EFFECTS OF ROOT KNOT NEMATODE (*Meloidogyne incognita*) ON GROWTH, YIELD AND SEED QUALITY OF OKRA (*Abelmoschus esculentus)* CULTIVARS IN MINNA, NIGERIA

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Okra (*Abelmoschus esculentus* L. Moench) originated from Ethopia and was cultivated by the ancient Egyptians in the 12th century B.C.). It was domesticated in West and Central Africa but is now widely cultivated throughout the tropics primarily for local consumption. In Nigeria, it ranks third in terms of production and consumption following tomato and pepper (Ijoyah *et al*., 2009). Okra is one of the most widely known and utilized species of the family Malvaceae (Naveed *et al*., 2009). Okra commonly known as lady's finger, is among the most heat and drought tolerant vegetable species in the world (Priya *et al*., 2014) and an economically important vegetable crop grown in tropical and subtropical parts of the world (Oyelade *et al*., 2003). Okra is an herbaceous annual plant and can grow up to 1.2 – 1.8 meter-tall and can survive only one growing season. The plant has small erect stems that can be bristly or hairless with heart-shaped leaves, the leaves are 10–20 cm long with 5–7 lobes. The plant produces flower with five white to yellow petals which are 4–8 centimeter (cm) in diameter, and the seed pod is a capsule up to 25 cm long containing numerous seeds. High-yielding plant which varies in size, pod shape, pigmentation, degree of branching, period of maturity, and plant height (Purquerio *et al.*, 2010).

Okra has great potential as foreign exchange earner and accounts for about 60% of the export of fresh vegetables from India to the Middle East and European countries (Singh *et al*., 2014). Production of okra constitutes about 4.6 percent of the total staple food production in Nigeria (CBN, 2016). It is found in almost every market in Nigeria (Atiri *et al*., 2000). It is consumed in almost every household (Babatunde *et al*., 2007).

The crop contributes immensely to the economic status of farmers especially those engaged in large scale production of the crop in dry season and can be regarded as one of the crops which sufficiently contributes to food security since many families' plant okra as a garden crop (Roy *et al*., 2014). Okra is one of the most important vegetable crops of the world, being popular in many tropical and subtropical countries, and mostly cultivated for human consumption and also for industrial use as fibre (Hussain *et al*., 2012). Different part of okra seems to offer some useful purpose (National Research Council, 2006). It is a multipurpose crop due to the various uses of its edible parts like the fresh leaves, buds, flowers, pods, stems and seeds (Yonas *et al*., 2014). Okra is a popular health food due to its high fiber, vitamin C, and folate content, it is also known for being high in antioxidants (Maramag *et al*., 2013) The crop is also a good source of calcium and potassium . The mucilage can be used as a plasma replacement (Gemede *et al*., 2015). An infusion of the roots is used in the treatment of syphilis (Tian *et al*., 2015). The juice of the roots is used externally in Nepal to treat cuts, wounds and boils (Sathishand Eswar,2013).

The optimum production of vegetables throughout the world is threatened by large number of biotic factors including plant-parasitic, nematodes (Hussain *et al.*,2016c). The root-knot nematode (*Meloidogyne incognita*) has been referred to as one of the most widespread nematodes severely injuring vegetables, it causes high losses to crop production particularly in infested fields of sandy soils (Ibrahim *et al*., 2010). Like all plant-parasitic nematodes, root-knot nematodes possess a stylet for injecting secretions as well as ingesting nutrients from host plant cells (Kayani *et al.*, 2017). Nematodes have no internal skeletal framework, and their "skin" or cuticle acts against internal turgor pressure to maintain body shape and aid locomotion (Kamran *et al.*,2013). Root-knot nematodes attack different crop plants causing severe growth retardation due to

formation of typical galls. Susceptible vegetables include; okra, parsley, peas, pumpkin, squash, sweet pepper, tomato, bambara nut, brassicas, beans, chili pepper, garlic, beetroot, radish leek, carrot, celery, turnip, cowpea, rhodes grass, cucumber, sesame, eggplant, sorghum, gourd sudan grass, irish potato,sweet corn, lettuce, melon (Dobson *et al*., 2002). *Meloidogyne* extensively disrupt xylem tissues and greatly retard absorption and upward movement of water and nutrients (Silva *et al.,* 2015). The most reliable control of root-knot nematodes can be achieved by integrating two or more methods including an effective rotational scheme, resistant varieties and selected cultural practices give excellent control with little added cost (Collange *et al.*, 2014).

1.2 Statement of the Research Problem

Many vegetable farmers today have suffered lots of losses as a result of nematode infections, the root-knot nematode (RKN), *Meloidogyne incognita* has been referred to as one of the most widespread nematodes severely injuring vegetables (Hussain *et al.*,2016a). Nematodes can also cause a reduction in seed production and quality (Patil and Gaur 2014). During infection, dry matter accumulation in seeds is interrupted, hence maximum dry weight (physiological maturity) will not be reached resulting to poor seed viability (Franca *et al*., 2012).

The farmers unknowingly sow such seeds expecting high germination and good seed emergence rate which will not be realized due to poor seed viability. This is coupled with poor growth rate (stunted growth) of already infected okra plant which will definitely results in losses to the farmer.

1.3 Justification of the Study

Root knot nematodes can cause serious economic losses in okra production for commercial growers and home gardeners. Nematode management has been attempted by adopting various methods either singly or in combination of two or more methods,

resulting in varying degrees of effectiveness (Collange *et al.*, 2014). Root-knot nematodes are considered among the top five major plant pathogens and the first among the ten most important genera of plant parasitic nematodes in the world (Mukhtar *et al*., 2013b). Keeping in view the economic importance of *M. incognita* in reducing the quantity and quality of crop production, the present study is designed to determine the effects of different inoculum levels of *M. incognita* on the growth, fruit , yield and seed quality of two okra varieties which will help in the determination of economic threshold level in the control and management of the root knot nematode in the production of these two varieties of okra in Minna soils. This study will help farmers to identify nematode infection and the consequences so that they can take possible measures to reduce and manage the occurrences so as to obtain maximum

yield.

1.4 Aims and Objectives of the Research

The aim of the study is to evaluate the effect of root knot nematode (*Meloidogyne incognita*) on the growth, yield and seed quality of two varieties of okra for effective recommendation of suitable variety to okra farmers in Minna, Southern Guinea Savannah of Nigeria;

The Objectives were to;

- determine the effect of root knot nematode on growth parameters of two okra varieties.
- examine the effect of root knot nematode on the yield of two varieties of okra.
- assess the effect of root knot nematode on seed germination of the two cultivars of okra.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Soil and Climatic Requirement of Okra

Okra grows best on well-drained sandy loam soils. Poorly drained soils may result in drowning (low oxygen) of the plants (Akanbi *et al*., 2010). Soil temperatures should be at least 18.3 °C with optimal growth of the plants occurring at soil temperatures between 23.9 – 32.3 °C. The crop is typically propagated from seed (Aguair *et al.,* 2011).

Okra prefers slightly acidic soils with a pH between 5.8 and 6.5. On clay soils, seedlings have difficulty in emerging. The crop grows best in hot weather temperatures above 26^0 C (Ndunguru and Rajabu.,2004). The crop is a hot weather crop, while the minimum soil temperature is 18 ° C (Yonas *et al.,* 2014). Damping off and seed decay are likely to occur at soil temperatures below 21 °C (Roy *et al.,* 2014) Recommended row spacing is 71.0 to 96.0 centimeter with 20.0 to 35.0 centimeter between plants (Satish and Eswar, 2013). Seeds should be chemically treated to reduce damping off (seedling rot) and planted about 2 to 3 centimeter deep (Akintoye *et al.*,2011). A seeding rate of four to six seeds per 30.4 cm is recommended (Akanbi *et al*., 2010).When okra is 8 centimeter-tall, plants should be thinned (Singh *et al.*,2014).

Weeds compete with the crop thereby reducing yield and quality of okra and other vegetable crops due to their competitiveness (Hager *et al*., 2002), grass weeds being the most common species, weeds can be controlled by manual weeding at 2-3 weeks after planting, and 5-6 weeks after planting ffor manual or chemical weed control (Ziska *et al.,* 2010).

Okra requires adequate amount of nutrient in the soil. NPK (15;15;15) can be applied by side placement at 4 weeks after sowing 4 cm away from the base of the plant. Application of 200 kg/ha of NPK fertilizer will be adequate for effective growth and high yield of okra (Iyagba*et al*., 2013),

Okra is subjected to attack by many insects and pathogens including fungi, viruses, mycoplasmas and nematodes (Hussain *et al*., 2011). Southern stem blight, verticillium and fusarium wilts are some of the more serious diseases attacking okra. The most frequent disease is blossom blight caused by the fungus : *Choanepbora cucurbitarum*. The disease is more severe during periods of very high humidity, which is often the entire growing season. Although okra is considered a robust crop under commercial production, yield losses are very high due to the incidence of a number of Biotic and Abiotic stresses. The most relevant biotic stress of okra is the leaf curl disease caused by the *begomo virus*. Okra leaf curl virus, (OLCV) is transmitted by the white fly (*Bemisia tabaci*) (Youm*et al*., 2005). Among biotic factors which account for the reduction in crop production, root-knot nematodes are regarded as serious pests and are of substantial economic significance. Root-knot nematodes have also been found to be associated with fungal and bacterial pathogens resulting in disease complexes and aggravate the severity of the latter (Mukhtar *et al*., 2018).

Okra pods are generally ready for harvest 4 to 6 days after flowering; pods should be harvested every 2–3 days when they have reached 7.6–15.2 cm (3–5 in) in length. Dry pods are ready to be harvested when the pods have turned straw coloured fruits and ridges completely split; the seeds would have turned black in colour, Ibrahim and Oladiran, (2011).

Under good management over 40 tons per hectare can be realized under optimal conditions (Kumar *et al*., 2013). An average yield of okra varies from 6.5-7.5 t/ha of pods during the dry season and 11.5 -12.5 t/ha during the rainy season (Ahmad *et al*., 2015). On a commercial scale, it is possible to get 1500 kg of seeds per hectare as against the seed yield of 500 kg/ha in subsistence farming (Akanbi *et al*., 2010). In general

average yields seeds of okra are in the range of 500-1000 kg/ha. Seed yields are usually low (2–4 t/ha) as a result of non-intensive growing methods (Sathish and Eswar, 2013).

2.2 Biology and Ecology of Root Knot Nematode

Unlike most other plant-parasitic nematodes, root-knot nematode females are globose and sedentary at maturity. Once they establish a feeding site, they permanently remain at that location within the plant root (Perry *et al.*, 2009). In highly sensitive crops such as lettuce and carrots, initial density of 2 or 1 egg/cc soil, are sufficient to cause economic losses. At high densities, root-knot nematodes can actually kill host plants particularly if the high populations occur early in the growing season when plants have minimal root mass.

Under average conditions, a female produces 300 to 800 eggs (Dong *et al*., 2012)also further stated that the most widespread and economically important are the root-knot nematodes (*Meloidogyne spp*.) with which their life cycle is completed in 25 days at 27 ^{0} C but takes longer at lower or higher temperatures. Root-knot nematodes measure about 0.5 mm to 1.5 mm in length. Juveniles (young nematodes) penetrate the root tips and occasionally invade roots in the zone of root elongation. Invaded nematodes initiate the development of giant cells in the root tissues and galling of roots occurs (Hussain *et al* 2016a). To reproduce, the infective second-stage juveniles must be attracted to host roots, penetrate the epidermis and migrate through the root cortex to establish a feeding site in the vascular parenchyma that provides sufficient nutrition for development and eggproduction (Abad *et al*., 2009).Variations occurs among okra cultivars in their response to the nematode and resistance within a plant species is often due to specific genes that segregate within the species, and for non-host species or resistance cultivars,

nematode cannot reproduce on that plant due to absence of host trait required for parasitism (Hussain *et al*.,2014).

The infection also greatly reduces permeability of roots to water which is a vehicle for transporting nutrients from parent plant to the developing seed resulting to poor reserve accumulation of nutrients during maximum seed dry weight, this however, result in seeds produced with; poor seed weight, and poor germinability potentials. Incidence and severity of wilt diseases caused by fungi and bacteria have been reported to increase in many crops by root-knot infections (Tariq-Khan *et al*. 2017). Root-knot nematodes have also been found associated with fungal and bacterial pathogens resulting in disease complexes and aggravate the severity of the latter (Mukhtar *et al.*, 2017). To kill nematodes in the soil, heat small quantities of moist soil to 59.94 ^{0}C in the oven or by solarization which involves tightly placing a clear, plastic cover over the soil and letting it remain in the sun three to five days

(Collange*et al.*, 2014).

