**EFFECT OF DIFFERENT LIVE MULCH ON SOIL PHYSIOCHEMICAL PROPERTIES, GROWTH AND YIELD OF OKRA**

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**CHAPTER ONE**

**INTRODUCTION**

**1.1 Background of the Study**

Okra (*Abelmoschus esculentus*) is a nutritious vegetable which plays important role to meet the demand of vegetable are scanty in the market (Ahmed *at al.,* 1995). It belongs to family *malvaceae* and genus *Abelmoschus*. The geographical origin of okra is disputed, with supporters of South Asian, Ethiopian and West African origins. The plant is cultivated in tropical, subtropical and warm temperate regions around the world (NRC, 2006). Okra (*Abelmoschus esculentus*) can be grown on wide range of soils, but well drained fertile soils with adequate organic matter result to high yield (Akinyele and Temikotan, 2007). The crop is widely cultivated throughout the year in the tropics. In 2009-2010, the total world area under cultivation was 0.43 million hectares and the production stood at 4.54 million tons and the production of okra 5784 thousand tones and productivity 11.1 tones/hectare (Varmudy, 2011). The yield is very low in Nigeria as compared to the yield 9.710 ton per hectare of other developing countries (Akinyele and Temikotan, 2007). The low production capacity could be attributed to the myriads of constraints facing Okra production; biotic, abiotic and socio-economic challenges (Benjawan *et al.,* 2007). Mulching is the spreading of various covering materials (mulch) on the surface of soil to minimize moisture losses and weed population and to enhance crop yield (Nalayini 2007; Kader *et al.,* 2019). Mulch is any covering material including either organic or inorganic applied on the soil surface to for a variety of reasons: Soil moisture retention, heat trapping, reduce runoff losses, Increases germination percentage, improve soil structure, weed prevention and control, protecting roots from fluctuating and extreme temperatures and help control soil erosion (Nicholas and Rebecca, 2015). Mulching is one cultural practice which can be used to addresses these problems. Some examples of inorganic mulch could be; poly ethene plastics, marbles, etc. whereas organic mulch could include; compost, straw, bark clipping, among live mulch (Osunde and Musa, 2007). Live mulch are simply intercrops with shading properties and capable of protecting the soil from variety of constraint which may invariably affect the sole crop in the field (Nicholas and Rebecca, 2015). *Telferia occidentalis* (fluted pumpkin), melon, cowpea, *calopogonium*, grasses are some of the plants used as live mulch in crop production (Anish *et al.,* 2015). From researches, these live mulches add significant improvement in yield, growth in varieties of crops and also affects soil physiochemical properties such as; CEC, bulk density, organic matter content, organic carbon, soil texture, soil structure, total phosphorus, total nitrogen, among others (Anish *et al.,* 2015). To boost the production capacity of okra to meet the demand of vegetables, there is need to employ sustainable and cultural measures to achieve the goal. Hence, the objective of this study to evaluate the effect of different live mulch (fluted pumpkin, melon, cowpea, calopogonium) on the soil physiochemical properties, yield and growth parameters of Okra (*Abelmoschus esculentus*).

**1.2 Objectives of the Study**

The general objective of the study is;

* To determine the effect of different live mulch on soil physiochemical properties, yield and growth of Okra (*Abelmoschus esculentus*)

The specific objective includes;

1. To determine the effect of different live mulch on soil physical properties
2. To determine the effect of different live mulch on soil chemical properties
3. To determine the effect of different live mulch on yield of Okra (*Abelmoschus esculentus*)
4. To determine the effect of different live mulch on growth parameters of Okra (*Abelmoschus esculentus*)

**CHAPTER TWO**

**LITERATURE REVIEW**

**2.1 Origin and Distribution of Okra**

Okra is one of the important crops in the diet of Africans, especially west Africa. Okra is known by the Latin binomial names; *Abelmoschus esculentus* or *Hibiscus esculentus* (Kumar *et al.,* 2010). Okra plant was previously included in the genus Hibiscus. Later, it was designated to *Abelmoschus*, which is distinguished from the genus *Hibiscus* (Kumar *et al.,* 2010). *Abelmoschus* was subsequently proposed to be raised to the rank of distinct genus by Medikus in 1787. Okra originated somewhere around the Ethiopia, and was cultivated by the ancient Egyptians by the 12th century BC. Its cultivation spread throughout Middle East and North Africa (Lamont 1999). Okra is grown in many parts of the world, especially in tropical and sub-tropical countries (Arapitsas, 2008, Saifullah and Rabbani, 2009). This crop can be grown on a large commercial farm or as a garden crop (Nicholas and Rebecca, 2015). Okra plants are grown commercially in many countries such as India, Japan, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Myanmar, Malaysia, Thailand, India, Brazil, Ethiopia, Cyprus and in the Southern United States (Benjawan *et al.,* 2007; Qhureshi 2007). Okra plants are grown commercially in many countries such as India, Japan, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Myanmar, Malaysia, Thailand, India, Brazil, Ethiopia, Cyprus and in the Southern United States (NRC, 2006). Most Okra grown is for the fresh market and the remainder used for processing. Okra is used in soups, stews, gumbos, and Creole dishes together with many other vegetables. In some countries, Okra is used in folk medicine as anti-ulcerogenic, gastro protective, diuretic agents (Gurbuz, 2003).

**2.2 Botanical Classification of Okra**

Kingdom *Plantae*

Division: *Spermatophytes*

Class: *Magnoliopsida*

Order: *Malvace*

Family: *Malvaceae*

Genus: *Abelmoschus*

Species: *esculentus*

Botanical name: *Abelmoschus esculentus*

(Benjawan *et al.,* 2007)

**2.3 Benefits of Okra**

About 60 percent of Okra (*Abelmoschus esculentus*) grown is for the fresh market and the remainder used for processing (Gosslau and Chen, 2004). Okra is used in soups, stews, gumbos, and Creole dishes together with many other vegetables. Aside from being a major source of income to the producers, in some countries Okra is used in folk medicine as anti-ulcerogenic, gastro protective, diuretic agents (Gurbuz, 2003). The frequent usage of Okra might help avoid kidney disease (Trombino *et al.,* 2004). Consumed Okra every day decreased clinical indications of kidney damage a lot more than the ones that simply consumed a diabetic diet. This ties along with diabetes, as almost 50% of kidney disease cases are generated by diabetes (Lengsfeld *et al.,* 2004). The Okra is a high intake of plant products is associated with a reduced risk of a number of chronic diseases, such as atherosclerosis and cancer (Gosslau and Chen, 2004). These beneficial effects have been partly attributed to the compounds which possess antioxidant activity. The major antioxidants of vegetables are vitamins C and E, carotenoids and phenolic compounds, especially flavonoids (Rossetto *et al.,* 2002). Vitamin E and carotenoids also contribute to the first defense line against oxidative stress, because they quench singlet oxygen (Krinsky, 2001). Flavonoids as well as vitamin C showed a protective activity to α-atocopherol in human, and they can also regenerate vitamin E, from the α- chromanoxy radical (Davey *et al.,* 2000). Okra seed is rich in protein and unsaturated fatty acids such as linoleic acid (Oyelade *et al.,* 2003). Okra is also a popular health food due to its high fiber, vitamin C, and foliate content. Okra is also a good source of calcium and potassium. Okra pod contains thick slimy polysaccharides, which are used to thicken soups and stews, as an egg white substitute, and as a fat substitute in chocolate bar cookies and in chocolate frozen dairy dessert (Sengkhamparn *et al.,* 2009). Okra contains high fiber, which “helps to stabilize blood sugar by regulating the rate at which sugar is absorbed from the intestinal tract”. It is because of the Fiber along with other nutrition, Okra shows useful for minimizing blood sugar levels within the body, assisting along with diabetes. The fiber likewise helps support blood sugar levels simply by slowing down sugar assimilation through the intestines (Ngoc *et al.,* 2008)

