexual with five free sepals, five fused petals, and five stamens fused at the base of the corolla tube. The fruit is a dehiscent capsule. The characteristics of the ovary, styles, and stigmas are used to differentiate up to 10 tribes of genera (Heywood, 1985).

Semi-Dwarf Pawpaw

Semi-dwarf pawpaw trees are characterized by a growth habit that is significantly more compact than the standard wild species, which can reach over 25 feet tall, making them suitable for smaller gardens and high-density orchards (Pomper and Layne, 2005). The most prominent named semi-dwarf cultivar is Asimina triloba 'Sunflower', which is known for its tendency to produce a rounded, densely branched tree that typically matures at a height of 12 to 15 feet. 'Sunflower' and similar selections achieve their semi-dwarf stature primarily through their genetic growth habit rather than the use of dwarfing rootstocks, as no commercial dwarfing rootstock for pawpaw has been widely adopted. Another cultivar exhibiting a semi-dwarf growth form is Asimina triloba 'NC-1', which was developed for its precocious fruiting and a moderately compact tree size, often reaching about 15 to 20 feet at maturity. The management of semi-dwarf pawpaw trees is further enhanced through horticultural practices, such as pruning the central leader to control height and encourage a lower, more shrub-like form (Schlabach, 2010). These semi-dwarf cultivars are valued not only for their manageable size but also for their tendency toward precocity, often bearing fruit within 3 to 4 years after planting, which is earlier than many seedling trees (Pomper, 2008). The fruit produced on semi-dwarf varieties like 'Sunflower' is typically of high quality, with a rich, creamy texture and a flavor often compared to a combination of banana, mango, and vanilla (Brannan and Hoskins, 2017). Research and cultivar development of compact pawpaw selections, including semi-dwarf types, have been a focus of institutions like Kentucky State University, which serves as the USDA National Clonal Germplasm Repository for *Asimina triloba*.

2.7 Soil Fertility Management

Soil fertility refers to a soil's ability to support plant growth through favorable chemical, physical, and biological conditions, including providing essential nutrients. Regular soil testing can help farmers understand their soil's nutrient levels and needs. Factors that affect soil fertility include organic matter content, soil texture, pH, moisture, aeration, temperature, and biota activity. Management practices like crop rotation, cover cropping, organic fertilization, reduced tillage, and intercropping can improve soil fertility over time. Earthworms, microbes, fungi, and other soil biota play an important role in soil fertility by breaking down organic matter, improving soil structure, and making nutrients availability.

2.7.1 Soil fertility

Soil fertility is critical for the development of plants and influences their yield. Fertile fields are a great asset to farmers. But improper agricultural management can lead to land depletion. It is critical to remember the importance of fertilizers and environmentally friendly cultivation methods in increasing field fertility. High yields can be obtained from poor fields with appropriate soil fertility management practices. Hence, growers who understand how to preserve soil fertility can maximize farmland productivity and maintain it over time.

2.7.2 What is soil fertility and why does it matter?

Soil fertility is the capacity of a soil to receive, store, and transmit energy and matter to support plant growth (Brady and Weil, 2007). It matters because fertile soils are the foundation of global agricultural systems, providing over 99% of the world's food calories (FAO, 2015). A key component of soil fertility is the presence of essential plant nutrients, such as nitrogen, phosphorus, and potassium (Havlin, 2013). The availability of these nutrients directly controls the yield and nutritional quality of food crops (Mueller, 2012). Soil organic matter is a critical indicator of fertility as it improves the soil's water-holding capacity and nutrient retention (Lal, 2004).

Furthermore, a fertile soil with good structure and biological activity helps to mitigate climate change by sequestering atmospheric carbon (Paustian, 2016). The degradation of soil fertility through erosion and mismanagement poses a direct threat to food security, particularly for smallholder farmers (Tully, 2015). Ultimately, maintaining soil fertility is essential for achieving the United Nations Sustainable Development Goals related to zero hunger and life on land (Kopittke, 2019).

2.7.3 What makes soil fertile?

Factors that affect soil fertility are classified as direct and indirect. The amount of organic matter, moisture, and field aeration are direct factors. The indirect ones include soil biota activity, tillage methods, and many others and the most important soil fertility factors.