2.3 Types of Root Knot Nematode Species (*Meloidogyne Spp*)

Some species of *Meloidogyne;Meloidogyneacronea, M. brevicauda, M. ardenensis, M. are alia, M. artiellia, M. chitwood, M. coffeicola, M. exigua, M. fruglia, M. gajuscus, M. hapla, M. incognita,* (Moens*et al,* 2009). From this description, Chit wood obtained the name currently used for the root-knot nematodes. The name *Meloidogyne* is of Greek origin, meaning "apple-shaped female." Approximately 100 species of *Meloidogyne* have been described. The most widespread and economically important species are *M. incognita, M. javanica, M. arenaria, M. hapla, M. chitwoodi and M. graminicola*. Root-knot nematodes are primarily tropical to sub-tropical organisms, however *M. hapla and M. chitwoodi* are well adapted to temperate climate change (Perry *et al.*, 2009).

2.4 Effects of Root-Knot Nematodes on Vegetable Crops

Root-knot nematodes attack different crop plants including vegetables causing severe growth retardation due to formation of typical galls (Mihretu*et al*.,2014). Susceptible vegetables include; Okra, Bambara nut, Beans, Chili pepper, Garlic, Beetroot, Radish Leek, Carrot, Sweet potato, Celery, Turnip, Cowpea, Rhodes grass, Cucumber Sesame, eggplant, Gourd Sudan grass, Irish potato, Lettuce, Melon., Parsley, Peas, Pumpkin, Squash, Sweet pepper, and Tomato (Dobson *et al*. 2002). Many crops grown as vegetables are susceptible to the nematode particularly tomato, aubergine, okra, cucumber, melon, carrot, gourds, lettuce and peppers (Mukhtar *et al*., 2013a). Common bean *(Phaseolus vulgaris*) is very badly damaged by *Meloidogyne species* in the tropics. Cowpea (*Vigna unguiculata*) is another very susceptible host crop of *M. incognita* (Mukhtar *et al*., 2017).Of all the pathogens, the attack of root-knot nematodes (*Meloidogyne* spp.) is the most serious, widespread and alarming which cause tremendous yield losses (Hussain *et al*., 2011). The optimum production of vegetables throughout the globe is threatened by large number of biotic factors including plant-parasitic nematodes (Hussain *et al*., 2016a). Root-knot nematodes affect a wide range of crops, particularly vegetables. *M. incognita* is a major economic pest of food legumes in the tropics and subtropics (Khan *et al*., 2017).

Root-knot nematode problems can be detected by examining the roots of vegetables soon after harvest is completed or through an assay of a soil sample. Root-knot affects cantaloupe, cucumber, eggplant, okra, squash, tomato, and other susceptible crops will have very conspicuous root galls (swellings). Local damage due to heavy infestations by certain species is often higher Sikora and Fernandez (2005). Among plant-parasitic nematodes, the root-knot nematode alone or in combination of other pathogens, is a very

destructive one and tremendously reduces both quantity and quality of vegetables.Estimates of vegetable crop losses due to *Meloidogyne species*, mainly *M. incognita* and *M. javanica* , have ranged from 17 to 20 % for aubergine (*Solanum melongena*), 18 to 33% for melon and 24 to 38 % for tomato. Losses of potatoes due to Meloidogyne species, mainly *M. incognita*, are estimated at 25% or more (Kayani *et al.*, 2013).

2.5 Effects of Root Knot Nematodes on Okra Production

Okra is particularly susceptible to root knot nematodes. Basically, when nematode feeds on the plant roots, it interrupts the flow of nutrients and water the plant can absorb. This leaves a plant that is stunted and wilting, with chlorotic or pale green leaves and eventual reduced yields, severely infected plants may wilt or may exhibit nutrient deficiency symptoms and may show nematode induced chlorosis (Bairwa and Patel 2016).

Infected roots swell at the infected site and form galls, the infected roots are stunted and lack fine feeder roots later in the growing season, roots may begin to rot. Plants growing in nematode-infested soils usually are unthrifty, stunted, yellowish, and have galled and decayed roots. Plants with infected roots are more susceptible to other diseases caused by fungi and bacteria and tend to stop producing early (Dhaliwal *et al*., 2012). Root-knot nematode problems can be detected by examining the roots of vegetables for the conspicuous root galls (swellings) as soon as harvest is completed or through a soil assay. Affected plants are stunted and yellow and have a tendency to wilt in hot weather. Very heavily infested plants are killed, affected plants appear in patches. If infested plants are pulled from the soil, the roots are severely distorted, swollen and have lumps known as galls or root knot Archana and Saxena (2012). Pathological changes manifested into short heights due to the significant effect of nematodes,these

pathological changes manifested in shoot heights, fruit weights, root weights, and most importantly in fruit development and maturation (Agwu and Ezigbeo, 2005) .

Infected cowpeas with various inoculums of *M. incognita* with different inoculum densities of the same root knot- nematode resulted to growth stimulation at low infection levels but suppress the growth rate at higher infection levels (Agwu and Ezigbeo 2005)

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Plant-parasitic nematodes are often associated with soil and roots and produce little typical symptoms on aerial parts of host plants (Wyss 2002; Di Vito and Castillo 2004). *Meloidogyne* extensively disrupt xylem tissues and greatly retard absorption and upward movement of water and nutrients. The infection also greatly reduces permeability of roots to water. The infection in plant roots by *Meloidogyne* induces the formation of nurse cells and regulates greater translocation of photosynthates, towards infected root tissue while other parts (foliage) experience shortage Di Vito and Castillo. (2004). Infection of *Meloidogyne* caused stimulation in additional lateral root growth at the stellar region of the galls enhanced the uptake of water and mineral salts, this enhanced increased nutrient supply to the shoot of the treated plants, until the damage of root cells by the entry of the second stage infective larvae Answar and Mckenry (2012). Nematode attacked plant root system, stressed plants flowered early as a mechanism to reduce exposure to the stress and complete the reproductive cycle

(Daramola *et al*., 2015).The poor growth of foliage subsequently leads to decreased in okra production (Hussain *et al*.,2016b), Due to the inadequate supply of water, nutrients, photosynthates and energy, growth and developments of leaf tissue and its constituents, especially chlorophyll pigments, are adversely affected (Hussain *et al.*, 2016c). Plant parasitic nematodes are involved in the mechanism of senescence, the shedding of

leaves could also be a coping mechanism for stress by the plant infection with *M. incognita* resulted in the production of few and smaller fruits (Koyama, 2014). Higher yield reduction in susceptible cultivar over the resistant one might be due to faster development of nematode female even when both are subjected to nematodes at equal time frame (Anwar *et al.*, 2007).

Induction of galls in the roots and giant cells in the stellar region by *Meloidogyne incognita* which extensively disrupt xylem tissues and greatly retard absorption and upward movement of water and nutrients hence increased inoculum levels lead to increased root galling in *A. esculentus* (Kamran *et al.*, 2013), genes in response to resistance nematode infection block or suppress one or more of several critical steps in nematode parasitism (Roberts *et al*., 2008). Differences in the susceptibility to *M. incognita* in okra cultivars is due to differences in their genetic makeup which can be explained in terms of number of galls in the roots,the galls range in size from smaller than a pinhead to 25 mm or more in diameter (Castagnone-Sereno, 2006) as indicated in plate 1.

2.6 Effects of Root- Knot Nematode on Seed Quality

Nematode infection in soybean caused significant reductions in pod, seed number and 100-seed dry weight there by leading to reduction in seed production and quality (Bneventi *et al*., 2013). The effect on seed quality can also be due to nematode action interfering with the seed formation process resulting in low quality seeds. (Patil and Gaur 2014) showed that rice plants infected by root-knot nematode, *Meloidogyne graminicola*, produced seeds with lower germination percentage and plant length. (Patil and Gaur 2013) also reported that rice plants infected by root-knot nematode produced seeds with lower germination percentage and reduced plant height, flower abortion,

(fewer flowerproduction), an increase in production of empty pods which reduces number of seeds and deficiencies in assimilation process.

Plate I: Roots of okra plants with underground symptoms infected with *Meloidogyne incognita* showing galls on Okra plants root system

Franca *et al*., (2012) revealed that nematode parasitism inhibited plant maturity, seed maturity, producing greenish seeds and the reducing their physiological potential. (Cirrinicione *et al.*, 2009) reported that low seed weight is an indication that nematodes have reduced the efficiency of nutrient uptake due to a damaged and smaller root system and acted as a metabolic drain during their development on roots which also affected the seed formation process; thereby reducing seed weight.

(Kenanoglu *et al*., 2013) reported that low germination recorded with pepper seeds can also be due to nematode action interfering with the seed formation process (Pádua *et al.*,2009).

Under stress conditions, seed can mature faster than normal and enzyme activity stops before all the chlorophyll has been degraded. Soybean plants subjected to hydric and

thermal stress after R6 produce high numbers of green seeds with a smaller size and weight and high chlorophyll content and low chlorophyllase activity.

2.7 Control and Management of Okra root- Knot Nematode

For the home gardeners and commercial farmers, a combination of control methods should help control root knot nematodes populations. First of all, practice crop rotation, avoid planting of okra in the same area of the garden or farm for a couple of years. Utilize area of the garden to grow nematode resistant crops instead such as nematode resistant okra varieties. Nematicides can also be used but, unlike other chemical methods of control, they tend to reduce nematode populations slowly over time. Chemicals are being used to control nematodes successfully (Dong *et al*., 2014) but due to their high cost and hazardous effects, nematicides are not attractive to farmers.

The most reliable control of root-knot nematodes can be achieved by integrating two or more of the tactics described herein; combining an effective rotational scheme, resistant varieties, and selected cultural practices gives excellent control with little added cost. Frequent incorporation of organic matter, of composted leaves, grass clippings, and manure, into the soil is also beneficial for improving soil structure and moisture retention (Kayani *et al*., 2017), and it will also encourage biological control of nematodes (Mukhtar *et al.,* 2013c). The use of such organic materials may require additional nitrogen (Tiamiyu *et al.,* 2012). To kill nematodes in soil, heat small quantities of moist soil to 59.94 °C in the oven or by solarization. The method involves tightly placing a clear, plastic cover over the soil and letting it remain in the sun three to five days (Collange *et al*., 2014).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Location

The study was carried out in the year 2019 at the Screen House of School of Agriculture and Agricultural Technology, Federal University of Technology at GidanKwano Campus, Minna, Niger State Nigeria.

3.2 Source of Seeds

Seeds of two Okra varieties (NHAe-47 and LD88) were sourced from National Horticulture Research Institute (NIHORT) Ibadan.

3.3 Description of the Varieties

3.3.1 NHAe47-4:

This is a seed bred by NIHORT, it is an erect plant that can attain a height of 0.8 -1 meter. Leaves of the plant are heart-shaped with three- to five-lobed. The flowers possess large and yellow colour with a crimson center. The plant produces large pods of about 10 centimeters in length and 4.5 to 5 centimeters in diameter depending on the fertility of the soil. The size of physiologically matured seed is about 4 – 4.5 mm in diameter with colour ranging from dark to grey (Omotoso and Shittu, 2007).

Plate. II: NHAe 47-4variety of okra plant

3.3.2 LD**88:**

This Okra is also a NIHORT bred variety. It is an erect plant that can grow up to the height of 1.5 meter at flowering. Leaves formed are heart-shaped with three to five lobed with brightly yellow flowers. The maturity of the variety is within the period of about three months. The length of the pods it produces is about 9 centimeter (cm) in length and 3.5 to 4centimeter (cm) in diameter. The seeds are oval dark-colour and are about 3.5 centimeters (cm) in diameter. The performance of the variety with good yield is due to the higher and genetic potentials of the plant to be able to tap nutrients from the soil (Omotoso and Shittu, 2007).

Plate III: LD88 Variety of okra plant.

3.4 Collection and Sterilization of Soil Samples

Topsoil of 0-15 cm depth was collected from the Teaching and research farm of Federal University of Technology, Minna. The collected soil was sterilized using a metal tray for one hour at 98.5 ^{0}C with fire wood as the source of heat. The sterilized soil was spread on a large metal sheet after heating and left-over night to cool off before it was used. Ten (10 kg) of sterilized soil was thoroughly mixed and fill into forty (40) polythene pots and labelled to correspond to the number of treatments which were arranged in four replicates.

3.5 Sowing and Thinning of Seedling

All the polythene pots were filled with sterilized soil (10 kg) which were arranged inside the Screen House. Water was applied to each pot a day to sowing. Five seeds of each cultivar were sown into 10 kg sterilized soil in a hole at the depth of 3 centimeters. Two weeks after emergence, seedlings were thinned to two plants per stand in each pot.

3.6 Sources of Inoculum

The inoculum used for the experiment was the eggmasses of root knot nematode (*Meloidogyne incognita)* which was obtained from the roots of heavily infested okra plant (*Abelmoschus esculentus*), cultured in the screen house of School of Agriculture and Agricultural Technology, Minna.