**2.4 Agronomic and Ecological Requirement of Okra**

Okra are cultivated through the seeds. The seeds are frequently soaked for 24 hours before being sown in deeply cultivated soil on ridges or beds in rows 60-80cm apart, 20-30cm between plants approximately 8-10kg of seed is required per hectare (Trombino *et al.,* 2004). Vigorous cultivars require generous spacing. The terminal bud is sometimes removed to encourage lateral branching. Most cultivars respond to applications of nitrogen before sowing, together with dressings of potash and phosphate if these are relatively lacking (Liao and Yin, 2000). Subsequent dressings of nitrogenous fertilizer at pod set are recommended in some areas but excessive nitrogen applied before pod set delay maturity (Saifullah and Rabani, 2009). Young pods may be harvested 60-180 days from sowing, about 5-10 days after flowering, depending on the cultivar grown; succession harvesting of young pods is generally recommended since mature pods become fibrous (Saifullah and Rabani, 2009). The pods are detached by giving them a slight twist with breaks the fruit stalk. Yield up to 2-3 t/ha of green pods may be produced, approximately 4-6 fruits per plant, over a harvesting period of 30-40 days (Trombino *et al.,* 2004).

Soil type does not appear to influence growth or development of Okra; a wide range of soil types has been found suitable (Trombino *et al.,* 2004). Well-drained, fertile soils with an adequate content of organic material and reserves of the major elements generally prove suitable. Some cultivars are sensitive to excessive soil moisture; others are slightly tolerant to salt. Most cultivars are adapted to high temperatures throughout the grown period, with little diurnal or seasonal fluctuation (Gosslau and Chen, 2004). Seeds of Okra can only germinate in relatively warm soils; no germination occurs below 16ºC. A monthly average temperature range of 20-30ºC is considered appropriate for growth, flowering and pod development. Okra is tolerant to a wide range of rainfall; supplementary irrigation may be required up to the fruiting period, if the rainfall is marginally adequate to maintain vigorous growth (Rubatzky and Yamaguchi, 1997). Most selections are well adapted to cultivation in the lowland humid tropics up to elevations of 500m. Many cultivars grown in the lowland humid tropics are adapted to short day lengths (Benjawan *et al.,* 2007). Hence, Okra requires a tropical or sub-tropical environment.

**2.5 Constraints in Okra Production**

The production statistics of okra (*Abelmoschus esculentus*) would be increase, but there are some setbacks due to challenges faced by producers. According to NRC, (2006) and Benjawan *et al.,* 2007, small holders and medium scale producers are faced with myriads of challenges which are broadly classified into these five factors which constitute the mayor constraint on cropping, storage and consumption of okra. These constraints include the following:

1. **Abiotic:** erratic rainfall, high soil temperatures, low soil fertility and degraded fragile soils
2. **Biotic:** insect pests, parasitic weed, diseases induced by fungi, viruses and nematodes
3. **Socio-economic:** farmer capacity to produce inputs is limited and input delivery systems function poorly. Seed of improved varieties is not widely available. The difficulty is linked to the high value of okra fruits for family consumption and sale. Farmers are reluctant to leave any improved variety mature for seed (Benjawan *et al.,* 2007).
4. **Socio-cultural:** low acceptability of okra new formulation as well as low adoption of some improved post-harvest technologies. Change in taste and urbanization, which has favored the importation of food and the neglect of indigenous food crops.
5. **Political:** negative or neglected position of the developing countries governments to resolve the problems associated with the development of post-harvest systems.

Conclusively, the challenges which affect the production capacity of Okra (*Abelmoschus esculentus*) is numerous but few challenges can only be resolved by employing sustainable research solutions to meet up the demand for this vegetable (NRC, 2006).

**2.6 The Concept of Mulching**

The word “*mulch*” has been derived from the German word “*molsch*” means “*easy to decay,*” and mulches have widely been used as one of the cultural practices for vegetable production since ancient times (Nicholas and Rebecca, 2015). Mulching is referred as spreading various covering materials on the surface of soil to minimize moisture losses and weed population and to enhance crop yield (Nalayini 2007; Kader *et al.,* 2019). Mulch is any covering material including either organic or inorganic applied on the soil surface to reduce evaporation losses. Wheat straw, grass clippings and leaf debris are fairly abundant byproducts. Many producers already generate these mulching materials and currently spend resources to dispose of them (Nalayini 2007). Mulching using this waste is a cost effective practice which would conserve water, moderate soil temperature, reduce waste and improve the soil health (Arora, 2011). Mulches are used as a soil covering, for a variety of reasons: Soil moisture retention, heat trapping, reduce runoff losses, Increases germination percentage, improve soil structure, weed prevention and control, protecting roots from fluctuating and extreme temperatures and help control soil erosion (Patil *et al.,* 2013).

**2.7 Mulching Materials**

There are varieties of mulching and they are broadly classified into two; Organic and inorganic mulches (Arora *et al.,* 2011)

**2.7.1 Organic mulches**

Organic mulch material includes; grass, straw, dry leaves, bark, saw dust, compost and cover crops or live mulch (Ather *et al.,* 2013). Most organic mulch has the capacity to easy degradable due to attraction of insects, slugs and cutworms that eat them and it will help to degraded rapidly and it add some amount of organic matter and nutrient in soil (Balasubramanian *et al.,* 2013).

***2.7.1.1 Grass Clipping***

Grass Clipping is one of the most abundantly and easily available mulch materials across the country (Buban *et al.,* 1996). If incorporated fresh in soil, it added some amount of nitrogen to the soil. It also provides some organic matter in the soil. However, if we added green grass material it has capacity to develop its root system it will harm to crops growth and development. Therefore, use of dry grass as mulch material is usually suggested (Balasubramanian *et al.,* 2013)

***2.7.1.2 Straw***

Paddy and wheat straw and other crop residues like; stubbles, groundnut shells, cotton shells, cassava peels, among other residues during crop processing are the commonest mulching materials used as mulches on soil surface for moisture conservation (Calkins *et al.,* 1996). Though straw is poor in nutrient value but after decomposition, it makes soil more fertile. Straw mulches reduce both the amount of energy absorbed by the soil and its movement above the soil and hence reduce evaporation (Cahill *et al.,* 2005).

***2.7.1.3 Dry leaves***

Leaves are easily and abundantly available material, are good for mulching (Chalker-Scott, 2007). Though leaves are good for protecting dormant plants during winter by keeping them warm and it help to initiate germination during cold season but dry but due to light weight they may be blown away even by light wind (Chalker-Scott, 2007). To reduce these problems to used stone, bark or any other material that help to reduce wind problem (Chalker-Scott, 2007).

***2.7.1.4 Bark clippings***

Bark clippings are good mulch materials as they are long lasting and allow proper aeration to the soil underneath (Calkins *et al.,* 1996). Wood bark has capacity to hold more water and bark mulch material is used in both the region very dry and very wet because if rain is too much the bark will absorb excess water and reduce waterlogged condition. When it rains too little, the wood chips will release the water they’ve been holding, providing your plants with water even in dry times (Chalker-Scott, 2007). Hardwood bark clippings contain more nutrients than soft wood but bark clippings are not easily and abundantly available, and some bark products may cause phytotoxicity (Chalker-Scott, 2007).