1. Humus content: Land fertility is proportional to the amount of humus present. Humus contains nutrients, particularly nitrogen and phosphorus, necessary for most plants. Humus increases soil fertility, creating an ideal microclimate for crop development with a favorable temperature, adequate moisture, and air. Humus content is closely related to types of soil.

2. Soil texture: Soil texture refers to the relative proportions of sand, silt, and clay particles that make up a soil (Brady and Weil, 2016). These particles, which are the inorganic components of soil, vary in size, with sand being the largest, followed by silt, and then clay being the smallest (USDA, 2017). This size distribution significantly impacts soil properties such as water infiltration, drainage, aeration, and nutrient retention (Hillel, 2004). Soil texture is a fundamental characteristic of soil that influences its overall behavior and suitability for various uses, from agriculture to construction (Foth and Turk, 1972).

3. Mineral composition: Mineral composition refers to the specific chemical elements that make up a mineral and the proportions in which they are present. This defines the mineral's fundamental properties. For example, the mineral quartz is composed primarily of silicon and oxygen, with a chemical formula of $SiO2$ (Klein and Dutrow, 2017). The exact arrangement and bonding of these atoms further dictate the mineral's crystal structure and physical characteristics (Deer, Howie, and Zussman, 2013). Variations in the proportions of elements, or the presence of trace elements, can lead to different varieties of the same mineral, like the diverse colors observed in tourmaline due to the incorporation of various metal ions (Hurlbut and Klein, 1985). This makes mineral composition a crucial aspect of mineral identification and classification (Blatt and Tracy, 1996).

4. Soil pH: Soil pH is a measure of the acidity or alkalinity of a soil sample (Hillel, 2004). The pH scale ranges from 0 to 14, with a pH of 7 being neutral, values below 7 being acidic, and values above 7 being alkaline or basic (Brady and Weil, 2017). Soil pH is a critical factor influencing plant nutrient availability, microbial activity, and overall soil health (Havlin *et al*., 2014). For example, many essential plant nutrients are most available in a slightly acidic to neutral pH range, typically between 6.0 and 7.0 (Marschner, 2012). Deviations from this optimal range can lead to nutrient deficiencies or toxicities, affecting plant growth and yield (Munns, 2002).

5. Moisture content: Because plants take nutrients directly from water rather than the solid phase of the soil, fertility is heavily dependent on the amount of moisture in the ground. As a result, growers should select lands that provide sufficient hydration to plants.

6. Aeration: Aeration is an essential factor in ensuring field fertility. Plant roots require oxygen to thrive. Furthermore, oxygen promotes the vital activity of beneficial microorganisms in the ground, such as aerobic denitrifying and nitrogen-fixing bacteria.

7. Soil temperature: The temperature of the ground influences the activity of beneficial bacteria, nutrient solubility, and plant uptake. Temperatures ranging from 18 to 24°C (65 to 75°F) are ideal for most plants. All processes slow down at low soil temperature, while high temperatures cause pathogens and pests to reproduce quickly and plants to dry out.

8. Soil Biota: The biota of soil is exceptionally diverse, containing viruses, bacteria, fungi, and lichens. Microbes can be either plant pathogens or plant growth promoters.

So how do microbes contribute to soil fertility? Microorganisms increase land fertility, especially by helping plants to assimilate mineral compounds and participating in the decomposition and decay of organic substances.

2.7.4 How to measure soil fertility

Measuring soil fertility involves assessing various physical, chemical, and biological properties that impact its ability to support plant growth.

1. Physical Properties

Soil Texture: This refers to the proportion of sand, silt, and clay particles in the soil. It significantly affects water infiltration, drainage, aeration, and nutrient retention. Texture is often determined using the "feel method" (hand texturing) or by more accurate laboratory methods like the hydrometer test or sieve analysis (Brady and Weil, 2017).

Soil Structure: This describes how soil particles aggregate together to form peds (clumps), which influences pore space and, in turn, affects water movement, aeration, and root growth. Structure is evaluated by observing the size, shape, and stability of these aggregates. (Hillel, 2008).

Bulk Density: This measures the mass of soil per unit volume, indicating the compactness of the soil. Higher bulk density can restrict root growth and reduce water infiltration. It is determined by oven-drying a known volume of soil and measuring its weight. (USDA-NRCS, 2023)

Water Holding Capacity: This is the soil's ability to retain water available for plant uptake. It's often determined in the laboratory by saturating a soil sample, allowing it to drain, and then measuring the amount of water retained. (Klute, 1986)

Infiltration Rate: This is the rate at which water enters the soil. It's measured using infiltrometers or by observing the time it takes for a known volume of water to infiltrate (Hillel, 1998).