3.6.1 Collection of Eggmasses

For collection of eggmasses, okra plant roots infected with *M. incognita* were uplifted from pots, washed under a running tap water, cut into approximately 1-2 cm pieces and was vigorously shaken in a bottle containing 0.5 % Nacl for 5 minutes to remove adhering soil and separation (Hussey and Barker 1973). The eggmasses were collected on a 38 m sieve and washed in a beaker and the eggmasses collected into plastic Petri dishes labelled according to different levels of treatment for inoculation.

3.6.2 Determination of Lavae per Eggmass

Estimation of number of lavae per eggmass used for the experiment was determined by setting up six plastic Petri dishes in the crop laboratory of crop department, Federal University of Technology Minna. Collection process of eggmass as described in (3.6.1) was applied. Six uniform sizes of eggmasses were collected from the infected okra roots cultured in the screen house of Federal University of Technology Minna, and were placed each in a plastic Petri dish containing 10ml of distilled water and arranged on a table in the crop laboratory. The eggmasses were observed for hatching which were counted under an electric microscope in the crop laboratory. Mean number of the juveniles obtained from the six Petri-dishes (250) was estimated per eggmass which determined the number of eggmasses that were used for each treatment. The following were the estimation of lavae per eggmass.

2eggmasses (500 lavae) 4 eggmasses (1000 lavae), 6 eggmasses (1500 lavae), 8 eggmasses (2000 lavae) and the control (0 eggmass). However, estimation of mean (250) lavae was estimated per eggmass.

3.6.3 Treatments and Experimental Design

The experiment was a 5× 2 factorial combination of 5 inoculums rates (2, 4, 6, 8 eggmasses and control) and 2 varieties of okra (NHAe47-4 and LD88) replicated 4 times. ten treatments replicated four times laid out in a completely randomized design (CRD)

3.6.4 Inoculation:

Three weeks after planting, grooves were created around the base (2.0 cm) from the plants, eggmasses of *M. incognita* were inoculated early in the evening,and gently covered for all the replicates. Water was applied to each pot immediately after inoculation.

3.6.5 Cultural Practices;

3.6.6 Weed control

Weeds were controlled by hand pulling in each polythene pot as found necessary throughout the period of the research work.

3.6.7 Water Application

Pots were kept constantly moist; water application was done early in the mornings and evenings to field capacity, daily.

3.7 Data Collection

Data were collected based on the following parameters.

3.7.1 Plant height (cm)

Plant height was taken using a meter rule measuring from the base of the plant to the tip of the apical leaf at 5, 7, 9 and 11weeks after sowing.

3.7.2 Number of leaves per plant

Number of leaves were counted on a plant stand in each pot at ; 5 ,7 ,9 and 11 weeks after sowing in all the treatment in each replicate and mean values recorded.

3.7. 3 Stem girth

Vinear caliper was used to measure the girth of the stems, 5 cm from the base of the plant at 5,7,9 and 11 weeks after sowing; mean values records were taken and expressed in centimeter (cm).

3.7.4 Leaf area

The length and breadth of the leaves were measured using the meter rule, the values obtained were multiplied by a constant (0.62) for each leaf area (Musa and Usman 2016).

3.7.5 Number of days to first flower bud

This was recorded as the number of days from sowing to when the first flower bud wassighted on the plant in all the treatments for all replicates and mean number of days were recorded.

3.7.6 Number of days to first flower bud opening

This was recorded as the number of days beginning from sowing towhen flower bud opening was first noticed in a treatment for all the replicates.

3.7.7 Number of days to 50 % flowering

This record was taken when half of the plant population in a treatment flowered (i.e when one out of the two plants in a pot in a treatment flowered).

3.7.8 Number of productive branches

At nine (9-10) weeks after sowing, number of branches that produced fruits were counted on a plant in each pot for all the treatments and mean values were recorded.

3.7.9 Fruit tagging

Flowers on one out of the two plants in each pot was date- tagged as they opened to index anthesis. Successful fruits from the tagged flowers were harvested at 42 days after anthesis (DAA). The aim was to investigate the effects of the treatments on the quality of seeds at physiological maturity stage of the seeds as reported by (Ibrahim and Oladiran , 2011) which stated that; germination of up to 97% and the ability of the seeds to maintain viability for long were obtained at 42 days after anthesis when fruits were straw-coloured, ridges completely split and the seeds were black in colour.

3.7.10 Fruit harvesting, handling and yield determination

Harvesting was done using a small knife to cut the stalk of fresh fruit from the mother plants when fruit bearing commenced. Soon after each harvest one fresh fruit each was randomly selected from one plant in a treatment, fresh fruit weight was determined using a Metler balance model; pm 2000 swiszaland; the length and diameter of the harvested fruits were taken using a pair of Vineer caliper.

Dry fruits were collected from the remaining plant in the pots at 42 days after anthesis (DAA) for seed viability studies as influenced by the treatments.

3.7.11 Number of fruits per plant

Progressive harvest was done on the remaining plant per pot, number of fruits harvested from mother plants were recorded for each treatment and recorded in (g).

3.7.12 Total fruit weight per plant

Following harvest of fresh fruits from one mother plant three to four days' interval for control plants, and six to seven days' interval for all the inoculated two okra cultivars. All fresh fruits were bulked, weighed and recorded for all replicates in gram(g). Similarly, following harvest from tagged fruits, progressive harvest of (dry fruits) was carried out on the remaining mother plants which were also bulked and weighed using the Metler Balance model(pm,2000 swiszaland) . However, all records obtained as total weight per plant per pot for all the replicates in all treatments were expressed in gram (g).

3.7.13 Scoring of root-knot/galls

The galls on the roots of okra plantwere randomly sampled, one plant per treatment was viewed under the electronic microscope in the laboratory of Crop Production Department, galls on the roots were counted and recorded in all the treatments which were scaled using the method as reviewed by (Otipa *et al*., 2003) as indicated in;
3.7.14 below;

3.7.14 Scale for Scoring

0= No knot on roots,

1= Small knots difficult to see,

2= Small knots only but clearly visible, main roots clean,
3=Few large knots visible, but main roots clean,

4= Large knots predominate but main root clean,

5 = 50 % of Knotted; knotting on parts of main root system,

6= knotting on some of main roots,

7= Majority of main roots knotted,

8= All roots knotted; few clean roots visible,

9= All roots severely knotted; plant usually dying,

10. All roots severely knotted; no root system; usually dead.

3.7.15 Weight of fresh plant

The weight of the fresh plant in all the treatments for all replicates, after gall scoring was taken using electronic Metler balance (pm,swiszaland) in the laboratory of Crop Department, mean was recorded in gram (g).

3.7.16 Weight of dry matter

To obtain the weight of dry matter; fresh plants were subjected to accelerated drying using oven drying method for one hour at temperature of 120 ^{0}C (Demir *et al* .,2016) and were allowed to cool off for sixty minutes and weighing was conducted using Metler balance (pm, 2000 swiszaland), mean weight were recorded in (g).

3.7.17 One hundred -Seed weight

For 100 seed weight determination, 100 seeds were obtained from randomly selected tagged fruits from four replicates per treatment which were counted and weighed on a Metler balance (pm, 2000 swiszaland) and mean values were recorded in gram (g).

3.7.18 Seed moisture content determination

The initial moisture content (MC %) of the seed at 42 days after anthesis,was determined using the oven drying method at 130 ^{o}C for one hour according to Rao *et al.* (2006) and was expressed on wet weight basis as follows:

$$\frac{Weh \text{ of wet seeds} - \text{Weight of oven dried seeds}}{W\,W} \times 100\; Weh\; o$$

3.7.19 Seed germination percentage (viability test)

Germination test was carried out by counting 50 seeds of four replicates from each of the treatment combinations and placed on layers of moist absorbent paper placed in plastic Petri-dishes and carefully arranged on the germination chamber at 30 ^{0}C and relative humidity of 90 %. Germination count was taken every- other- day for a period of 28 days. The values were expressed as percentage germination for each treatment.

$$\frac{Nu\; o\; rW\; W}{r} \times 100\; Nu\; o\; W$$

3.8 Data Analysis

All data collected on plant growth, yield and seed germination parameters were subjected to Analysis of Variance (ANOVA) for CRD using Statistical Analysis System (SAS) package (2017). Means were separated using Least Significance Difference (LSD) at 5% level of significance ($P < 0.05$).

CHAPTER FOUR.

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Effects of Inoculum (*Meloidogyne incognita*) levels on plant height of two varieties of okra plants at different stages of growth

The effects of *Meloidogyne. incognita* on two varieties of okra plants at 5, 7, 9 and 11 weeks after planting (WAP) as showed in Table 4.1. *M. incognita* had significant effect on plant height throughout the sampling periods in this study.

Inoculating with eight (8)eggmasses significantly reduced plant height (19.5cm) than oth2er inoculum levels, however effects of inoculums caused similar reduction in heights of the plants (20.9 and 20.8cm) which were inoculated with 4 and 6 eggmasses respectively at 5weeks after planting. Following plant growth for 7 - 11 WAP, a similar trend was recorded. Generally, plant heights decreased with increase in number of eggmasses, plants inoculated with eight (8) eggmasses produced plants that were significantly shortest (25.6cm) than all other treatments throughout the growth stages of the plants.

Plant height was significantly different amongst okra varieties at 5 and 9 WAP only. At 5 WAP, LD88 produced significantly taller plants (23.5cm) than NHAe47-4 (22.8 cm).

Conversely, at 9 WAP, NHAe47-4 recorded significantly taller plants (34.9 cm) than the LD88 (33.1 cm).

Table 4.1 Effects of inoculum (*M. incognita*) levels on plant height of two varieties of okra Plants at different stages of growth

	Plant Height			
Treatment	**5 WAP**	**7 WAP**	**9 WAP**	**11 WAP**

Inoculum (I)				
Two (2) eggmasses	22.6 b	29.4 b	34.2 b	30.0 b
Four (4) eggmasses	20.9 c	27.9 c	32.8 b	27.7 bc
Six (6) eggmasses	20.8 c	27.7 c	32.7 b	27.6 bc
Eight (8) eggmasses	19.5 d	24.8 d	27.08c	25.6 c
Control	31.4 a	37.2a	43.10a	53.6 a
SE ±	0.46	0.81	1.17	1.50
LSD (0.05)	0.96	1.67	2.38	3.07
Variety (V)				
NHAe47- 4	22.8 b	29.08 a	34.79a	33.2a
LD88	23.3 a	27.7 a	33.9 b	32.9 a
SE±	0.29	0.51	0.74	0.95
LSD (0.05)	0.60	0.05	1.51	1.94
Interaction				
I ×V	NS	NS	NS	NS

Means with the same letter within column are not significantly different at (P< 0.05) level of probability using LSD,

NS -Not Significant

WAP – Weeks After Planting.

4.1.2 Effects of inoculum levels (*M. incognita*) on the number of leaves produced by two varieties of okra plants at different weeks after planting

The effect of inoculum levels on number of leaves of two varieties of okra plants at 5, 7,

9 and 11 WAP as indicated in (Table 4.2) revealed that the parasite (*M. incognita*) significantly affected the number of leaves of the two okra varieties throughout the growth periods evaluated. However, plants inoculated with 8 eggmasses produced the significantly lower number of leaves (3) amongst the treatments. Growing plants of the two varieties on uninoculated (control plots) soils produced plants with significantly

higher leaf number with values ranging between 7 and 8 leaves across the sampling dates 5 – 11 WAP. Leaf number per plant reduced significantly with increase in number of eggmasses across the treatments. At 5 WAP, the number of leaves from the two varieties was statistically similar NHAe47-4 (5) and LD88 (5). A similar trend with (3) number of leaves were produced by plants inoculated with 2, 4 and 6 eggmasses at 9 WAP respectively. Generally, decline in number of leaves was recorded on all treated plants where plants inoculated with 8 eggmasses produced significant lower number of leaves more than other treatments. However, NHAe47-4 plants produced significantly higher leaf numbers (5 and 3) than the (4 and 2) number of leaves obtained with LD88 plants at 7 and 11 WAP respectively.

Table 4.2 Effects of inoculum levels on number of leaves of two varieties of okra Plants at different stages of growth.

	Number of Leaves per plant			
Treatment	5 WAP	7 WAP	9 WAP	11 WAP
Inoculum (I)				
Two (2) eggmasses	5 b	5 b	4 b	2 b
Four (4) eggmasses	5 b	4 c	3 c	2 b
Six (6) eggmasses	4 c	3 d	3 c	2 b
Eight (8) eggmasses	3 d	3 d	2 d	1 c
Control	8 a	8 a	7 a	7 a
SE ±	0.27	0.34	0.45	0.49
LSD(0.05)	0.56	0.69	0.93	0.99
Variety (V)				
NHAe47-4	5 a	5 a	3. a	3 a
LD88	5 a	4 b	3. a	2 b
SE ±	0.17	0.21	0.29	0.30

LSD (0.05)	0.35	0.44	0.59	0.63
Interaction				
I × V	*	*	NS	NS

Means with the same letter within column are not significantly different at (P< 0.05) level of probability using LSD.