***2.7.1.5 Saw dust and Compost***

Saw dust, obtained during finishing operation of wood and furniture is very poor in nutritive value as it contains only half the nutrients of straw. It decomposes slowly. Being acidic in nature, it should not be used in acidic soils (Chaudhary *et al.,* 2003). The compost is one of the best mulch materials. It increases microbial population, improves the soil health and adds some amount of nutrients (Dahiya *et al.,* 2007). Compost tends to be slightly acidic, so it’s an especially great addition to a soil with alkaline nature. However, compost has one drawback. It is very fine and full of nutrients, so it doesn’t have much weed suppressing capability (Chaudhary *et al.,* 2003).

***2.7.1.6 Live Vegetative Barriers***

Live mulch can also be known as Vegetative Barriers. Living mulch systems allow cover crops to be grown during periods of cash crop production, thereby extending the duration of cover crop growth and associated beneﬁcial agroecosystem services (Dahiya *et al.,* 2007). However, living mulches may also result in agroecosystem disservices such as reduced cash crop yields if the living mulch competes with the crop for limiting resources. Living mulch systems is a form of intercropping that involves growing a cover crop or cover crop mixture simultaneously with a cash crop for part or all of the cropping season, may provide an opportunity to establish cover crops earlier in the growing season and thereby increase the duration of cover crop growth. living mulch system can also be referred to as a mixed cropping system in which one partner acts chiefly as a live soil cover for a considerable part of the life cycle of the main crop (Nicholas and Rebecca, 2015). In many instances, however, yields of the main crops are lower in living mulch systems than in other cropping systems. This is due mainly to the fact that main and cover crops compete for growth factors (nitrogen, water, light). Thus far, the living mulch concept has been tested with a number of typical row crops, e.g. maize *(Zea mays L.)*, soybeans *(Glycine max (L.) Merr.)*, cabbage *(Brassica oleracea L. var. capitata L.)* (Snapp *et al.,* 2005). Since there are many possible combinations of main crops, cover crops, and methods for regulating cover crops, living mulch systems provide numerous opportunities for interdisciplinary research. Cover crops provide many beneﬁcial ecosystem services to agricultural production systems, including soil and nutrient retention, resources and habitat for beneﬁcial organisms, and weed suppression (Hartwig and Ammon, 2002). Researches as reveal that the use of live vegetative barriers on contour key lines not only serve as effective mulch when cut and spread on ground surface but also supply nitrogen to the extent of 25 to 30 kg per ha, besides improving soil moisture status (Dahiya *et al.,* 2007). Some examples of crops that can be used as living mulch include; cowpea, fluted pumpkin, calopogonium, melon, among other shading crops (Hartwig and Ammon, 2002)

* ***Calopogonium Mucunoides* as A Live Mulch**

*Calopogonium Mucunoides*isvigorous, hairy annual or short-lived creeping, twining or trailing, herb, up to several metres long, forming a tangled mass of foliage 30-50 cm thick, with densely pilus stems with long rust-coloured hairs with useful part which is the seed and leaves (Nicholas and Rebecca, 2015). It is an important and mostly used cover crop for plantation crops also a green manure to protect the soil surface and serve as weed controller. *Calopogonium Mucunoides* does not contain toxic factors and has the capacity to control weed (Hartwig and Ammon, 2002).

* **Cowpea As A Live Mulch**

Cowpea is an important leguminous crop and mostly known as beans in Nigeria. The crop is mostly used in crop rotation to incorporate loss nutrients into the soil (Udo and Udom, 2022). The crop has nitrogen fixing bacteria in it root nodules and cowpea being used as a cover crop or live mulch as the capability to fix nitrogen, hence increasing the soil fertility (Udo and Udom, 2022). Utilization of cowpea as a live mulch would suppress weed, conserve soil moisture and provide resistance to erosion or runoff (Campbell, 2012)

* **Melon as a live mulch**

Melon is commonly known as ‘egusi’ in Nigeria, West Africa (Udo and Udom, 2022). The crop is essential in the populace diets. The morphology of this plant has attracted interest from researcher for use as a cover crop from sole crops (Nicholas and Rebecca, 2015). The crop is creeping with large vigorous leaves which has the capacity to suppress weed, retain soil moisture, control erosion and could improve soil structure (Campbell, 2012)

* **Fluted Pumpkin as a live mulch**

Fluted pumpkin with native to Southeastern Nigeria, West Africa is one of the abundant and important vegetable (Udo and Okon, 2022). The crop has a creeping vine with trifoliate leaves and has capability to be used as a mulching material. The creeping vine suppresses weed, improves soil structure, retain soil moisture and capable of controlling soil erosion (Udo and Okon, 2022). This crop is not toxic to the sole crop, hence beneficial as a live mulch (Campbell, 2012)

**2.7.2 Inorganic Mulches**

The inorganic mulches materials do not decompose, or they break down gradually after a long time period. The various kinds of inorganic mulch are rocks or gravel, plastic sheeting, landscape fabrics, and rubber mulch (Chaudhary *et al.,* 2003). The inorganic materials used as mulch can certainly add attractive value and they work proper well to suppress the weeds (Chaudhary *et al.,* 2003).

***2.7.2.1 Gravel and stones***

These materials are used successful for dryland fruit crops. Small rock or stone layer of 3-4 cm place on soil surface to provides good weed control, reduced evaporation and facilitate infiltration of rain water into the soil (Dil Baugh *et al.,* 2011). But they reflect solar radiation and can create a very hot soil environment during summer (Dong *et al.,* 1996).

***2.7.2.2 Plastic mulch***

Plastic mulches are very effective as mulches for evaporation controls provided cost is not limiting factors. Both, black and transparent films are generally used for mulching. Advancement in plastic chemistry has resulted in development of films with optical properties that are ideal for a specific crop in a given location (Steinmetz *et al.,* 2016).

Photo-degradable plastic mulch is a type of plastic mulch material is easily destroyed by sun light in a shorter period (Dong *et al.*, 1996). Bio-degradable plastic mulch is also a type of plastic mulch film is easily degraded in the soil over a period of time (Downer *et al.,* 2002). Films are available in variety of colors including black, transparent, white, silver etc. But the selection of the color of plastic mulch film depends on specific targets (Downer *et al.,* 2002).

**2.8 Benefits of Mulching**

***2.8.1 Soil moisture conservation***

Many abiotic factors are responsible for the loss of moisture from the soil and converting it into barren land. These variables could be high winds, elevated temperature levels, harsh climatic conditions, and competing plantation such as weeds. It has been estimated that presence of weeds could result in loss of water up to 25% due to evapotranspiration (Harris *et al.,* 2004). Mulches can potentially reduce weed infestation and evaporation losses and enhance the percolation and retention rate of soil. It was reported that straw mulch can decrease the rate of evaporation by 35% (Arthur and Wang 1999). Arthur and Wang, (1999) also reported that reported that non-living mulch materials had greatest capability in moisture conservation in soil as compared to un-mulched soil. The organic mulches have attained greater value than the inorganic mulches in agricultural lands, as the organic mulches could increase the percolation and water retention of soil. Organic and inorganic mulches can better conserve the soil water as compared to synthetic and barren soil (Lakatos *et al.,* 2000).