2. Chemical Properties

Soil pH: This measures the acidity or alkalinity of the soil, impacting nutrient availability. It's measured using a pH meter or pH indicator kits. Most plants thrive within a specific pH range. (Tisdale *et al.*, 1985)

Organic Matter Content: This represents the amount of decomposed plant and animal material in the soil. It improves soil structure, water retention, and nutrient availability. It's often measured by the loss-on-ignition method in the laboratory, or by the Walkley-Black method for soil organic carbon (SOC) (Nelson and Sommers, 1996).

Nutrient Levels: Analyzing the concentration of essential nutrients (nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and micronutrients) is vital. This is done through soil testing in a laboratory using various extraction methods (e.g., Mehlich 3, Olsen, Bray) followed by analysis using techniques like spectrophotometry or inductively coupled plasma (ICP) spectroscopy (Benton Jones, 2012).

Cation Exchange Capacity (CEC): This is the soil's ability to hold and exchange positively charged ions (cations) like calcium, magnesium, potassium, and ammonium. A higher CEC generally indicates a greater capacity to store and provide nutrients. It's measured through laboratory analysis using ammonium acetate or other methods (Sposito, 2008).

Electrical Conductivity (EC): This measures the salt content in the soil. High EC can indicate salinity issues, which can inhibit plant growth. EC is measured using an EC meter (Rhoades *et al*., 1989).

3. Biological Properties

Soil Microbial Biomass: This quantifies the mass of living microorganisms (bacteria, fungi, etc.) in the soil, which are crucial for nutrient cycling and decomposition. It's often measured by the substrate-induced respiration (SIR) method, or through molecular techniques (e.g. DNA sequencing) (Sparling, 1985).

Enzyme Activity: Enzymes are involved in various soil processes, such as nutrient cycling. Measuring enzyme activity (e.g., phosphatase for phosphorus turnover) can indicate the functional capacity of the soil (Acosta-Martinez and Tabatabai, 2000).

Earthworm Population: Earthworms contribute to soil aeration, aggregation, and nutrient cycling. Their presence and abundance can be assessed through visual observation or by counting them in a soil sample (Edwards and Lofty, 1977).

Nematode Population: Nematodes can be both beneficial and harmful to plant health. A nematode assay can identify their numbers and identify the type (e.g., parasitic nematodes on plant roots) (Barker *et al*., 1994).

2.7.5 How to improve soil fertility in a snailery

To improve soil fertility in a snailery, focus on incorporating organic matter and ensuring adequate calcium content, while maintaining proper soil conditions like moisture and texture (Adediran, *et al*., 2003).

Even fertile land depletes over time, so fertility must not only be preserved but also improved. Crop rotation, fertilization, mixed planting, sowing green manure, mulching, and fallowing help to increase field fertility. The impact of living organisms on farmland fertility is also hard to overestimate: earthworms, beneficial fungi, bacteria, and protozoan unicellular organisms are extremely helpful to the soil. They improve its structure and water-holding capacity by processing organic residues or parasitizing microorganisms. Natural pest enemies, such as birds that eat insect larvae or weed seeds, also indirectly increase soil fertility.

1. Crop Rotation: Repeated cultivation of the same crops in the same field, season after season, reduces field fertility by removing the same chemical elements from the ground. Crop rotation is a viable solution to this problem, as it not only slows land depletion but also aids in improving soil fertility. Because each plant has different microbiological preferences, crop rotation promotes microflora diversity. Crops that improve soil fertility include hay plants and legumes.

2. No-Till farming: The rejection of tillage allows for the strengthening of soil structure and the slowing of erosive processes. At the same time, the amount of organic matter in the ground increases, carbon dioxide emissions into the atmosphere decrease, and the life of beneficial microorganisms and worms is preserved. Furthermore, farm workers can devote time previously spent on tillage to other, more useful activities. Thus, no-till farming benefits everyone: it improves soil fertility, saves farmers time and resources, and positively impacts the environment.

2.7.6 What minerals make soil rich and fertile?

Mineral content is one of the vital characteristics of fertile soil. Plants require six essential elements to grow. There are three critical minerals and three additional ones, each with its own unique role.