* Significant at 0.05

NS - Not Significant

WAP – Week After Planting.

The interaction effects of inoculum levels on number of leaves of two okra varieties at 5 WAP as showed in (Table 4.3) indicated that inoculum had significant effect on reduction of leaf area of okra plants under study. However, the results indicated that NHAe47-4 variety inoculated with eight (8) eggmasses had significant reduction in number of leaves (3) which may be due to severity of infection rate by *Meloidogyne* larvae. On the other hand, LD88 variety plants inoculated with 6 and 8 eggmasses recorded the similar significant reduction in number of leaves (3) than other levels of inoculum.

The interaction effects of inoculum levels on number of leaves of two varieties of okra plants at 7 WAP showed in (Table 4. 4) revealed significant decrease in the number of leaves per plant. NHAe47- 4 inoculated with six (6) and eight (8) eggmassesproduced significantly similar lower number of leaves (3), respectively. These values were significantly lower than the (5) number of leaves obtained with two and four eggmases respectively. However, in LD88 plants the significantly lower number of leaves (3) were obtained with 4, 6 and 8 eggmasses respectively.

4.1.3 Effects of Inoculum levels on stem girth of the two okra varieties at different stages of growth

The effects of inoculum levels on stem girth of two okra varieties at 5, 7, 9 and 11WAP is shown in (Table 4.5) the results revealed that there was a significant effect on plant stem girth throughout the sampling periods in this study. At 5 WAP, plants inoculated with 2, 4, 6 and 8 eggmasses recorded statistically similar stem girth (2.1,1.9,1.9, and 1.7cm respectively). At 7 and 9 WAP, inoculating plants with 2 eggmasses produced girth of plants (2.5 and 2.8cm) respectively which were significantly bigger than those of the plants inoculated with 8 eggmasses (1.9 and 2.3 cm respectively). Values obtained with plants inoculated with 4 and 6 eggmasses at this stage were similar with values

Table 4.3: Interaction Effects of inoculum levels on number of leaves of two varieties of okra Plants at 5 weeks after planting.

Variety		NHAe47-4
Inoculum (i)		
Two (2) eggmasses	5 b	5 b
Four (4) eggmasses	5 b	4 c
Six (6) eggmasses	4 bc	3 d
Eight (8) eggmasses	3 c	3 d
Control	7.5a	8.5a
SE±	0.38	

Means with the same letter are not significantly different at (P< 0.05) level of probabilityusing LSD.

LD88

Table 4.4 Interaction effects of inoculum levels on number of leaves of two varieties of okra plants at 7 weeks after planting

	Variety	
Inoculum (i)	NHAe47-4	LD88
Two (2) eggmasses	b	b
Four (4) eggmasses	b	c
Six (6) eggmasses	c	c
Eight (8) eggmasses	c	c
Control	a	a
SE±	0.48	

Means with the same letter are not significantly different at (P< 0.05) level of probability using LSD

Table 4.5 Effects of (*M. incognita*) inoculum levels on stem girth of two varieties of okra plants at different stages of growth.

Stem Girth (cm)

Treatment	5 WAP	7 WAP	9 WAP	11WAP
Inoculum (I)				
Two (2) eggmasses	2.1 b	2.5 b	2.8 b	2.9 b
Four (4) eggmasses	1.9 bc	2.4 bc	2.6 bc	2.8 bc
Six (6) eggmasses	1.9 bc	2.3 c	2.4 c	2.8 b
Eight (8) eggmasses	1.7 bc	1.9 d	2.3 d	2.7 c
Control	2.7 a	3.0 a	3.6 a	3.7 a
SE ±	0.06	0.10	0.08	0.07
LSD (0.05)	0.12	0.21	0.17	10.12
Variety (V)				
NHAe47-4	2.13 a	2.48 a	2.83 a	3.01 a
LD88	2.10 a	2.37 a	2.73 a	3.01 a
SE ±	0.04	0.06	0.05	0.05
LSD (0.05)	0.08	0.13	0.11	0.10
Interaction				
I × V	NS	NS	NS	NS

Means with the same later within column are not significantly different at ($P < 0.05$) level of probability using LSD.

NS – Not Significant WAP – Week After Planting. ranging between 2.3 and 2.6 cm. At

11 WAP, inoculating with 2 - 6 eggmasses

produced statistically similar girth of stems (2.9, and 2.8 cm, respectively) while the uninoculated plants recorded significantly biggest stem girths at all the stages of the plant growth (5-11 WAP).

4.1.4 Effects of inoculum levels (*M. incognita*) on the leaf area of two varieties okra plants at different stages of growth

The (Table 4.6) shows the effect of inoculum levels on leaf area of two varieties of okra plants at 5, 7, 9 and 11 WAP. Generally, a decrease in the leaf area was recorded with increase in the number of lavae in the inoculum. For instance, at 5WAP, inoculating plants with 6 and 8 eggmasses produced significantly lower leaf area (50.3 and 48.7 cm) than when plants were inoculated with 2 eggmasses (63.2cm). At 7 and 9 WAP, significantly smallest leaf areas were obtained on plants inoculated with 8 eggmasses (51.5 and 35.1 cm respectively) than the 64.4 and 46.3 cm leaf area values recorded with leaves of plants inoculated with 2 eggmasses. Results at 11 WAP, revealed that the significantly lowest leaf areas were obtained with leaves of plants that were inoculated with 6 and 8 eggmasses which values were 38.9 and 37.3cm
respectively.

However, plants of the uninoculated plots (control) yielded leaves with significantly largest leaf areas during the sampling stages. Variety on the other hand did not affect the trait significantly except at 11 WAP where LD88 plants produced leaves with 53 cm: a value which was significantly larger than the 49 cm recorded by NHAe47-4 leaves.

The interaction effects of inoculum levels on leaf area of two varieties of okra plants at 11 WAP is shown in (Table 4.7), NHAe47-4 plants inoculated with different

noculums levels exhibited significant differences in the leaf areas. Plants inoculated with eight (8) eggmasses produced significantly smallest leaf areas (35 cm) than (53 and 47cm) recorded with leaves of the plants inoculated with 2 and 4 eggmasses. Conversely, in LD88, inoculating plants with 6 and 8 eggmasses resulted in the significantly smallest leaf areas than the (51 cm) recorded with plants inoculated with 2 eggmasses.

Similarly, plants of the two varieties in the control plots produced leaves with significantly largest areas (69 and 95 cm respectively).

Table 4.6 Effects of inoculum levels on leaf area of two varieties of okra plants at different stages of growth.

	Leaf Area (cm^2)			
	5 WAP	7 WAP	9 WAP	11 WAP
Inoculum (I)				
Two (2) eggmasses	63.2 b	64.4 b	46.3 b	52.4 b
Four (4) eggmasses	56.2bc	61.5 b	44.3 b	46.1 c
Six (6) eggmasses	50.3 c	57.5bc	40.6bc	38.9 d
Eight (8) eggmasses	48.7 c	51.5 c	35.1 c	37.3 d
Control	85.3 a	86.6 a	72.9 a	81.8 a
SE ±	4.96	4.32	3.11	2.73
LSD (0.05)	10.12	8.81	6.34	5.56
Variety				
NHAe47-4	60.4a	62.9a	47.5 a	49.4 b
LD88	61.3a	65.4 a	48.1 a	53.1 a
SE ±	6.40	5.58	4.01	3.52

LSD (0.05)	0.08	0.13	0.11	0.10
Interaction				
I × V	NS	NS	NS	*

Means with the same letter within column are not significantly different at ($P < 0.05$) level of probability using LSD.

* Significant at 0.05

NS –Not Significant

Table 4.7 Interaction effects of inoculum levels on leaf area(cm^2) of two varieties of okra plants at 11 Weeks after planting

Variety		
	NHAe47-4	LD88
Inoculum (I)		
Two (2) eggmasses	53.7 b	51.1b
Four (4) eggmasses	47.7bc	44.6bc
Six (6) eggmasses	40.5cd	38.7c
Eight (8) eggmasses	35.8 d	37.4c
Control	69.7a	93.9a
SE±	3.86	

Means with the same are not significantly different at (P uyy< 0.05) level of probability using LSD.

4.1.5 Effects of inoculum on the number of days to flower bud on two varieties of okra.

The effects of inoculum levels on the number of days to first flower bud on two varieties of okra plants as showed in (Table 4.8) The result indicated that inoculum (*M. incognita*) had significant effect on number of days in sighting first flower buds on the two varieties of okra cultivars under study. *M. incognita* induced bud initiation, the rate increased with increase in the levels of eggmasses. Flower bud sight was significantly delayed with 44 days from planting in the uninoculated plants against the earliness recorded with inoculated plant irrespective of the levels of eggmasses, with values ranging between 40 and 42 days.

Variety did not affect days to first flower bud significantly, the days to first flower b2ud sight on plants of NHAe47-4 and LD88 were (42 and 41, days respectively).

Variety significantly varied in their attainment to first flower bud sight when subjected to different levels of eggmasses of the *M. incognita* (Table 4.8). In NHAe47-4,

inoculation of plants with 2, 4, 6 and 8 egmasses resulted in significant earliness to flower bud formation; which were in the range of between 40 and 41 days. Flower bud initiation was significantly delayed with plants that were uninoculated (45 days). Conversely, the significant earliness to flower bud initiation on LD88 plants was recorded when 8 eggmasses of the *M. incognita* was used for inoculation. Inoculating LD88 plants with any of 2, 4, and 6 eggmasses yielded flower buds at statistically similar days from planting (41 – 42 days).

4.1.6 Effects of inoculum levels on number of days to flower bud opening on two varieties of okra plants

Inoculating the two varieties in this study with any of the eggmass treatment between 2 and 8 eggmasses resulted to opening of the formed flowers at about 55 days (Table 4.8). Flower bud opening was significantly delayed (59 days) when plants were not inoculated compared to the results of other eggmass treaments. Variety in this case did not 2affect this trait significantly. Flowers on the two varieties opened at about (56 days).

4.1.7 Effects of inoculum levels on number of days to 50% flower opening of the two varieties of okra plants

The effects of inoculum on number of days to 50 % flower opening of the two okra varieties was significant (Table 4.8). Plants inoculated with 2, 4, 6 and 8 eggmasses attained 50% flowering significantly earlier (56 - 58 days) than the uninoculated plants (60.8 days). Variety did not affect days to 50% flowering significantly in this study (57 – 58 days).

The results showed in (Table 4.9) indicated the interactions effects of inoculums on two cultivars tested. Number of days, 40 and 41 days flower buds were sighted on NHAe47-4 plants inoculated with 4, 6 and 8 eggmasses were statistically similar to LD88 cultivar inoculated with 8 eggmasses which indicated the earliness in sighting of buds .

However, number of days, 43 and 45 days were recorded for the control plants which were significantly highest for the two cultivars in sighting flower buds,

Table 4.8 Effects of inoculum levels on number of days to first flower bud, flower bud opening, and 50% flowering of two varieties of okra plants

Treatment	Days to 1st flower bud	Days to flower bud opening	Days to 50% Flower opening
Inoculum (I)			
Two (2) eggmasses	42 b	55 b	58 b
Four (4) eggmasses	41c	55 b	57 bc
Six (6) eggmasses	41 c	55 b	57 bc
Eight (8) eggmasses	40 d	54 b	56 c
Control	44 a	59 a	60 a
SE ±	0.43	0.65	0.85
LSD(0.05)	0.88	1.33	1.73
Variety (V)			
NHAe47-4	42 a	55 a	58 a
LD88	41 a	56 a	57 a
SE ±	0.27	0.41	0.54

LSD(0.05)	0.55	0.84	1.10
Interaction			
I X V	*	NS	NS

Means with the same letter within column are not significantly different at (P < 0.05) level of probability using LSD. * Significant at 0.05

NS- Not Significant

Table 4.9 Interaction effects of inoculum levels on number of days to first flower bud of the two varieties of okra plants

	Variety	
Inoculum (I)	NHAe47-4	LD8
Two (2) eggmasses	43 b	42 ab
Four (4) eggmasses	41 c	42 ab
Six (6) eggmasses	41 c	41 b
Eight (8) eggmasses	40 c	40 c
Control	45 a	43 a
SE±	0.61	

Means with the same letter are not significantly different at (P < 0.05) level of probability using LSD.

4.1.8 Effects of inoculum levels on number of productive branches of two varieties of okra plants

The results on the effects of inoculum levels on number of productive branches on two varieties of okra plants as indicated in Table 4.10 shows that inoculum caused significant reduction on number of productive branches produced by the okra plants under study. In this case, similar fewer number of branches were produced by plants inoculated with 2 and 6 eggmsses. Inoculating plants of the two varieties with 8 eggmasses produced significantly fewer number 1 of productive branch per plant than those inoculated with 2 and 4 eggmasses which produced 2 branches each. *M. incognita* free plants, control produced average of 4 productive branches per plant which was significantly highest in the values obtained with other treatments.