***2.8.2 Minimizing soil compaction and erosion***

The mulching materials protect the soil from wind and water erosion phenomenon and reduce the compaction of soil which can badly affect the roots of crops consequently reducing the growth and development of plants. Growing grass is the best example of living mulch on the slopes which reduces the soil erosion by aggregating the soil particles by binding in a complex unit (Tanavud *et al.,* 2001). Mulch materials immediately break the speed of water in hilly areas and increase the infiltration rate of soil, and to maintain the slope stabilization, engineering techniques must be used instead of merely dependent on mulching method (Chalker-Scott 2007). The problem of compaction due to the heavy implements or machinery is getting severe in many agricultural lands (Chalker-Scott 2007). The problem of compaction can be solved with the addition of organic mulch materials such as bark (Oliveira and Merwin 2001). The mulch material can reduce the beating action of rain drops or alleviate the heavy weight of feet and tires of heavy implements. It was suggested that mulching should be performed before the development of soil compaction, as once compaction was developed, there will be no significant improvement in soil aggregates (Lakatos *et al.,* 2000).

***2.8.3 Regulation of soil temperature***

Mulching covers the soil surface, and hence, it is helpful in maintaining the soil temperature which is beneficial for overall crop growth. Many studies demonstrated that the application of mulch could keep the soil cool during very hot climatic conditions (Kader *et al.,* 2019; Long *et al.,* 2001), while at normal/warm temperature in chilling days (Kader *et al.,* 2019). The temperature extremes affect the newly growing roots of plants adversely reducing the uptake of nutrients and water. The extreme temperature condition under early growth stages of plants may cause the plants to go under stress conditions as newly established roots are not able to uptake the proper amount of water and essential plant nutrients (Chalker-Scott 2007). Therefore, the judicious maintenance and regulation of soil temperature is a very critical factor for optimum plant growth. However, in hot and dry conditions such as in deserts, mulches decrease the temperature by 10°C (barren soil) (Kader *et al.,* 2019). The selection of specific mulching type for particular purpose is of significant importance.

***2.8.4 Soil fertility improvement***

The organic and living mulches possess numerous beneficial impacts on soil quality in terms of enhancing nutrients levels. However, the type of the material, soil characteristics, and climatic conditions determine the increase, decrease, or no effect on soil nutrients. The application of organic mulches is more beneficial because these can be decomposed in an appropriate environment, providing the nutrients. Different studies demonstrated that wood chips, straw, green manures, and bark mulches provide more nutrients as compared to inorganic mulches (Ansari *et al.,* 2001). However, the organic mulches with higher nutrient supply capability are mostly used for the landscaping, as the extensive application of these mulches to agricultural lands can damage the sensitive crops, living organisms, and water resources. Therefore, the mulches with higher ability of providing nutrients must be managed properly (Chalker-Scott 2007).

***2.8.5 Plant growth, development, and yield***

Mulching materials are widely used for the establishment of many herbs and tree species. There are many research studies which showed the positive impacts of mulches on the germination, survival of newly grown plants, and transplantation of seedlings and overall performance of crop plants in relation to un-mulched treatments. In this way, mulching is favorable for maximum yield with very low input resources (ChalkerScott 2007; Kader *et al.,* 2019). Straw mulching combined with wide precision planting is a suitable measure to compensate winter wheat grain yield reduction and increase grain quality (Ahmad *et al.,* 2015). The adoption of the planting basin tillage under sorghum stover mulching, a technology designed for smallholder farmers with limited access to animal draft power, can improve considerably the dry-land sorghum grain yield and weight of 1000 kernels (Masaka *et al.*, 2019)**.**

***2.8.6 Depression of weeds***

Mulching is a favorable tool for controlling the weed populations in nursery as well as field conditions. However, the phenomenon of weeds reduction is not fully understood till now. Wilen *et al.* (1999) found that there was 92% reduction of weed population as compared to non-mulched treatment. When mulch is spread on the soil surface, they act as barriers in the passing of light resulting in reduced germination of small-seeded weed species. Different types of mulches (15 different mulch types) were used in comparison to non-mulched, and outcomes of the study showed that there was no difference between all mulch types but a significant difference exists for reduction of weeds with bare soil treatment (Kader *et al*. 2019). Mulches act as physical obstacles in the emergence of weeds (Ahmad *et al.* 2015; Ahmad *et al.* 2020); however, when the organic mulches decompose, they quickly come out the soil surface. Some organic mulch also acts as the allelopathic and releases some toxic chemicals which are helpful for the reduction of weeds. Besides this, the environment that is created through the mulch is very helpful for beneficial microbes which feed on the weed species or weed seeds (Chalker-Scott 2007). Likewise, the living mulches are useful to reduce the weeds by competing for the basic resources such as light, moisture, nutrients, and oxygen. They also have the allelopathic effects on the weed species. Some cover crops and ground cover are also supportive for lessening of weed seed germination and their establishment (Griffiths and Fairhurst, 2003).

**2.9 Soil Properties**

Soils are complex mixtures of minerals, water, air, organic matter, and countless organisms that are the decaying remains of once-living things. It forms at the surface of land – it is the skin of the earth and there are many soil properties that enables soil description and management (Tapas and Pal, 2016).

**2.2.1 Soil Chemical Properties**

Soil is a complex mixture of organic and mineral components (Balasubramanian, 2017). Soil chemical properties indicate biogeochemical processes in soils and their influence on the bioavailability, mobility, distribution, and chemical forms of both plant essential elements and contaminants in the terrestrial environment (Balasubramanian, 2017). Soil chemical properties include; soil pH, electrical conductivity, total organic carbon, cation exchange capacity and heavy metals concentration. Soil pH measures the concentration of hydrogen ion (H+) in the soils and is the major cause of soil acidity which affects the performance of crops and activities of micro-organisms (Francis *et al.,* 2020). Soil pH refers to a soil’s acidity or alkalinity and is the measure of hydrogen ions (H+) in the soil and it is one of the soil chemical properties. A high amount of H+ corresponds to a low pH value and vice versa. The pH scale ranges from approximately 0 to 14 with 7 being neutral, below 7 acidic, and above 7 alkaline (basic) (Francis *et al.,* 2020). Electrical conductivity is the potential of the soil to conduct electricity. This chemical property is anchored in a lot of determinant especially; salt accumulation in the soil (Essien and Hanson, 2013). CEC is the sum total of the acidic and basic cation present in the soil solution (Essien and Hanson (2013). A high basic cation content may imply that the fertility status of the soil may be better than that of surrounding soil. Organic carbon reflects organic matter (the decomposed carbon in a material) (Edem, 2007).

**2.9.2 Soil Physical Properties**

Soil physical properties of soil include; color, texture, structure, porosity and density, consistence. Colors of soils vary widely and indicate such important properties as organic matter, water and redox conditions. Soil texture, structure, porosity, density and consistence are related with types of soil particles and their arrangement. There are two types of soil particle: primary and secondary soil particles (Edem, 2007). Soil is comprised of minerals, soil organic matter (SOM), water, and air. The composition and proportion of these components greatly influence soil physical properties, including texture, structure, and porosity, the fraction of pore space in a soil. In turn, these properties affect air and water movement in the soil, and thus the soil’s ability to function. Soil texture can have a profound effect on many other properties and is considered among the most important physical properties (Tripathi and Misra, 2010). Texture is the proportion of three mineral particles, sand, silt and clay, in a soil (Agunwam, 2010). These particles are distinguished by size, and make up the fine mineral fraction. Particles over 2 mm in diameter (the ‘coarse mineral fraction’) are not considered in texture, though in certain cases they may affect water retention and other properties. The relative amount of various particle sizes in a soil defines its texture, i.e., whether it is a clay, loam, sandy loam or other textural category (Agunwam, 2010). Soil structure is the arrangement and binding together of soil particles into larger clusters, called aggregates or ‘peds.’ Aggregation is important for increasing stability against erosion, for maintaining porosity and soil water movement, and for improving fertility and carbon sequestration in the soil (Nichols *et al.,* 2004). ‘Granular’ structure consists of loosely packed spheroidal peds that are glued together mostly by organic substances (Isirimah, 2000). Soil texture and structure influence porosity by determining the size, number and interconnection of pores (Agunwam, 2010). Coarse-textured soils have many large (macro) pores because of the loose arrangement of larger particles with one another. Fine-textured soils are more tightly arranged and have more small (micro) pores. Unlike texture, porosity and structure are not constant and can be altered by management, water and chemical processes (Edem, 2007).