2.7.7 How does fertilization enhance soil fertility?

A bountiful harvest is directly proportional to the availability of micro and macro elements required by plants. Fertilization of fields is thus one of the farmers' primary and ongoing tasks.

1. Organic fertilizers are safe and environmentally friendly because they are obtained from natural (organic) substances, such as manure and compost. Organic fertilizers assist in restoring soil fertility in the long run. Their disadvantage is that they do not dissolve in water, minerals are slowly released from them, and the participation of microorganisms is required to acquire a form that can be assimilated by plants.

2.7.8 Green Manure Seeding and Earthworms

Green manures cover the field with vegetation, preventing erosion and retaining moisture. However, the advantages of green manure go beyond this. They are high in nitrogen, phosphorus, potassium, starch, and protein. Green fertilizers include buckwheat, radish, mustard, barley, wheat, rye, and legumes.The presence of nutrients in the ground does not imply that its physical conditions are plant-friendly. Because ground compaction makes it difficult to deliver necessary chemical elements to crop roots, fertility is also determined by the number of earthworms. How do earthworms improve soil fertility? The role of earthworms in soil fertility is enormous: they loosen the ground, digest organic residues, increase oxygen supply, and produce humus.

Table 2.1: Essential nutrients for plant growth and development

Name	Functions
Nitrogen (N)	• Is required for the formation of chlorophyll; • Contributes to the development of leaves and overall crop growth.
Phosphorus (P)	• Promotes the development of roots, buds, flowers, and seeds; • Helps plants to survive extremely cold winters and general environmental stress.
Potassium (K)	• Improves metabolism and moisture retention; • Increases resistance to pathogens.
Magnesium (Mg)	• A chlorophyll component required for the formation of the green color of leaves and photosynthesis.
Sulphur (S)	• Aids in disease resistance; • Is found in enzymes, amino acids, proteins, and vitamins.
Calcium (Ca)	• Contributes to plant immunity by participating in the formation of cell walls; • Facilitates nitrogen metabolism and assimilation.

In addition to the minerals listed, plants also need trace amounts of the following eight micronutrients: iron (Fe), copper (Cu), manganese (Mn), molybdenum (Mo), boron (B), zinc (Zn), nickel (Ni), chlorine (Cl).

2.8 Crop Selection

Different crops need different type of soils, different types and amounts of nutrients, and different types and amounts of water. The amount of water required by the plant is also dependent on the growing season and the climate where it is grown. By selecting the right crop for the given soil conditions and climate, one can optimise yields and save water requirements for irrigation. Selecting crop varieties is a key resilience strategy for farmers facing changing climatic conditions. There are two types of seed varieties: traditional varieties and improved varieties. Traditional varieties have been selected by farmers for their special characteristics and due to many years of selecting the strongest seeds over generations, they are generally adapted to local natural conditions. In some respects, these seeds increase the chance of getting a return on investment in stable environments, but are less likely to mitigate GHG emissions. Traditional crop varieties are usually selected by small scale farmers due to their relatively low cost and availability and can be saved and replanted for further growing seasons. Improved varieties are seeds that have been altered by scientific processes to incorporate desired characteristics using techniques such as following pure line breeding, classical breeding, hybridisation and molecular breeding. Desirable characteristics include higher yields, shorter growing seasons, drought resistance, salt tolerance, etc. Improved varieties are selected when facing adverse conditions such as higher temperatures and/or less predictable rainfall and normally result in the efficient use of water reducing use of energy for irrigation systems. While these seeds offer improvements they are usually commercial products and as a result can be expensive. Furthermore, as they are sold by seed companies availability is driven by demand. The crop water needs mainly depend on:

1. The climate

2. The growth stage

3. The crop type

The crop water needs are high in sunny, hot and windy climates and low in cloudy, cool, humid climates with little wind speed.

2.8.1 The climate

In a sunny and hot climate, crops need more water per day than in a cloudy and cool climate. One has to consider the amount of rainfall and water loss trough percolation and evapotranspiration in order to calculate the right amount of irrigation water needed. Soil moisture conservation through mulching, tillage techniques, soil cover or soil amendment.