NHAe47-4 and LD88 plants produced 2 branches each which were statistically similar.

4.1.9 Effects of noculum levels on number of fruits per plant of two varieties of okra

Effects of inoculums levels on average number of fruits per plant of two varieties of okra per plant is shown in Table 4.10. Eggmasses of M. *incognita* decreases fruits production per plant. The severity increases with increase in the levels of the eggmasses in the inoculum. For example, an average of one fruit per plant was produced when 8 eggmasses were used to inoculate a plant. This value represents a significant difference between the two fruits produced by plants inoculated with 2- 6 eggmasses. Uninoculated plants produced an average of four fruits per plant which is significantly higher than the (1 and 2) fruits from plants which received 2 - 8 eggmasses inoculation. Variety did not significantly affect fruit number per plant.

4.1.10 Effects of inoculum levels on fruit length of two varieties of okra plants

The result in (Table 4.10) shows the effect of inoculum on fruits of two cultivars, plants inoculated with 8 eggmasses produced significantly shortest fruit length, 4.7 cm than those of other inoculum levels 6.2 and 6.8 cm each which were statistically similar in length. Uninoculated plants produced fruits which measured 8.5cm; this value was significantly longer than other treatments. Though, NHAe47-4 plants produced fruits that measured 6.9cm, the value was statistically similar to 6.5 cm fruit length from LD88 plants.

4.1.11 Effects of inoculum levels on fruit diameter of two varieties of okra plants

The effects of inoculum levels on fruit diameter of two varieties of okra plants as shows in Table (4.10) reveal that inoculum had significant effects in the reduction of fruit diameter of okra plants. Plants inoculated with eight (8) eggmasses produced significantly lower fruit diameter (3.2 cm) than other inoculum levels (2 - 6 eggmasses)

which measured 4.2cm each. Fruits of LD88 measured 4.5cm in diameter, this value was significantly bigger than 3.9cm diameter produced by plants of NHAe47-4.

The interaction between inoculum levels on fruit diameter of two varieties of okra plants is shows in (Table4. 11). Inoculating NHAe47-4 plants with 8 eggmasses produced fruits which measured 2.3cm in diameter. This value was significantly smaller than the 4.1, 4.0 and 3.8cm diameters produced by NHAe47-4 plants inoculated with 2, 4, and 6 eggmasses, respectively. Irrespective of levels 2 - 8 eggmasses in the inoculum, fruits produced by LD88 plants were statistically similar in diameters 4.1 – 4.3cm as shows in (Plate IV). The diameter of fruits of uninoculated LD88 plants was (5.5cm) which was significantly biggest than those of other treatments as shows in (Plate V)

Table 4.10 Effects of inoculum levels on the number of branches, number of fruit per plant, fruit length and fruit diameter of two varieties of okra plants.

Treatment	Number of branches/plant	Number of fruit / plant	Fruit length (cm)	Fruit diameter (cm)
Inoculum (I)				
Two (2) eggmasses	2 b	2.3 b	7.4ab	4.2 b
Four (4) eggmasses	2 b	2.1 b	6.8 bc	4.2 b
Six (6) eggmasses	1 c	1.9 b	6.2 c	4.1 b
Eight(8)eggmasses	1 c	1.1 c	4.7 d	3.2 c
Control	4 a	3.9a	8.5a	5.3a
SE ±	0.39	0.32	0.58	0.27
LSD (0.05)	0.80	0.64	1.84	0.55
Variety (V)				
NHAe47-4	2 a	2.5a	6.9a	3.9b
LD88	2 a	2.05a	6.5a	4.5a
SE ±	0.25	0.20	0.37	0.17
LSD (0.05)	0.51	0.41	0.75	0.35
Interaction				
I × V	NS	NS	NS	*

Means with the same letter within column are not significantly different at ($P < 0.05$) level of probability using LSD.

* Significant at 0.05

NS – Not Significant

Table 4.11 interaction effects of inoculum levels on fruit diameter (cm) of two varieties of okra plants.

Four (4)	Variety	
	NHAe47-4	LD88
Inoculum (I)		
Two (2) eggmasses	4.1 b	4.3 b
eggmasses 4.0 b	4.3 b	
Six (6) eggmasses	3.8 b	4.3 b
Eight (8) eggmasses	2.3 c	4.1 b
Control	5.08 a	5.53 a
SE±	0.38	

Means with the same letter are not significantly different at (P< 0.05) level of probability using LSD.

Two eggmasses Four eggmasses Six eggmasses Eight eggmasses Control

Plate IV: Dry fruit of NHAe47-4 okra (control) and (infected) plants inoculated at different inoculum levels harvested at 42 days after anthesis (DAA)

Two eggmasses Four eggmasses Six eggmasses Eighteggmasses control

Plate V: Dry fruit of LD88 (control) and inoculated plants at different inoculum levels harvested at 42 days after anthesis (DAA)

4.1.12 Effects of inoculum levels on fresh fruit weight of two varieties of okra plants.

The effects of inoculum levels on fresh fruit weight of two varieties of okra as shown in (Table 4.12) indicates that inoculum had significant reduction on weight of fresh fruit per plant. When plants were inoculated with 8 eggmasses, the average weight of fruit per plant of the two varieties was (9.2g). This value was significantly lower than those obtained with the inoculation with any of the following,: 2 eggmases (18.7g), 4 eggmasses (18.6g), and 6 eggmasses (17.8g). Fruits of 2, 4, and 6 eggmasses weighed statistically similar. Growing or cultivating plants of the two varieties on *M. incognita* free plot, produced fruits which weighed 45.4g, a value significantly higher than those obtained from any of the other treatments. LD88 fresh fruit per plant produced significantly heavier (23.05g) fruit per plant than the (20.80g) weight of fruits from NHAe47-4 plants.

4.1.13 Effects inoculum levels on dry fruit weight of two varieties of okra plants

Application of any of the 2, 4, and 6 eggmasses of the inoculation to plants of the two varieties yielded (16.6g, 14.6g, 14.7g) of dry fruit weights, respectively; these values were statistically similar and significantly higher than the (9.3g) weight of dry fruit obtained when plants were inoculated with 8 eggmasses (Table 4.12) and significantly higher (23.4g) than ones obtained with all the other treatments. Variety did not influence dry fruit weight significantly.

4.1.14 Effects of inoculum levels on fresh plant weight of two varieties of okra plants

The results in (Table 4.12) shows the effects of inoculum levels on weight of fresh plant of the two cultivars of okra. Inoculating plants with any of 4, 6, and 8 eggmasses resulted in weight of fresh plants the values were statistically similar (21.0, 17.4 and 11.9g

respectively). When plants were cultivated on *M. incognita* free plots, the value for weight of fresh fruit plant was 44.0g which was significantly highest than those obtained with each of other treatments. Plants of the NHAe47-4 weighed significantly heaviest 28.8g than the 18.87g recorded in LD88.

4.1.15 Effects of inoculum levels on dry plant weight of two varieties of okra plants

The results in (Table 4.12) indicates significant effects of inoculum in the reduction of dry plant weight of okra varieties under this study. A progressive decrease in weight of dry plant was recorded with increase in the levels of lavae in the inoculum. When 2 and 4 eggmasses were used, dry plants weighed of 8.0 and 7.7g, respectively were obtained, these values were statistically similar and significantly heaviest than the 3.8 and 3.6g weights recorded with the inoculation of 6 and 8 eggmassses, respectively. *M. incognita* free Plants weighed (14.7g) on the average; a value which was significantly heaviest than those of all other treatments. Dry plants weight of LD88 was significantly (8.7g) heavier tha2n the dry weight (6.4g) of NHAe47-4 plants.

The interaction between inoculum levels on fresh fruit weight of two varieties of okra plants as showed in (Table 4.13) reveals that NHAe47-4 plants inoculated with 8 eggmasses produced fresh fruit with the lowest weight (9.8 g) inoculating with 4 and 6 egmasses produced fruits weight (16.5 and 14.3g respectively) which was statistically similar and significantly (heavier) than the ones obtained with 8 eggmasses. Plants on the control plots yielded significantly higher weights (40.2g) of fruits than all the other treatments. In LD88, inoculating with 4 and 6 eggmasses resulted in fruits weights of 20.1g and 12.3g respectively which were significantly different from each other. LD88 plants on the *M. incognita* free plots produced more fruits which translated to weight of

50.7g, this fruit weight was significantly the heaviest compared to those of other treatments.

The interaction effects of inoculums levels on fresh fruit weight of two okra varieties was significant. NHAe47-4 plant inoculated with 8 8eggmasses produced significantly lowest fruit weight (9.8g) than other treatments (14.3, 16.5, and 23.4g), and in a similar case with LD88 plant inoculated with 8 eggmasses produced significantly lowest fresh fruit than the other treatments (12.3, 20.1 and 23.7g) respectively.

The interaction effects of inoculum levels on dry plant weight of the two varieties of okra was also significant (Table 4.14). NHAe47-4 plants inoculated with 2 (6.0g) and 4 (5.5g) differ significantly with each other in dry weights. However, in LD88 the weight recorded from inoculation of the same 2 (10.1g) and 4 (10g) eggmasses had statistically similar weights for the two varieties, dry plant weights decrease with increase in eggmasses in the inoculum. The best weights were recorded with uninoculated plants.

4.1.16 Effects of inoculum levels on number of seed per fruit of two varieties of okra plants

Inoculum levels on number of *M. incognita* had significant effects on the number of seeds per fruit (Table 4.15). Number of seeds per fruit decreased with increase in the level of inoculum. When 2 eggmases were used to formulate the inoculum, 43 seeds were counted per fruit; the seed number decreased to 34, 31 and 24 seeds with 4, 6 and 8 eggmasses in the inoculums, respectively. The values obtained when 4 and 6 eggmasses were used were statistically similar and significantly higher than the one obtained with 8 eggmasses. *M. incognita* free plants established better and yielded more on the average of 90 seeds per fruit.This number was significantly higher than those of

other treatments. Fruits of NHAe47-4 produced significantly higher seed number (51) than the (38) seeds obtained from LD88 fruits

Table 4.12 Effects of inoculum levels on the weight of fresh fruit per plant, dry fruit per plant, fresh plant, dry plant on two varieties of okra plants roots.

Treatment	Weight of fresh fruit per plant(g)	Weight of dry Fruit per plant(g)	Weight of fresh plant (g)	Weight of dry plant (g)
Inoculum (I)				
Two (2) eggmasses	18.7b	16.6b	21.0 b	8.0 b
Four (4) eggmasses	18.6b	14.6b	17.4bc	7.7 b
Six (6) eggmasses	17.8b	14.7b	12.4c	3.8 c
Eight (8) eggmasses	9.2c	9.0 c	11.9c	3.6 c
Control	45.4a	23.4a	44.0a	14.7 a
SE ±	1.53	1.58	3.25	0.17
LSD(0.05)	3.13	2.23	6.64	0.35
Variety (V)				
NHAe47-4	20.8 b	15.1 a	28.8 a	6.4 b
LD88	23.1 a	15.9a	18.8 b	8.7 a
SE ±	0.97	1.00	2.05	0.12
LSD(0.05)	1.97	2.04	4.19	0.22
Interaction (I)				
I × V	*	NS	NS	*

Means with the same letter within column are not significantly different at (P< 0.05) level of probability using LSD.

* Significant at 0.05

NS – Not Significant.

Table 4.13 interaction effects of inoculum levels on the mean weight of fresh fruit per plant of two varieties of okra plants.

	Variety	
	NHAe47-4	LD88
Inoculum (I)		
Two (2) eggmasses	23.4 b	23.7 b
Four (4) eggmasses	16.5 c2	20.1 b
Six (6) eggmasses	14.3 c	12.3 c
Eight (8) eggmasses	9.8 d	8.6 d
Control	40.2 a	50.7 d
SE±	2.17	

Means with the same letter are not significantly different at (P< 0.05) level of probability using LSD.

Table 4.14 interaction effects inoculum levels on weight of dry plant of two varieties of okra plants.