**2.10 Effect of Live Mulches on Soil Physiochemical Properties**

Several researches has been carried out to assess the impact of live mulches on soil physical and chemical properties. Qu *et al.,* 2019 conducted a study to improve our understanding on the effect of various mulches on soil properties and tree growth after two years of the treatment justifying its implication in soil fertility and tree growth. A comparison study was conducted to determine the effects of inorganic (cobblestone—CB; water permeable brick—WPB), organic (pine bark—PB; green waste compost—GWC), and living (turf grass—TG) mulches on soil physical and chemical properties at three different depths (0–10 cm, 10–20 cm, and 20–40cm), and on tree growth (Sophora japonica) in urban tree pits. They reported that during the most months, all types of mulches significantly affected the moisture content of the soil at all the depths analyzed. In July and August, however, the moisture content of PB and TG treated soil decreased when compared with that of unmulched bare soil. Two years after mulching, the bulk density of the soil treated with PB, GWC, and TG was significantly affected at10–20 cm, with GWC exhibiting a relatively better effect. The treatments with PB, GWC, and TG also improved the total porosity, macroporosity, and microporosity of the soil at lower depths. Further, WPB worsened the bulk density and porosity of the soil, elevating the pH at lower depths. The organic matter, total N, mineral N, available P, and available K contents of the soil at lower depths increased when mulched with organic material. Turf grass significantly increased only the total N and available K at 0–10 and 10–20 cm. There was no significant difference in the soil properties among the treatments at 20–40 cm. Furthermore, the trunk diameter and tree height were not affected by the mulches two years after mulching. In conclusion, organic mulches especially green waste compost and the living mulch did not only increased soil fertility significantly but improved soil physical characters (0–10 cm depth) comparing to other mulches, are suitable to cover bare soil in urban tree pits.

Ewulo *et al.,* (2011) also conducted field experiments Akure in the rainforest zone of Southwest Nigeria to study the effect of tillage and mulching in production of pepper (Capsicum amnum) and sorghum (sorghum bicolor). The soil physical properties, plant nutrient content, growth and yields of pepper and sorghum were evaluated. Zero tillage (herbicide based), manual clearing (MC), ridge (R) and heap (H) without and with weed residue mulch (M) were studied, Ridge or heap without mulch reduced soil bulk density and temperature compared with MC or MC + M. Tillage (H, R) increased leaf N, P and Ca in pepper, mulch increased leaf N, P, K, Ca and Mg and highest values of P, K, Ca and Mg were recorded for H + M and R+M. Tillage plus mulching significantly enhanced performance of pepper and sorghum. From research reviews, it could be ascertaining that live mulch (organic mulches) have the capacity to increase soil physical and chemical properties.

**2.11 Effect of Live Mulch on Growth and Yield of Crops**

Mulching is one of the cultural practices that has been employed in ancients’ times to improve crop performance. There are researches which are aimed to determine the growth and yield of diverse crops by employing the use of live mulch or organic mulching materials.

Anish *et al.,* 2015 carried out a research to identify the production performance of cash crop cowpea at subtropical climatic condition of Nepal (Rupandehi) during dry to wet season transition period. In their study, Significant result at 5% level of probability with moisture retention of 14.463% in case of mulching and 12.970% in case of no mulched was observed. Similarly, highly significant (at 1% level of probability) result was found for plant height at 13 days after sowing with plant height of 17.498cm in case of mulching and 14.459cm in case of no mulching. The result shows highly significant result for effect of mulching in cowpea yield (p ≤ 0.05) yielding 5.706 ton/ha in mulched field and 4.215 ton/ha in no mulched field. Effect of mulching shows significant result at 5% level of probability in case of pod length. The length of pod recorded in mulched plot was found to be 43.651 cm and 39.531 cm in no mulched plot. Similarly, significant results (at p ≤ 0.05) in interaction of both mulching and recommended doses of phosphorous shows maximum pod length recorded of 46.920 cm and minimum of 38.497 cm when control dose of phosphorous interacted with no mulching condition. Since organic matter formation and change in soil chemical properties is long and gradual period no significant results are found in soil chemical properties. Significant results of phosphorous solely are not achieved during this short research duration. Data from economic analysis revealed that Mulching leads to significant high yield as compared to non-mulching with B: C ratio calculated 1.58 and 0.99 respectively in mulched and no mulched condition. Cowpea yield shows significant difference between mulching and no mulching effect and was successfully harvested within the short period. Hence, mulching is beneficial to crops to have better yield and aid soil nutrients.

Additionally, Nicholas and Rebecca (2015) also conducted a study using living mulch systems which hallow cover crops to be grown during periods of cash crop production, thereby extending the duration of cover crop growth and associated beneﬁcial agroecosystem services. They examined the effects of an Italian ryegrass *(Lolium multiﬂorum (Lam.) Husnot)* and white clover (*Trifolium repens L., cv. New Zealand*) living mulch on broccoli *(Brassica oleracea L. var. italica)* yield and yield components which were dependent on fertilizer rate in ﬁeld experiments. Drip-irrigated broccoli was grown under a range of organic fertilizer application rates in beds covered with plastic, with and without a living mulch growing in the uncovered, interbed space. Broccoli yields were similar in the living mulch and bare soil controls under the highest rates of fertilizer application, living mulch reduced broccoli yields from 28% to 63%, depending on fertilizer rate. Differences in leaf SPAD values suggest that yield reductions were attributable, in part, to competition for nitrogen; however, other factors likely played a role in determining living mulch effects. Despite yield reductions, the living mulch reduced the prevalence of hollow stem in broccoli. Hence, they concluded that Organic fertilizer may have inconsistent effects on broccoli yields in living mulch systems and this report was similar to the studies of Katarzyna and Eugeniusz (2008).

**CHAPTER THREE**

**MATERIALS AND METHODS**

**3.1 Description Of The Experimental Site**

This experiment was carried out in Soil Science and Land Resources Management research farm, Faculty of Agriculture, Nnamdi Azikiwe University Awka. South Local Government, Anambra state. And it is located within latitude 6°24' N and longitude 7°11' E and with an altitude of 422m and an average rainfall of 1650mm to 2000mm per annum, a mean minimum and maximum temperature of 27°C and 30°C respectively and a relative humidity of 75 - 80% ( Ezenwaji et al., 2014 ). The climate of the area is tropical indicating that it is basically within the tropical rainforest ecological zone; with mean temperature of 26.3°C. Awka has seasonal climatic conditions; the rainy and dry seasons with a short spell harmattan; a rainfall pattern ranging from 1828 mm – It has weeds such as mimosa pundica and Elephant grasses which dominated the vegetation of the experimental farm.

**3.2 EXPERIMENTAL DESIGN AND FIELD LAYOUT**

The experimental design was laid out using Randomized complete block design (RCBD) having 5 treatments and 5 replications.