2.8.2 The growing stage

A fully-grown crop will need more water than a crop that has just been planted. It is estimated that 50% of the crop water is needed during the mid-season stage, when the crop is fully developed. During the so-called crop development stage the crop water need gradually increases to the maximum crop water need (100%). The maximum crop water need is reached at the end of the crop development stage, which is the beginning of the mid-season stage. Fresh harvested crops, such as lettuce, cabbage, etc. need the same amount of water during the late season stage as during the mid-season stage. The crops are harvested fresh and thus they need water up to the last moment. Dry harvested crops, such as cotton, maize (for grain production), sunflower, etc. are allowed to dry out and sometimes even die during the late season stage these crops. Thus their water needs during the late season stage are minimal.

2.8.3 The crop type

There exist crops like rice or sugarcane, which need more water than crops like beans and wheat. The table below gives some idea about the different seasonal water needs of the most important field crops.

Table 2.2: Approximate values of seasonal crop water needs

Crop	**Crop water need (mm/ total growing period)**
Alfalfa	800- 1600
Banana	1200- 2200
Barley/Oats/Wheat	450- 650
Beans	300- 500
Maize	500- 800
Melon	400- 600
Potato	500- 700

Source: FAO (1986)

2.8.4 Water need

The water need of a crop is usually expressed in mm/day, mm/month or mm/season. Suppose the water need of a certain crop in a very hot, dry climate is 10 mm/day. This means that each day the crop needs a water layer of 10 mm over the whole area on which the crop is grown. It does not mean that this 10 mm has to indeed be supplied by rain or irrigation every day. For example, it is still possible to supply 50 mm of irrigation water every 5 days. The irrigation water will then be stored in the root zone and gradually be used by the plants: every day 10 mm will be used (adapted from FAO 1986). In terms of volume, with a rainfall of 10 mm, every square metre of the field receives 0.01 m, or 10 litres, of rain water. With a rainfall of 1 mm, every square metre receives 1 litre of rain water (FAO 1985).

2.8.5 Nutrient requirements

Proper nutrition is essential for satisfactory crop growth and production. The use of soil tests can help to determine the status of plant-available nutrients to develop fertiliser recommendations in order to achieve optimum crop production. There are at least 16 elements known, which are normally derived from the soil in the form of inorganic salts, to be essential for plant growth (see table below). 94 to 99.5 % of fresh plant material is made up of carbon, hydrogen and oxygen. The other nutrients make up the remaining 0.5 to 6.0 per cent. Macronutrients refer to those elements that are used in relatively large amounts, whereas micronutrients refer to those elements that are required in relatively small amounts (Mckenzie, 1998).

Table 2.3: Essential plant nutrients

Supplied from air and water	Supplies from soil and fertilizer sources	
	Macro nutrients	**Micro nutrients**
Carbon (C)	Nitrogen (N)	Zinc (Zn)
Hydrogen (H)	Phosphorus (P)	Copper (Cu)
Oxygen (O)	Potassium (K)	Iron (Fe)
	Sulphur (S)	Maganese (M)
	Calcium (Ca)	Boron (B)
	Magnesium (Mg)	Chlorine (Cl)
		Molybdenum (Mo)
		Cobalt (Co)

Source: Mckenzie (1998)

Plant tissue analysis measures nutrient levels in the plant during their growth. The supply of available nutrients is reflected in the nutrient content of the crop. Therefore, use of plant tissue analysis allows a producer to evaluate the effectiveness of fertiliser recommendations from a soil testing service. Producers who do not soil test can still use routine plant tissue analysis to evaluate their fertiliser management programme to determine whether they used the correct kinds and amounts of nutrient (Mckenzie 1998).

2.8.6 Soil texture

Soil texture is an important soil characteristic that drives crop production and field management. The textural class of a soil is determined by the percentage of sand, silt, and clay. Soils can be classified as one of four major textural classes: (1) sands; (2) silts; (3) loams; and (4) clays. Soils can be improved with help of tillage, soil cover and reforestation, soil amendment, mulching or adding compost. There are several soil properties which are influenced by the texture (Berry *et al*. 2007):

1. Drainage

2. Water holding capacity

3. Aeration

4. Susceptibility to erosion

5. Organic matter content

6. Cation exchange capacity (CEC)

7. pH buffering capacity

8. Soil tilth

Sandy soils have large particles and gaps between them. This allows water and nutrients to drain away freely, making sandy soils less fertile than heavier soils. Sandy soils also tend to dry out in the summer. But they warm up quickly in spring (allowing seedlings a good start) and they are much easier to dig than clay-based soils. If your soil is sandy, you should have no trouble growing root vegetables (such as carrots and parsnips), but you may struggle with nutrient-hungry brassicas (such as cabbages and broccoli). Also, plants and trees with shallow roots are prone to drying out as sandy soils lose moisture faster than heavier soils.