	Variety	
	NHAe47-4	LD88
Two (2) eggmasses	6.0 b	10.1 b
Four (4) eggmasses	5.0 c	10.0 b

Six (6) eggmasses	3.9 d	3.7 c
Eight (8) eggmasses	3.7 d	3.5 c
Control	13.02 a	16.32 a
SE ±	0.24	

Means with the same letter are not significantly different at (P< 0.05) level of probability using LSD.
Inoculum (I)

4.1.17 Effects of inoculum levels on the 100- seed weight of two varieties of okra plants

(Table 4.15) show that *M. incognita* levels affected 100-seed weight significantly. Inoculating plants of the two varieties with 2, 4, and 6 eggmasses of the *M. incognita* resulted in seeds which average. The 100-seed weighed (3.6, 3.3, and 3.2g, respectively). These values were statistically similar and significantly heavier (2.2g) than 100 –seeds produced by plants inoculated with 8 eggmasses. 100-seeds extracted from fruits which plants received no inoculation were heaviest (3.9g) than those of other treatments. The table further revealed that 100-seeds of NHAe47-4 variety weighed significantly heavier (4.9g) than the (3.7g) weight of seeds from LD88

4.1.18 Effects of inoculum levels on seed moisture content of two varieties of okra plant

The effects of inoculum levels on seed moisture content of two varieties of okra is shown in (Table 4.15). Results indicated that plants inoculated with any of 2, 4, 6 and 8 eggmasses did not differ significantly in seed moisture content with values of 34.4, 34. ,31.5, and 34.6%) respectively. Moisture content of seeds obtained from uninoculated plants contained significantly lowest seed moisture content (28.39%) compared to seeds from other treatments, seed moisture content was also significantly different amongst the two varieties. Significantly higher moisture content (36.9%) was recorded in seeds of LD88 than those of NHAe47-4 (28.9%).

4.1.19 Effects of inoculum levels on the germination percentage of seed of two varieties of okra plants

The effects of inoculum levels on percentage germination of two varieties of okra as shown in (Table 4.15) shows that inoculum had significant effect on reduction of

percentage germination of seeds sampled during the study. Plants inoculated with eight (8) eggmasses produced seeds with significant lower germination percentage (37.1%) amongst all the other treatments. Seeds extracted from plants which were inoculated with 2, 4, and 6 eggmasses had statistically similar values of 70.5, 65.3, and 62.0% respectively. Uninoculated plants produced seeds which germinated readily and significantly highest (98.3%) than those of other treatments.

Variety did not affect germination of seeds (NHAe47-4 (68.3%)and LD88 (66.3%).

Table 4.15 Effects of inoculum levels on number of seed per fruit, 100 -seed weight, seed moisture content and percentage germination of two varieties of okra plants.

Treatment	Number of seed per fruit	100-seed weight (g)	Seed moisture content (%)	Germination (%)
Inoculum (I)				
Two (2) eggmasses	43.3 b	3.6 b	34.4 a	70.5 b
Four (4) eggmasses	34.4 c	3.3 b	34.2 a	65.3 b
Six (6) eggmasses	31.6 c	3.2 b	31.5 a	62.0 b
Eight (8) eggmasses	24.5 d	2.3 c	34.6 a	37.1 c
Control	90.9 a	4.0 a	28.3 b	98.3 a
SE ±	3.71	0.39	1.90	4.89
LSD(0.05)	7.58	0.80	3.89	9.98
Variety (V)				
NHAe47- 4	51.1 a	4.9 a	28.9a	68.3a
LD88	38.8 b	3.7 b	36.9 b	66.3a
SE±	2.35	0.25	1.20	3.09
LSD(0.05)4.70	0.50	2.45	6.32	
Interaction				
I × V	*	NS	NS	NS

Means with the same letter within column are not significantly different at ($P < 0.05$) level of probability using LSD. * Significant at 0.05
NS- Not Significant.

NHAe47-4 plants inoculated with 4, 6 and 8 eggmasses produced 36, 34, and 31 seeds per fruit respectively which were statistically similar in number and significantly fewer than those of 2 eggmasses (47) and control plants 106 (Table 4.16). Plants on the control plots established and developed better and produced fruits which contained significantly more (higher) number of seeds than fruits of the plants inoculated with either 2, 4, 6 and 8 eggmasses as shown in (Plate VI).

In LD88 plants, inoculating plants with 2, 4, and 6 eggmasses yielded 39, 32 and 29 seeds per fruits, respectively. The difference between these seed numbers were not significant. The significantly fewer seed number per fruit was recorded only when 8 eggmasses was used for inoculation compared with other treatments. Again, an average of (75) seeds was counted per fruit when plants were inoculated.This represents a significant value compared with other treatments for this variety as shown in(Plate VII)

Table 4.16 Interaction effects of inoculum levels on the mean number of seed per fruit of two varieties of okra plants.

	Variety	
	NHAe47-4	LD88
Inoculum (I)		
Two (2)eggmasses	47.3 b	39.3 b
Four(4) eggmasses	36.5 c	32.3 b
Six (6) eggmasses	34.0 c	29.3 b
Eight (8) eggmasses	31.0 c	18.0 c
Control	106.5 a	75.3 a
SE±	5.25	

Means with the same letter are not significantly different at ($P< 0.05$) level of probability using LSD.

Two eggmasses Four eggmasses Six eggmases Eight eggmassescontrol

Plate VI: Number of seeds per fruit of (control and inoculated)NHAe47-4 okra plants at different inoculum levels.

Two eggmasses Four eggmasses Six eggmasses Eight eggmass Control.

Plate VII : Number of seeds per fruit of (control and inoculated)LD88 Okra plants at different inoculum levels.

4.1.20 Effects of inoculum levels on total fresh fruits weight per plant of two varieties of okra

The effect of inoculum levels on the total fresh fruits weight per plant of two varieties of okra as described in (Table 4.17) indicate that inoculum had significant effect on reduction of total weight of fresh fruits produced by the two okra varieties under the study. Plants inoculated with 8 eggmasses produced the significant lowest total fresh fruit weight per plant (16.4g) amongst the treatments; 2 eggmasses (36.7g), 4 eggmasses (36.5g), 6 egmasses (31.9g), and the control (212.0g). The significant highest fresh fruits weight amongst the treatments was obtained when plants were not inoculated values of fresh fruits weight obtained amongst the two varieties did not statistically differ from each other (NHAe47-4 65.8g, LD88 67.8g).

4.1.21 Effects of inoculum levels on the total weight of dry fruits per plant of two varieties of okra plants (g)

Inoculum had significant effect in reduction of total weight of dry fruits of okra in this study (Table 4.17). When plants were inoculated with 6 and eight 8 eggmasses, the plant produced significant lowest dry fruit weight per plant amongst the treatments, (2 eggmasses 29.9g), (4 eggmasses 23.5g). Control plants produced dry fruits per plant with the significant highest total weight of dry fruits (50.7g). Again, variety did not affect total weight of dry fruits per plant in this study NHAe47-4, (27.97g) and LD88, (24.3g).

4.1.22 Effects of inoculum levels on severity of galls on the roots of two varieties of okra plant

Inoculum levels affected this trait significantly (Table 4.17). The severity of galls on the roots of two varieties of okra increased with increased in the levels of eggmasses in the

inoculum. For example, inoculating plants with 2 and 4 egmasses presented roots which were moderately resistant (2). When 6eggmasses were used for

inoculation, roots of the affected plants were observed to be moderately susceptible (3). Plants which received inoculation of 8 eggmasses showed roots which were all susceptible to *M. incognita* (4). Wheras uninoculated plants produced roots which were not infected (0) by the *M. incognita* as shown in (Plates VIII and XIX).

Table 4.17 Effects of inoculum levels on total weight(g) of fresh fruits per plant, dry fruits per plant and severity of galls of two varieties of okra plants.

	Total weightof freshfFruits (g)	Total weight of dry fruits(g)	Severity of galls on the roots
Treatment			
Inoculum (I)			
Two (2) eggmasses	36.7 b	29.9 b	2 c
Four (4) eggmasses	36.5 b	23.5 b	2 c
Six (6) eggmasses	31.9 b	13.6 c	3 b
Eight(8) eggmasses	16.4 c	13.1 c	4 a
Control	212.0 a	50.7 a	0 d
SE ±	12.44	4.51	0.31
LSD(0.05)	25.39	9.23	0.63
Variety			
NHAe47- 4	65.81 a	27.9 a	2a
LD88	67.81 a	24.3 a	2 a
SE±	7.86	2.85	0.19
LSD(0.05)	16.10	6.82	0.39
Interaction (I)			
I × V	NS	NS	NS

Means with the same letter within column are not significantly different at (P< 0.05) level of probability using LSD.

NS - No Significance

Variety	Inoculum	Gall index
NHAe47-4	Two (2)eggmasses	2.

	Four (4) eggmasses	3.	**4.18 Rating scale for the assessment of root-knot nematode (*Meloidogyne incognita*) infection on roots of two varieties of okra plants (Otipa et al., 2003)**
	Six (6) eggmasses	3	
	Eight (8) eggmasses	4	
	Control	0	
LD88	Two (2) eggmasses	2.	
	Four (4) eggmasses	2.	
	Six (6)eggmasses	3.	
	Eight (8)eggmasses	.	
	Control	0	

Galls score on roots;(0) Not infected, (2) Moderately resistant (3.) Moderately susceptible (4) Highly susceptible.

Two eggmasses Four eggmasses Six eggmasses Eight eggmasses Control

Pate VIII : Control and infected roots of NHAe47-4 okra cultivar inoculated at different inoculum levels.

Two eggmasses Four eggmasses Six eggmasses Eight eggmasses control

Plate XIX: : Control and infected roots of LD88 (control) and inoculated plants at different inoculum levels

4. 2 Discussion

The significantly shorter plants recorded with higher eggmasses of root knot nematode (*Meloidogyne incognita*) may be attributed to the ability of the nematode second stage larvae to have eaten up part of the roots of the inoculated plants which inhibited the utilization of growth factors such as nutrients, water among others. This condition is known to translate into the production of shorter plants. This finding supports the earlier report of Agwu and Ezigbeo (2005) who observed some pathological changes on the inoculated plants. The authors stated that the pathological changes manifested into shorter shoot heights.

Lower fruit weights, root weights and most importantly poorer fruit development and maturation were noticeable in this study due to the significant effect of nematodes. The significant reduction in growth observed on aerial parts of all the inoculated plants

during the study such as fewer number of leaves, lower stem girth reduced leaf area with coloration (chlorotic), reduced fruit length and diameter, fewer number of fruits per plant, may be linked to damages caused by nematodes when they became sedentary and established feeding sites on the roots of treated plants; these consequently resulted to poor growth as observed on growth parameters during this
study.

This confirms the report of Hussain *et al.*,(2016b) who stated that due to the inadequate supply of water, nutrients, photosynthates and energy, growth and developments of leaf tissue and its constituents especially chlorophyll pigments are adversely affected. Kayani *et al*., (2017) also stated that poor growth of foliage subsequently leads to decreased production. Dhaliwal *et al*., (2012) reported that plants with infected roots are more susceptible to other diseases caused by fungi and bacteria and tend to reduce production capacity of crop species.

However, increased in nematode (*Meloidogyne incognita*) population also affected number of days to first flower buds were sighted, and when plants attained 50%flowering. This could be as a result of stress from nematode attack on plant roots which was responsible for slow release of bio-degradable foods substances, photosynthate and other minerals to be transported by water which is a vehicle for transporting nutrients from the roots to all parts of the shoot (growing points). This is in agreement with Daramola *et al*. (2015) who stated that stressed plants flowered early as a mechanism to reduce exposure to the stress and complete the reproductive
cycle.

Effects of inoculum caused reduction of fruit number, fruit length, fruit diameter and productive branches. Few numbers of fruits per plant, small fruit diameter and poor branching produced by plants could be due to infection with *M. incognita*. The study further indicated that plants inoculated with 8 eggmasses significantly reduced fresh fruit weight, dry fruit weight, fresh plant, while reduced dry plant weight recorded for plants inoculated with 6 and 8 eggmasses could be as a result of impaired roots attacked by nematode which limited nutrient supply to the upper parts of the plant for the formation and development of fruits.

This is in agreement with the findings of Di Vito *et al*., (2004) who stated that infection also greatly reduces permeability of roots to, the infection in plant roots by *M.incognita* induces the formation of nurse cells and regulates greater translocation of photosynthates towards infected root tissue while other parts (foliage) experience shortage. Low stimulation in root tissues formation occurs when there is a build-up in nematode population in the plant roots resulting to poor shoot growth and branches resulting to low fruits on the mother plants.

Low nematode levels stimulating plant growth, food production and maturation have been reported by Agwu and Ezigbeo (2005). Significant reduction in number of seeds,100 seed weight, seed moisture content (%) and percentage germination recorded for all the parameters indicated effects of inoculum resulting from activities of nematodes which inhibited optimum production, this is supported by findings of Patil and Gaur (2014) who reported that nematode infection in soybean caused significant reduction in pod, seed number and 100-seed dry weight thereby leading to reduction in seed production and quality.

The reductions in yield parameters in the two okra cultivars investigated were attributable to root injuries due to penetration or feeding by the nematodes leading to

impairment of the efficiency of root systems to absorb water. However, plants inoculated with 6 and 8 eggmasses which showed significant effects of inoculum resulted to reduced total weight of fresh fruits, dry fruits, yield per hectare of fresh, dry fruits and seed yield. This could be attributable to low absorption of minerals and other photosynthates which resulted to reduced fruit weight due to poor dry matter accumulation during physiological maturity and consequent yield reduction hence this agreed with the report of Hussain *et al* (2011) who stated that of all the pathogens, the attack of root-knot nematodes (*Meloidogyne incognita*) are the most serious, widespread and alarming which caused tremendous yield losses.