Treatment 1 = cowpea + Okra

Treatment 2 = melon (Egusi) + Okra

Treatment 3 = pumpkin + Okra

Treatment 4 = Calopogonium + Okra

Treatment 5 = control (sole Okra)

**3.3 Field Operations And Land Preparation**

A field size of 16m by 22m was marked out using measuring tape, rope, and peg. Land clearing was done using cutlass. The debris was packed where necessary using rake. The land was ploughed, harrowed and ridged with a hoe at 4m x 2m. The experimental field has five treatments replicated five times. The plots and adjacent blocks were separated by 1m respectively. Organic amendment (Poultry manure) was applied on each bed at the rate of 10t/ha and was left to cure for one week before planting. These were laid in a Randomized Complete Block Design (RCBD). The test crop (okra seeds) was soaked overnight and drained before planting to speed up the germination. Seeds were sown at the recommended spacing of 0.6 by 0.9 at two seed per hole which was later thinned down to one. A total of 20 seeds were sown on each plot. Weeding was done manually using hoe as at when necessary after sowing so as to reduce weed competition and destruction of the crop.

**3.4 Materials And Sources**

Okra seeds (Cajun delight - Dwarf green pod) (Abelmoschus esculentus ) was sourced from Agricultural Development programme in Awka. Melon, cowpea, and pumpkin seeds were sourced from seed vendors in Awka while Calopogonium was sourced from the faculty of Agriculture Unizik, Awka.

**3.5 Pre-Cropping Soil Sampling And Post Harvest Processes**

Before the application of any treatment, soil samples were randomly collected from different locations within the experimental field at a depth of 0-15cm using a soil auger. In the same vein, soil samples were collected after harvest from each bed and tagged separately. Core samplers were used to collect undisturbed soil samples. Both samples (Pre-cropping and post harvest) were handled appropriately and taken to the laboratory for the analysis of selected physical and chemical properties.

**3.6 LABORATORY ANALYSIS**

The collected soil samples were taken to the laboratory for the following analysis:

**3.6.1 Particle Size Distributions**

This was determined using Bouyoucus hydrometer method as described by Bouyoucus (1962).

**3.6.2 Soil pH**

Soil pH was determined in H20 and Kcl using glass electrode pH meter at a soil liquid ratio of 1:2.5 as modified by Udo *et al* (2009).

**3.6.3 Soil Organic Carbon/Organic Matter**

Thiswas determined by Walkley *and* Black wet oxidation method as modified by Nelson and Sommers (1996).

**3.6.4 Total Nitrogen**

Thiswas determined by Kjeldhal digestion method (Bremmer and Mulvaney (1996).

**3.6.5 Available Phosphorus**

Thiswas determined by Bray 2 method as described by Bray and Kurtz (1945).

**3.6.6 Exchangeable Bases**

Exchangeable Bases (Ca, Mg, K and Na) were determined by ammonium acetate saturation (NH4AOC) method by Udo *et al.* (2009).

**3.6.7 Exchangeable acidity**

This was determined by 1N KCl extraction method Udo *et al.* (2009).

**3.6.8 Effective Cation Exchange Capacity (ECEC) and Percentage Base Saturation**

Effective Cation Exchange Capacity (ECEC) and Percentage Base Saturation(%BS) was calculated as the summation of TEB and TEA;{ ECEC – EA ÷ ECEC} × 100.

**3.7 Data Collection**

* Growth and yield characteristics of the okra
* Plant height
* Number of pods
* Number of leaves and leaf index

**3.8 Statistical Analysis**

Data collected was subjected to Analysis of variance (ANOVA) for Randomized Complete Block Design (RCBD) using Genstat Release 12.1, 3rd edition and significant means were separated using the least significant difference (LSD) at 0.05 probability level.

**CHAPTER FOUR**

**RESULTS AND DISCUSSION**

Table 4 showed the result of the physical and chemical properties of the experimental soil before planting.

From the results in tables 4, the soil texture of the experimental site was sandy loam (SL), the bulk density was 1.44g/cm3, the pH was 5.3, Total organic carbon and organic matter were low, 1.21 and 2.09 % respectively, exchangeable hydrogen and aluminium levels were, 1.06 and 0.52 cmol/kg, while basic cations were 4.3, 1.60 and 0.151 cmol/kg for Calcium, Magnesiumand potassiumrespectively. ECEC was 7.74cmol/kg and the base saturation was 79.53%.

Table 4: physical and chemical properties of the soil before planting

**Soil properties Mean values**

Sand (%) 70.30

Silt (%) 15.20

Clay (%) 14.50

Soil texture Sandy loam

Moisture content (%) 14.10

Bulk density (gcm-3) 1.44

pH (H20) 5.3

Average phosphorus (mg/kg) 15.8

Nitrogen (%) 0.108

Organic Carbon (%) 1.21

Organic Matter (%) 2.09

Ca2+ (cmol/kg) 4.30

Mg2+ (cmol/kg) 1.6

K+ (cmol/kg) 0.151

Na+(cmol/kg) 0.105

Al3+ (cmol/kg) 0.52

H+ (cmol/kg) 1.06

Exchangeable acidity 1.58

ECEC (cmol/kg) 7.74

Base saturation (%) 79.53

**Mean Effect of Live Mulch on Physical Properties of Soil**

**Particle Size Distribution**

Result in table 5 showed that sand particles ranged from 70.3 to 70.7 %. Silt particles ranged from 15.0 to 15.2 %, while clay particles ranged from 14.3to 14.5 %. Textural class of the soil in the experimental field is sandy loam (SL). The result was not significant (p≤0.05) when compared the control plot.

**Moisture Content (MC)**

Moisture content value ranged from 12.9 to 26.68 %. Highest value of soil moisture was recorded from plot with Calopogonium + Okra (26.68 %) followed by 18.2 and 17.5 % from plots with Cowpea + okra and Melon + Okra. While plot with Pumpkin + Okra had the least moisture content of 16.28 % among the live mulches tested. This value is however, higher than control with the value of 12.9 %. The increase in soil moisture content recorded on plots with live mulch may be attributed to the ability of live mulch (calopogonium mucunoides, cowpea, pumpkin and melon) to intercept and break the impact of rain drops thus preventing surface sealing which facilitates better water infiltration resulting to higher soil moisture content. The findings of this study is in line with Duda *et al*., (2003) where they reported increase in soil moisture from 22% to 34% on the plots mulched with live leguminous mulch.

**Bulk density (BD) and Total porosity (TP)**

Bulk density value ranged from 1.3 to 1.48 g/cm3 with control (sole okra) plot given highest value on bulk density (1.48 g/cm3) followed by melon and pumpkin live mulch (1.39 and 1.43 g/cm3) respectively. while the lowest value was recorded on plot with calopogonium (1.32 g/cm3). The result showed a significant (p>0.05) decrease in bulk density across plots with live mulch. The decrease in bulk density may be attributed to addition and decomposition of organic matter from the biomass of the different live mulches. The result is in accordance with the report of Assouline (2006); where he observed a reduction in bulk density on plots with bio-mulch (live mulch).