Clay and silt soils – ‘heavier soils’ – have small particles. This means water is less likely to drain away but the soil is more likely to become waterlogged. Heavier soils are fertile, but take longer to warm up in the spring and are harder to dig. If you have clay soil, you should find that brassicas (such as cabbages and broccoli) grow well, but root vegetables (such as carrots and parsnips) are likely to struggle as they have to push through the heavy, often compacted soil. Shallow-rooted trees (such as pear trees) are likely to thrive in this soil as it holds moisture better than sand.

Crop selection for a more effective use of irrigation water is useful and adaptable for every farm. It needs at least some basic knowledge about soil texture, nutrient and water requirements. Furthermore, yield production due to better soil quality (e.g. infiltration rate, aeration, water holding capacity) can be improved if there are implemented some technologies such as mulching, tillage techniques, soil cover or soil amendment.

CHAPTER THREE

MATERIALS AND METHOD

3.1. Site of Experiment

The experiment was conducted at University of Benin Teaching and Research Farm, screen house unit. The site was chosen to mimic the natural habitat of snails in the wild.

3.2 Duration of the Experiment

The experiment commenced from the last week of May and ended in the first week of October; 18 weeks.

3.3. Screen House Preparation

The house was constructed east-west direction, dwarf wall or fence, with poles around for the net. The soil was prepared by allowing Mucuna to dominate the unit, providing nutrient, coverage/shade and recovery for the soil. The different crops were planted without bias, all over the screen house unit, from the edges to the open space. The fences were raised higher, the poles were welded and made to stand upright and horizontally. The soil of the screen house was already available, new soil were not introduced. *Mucuna spp.* plant is the natural cover of the soil, but was reduced occasionally because of it's wild growth. The selected crops (Cocoyam, Banana, Waterleaf, Sweet potatoes, Pawpaw) were brought in by transplanting

3.4 Materials

1. Dried leaves and plantain leaves.

2. Weeding tools

3.5. Methods

1. Dried leaves and plantain leaves: Dried leaves, particularly plantain leaves, are used as mulch in screen houses for snails to provide shelter, improve humidity, and enrich the soil. Before use, the leaves should be sterilized with hot water to remove pests and then dried before adding them to the snail habitat.

How to use dried and plantain leaves for mulching

1. The plantain leaves were harvested and allowed to wilt for 2-3 days under good sunlight, after wilting it was spread on the ground.
2. The plantain leaves were utilized fresh after harvesting.

Application in the screen house: A layer of dried leaves was created at the bottom of the screen house as a substrate, which helped retain moisture.

Monitoring and maintenance: Regular misting or wetting of the leaves and the habitat with water to maintain a high level of humidity was done..

Replacement of the leaves with new ones as they decompose to keep the habitat clean and healthy was also done.

2. Weeding tools

Method 1: The safest approach (hand weeding): Hand weeding was the most reliable method, when the weeds were too close to the plantain.

Method 2: Use of a hoe: For larger areas free or not too dominated by the desired plants, hoe was used to make the work faster and efficient.

3.6 Data Collection

1. Plant height

2. Number of leaves

3. Greenness of the leaves

4. Shell weight

5. Clutch size

6. Incubation and hatching

CHAPTER FOUR

RESULT

The results obtained, are reported in the plates below, showing the growth pattern of the plants in sequence:

Plate 1: Early period of the screen house, still scanty and not fully established. It was weeded and cocoyams were recently transplanted so they are wilting.

Plate 2: The semi-dwarf pawpaw at it's early stage still in the poly pot. They were 10 in number and were raised in the Department of Crop Science.

Plate 3: The waterleaf recently transplanted from the screen house surrounding.

Plate 4: Showing recently transplanted plantain from a matured plantain outside the screen house

Plate 5: Cocoyam growing after weeks of transplanting and the banana still growing well.

Plate 6: After some months of weeding and good rainfall, this is the condition of the screen house.