This translated to significant yield reduction according to various inoculum levels in the two okra cultivars evaluated leading to significant yield reduction in terms of dry matter and fruit yield as observed on plants inoculated with 6 and 8 eggmasses.

The significantly taller plants recorded by NHAe47-4 variety could be attributed to its inherent genetic potential towards exhibiting resistance to nematode effect by not allowing the nematode attack during early growth than LD88. This finding is in agreement with the work of Hussain *et al*., (2014) who reported that variations were noticed among okra cultivars in their response to the nematode and suggested that resistance within a plant species is often due to specific genes that segregate within the species, and for non-host species or resistance cultivars, nematode cannot reproduce on that plant due to boarder absence of host trait required for parasitism. Early emergence of first flower bud observed on plants inoculated with different levels of inoculum might be attributable to presence of nematodes juveniles second stage which caused stress resulting from injuries on roots which stimulated the plants into emergence of flower buds earlier than the control plants.

However, similar trend observed on the two cultivars of plants inoculated with 8 eggmasses recorded the least number of days, followed by other inoculum levels which varied in number of days first bud was sighted on each plant. This finding was in conformity with the findings of Daramola *et al*., (2015) who reported that stressed plants flowered early as a mechanism to reduce exposure to the stress and complete the reproductive cycle and that infection with *M. incognita* resulted in the early dropping of flowers and per-mature dropping of fruits which results to fewer and
smaller fruits.

The effect of interaction of inoculum levels on dry plant weight of two varieties of okra showed reduction in dry plant weight due to significant effect of different levels of inoculation in this study. Lower dry weight recorded by NHAe47-4 plant inoculated with 6 and 8 eggmases and similar effects also on LD88 plant inoculated with (6) and (8) eggmasses could be due to low nematode levels which stimulated plant growth, food production and maturation, however, stimulation of growth occurred at low infection levels of 2 and 4 eggmasses levels of inoculation while at higher infection levels, suppression of growth occurred. Production of lateral roots was stimulated at low infection depending on the level of susceptibility of the plant, which accounted for the increased root weight of the plants and possibly increased nutrient uptake to the shoot. This finding explained why LD88 dry plant inoculated with 2 and 4 eggmasses which recorded heavier dry plant weight than NHAe47-4 inoculated with the same level of inoculums and this is supported by the findings of Castagnone-Sereno (2006) who reported that the differences in the susceptibility to *M. incognita* in okra cultivars is due to differences in their genetic make up which can be explained in terms of number of galls in the roots.

Higher moisture content observed in seeds of two okra varieties investigated in this study could be due to nematode infection which subjected the plants to stress of nutrient uptake during seed formation and development. This finding is in agreement with Pádua *et al.*, (2009) who stated that, when under stress conditions, seed can mature faster than as normal, and enzyme activity stops before all the chlorophyll has been degraded, also stated that soybean plants subjected to hydric and thermal stress produce high numbers of green seeds with a smaller size and weight and high

chlorophyll content with low chlorophyllase activity. Therefore, from this finding, the effects of nematode could be responsible for small size, low weight of seeds and high seed moisture content as a result of little dry matter which only accumulated during seed maturation following enzymatic activity which stopped early in the seeds of plants infected by root- knot nematode (*Meloidogyne incognita*).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The results of this findings did not showed any significant differences between okra cultivars in their responses to *M. incognita* which indicated that inoculum of nematode (*Meloidogyne incognita*) at all levels of inoculation caused reduction in plant height, leaf area, stem girth, number of leaves, number of days to first flower bud,50% flowering ,number of fruit per plant, fruit length, total weight of fresh and dry fruit yields on the plants investigated. However, effects of nematodes (*M .incognita*) also caused reduction in number of seeds per fruit, 100-seed weight and poor germination percentages obtained from okra cultivars inoculated with 2, 4, 6 and 8 eggmasses compared to seeds of control plants which produced significantly higher germination percentages.

This indicated that lower number of nematode has minimal effect on the okra varieties tested.

5. 2 Recommendation

Based on the results of this study, it is recommended to undertake a further study to investigate various management and control approaches to mitigating the growth inhibitory and in some cases total crop failure. The use of organic nutrients sources, cultural practices and chemical substances are amongst the possible alternatives.

5. 3 Contribution to Knowledge

(i) The study provided knowledge on the pathogen as one of the highly known and widely spread pathogen injuring okra plants.

(ii) The knowledge from the study is beneficial to farmers who produces okra either in small or in commercial scales on the identification and management of the pathogen in okra fields.

(iii) The study provided knowledge which revealed that parasite (*Meloidogyne incognita)* caused serious decrease in growth, quantities and qualitiesn in both fruit and seed yields at all levels of inoculation of okra plants (2, 4, 6 and 8 eggmasses).

REFERENCES

Abad, P., P. Castagnone-Sereno, M.N. Rosso, J. de Almeida Engler & B. Favery. 2009. Invasion, feeding and development. In: R.N. Perry, M. Moens, J.L. Starr (eds.), Root-knot Nematodes. *CABI International, London, UK,* pp.163-181

Aguair, J. L., Mc Giffin, M., Natwick, E. &Takele, E. (2011).Okra production in California.U.C Ahmad, Z.,Saifullah, F. Raziq, H. Khan and M. Idrees. 2012.Chemical and biological control of *Fusarium* root rot of okra. *Pakistan Journals of Botany*. 44(1), 453-4.

Agwu, J. E. & J. C.Ezigbeo, (2005).Effect of root-knot nemetode (*Meloidogyne incognita*) on the development of *Abelmoschus esculentus* (Okra). *Animal Research International*, 2: 358-362.

Ahmad T, Abraham F, Mohammedsaid H, Welday N & Gebrehiwet. S (2015). Seasonal incidence of insects and diseases on okra (*Abelmoschus esculentus*) crop in zoba Anseba. *International Resources Journal of Biological Sciences.*4 (1),71-74.

Akanbi, W. B., Togun, A. O., Adediran, J. A., & Ilupeju, E. A. O. (2010). Growth, dry matter and fruit yields components of okra under organic and inorganic sources of nutrients. *American-EurasianJournal of Sustainable Agriculture*, 4(1), 1-13.

Anwar, S.A. & M.V. McKenry (2012). Incidence and population density of plantparasitic nematodes infecting vegetable crops and associated yield losses. *Pakistan Journal of Zoology.* 44:327-333**.**

Anwar, S.A., A. Zia, M. Hussain, & M. Kamran (2007). Host suitability of selected plants to *Meloidogyneincognita*in the Punjab, *Pakistan. International Journals of Nematology*. 17:144-150.

Archana, B. & R. Saxena (2012). Nematicidal effect of root extract of certain medicinal plants in control of *Meloidogyne incognita in vitro* and *in vivo* conditions. *Pakistan Journal of Nematology*. 30 (2): 179-187.

Atiri, G.I., A.P. Njukeng& E.J.A. Ekpo, (2000). Climate in Relation to Plant Virus Epidemiology and Sustainable Disease Management in West Africa. *Journal of Sustainable Agriculture*, 16, 17-30.

Akintoye, H. A., Adebayo, A. G., & Aina, O. O. (2011). Growth and yield response of okra intercropped with live mulches. *Asian Journal of Agricultural Research*,5 (2), 146-153.

Babatunde, R.O., A. O. Omotesho&Sholotan, (2007). Socio-Economic Characteristics and foodBegomovirus characterization and development of phenotypic and DNA-based diagnostics. *Biotechnology*.3(6),461 – 470.

Bairwa, A. & H.R. Patel, (2016). Comparative pathogenicity of reniform nematode on root-knot resistantand susceptible bidi tobacco. *Journal of Parasitic Diseases*, 40, 714-723.

Beneventi, M.A., Silva, O.B., Sá, M.E.L., Firmino, A.A.P., Amorim, R.M.S., Albuquerque, E.V.S., Silva,M.C.M., Silva, J.P., Campos, M.A., Lopes, M.J.C., Togawa, R.C., Pappas, G.J. &Grossi-de-as, M.F.(2013). Transcripton profile of soybean-root-knot nematode interaction reveals a key role of phythormones in the resistance reaction. *BMC Genomics*, 14, 322-339.

Castagnone-Sereno,P.(2006).Geneticvariabilityand adaptive evolution in parthenogenetic root knot nematodes. *Heredity* 96, 282–289.

Central Bank of Nigeria CBN (2016) Annual Statistical Bulletin. Available *at http://www.cbn.gov.ng/documents/statbulletin.asp.* Accessed June 27, 2018.

Cirrinicione, P., Tefft, P.M. & Springer, C.J. (2009). The effect of early soybean cyst nematode infection on soybean growth and physiology. *Journal of Nematology*, 41,319.

Collange, B., M. Navarrete, F. Montfort, T. Mateille, J.Tavoillot, B. Martiny& M. Tchamitchian (2014).Alternative cropping systems can have contrastingeffects on various soil-borne diseases: Relevance of a systemic analysis in vegetable cropping systems. *CropProtection*. 55, 7-15.

Daramola, F.Y., J.O. Popoola, A. O. Eni & O. Sulaiman, (2015). Characterization of Root-knot Nematodes (*Meloidogyne* spp.) Associated with *Abelmoschus esculentus*, *Celosia argentea* and *Corchorus olitorius*. *Asian Journal of Biological Sciences*, 8, 42-50.

Dhaliwal, G.S., O. Koul,S. Khokhar & R. Singh (2012). Bio pesticides in Environment and Food Security: Issues and Strategies. *Scientific Publishers*,pp 492

Di Vito,M.,Vovlas, N. & Castillo, P. (2004). Host-parasite relationships of *Meloidogyne incognita*on spinach. Plant Pathology,53, 508-514. *http://dx.doi.org*/10.1111/j.1365- 3059.2004.01053.

Dobson, H., Cooper, J., Manyangarirwa, W., Karuma, J., Chiimba,W (2002). Integrated Vegetable Pest Management. Natural ResourcesInstitute, University of Greenwich, UK. ISBN: 0-85954-536-9 OISAT. *Organisation for NonChemical Pest Management in the Tropics*www.oisat.org.

Dong, L., C. Huang, L. Huang, X. Li & Y. Zuo. (2012). Screening plants resistant against *Meloidogyne incognita* and integrated management of plant resources for nematode control. *Crop Protection*. 33: 34-39.

Dong, S., K.Qiao, Y. Zhu, H. Wang, X. Xia & K. Wang.(2014). Managing Meloidogyne incognita and Bemisiatabaci with thiacloprid in cucumber crops in China. *Crop Protection*. 58, 1-5.

Demir, I., Ozden, E., Kara, F., Hassanzadeh, M. & Mavi, K. (2016). Effects of ambient storage temperature and seed moisture content on seed longevity of lettuce (*Lactuca sativa*). *American Journal of Experimental Agriculture*, 12(3), 1 - 5.

França Neto, J. B., Pádua, G.P., Krzyzanowski, F.C., Carvalho, M.L.M. de, Henning, A.A. & Lorini, I. (2012).SementeEsverdeada de Soja: Causas e Efeitossobre o DesempenhoFisiológico – Série Sementes. [SoybeanGreen Seeds: Cause and Effects on the Physiological Performance], *Circular Técnica* 91**,** *embrapacnpso, Londrin*.

Gemede, H. F., Haki, G. D., Beyene, F., Woldegiorgis, A. Z., &Rakshit, S. K. (2015). Proximate mineral,and antinutrient compositions of indigenous Okra (*Abelmoschus esculentus*) pod accessions: implications for mineral bioavailability. *Food science & nutrition*. 4(2), 223–233.

Hager GA, Wax M.L, Bollero A.G (2002). Common water hemp (*Amaranthus rudis*) interference in soybean. *WeedScience*. pp. 607 – 610.

Hussain, M. A., Mukhtar, T. & Kayani, M. Z. (2014). Characterization of susceptibility and resistance responses to root-knot nematode (*Meloidogyne incognita*) infection in okra germplasm. *Pakistan Journals of Agricultural Sciences*, 51, 319-324.

Hussain, M. A., Mukhtar, T. & Kayani, M. Z. (2016a). Reproduction of *Meloidogyne incognita* on resistant and susceptible okra cultivars. *Pakistan Journal of Agricultural Sciences*, 53, 371- 375.

Hussain, M. A., Mukhtar, T., Kayani, M. Z., Aslam, M. N. & Haque, M. I. (2012). A survey of okra (Abelmoschus esculentus) in the Punjab province of Pakistan for the determination of prevalence, incidence and severity of root-knot disease caused by *Meloidogyne spp*. *Pakistan Journal of Botany*, 44, 2071-2075.

Hussain, M., M. Kamran K. Singh M.Zouhar,P.Ryšáne& S.A Anwar (2016c). Response of selected okra cultivars to *Meloidogyne incognita*. *Crop Protection*. 82,1-6.