**Table 5: Effects of different Live Mulch on Soil Physical Properties**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Sand**  **%** | **Silt**  **%** | **Clay**  **%** | **Tex** | **MC**  **%** | **BD**  **g/m3** |
| Cowpea + okra | 70.5 | 15.1 | 14.4 | SL | 18.22 | 1.36 |
| Calopogonum + okra | 70.3 | 15.2 | 14.3 | SL | 26.68 | 1.32 |
| Pumkin + okra | 70.7 | 15.0 | 14.3 | SL | 16.28 | 1.39 |
| Melon + okra | 70.5 | 15.1 | 14.4 | SL | 17.5 | 1.43 |
| Control (sole okra) | 70.3 | 15.2 | 14.5 | SL | 12.9 | 1.48 |
| **Mean** | **70.46** | **15.12** | **14.42** | **SL** | **17.52** | **1.39** |
| **LSD(0.05)** | **NS** | **NS** | **NS** |  | **0.38** | **0.02** |

Note: tex = texture, Mc = moisture content, BD = Bulk density

**Effect of live mulches on soil chemical properties**

**Soil pH**

Result on chemical properties (table 6) shows that soil pH ranged from 6.62 to 4.9; the highest pH value was recorded on the plot planted to calopogonium and okra (6.62), followed by melon + okra (6.34) and pumkin + okra (5.84) while the least value was recorded on control (sole okra) 4.9. pH result across plots with live mulch significantly (p≤0.05) increased when compared with control. The observation made on this study is in line with Amelung *et.al*; (2002) where they obtained similar result on plots with live mulch.

**Available Phosphorus (Av.P)**

Result of available phosphorous as shown on table 6, revealed that live mulch significantly (p>0.05) increase phosphorus content of the soil across the mulched plots. Available phosphorus ranged from 20.96 to 14.58 mg/mg. Highest value of phosphorus 20.96 mg/kg was recorded in plot with calopogonium as live mulch, followed by 20.18 and 18.6 mg/kg in plot planted to melon + okra and cowpea + okra. While the least value (14.58mg/kg) was recorded in the control plot. The result on available phosphorus is in line with the report of Pervaiz *et.al*; (2009) where they recorded similar increase in available phosphorus in plot planted to leguminous live mulch.

**Total Nitrogen (TN)**

Total nitrogen was significantly (p>0.05) increased as a result of using live mulch on the experimental plots. Total nitrogen ranged from 0.154 to 0.092 %, with highest value recorded in plot planted with calopogonium (0.154%) followed by plots planted with cowpea (0.138%) and pumpkin (0.131%), while the least value was recorded in control (0.092%). Highest nitrogen recorded in plot with calopogonium and cowpea (live mulches) may be due to the fact that leguminous crops generally have the ability to fix nitrogen through their root nodules, also leguminous crops have higher foliar nitrogen contents, so when legume residue decomposed, soil microbes helps to feed on the organic matter thus releasing nitrogen to the soil. The result is in line with the report of Lehmann *et.al*; (2000) who reported similar increase in nitrogen as a result of using live mulch on experimental plots planted to ....

**Organic matter (OM)**

Result of organic matter showed that live mulch positively affected organic matter of the studied soil. Organic matter ranged from 1.81 to 2.86 %. With plot planted with calopogonium live mulch giving the highest value of 2.86 % followed by cowpea (2.68 %), while the least value was observed in the control plot (1.81 %). The increase in organic matter observed on the mulched plots may be attributed to the production of biomass/residues from different live mulches which decomposed and increased the organic matter of the soil. The result obtained from this work is in accordance with the report of Assouline (2006) where he observed an increase in organic matter as a result of using leguminous crops as live mulch

**Table 6: Effect of Cropping System on Soil Chemical Properties**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **pH**  **H20** | **pH**  **kcl** | **Av.P**  **mg/kg** | **TN**  **%** | **OC**  **%** | **OM**  **%** |
| Cowpea + okra | 5.62 | 4.84 | 18.6 | 0.138 | 1.56 | 2.68 |
| Calopogonum + okra | 6.62 | 6.12 | 20.96 | 0.154 | 1.66 | 2.86 |
| Pumkin + okra | 5.84 | 5.2 | 18.58 | 0.131 | 1.51 | 2.61 |
| Melon + okra | 6.34 | 5.74 | 20.18 | 0.124 | 1.44 | 2.48 |
| Control (sole okra) | 4.9 | 4.12 | 14.58 | 0.092 | 1.06 | 1.84 |
| **Mean** | **5.87** | **5.20** | **18.58** | **0.128** | **1.44** | **2.49** |
| **LSD (0.05)** | **0.09** | **0.19** | **0.62** | **0.005** | **0.05** | **0.08** |

**Calcium (Ca) and Magnesium (Mg)**

Calcium value ranged from 6.44 to 3.8cmol/kg while Magnesium ranged from 3.62 to 0.96 cmol/kg. Highest value on Calcium and Magnesium was recorded in plot with calopogonium + okra Ca (6.44 cmol/kg) and Mg (3.62 cmol/kg) followed by plot with cowpea + okra Ca (5.8 cmol/kg) Mg (3.04 cm/kg) least values among live mulch were obtained in plot with pumpkin + okra Ca (5.08 cmol/kg) Mg (2.38 cmol/kg) though the values were significantly (P>0.05) higher when compared with control values of Ca (3.8 cmol/kg) Mg (0.96 cmol/kg). This result is in accordance with the report of Sultani *et al*; (2007) where they reported that cowpea and other leguminous live mulch conserved soil moisture, builds up organic matter, improves soil properties and activity of microbes supporting mineralization of nitrogen, calcium, potassium and magnesium in greater proportion.

**Potassium (K) and Sodium (Na)**

Potassium value ranged from 0.095 to 0.355 cmol/kg. While Sodium ranged from 0.075 to 0.0310 cmol/kg. Plots with calopogonium + okra gave highest value of K (0.355 cmol/kg) and Na (0.310 cmol/kg) followed by plot with cowpea + okra K (0.294 cmol/kg) Na (0.255 cmol/kg) while plots planted with pumpkin + okra had lower value of k (0.246 cmol/kg) Na (0.202 cmol/kg) but higher when compared with control plot that had the least value of K (0.095 cmol/kg) and Na (0.075 cmol/kg). The result was significant (p>0.05) when compared with control. The observation made from this study is in line with Sultani *et.al*; (2007).

**Hydrogen (H+) and Aluminum (Al3+)**

The result from the study showed that hydrogen ion (H+) and Aluminum (Al3+) significantly (p≤0.05) decreased at the plot with live mulch. Highest value on H+ (1.19 cmol/kg) and Al3+ (0.77 cmol/kg) were recorded in the control plot, followed by 1.14 and 0.56 cmol/kg of H+ and Al3+ in plot with cowpea + okra, while the lowest value of H+ and Al3+ were recorded on plot with calopogonium + okra H+ (0.52 cmol/kg) and Al3+ (0.32 cmol/kg). The decrease in hydrogen and aluminium ion recorded on plots with live mulch may be attributed to increase in pH as a result of increase in organic matter as a result of litter fall from live mulch. The result is in agreement with Amelung *et.al;* (2002) where they recorded similar result on H+ and Al3+ ion on plots treated with leguminous crops as live mulch.