Plate 7: Pawpaw after some months of been transplanted from the poly pot

Plate 8: Cocoyam after some period of time of rainfall and weeding having good stem and green leaves

Plate 9: Waterleafs growing at various locations in the screen house, with green healthy leaves

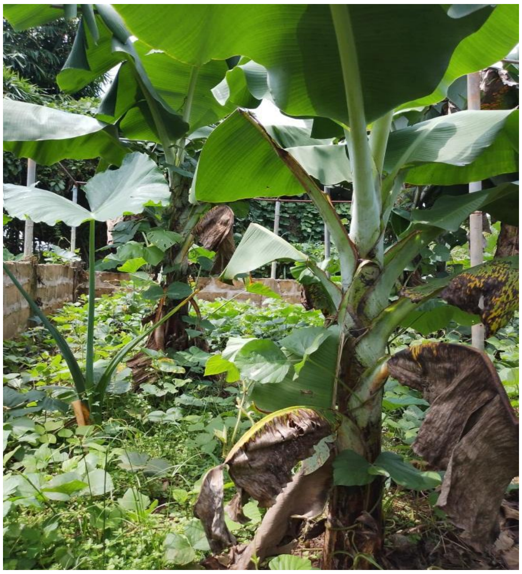

Plate 10: The plantain present state after some months of good rainfall and soil nutrient availability having green leaves and strong stems

Plate 11: Banana after some months, with good strong stem, healthy leaves and good fruits

Plate 12: Sweet potato after some months of been transplanted from a nursery spreading around the screen house with healthy green leaves

CHAPTER FIVE

DISCUSSION

The screen house was weeded but little Mucuna was left and the selected crops were introduced. Cocoyam was the first crop to be transplanted into the soil. The bananas were already present. The cocoyams were planted from the east wall to the west wall, one stand per pole in 3 rows. After transplanting, it was watered and rain fell on them. Their vigor was low for some days, and this is true in other research: When cocoyam is transplanted, the plant typically undergoes a period of transplant shock, characterized by temporary wilting and a slowdown in growth as the root system is disturbed and struggles to establish in the new environment (Onwueme, 1999). The semi-pawpaw seedling raised in the nursery in a polypot. The Semi-dwarf pawpaw trees were typically ready for transplanting into the field 12 to 18 months after the seeds have germinated. The key factor was not just age, but the size and root development of the seedling. From a research: A seedling is typically ready for out planting from the nursery when it has reached a height of 12 to 18 inches (30 to 45 cm) and has a well-established root system, which usually corresponds to a 1- or 2-year-old seedling. (Kentucky State University Cooperative Extension Program, 2021). Waterleaf plants were transplanted into the screen house, from outside the snailery unit.

The screen house is mostly dominated by banana, and to provide more shade for the snails, plantain was transplanted as well. So plantain suckers were gotten from outside the screen house from the matured plantains there. The hoe was dug and then the sucker was brought into the hoe. After a period of 1-2 weeks, the cocoyams recovered from the shock and started growing well again. According to a past research: A transplanted Cocoyam is generally considered fully established and recovered from transplant shock once it resumes the production of new leaves, which usually occurs within 2 to 3 weeks after transplanting, signaling that the root system is functionally mature (Lebot, 2009). After a period of 8 weeks, the screen house was looking well establishment, it was no longer scanty and there was high volume of plants everywhere. Although periodic weeding was done to reduce the concentration of weeds and Mucuna. After transplanting, from availability of water and soil nutrients it grew reaching a height of 30cm and having 15 leafs. There are some similarities with a research carried out: At three months old, a semi-dwarf papaya plant (e.g., the 'Red Lady' cultivar) typically reaches a height of 30 to 40 centimeters under optimal growing conditions (University of Florida IFAS Extension, 2020). By the three-month stage, a healthy semi-dwarf papaya plant usually had developed between 8 and 12 true leaves, as the plant begins to establish a strong canopy for future growth and fruit production (Department of Agriculture, Malaysia, 2017).

After a period of good rainfall the cocoyam became greener and bigger, growing to a height of 40cm taken with it's tallest leaf and have 5 stemmy leaves. With the result of a past research: At three months (approximately 12 weeks) after planting, a cocoyam plant (*Xanthosoma sagittifolium* or *Colocasia esculenta*) typically reaches a vegetative height, measured to the top of the tallest leaf, of between 30 cm and 60 cm, depending on the variety and growing conditions (Onwueme and Charles, 1994), I think there's a positive correlation between the results.