Hussain, M.A., T. Mukhtar & M.Z. Kayani. (2011). Assessmentof the damage caused by *Meloidogyne incognita* on okra. *Journals ofAnimal and Plant Science*. 21, 857-861.

Hussain, M.Zouhar.,M., Rysanek,P. & Anwar, S.A.,(2016b). Relationship between *Meloidogyne incognita* density and plant growth of okra. *Journal of Animal and Plant Science.*, 26 , 739-744

Hussey, R.S. & K.R. Barker. 1973. A comparison ofmethods of collecting inoculum of Meloidogyne spp including a new technique. *Plant Diseases*. Rep. 57: 1025–1028.

Ibrahim, H. &Oladiran, J.A. n (2011). Effect of fruit age and position on mother-plant on fruit growth and seed quality in Okra (*Abelmoschus esculentus* L. Moench.). *International Journal of Science and Nature* (I.J.S.N.), 2**,**587-592.

Ibrahim, I.K.A.; Mokbel, A.A. &Handoo, Z.A. (2010)**.** Current status of phytoparasitic nematodes and their host plants in Egypt. *Nematropica* 40 (2), 239-262.

Ijoyah, M.O., Atanu, S.O. &Unah, P.O. (2009). Productivity of okra (*Abelmoschus esculentus* L.) Moench) varieties as influenced by seasonal changes in Makurdi, Nigeria. *Proc. of 27th Annual Conference of the Horticultural Society* of Nigeria held at Kano, Nigeria 11 – 16 Oct. 2009 pp159 - 165 Medagam, T. R., Mutyala, H. B., Konda, C. R.,

Iyagba, A.G., Onuegbu, B. A. Ibe,A. E. (2013).Growth and response of Okra (*Abelmoschus esculentus* (L) Moench) to NPK Fertilizer rates and Weed interference in Southern Nigeria. *International Resources Journals of Agricultural Society of Soil Science*. 3(9), 328-3.

Kamran, M., S.A. Anwar, N. Javed, S.A. Khan, H.Abbas, M. A. Iqbal & M. Zohaib (2013).The Influence of *Meloidogyne incognita* density on susceptible tomato. *Pakistan Journals of Zoology* 45,727.

Kayani, M. Z., Mukhtar, T. & Hussain, M. A. (2017). Effects of southern root knot nematode population densities and plant age on growth and yield parameters of cucumber. Crop Protection, 92, 207-212http://dx.doi.org/10.1016/*journals of crop production*. 2016.09.007.

Kayani, M.Z., T. Mukhtar, M.A. Hussain, & M.I. Haque (2013). Infestation assessment of root-knot nematodes(*Meloidogyne* spp.) associated with cucumber in the Pothowar region of *Pakistan Crop Protection.* 47, 49-54.

Kenanoglu, B.B., Demir, I. &Jalink, H. (2013). Chlorophyll Fluorescence sorting method to improve quality of *Capsicum* Pepper seed lots produced form different maturity fruits. *Horticultural Science*, 48, 965-968.

Khan, A. R., Javed, N., Sahi, S.T., Mukhtar, T., Khan, S.A. & Ashraf, W., (2017). BSecurity Status of Farming households in Kwara State, North Central Nigeria. *Pakistan Journal of Nutrition*, 6, 49-58.

Koyama, T., (2014). The roles of ethylene and transcription factors in the regulation of onset of leaf senescence. Frontiers in Plant Science, 5: 650. Maramag, R.P., (2013). Diuretic Potential of *Capsicum frutescens* Linn., *Corchorus oliturius* Linn., And *Abelmoschus esculentus* Linn. *Applied Sciences* 2,10

Kumar, D. S., Tony, D. E., Kumar, A. P., Kumar, K. A., Srinivasa, D. B., &Nadendla, R. (2013). A review on Abelmoschus esculentus (Okra). *International Research Journal of Pharmaceuticaland Applied Science, 3*, 129-32.

Maramag, R. P.(2013). Diuretic potential of *Capsicum frutescens* L., *Corchorus oliturius*L., and *Abelmoschus esculentus* L. *Asian journal of natural and applied science,* 2(1), 60- 69. *Meloidogyne incognita*. *Crop Protection*. 44, 13– 17.

Mihretu, Y., G. Weyessa& D. Adugna, (2014). Variability and Association of Quantitative Characters among Okra (*Abelmoschus esculentus* (L.) Moench) Collection in South Western Ethiopia. *Journal of Biological Sciences,* 14, 336342.

Moens, Maurice, Roland. N. Penny &James.L. Starr.(2009) *Meloidogyne species;* a diverse Group of Novel and Important parasites". Wallingford, *United Kingdom Centre for Agricultural and Bio Sciences International (CABI). Publishing*.

Mukhtar, T., Hussain, M.A. & Kayani, M.Z., (2017). Yield responses of 12 okra cultivars to southern root-knot nematode (*Meloidogyne incognita*).

Mukhtar, T., I. Arshad, M.Z. Kayani, M.A. Hussain, S.B. Kayani, A.M. Rahoo and M. Ashfaq. (2013a). Estimation of damage to okra (Abelmoschus esculentus) by root Hussain,Mukhtar and Kayani 31 4 knot disease incited by *Meloidogyne incognita*. *Pakistan. Journal of.Botany*. 45, 1023-1027.

Mukhtar, T., Jabbar, A., Raja, M.U. & Javed, H., (2018). Re-emergence of wheat seed gall nematode (*Anguinatritici*) in Punjab, Pakistan.*Pakistan Journals of Zoology*.,50:1195-1198. https://doi.org/10.17582/journal.pjz/2018.50.3.sc4.

Mukhtar, T., M.Z. Kayani and M.A. Hussain (2013b) Response of selected cucumber cultivars to root-knot nematode (*Meloidogyne incogn*ita). *Crop protection*.44, 13- 17.

Mukhtar, T., M.Z. Kayani &M.A. Hussain. (2013c).Nematicidal activities of *Cannabis sativa*L.and*Zanthoxylum alatum*Roxb. against *Meloidogyne incognita*. *Indonisian Crop Production*. 42, 447–453.

Musa, U.T., & Usman, T. (2016). Leaf Area Determination for Maize (*Zea mays* L), Okra (*Abelmoschus esculentus*L.Moench) and Cowpea (*Vigna inguiculata* L) crops using linear measurement. *Journal of Biology, Agriculture and Healthcare*www.iiste.org ISSN 2224-3208 (Paper) ISSN 2225-093×*(Online)* .6, No. 4.

National Research Council, (2006). "Okra". Lost Crops of Africa, Volume II, Vegetables. Lost Crops of Africa. 2. *National Academies Press.* ISBN: 0-309-66582-5, 378 pages

Naveed, A., A.A. Khan & I.A. Khan, (2009). Generation mean analysis of water stress tolerance in okra (*Abelmoschus esculentus* L.*). Pakistan Journal of Botany*, 41, 195-205.

Ndunguru, J. & A. Rajabu, (2004). Effect of okra mosaic virus disease on the aboveground morphological yield components of okra in Tanzania. *Scientia Horticulturae*, 99: 225-235.

Omotoso.S.O. & O, S. Shittu (2007) Effect of NPK Fertilizer rates and Method of Application on Growth and Yield of Okra (*Abelmoschus esculentus* L.Moench*).Research journal of Agronomy* ,1, 84-87.

Otipa , M. J., Kimenju ,J. W., Mature .E.W., &Karanja,N.K (2003) potential rotation of crops And cropping cycles for root-knot Nematode (*Meloidogyne spp*).Nematode control in tomato, African crop science society., volume 6. 191- 197. *Pakistan Journal of Zoology* 49, 841-847. https://doi.org/10.17582/*journal of pakistan zoology. z*/2017.49.3.841.84

Oyelade, O., B.I. Ade-Omowaye& V. Adeomi, (2003). Influence of variety on protein, fat contents and some physical characteristics of okra seeds. *Journal of Food Engineering,* 57, 111-114.

Pádua, G.P., Carvalho, M.L.M., França Neto, J.B., Guerreiro, M.C. &Guimarães, R.M. (2009). Response of soybean genotypes to the expression of green seed under temperature and water stresses. *RevistaBrasileiradeSementes*, 31, 140-149.

Patil, J. & Gaur, H.S. (2014). The effect of root-knot nematode, *Meloidogyne graminicola*, on the quality andvigour of rice seed. *Nematology*, 16, 555-564.

Patil, J., Miller, A.J. & Gaur, H.S. (2013). Effect of nitrogen supply on the invasion of rice roots by the root-knot nematode, *Meloidogyne graminicola*. *Nematology*, 15, 483-492.

Perry, R.N., M. Moens& F.J. Starr, Eds. (2009). Root-Knot Nematodes.*CABI International, Wallingford, United Kingdom. Glomus mosseae* (Gerd and Trappe) and neemex reduce invasion and development of *Meloidogyne incognita.*

Priya, S., Varun, C., Brahm, K., Shubhendra, S.C., Sobita, S., Bilalc, S., &Abidia, AB. (2014). An Overview on Okra (*Abelmoschus esculentus*) and It's importance as a Nutritive Vegetable in the World. *International Journal of Pharmacy and Biological Sciences* 4(2):227-233.

Purquerio, L. F. V., Lago, A. A. &Passos, F. A. (2010). Germination and hard seedness of seeds in okra elite lines. *Horticulture Brasil Brasília* 28(2), 23–32.

Rao, N. K., Hanson, J.,Dulloo, M. E., Ghosh, K., & Nowell, A.(2006). Manual of seed handling in genebanks. *Bioversity International*. 8, 1 - 2.

Roberts, P.A., W.C. Matthews, J.D. Ehlers & D. Helms (2008). Genetic determinants of differential resistance to root-knot nematode reproduction and galling in lima bean. *Crop Science*. 48, 553–561.

Roy, A., Shrivastava, S. L., & Mandal, S. M. (2014). Functional properties of Okra *Abelmoschus esculentus* L.(Moench): traditional claims and scientific evidences. *Plant Science Today*.1(3), 121-130.

Sathish, D.,& Eswar, A. (2013). A Review on*: Abelmoschus esculentus* ("Okra"). *International Resources Journals of Pharmaceutical and Applied Sciences*., 2013; 3(4),129-132.

Sikora, R. A. & Fernandez, E. (2005). Nematode parasites of vegetables. In M. Luc, R. A. Sikora & J. Bridge (Eds.), Plant parasitic nematodes in subtropical and tropical agriculture pg. 319-392*). London: Center for Agricultural BioSciences International publishing*.

Silva, R.V., Oliveira, R.D.L., Ferreira, P. S., Castro,D.B. & Rodrigues. F.A. (2015) . Effects of silicon on the penetration and reproduction events of *Meloidogyne exigua*on coffee roots. *Bragantia,* 74,196 -199.

Singh, B., Singh, P. M., Sanwal, S. K., & Pal, A. K. (2014). Standardization of costeffective hybridization technique for hybrid seed prospection in okra (*Abelmoschus esculentus*). *Indian Journals of Agricultural Sciences.* 84, 1111–1114.

Tariq-Khan, M., Munir, A., Mukhtar, T., Hallmann, J. & Heuer, H., (2017). Distribution of root-knot nematode species and their virulence on vegetables in northern temperate agro-ecosystems of the Pakistani-administered territories of Azad Jammu and Kashmir. *Journals of Plant and Disease Protection.*,124, 201-212. https://doi.org/10.1007/s41348-016-0045-9.

Tiamiyu, R. A., Ahmed, H. G., & Muhammad, A. S. (2012). Effect of sources of organic manure on growth and yields of okra (Abelmoschus esculentus L.) in Sokoto, Nigeria. *Nigerian Journal ofBasic and Applied Sciences*, *20*(3), 213216.

Tian, Z. H., Miao, F. T., Zhang, X., Wang, Q. H., Lei, N., & Guo, L. C. (2015). Therapeutic effect of okra extract on gestational diabetes mellitus rats induced by streptozotocin. *Asian Pacific journal oftropical medicine*, 8(12), 1038-1042.

Wyss, U. (2002). Feeding behaviour of plant parasitic nematodes. In D. L. Lee (Ed.), The biology of nematodes (p. 233-260*). London: Taylor and Francis.* Received, January 01, 2016; Accepted: April 25, 2016

Yonas, M.,Garedew, W., &Debela, A. (2014). Multivariate analysis among okra (*Abelmoschus esculentus*) collection in South Ethiopia. *Journal of Plant Sciences*, 9(2), 43.

Youm OSS, Vaissayre M, Nibouche S, Martin T, Ochou GO, MonmanyiG (2005). Bio-ecology and management of *Helicoverpa*for sustainable crop production in Africa.

Ziska L. H, Blumenthal D.M, Runion G.B, Hunt ER, Jr. & Diaz-Soltero H (2010). Invasive species and climate change, an agronomic perspective. *Climate Change*. 105,13-42.