**Cation Exchange Capacity (CEC) and Base saturation (BS)**

The result on CEC and BS from mulched plots were significant (p>0.05) when compared with control. Cation exchange capacity ranged from 6.89 to 11.56cmol/kg, while Base saturation ranged from 71.52 to 95.77 %. Highest value of CEC (11.56 mol/kg) and BS (92.77 %) were recorded in plot planted to calopogonium live mulch, followed by CEC (11.09 cmol/kg) from plot planted with cowpea + okra and BS (87.71 %) in plot planted with pumpkin + okra, while control plot had lowest value of CEC (6.89 cmol/kg) and BS (71.52 %). The finding from this study is in line with the report Sultani *et.al*; (2007)

**Table 7: Effect of different live mulches on Soil Chemical Properties**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | Ca++  cmol/kg | Mg++  cmol/kg | K+  cmol/kg | Na+  cmol/kg | H+  cmol/kg | Al3+  cmol/kg | CEC  cmol/kg | BS  % |
| Cowpea + okra | 5.8 | 3.04 | 0.294 | 0.255 | 1.14 | 0.56 | 11.09 | 84.68 |
| Calopogonum + okra | 6.44 | 3.62 | 0.355 | 0.310 | 0.52 | 0.32 | 11.56 | 92.77 |
| Pumkin + okra | 5.08 | 2.38 | 0.246 | 0.202 | 1.08 | 0.51 | 9.51 | 83.16 |
| Melon + okra | 5.48 | 2.80 | 0.279 | 0.230 | 0.81 | 0.42 | 10.02 | 87.71 |
| Control (sole okra) | 3.8 | 0.96 | 0.095 | 0.075 | 1.19 | 0.77 | 6.89 | 71.52 |
| **Mean** | **5.32** | **2.60** | **0.254** | **0.214** | **0.95** | **0.52** | **9.81** | **83.96** |
| **LSD (0.05)** | **0.12** | **0.14** | **0.014** | **0.013** | **0.05** | **0.02** | **0.24** | **0.49** |

**Effect of Live mulch on plant height**

Effect of different live mulch on plant height at 4, 6 and 8 weeks after planting (table 8) showed that plant height at 4 weeks after planting (4WAP) ranged from 24.79 to 31.88cm. At 6 weeks after planting, plant height ranged from 72.8 to 78.8 cm, while at 8 weeks after planting, plant height ranged from 106.4 to 116.

The result showed that plant height in plots planted with pumpkin gave the highest value of 31.88 cm at 4 weeks after planting, followed by calopogonium (31.81 cm), while the least value of 24.79 cm was obtained in the control. At 6 WAP, plot with cowpea gave highest value of plant height (78.8 cm) while plots planted with pumpkin and melon gave the lowest values of 72.8 cm each. At 8 weeks after planting, control plot had the least value of plant height (106.4 cm). The increment recorded on plots with live mulches were not significant (p<0.05) when compared with control plot.

**Table 8: Effect of different live mulches on plant height**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment** | **Plant height**  **4WAP** | **Plant height**  **6WAP** | **Plant height**  **8WAP** |
| Cowpea + okra | 30.09ab | 78.8a | 111.7a |
| Calopogonum + okra | 31.81a | 77.4a | 116.0a |
| Pumkin + okra | 31.88a | 72.8a | 112.1a |
| Melon + okra | 30.47ab | 72.8a | 107.9a |
| Control (sole okra) | 24.79b | 74.0a | 106.4a |
| **Mean** | **29.81** | **75.1** | **110.8** |
| **LSD (0.05)** | **NS** | **NS** | **NS** |

**Effect of Live mulch on the Number of Leaves**

Effect of different live mulch on number of leaves at 4, 6 and 8 weeks after planting (table 9) showed that number of leaves ranged from 20 to 17 at 4 weeks after planting (4WAP), 26 to 23 at 6 weeks after planting and 32 to 29 at 8 weeks after planting. Plot planted with melon as live mulch gave highest number of leaves at 4, 6 and 8 weeks after planting (4WAP= 20), (6WAP= 26) and (8WAP = 32). While plots with cowpea recorded lowest values of number of leaves 4 at 8 weeks after planting (17 and 29). There is no significant (p<0.05) variation in number of leaves when compared with control.

**Table 9: Effect of different live mulches on Number of Leaves**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment** | **Number of Leaves**  **4WAP** | **Number of Leaves**  **6WAP** | **Number of Leaves**  **8WAP** |
| Cowpea + okra | 17a | 24a | 29a |
| Calopogonum + okra | 19a | 24a | 31a |
| Pumkin + okra | 17a | 25a | 31a |
| Melon + okra | 20a | 26a | 32a |
| Control (sole okra) | 18a | 23a | 30a |
| **Mean** | **18** | **24** | **31** |
| **LSD (0.05)** | **NS** | **NS** | **NS** |

**Effect of Live mulch on Leave** A**rea Index**

Effect of different live mulch on leave area index at 4, 6 and 8 weeks after planting (table 10) showed that leave area index ranged from 126.2 to 116 cm2 at 4 weeks after planting (4WAP), 211 to 193 cm2 at 6 weeks after planting and 305.4 to 259 cm2 at 8 weeks after planting. Plot planted with cowpea gave highest value of 126.2 cm2 at 4 weeks after planting., while plots with melon as live mulch gave highest values on leave area index at 6 and 8 weeks after planting (6WAP= 211 cm2) and (8WAP = 305.4 cm2). Control Plots recorded lowest value of leave area index 4 and 6 weeks after planting (116 and 191.2 cm2). There is no significant (p<0.05) variation in leave area index as a result of using live mulch in this experiment.

**Table 10: Effect of different live mulches on Leave Area Index**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment** | **Leave Area Index**  **4WAP (cm2)** | **Leave Area Index**  **6WAP** | **Leave Area Index**  **8WAP** |
| Cowpea + okra | 126.2a | 193.8a | 259.0a |
| Calopogonum + okra | 118.4a | 194.0a | 266.8a |
| Pumkin + okra | 119.0a | 206.8a | 287.6a |
| Melon + okra | 120.0a | 211.6a | 305.4a |
| Control (sole okra) | 116.0a | 191.2a | 273.2a |
| **Mean** | **119.9** | **199.5** | **278.4** |
| **LSD (0.05)** | **NS** | **NS** | **NS** |

**Effect of Different Live Mulch on Number of Flowers and Pods**

Effect of different live mulch on number of flowers at 4weeks after planting are shown on table 11, number of flowers ranged from 5 to at 4, with plot planted with pumpkin and melon giving highest number of flowers (5), while control and every other treatment had 4 flowers each.

Number of okra pods ranged from 10 to 7 at 6 weeks after planting and 13 to 12 at 8 weeks after planting. Highest number of pods at 6 weeks after planting was recorded in plot with pumpkin (10 pods) followed by calopogonium and melon with 9 pods each, while control plot had lowest number of pods (7). At 8 weeks after planting, plot planted with cowpea, pumpkin and melon gave the highest number of pods (13) each, while plot planted with calopogonium and control gave 12 pods each.

**Table 12: Effect of different live mulches on Number of Flowers and Pods**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment** | **Number of flowers**  **4WAP** | **Number of Pods**  **6WAP** | **Number of Pods**  **8WAP** |
| Cowpea + okra | 4ab | 8b | 13a |
| Calopogonum + okra | 4ab | 9ab | 12a |
| Pumkin + okra | 5a | 10a | 13a |
| Melon + okra | 5a | 9ab | 13a |
| Control (sole okra) | 4ab | 7b | 12a |
| **Mean** | **4** | **9** | **13** |
| **LSD (0.05)** | **NS** | **1.52** | **NS** |

**CHAPTER FIVE**

**CONCLUSION AND RECOMMENDATION**

* 1. **CONCLUSION**

Live mulch not only conserved the soil moisture and reduced bulk density of the soil, it also increased soil pH, Organic matter, nitrogen, phosphorus and most basic cations (Ca, Mg, K, Na) tested. It improved the growth and development of the crop (okra). Among the live mulch tested, calopogonium and cowpea have shown better capability in improving soil properties and okra growth and development.

* 1. **RECOMMENDATION**

Therefore calopogonium and cowpea are recommended for farmers to use as live mulch since they have proved to be more efficient in adding nutrients to the soil through biomass addition to the soil.

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