Waterleafs from different sections of the screen house; they grow fast and can survive been trampled upon for some time. After 2 weeks, it became greener from there it grew younger parts thereby increasing in its leave number, having between 90-96 leaves in the multiple stems. The height is about 9-10cm. From a research: A three-month-old waterleaf plant (*Talinum fruticosum* or *T. triangulare*) typically has between 15 and 25 mature leaves on its main stem and primary branches, as the plant has a prolific branching habit and produces leaves in an alternate arrangement (Adeniji *et al*., 2012). At three months of age, under optimal conditions, a waterleaf plant typically reaches a height of 30 to 50 centimeters (approximately 12 to 20 inches), as its growth shifts from initial vertical establishment to a more pronounced lateral branching and leaf production phase (Udoh *et al*., 2005). The plantain sucker have now grown to a height of 85cm and have 15 matured leaves and 4 upcoming leaves during a period of 15 weeks under good rainfall. From a research: After three months in the field, a plantain sucker (now considered a plantain plant) typically reaches a height of 0.8 to 1.2 meters (approximately 2.6 to 4 feet) from the base of the pseudostem to the top of the highest leaf (Irizarry *et al.*, 1991). By this three-month stage, the plant will have typically produced between 8 and 12 functional leaves, not counting the initial withered or senesced leaves from the sucker stage (Swennen, 1990). The rate of leaf production is a key indicator of health, with a well-established plant under optimal conditions producing approximately one new leaf every 7 to 10 days, which directly contributes to the final leaf count at the three-month mark (Robinson and Saúco, 2010).

The banana has become more matured with the fruit ready for harvest under a period of 18 weeks (4 months and 2 weeks). From a research: From planting to flowering, a banana plant typically takes between 9 to 12 months to produce a flower stalk, depending on the climate, cultivar, and growing conditions (Crane, and Balerdi, 2020). The sweet potato which was transplanted from a nursery after germinating after 2 weeks. After germination, it was carried with the polypot to the screen and transplanted into the soil. After 2 weeks, it grew having more leaves and spreading gradually till it the 4th, 8th, 12th, 16th week and it's still growing. The period of growth was 16 weeks and counting. It has numerous leaves which is laborious to count but from a research: Based on available growth data, a four-month-old sweet potato plant (*Ipomoea batatas*) typically has more than 20 leaves, as plants can develop a mature vine structure covering several feet by this stage (Mozumder *et al*., 2007). The exact leaf count is highly variable and dependent on cultivar and growing conditions, with some vigorous varieties producing a dense canopy with dozens of leaves per vine by the fourth month (Laurie *et al.*, 2015). The growing tall plants (Cocoyam, plantain and banana) all served as a means for the Mucuna to climb making the plant densed, so occasionally they were pruned off.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study of soil fertility management and crop selection in a screen house has provided valuable insights about how different soil fertility management techniques or practices influence the growth performance and productivity of different crops. A fertile soil which is rich in all adequate and required nutrients is needed by the snails for shell growth and development and plants for production which serve as feed to the snails. The result obtained shows that, there are set of integrated practices which must be followed accordingly in order to see the desired effect in the snail farm, which in the long run will enhance the productivity of the snails as well as generate more revenue and profits for the farmer. This approach is not only concerned with the effect on the soil, crops or snails but also contribute to the overall sustainability of the snail farm.

6.2 Recommendations

1. Prepare your land before introducing the selected crops; introducing selected crops into a land already habituated by other plants, will result in high weed evasion problem which is very cumbersome to handle. Also, fertilization and compost application is not advisable; the weeds will utilize it instead of the crops.
2. Monitor the level of fertilization either by composting and organic fertilization to avoid toxicity, which is harmful to the plants.
3. Monitor the response of Giant African land snails to the manure or fertilizer level and make adjustments when necessary.
4. Fertilise the soil appropriately. Well-composted poultry manure can be used, but it must come from a verified, disease-free source to prevent contamination and disease transfer.
5. To maximize profit, organic manure and fertilizers should be made from other non-conventional materials like: fruit and vegetables scraps, egg shells, grass clippings and soft plant pruning.

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